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BAW-3238-9: page 44, equation 2 — change
 $+0.000981\Delta H_{si}$ to $+0.000891\Delta H_{si}$;

BAW-3238-13: page 5-4, equation 14 —
change $+0.000981\Delta H_{si}$ to $+0.000891\Delta H_{si}$.

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EURAEC-1846

NONUNIFORM HEAT GENERATION
EXPERIMENTAL PROGRAM

— Final Report —

April 1967

CAUTION

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PREFACE

The Babcock & Wilcox Company and the United States Atomic Energy Commission, acting for the Joint U.S. -Euratom Research and Development Board, signed an agreement for a nonuniform heat generation experimental program.

The program includes experimental and analytical investigations to determine how nonuniformly distributed heat flux along lengths of tubular and annular channels affects the onset of burnout (critical heat flux). The experimental program was conducted in the 1.8-MW heat transfer facility at B&W's Research Center, Alliance, Ohio. The analytical program was conducted by the Atomic Energy Division, Lynchburg, Virginia.

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SUMMARY

On July 1, 1963, The Babcock & Wilcox Company, as part of the Joint U.S.-Euratom Research and Development Program, began an experimental and analytical program to determine how irregular heat flow through reactor channels affects the operating conditions that cause critical heat flux (burnout). Experimental work on tubular specimens with four axial power shapes was completed in December, 1964. Annular specimens with five power configurations were tested, and the effort to correlate the experimental data with empirical and analytical models is reported. The completion date of the program, with one extension, was June 30, 1966.

The data and results from the test sections are presented herein. The experimental parameters were chosen to cover a range of design conditions for nuclear power reactors. The following critical heat flux conditions were run in all combinations:

Axial flux shape		Pressure, psia	Mass velocity, lb/hr-ft ² × 10 ⁶	Inlet subcooling, F	
1. Uniform		[			
2. Peak near midpoint					
3. Peak near inlet					
4. Peak near outlet					
			1000	0.5	20
			1500	1.5	50
<u>Inside</u>	<u>Outside</u>		2000	2.5	100
					150
5. Uniform	--				
6. --	Uniform				
7. Uniform	Uniform				
8. --	Cosine				
9. Uniform	Cosine				

The tubular test sections were nominally 0.446-inch-ID tubes 72 inches long with water flowing inside; the tubular geometry was chosen in order

to compare the results with the industry's past experiments, most of which were performed with tubes and uniform heat flux. The annular channels had 1.053-inch OD and 0.607-inch ID to give a hydraulic diameter equal to that of the tubes.

The analysis presents observations regarding critical heat flux location and magnitude along with equations which evaluate the effect of operating parameters on critical heat flux location and magnitude. A suggestion for basic study of the critical heat flux phenomenon is given.

ACKNOWLEDGMENT

The principal investigators gratefully acknowledge the valuable contributions of others to the program, especially those who performed the major portion of the experimental work: Mr. J. W. Ackerman, Mr. J. S. Gellerstedt, and Mr. W. J. Oberjohn.

Mr. Ronald M. Scroggins of the USAEC served as cognizant engineer for the program, which was sponsored by the Joint U.S. -Euratom Research & Development Board.

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1. INTRODUCTION

1.1. The Critical Heat Flux Problem

The essential condition for the occurrence of the phenomenon called "critical heat flux" begins with a liquid in contact with a heated solid. In certain applications, notably in liquid-cooled nuclear reactor cores, heat transfer from the solid to the liquid at as high a rate as possible per unit area of surface is desirable for both physical and economic reasons. If this rate exceeds a certain value, which depends upon many factors, a phenomenon called the critical heat flux condition intervenes and causes the temperature of the solid surface to rise abruptly to maintain the rate of heat transfer. Under some conditions this temperature rise is sufficient to melt or burn the solid, in which case the result is called "physical burnout". From the viewpoint of classical physics this phenomenon is too poorly understood to be predicted by theory or first principles. However, factors affecting the initiation of this undesirable situation have been observed. The movement of fluid, the pressure, the geometry of the solid, the heat content of the mainstream of fluid, and the thermodynamic process by which the fluid acquires this heat content all appear to be related to critical heat flux. These are the observed macroscopic effects, and the most successful efforts to quantitatively relate them to critical heat flux have been empirical. Some fundamental studies of critical heat flux have attempted to include surface roughness, chemical composition of the liquid, and properties such as surface tension. Since these studies have failed to predict critical heat flux in practical equipment, the empirical approach has been relied upon.

The application of empirical critical heat flux data to nuclear reactors is risky unless the reactor design conditions are simulated accurately in the experiment. Past experiments have accurately duplicated the movement of fluid (mass velocity) and the pressure.¹⁻³ However, the geometry of the solid and the thermodynamic process by which the

fluid acquires its heat content have, in general, been very poorly simulated in the experiments. The reasons are the expense of constructing prototype test sections, supplying power to heat these test sections, and providing sufficient instrumentation to yield the desired information. Much critical heat flux data are available from test sections of simple geometry, short length, and uniform heat flux. Nuclear reactors, however, have complex geometry, long fuel elements, and nonuniform heat flux distributed along the length. These conditions provide the main incentive for the program reported here. Although the geometry does not have the complexity desired, this program advances the study of critical heat flux by obtaining data from test sections with nonuniform axial heating. When the program began, only a few sources of data for such test sections were available.^{4,5}

1.2. Scope of the Data

On July 1, 1963, The Babcock & Wilcox Company began this USAEC-EURATOM experimental and analytical investigation of flow inside round tubes and flow in annular channels.

1.2.1. Range of Fluid Conditions for All Test Sections

The objective was to attain the critical heat flux in each test section for all combinations of the following fluid conditions:

<u>Pressure, psia</u>	<u>Mass velocity, lb/hr-ft² × 10⁻⁶</u>	<u>Inlet subcooling, F</u>
1000	0.5	20
1500	1.5	50
2000	2.5	100
		150

Some data were obtained at other conditions, but the parameters shown were used for all test sections.

1.2.2. Tubular Test Sections

The chosen dimensions for the tubular test sections were:

Nominal ID, in.	0.446
Nominal length, in.	72

The longitudinal heat flux shapes, described in detail later, were designated as follows:

1. Uniform.
2. Chopped cosine.
3. Peak near inlet.
4. Peak near exit.

1.2.3. Annular Test Sections

The annular test sections were specified to have the same hydraulic diameter as the tubular test sections, 0.446 inch. The dimensions were as follows:

Nominal OD of flow channel, in.	1.053
Nominal ID of flow channel, in.	0.607
Hydraulic diameter, in.	0.446
Nominal length, in.	72

The longitudinal heat flux shapes of the inner and outer tubes were designated as follows:

<u>No.</u>	<u>Inner tube</u>	<u>Outer tube</u>
5	Uniform	Unheated
6	Unheated	Uniform
7	Uniform	Uniform
8	Unheated	Chopped cosine
9	Uniform	Chopped cosine

1.3. Study of the Results

The data and analysis from the tubular test sections were presented in an earlier report.⁶ The present report contains both tubular and annular data.

2. EQUIPMENT

2.1. Test Facility

The test facility is shown in Figure 1. The facility is 35 feet high and has a floor area of about 670 square feet. The equipment housed within the facility can accommodate two independent test sections at separate times. Changeovers in the test section power supplies and main flow loop circuits permit test section alternation. An automatic digital data acquisition system provides flexibility in gathering data. The following subsection describes equipment used in collecting data on the Euratom contract.

2.1.1. Test Apparatus

The test apparatus is shown in Figure 2. It is a recirculating pressurized-water loop capable of operating at 2700 psia, 680 F, and 150 gpm. The entire loop can be controlled automatically, thereby enabling unattended operation. The fluid in the loop is kept at operating temperature and pressure continuously.

The d-c power supply is energized only when the loop is attended. It consists of two 900 kw silicon diode rectifier units. These units can be operated as single 900 kw units, or they can be connected to heat simultaneously two separate loads such as the inner and outer tubes of an annular test section. In this service they are both regulated by the same control unit.

Basically, the main flow loop consists of an interchangeable test section, heat exchangers, a circulating pump, a flow control valve, flow elements, and a main loop heater. These components are joined together with 3.25-inch-OD by 0.380-inch-thick tubing to complete the closed loop. Feedwater technology and control permit the use of carbon steel materials in most of the loop. All test sections are fabricated from AISI Type-304 stainless steel, chosen because its resistivity

closely approximates the values required for a matched electrical load when using the necessary tube wall thickness at design pressure. The primary side of the heat exchangers is fabricated from Inconel, ASME specification SB-167. Inconel is used to prevent stress corrosion and to eliminate the need for deaerating the secondary water supply.

The primary circulating pump is made of stainless steel, has a canned motor, and is rated at 150 gpm and 295 feet of head. The flow control valve is pneumatic and has equal percentage characteristics with interchangeable trim. The flow elements consist of 1- and 2-inch calibrated flow nozzles in series with interchangeable turbine meters.

Three boiling water heat exchangers are used to remove the heat generated in the test sections. Heat removal rates from 30 to 1800 kw are possible within a mass flow range from 500 to 42,000 lb/hr. The water temperature at the test section inlet can be varied from the saturation temperature to about 300 F subcooling by using the main loop heaters. The test section inlet temperature can be set within ± 3 F of any desired value down to 200 F subcooling.

2.2. Test Sections

Critical heat flux data were collected for both uniformly and non-uniformly heated tubular and annular test sections. Table 1 shows the heat flux shapes used in the nine test sections during the program.

The curves shown in Figure 3 are best fits of measured heat flux data for tubular test sections 2 (chopped cosine), 3 (inlet peak), and 4 (outlet peak) and for the outer tubes of annular test sections 8 and 9 (chopped cosine).

2.2.1. Tubular Test Sections

The general arrangement of the tubular test sections is shown in Figure 4. All test sections had the inside diameters in the as-drawn condition. These diameters were 0.445 inch for test section 1 and 0.448 inch for test sections 2, 3, and 4. The overall test section lengths included a 4-foot unheated approach section, a 6-foot heated length, and an 8-inch unheated discharge section. Copper lugs were brazed to the test sections to provide electrical connections to the d-c power supply. Direct current was passed through the heated length to simulate nuclear heating. Nonuniform axial heat generation was obtained

by machining the outer surface of the test sections. This was done in a series of 2-inch tapers to vary the cross sectional area of the wall. Evenly distributed circumferential heat generation was obtained by controlling the eccentricity of the outer surface along the tube length during machining. A Vidi-gauge was used for this purpose. The uniformity of the circumferential heat flux was held to within $\pm 2\frac{1}{2}\%$.

2.2.2. Annular Test Sections

The general arrangement of the annular test sections is shown in Figure 5. The following geometry had minor variations ($\pm 0.5\%$) between test sections:

OD (inside tube), in.	0.607
ID (outside tube), in.	1.053
Heated length, in.	72
Hydraulic diameter, in.	0.446

Although not shown in Figure 5, the overall test section lengths included a 4-foot unheated approach section and an 8-inch unheated discharge section. Copper lugs were brazed to both the inner and the outer tubes as shown to provide the electrical connections to the d-c power supply. Direct current was passed through the inner and/or outer tubes to simulate nuclear heating. Since the power supply consisted of two units, both units could be connected to heat simultaneously the inner and outer tubes. Although the units were electrically independent, both units were regulated through the same control unit. Nonuniform axial heat generation was obtained by the same method described for the tubular test sections. Spacer pins were located on 18-inch center lines over the entire test section length. The subject of spacer pins and their influence on burnout is treated more fully in section 5.3.

2.3. Instrumentation

Both manual and automatic equipment are used in taking data. Figure 6 shows how either manual or automatic data are used in supplying experimental information to our RCA 301S digital computer. Transducers of various types, a digital data system, a manual system, and recorders of various types make up our instrumentation complex. Table 2 is a listing of the measured variables and the instrumentation used for both automatic and manual systems.

The automatic data system is shown in Figure 7. It is used to read and record up to 200 different voltages, frequencies, or time periods on each individual scan of the inputs. Low-level inputs (d-c voltages) can be measured from thermocouples, pressure transducers, strain gauges, etc. in the presence of severe common mode and superimposed noise. The system reads and records in six digits and includes a low-level range to 10 mv and a high-level range to 1000 v. Intermediate ranges of 100 mv, 1 v, 10 v, and 100 v have automatic ranging between levels. Voltages are read by an integrating digital voltmeter with integration periods of 1, 0.1, and 0.01 sec. For a 1 sec integration period the accuracy of the readings is $2 \mu\text{v} + 0.02\%$ of the reading. Above $10^6 \mu\text{v}$ (1 v) the accuracy is better than 0.01% of the reading. Overall system accuracy is maintained with an external d-c voltage standard which has six overlapping ranges from 1 mv to 1000 v. The accuracy of the standard is $0.01\% \pm 1 \text{ ppm}$ of full scale. Digital recording is by an incremental magnetic tape unit and a digital printer. In addition to the digital recordings, analog recordings of eight different variables are available from strip chart recorders in the system (see Figures 6 and 7).

2.3.1. Burnout Detection

Two critical heat flux (CHF) detectors have been developed. The first is a bridge detector, where a test section is electrically divided in half and incorporated in a Wheatstone bridge circuit. A strip chart recorder indicates the unbalance in the bridge circuit caused by the local temperature rise at CHF. However, disadvantages of the bridge detector are: (1) it cannot precisely locate a CHF, and (2) it cannot sense multiple critical heat fluxes, which may occur in nonuniformly heated test sections. In order to overcome these disadvantages, we have developed a second detector, which we call a segmental detector.

The segmental detector permits us to electrically divide a test section into short segments. The segmental detector shown in Figure 8 operates on the principle that a segmental temperature rise initiated by a CHF produces a detectable change in the resistance (voltage drop) of that segment. The detector consists of two-coil differential voltmeters, each having a full-scale deflection of $\pm 30 \text{ mv}$. The meters

respond to changes in voltage during a crisis. They are connected so that the local voltage drop across a segment is applied to one coil of a meter, and an adjustable fraction of the total test section voltage drop is applied as a reference voltage to the other coil. The reference voltage is initially adjusted to equal the segment voltage and remains practically constant. Both the bridge and segmental detectors have limited usefulness because they provide only indirect measurements of the test section tube wall temperatures.

Since the CHF on a uniformly heated tube occurs at the outlet of the tube, thermocouples alone were used to detect the CHF for test section 1. The operation of the segmental detector was also checked on this test section against temperature rises measured with exit thermocouples. However, because the CHF location on nonuniformly heated tubes is unpredictable, the segmental detector was used on test sections 2 through 9 to locate the CHF, and thermocouples were used as a backup. Figures 9, 10, and 11 show the thermocouple and voltage tap locations used on tubular test sections 2, 3, and 4. Figures 12 and 13 show the outer tube thermocouple and voltage tap locations used on annular test sections 6 through 9. Figures 14 and 15 show the inner tube thermocouple and voltage tap locations used on annular test sections 5, 7, and 9. It is noted that the taps are located on 6-inch centers (with the minor exception shown in Figure 11) and are usually installed over the entire 6-foot heated length. However, for test sections 7, 8, and 9 they are installed only over the upper 3 feet of the 6-foot heated length (see Figures 13 and 15). This causes a change in the tube segment numbering system. The changes in station numbers must be noted in a comparison of other data with data from test sections 7, 8, and 9.

Thermocouples directly attached to the test sections are electrically insulated to reduce the amount of d-c voltage pickup. A typical installation of the 20-gauge chromel-alumel thermocouples originally used is shown in Figure 9. These thermocouples had a time constant of about 5.5 sec. Later we used small (0.014-inch-diameter) stainless steel sheath thermocouples, which had insulated junctions and a response time of 0.1 sec. These thermocouples were spot welded on annular test sections 6 through 9 (see Figures 12, 13, and 15). The signals from the test section thermocouples are routed to a metal temperature measuring system. This is a manual system consisting of strip

chart recorders, selector switches, and a common 150 F automatic reference junction. Nine different metal temperatures can be simultaneously and continuously recorded.

2.3.2. Flow

The flow rate was measured by both 1-inch and 2-inch flow nozzles calibrated by the Engineering Experiment Station of Ohio State University. The nozzle differentials were measured by the instruments listed in Table 2. The flow rate was also measured by 5/8-inch and 3/4-inch turbine meters calibrated by the manufacturer and covering a range from 1.5 to 30 gpm (see Table 2). Both the nozzles and the turbine meters were used interchangeably between the tubular and annular test sections. The agreement between flow rates measured by the nozzles and the turbine meters was within $\pm 1\%$, but at low flow rates the turbine meters required calibration as a function of water temperature to hold this $\pm 1\%$. The flow rate was continuously recorded to observe any hydrodynamic perturbation during the crisis.

2.3.3. Pressure

The test section inlet pressure was also continuously recorded. The pressure transducer (see Table 2) is water cooled and located about 1 foot from the pressure tap. This arrangement is consistent with frequency response requirements.

Test section pressure drop was also measured by both the manual and automatic data systems. This instrumentation is listed in Table 2. Through the use of the automatic system this data can be continuously recorded or used as a direct input to the automatic data logger. The manual data system provides only a visual readout.

The test section exit pressure was measured with a 3000 psig Heise gauge. The readings from the Heise gauge were compared with those from the transducer at frequent intervals throughout testing. Frequent calibration with a deadweight tester indicated the overall accuracy of the gauge was ± 1 psi over the range of pressure tested.

2.3.4. Inlet and Exit Temperatures

Fluid temperature measurements at the test section inlet and exit are measured with chromel-alumel sheath thermocouples and

resistance thermometers. A 3-inch length of the sheath is located along the center line of the flow channel to minimize conduction errors. The sheath thermocouple reference junctions are maintained at 32 F in an ice bath, and the output voltages are read with a potentiometer. Calibration checks against the saturation temperature of steam indicated that the overall accuracy of the thermocouple readings was within ± 2 F of the National Bureau of Standards Tables. The resistance thermometers are 100-ohm platinum resistance temperature sensors inserted at a right angle to the center line of the flow channel. The immersion is to the center line of the channel. Standard power supplies are used in conjunction with the sensors and operate on a constant voltage basis. Each individual sensor has been calibrated by the manufacturer. Calibration checks against the chromel-alumel thermocouples indicate that the resistance thermometers agree to within ± 0.4 F over a wide range of fluid conditions (350 to 600 F).

Table 1. Heat Generation Shapes

<u>Tubular test sections</u>		
<u>No.</u>	<u>Heat generation shape</u>	
1	Uniform	
2	Chopped cosine	
3	Peak near inlet	
4	Peak near outlet	
<u>Annular test sections</u>		
	<u>Heat generation shape</u>	
<u>No.</u>	<u>Inner tube</u>	<u>Outer tube</u>
5	Uniform	Unheated
6	Unheated	Uniform
7	Uniform	Uniform
8	Unheated	Chopped cosine
9	Uniform	Chopped cosine

Table 2. Instrumentation — Manual and Automatic

<u>Measured variable</u>	<u>Transducers</u>	
	<u>Manual system</u>	<u>Automatic system</u>
<u>Pressure</u>		
Test section outlet	Heise bourdon tube gauge, 0 - 3000 psig	Baldwin-Lima-Hamilton transducer, 0 - 3000 psig
Test section inlet	Dynisco transducer, 0 - 3000 psig	Dynisco transducer, 0 - 3000 psig
<u>Pressure drop</u>		
Test section	Meriam mercury manometer, 40-inch	Data sensor differential transducer, 0 - 5 psid
	Barton differential pressure gauge, 0 - 50 psid	Data sensor differential transducer, ± 25 psid
Flow nozzle	Meriam manometer, 40-inch (Mercury, No. 3 oil, and CCl_4)	Barton differential transducer, 0 - 25 inch WC
		Data sensor differential transducer, ± 5 psid
		Data sensor differential transducer, 0 - 25 psid
<u>Fluid temperature</u>		
Test inlet, outlet, and flow element	Chromel-alumel sheath thermocouples	Chromel-alumel sheath thermocouples Rosemont engineering resistance thermometers
<u>Flow rate</u>		
	Bailey Meter flow nozzles, 1- and 2-inch	Same as manual system
	Potter aeronautical turbine meter, 5/8- and 3/4-inch	
<u>Power</u>		
Test section voltage drop	Dymec digital voltmeter 405 C/CR	Dymec digital voltmeter 2401 B
Test section electric current	Esterline-Angus current shunts and Greibach precision d-c ammeter, 0 - 20,000 amp	Esterline-Angus current shunts and Dymec digital voltmeter 2401 B

Figure 1. Test Facility

Figure 2. Schematic Diagram of Test Apparatus

Figure 3. Nonuniform Axial Flux Shapes

Figure 4. Arrangement of Tubular Test Sections

Figure 5. Arrangement of Annular Test Sections

Figure 6. Data Reduction Process

Figure 7. Automatic Data Acquisition Equipment

Figure 8. Schematic Diagram of Segmental Critical Heat Flux Detector

Figure 9. Test Section 2 Instrumentation

Figure 10. Test Section 3 Instrumentation

Figure 11. Test Section 4 Instrumentation

Figure 12. Outer Tube Instrumentation for Test Section 6

Figure 13. Outer Tube Instrumentation for Test Sections 7, 8, and 9

Figure 14. Inner Tube Instrumentation for Test Section 5

Figure 15. Inner Tube Instrumentation for Test Sections 7 and 9

3. PROCEDURES

3.1. Checkout

Before actual CHF test runs were conducted, several test-section and system checks were performed. The normal checkout routine consisted of instrument calibrations, isothermal test-section pressure drop tests, heat loss tests without power, and heat balances with power.

3.1.1. Instrument Calibration

Every effort was made to ensure accurate measurement of the primary variables. For this reason all instruments used in determining these variables were calibrated before testing began. Table 2 lists the transducers used for obtaining data either manually or with the data acquisition system.

3.1.1.1. Pressure

The total-pressure transducers were calibrated using a deadweight tester, and the differential-pressure transducers were calibrated using a manometer as the standard. Transducers reading the same variable were checked against each other throughout the tests.

3.1.1.2. Temperature

Fluid temperatures at the flow elements and at the entrance and exit of the test section were measured by fluid thermocouples and resistance thermometers. The nominal calibrations supplied with the resistance thermometers were checked by saturating the fluid around the installed temperature sensors and comparing the indicated reading with the saturation temperature. At the same time the fluid thermocouples were calibrated. The calibrated thermocouples and resistance thermometers were also checked against each other throughout the test program.

3.1.1.3. Flow Rate

The flow rate through the test section was determined by a flow nozzle and a turbine flowmeter. During initial flow tests and throughout the test program, the two elements were checked against each other.

3.1.1.4. Power

The power added to the test section was determined from measurements of voltage and electric current. The accuracy of the voltage reading was ensured by frequent calibration of the digital voltmeter. Electric current was determined from the voltage drop across a precision current shunt.

3.1.2. Isothermal Pressure Drop Tests

The pressure drop across each test section was measured at various flow rates with both cold and hot pressurized water (100 F to 600 F) flowing through the test section. Figure 16 shows the two curves generated by the data, one curve for tubular and the other curve for annular test sections. Although both types have the same equivalent diameter, the annular test sections have a higher pressure drop for given conditions due to the additional pressure drop across the spacer pins in the flow channel. Pressure drop data were also taken each day to detect whether changes to the flow channel occurred.

3.1.3. Heat Loss

The heat loss for each test section was determined by passing subcooled pressurized water through the test section and calculating the enthalpy drop between the inlet and outlet. The product of the enthalpy drop and the weight flow is equal to the heat loss. The heat loss corrections are then applied to the CHF data.

3.1.4. Heat Balance

The heat balance with power was calculated by equating the electric heat input to the test section with the heat pickup of the fluid. The difference between these two measured values was accounted for by heat loss correction and correction for the ripple imposed on the d-c power supply voltage and current. After the ripple correction was

determined, the electric heat input agreed to within $\pm 1\%$ of the heat pick-up of the fluid.

3.2. Critical Heat Flux Detection

The CHF data were obtained by controlling the independent parameters of pressure, flow rate, and inlet temperature at the desired values while the test section power was increased to near the CHF. Then data were taken continuously as the power was increased until the crisis occurred. When the crisis occurred, the electric power was either quickly reduced or cut off entirely to keep the test section from failing.

Initially all data were recorded manually, but after June 22, 1965, all data were recorded by the automatic data acquisition system (see Figures 6 and 7). The two methods of data recording are described below.

3.2.1. Manual Data

The independent parameters were recorded about once a minute, and the test section voltage and current were continuously monitored by one of the operators as he increased the power. The critical conditions were defined by the last set of data taken before a metal temperature rise was indicated. A record was made of the station number for which the CHF detector indicated the temperature rise.

3.2.2. Automatic Data

When the operator started to increase power, he switched the data system to scan continuously. A scan is one complete set of data recorded on magnetic tape and printed on paper tape. Data were recorded at a rate of about six scans per minute. As before, the critical conditions were defined by the last set of data taken before a metal temperature rise was indicated. Records of the run numbers, times when CHF occurred, and CHF station numbers were kept for manual data inputs to the Research Center digital computer, which reduced the data from the magnetic tape.

3.3. Water Treatment

The demineralized and deaerated loop feedwater was treated with ammonium hydroxide to control the pH at 9.7 throughout the tests. Daily

analysis by our Chemistry Laboratory enabled us to maintain the limits listed below.

<u>pH</u>	<u>Conductivity, mmhos/cm</u>	<u>Dissolved oxygen, ppm O₂</u>
9.6 to 10.0	15 to 30	0.002 to 0.005

This water treatment prevented fouling of the test section at CHF conditions.

Figure 16. Results of Pressure Drop Tests

4. EXPERIMENTAL DATA

4.1. Data Tables

A prime objective of this program was to learn the experimental effect on CHF of imposing certain conditions on a system, as discussed in the introduction. The experimental results, along with the laboratory conditions imposed on the systems, are shown in Tables A-1 through A-9, which contain all of the authenticated CHF data obtained under the program. Both tubular and annular data are included. This report emphasizes the annular data, since the tubular data are discussed in detail in an earlier topical report.⁶ The annular data are given in Tables A-5 through A-9. The symbols in the tables are explained at the beginning of Appendix A.

4.2. Graphical Representation of Uniform Heat Flux Data

4.2.1. Interpretations of CHF Data

Data can appear very different depending on the background and orientation of the viewer. Of course, much of the data presented here suffers an additional complication because of the nonuniform axial distribution; however, some informative analyses about views of the data can be presented if we remove the flux-shape consideration and consider two ways of looking at uniform data.

In general, one of two assumptions is made in the graphical presentation of the CHF data. One assumption focuses attention on the inlet fluid condition, as in Figure 17a, and leaves the exit fluid condition undefined. The other focuses on the exit fluid condition (for uniform heat fluxes), as in Figure 17b; and leaves the inlet fluid condition unevaluated. The link between these two representations is called a heat balance, which says that the heat content of a unit mass of fluid at the channel exit is equal to the heat content at the entrance plus the heat added as the unit mass passes through the heated channel:

$$H_{\text{exit}} = H_{\text{in}} + \frac{q}{W} \quad (1)$$

This, of course, can be combined with the definition of quality

$$X_{\text{exit}} = \frac{H_{\text{exit}} - H_f}{H_{fg}} \quad (2)$$

to give

$$X_{\text{exit}} = \frac{H_{\text{in}} + \frac{q}{W} - H_f}{H_{fg}} \quad (3)$$

Writing equation 3 in more usable terms

$$X_{\text{exit}} = \frac{H_{\text{in}} + \frac{P_h L \phi}{A_f G} - H_f}{H_{fg}} \quad (4)$$

Notice that the quality is a function of all the other variables of the system. This should not be surprising since the exit fluid condition is not measured, but must be calculated.

It has become customary to consider the heat flux as the dependent variable in CHF discussions. There should be a word of caution here regarding the use of equation 4 for CHF analysis. In such a sense it has no meaning unless it describes conditions at which critical heat flux has been achieved. More precisely, equation 4 would be

$$X_{\text{CHF}} = \frac{H_{\text{in}} + \frac{P_h L \phi_{\text{CHF}}}{A_f G} - H_f}{H_{fg}} \quad (5)$$

This is the condition used for making the plots in Figure 17b, where ϕ_{CHF} is plotted versus X_{CHF} . From equation 5 it is seen that a given test section geometry at a given pressure, mass velocity, and inlet

enthalpy would always, within experimental precision, give the same CHF point. Holding the geometry, pressure, and mass velocity constant, the experimenter usually achieves different CHF points by changing the inlet enthalpy, H_{in} . This has caused a movement toward the consideration of H_{in} as a prime variable, rather than X_{CHF} . Thus, we have two ways of looking at uniform CHF data:

$$\phi_{CHF} = F(X_{CHF}) \quad (6)$$

and

$$\phi_{CHF} = F(H_{in}) \quad (7)$$

One cannot escape the imminently practical aspects of equation 7. From the operational and the design viewpoints, the inlet condition can be measured and specified, or even controlled. On the other hand, equation 6 has theoretical implications that appeal to correlators of CHF data.

This is logical because CHF ought to be a function of the vapor fraction of the fluid flowing on the heated surface. One trouble with equation 6 is that, in applications to operation and design, people tend to assume that

$$\phi_{CHF} = F(X) \quad (8)$$

where the quality, X , does not represent the CHF quality. This oversight has unfortunately created confusion throughout the world with respect to the apparent margin between safe operating conditions and CHF conditions. Equation 8 gives larger margins than does equation 6.

Returning to the comparison of equations 6 and 7, the inlet versus the exit viewpoints appear to show opposite effects resulting from changes in some of the system parameters. For example, if one changes the test parameter by increasing the heated perimeter, then apparent opposite results are given by equations 6 and 7. This is illustrated by the plots in Figure 17. Attention is called to the runs made under the following conditions:

Pressure, psia	1000
Mass velocity, lb/hr-ft ²	1.5×10^6
Length, in.	72
Annular channel, in.	
OD	1.053
ID	0.607

The difference being considered is between the heated perimeters. In test section 5 only the inside diameter was heated, and in test section 6 only the outside diameter was heated. A cursory examination of these conditions as plotted in Figure 17 might lead one to assume that in Figure 17b the data from test section 6 "lie above" the data from test section 5. Such an observation has caused some observers to state that increasing the ratio of heated-to-unheated perimeter increases the critical heat flux. On the other hand, after examining Figure 17a one might say that the data from test section 5 "lie above" the data from test section 6. This may cause the observer to say that decreasing the ratio of heated-to-unheated perimeter increases the critical heat flux.

Actually, the concept of increasing or decreasing the critical heat flux by changing this parameter is irrelevant because it does give contradictory answers, depending on whether one is looking at the channel entrance or the channel exit. Perhaps the most realistic way of considering Figure 17b is to observe that the use of quality as the abscissa causes the curve of test section 6 to lie to the right of the curve of test section 5. Conversely, in Figure 17a the curve of test section 5 lies to the right of the curve of test section 6. Actually, these are the same CHF data plotted against two different sets of abscissas. The different appearances of the data are not surprising when the nature of the abscissas is considered.

4.2.2. Average Heat Flux Vs Inlet Condition

In Figures 18, 19, and 20 the average heat flux over the heated length of the channel is shown versus inlet subcooling for annular test sections with uniform flux. Also shown for comparison is the curve for the tube with uniform flux. It can be seen that the highest heat fluxes are in test section 5, where only the inside surface of the annulus is

heated. Next lower in the order of heat flux is test section 6, where only the outside surface is heated. This relative heat flux capability may be expected, since the ratio of heated perimeter to cross sectional flow area is decreasing. Further, because the hydraulic diameter of the annulus is equal to that of the tubes previously tested, one might expect the CHF of test section 7 (both surfaces heated equally) to coincide with that of the tube. It can be seen that this does not occur, except possibly at the lowest mass velocity (0.5 million lb/hr-ft²) and at 1500 and 2000 psia. In most cases the annulus produced a higher CHF than the tube did; a possible explanation is related to the spacer pins, which are discussed later. Regarding the tube and the annulus with both surfaces heated, it appears anomalous that at 1000 psia and 0.5 million lb/hr-ft² the annulus shows lower CHF than the tube shows; however this behavior is supported by the nonuniform tests, which are described later.

4.2.3. Local Critical Heat Flux Vs Local Quality

In the discussion so far, the average heat flux has been used as the basis for comparing the various data obtained. Because the average heat flux is proportional to the overall channel performance, a study of results from this viewpoint is very important. However, in describing the physical occurrence of CHF, the local heat flux and the local fluid conditions at the location of CHF are often considered.

In most CHF work the chosen local fluid condition is usually expressed as quality and calculated as follows:

$$x = \left(H_{in} + \frac{q}{W} - H_f \right) / H_{fg} \quad (9)$$

where

H_{in} = enthalpy at inlet to heated length of test section, Btu/lb

q = heat added to fluid between inlet and location under consideration, Btu/hr

W = channel flow rate, lb/hr

H_f = enthalpy of saturated liquid, Btu/lb

H_{fg} = latent heat of vaporization, Btu/lb

The quality is often quoted because in two-phase flow the vapor fraction is considered to have significance at the burnout location. The significance of the vapor fraction cannot be denied. The difficulty is that the quality computed from a heat balance (as above) is likely to bear little resemblance to the actual situation at the burnout location. Nevertheless, data are often studied by plotting the local burnout heat flux as a function of the local computed quality. It is interesting to take some of the data shown on previous plots (Figures 18, 19, and 20) and note the appearance when the "local" conditions are plotted.

Figures 21, 22, and 23 show the local CHF versus local quality for the annular test sections with uniform flux. Here, again, the uniform data from the tubular test section are shown for comparison.

From the plots shown in Figure 17, one would expect test sections 1 and 7 to have the highest heat fluxes, followed by test sections 6 and 5 in that order. (Notice that some of the test conditions produced this arrangement, but under other conditions the situation is somewhat mixed.) It is felt that in some cases the extra turbulence, caused by the spacers in the annular test sections, increases the CHF so that even in this kind of plot the annuli sometimes produce higher CHF than the tube does. In addition, the spacers apparently affect the CHF location, sometimes moving it upstream from the exit. This fact should be considered when studying individual points in Figures 21, 22, and 23.

4.3. Graphical Representation of Nonuniform Heat Flux Data

4.3.1. Average Heat Flux Versus Inlet Condition

Since the major parameter of this program is the flux shape, the data are presented to show the effect of changing the flux shape, while all other test parameters are nearly constant. It is desirable to compare the data from the various test sections to show the effect of flux shape on the channel power that can be transferred at conditions leading up to the CHF or burnout point. Because the average heat flux is proportional to the overall channel performance, the various data have been compared on that basis. In Figures 24, 25, and 26 the average heat flux over the length of the channel is shown versus inlet subcooling for tubular test sections. At each condition of mass velocity and pressure, the data from the four flux shapes are shown together so

that the effect on channel power can be observed. The uniform flux delivers channel powers comparable to those of the inlet peak and the cosine in all cases except at 1000 psia and at the two higher mass velocities, 1.5 and 2.5 million lb/hr-ft². Here the uniform flux shows significantly higher power before the crisis occurs. Perhaps the most interesting behavior is exhibited by the inlet peak flux shape. In some cases, notably at 1000 psia and a mass velocity of 2.5 million lb/hr-ft², the flux seems to run the gamut of power delivery. At low inlet subcooling, the average heat flux is very nearly the lowest; at high inlet subcooling, the average heat flux is the highest. It is apparent that this flux shape can offer heat transfer advantages under some conditions. The outlet peak exhibited the lowest capability in all cases. The cosine shape appears to rank with the uniform cases except at the two conditions previously mentioned.

The annular test sections involving the cosine flux shape have their average heat fluxes plotted versus inlet subcooling in Figures 27, 28, and 29. For comparison, the tubular test section with the cosine flux shape is also shown. The flux shape on the inside surface is uniform. The cases where this surface alone was heated are shown in the previous uniform flux comparisons. Figures 27, 28, and 29 show that the annulus with the outer surface heated produces the highest average heat flux at comparable conditions. The next highest is produced by the annulus with both sides heated, where the average heat flux having the cosine shape on the outer surface is equal to the uniform heat flux on the inner surface. The one exception to this relative order occurs at 1000 psia and 0.5 million lb/hr-ft². Here the annulus gives a lower average CHF than the tube does. This parallels the previously mentioned case where all the experimental conditions are the same except that the outer surface has uniform heat flux.

4.3.2. Local Critical Heat Flux Versus Local Quality

The data from the tubular test sections are shown in Figures 30, 31, and 32. The plot in Figure 30 appears rather chaotic in contrast to the ordered appearance in Figure 24. Figure 30 would also appear ordered if the CHF location were always the same. This program has shown that extreme nonuniform axial heat fluxes (in test

sections 3 and 4, peak near inlet and peak near outlet) have variable CHF locations. Thus, the length to the CHF location and, hence, the quality and the local heat flux vary considerably. Obviously, the variation of the location does not allow the points to appear consistent and orderly in Figure 30. The CHF location is discussed more in a following section. At 1500 psia in Figure 31 the points seem to acquire more consistency, and at 2000 psia in Figure 32 they appear even more orderly. In all three figures it is apparent that the uniform flux shape gives the highest CHF at constant quality. The relative rank of the other flux shapes is somewhat mixed.

Local CHF versus local quality for annular channels involving nonuniform heat fluxes are plotted in Figures 33, 34, and 35, along with the chopped cosine tubular data for comparison. These data also have some erratic features due to the variable CHF location, but there is more order here than in Figure 30. This is explained by the observation that in some respects the behavior of the chopped cosine flux is similar to that of the uniform flux. The CHF location does move upstream from the outlet, but it does not vary over as wide a range as it does for more extreme flux shapes, such as the peak near the inlet. In most of the cases in Figures 33, 34, and 35 the tube shows the lowest CHF; this may surprise the observers who remember the effect illustrated in Figure 17b for uniform fluxes, where the test sections with the greater heated-to-unheated perimeters show the greater values of CHF. This apparent reversal in Figures 33, 34, and 35 comes about because local conditions at the CHF point farthest upstream are plotted. For example, in Figure 35 (at 2.5×10^6 lb/hr-ft²) the annular data from test section 8 appear to lie above the tubular data when the local conditions are plotted. These data are replotted in Figure 36, showing average heat flux versus exit quality. Here the tubular data appear to lie above the annular data with one side heated, and in this respect are consistent with Figure 17b. Thus, the use of local conditions gives rise to anomalies with respect to previous uniform data, while the use of average conditions can, at least in some cases, give results comparable to the uniform data results.

4.4. Comparisons With Other Sources

Comparisons with data from other sources are desirable when possible. It is difficult to find two sources of data where the test section geometry, flux shape, pressure, mass velocity, and inlet conditions are the same so that the CHF results can be compared directly. However, it was found that two points of annular data from this program have pressure and mass velocity identical to some of the data from another source.⁷ Another similarity is that the inside surface of the annulus is heated uniformly and the outside is unheated, but the lengths are different, as shown in Figure 37. In the plot of CHF versus the exit quality in this figure, these two sources of data seem to agree.

A source of high-pressure, nonuniform data from tubular test sections is given in reference 8. A sample of these data with an outlet peak flux shape is compared with the outlet peak data of this program in Figure 38. While the flow rates, pressures, and diameters of the two experiments are comparable, the lengths and the maximum-to-average ratios are significantly different. These differences may account for the fact that the data from reference 8 do not lie between the lines representing two flow rates from test section 4 of this program. The inlet peak comparison in Figure 39 shows the data from reference 8 failing to fall between the bracketing flow rates of test section 3 of this program. Evidence that the discrepancies in these data are due to differences in test parameters, rather than to differences in data source, is cited in Figure 40, where the uniform data from both sources are in remarkable agreement.

4.5. Operational Critical Heat Flux Observations

4.5.1. Continuous Records During Operation

Recordings (charts) of test section inlet pressure, primary loop flow, and test section metal temperature are shown in Figures 41, 42, and 43. Run 432 from test section 6 (uniform outside flux) has been selected because it is representative of the results obtained. Figure 41 (pressure), Figure 42 (flow), and Figure 43 (temperature) provide a graphical aid in determining CHF.

Run 432 starts when the flow, pressure, and temperature have reached steady state conditions. For example, the "datum point" as shown in Figures 41, 42, and 43 is representative of steady state conditions before the crisis. The procedures used in obtaining the CHF after the data point are as follows:

1. Start Power Increase: The test section power is increased, as shown in all figures, until some indication of the crisis is recorded—the onset of CHF is observed in Figure 43 as a fluctuating test section metal temperature at thermocouple 1C. The location of thermocouple 1C is at the outlet, as shown in Figure 12. Thermocouple 9 is 9-1/2 inches from the outlet and provides a reference temperature in Figure 43.

2. CHF Point ($\phi = 945,000 \text{ Btu/hr-ft}^2$): The CHF point is approached in two steps. The first is to reduce the test section power about 1% ($\phi < 945,000 \text{ Btu/hr-ft}^2$) at the first indication of burnout and then to take data. The second step is to increase power to its initial value ($\phi = 945,000 \text{ Btu/hr-ft}^2$), take only power data, and check the flow nozzle pressure differential and test section inlet temperature. The CHF ($\phi = 945,000 \text{ Btu/hr-ft}^2$) is the highest actual flux observed and is that reported in Table A-6 for CHF points. The techniques used in defining the CHF (DNB point) make it possible to repeat the flux to within $\pm 5000 \text{ Btu/hr-ft}^2$.

3. Decrease Power: Decreased power is shown in all three figures and is representative of postburnout conditions brought about by manually reducing the test section power. Figure 41 shows an abrupt decrease in pressure; Figure 42 shows a rise in flow; Figure 43 shows a decrease in metal temperature. The changes in pressure and flow result from a reduction in the specific volume of the fluid within the test section.

4.5.2. Comparison of Segmental and Thermocouple Detection

The crisis indications and locations as determined from both thermocouples and detectors were compared for test sections 8 (cosine outside flux) and 9 (cosine outside flux, uniform inside flux).

Agreement was shown in 68 out of 96 runs. Runs that showed lack of agreement, but not necessarily contradiction, are listed in Table 3. An examination of Table 3 reveals that a crisis with the detectors was observed at some location for every run. For nine runs we observed no crisis with the thermocouples, even though the detectors indicated a crisis at a thermocouple location. However, it is felt that the critical condition was reached for every run shown for test sections 8 and 9.

4.6. Stability of Flow and Pressure

The continuous recordings of test section inlet pressure, primary loop flow, and test section metal temperature, shown in Figures 41, 42, and 43 and discussed in connection with CHF detection, also apply to a discussion of system stability. If a dynamic coupling (pulsating inlet pressure and flow) exists between the test section and the loop, then the flow characteristics could be defined as unstable. Unstable flow characteristics could affect the data. The various indicators of loop stability are discussed below.

4.6.1. Test Section Inlet Pressure (Figure 41)

The time interval from the data point to the DNB point (CHF) shows the history of test section inlet pressure. The frequency of the pressure oscillation is about 5 cpm at an amplitude of ± 3 psi. It is clear that the pressure oscillations at the DNB point and the data point are about the same.

4.6.2. Primary Loop Flow (Figure 42)

The time interval from the data point to the DNB point shows the history of the primary loop flow. The frequency of flow oscillation is judged to be about 6 cpm at an amplitude of ± 0.1 gpm. It is clear that the flow oscillations at the DNB point and the data point are about the same.

Based on the evidence presented above, this conclusion appears justified: the pressure and flow perturbations are normal, and they are not causing premature crises. Since this conclusion is based only on run 432, additional evidence is necessary. We have chosen to compare our data for test sections 5 and 6 with the reference 9 criteria in the following section.

4.6.3. Reference 9 Criteria

It is reported⁹ that CHF data can depart from the normal trend because of loop flow characteristics. The dynamic coupling between the test section and the loop can amplify a hydrodynamic instability, which is given the name "pulsating regime". The pulsating regime occurs at minus inlet qualities ($x < 0$) and zero exit quality ($x = 0$). This regime has divergent oscillations in pressure and flow rate. For example, pressure oscillations with frequencies of 12 to 18 cpm and amplitudes of ± 212 psi are reported;⁹ under these conditions the CHF is substantially lower than expected. Criteria were needed for determining the existence of the steady flow condition, which is considered normal for CHF data.

The reported criteria for a steady flow regime can be stated as follows: (1) the normal trend of the data is linear or monotonically decreasing when test section power (critical power) is plotted as a function of inlet quality ($x < 0$), and (2) there should be no divergence of the normal trend (linearity) around a line of zero exit quality. Figure 44 shows that these criteria have been satisfied—the figure shows data at mass velocities of 1.5×10^6 and 2.5×10^6 lb/hr-ft² from test sections 5 and 6. Data at 0.5×10^6 lb/hr-ft² have been omitted since critical power occurred at exit qualities greater than 12%. It follows from Figure 44 that (1) the data is linear and (2) does not depart from the normal (linear) trend around the line of zero exit quality. It appears that the loop flow characteristics are stable according to these criteria.

Table 3. Comparison of Thermocouples and CHF Detector Segment Numbers

Run	CHF detector		Thermocouples		Test section
	Inside	Outside	Inside	Outside	
962		7		6, 7	8
970		3		(b)	8
975		4		(b)	8
976		3		(b)	8
981		3		(b)	8
982		3		(b)	8
985		3		(a)	8
991		4		(b)	8
992		3		(b)	8
994		3		(a)	8
995		3		(a)	8
996		3		(a)	8
998		6		3, 6	8
999		2, 3		3	8
1000		2, 3		3	8
1011	7	6	7	(a)	9
1028		6	7	6	9
1033		6		(a)	9
1035		4, 5, 6		6	9
1036		4, 5, 6		6	9
1037		6		(a)	9
1038	7	6	7	(a)	9
1042	7		(a)	6	9
1045	7		(a)		9
1050		6, 7		7	9
1054		7		6	8
1055		7		(a)	8
1057		7		(a)	9

(a) No indication.

(b) Not recorded.

Figure 17. Two Ways of Plotting Uniform CHF Data (1000 psia)

(a) CHF Vs Inlet Enthalpy

(b) CHF Vs Exit Quality

Figure 18. Uniform Heat Flux Vs Inlet Subcooling at 1000 psia

Figure 19. Uniform Heat Flux Vs Inlet Subcooling at 1500 psia

Figure 20. Uniform Heat Flux Vs Inlet Subcooling at 2000 psia

Figure 21. Uniform Heat Flux Vs Local Steam Quality at 1000 psia

Figure 22. Uniform Heat Flux Vs Local Steam Quality at 1500 psia

Figure 23. Uniform Heat Flux Vs Local Steam Quality at 2000 psia

Figure 24. Channel Average Heat Flux Vs Inlet Subcooling for Tubes at 1000 psia

Figure 25. Channel Average Heat Flux Vs Inlet Subcooling for Tubes at 1500 psia

Figure 26. Channel Average Heat Flux Vs Inlet Subcooling for Tubes at 2000 psia

Figure 27. Channel Average Heat Flux Vs Inlet Subcooling With Nonuniform Flux at 1000 psia

Figure 28. Channel Average Heat Flux Vs Inlet Subcooling With Nonuniform Flux at 1500 psia

Figure 29. Channel Average Heat Flux Vs Inlet Subcooling
With Nonuniform Flux at 2000 psia

Figure 30. Local Heat Flux Vs Local Steam Quality for Tubes at 1000 psia

Figure 31. Local Heat Flux Vs Local Steam Quality for Tubes at 1500 psia

Figure 32. Local Heat Flux Vs Local Steam Quality for Tubes at 2000 psia

Figure 33. Local Heat Flux Vs Local Steam Quality With Nonuniform Flux at 1000 psia

Figure 34. Local Heat Flux Vs Local Steam Quality With Nonuniform Flux at 1500 psia

Figure 35. Local Heat Flux Vs Local Steam Quality With Nonuniform Flux at 2000 psia

Figure 36. Average Conditions Used to Show Effect of Non-uniform Heat Flux

Figure 37. Comparison of Annular Data From Two Sources

Figure 38. Peak-Near-Outlet Data From Two Sources

Figure 39. Peak-Near-Inlet Data From Two Sources

Figure 40. Uniform Tube Data From Two Sources

Figure 41. Test Section Inlet Pressure, Run No. 432

Figure 42. Primary Loop Flow, Run No. 432.

Figure 43. Test Section Metal Temperature, Run No. 432

Figure 44. Total Test Section DNB Power Vs Inlet Steam Quality for Test Sections 5 and 6

5. DATA ANALYSIS

5. 1. Critical Heat Flux Location

Most investigators have found that, for uniform-flux test sections, the CHF occurs at or near the exit end of the heated length. When the axial heat flux varies, as it does in this program, the CHF occurs at other locations. Prediction of location, as well as overall channel power or average heat flux, would be of considerable interest to reactor designers. Therefore the results were studied with respect to the observed CHF location. As reported earlier,⁶ sets of empirical equations were developed. These to some degree express the behavior of the CHF location, as well as the average heat flux and the local integrated heat flux. This behavior is reviewed in the next section.

5. 1. 1. Empirical Equations for Tubular Test Sections

The data were studied to observe the effects of the various parameters on the CHF and on the associated channel power. The pressure and mass velocity were considered constant at their nominal values. The inlet condition, on the other hand, varied from run to run; therefore the runs were plotted and interpolated to obtain parametric inlet conditions. The data appear consistent enough to justify this procedure, as can be seen in Figures 24, 25, and 26. In the actual study, inlet enthalpy was the quantity used to make the working plots, but during this analysis it was discovered that inlet subcooling, expressed as the difference between inlet enthalpy and saturated liquid enthalpy, was a more useful parameter. As a result, the following parameters were considered in all combinations:

Flux shape	Mass velocity, lb/hr-ft ² × 10 ⁻⁶	Pressure, psia	Inlet subcooling, Btu/lb
1. Uniform	0.5	1000	40
2. Peak near midpoint	1.5	1500	110
3. Peak near inlet	2.5	2000	170
4. Peak near outlet			

The procedure was to select a given flux shape, pressure, and inlet subcooling. With these fixed, the local heat flux, integrated average heat flux, and the burnout location were plotted as dependent variables versus mass velocity as the independent variable. The integrated average heat flux is defined by

$$\phi_0 = \frac{1}{L} \int_0^L \phi dZ \quad (10)$$

where

ϕ_0 = integrated average heat flux

L = distance from inlet of heated channel to point of interest

ϕ = local heat flux as a function of distance from inlet of heated channel

Z = variable distance along channel

The relationship between the local heat flux and the integrated average is shown in Figure 45 for flux shape 3. An example of the working analysis plots is given in Figure 46. Most of the nonuniform runs exhibited multiple burnout locations. In this study, the distance from the inlet of the heated portion of the tube to the burnout location nearest the inlet end was taken as a measure of the burnout location. This decision was based on the reasoning that burnout occurred at the highest heat flux and hence was most significant since the highest heat fluxes are most likely to be destructive under critical conditions. The heat flux information from the foregoing plots was condensed in tabular form (Table 4) to permit further observations.

Table 4 shows the trends of behavior; the most striking observation is the relatively constant behavior of the integrated average

heat flux at a given pressure and inlet subcooling associated with the low mass velocity (0.5×10^6 lb/hr-ft²). A notable exception is one measurement of flux shape 3 (peak near inlet) at inlet subcooling of 110 Btu/lb and 2000 psia. However, the relative independence of the integrated average heat flux with respect to the flux shape for most of these low-mass-velocity runs is remarkable. We may also observe that, as the mass-velocity values are increased, the integrated average flux acquires a dependence on the flux shape. This dependence is further increased as the pressure and mass velocity are increased. The foregoing observations are a basis for correlating the data.

Further investigation has shown that the integrated heat flux, apart from the integrated average, offers even more possibilities for empirical correlation of the data. This quantity is defined by

$$\int_0^L \phi dZ$$

The values of the integrated heat flux as a function of pressure, mass velocity, inlet subcooling, and flux shape are given in Table 5. Also shown are the distances from the inlet of the heated channel to the burn-out locations. As previously mentioned, in the case of multiple burnout indications, the location farthest upstream is the one considered. Analysis of these data produced the following equation:

$$\frac{1}{10^6} \int_0^L \phi dZ = 49.52 - 0.0218P + \left(3.56 + 0.00352P - 4.27 \frac{\phi_m}{\phi_a} + 0.0504 \Delta H_{si} \right) \left(\frac{G}{10^6} + 0.372 \right) \quad (11)$$

where

P = pressure, psia

ϕ_m / ϕ_a = ratio of maximum to average heat flux for the flux shape

ΔH_{si} = inlet subcooling, Btu/lb

G = mass velocity, lb/hr-ft²

This form of the equation was suggested by graphical parametric studies, and the constants were evaluated by a curve-fitting computer program which was able to handle all the experimental data from the tubular test sections. Comparison of the ratio of the experimental value of the integrated heated flux with that computed by the equation shows good agreement, as revealed by a mean ratio of 1.0014 and a standard deviation of 0.0875.

Equation 11 provides a correlation between the variables of the experimental work; however, if we desire to use this equation for predicting CHF, we have difficulty with the left-hand member. The significance of the left-hand member is more fully explained as follows:

$$\int_0^L \phi dZ = \int_0^L \phi_a \phi_N dZ = \phi_a \int_0^L \phi_N dZ \quad (12)$$

where

ϕ_a = average heat flux for the heated channel length

ϕ_N = normalized function describing the flux shape;
at any location Z, $\phi_N = \phi_{\text{local}} / \phi_a$

Substitution in equation 11 gives

$$\begin{aligned} \frac{\phi_a}{10^6} \int_0^L \phi_N dZ &= 49.52 - 0.0218P \\ &+ \left(3.56 + 0.00352P - 4.27 \frac{\phi_m}{\phi_a} + 0.0504 \Delta H_{si} \right) \left(\frac{G}{10^6} + 0.372 \right) \end{aligned} \quad (13)$$

Two unknowns exist: ϕ_a and L; one solution is to go back to the data and see whether ϕ_a is predictable. Following a process similar to that used for the integrated heat flux, we find that the uniform, the inlet peak, and the cosine flux shapes can be correlated by

$$\begin{aligned} \frac{\phi_a}{10^6} &= 0.701 - 0.000305P \\ &+ \left(-0.0287 + 0.0000503P + 0.000981 \Delta H_{si} \right) \left(\frac{G}{10^6} + 0.256 \right) \end{aligned} \quad (14)$$

The fit of this equation with the data is sufficient to give a mean ratio of 0.9999 and a standard deviation of 0.0848 about this mean.

The outlet peak data are correlated by

$$\frac{\phi_a}{10^6} = 0.660 - 0.000266 P + \left(-0.0933 + 0.0000663 P + 0.000888 \Delta H_{si} \right) \left(\frac{G}{10^6} - 0.0576 \right) \quad (15)$$

to give a mean of 0.9996 and a standard deviation of 0.0524. Thus, using equation 14 or 15 it is possible to calculate the average heat flux for a burnout condition, and, using equation 13, it is possible to study the behavior of burnout location with respect to the other variables.

5. 1. 2. Significance of CHF Location

The equations in section 5. 1. 1 can be used to analyze the effect of CHF location. For example, if we fix the pressure, flux shape, inlet condition, and mass velocity, equation 13 acquires the mathematical form $xy = C$. The results for a chosen set of conditions are shown in Figure 47. Note that equation 13 gives the same curve for the inlet peak and the outlet peak ($\phi_m / \phi_a = 1.94$), but it gives a separate curve for the uniform flux ($\phi_m / \phi_a = 1$). Equation 14 gives the average heat flux (abscissa) for the uniform and the inlet peak, while equation 15 gives the average heat flux for the outlet peak. Since the ordinate gives only the corresponding values of the integral, it is difficult to realize the significance of this figure. To overcome this problem, the ordinates have been transformed into length for their respective conditions, and the result is shown in Figure 48. Note that the inlet and outlet peak now have separate curves. This results from the fact that the integral for each flux shape is a unique function of L . The outlet peak CHF location occurs at 63.5 inches, and the inlet peak CHF location occurs at 36 inches. The uniform CHF is calculated to occur at 66.5 inches, which is slightly in error, but reasonable, since CHF was often indicated at 69 inches in the experiments. The curves from equation 13 are associated with the possible ranges for the CHF location. It is not difficult to fix practical limits along these curves and establish possible zones

of CHF. One limit for both curves is 72 inches, which is the terminus of the heated test section. The other limit of outlet peak curve is 54 inches, because no CHF has been observed upstream of the maximum heat flux location. The corresponding limit for the inlet peak is 18 inches, the location of maximum local heat flux for this shape. Assuming that the channel average heat flux and the CHF location must follow the line of equation 13, it is desirable that the CHF occur as far upstream as possible, since this increases the power capabilities of the channel. Unfortunately, the CHF location is a dependent variable, as is the CHF itself. Since the CHF location is not a controlled variable at the present time, we can only observe that when it is found to occur farther upstream, it is associated with higher channel power, other conditions being equal.

A casual look at the burnout location data shows some scatter. However, it is possible that this scatter represents deviations from an empirical curve showing trends in the data. Following this reasoning, it is believed that the preceding equations express data trends that might otherwise be obscured. Calculations of the integrated heat flux, the average burnout heat flux, and the burnout location are shown along with the experimental results for the cosine flux shape (test section 2) in Table 6. Results for all four flux shapes are given in reference 6, but results for the cosine shape are repeated here because it is the nonuniform flux shape tested in the annular test sections.

5.1.3. Extension of Empirical Equation to the Annular Results

Since the tubular test section had its entire perimeter heated, it is logical to test the empirical equation against the annular test section with its entire perimeter heated. Test section 9 was selected because it has a chopped cosine shape on one surface. The experimental data were plotted in Figures 49 through 57. As in the tubular work, the pressure and mass velocity were considered constant at their nominal values; thus interpolation provides the expected experimental results at inlet subcooling of 40, 110, and 170 Btu/lb. These experimental results are shown in Table 7 along with some calculated results for comparison. The first set of calculations used the chopped

cosine maximum-to-average ratio, which is 1.4. A comparison of these calculated values with the experimental values indicates that improved agreement is desired.

One idea for improving the agreement is to consider the nonuniform flux as being superimposed on the uniform heat flux. Further thought on this suggests that the average heat flux on each surface should be weighted according to the circumference of each surface. Since the circumference is proportional to the diameter, this weighting can be done according to the diameters. Following this procedure gives a maximum-to-average ratio of 1.252 for test section 9 when the average heat flux is the same for the two surfaces, as it is intended to be in this program. As shown in Table 7 a set of calculations was made with the maximum-to-average ratio of 1.252. At each condition the results using the 1.4 and 1.252 ratios were compared with the experimental values. The 1.252 ratio more often gave values of critical length and integrated heat flux that were closer to the experimental values. Thus, the superimposed maximum-to-average ratio improves the agreement between the experimental and the calculated values for the situation investigated here.

5. 1. 4. Saturated Length Concept for Correlation

The use of the computed saturated length (L_S) for correlating CHF data has been advanced by the authors of reference 9. This length is defined as the distance between the location of the CHF and the position of zero quality as determined from a steady-state energy balance calculation. The quantity that was correlated with L_S in reference 9 was q_S , the power being transferred by the surface associated with the length L_S . The plan here is to compare some of the present data with this concept, except that it is convenient to use the average heat flux (ϕ_S), instead of q_S ,¹⁰ over the length L_S .

5. 1. 4. 1. Assumed CHF Location

To use the saturated length method, the CHF location must be established by some independent means.¹⁰ If the heat flux is axially uniform, the location is considered to be at the exit end of the heated length. For nonuniform fluxes, the experimental locations

of CHF were tried but gave poor results. It was observed that the CHF often occurs in the vicinity of the maximum point of the integrated average heat flux curve. Therefore, this location was substituted for the experimental crisis locations (otherwise indicated) in the calculations of the saturated length. The integrated average heat flux curve is defined by equation 10 and illustrated in Figure 45, where the maximum appears at an abscissa of about 40%.

5.1.4.2. The ϕ_S and L_S Functional Relationship to Experimental Data

A heat balance function of prime interest here is the equation that defines L_S and its relation to ϕ_S :

$$L_S = \frac{(H - H_f) GA_f}{P_h \phi_S} \quad (16)$$

There is also a heat balance equation that gives the relationship between the inlet condition (H_{in}) and the enthalpy (H):

$$H = H_{in} + \frac{P_h L \phi_o}{GA_f} \quad (17)$$

Substituting this in equation 16, we have the ϕ_S versus L_S function transformed to handle the inlet enthalpy as a parameter:

$$L_S = L \left(\frac{\phi_o}{\phi_S} \right) - \frac{(H_f - H_{in}) GA_f}{\phi_S P_h} \quad (18)$$

If the heat flux is uniform, then

$$\frac{\phi_o}{\phi_S} = 1$$

and

$$L_S = L - \frac{(H_f - H_{in})GA_f}{\phi_S P_h} \quad (19)$$

One further convenience associated with the uniform flux is the fact that $\phi_S = \phi_a$ so that L_S is easily obtained from equation 19; the uniform heat flux coordinates are then computed for Figure 58 using the experimental CHF value of the average heat flux (ϕ_a). For the nonuniform fluxes a second relationship must be established between ϕ_S and L_S so that equation 18 can be solved. This is easily done, since we know the flux shape and experimental power for each CHF run, and the nonuniform heat flux coordinates are then computed for Figure 58.

The present program has given CHF data for a variety of pressures, flows, inlet conditions, and flux shapes. Using heat balance equations like those just described, ϕ_S and L_S are computed for each data point and the results are examined. These computations work well for experimental data because the enthalpy at the CHF location, the inlet condition, and the power (or average heat flux) for the CHF condition are known. It will be recalled that the CHF locations are assumed to be fixed for each flux shape at the maximum point of the integrated average heat flux curve. The distances from the inlet are 55 inches for the cosine flux shape, 28 inches for the inlet peak flux shape, and 67 inches for the outlet peak flux shape. It is desired to test the ϕ_S versus L_S concept as a means of compensating for flux shape in the correlation of CHF data. To accomplish this, groups of data from the four flux shapes are plotted at parametric values of mass velocity and pressure as shown in Figures 58, 59, and 60. From Figures 58 and 59 it is seen that the data line up fairly well at mass velocities of 0.5×10^6 and 1.5×10^6 lb/hr-ft². One can put mean lines through the data, as was done here, and use these as upper limits for the most probable predicted CHF. Or it would also be feasible to take the conservative approach and draw lines under each group of data to predict the prevention of CHF.

At a mass velocity of 2.5×10^6 lb/hr-ft² the scatter in Figure 60 seems to leave something to be desired. The

question arises as to whether it is better to use the experimental locations or to use the locations determined by the maximum of the integrated average, as was done in Figure 45. For comparison the data at 2.5×10^6 lb/hr-ft² and 1000 psia are shown in Figure 61, where the experimental lengths from the inlet to the CHF location are used. There is no improvement, and, as a matter of fact, the scatter appears worse. The points that go "astray" by falling so far below the others are points where differences between the assumed and experimentally indicated CHF locations are the greatest.

5.1.4.3. Heat Balance Functions

Equations 16 and 18 have been given as a model for computing the points in Figures 58, 59, and 60. These equations are used for additional study of the saturated length concept and its relation to constant outlet and constant inlet conditions. For example, if the enthalpy (H) at the assumed CHF location (section 5.1.4.1) is held constant at 1043 Btu/lb, then it is expedient to use equation 18 and compute ϕ_S as a function of L_S and show the resulting curve in Figure 62. It must be remembered that this is only a constant H curve and not a correlation of CHF; each value of H determines a separate curve, the mass velocity, pressure, and test section geometry being fixed. To illustrate this, a second curve is shown in Figure 62 where H is 800 Btu/lb.

The experimental values for the uniform flux are shown on Figure 62. It is interesting to note how they very nearly coincide with the heat balance curve. This characteristic creates an uncertainty in the task of predicting the ϕ_S when only the desired H is specified. However, such a curve supported by experimental points can be very useful if a second condition such as the inlet enthalpy is also considered. The curve generated by equation 19 for an H_{in} of 400 Btu/lb and a length of 72 inches is shown in Figure 62. This is a curve of constant inlet condition and increasing heat flux, sometimes called the "operating line" for a system. Note that this line intersects the line of constant enthalpy ($H = 1043$ Btu/lb) at a very definite point. This point represents the upper limit of operation at the given inlet condition, since the heat balance line ($H = 1043$ Btu/lb) lies close to the data points obtained from CHF experiments. Thus, it is seen that in

order to use this scheme for predicting CHF, two conditions must be specified.

This study can also be extended to the nonuniform flux conditions. It so happens that a heat balance line ($H = 800$ Btu/lb) passes through the data points for the nonuniform heat flux test section with the peak near the inlet. It will be recalled that the length to the CHF location (L) for this shape is the maximum point of the integrated average curve and is considered to occur 28 inches from the inlet. The heat balance curve for constant inlet conditions ($H_{in} = 400$ Btu/lb, $L = 28$ inches) intersects its companion curve at a ϕ_S of about 0.96×10^6 Btu/hr-ft².

5.1.4.4. Comparison With Other Results

The saturated length concept allows correlations developed from uniform heat flux data to be used to predict the critical heat flux for nonuniformly heated tubes provided that the crisis location is known or can be predicted. The coordinates $1/\phi_S$ versus L_S were selected for comparing the data with this concept, which can be used to represent the predictions of references 9 and 11. The advantage of these coordinates is that the resulting functions are linear when mass velocity, pressure, and diameter are held approximately constant for each plot.

Since both the uniform and nonuniform flux data from this program are correlated by the saturated length concept, it is sufficiently informative to show comparisons of the uniform flux data with other uniform flux data for test sections of similar diameter. A typical comparison with the data of references 4, 12, and 13 is shown in Figure 63 for a mass velocity of approximately 1.5×10^6 lb/hr-ft² at pressures of 1000, 1500, and 2000 psia. Comparisons at other mass velocities yield similar results, which indicate that the data from this program are in good agreement with data obtained by other investigators.

5.1.4.5. Boiling Regimes in Critical Heat Flux Testing

It is reasonable to expect that there is more than one mechanism for the forced convection boiling process since the thermodynamic quality at the location of the crisis can vary from

subcooled liquid to very nearly saturated vapor. Therefore, attempts have been made to separate data by boiling regimes for correlation purposes. For example, reference 14 separated critical heat flux data into two regimes: a low-velocity, high-quality regime, and a high-velocity regime. The authors of reference 13 separated their data into two regimes: a nucleate-boiling regime at negative and low qualities, and an annular-flow regime at higher qualities.

By examining uniform flux data from the literature, it was discovered that there are likely three, rather than two, separate regimes that affect the critical heat flux. The three boiling regimes are shown in Figure 64, which presents critical heat flux data at 1000 psia and a mass velocity of 3.0×10^6 lb/hr-ft². The data were obtained^{12, 15, 16} for tubular test sections of 0.375, 0.404, 0.426, and 0.4 inch inside diameter. Two transition points are observed in the data, one at a saturated length of 15 inches and the other at a saturated length of about 95 inches.

The data at saturated lengths less than about 15 inches are in the nucleate-boiling regime proposed in reference 13. At saturated lengths between 15 and 95 inches, the data are in the annular-flow boiling regime. This regime also corresponds to the reference 14 high-velocity regime. At saturated lengths greater than 95 inches, the data are in the low-velocity regime.

Similar plots of additional data from reference 11 indicate that the saturated length at the transition points depends on pressure, diameter, and mass velocity. Plots of $1/\phi_S$ versus L_S are useful for determining the transition points between boiling regimes.

The failure of the correlations of references 9 and 11 to predict accurately the critical heat flux data of this program can be largely explained by noting that data from all three regimes were used to develop the correlations.

5.2. Comparisons of Experimental Data With Correlations

The possession of new CHF data always brings up the question of how it compares with certain correlations. One interesting way of presenting such comparisons on a limited scale is to substitute the experimental conditions into various correlations and compute the CHF. Then

these predicted values of CHF are shown graphically along with the experimental results as in Figures 65 through 74. The designated figures are for four correlations^{9, 11, 17, 18} and four test sections at one pressure and two mass velocities. The correlations cited were developed from tubular data and contain a diameter function. Comparison with annular data suggests two ways of considering the diameter. The usual hydraulic equivalent diameter based on the wetted perimeter may be used:

$$D_W = \frac{4(\text{cross-section area})}{\text{wetted perimeter}}$$

However, the following equivalent diameter based on the heater perimeter may be applicable instead:

$$D_H = \frac{4(\text{cross-section area})}{\text{heated perimeter}}$$

Consideration of these two equivalent diameters effectively doubles the number of correlations when comparisons are made with annular test sections that have one surface heated and the other unheated.

Since Figures 65 through 74 represent only a small portion of the data, it is obvious that a continuation of such comparisons for all the data of this program would become tiresome and inconclusive. Some relief from this may be achieved by finding a method to give a measure of the agreement between a group of data and a correlation. Such a method is suggested by the statistical concepts of mean value and standard deviation, which readily lend themselves to programming for automatic data processing. Using the computer program written for this purpose, the data from the nine test sections have been compared with the burnout correlations from references 5, 9, 11, 17, and 18. The data from the annuli have been grouped in various ways for the comparisons discussed in the following section. For each group and correlation, the mean ratio of experimental-to-calculated heat flux and the standard deviation have been computed by

$$\bar{R} = \frac{\sum R}{N} \quad (20)$$

where

$$R = \frac{\text{experimental CHF}}{\text{predicted CHF}}$$

N = number of ratios

$\bar{R}$ = mean ratio

and

$$S \text{ (standard deviation)} = \sqrt{\frac{\sum (R - \bar{R})^2}{N - 1}} \quad (21)$$

The tubular results are shown in the topical report.⁶ The annular results are shown in Figures 75, 76, and 77. The agreement of a group of data with a specific correlation can be estimated by noting the proximity of the plotted point to coordinates 1.0 and 0. Perfect agreement between the data and a correlation would show a mean ratio of 1.0 and a standard deviation of 0.0. Some of the results could not be shown on the figures because the numbers were too divergent. These are shown in Table 8. The ranges of several of these equations are exceeded by the data produced in this program, but the data here in many respects fall in the range of interest for nuclear reactor applications. For this reason, it is informative to compare these data with proposed burnout criteria in order to determine whether ranges of the correlations can be extended.

5.2.1. Effect of Pressure in the Correlations

The plot of standard deviation versus mean ratio in Figure 75 shows how well the various correlations account for pressure in the CHF calculations for test section 5. The points for the correlation from reference 17 are well grouped, especially when the equivalent diameter is based on the heated perimeter. The points for the correlation from reference 5 are also well grouped, even though the distance from the coordinates (1.0 to 0.0) is greater than desired. Even though the correlation from reference 11 has sets of constants for the different pressures, it still fails to account for the pressure effect in this test section. As can be seen from Figure 75, the standard deviation remains reasonably low, but the mean ratio varies widely. In fact, for the heated perimeter case, the variation is so great that two of the

values are beyond the limits of Figure 75 and have to be shown in Table 8. The correlation from reference 9 has the worst scatter; the correlation from reference 18 has a scatter almost the same.

5.2.2. Effect of Flux Shape and Geometry

For each group and correlation, the mean ratio of experimental-to-calculated heat flux and the standard deviation have been computed as before, and the results are shown in Figure 76. Here, the data are grouped according to test section so that the point for a given test section and a given correlation includes all the pressures for that test section. The use of the heated perimeter improves the precision of the correlation from reference 17 by grouping the points more closely. On the other hand, the correlation from reference 5 is slightly hindered by the use of the heated perimeter. The correlation from reference 11 is made far worse by the use of the heated perimeter; in fact, one of the extreme points is beyond the limits of the graph and is shown in Table 8. The heated perimeter used in the correlation from reference 9 worsens the agreement with the data. One of the heated perimeter points is so scattered that it also must be shown in Table 8 instead of Figure 76. Finally, the correlation from reference 18 appears to be far worsened by the use of the heated perimeter.

5.2.3. Implicit Versus Explicit Comparisons

Whenever a CHF equation is originated, it is compared with various points of experimental data. Some CHF equations are difficult to compare properly with data points. An example is the following CHF correlation familiar to many:⁵

$$\phi = \frac{0.28 \times 10^6 \left(1 + \frac{G}{10^7}\right)^2}{\left(\frac{H}{10^3}\right)^{2.5} \exp 0.0012 \frac{L}{D}} \quad (22)$$

The enthalpy computed from the data can be substituted to obtain a solution for the CHF. This computed CHF can then be compared with the experimental heat flux in the ratio of experimental-to-calculated burnout

heat flux (ϕ_E/ϕ_C). The difficulty of comparing this equation to data in this manner can be illustrated by considering the equation

$$H = H_{in} + \frac{4L\phi}{DG} \quad (23)$$

This is a heat balance equation showing the relationship between the critical enthalpy and the CHF for round tubes. If H is the experimental enthalpy, then ϕ is the experimental CHF, which is usually different from the computed CHF obtained from equation 22. The computation process may be accomplished as follows: the experimental heat flux is substituted in the second equation, and the experimental enthalpy is computed. The latter is substituted in the first equation, which yields a calculated CHF. This is then compared with the experimental heat flux. Such practice appears somewhat inconsistent. Another procedure may be adopted: substitute the second equation into the first to give

$$\phi = \frac{0.28 \times 10^6 \left(1 + \frac{G}{10^7}\right)^2}{\left(H_{in} + \frac{4L\phi}{10^3}\right)^{2.5} \exp 0.0012 \frac{L}{D}} \quad (24)$$

This equation is an implicit function of the CHF; even though the CHF appears in two places, the equation can be solved. This computed CHF can then be compared with the experimental CHF.

Correlations that exhibit the characteristic just described are called implicit. Other examples of this type of equation are found in references 9 and 18. Other correlations do not involve the CHF in this implicit manner, but are functions that yield the predicted CHF explicitly. The result of implicit versus explicit comparisons of equations with data is shown in Figure 77. In most of the comparisons the implicit form shows better agreement with the data.

5.3. Spacer Effects in Annuli

The inner tube of the annulus is centered by three spacer pins in each of eight sets located at 18-inch intervals along the length of the test

section. The pins in each set are spaced at 120-degree intervals around the circumference of the tube. Figure 78 shows the position of the pins, and Figure 79 shows the details of the spacer pin design. This SS pin contains a cylindrical insert made of aluminum oxide.

One would certainly expect these spacers to affect the heat transfer rate and, consequently, the CHF. A check of Figures 18, 19, and 20 gives evidence that this is the case. Comparison of test section 7 (annulus with both sides heated equally) with test section 1 (tubular with flow inside) shows that in most situations the annulus gives the higher CHF.

5.3.1. Turbulence

One rather obvious explanation for the increased CHF is the increased turbulence due to the presence of the spacer pins. One theory¹⁹ assumes that, in the case where one wall of the annulus has no heat flux (or lower heat flux than the other), liquid film flow from the cool wall is diverted to the hot wall by the spacers. However, since test section 7 has the same heat flux on each surface, there should be no "cold film" flow to serve as a liquid source. This leads to the deduction that the pins may, indeed, divert liquid to the wall(s), but the source of the cooling liquid must, of necessity, be the bulk flow region between the two walls of the annulus. This possibility is mentioned in reference 19, and the experiments in this program seem to support it.

Data from another source¹⁹ qualitatively support the observation that spacers, in general, increase the CHF in annuli. In the case cited, only the inside surface was heated. One section was tested without spacers, and a second section with three sets of spacers was tested under similar conditions. Higher CHF's occurred in the channel with spacers.

There is the possibility that the pins create relatively "calm" zones upstream or downstream of their location. This could be the explanation for the lower CHF delivered by the annulus at the lowest mass velocity (0.5×10^6 lb/hr-ft²).

5.3.2. Critical Heat Flux Location

Whether or not the pins produce significant "calm" zones is open to question, but Figure 80 offers some evidence about CHF

location. When test section 5 was disassembled it was examined for useful information. One of the observations pertains to the question of CHF location with respect to spacers. Overheat apparently occurred upstream from the pins near station 11. The overheat is indicated by a blue crescent upstream of the pin position, which appears as an area of different shading in the black-and-white photograph (Figure 80). This supports the work of reference 19, which reports the possibility of critical conditions upstream from the spacers. The explanation is based on the turbulence, or the diversion of liquid from the cold to the hot surface by the spacer, which suppresses the CHF for a distance downstream from the spacer, so that a point just upstream from the spacer behaves as the end of a channel and allows the critical condition to occur.

Other evidence supports, but does not prove, the association of CHF with spacer pin location. In test section 5 during run 388 a single critical location was indicated at station 8, the segment that includes a set of spacer pins. Whether or not the condition occurred upstream or downstream of the spacers is not known, but association with the spacers is clearly indicated. However, Table A-5 shows that most of the CHF's on test section 5 occurred near the exit of the heated test section.

Test sections 8 and 9 had spacer pins and nonuniform axial heat fluxes. It is interesting to note that many CHF indications occurred at station 3 (45 inches from inlet) or station 6 (63 inches from inlet). Both of these segments include a set of spacers. This, again, indicates a tendency of the CHF to associate itself with the spacers although many CHF points occurred at the end of the channel and a few occurred between the spacer sets. Admittedly, the spacers complicate the correlation of the data. They provide realism, however, since most nuclear reactors have spacers or mechanical structures of some sort at intervals along the channels. The results of this program indicate that these obstructions are beneficial at high mass velocity, but the benefit may be reversed at low mass velocity (0.5×10^6 lb/hr-ft²).

5. 4. Fundamental Critical Heat Flux Study

5. 4. 1. Background Information

The deterioration of boiling heat transfer coefficients under certain conditions has been observed since 1934.^{20, 21} Since then, especially in the last decade, efforts to understand the phenomenon have lead to many studies and experiments. However, it still has not been adequately explained, nor can it be adequately predicted.

According to one popular theory, when steam production at a liquid-solid interface reaches a certain high rate, the solid is blanketed by a layer of steam since the steam cannot escape from the wall at a sufficient rate. This theory seems inadequate because it explains neither the suddenness with which this phenomenon sometimes occurs nor the stability of such a dry steam layer in highly turbulent channels at qualities well below 100%.

An effort to advance beyond the steam-blanket concept is offered in the proposed climbing-film theory.²² This theory is based on the existence of a liquid film adjacent to the heated wall of a channel. The CHF is produced by the breakup or the dryout of the film. This continuous film may exist, and one cannot dispute the assertion that its breakup would produce a heat transfer crisis. Granted this, the basic physical principle behind the phenomenon is still being sought.

The preceding theories recognize that the CHF occurs when the heat transfer rate suddenly begins to approach that of dry steam. This phenomenon can occur when the bulk condition of the fluid is near 100% quality, which is not surprising. On the other hand it can occur at very low qualities or even during bulk subcooling. This is the part of the problem that makes prediction and explanation difficult. Most indicated CHF points measured in laboratories have occurred in the presence of considerable amounts of liquid in the two-phase mixture. In fact, some observations have indicated that the crisis can occur and that the heat transfer conditions can continue to deteriorate as a function of time without any discernable change in the liquid content of the flowing fluid.²³ The apparent reason is that something causes the heated wall to prefer the vapor to the liquid. These observations indicate that CHF may be heavily dependent upon additional variables not usually considered

in burnout studies. If this is true, a study of CHF in the light of theories of interfacial phenomena is long overdue. In other words, the wettability of metals by liquids at high temperatures and pressures under conditions of heat and mass transfer should be studied seriously and carefully.

Studies of interfacial phenomena include several works covering conditions at atmospheric pressure and room temperature.^{24,25} Much study has been conducted in connection with spray-type insecticides, which must cling effectively to plants and bugs. Wetting in high-temperature and low-pressure systems has been studied in the field of metallurgy with respect to intermetallic bonding or welding.^{26,27} On the other hand, very little work has been done on the wettability of heated solid surfaces in contact with power transport liquids, such as water, at high temperatures and pressures. The three phases of the system to be studied are solid metal, liquid coolant, and vapor coolant; the two components are solid metal and fluid coolant.

5.4.2. Criterion for Measuring Wettability

One of the most common ways of designating the wettability of a solid by a liquid in the presence of vapor or gas is to quote the contact angle, illustrated by θ in Figure 81. The theory of wetting depends on the concept of surface energy, which for ideal systems can be computed from the equations of Gibbs²⁵ or Helmholtz.²⁴ These equations are not quoted here. For now, the equation of "wetting" or "nonwetting" is as follows:

$$\theta = \arccos \frac{F_{SV} - F_{SL}}{\gamma_{LV}} \quad (25)$$

where

θ = contact angle measured through the liquid between the tangent to the liquid and the plane of the solid at the solid-vapor-liquid intersection

F_{SV} = free energy of the solid-vapor interface

F_{SL} = free energy of the solid-liquid interface

γ_{LV} = surface tension at the liquid-vapor interface = free energy of the liquid-vapor interface

It is convenient to use the same kind of symbol for all of the free energies; hence equation 25 is often written as

$$\theta = \arccos \frac{\gamma_{SV} - \gamma_{SL}}{\gamma_{LV}} \quad (26)$$

If θ is 0 degrees, the solid is considered to be completely wetted. If 0 degrees $< \theta \leq 90$ degrees, the solid is considered by some authors to be "partially" wetted. If 90 degrees $< \theta \leq 180$ degrees, the solid is considered to be nonwetted. This equation is valid for θ over the range of 0 degrees $\leq \theta \leq 180$ degrees. If there is a transition from wetting to nonwetting in a system, the free energies must have certain limitations. For example,

$$|\gamma_{SV} - \gamma_{SL}| \leq \gamma_{LV} \quad (27)$$

If $\gamma_{SV} = \gamma_{SL}$, θ is 90 degrees. The problem is determining the various free energies. Values for γ_{LV} are the easiest to obtain. They have been published for many liquids, especially water, but where they have not, laboratory methods for measuring surface tension are readily available.

The difficulty in the application of this wetting theory is the calculation or measurement of γ_{SV} and γ_{SL} . There is some indication in the literature that these values are large. In considering the wetting of metal by liquid metals, Gilliland²⁶ used a γ_{SV} value of 1863 dynes/cm for beryllium. Taylor²⁷ quotes values of 1400 dynes/cm for gold and 1670 dynes/cm for copper. Therefore, iron or steel probably has a value near 2000 dynes/cm. This points to another difficulty. If the value is this large, only a low-percentage error is allowable in the study of the steel-water-steam system, because γ_{LV} for water ranges from about 80 dynes/cm at room temperature to zero at the critical temperature, and the difference between γ_{SV} and γ_{SL} must be less than γ_{LV} (according to equation 27). Obtaining an accurate difference between two large, close values can be difficult.

5.4.3. Study of Contact Angle Using Observed Effects

Without considering how these numbers might be obtained, investigating the feasible ranges of equation 26 is useful to determine whether boiling phenomena can possibly be due to changes in the free energy of interfaces. Of first interest are the trends of these values as a function of some variable, such as temperature. The study of the Leidenfrost effect²⁸ is related. Leidenfrost reported his work in 1756, but three modern sources of data on this subject are Gottfried,²⁸ Poppendiek,²⁹ and Borishansky.³⁰ The data by Borishansky are used here, since his paper presents the most complete information about water in the nucleate boiling regime, which precedes the regime of the Leidenfrost phenomenon as surface temperature increases.

Borishansky performed rather simple droplet vaporization experiments which yielded the results shown in Figure 82. The data were obtained by placing standard-sized, known-volume droplets on a heated metal surface having known temperatures greater than the boiling point. The lifetimes of the droplets were measured to give an indication of the rate of heat transfer from the plate to a droplet. Figure 82 shows the extremes of heat transfer rates experienced during boiling processes. At the left side of the figure, the rate of heat transfer is good; as the surface temperature increases, the rate improves until a minimum vaporization time is reached, corresponding to the best boiling heat transfer coefficient. As the surface temperature increases further, the droplet vaporization time increases to a maximum where the poorest heat transfer rate, corresponding to film boiling, occurs. The investigators quoted were most interested in film-boiling heat transfer, shown by the right-hand branch of the curve. Although this regime is not directly applicable to the present study, certain interesting calculations concerning the transition from nucleate boiling to film boiling can be accomplished.

First, a model is chosen to represent a droplet on a surface. Experience seems to support the notion that high boiling heat transfer rates exist only when the liquid can contact the heated surface. Consequently, the area of contact between a liquid droplet and the heated solid is quite important. The droplet is assumed to be a segment of a

sphere; this assumption is good if the volume is small. It is now possible to derive an expression for the contact area as a function of the contact angle and the volume of the droplet. Figure 83 shows a segment of a sphere having height Z and radius r . The volume of this spherical segment is given by

$$V = \frac{1}{3} \pi Z^2 (3r - Z) \quad (28)$$

From Figure 83,

$$Z = r(1 - \cos \theta), \text{ where } 0 \text{ degrees} \leq \theta \leq 180 \text{ degrees.} \quad (29)$$

Substituting equation 29 in equation 28 and solving for r gives

$$r = \left\{ \frac{3V}{\pi [3(1 - \cos \theta)^2 - (1 - \cos \theta)^3]} \right\}^{1/3} \quad (30)$$

The contact area is given by

$$A = \pi r^2 \sin^2 \theta, \text{ where } 0 \text{ degrees} \leq \theta \leq 180 \text{ degrees.} \quad (31)$$

Substituting equation 30 in equation 31 gives

$$A = \frac{\pi^{1/3} 3^{2/3} V^{2/3} \sin^2 \theta}{[3(1 - \cos \theta)^2 - (1 - \cos \theta)^3]^{2/3}} \quad (32)$$

Let

$$\frac{[3(1 - \cos \theta)^2 - (1 - \cos \theta)^3]^{2/3}}{\pi^{1/3} 3^{2/3} \sin^2 \theta} = R \quad (33)$$

Then,

$$A = \frac{V^{2/3}}{R} \quad (34)$$

If, during time increment Δt , the droplet volume decreases by increment ΔV , then

$$q'' A \Delta t = -\rho H_{fg} \Delta V$$

where

q'' = heat flux

ρ = liquid droplet density

H_{fg} = latent heat of vaporization

Recalling that A is a function of V and allowing Δt and ΔV to become very small,

$$q'' dt = -\rho H_{fg} R \frac{dV}{V^{2/3}} \quad (35)$$

Integrating over the time interval $0 \leq t \leq t_1$ and over the volume interval $V_1 \geq V \geq 0$, and solving for q'' , gives

$$q'' = \frac{3\rho H_{fg} R V_1^{1/3}}{t_1} \quad (36)$$

The heat transfer coefficient h for area A can be defined by

$$q'' = h \Delta T \quad (37)$$

where ΔT is the difference between the plate temperature and the droplet saturation temperature. Eliminating the heat flux from equations 36 and 37 gives

$$h = \left(\frac{3\rho H_{fg} V_1^{1/3}}{\Delta T t_1} \right) R \quad (38)$$

The data used contain no information about the contact angle. However, Borishansky³⁰ makes one observation that leads to some relative calculations to test the feasibility of the model. Concerning the nucleate

boiling portion of the curve (Figure 82 in the temperature range of 100 to 175 C) he states that the droplet spreads over an area equal to five times the projected area of the droplet. Assuming that the droplet is a sphere, the projected area is

$$A_p = \pi^{1/3} \left(\frac{3V}{4} \right)^{2/3} \quad (39)$$

The contact area for the spherical segment is

$$A = \frac{V^{2/3}}{R} \quad (34)$$

Therefore,

$$\frac{A}{A_p} = \frac{V^{2/3}}{R} \div \pi^{1/3} \left(\frac{3V}{4} \right)^{2/3} \quad (40)$$

and

$$\frac{A}{A_p} = 5 \quad (41)$$

Solving equations 40 and 41 gives

$$R = 0.1654$$

The most convenient solution for θ as a function of R is from a graph of R versus θ . Figure 84 indicates that θ is approximately 26 degrees. This seems to be a reasonable contact angle for water on a metal surface. If it is assumed that this contact angle is maintained along the left-hand branch of the curve in Figure 82 until the minimum vaporization time is reached, then the heat transfer coefficients can be computed with equation 38. The results of these calculations are shown in Table 9. The coefficient, 22,500 Btu/hr-ft², seems rather high, but it is considered attainable. McAdams³¹ quotes values in the range of 10,000 Btu/hr-ft². The validity of the higher coefficients in Table 9 is borne out by more computations with the assumed model.

Borishansky³⁰ states that, after the temperature of the plate is increased beyond that which produces the minimum vaporization time, the droplet begins to acquire a spheroidal shape; when the vaporization time is a maximum, the droplet shape is completely spheroidal. In this region of increasing vaporization time, one may assume that the heat transfer coefficient is constant and that the contact angle increases with increasing plate temperature. Using

$$h = 22,500 \text{ Btu/hr-ft}^2$$

equation 38 determines R and, indirectly, θ for data points between the minimum and the maximum vaporization times in Figure 82. These results are also shown in Table 9. Note that, for the maximum vaporization time,

$$\theta = 175 \text{ degrees}$$

which is close to the contact angle of 180 degrees for a perfectly spherical droplet.

5.4.4. Surface Factors in Critical Heat Flux

The experimental information from Borishansky gives support to the proposed model. It should be kept in mind, however, that the data suggesting the model and used to make the supporting calculations were taken at atmospheric pressure and in the presence of air. Unfortunately this tells nothing about vaporization at high pressures and in the exclusive presence of the liquid's own vapor. It is logical that such data would be very enlightening with respect to the fundamental CHF question. The several points of view regarding the importance of heat flux, surface temperature, and bulk fluid condition have not yet been resolved. For example, a study of some of the individual data runs of this program seems to indicate that some physical principles may have been overlooked in current efforts to correlate CHF. The most interesting test section from this viewpoint is test section 3 (tube with peak near inlet). The most striking aspect is the range of heat fluxes present at several indicated CHF locations during

a given run. Table 10 shows these data for three selected runs. Run 265 had a flux as high as 0.688×10^6 Btu/hr-ft² without any indication that it was critical. Farther toward the end of the channel, where the flux dropped to 0.426×10^6 , the critical condition was indicated. Furthermore, it was indicated the rest of the way to the end of the channel, where the heat flux decreased by a factor of 3. Run 279 had the critical condition at 0.304×10^6 and again at 0.102×10^6 , but no critical condition occurred in between. Run 259 had the critical condition at 0.554×10^6 and 0.383×10^6 , but failed to show it at higher or lower heat fluxes. If these indications are correct, then something besides geometry, pressure, flow, heat flux, and fluid enthalpy ought to be considered in CHF theory. Droplet vaporization studies and the Leidenfrost effect suggest that some kind of surface phenomenon or interfacial phenomenon is the missing link. Fundamental surface energy measurements would be useful and extremely interesting from this viewpoint, but the acquisition of accurate values for these numbers would probably be very difficult, as discussed earlier. Since this procedure appears unfeasible, another attack on this problem is suggested. This involves the observable effects of the surface phenomenon that alter the boiling heat transfer rates. Water droplet vaporization experiments in a steam atmosphere at high pressures would yield such information. Attempts to measure the contact angles are also recommended. The range of pressures should run from subatmospheric to the critical pressure in order to be applicable to space age equipment and to modern steam production plants.

Table 4. Tabulated Parametric Observations

ΔH_{si} , Btu/lb	P, psia	G, lb/hr-ft ² $\times 10^{-6}$	Integrated avg heat flux, Btu/hr-ft ² $\times 10^{-6}$				Local heat flux, Btu/hr-ft ² $\times 10^{-6}$			
			Flux shape(a)							
			1	3	2	4	1	3	2	4
40	1000	0.5	0.43	0.43	0.42	0.39	0.43	0.16	0.17	0.36
		1.5	.61	.67	.55	.47	.61	.33	.22	.53
		2.5	.65	.67	.59	.46	.65	.33	.39	.43
	1500	0.5	.28	.28	.28	.27	.28	.10	.11	.15
		1.5	.39	.37	.38	.32	.39	.13	.24	.26
		2.5	.42	.45	.39	.33	.42	.17	.15	.28
	2000	0.5	.19	.20	.18	.17	.19	.07	.12	.23
		1.5	.27	.32	.27	.23	.27	.12	.18	.34
		2.5	.40	.55	.41	.31	.40	.43	.35	.45
110	1000	0.5	.47	.47	.47	.43	.47	.17	.19	.40
		1.5	.69	.75	.62	.50	.69	.33	.25	.28
		2.5	.75	.91	.69	.56	.75	.51	.28	.52
	1500	0.5	.33	.32	.32	.30	.33	.11	.12	.17
		1.5	.47	.52	.46	.39	.47	.19	.18	.21
		2.5	.56	.81	.59	.50	.56	.42	.23	.40
	2000	0.5	.23	.36	.22	.19	.23	.28	.15	.27
		1.5	.39	.57	.41	.33	.39	.38	.27	.48
		2.5	.58	0.89	.60	.47	.58	.81	.38	.68
170	1000	0.5	.51	0.52	.51	.46	.51	.18	.21	.43
		1.5	.76	0.97	.71	.57	.76	.56	.28	.50
		2.5	.84	1.18	.81	.71	.84	.68	.33	.67
	1500	0.5	.36	0.37	.36	.33	.36	.13	.14	.25
		1.5	.57	0.80	.57	.49	.57	.40	.23	.39
		2.5	.74	1.18	.77	.64	.74	0.87	.31	.83
	2000	0.5	.25	0.31	.27	.22	.25	0.11	.18	.32
		1.5	.49	0.79	.53	.41	.49	0.65	.35	.60
		2.5	0.74	1.14	0.79	0.62	0.74	1.28	0.53	0.90

- (a) 1 Uniform
3 Peak near inlet
2 Chopped cosine
4 Peak near exit

Table 5. Correlating Variables

ΔH_{si} , Btu/lb	P, psia	G, lb/hr-ft ² $\times 10^{-6}$	Integrated heat flux, Btu-in./hr-ft ² $\times 10^{-6}$				Length to burnout, inches			
			Flux shape(a)							
			1	3	2	4	1	3	2	4
40	1000	0.5	30	30	29	26	69	69	69	67.5
		1.5	42	28	38	31	69	42	69	65
		2.5	45	28	37	31	69	42	63	67.5
	1500	0.5	19	19	19	19	69	69	69	70.5
		1.5	27	23	23	22	69	61	61	69
		2.5	29	23	27	22	69	51	69	68
	2000	0.5	13	11	11	11	69	67	63	63
		1.5	19	16	17	14	69	50	63	63
		2.5	28	18	23	20	69	33	57	63
	1000	0.5	32	32	32	29	69	69	69	67.5
		1.5	48	49	43	35	69	65	69	70.5
		2.5	52	36	48	38	69	40	69	67.5
110	1500	0.5	23	22	22	21	69	69	69	70.5
		1.5	32	30	32	27	69	57	69	70.5
		2.5	39	35	41	34	69	43	69	68
	2000	0.5	16	13	14	12	69	33	63	63
		1.5	27	22	26	21	69	38	63	63
		2.5	40	27	38	30	69	30	63	63
170	1000	0.5	35	36	35	31	69	69	69	67.5
		1.5	52	37	49	38	69	38	69	67.5
		2.5	58	46	56	48	69	39	69	67.5
	1500	0.5	25	26	25	22	69	69	69	68
		1.5	39	32	39	33	69	40	69	68
		2.5	51	40	53	41	69	34	69	64
	2000	0.5	17	20	17	14	69	63	63	63
		1.5	34	26	33	26	69	33	63	63
		2.5	51	31	50	39	69	27	63	63

- (a) 1 Uniform
 3 Peak near inlet
 2 Chopped cosine
 4 Peak near exit

Table 6. Data Trends From Correlation and Experiment for
Tubular Test Section 2 (Chopped Cosine)

ΔH_{si} , Btu/lb	P, psia	G, lb/hr-ft ² $\times 10^{-6}$	Calculated			Experiment		
			Integrated heat flux, Btu-in./hr- ft ² $\times 10^{-6}$	Avg heat flux, Btu/hr-ft ² $\times 10^{-6}$	Length to burnout, inches	Integrated heat flux, Btu-in./hr- ft ² $\times 10^{-6}$	Avg heat flux, Btu/hr-ft ² $\times 10^{-6}$	Length to burnout, inches
40	1000	0.5	30.4	0.440	66	29	0.42	69
		1.5	33.5	.497	63	38	.55	69
		2.5	36.7	.554	61	37	.57	63
	1500	0.5	21.0	.306	65	19	.27	69
		1.5	25.9	.389	62	23	.36	61
		2.5	30.8	.471	60	27	.39	69
	2000	0.5	11.7	.173	63	11	.19	63
		1.5	18.3	.280	60	17	.26	63
		2.5	24.9	.388	59	23	.39	57
	110	0.5	33.5	.487	65	32	.47	69
		1.5	40.1	.606	62	43	.62	69
		2.5	46.8	.726	59	48	.67	69
	1500	0.5	24.1	.353	64	22	.32	69
		1.5	32.5	.498	60	32	.47	69
		2.5	40.9	.643	58	41	.59	69
	2000	0.5	14.7	.220	63	14	.23	63
		1.5	24.9	.390	59	26	.40	63
		2.5	35.1	.560	58	38	.58	63
	170	0.5	36.1	.527	65	35	.51	69
		1.5	45.8	.700	60	49	.69	69
		2.5	55.5	.873	58	56	.81	69
	1500	0.5	26.8	.394	64	25	.36	69
		1.5	38.2	.592	59	39	.58	69
		2.5	49.6	.790	58	53	.76	69
	2000	0.5	17.4	.260	62	17	.27	63
		1.5	30.6	.484	58	33	.52	63
		2.5	43.8	0.707	57	50	0.75	63

Table 7. Data Trends From Correlation and Experiment for Annular Test Section 9 (Cosine Outside, Uniform Inside)

ΔH_{si} , Btu/lb	P, psig	G, lb/hr-ft ² $\times 10^{-6}$	Calculated, $\phi_m/\phi_a = 1.4$			Calculated, $\phi_m/\phi_a = 1.252$			Experiment		
			Integrated heat flux, Btu-in./hr- ft ² $\times 10^{-6}$	Avg heat flux, Btu/hr-ft ² $\times 10^{-6}$	Critical length, inches	Integrated heat flux, Btu-in./hr- ft ² $\times 10^{-6}$	Avg heat flux, Btu/hr-ft ² $\times 10^{-6}$	Critical length, inches	Integrated heat flux, Btu-in./hr- ft ² $\times 10^{-6}$	Avg heat flux, Btu/hr-ft ² $\times 10^{-6}$	Critical length, inches
40	1000	0.5	30.4	0.440	66	31.0	0.440	70	24	0.36	69
		1.5	33.5	.497	63	34.7	.497	69	38	.57	63
		2.5	36.7	.554	61	38.5	.554	68	43	.63	63
	1500	0.5	21.0	.306	65	21.6	.306	70	21	.32	63
		1.5	25.9	.389	62	27.1	.389	69	27	.41	63
		2.5	30.8	.471	60	32.6	.471	68	33	.49	63
	2000	0.5	11.7	.173	63	12.2	.173	70	14	.21	64
		1.5	18.3	.280	60	19.5	.280	68	18	.37	45
		2.5	24.9	.388	59	26.8	.388	67	33	.47	69
110	1000	0.5	33.5	.487	65	34.0	.487	69	29	.42	69
		1.5	40.1	.606	62	41.3	.606	66	45	.67	63
		2.5	46.8	.726	59	48.6	.726	65	52	.76	63
	1500	0.5	24.1	.353	64	24.7	.353	69	23	.35	63
		1.5	32.5	.498	60	33.7	.498	66	35	.52	63
		2.5	40.9	.643	58	42.8	.643	64	44	.65	63
	2000	0.5	14.7	.220	63	15.3	.220	68	18	.26	69
		1.5	24.9	.390	59	26.1	.390	65	24	.46	48
		2.5	35.1	.560	58	36.9	.560	63	42	.61	67
170	1000	0.5	36.1	.527	65	36.7	.527	68	34	.48	69
		1.5	45.8	.700	60	47.0	.700	65	52	.77	63
		2.5	55.5	.873	58	57.3	.873	63	60	.90	63
	1500	0.5	26.8	.394	64	27.3	.394	68	25	.37	63
		1.5	38.2	.592	59	39.4	.592	64	42	.62	63
		2.5	49.6	.790	58	51.4	.790	62	53	.78	63
	2000	0.5	17.4	.260	62	17.9	.260	67	20	.30	65
		1.5	30.6	.484	58	31.8	.484	63	34	.54	59
		2.5	43.8	0.707	57	45.6	0.707	62	49	0.72	63

Table 8. Critical Heat Flux Equations Compared With Data

Test section	Equation from ref	Pressure, psia	Explicit calculation			
			Wetted perimeter		Heated perimeter	
			Mean ratio	Standard deviation	Mean ratio	Standard deviation
5. Uniform inside	11	2000	--	--	5.7113	11.359
	11	2200	--	--	5.4122	49.863
	9	1000	--	--	2.5623	0.637
	9	1500	--	--	2.6200	0.574
	9	2000	--	--	2.7250	0.527
	--	2200	--	--	3.2656	0.906
	11	Variable	--	--	3.3726	28.930
	9	Variable	--	--	2.8407	0.762
7. Uniform both sides	18	Variable	0.5186	1.3053	--	--

Table 9. Contact Angles and Heat Transfer Coefficients

ΔT , F	t, sec	R	θ , degrees	h, Btu/hr-ft ²	Drop shape
34	12.2	0.1654	26	2,930
43	8.0	.1654	26	3,540	
50	4.2	.1654	26	5,790	
59	3.0	.1654	26	6,860	
65	1.8	.1654	26	10,400	
72	1.6	.1654	26	10,600	
76	0.8	.1654	26	20,000	
90	0.6	.1654	26	22,500	
124	1.6	0.608	98	22,500
126	2.6	1.004	121	22,500	
178	9.0	4.89	156	22,500	
184	10.0	5.62	158	22,500	
214	22.0	14.05	166	22,500	
259	135.4	107.1	175	22,500

Table 10. Examples of Local Critical Heat Flux Occurrences

Run No.	Inlet enthalpy, Btu/lb	Pressure, psia	Mass velocity, lb/hr-ft ² × 10 ⁻⁶	Length, in.	Local heat flux, Btu/hr-ft ² × 10 ⁻⁶
265	638.3	2000	2.52	25	0.688
				27	.581
				33	.426 (CHF)
				39	.296 (CHF)
				45	.222 (CHF)
				51	.180 (CHF)
				57	.155 (CHF)
				63	.145 (CHF)
				69	0.139 (CHF)
279	544.2	1995	0.51	33	0.304 (CHF)
				39	.210
				45	.156
				51	.128
				57	.110
				63	.102 (CHF)
				69	0.098 (CHF)
259	533.7	2000	1.50	25	0.888
				27	.753
				33	.554 (CHF)
				39	.383 (CHF)
				45	.286
				51	.235
				57	.201
				63	.186
				69	0.179

Figure 45. Heat Flux Distribution of Shape 3

Figure 46. Critical Heat Fluxes and Locations

Figure 47. Channel Power as a Function of Integrated Heat Flux, Expressed as Average Heat Flux Vs the Integral

Figure 48. Channel Power as a Function of Length to CHF, Expressed as Average Heat Flux Vs Length

Figure 49. Critical Heat Fluxes and Locations at 0.5×10^6 lb/hr-ft² and 1000 psia

Figure 50. Critical Heat Fluxes and Locations at 1.5×10^6 lb/hr-ft² and 1000 psia

Figure 51. Critical Heat Fluxes and Locations at 2.5×10^6 lb/hr-ft² and 1000 psia

Figure 52. Critical Heat Fluxes and Locations at 0.5×10^6 lb/hr-ft² and 1500 psia

Figure 53. Critical Heat Fluxes and Locations at 1.5×10^6 lb/hr-ft² and 1500 psia

Figure 54. Critical Heat Fluxes and Locations at 2.5×10^6 lb/hr-ft² and 1500 psia

Figure 55. Critical Heat Fluxes and Locations at 0.5×10^6 lb/hr-ft² and 2000 psia

Figure 56. Critical Heat Fluxes and Locations at 1.5×10^6 lb/hr-ft² and 2000 psia

Figure 57. Critical Heat Fluxes and Locations at 2.5×10^6 lb/hr-ft² and 2000 psia

Figure 58. ϕ_S as a Function of Saturated Length ($G = 0.5 \times 10^6$)

Figure 59. ϕ_S as a Function of Saturated Length ($G = 1.5 \times 10^6$)

Figure 60. ϕ_S as a Function of Saturated Length ($G = 2.5 \times 10^6$)

Figure 61. ϕ_S - L_S Plot Using Experimental CHF Locations

Figure 62. ϕ_S - L_S Plots Showing Heat Balance Functions

Figure 63. $1/\phi_S$ as a Function of Saturated Length ($G = 1.5 \times 10^6$)

Figure 64. $1/\phi_S$ as a Function of Saturated Length ($G = 3.0 \times 10^6$
Boiling Regimes

Figure 65. Tube and Annulus Compared to Equations - Full Perimeter Heated, 2000 psia, 2.5×10^6 lb/hr-ft²

Figure 66. Tube and Annulus Compared to Equations - Full Perimeter Heated, 2000 psia, 0.5×10^6 lb/hr-ft²

Figure 67. Uniform Annulus Results Compared to Equations -
 Inside Heated, 2000 psia, 2.5×10^6 lb/hr-ft², Wetted
 Perimeter

Figure 68. Uniform Annulus Results Compared to Equations -
Inside Heated, 2000 psia, 2.5×10^6 lb/hr-ft², Heated
Perimeter

Figure 69. Uniform Annulus Results Compared to Equations -
Inside Heated, 2000 psia, 0.5×10^6 lb/hr-ft², Wetted
Perimeter

Figure 70. Uniform Annulus Results Compared to Equations -
Inside Heated, 2000 psia, 0.5×10^6 lb/hr-ft², Heated
Perimeter

Figure 71. Uniform Annulus Results Compared to Equations -
Outside Heated, 2000 psia, 2.5×10^6 lb/hr-ft², Wetted
Perimeter

Figure 72. Uniform Annulus Results Compared to Equations - Outside Heated, 2000 psia, 2.5×10^6 lb/hr-ft², Heated Perimeter

Figure 73. Uniform Annulus Results Compared to Equations -
Outside Heated, 2000 psia, 0.5×10^6 lb/hr-ft², Wetted
Perimeter

Figure 74. Uniform Annulus Results Compared to Equations - Outside Heated, 2000 psia, 0.5×10^6 lb/hr-ft², Heated Perimeter

Figure 75. Explicit Comparisons of Data From Test Section 5
With Correlations

Equivalent diam*	Equation from reference									
	17		5		11		9		18	
	W	H	W	H	W	H	W	H	W	H
Pressure, psia										
1000	○	●	△	▲	□	■	◇		▽	▼
1500	○	●	△	▲	□	■	◇		▽	▼
2000	○	●	△	▲	□		◇		▽	▼
2200	○	●	△	▲	□		◇		▽	▼

*W is based on wetted perimeter; H is based on heated perimeter.

Figure 76. Explicit Comparisons of Data From Test Sections 5, 6, and 8 With Correlations

Equivalent diam*	Equation from reference									
	17		5		11		9		18	
	W	H	W	H	W	H	W	H	W	H
Test section										
5. Uniform inside	○	●	△	▲	□	■	◇	◆	▽	▼
6. Uniform outside	○	●	△	▲	□	■	◇	◆	▽	▼
8. Cosine outside	○	●	△	▲	□	■	◇	◆	▽	▼

* W is based on wetted perimeter; H is based on heated perimeter.

Figure 77. Implicit Vs Explicit Comparisons of Correlations With Data

Equivalent diam*	Explicit equations from reference				Implicit equations from reference			
	5		9		5		9	
	W	H	W	H	W	H	W	H
Test section								
5. Uniform inside	○	□	△		●	■	▲	◆
6. Uniform outside	○	□	△	◇	●	■	▲	◆
7. Uniform both sides	○		△		●		▲	
8. Cosine outside	○	□	△	◇	●	■	▲	◆
9. Cosine outside, uniform inside	○		△		●		▲	

*W is based on wetted perimeter; H is based on heated perimeter.

Figure 78. Annular Test Section Detail

Figure 79. Detail of Annular Test Section Spacer Pins

Figure 80. Overheat Upstream of Spacer Pin

Flow →

Figure 81. Contact Angle and Surface Forces

Figure 82. Droplet Vaporization Data

Figure 83. Droplet Model as Spherical Segment

Figure 84. Plot of R as a Function of θ

6. CONCLUSIONS AND RESULTS

6.1. General

A. The objective of obtaining critical heat flux data from tubular and annular test sections with nonuniform axial heating has been achieved.

B. Methods of correlating the data have been developed, and the data are compared with previous correlations.

6.2. Specific

A. Comparison of the data from this program with that from other sources at comparable conditions (section 4.4) shows good agreement. Data from still other sources are in good agreement with the data from this program when used in illustrations of correlation techniques (section 5.1.4.4).

B. When the system concept of plotting average heat flux versus inlet subcooling is used, the following results are apparent:

1. The inlet peak and cosine flux shapes in tubes delivered channel power comparable to that of the uniform flux except at 1000 psia and at the two higher mass velocities (section 4.3.1).

2. The outlet peak in the tube exhibited the lowest capability in all cases (section 4.3.1).

3. The data from the uniform flux test sections exhibit the highest CHF in the annulus with only the inside heated. Next lower in order of heat flux is the annulus with only the outside heated. Next comes the annulus with both sides heated, and then the tube, except at 1000 psia, where the annulus is lowest (section 4.2.2).

4. The data from the nonuniform annuli indicate that the annulus with only the outer surface heated produces the highest average heat flux. The next highest flux is produced by the annulus with both surfaces

heated, except at 1000 psia and the lowest mass velocity, (section 4.3.1).

C. When the local conditions concept of plotting local CHF versus computed quality at the location is used, the following results are observed:

1. The uniform flux shape in tubes gives the highest CHF at constant quality; the relative rank of the other flux shapes is somewhat mixed (section 4.3.2).

2. In most cases the cosine tube shows lower CHF at constant quality than do the nonuniform annuli. This reverse of the effect observed in uniform fluxes appears to exist because local conditions are plotted (section 4.3.2).

D. The study of CHF location has produced the following observations:

1. For test sections 8 and 9 the thermocouples and the burn-out detector were in agreement on crisis indications and locations for 71% of the runs. The other 29% displayed lack of agreement, but not necessarily contradiction (section 4.5.2).

2. The CHF location was not a controllable variable, but when it was found to occur farther upstream, it was associated with higher channel power (section 5.1.2).

3. At one set of conditions it was shown that an equation representing uniform data predicted a channel power 22% higher than that of a corresponding equation representing the outlet peak flux shape (section 5.1.2). This method uses system conditions, but local conditions are taken into account by correlating experimental CHF locations.

E. The saturated length concept offers a promising method for correlating CHF data (section 5.1.4).

F. The use of surface energy concepts offers a possibility of correlating CHF conditions from the fundamental viewpoint. This exploratory work is supported by data in the literature (section 5.4.1).

G. Additional detailed conclusions are as follows:

1. Some CHF correlations can be considered as either explicit or implicit functions of heat flux. The implicit form is usually in better agreement with the data (section 5.2.3).
2. Spacers used in the annular test sections appear to affect the CHF, increasing channel power except at low mass velocity (section 5.3.1).

7. RECOMMENDATIONS

1. Additional experience with nonuniform fluxes is recommended, but the emphasis should be on the CHF locations and their predictability. This program, just completed, gives ample background for planning an additional program.

2. In addition to the study of the effects resulting from non-uniform heat fluxes, more-fundamental experiments related to other phenomena not now considered in CHF correlations are recommended. Surface energies and other interfacial phenomena observed in droplet vaporization are important in this work. Therefore, water droplet vaporization experiments in a steam atmosphere at high pressures are recommended.

APPENDIX A

Tables A-1 Through A-4

Tubular Test Sections — Tabulation
of Results

Tables A-5 Through A-9

Annular Test Sections — Tabulation
of Results

Definition of Symbols Used in Tables

DNB	0 or I indicates the station number at which DNB occurred. 0 on left side of column indicates DNB on <u>tubular test section</u> or <u>outside tube</u> of annular test section. I on right side of column indicates DNB on <u>inside tube</u> of annular test section.
P	Test section outlet pressure, psia.
ΔP	Total test section pressure drop, psid.
G	Test section mass velocity, lb/hr-ft ² .
KW	Net electrical power input to the test section, kilowatts.
Sta. No.	Location on test section for which local operating conditions are calculated.
ΔT_s	Fluid subcooling at center of station number indicated, degrees F.
h	Fluid enthalpy at center of station number indicated, Btu/lb.
x	Steam quality, by weight, at center of station number indicated, %.
V_m	Fluid mixture velocity at center of station number indicated (assuming zero slip), ft/sec.
$\phi_{1,o}$	Local heat input rate at station number indicated, for <u>tubular test sections</u> and <u>outside tube</u> in annular test sections, Btu/hr-ft ² .
ϕ_o	Integrated average heat input rate from test section inlet to center of station number indicated, for <u>tubular test sections</u> and <u>outside tube</u> in annular test sections, Btu/hr-ft ² .
$\phi_{1,i}$	Local heat input rate at station number indicated, for inside tube in annular test section, Btu/hr-ft ² .
ϕ_i	Integrated average heat input rate from test section inlet to center of station number indicated for inside tube in annular test section, Btu/hr-ft ² .

Table A-1. Data From Test Section 1
(Uniform)

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
4		5- 4-64	15:26	1015	15.30	2.528	130.9	INLET	26.1	512.2	-5.02	14.7				
	0							12	.0	666.7	19.19	71.4	.638	.638		
	0							EXIT	.0	675.5	20.24	74.4		.638		
5		5- 4-64	15:36	1015	15.30	2.528	130.9	INLET	29.4	508.1	-5.66	14.6				
	0							12	.0	664.6	18.55	69.5	.638	.638		
	0							EXIT	.0	671.4	19.60	72.6		.638		
12		5- 5-64	12:17	1000		1.504	119.9	INLET	19.5	518.1	-3.74	8.8				
	0							12	.0	758.9	33.34	68.1	.585	.585		
	0							EXIT	.0	769.4	34.96	71.0		.585		
16		5- 5-64	16:14	1000	1.27	.502	85.1	INLET	25.2	511.1	-4.81	2.9				
	0							12	.0	1024.6	74.25	46.9	.406	.416		
	0							EXIT	.0	1046.4	77.61	48.9		.415		
18		5- 6-64	13:30	1000	7.93	1.528	129.8	INLET	49.4	482.0	-9.30	8.6				
	0							12	.0	738.9	30.25	63.6	.632	.633		
	0							EXIT	.0	750.0	31.97	66.7		.633		
20		5- 6-64	15:22	1000	12.05	2.491	141.8	INLET	55.4	475.0	-10.38	13.9				
	0							12	.0	646.9	16.10	62.2	.706	.691		
	0							EXIT	.0	654.6	17.27	65.6		.692		
23		5- 7-64	11:12	995	1.36	.513	93.4	INLET	59.7	469.4	-11.10	2.9				
	0							12	.0	1019.5	73.48	47.8	.448	.456		
	0							EXIT	.0	1043.0	77.09	50.0		.455		
25		5- 7-64	14:15	1000		.506	100.0	INLET	107.4	416.2	-19.43	2.7				
	0							12	.0	1013.9	72.60	46.3	.486	.488		
	0							EXIT	.0	1039.7	76.58	48.6		.487		
28		5- 7-64	15:43	1005		1.517	147.6	INLET	102.4	422.5	-18.61	8.1				
	0							12	.0	716.6	26.75	56.6	.713	.720		
	0							EXIT	.0	729.3	28.71	60.1		.720		
32		5- 8-64	15:41	1005	8.79	2.495	155.2	INLET	100.0	425.2	-18.20	13.4				
	0							12	.0	612.7	10.73	46.3	.793	.755		
	0							EXIT	.0	621.3	12.05	50.2		.757		
35		5-11-64	11:24	1010		1.428	153.5	INLET	146.2	375.3	-26.03	7.4				
	0							12	.0	700.3	24.15	48.8	.741	.749		
	0							EXIT	.0	714.3	26.31	52.3		.749		
41		5-11-64	15:57	1000	6.98	2.461	173.5	INLET	145.2	375.2	-25.74	12.7				
	0							12	.0	588.3	7.06	35.2	.845	.846		
	0							EXIT	.0	597.5	8.49	39.4		.846		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{ij}}{10^6}$	$\frac{\phi_i}{10^6}$
45		5-18-64	13156	1000	6.64	2.468	172.6	INLET	152.3	367.5	-26.93	12.6				
								1	143.9	376.6	-25.53	12.7	.829	.829		
								2	127.0	394.8	-22.73	12.9	.843	.832		
								3	110.1	413.3	-19.88	13.1	.845	.838		
								4	93.8	431.3	-17.10	13.3	.846	.835		
								5	77.1	450.1	-14.21	13.5	.848	.841		
								6	61.0	468.6	-11.36	13.7	.843	.842		
								7	45.5	486.7	-8.98	13.9	.848	.839		
								8	29.8	505.5	-5.68	14.2	.845	.842		
								9	14.7	524.0	-2.84	14.5	.841	.843		
								10	.0	542.4	-.00	14.8	.845	.843		
								11	.0	560.5	2.78	22.9	.843	.842		
	0							12	.0	579.1	5.66	31.3	.824	.843		
	0							EXIT	.0	588.1	7.04	35.3		.842		
49		5-19-64	11155	1002	1.31	.506	106.3	INLET	157.5	362.3	-27.80	2.6				
	0							12	.0	997.9	70.14	44.7	.509	.519		
	0							EXIT	.0	1025.0	74.31	47.2		.519		
52		5-19-64	14149	1502		.505	76.1	INLET	155.6	420.6	-34.41	2.7				
	0							12	.0	875.8	47.47	20.1	.361	.371		
	0							EXIT	.0	895.0	50.94	21.4		.371		
56		5-20-64	11152	1502	2.22	1.513	123.1	INLET	146.8	430.2	-32.68	8.1				
	0							12	.0	676.2	11.58	22.2	.590	.600		
	0							EXIT	.0	686.7	13.47	24.2		.600		
59		5-20-64	15149	1495	4.40	2.513	164.5	INLET	154.8	420.8	-34.13	13.4				
	0							12	.0	618.8	1.40	18.9	.782	.803		
	0							EXIT	.0	627.2	2.91	21.9		.802		
64		5-21-64	13156	1500	4.85	2.505	133.6	INLET	111.9	469.4	-25.57	13.9				
	0							12	.0	630.6	3.41	22.4	.645	.652		
	0							EXIT	.0	637.5	4.66	24.6		.652		
66		5-22-64	10136	1503		.503	69.8	INLET	111.1	470.6	-25.44	2.8				
	0							12	.0	829.8	50.09	20.9	.338	.340		
	0							EXIT	.0	907.9	53.25	22.1		.340		
71		5-22-64	14125	1495	1.09	1.496	103.1	INLET	105.5	476.2	-24.18	8.3				
	0							12	.0	684.6	13.22	23.7	.496	.503		
	0							EXIT	.0	693.6	14.83	25.4		.503		
73		5-25-64	10116	1502		.502	61.3	INLET	59.1	533.1	-14.17	3.0				
	0							12	.0	902.0	52.19	21.7	.297	.299		
	0							EXIT	.0	917.9	55.05	22.7		.299		
75		5-25-64	12138	1501	2.90	1.487	88.0	INLET	53.6	539.8	-12.93	8.9				
	0							12	.0	718.8	19.26	29.9	.422	.430		
	0							EXIT	.0	726.5	20.64	31.3		.429		
78		5-25-64	15101	1503	5.48	2.450	100.2	INLET	55.0	538.3	-13.25	14.6				
	0							12	.0	661.8	8.97	31.4	.492	.488		
	0							EXIT	.0	667.3	9.95	33.1		.488		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
81		5-26-64	11:06	1502		.508	58.8	INLET	27.7	573.6	-6.87	3.1				
	n							12	.0	919.1	55.27	23.0	.277	.283		
	o							EXIT	.0	933.8	57.91	23.9		.283		
84		5-26-64	12:25	1509	3.35	1.505	82.4	INLET	26.6	575.8	-6.65	5.4				
	n							12	.0	741.5	23.21	34.2	.395	.402		
	o							EXIT	.0	748.6	24.49	35.5		.402		
86		5-26-64	14:20	1503	6.43	2.468	63.9	INLET	24.2	578.3	-6.05	15.4				
	n							12	.0	681.1	12.44	37.6	.406	.409		
	o							EXIT	.0	685.5	13.24	39.0		.409		
87		5-26-64	15:42	1515	5.48	2.435	97.3	INLET	52.3	543.0	-12.73	14.6				
	n							12	.0	663.7	9.06	31.3	.472	.474		
	o							EXIT	.0	669.0	10.02	32.9		.474		
89		5-28-64	11:37	2003		.507	38.5	INLET	27.1	627.8	-9.55	3.3				
	n							12	.0	657.6	40.08	12.7	.186	.186		
	o							EXIT	.0	667.4	42.22	13.2		.186		
92		5-28-64	13:30	2003	1.74	1.510	55.9	INLET	24.4	632.0	-8.65	10.0				
	n							12	.0	744.0	15.55	21.3	.267	.273		
	o							EXIT	.0	746.8	16.58	22.0		.273		
96		5-28-64	15:51	2003	5.86	2.486	66.1	INLET	28.7	625.4	-10.07	16.4				
	n							12	.0	730.2	12.56	31.8	.418	.420		
	o							EXIT	.0	734.7	13.54	32.9		.420		
102		5- 2-64	10:08	2010	1.47	1.486	66.1	INLET	53.0	591.6	-17.60	9.3				
	n							12	.0	725.9	11.50	16.3	.328	.322		
	o							EXIT	.0	731.9	12.79	19.1		.322		
107		5- 2-64	14:20	2005	5.12	2.510	105.8	INLET	55.0	588.4	-18.15	15.7				
	n							12	.0	715.7	9.39	28.5	.516	.516		
	o							EXIT	.0	721.3	10.59	29.9		.516		
110		5- 2-64	16:09	2000		.503	44.7	INLET	55.4	587.4	-18.19	3.1				
	n							12	.0	656.1	39.79	12.6	.218	.216		
	o							EXIT	.0	667.8	42.32	13.2		.216		
112		5- 3-64	10:02	2005		.497	50.7	INLET	106.8	522.3	-32.43	2.9				
	n							12	.0	631.2	34.36	11.2	.243	.248		
	o							EXIT	.0	644.3	37.20	11.8		.247		
115		5- 3-64	11:52	2000	1.52	1.513	94.0	INLET	105.8	523.1	-32.06	8.8				
	n							12	.0	710.3	8.33	16.5	.485	.487		
	o							EXIT	.0	716.9	10.29	17.7		.488		
120		5- 3-64	14:30	2000		2.498	139.4	INLET	104.2	525.1	-31.64	14.5				
	n							12	.0	693.6	4.73	23.1	.691	.679		
	o							EXIT	.0	701.1	6.34	25.0		.680		
123		5-04-64	11:35	2005	1.29	1.505	113.5	INLET	154.3	466.6	-44.48	8.3				
	n							12	.0	694.7	4.84	14.0	.547	.554		
	o							EXIT	.0	704.5	6.96	15.5		.554		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,e}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,j}}{10^6}$	$\frac{\phi_i}{10^6}$
124		5-04-64	13:37	2005		.501	56.1	INLET	157.9	462.5	-45.36	2.7				
	0							12	.0	801.2	27.87	9.8	.272	.274		
	0							EXIT	.0	815.8	31.04	10.6		.274		
129		5-04-64	14:32	2005	4.08	2.513	168.8	INLET	153.2	467.8	-44.21	12.8				
	0							12	.8	670.9	-1.30	17.9	.818	.823		
	0							EXIT	.0	679.7	1.60	19.8		.823		
132		5-10-64	12:55	1007	4.67	1.005	123.8	INLET	81.8	445.8	-15.07	5.5				
	0							12	.0	818.5	42.43	55.9	.592	.604		
	0							EXIT	.0	834.3	44.88	58.7		.604		
134		5-10-64	14:41	1010	9.83	1.991	144.0	INLET	81.0	447.1	-14.96	10.9				
	0							12	.0	665.9	18.84	55.6	.682	.703		
	0							EXIT	.0	675.1	20.27	58.9		.702		
137		5-11-64	11:00	1005	11.73	1.977	125.6	INLET	22.1	515.7	-4.24	11.5				
	0							12	.0	707.8	25.39	70.7	.601	.613		
	0							EXIT	.0	716.0	26.65	73.6		.612		
141		5-11-64	13:50	1000	5.37	1.002	107.9	INLET	20.1	517.4	-3.85	5.8				
	0							12	.0	843.4	46.35	68.7	.515	.527		
	0							EXIT	.0	857.2	48.48	63.2		.526		
144		5-12-64	11:31	1500	3.56	1.498	78.6	INLET	13.2	593.0	-3.24	9.5				
	0							12	.0	751.8	25.21	36.3	.379	.384		
	0							EXIT	.0	758.7	26.44	37.6		.383		
146		5-12-64	12:53	1500	5.14	1.970	78.8	INLET	10.0	597.5	-2.54	12.6				
	0							12	.0	718.5	19.21	36.6	.380	.385		
	0							EXIT	.0	723.7	20.15	40.8		.384		
149		5-12-64	14:38	1500	6.77	2.494	84.7	INLET	21.8	581.3	-5.45	15.6				
	0							12	.0	684.0	17.01	39.1	.410	.413		
	0							EXIT	.0	688.4	13.80	48.6		.413		
154		5-15-64	13:37	1500	1.29	.996	107.5	INLET	151.0	425.4	-33.48	5.3				
	0							12	.0	751.5	25.16	24.1	.516	.524		
	0							EXIT	.0	765.5	27.66	25.9		.524		
158		5-17-64	11:25	1990		.498	68.5	INLET	253.6	357.4	-67.30	2.5				
	0							12	.0	773.5	22.12	8.5	.329	.334		
	0							EXIT	.0	791.3	25.96	9.4		.334		
160		5-17-64	13:55	1995	.34	1.005	109.1	INLET	250.3	361.2	-66.74	5.1				
	0							12	.0	689.5	3.96	9.0	.522	.532		
	0							EXIT	.0	703.5	6.97	10.3		.532		

Table A-2. Data From Test Section 2
(Cosine)

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{j,i}}{10^6}$	$\frac{\phi_i}{10^6}$
163		08-26-64	12:33	1005	1.25	.506	86.2	INLET	24.9	512.2	-4.77	2.9				
	0							12	.0	1034.3	75.73	48.0	.174	.429		
	0							EXIT	.0	1043.4	77.15	48.8		.418		
164		08-26-64	13:57	1010	7.20	1.477	112.2	INLET	20.0	518.9	-3.86	8.6				
	0							12	.0	751.7	32.09	64.1	.228	.558		
	0							EXIT	.0	755.8	32.73	65.2		.544		
165		08-26-64	15:05	1010	12.75	2.504	115.3	INLET	17.7	521.8	-3.42	14.7				
	0							11	.0	656.5	17.38	65.7	.398	.599		
	0							12	.0	662.9	18.38	68.6	.234	.573		
	0							EXIT	.0	665.4	18.76	69.8		.559		
166		08-26-64	15:59	1025	8.97	2.535	119.2	INLET	52.6	481.8	-9.99	14.2				
	0							11	.0	619.2	11.33	48.1	.411	.619		
	0							12	.0	625.9	12.37	51.2	.243	.593		
	0							EXIT	.0	628.5	12.77	52.3		.578		
171		08-27-64	15:15	1020	6.93	2.524	141.8	INLET	99.9	427.3	-18.30	13.5				
	0							12	.0	559.5	8.37	39.5	.286	.765		
	0							EXIT	.0	602.5	8.84	40.9		.688		
176		08-28-64	12:42	1005	5.98	2.437	164.8	INLET	146.9	374.0	-26.08	12.5				
	0							12	.0	581.3	5.88	31.4	.334	.820		
	0							EXIT	.0	585.0	6.45	32.0		.799		
177		08-28-64	15:13	1025	5.89	1.467	117.7	INLET	56.3	477.5	-10.66	8.2				
	0							12	.0	723.3	27.48	55.0	.238	.585		
	0							EXIT	.0	727.7	28.15	56.1		.571		
179		08-31-64	10:37	1015	5.30	1.520	129.9	INLET	100.8	425.6	-18.42	8.1				
	0							12	.0	687.4	22.07	48.0	.264	.646		
	0							EXIT	.0	692.0	22.79	49.3		.630		
180		08-31-64	11:55	1005	4.46	1.512	143.3	INLET	147.7	373.2	-26.21	7.8				
	0							12	.0	663.7	18.58	42.0	.291	.713		
	0							EXIT	.0	668.8	19.38	43.4		.695		
182		08-31-64	13:45	1005	1.16	.510	106.1	INLET	154.4	366.0	-27.33	2.6				
	0							12	.0	1003.2	70.95	45.5	.216	.527		
	0							EXIT	.0	1014.6	72.70	46.5		.514		
183		08-31-64	14:50	1000	1.18	.504	100.1	INLET	105.1	418.8	-19.03	2.7				
	0							12	.0	1027.4	74.69	47.4	.263	.498		
	0							EXIT	.0	1038.2	76.35	48.4		.486		
184		08-31-64	17:04	1005	1.16	.494	89.1	INLET	49.3	482.8	-9.30	2.8				
	0							12	.0	1036.3	76.05	46.9	.181	.443		
	0							EXIT	.0	1046.1	77.56	47.8		.432		
185		09-01-64	09:27	1515	2.69	1.502	73.2	INLET	21.4	583.6	-5.41	9.4				
	0							10	.0	715.1	18.35	29.0	.345	.388		
	0							11	.0	726.1	20.35	31.0	.252	.381		
	0							12	.0	732.9	21.57	32.3	.148	.344		
	0							EXIT	.0	735.5	22.04	32.8		.355		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{li}}{10^6}$	$\frac{\phi_i}{10^6}$
186		09-01-64	10:23	1510	2.38	1.513	82.7	INLET	49.5	546.1	-12.04	9.1				
	0							12	.0	713.6	18.18	29.1	.167	.411		
	0							EXIT	.0	716.6	18.71	29.6		.401		
188		09-01-64	11:45	1510	2.08	1.491	101.8	INLET	101.0	483.0	-23.42	8.3				
	0							12	.0	692.2	14.32	24.6	.207	.506		
	0							EXIT	.0	695.9	14.99	25.3		.494		
189		09-01-64	12:48	1505	2.02	1.506	121.9	INLET	147.4	429.9	-32.84	8.0				
	0							12	.0	677.8	11.81	22.3	.249	.606		
	0							EXIT	.0	682.2	12.61	23.1		.591		
190		09-01-64	14:43	1510		.487	75.9	INLET	158.9	417.7	-35.19	2.6				
	0							12	.0	694.7	50.83	20.4	.155	.377		
	0							EXIT	.0	903.2	52.37	21.0		.368		
191		09-01-64	16:02	1508		.509	70.7	INLET	109.2	473.2	-25.12	2.8				
	0							12	.0	899.3	51.67	21.7	.144	.352		
	0							EXIT	.0	906.8	53.03	22.1		.343		
192		09-02-64	10:34	1508		.496	63.4	INLET	57.0	536.3	-13.76	2.9				
	0							12	.0	926.0	56.85	22.9	.129	.315		
	0							EXIT	.0	935.0	58.10	23.3		.307		
193		09-02-64	11:05	1510		.489	58.9	INLET	33.4	566.9	-8.29	3.0				
	0							12	.0	936.3	58.33	23.1	.120	.293		
	0							EXIT	.0	942.9	59.52	23.5		.286		
194		09-02-64	12:07	1505	5.30	2.518	78.1	INLET	26.2	576.0	-6.53	15.6				
								1	24.9	577.6	-6.23	15.7	.158	.158		
								2	21.5	582.2	-5.41	15.8	.266	.195		
								3	16.6	588.9	-4.20	15.9	.368	.244		
								4	10.3	597.6	-2.63	16.1	.446	.291		
								5	3.4	607.4	-1.87	16.3	.495	.328		
								6	.0	618.3	1.10	16.4	.526	.362		
								7	.0	629.6	3.13	22.0	.530	.386		
								8	.0	640.8	5.15	25.5	.497	.406		
								9	.0	650.9	6.96	28.7	.445	.414		
								10	.0	659.6	8.52	31.5	.366	.413		
								11	.0	666.1	9.69	33.5	.269	.403		
								12	.0	671.1	10.59	35.1	.158	.388		
								EXIT	.0	672.7	10.90	35.4		.379		
195		09-02-64	13:47	1500	4.98	2.511	93.3	INLET	46.3	549.1	-11.23	15.1				
	0							12	.0	663.0	9.24	32.7	.190	.444		
	0							EXIT	.0	665.0	9.60	33.3		.453		
198		09-02-64	15:37	1510	4.73	2.545	129.8	INLET	96.2	488.6	-22.41	14.3				
	0							12	.0	645.0	5.79	26.9	.264	.646		
	0							EXIT	.0	647.7	6.29	27.8		.630		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i1}}{10^6}$	$\frac{\phi_i}{10^6}$
201		09-03-64	09:53	1518	4.05	2.510	168.1	INLET	152.6	425.3	-34.09	13.4				
	0							12	.0	630.6	3.03	21.7	.343	.836		
	0							EXIT	.0	634.3	3.69	22.8		.815		
202		09-03-64	12:53	2005	1.27	1.484	54.4	INLET	24.1	632.6	-8.59	9.9				
	0							11	.0	739.3	14.49	20.2	.185	.281		
	0							12	.0	745.0	15.72	21.1	.108	.271		
	0							EXIT	.0	746.9	16.14	21.3		.264		
203		09-03-64	14:19	2008	1.29	1.508	67.5	INLET	48.4	597.7	-16.21	9.6				
	0							11	.0	728.5	12.11	19.0	.233	.351		
	0							12	.0	734.9	13.48	19.9	.137	.336		
	0							EXIT	.0	737.3	14.01	20.2		.327		
204		09-03-64	15:18	2005	1.38	1.544	95.6	INLET	100.5	530.0	-30.78	9.0				
	0							11	.0	712.1	8.60	17.0	.333	.500		
	0							12	.0	719.5	10.20	18.1	.196	.475		
	0							EXIT	.0	722.9	10.94	18.6		.464		
205		09-03-64	17:01	1970	1.40	1.565	117.5	INLET	143.3	476.2	-40.93	8.7				
	0							11	.0	695.2	5.75	15.3	.405	.609		
	0							12	.0	706.3	8.12	17.0	.239	.584		
	0							EXIT	.0	710.4	8.99	17.6		.570		
208		09-04-64	14:33	2003		.478	37.7	INLET	29.6	624.1	-10.35	3.1				
	0							11	.0	854.9	39.51	11.9	.128	.196		
	0							12	.0	865.9	41.86	12.4	.077	.188		
	0							EXIT	.0	870.2	42.81	12.6		.183		
209		09-08-64	10:39	2005		.504	60.6	INLET	155.8	465.0	-44.83	2.8				
	0							11	.0	816.8	31.25	10.7	.209	.315		
	0							12	.0	833.7	34.90	11.5	.123	.301		
	0							EXIT	.0	840.2	36.32	11.8		.294		
210		09-08-64	11:58	1995		.508	50.8	INLET	103.8	525.1	-31.44	3.0				
	0							11	.0	815.7	31.14	10.8	.176	.262		
	0							12	.0	831.5	34.55	11.6	.104	.253		
	0							EXIT	.0	837.0	35.73	11.8		.246		
211		09-08-64	13:11	1990		.491	41.4	INLET	52.1	590.9	-17.11	3.1				
	0							11	.0	835.4	35.43	11.4	.143	.213		
	0							12	.0	849.1	38.37	12.1	.085	.206		
	0							EXIT	.0	853.7	39.36	12.3		.201		
213		09-08-64	15:02	1995	4.87	2.475	99.9	INLET	50.5	593.5	-16.71	15.6				
	0							11	.0	711.4	8.68	27.4	.344	.518		
	0							12	.0	717.3	9.94	28.8	.204	.497		
	0							EXIT	.0	719.5	10.42	29.3		.485		
214		09-08-64	16:05	2005	5.43	2.480	78.9	INLET	22.2	635.5	-7.95	16.6				
	0							10	.0	721.1	10.55	29.6	.369	.418		
	0							11	.0	727.9	12.02	31.2	.268	.406		
	0							12	.0	732.7	13.07	32.4	.160	.392		
	0							EXIT	.0	734.4	13.44	32.8		.383		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
218	0	09-09-64	13:40	2000	4.21	2.495	136.8	INLET	99.3	531.0	-30.36	14.6				
								11	.0	691.4	4.26	22.6	.472	.711		
								12	.0	699.1	5.50	24.4	.279	.680		
								EXIT	.0	702.1	6.55	25.2		.663		
221	0	09-09-64	15:49	2010	3.94	2.504	172.4	INLET	147.6	474.6	-42.96	13.8				
								11	.0	675.3	.54	18.5	.595	.693		
								12	.0	685.6	2.77	21.0	.351	.657		
								EXIT	.0	689.4	3.58	21.9		.636		
222	0	09-10-64	09:44	2000	1.31	1.503	92.6	INLET	99.9	530.4	-30.50	8.8				
	0							11	.0	710.1	8.28	16.3	.316	.480		
	0							12	.0	719.3	10.27	17.7	.187	.461		
	0							EXIT	.0	722.6	10.96	18.2		.449		
223	0	09-10-64	17:23	1510		.478	57.1	INLET	29.4	572.3	-7.32	3.0				
	0							12	.0	638.7	58.76	22.7	.116	.284		
	0							EXIT	.0	645.2	59.64	23.1		.277		
224	0	09-10-64	14:43	1005	7.47	1.499	111.2	INLET	17.5	521.3	-3.38	8.8				
	0							12	.0	748.8	31.71	64.7	.221	.553		
	0							EXIT	.0	752.7	32.32	65.7		.539		
225	0	09-11-64	10:21	995	12.37	2.484	116.9	INLET	17.9	519.3	-3.44	14.5				
								11	.0	656.9	17.73	67.1	.402	.608		
								12	.0	663.5	18.75	70.1	.232	.581		
								EXIT	.0	666.0	19.13	71.2		.567		

Table A-3. Data From Test Section 3
(Peak Near Inlet)

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,e}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
229		09-21-64	12:07	998	1.49	.509	87.0	INLET	27.1	508.5	-5.17	2.9				
	n							12	.0	1033.4	75.60	48.5	.162	.433		
	n							EXIT	.0	1041.9	76.92	45.3		.422		
230		09-21-64	13:39	1005	6.66	1.503	101.1	INLET	22.0	515.7	-4.23	8.7				
	o							7	.0	677.5	20.71	45.5	.403	.698		
	o							8	.0	690.0	22.65	48.9	.301	.651		
	o							9	.0	700.3	24.23	51.7	.247	.609		
	n							10	.0	708.4	25.46	53.9	.211	.568		
	o							11	.0	714.7	26.45	55.6	.196	.531		
	o							12	.0	722.3	27.62	57.6	.188	.504		
	o							EXIT	.0	725.6	28.14	58.5		.490		
231		09-21-64	15:30	1010	5.89	1.494	106.6	INLET	49.3	483.6	-9.31	8.4				
	o							8	.0	667.8	19.13	42.3	.315	.685		
	o							9	.0	678.9	20.84	45.2	.259	.640		
	o							10	.0	687.7	22.21	47.6	.222	.599		
	o							11	.0	695.2	23.36	49.6	.208	.562		
	o							12	.0	702.6	24.50	51.6	.198	.531		
	o							EXIT	.0	706.1	25.05	52.6		.517		
232		09-22-64	10:28	1008	5.84	1.483	107.0	INLET	47.8	485.0	-9.05	8.4				
	o							8	.0	671.8	19.76	43.2	.318	.689		
	o							9	.0	682.5	21.44	46.0	.261	.643		
	o							10	.0	690.5	22.68	48.2	.222	.599		
	o							11	.0	699.1	24.00	50.5	.207	.564		
	o							12	.0	706.5	25.14	52.4	.199	.533		
	o							EXIT	.0	710.1	25.70	53.4		.519		
233		09-22-64	15:01	1005	4.87	1.512	121.4	INLET	99.4	425.8	-18.09	8.1				
	o							8	.0	632.9	13.84	33.6	.366	.779		
	o							9	.0	645.2	15.73	36.9	.296	.728		
	o							10	.0	654.5	17.18	39.5	.253	.679		
	o							11	.0	664.0	18.63	42.1	.234	.640		
	o							12	.0	672.2	19.90	44.3	.225	.604		
	o							EXIT	.0	676.2	20.52	45.4		.549		
234		09-22-64	16:27	1003	4.60	1.510	140.8	INLET	146.5	374.2	-25.99	7.8				
	o							7	.0	598.0	8.51	24.1	.560	.970		
	o							8	.0	614.7	11.07	28.7	.419	.903		
	o							9	.0	628.6	13.21	32.5	.343	.843		
	o							10	.0	639.8	14.94	35.6	.291	.788		
	o							11	.0	650.0	16.51	38.3	.271	.740		
	o							12	.0	660.5	18.13	41.2	.262	.701		
	o							EXIT	.0	665.1	18.84	42.5		.683		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,e}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
235		09-23-64	12:47	1000	1.27	.504	106.3	INLET	149.6	370.5	-26.48	2.6				
	0							12	.0	1018.5	73.31	46.5	.198	.530		
	0							EXIT	.0	1029.0	74.93	47.5		.516		
236		09-23-64	13:52	1000	1.29	.499	99.9	INLET	103.6	420.4	-18.78	2.7				
	0							12	.0	1032.5	75.47	47.4	.186	.496		
	0							EXIT	.0	1042.4	77.00	48.3		.483		
237		09-23-64	15:05	1000	1.34	.497	91.0	INLET	52.9	478.0	-9.92	2.8				
	0							12	.0	1040.3	76.67	47.9	.169	.453		
	0							EXIT	.0	1049.4	78.07	48.7		.441		
238		09-24-64	10:50	990	10.55	2.478	98.9	INLET	17.5	519.0	-3.35	14.5				
	0							7	.0	615.1	11.40	48.5	.396	.684		
	0							8	.0	622.3	12.51	51.8	.295	.637		
	0							9	.0	628.2	13.42	54.5	.243	.594		
	0							10	.0	633.7	14.25	56.9	.206	.558		
	0							11	.0	638.0	14.92	58.9	.194	.524		
	0							12	.0	641.4	15.44	60.5	.188	.492		
	0							EXIT	.0	643.4	15.75	61.4		.480		
239		09-24-64	11:41	1008	8.52	2.497	105.2	INLET	46.9	486.1	-8.88	14.1				
	0							8	.0	594.9	7.91	38.1	.311	.676		
	0							9	.0	601.2	8.88	40.9	.255	.631		
	0							10	.0	605.5	9.55	42.8	.220	.586		
	0							11	.0	611.1	10.41	45.3	.204	.554		
	0							12	.0	615.4	11.08	47.3	.196	.524		
	0							EXIT	.0	617.5	11.41	48.2		.510		
240		09-24-64	13:38	1010	7.18	2.513	140.6	INLET	101.7	423.9	-18.54	13.4				
	0							7	.0	557.7	2.13	21.3	.563	.965		
	0							8	.0	568.4	3.78	26.2	.419	.903		
	0							9	.0	576.7	5.06	29.9	.343	.843		
	0							10	.0	583.5	6.11	33.0	.293	.786		
	0							11	.0	589.6	7.05	35.7	.273	.740		
	0							12	.0	595.6	7.98	38.4	.262	.700		
	0							EXIT	.0	598.4	8.41	39.7		.682		
242		09-24-64	16:06	1005	6.84	2.462	175.0	INLET	149.0	371.8	-26.43	12.7				
	0							7	1.0	541.9	-1.20	14.8	.695	1.202		
								8	.0	555.3	1.87	20.2	.510	1.124		
								9	.0	566.3	3.57	25.1	.427	1.051		
								10	.0	575.1	4.93	29.8	.364	.983		
								11	.0	582.8	6.11	32.4	.340	.923		
								12	.0	590.0	7.22	35.6	.327	.872		
								EXIT	.0	593.5	7.77	37.2		.849		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
243		09-25-64	10:45	1495	2.23	1.516	130.6	INLET	151.0	425.0	-33.38	8.1				
	0							6	1.8	608.7	-4.40	5.9	.752	.945		
	0							7	.0	631.5	3.69	13.8	.520	.699		
	0							8	.0	648.4	6.72	17.1	.389	.843		
	0							9	.0	660.6	8.90	19.4	.317	.784		
								10	.0	670.7	10.72	21.4	.273	.732		
								11	.0	680.4	12.45	23.2	.255	.688		
								12	.0	689.4	14.07	25.0	.244	.651		
								EXIT	.0	693.7	14.85	25.8		.634		
244		09-25-64	12:27	1498	2.22	1.509	107.3	INLET	103.4	478.9	-23.79	6.4				
	0							10	.0	681.5	12.60	23.2	.225	.600		
	0							11	.0	689.8	14.10	24.8	.209	.565		
	0							12	.0	697.1	15.40	26.2	.200	.534		
	0							EXIT	.0	700.6	16.04	26.9		.520		
245		09-25-64	14:10	1495	2.17	1.499	76.7	INLET	46.1	548.8	-11.16	5.0				
	0							10	.0	656.6	15.36	26.0	.161	.435		
	0							11	.0	701.6	16.27	27.0	.150	.407		
	0							12	.0	705.8	17.02	27.8	.143	.382		
	0							EXIT	.0	708.4	17.48	28.3		.372		
246		09-25-64	15:08	1500	2.40	1.489	66.7	INLET	21.0	582.4	-5.25	5.3				
	0							11	.0	715.2	18.61	29.2	.129	.351		
	0							12	.0	719.8	19.45	30.1	.125	.332		
	0							EXIT	.0	722.1	19.86	30.5		.323		
247		09-28-64	11:00	1495		.483	56.3	INLET	20.7	582.2	-5.16	3.0				
	0							12	.0	939.7	59.00	23.3	.106	.280		
	0							EXIT	.0	945.6	60.05	23.7		.273		
248		09-28-64	11:49	1500		.496	62.0	INLET	59.2	532.7	-14.18	2.9				
	0							12	.0	916.4	54.79	22.3	.116	.309		
	0							EXIT	.0	922.7	55.92	22.7		.301		
249		09-28-64	13:06	1495		.508	69.8	INLET	103.3	478.8	-23.72	2.8				
	0							12	.0	900.5	51.96	22.0	.131	.348		
	0							EXIT	.0	907.4	53.20	22.4		.339		
250		09-28-64	14:06	1495		.511	79.3	INLET	149.3	426.8	-33.06	2.7				
	0							12	.0	902.7	52.36	22.2	.150	.395		
	0							EXIT	.0	910.6	53.77	22.7		.384		
251		09-29-64	10:07	1495	5.84	2.513	70.2	INLET	18.6	584.9	-4.67	15.8				
	0							9	.0	660.9	8.97	32.3	.171	.419		
	0							10	.0	664.2	9.56	33.4	.144	.391		
	0							11	.0	667.1	10.08	34.3	.136	.367		
	0							12	.0	670.6	10.71	35.4	.132	.349		
	0							EXIT	.0	672.1	10.96	35.8		.340		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^6$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i1}}{10^6}$	$\frac{\phi_i}{10^6}$
253		09-29-64	12:26	1500	5.21	2.487	97.5	INLET	51.9	541.9	-12.52	14.8				
	0							9	.0	649.0	6.73	28.0	.240	.585		
	0							10	.0	654.1	7.64	29.6	.203	.548		
	0							11	.0	657.8	8.31	30.8	.190	.512		
	0							12	.0	662.3	9.12	32.2	.182	.486		
	0							EXIT	.0	664.3	9.47	32.8		.473		
254		09-29-64	15:07	1490	5.12	2.500	137.1	INLET	99.3	482.9	-22.83	14.0				
	0							7	.0	615.2	.88	17.8	.548	.950		
								8	.0	625.1	2.65	21.0	.409	.884		
								9	.0	633.0	4.06	23.5	.337	.823		
								10	.0	639.6	5.25	25.6	.289	.769		
								11	.0	645.3	6.27	27.4	.267	.721		
								12	.0	651.2	7.32	29.3	.258	.683		
								EXIT	.0	654.0	7.82	30.2		.665		
256		09-30-64	13:08	1490	4.85	2.518	175.3	INLET	147.2	428.6	-32.55	13.4				
	0							6	23.8	577.4	-5.89	15.7	1.014	1.271		
								7	10.3	555.9	-2.59	16.1	.702	1.209		
								8	1.5	608.9	-.25	16.4	.524	1.129		
								9	.0	619.3	1.60	19.3	.429	1.054		
								10	.0	627.1	3.01	21.8	.368	.982		
								11	.0	634.9	4.41	24.3	.341	.923		
								12	.0	642.3	5.73	26.6	.328	.873		
								EXIT	.0	645.8	6.35	27.8		.850		
257		10-01-64	09:46	1995	1.36	1.491	53.8	INLET	21.8	635.1	-7.75	10.0				
								4	.0	662.4	2.42	12.3	.498	.375		
								5	.0	669.1	6.03	14.7	.423	.396		
								6	.0	712.4	8.50	16.6	.310	.391		
								7	.0	721.7	10.89	18.0	.215	.370		
								8	.0	728.1	12.27	18.9	.161	.345		
	0							9	.0	733.1	13.34	19.6	.132	.321		
	0							10	.0	737.9	14.37	20.3	.112	.301		
	0							11	.0	742.1	15.28	20.9	.104	.283		
	0							12	.0	745.9	16.10	21.5	.100	.268		
	0							EXIT	.0	747.7	16.49	21.8		.261		
258		10-01-64	11:30	1995	1.40	1.508	69.2	INLET	47.6	597.6	-15.84	9.6				
								4	7.8	657.7	-2.50	10.5	.638	.483		
								5	.0	678.5	1.59	11.8	.541	.506		
								6	.0	695.2	5.19	14.3	.395	.500		
								7	.0	706.9	7.70	16.0	.275	.473		
	0							8	.0	716.1	9.70	17.4	.205	.445		
	0							9	.0	722.5	11.66	18.3	.169	.414		
	0							10	.0	727.5	12.14	19.0	.145	.385		
	0							11	.0	732.6	13.25	19.8	.134	.362		
	0							12	.0	738.4	14.49	20.6	.130	.345		
	0							EXIT	.0	740.7	14.94	21.0		.336		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
259		10-01-64	11:05	2000	1.54	1.504	96.0	INLET	97.2	533.7	-29.79	8.8				
								1	92.1	539.9	-28.44	8.9	.352	.352		
								2	77.8	558.1	-24.52	9.1	.677	.457		
								3	56.9	585.4	-18.62	9.4	.879	.581		
								4	34.0	617.2	-11.76	9.8	.888	.670		
								5	15.1	646.1	-5.52	10.2	.753	.701		
	n							6	1.3	669.5	-.48	10.7	.554	.603		
	0							7	.0	686.0	3.08	12.8	.383	.657		
								8	.0	698.5	5.78	14.7	.266	.617		
								9	.0	707.9	7.82	16.0	.235	.575		
								10	.0	715.3	9.40	17.1	.201	.536		
								11	.0	722.7	11.01	18.2	.186	.505		
								12	.0	729.6	12.49	19.2	.174	.478		
								EXIT	.0	732.7	13.17	19.7		.445		
261		10-02-64	10:13	2000		.501	38.0	INLET	27.8	626.5	-9.76	3.3				
								4	.0	725.2	11.55	6.2	.351	.263		
								5	.0	759.0	18.83	7.8	.298	.275		
								6	.0	787.2	24.53	9.2	.219	.273		
								7	.0	806.2	29.03	10.1	.152	.258		
								8	.0	821.1	32.24	10.8	.113	.242		
								9	.0	832.4	34.68	11.4	.093	.226		
	n							10	.0	842.5	36.87	11.9	.080	.212		
	n							11	.0	851.4	38.77	12.3	.074	.200		
	n							12	.0	859.2	40.46	12.7	.072	.189		
	n							EXIT	.0	863.0	41.28	12.9		.184		
262		10-02-64	11:42	2000		.503	45.2	INLET	54.7	586.4	-17.57	3.2				
								4	.0	705.4	7.27	5.2	.414	.314		
								5	.0	746.8	14.20	7.3	.353	.331		
	n							6	.0	779.6	23.29	8.9	.259	.327		
								7	.0	803.2	28.38	10.0	.183	.310		
								8	.0	819.6	31.91	10.8	.134	.290		
								9	.0	832.8	34.77	11.5	.110	.270		
								10	.0	844.8	37.34	12.1	.094	.253		
								11	.0	853.4	39.20	12.5	.088	.247		
	n							12	.0	863.7	41.43	13.0	.085	.225		
	n							EXIT	.0	868.2	42.41	13.2		.219		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{11}}{10^6}$	$\frac{\phi_i}{10^6}$
263		10-02-64	13:51	1995		.509	56.5	INLET	106.9	521.4	-32.25	2.9				
								1	98.0	532.2	-29.92	3.0	.206	.206		
								2	73.0	563.8	-23.12	3.1	.397	.268		
								3	36.9	612.4	-12.64	3.3	.516	.346		
								4	3.4	665.6	-1.19	3.6	.522	.391		
								5	.0	716.1	9.68	5.9	.442	.411		
								6	.0	759.3	18.98	8.0	.325	.411		
								7	.0	788.2	25.21	9.4	.224	.390		
								8	.0	810.6	30.04	10.5	.168	.366		
								9	.0	826.6	33.48	11.3	.137	.341		
								10	.0	839.9	36.34	12.0	.119	.318		
	0							11	.0	851.5	38.85	12.6	.111	.298		
	0							12	.0	862.0	41.11	13.1	.106	.281		
	0							EXIT	.0	867.6	42.31	13.4		.274		
264		10-02-64	15:46	2000		.512	66.8	INLET	151.4	469.5	-43.64	2.8				
								6	.0	747.2	16.28	7.4	.384	.482		
								7	.0	779.9	23.35	9.0	.265	.456		
								8	.0	805.4	28.86	10.3	.199	.428		
								9	.0	824.9	33.06	11.3	.165	.400		
								10	.0	842.7	36.51	12.2	.140	.375		
	0							11	.0	855.4	39.63	12.8	.131	.351		
	0							12	.0	870.0	42.79	13.5	.125	.333		
	0							EXIT	.0	876.5	44.20	13.8		.324		
265		10-05-64	10:54	2000	5.50	2.517	74.0	INLET	20.1	638.3	-7.21	16.9				
								4	.0	676.8	1.11	19.2	.688	.517		
								5	.0	690.3	4.01	22.5	.581	.542		
	0							6	.0	701.4	6.40	25.2	.426	.538		
	0							7	.0	708.9	8.02	27.1	.296	.510		
	0							8	.0	714.4	9.21	28.4	.222	.477		
	0							9	.0	718.8	10.17	29.5	.180	.445		
	0							10	.0	722.4	10.94	30.4	.155	.416		
	0							11	.0	725.6	11.63	31.1	.145	.390		
	0							12	.0	728.5	12.25	31.9	.139	.368		
	0							EXIT	.0	729.9	12.57	32.2		.359		
266		10-05-64	11:57	1998	5.23	2.534	102.2	INLET	47.9	547.5	-15.95	16.0				
								4	12.1	650.8	-4.45	17.4	.947	.721		
								5	1.5	669.1	-1.50	18.0	.805	.753		
	0							6	.0	683.8	2.66	21.1	.590	.742		
	0							7	.0	694.5	4.97	23.8	.409	.706		
								8	.0	702.2	6.63	25.7	.306	.660		
								9	.0	708.0	7.88	27.1	.251	.615		
								10	.0	712.8	8.91	28.3	.213	.574		
								11	.0	717.3	9.89	29.4	.199	.540		
								12	.0	721.3	10.74	30.4	.192	.509		
								EXIT	.0	723.3	11.17	30.9		.496		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	X	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
270		10-15-64	14:39	2000	4.60	2.505	141.3	INLET	98.0	532.7	-39.00	14.7				
	0							4	41.1	607.0	-13.56	16.0	1.310	.992		
	0							5	23.8	632.5	-8.46	16.7	1.113	1.047		
								6	10.8	653.3	-3.98	17.3	.812	1.024		
								7	2.0	668.2	-.75	17.7	.564	.975		
								8	.0	678.5	1.47	19.5	.421	.909		
								9	.0	686.8	3.26	21.6	.345	.847		
								10	.0	693.5	4.70	23.2	.295	.791		
								11	.0	700.2	6.14	24.5	.276	.745		
								12	.0	705.8	7.36	26.2	.265	.703		
								EXIT	.0	708.6	7.57	26.9		.695		
273		10-06-64	10:40	1998	3.76	2.526	176.7	INLET	147.9	473.4	-42.72	14.0				
	0							4	72.2	565.1	-22.94	15.3	1.644	1.245		
								5	48.0	597.3	-16.00	16.0	1.384	1.208		
								6	30.5	622.3	-10.60	16.6	1.020	1.276		
								7	17.9	641.5	-6.47	17.1	.704	1.219		
								8	9.9	654.4	-3.67	17.5	.527	1.146		
								9	4.1	664.4	-1.52	17.8	.433	1.059		
								10	.0	673.3	.40	18.5	.368	.992		
								11	.0	680.8	2.00	20.3	.345	.931		
								12	.0	688.1	3.58	22.1	.331	.880		
								EXIT	.0	691.6	4.34	23.0		.857		
275		10-06-64	14:12	1995	1.34	1.514	123.1	INLET	148.9	472.0	-42.86	8.4				
	0							4	61.4	578.6	-19.87	9.4	1.146	.882		
	0							5	34.9	615.4	-12.00	9.8	.962	.800		
	0							6	15.1	645.6	-5.50	10.3	.711	.801		
								7	2.5	667.1	-.87	10.7	.491	.848		
								8	.0	682.4	2.43	12.5	.367	.792		
								9	.0	694.1	4.95	14.2	.301	.736		
								10	.0	703.9	7.07	15.6	.259	.649		
								11	.0	713.8	9.20	17.1	.240	.650		
								12	.0	721.5	10.86	18.2	.230	.613		
								EXIT	.0	725.6	11.74	18.8		.597		
276		10-07-64	10:45	1000	8.56	2.020	104.5	INLET	30.6	504.5	-5.84	11.6				
	0							4	.0	569.0	4.09	21.9	.972	.694		
	0							5	.0	591.9	7.62	30.2	.816	.732		
	0							6	.0	610.3	10.45	37.0	.603	.725		
	0							7	.0	628.3	13.22	43.6	.418	.718		
	0							8	.0	638.2	14.74	47.2	.311	.672		
								9	.0	646.3	16.00	50.2	.255	.629		
								10	.0	652.1	16.89	52.3	.218	.545		
								11	.0	657.6	17.73	54.3	.203	.549		
								12	.0	663.3	18.62	56.4	.195	.520		
								EXIT	.0	665.9	19.62	57.4		.507		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
277		10-07-64	12:38	1000	11.87	2.454	99.8	INLET	10.3	529.4	-2.00	14.5				
	0							4	.0	582.7	6.21	32.7	.928	.697		
	0							5	.0	601.2	9.05	40.9	.778	.730		
								6	.0	615.9	11.32	47.4	.574	.720		
								7	.0	626.7	12.97	52.2	.396	.685		
								8	.0	634.0	14.10	55.5	.297	.638		
								9	.0	640.3	15.07	58.3	.242	.597		
								10	.0	645.2	15.83	60.5	.204	.558		
								11	.0	649.6	16.51	62.4	.194	.524		
								12	.0	654.2	17.22	64.5	.187	.497		
								EXIT	.0	656.2	17.53	65.4		.484		
278		10-07-64	15:11	995	1.27	.516	119.2	INLET	219.0	296.9	-37.62	2.5				
								4	.0	598.9	8.81	8.5	1.108	.831		
								5	.0	706.7	25.28	18.6	.934	.877		
								6	.0	790.2	38.22	26.5	.688	.864		
								7	.0	852.7	47.83	32.3	.476	.823		
								8	.0	894.3	54.22	36.3	.356	.767		
								9	.0	928.5	59.48	39.5	.292	.715		
								10	.0	957.2	63.84	42.2	.249	.669		
								11	.0	981.6	67.65	44.5	.232	.626		
	0							12	.0	1005.6	71.24	46.7	.222	.593		
	0							EXIT	.0	1017.1	73.12	47.8		.578		
279		10-08-64	10:44	1997		.507	52.7	INLET	88.6	544.2	-27.42	3.0				
								4	.0	679.5	1.75	4.0	.490	.366		
								5	.0	728.5	12.32	6.4	.409	.387		
	0							6	.0	764.9	20.17	8.2	.304	.380		
								7	.0	792.8	28.17	9.6	.210	.362		
								8	.0	812.5	30.42	10.6	.156	.338		
								9	.0	827.8	33.72	11.3	.128	.316		
								10	.0	839.7	36.28	11.9	.110	.294		
	0							11	.0	851.0	38.72	12.5	.102	.276		
	0							12	.0	863.1	41.32	13.1	.098	.262		
	0							EXIT	.0	868.3	42.44	13.3		.255		
280		10-08-64	14:06	1995		.509	94.9	INLET	311.9	297.2	-80.52	2.5				
								4	90.5	541.5	-27.91	3.0	.882	.663		
								5	28.0	625.6	-9.80	3.4	.740	.694		
								6	.0	693.9	4.51	4.8	.546	.685		
								7	.0	742.4	15.34	7.2	.378	.651		
								8	.0	776.3	22.66	8.9	.283	.607		
								9	.0	805.4	28.52	10.3	.232	.568		
								10	.0	828.2	33.83	11.4	.199	.531		
								11	.0	850.0	38.53	12.5	.185	.500		
	0							12	.0	868.9	42.59	13.4	.178	.472		
	0							EXIT	.0	878.2	44.60	13.9		.460		

Table A-4. Data From Test Section 4
(Peak Near Exit)

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
242		10-26-64	15:58	1005	4.35	2.499	142.2	INLET	148.9	371.9	-26.41	12.8				
	0							12	1.0	541.9	-1.20	15.0	.659	.704		
	0							13	.0	547.3	.64	16.9	.382	.696		
	0							EXIT	.0	549.3	.95	17.8		.690		
283		10-27-64	10:17	1015	5.07	2.528	117.5	INLET	105.3	420.6	-19.19	13.5				
	0							12	.0	559.4	2.28	21.9	.544	.582		
	0							13	.0	563.9	2.98	23.9	.313	.575		
	0							EXIT	.0	565.6	3.23	24.7		.570		
284		10-27-64	13:30	1010	6.66	2.486	95.9	INLET	52.0	480.4	-9.81	14.0				
	0							12	.0	595.6	7.98	38.0	.440	.475		
	0							13	.0	599.3	8.56	39.7	.257	.469		
	0							EXIT	.0	600.7	8.77	40.3		.465		
286		10-27-64	15:44	1000	9.92	2.494	93.7	INLET	21.3	515.9	-4.08	14.5				
	0							12	.0	628.1	13.20	53.7	.431	.464		
	0							13	.0	631.8	13.77	55.4	.251	.459		
	0							EXIT	.0	633.1	13.97	56.0		.455		
287		10-29-64	14:14	1000	2.58	1.507	116.4	INLET	152.5	377.3	-26.96	7.7				
	0							12	.0	597.9	8.54	24.2	.534	.576		
	0							13	.0	605.4	9.70	26.3	.313	.570		
	0							EXIT	.0	608.2	10.13	27.0		.564		
289		10-29-64	15:49	1000	3.55	1.504	103.7	INLET	99.0	495.5	-18.00	8.1				
	0							12	.0	631.5	13.72	33.3	.478	.514		
	0							13	.0	638.1	14.73	35.1	.275	.508		
	0							EXIT	.0	640.5	15.11	35.8		.503		
290		11-02-64	10:44	1007	4.73	1.583	96.5	INLET	47.7	485.1	-9.01	8.9				
	0							12	.0	667.1	19.68	44.8	.442	.478		
	0							13	.0	673.0	19.99	46.5	.258	.472		
	0							EXIT	.0	675.2	20.33	47.1		.468		
291		11-02-64	12:20	993	5.93	1.477	93.3	INLET	18.9	517.8	-3.61	8.8				
	0							11	.0	690.1	22.86	49.8	.658	.452		
	0							12	.0	706.4	25.37	53.4	.426	.462		
	0							13	.0	712.6	26.32	55.0	.248	.457		
	0							EXIT	.0	714.9	26.67	55.8		.453		
292		11-02-64	14:51	998	.84	.497	78.1	INLET	25.0	511.0	-4.78	7.6				
	0							12	.0	579.7	67.34	42.5	.357	.387		
	0							13	.0	595.0	69.70	43.9	.219	.382		
	0							EXIT	.0	1000.6	70.57	44.4		.379		
293		11-03-64	10:36	1010	.82	.504	81.9	INLET	52.6	479.7	-9.91	7.8				
	0							12	.0	965.0	65.03	41.2	.375	.406		
	0							13	.0	980.6	67.45	42.8	.217	.401		
	0							EXIT	.0	986.4	68.34	43.1		.397		
295		11-03-64	12:06	998	.86	.507	88.7	INLET	101.7	422.3	-18.44	7.7				
	0							12	.0	943.6	61.81	40.1	.407	.439		
	0							13	.0	961.4	64.53	41.7	.236	.434		
	0							EXIT	.0	967.6	65.48	42.3		.430		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{l,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{l,i}}{10^6}$	$\frac{\phi_i}{10^6}$
296		11-03-64	13:20	995	.84	.505	93.9	INLET	150.0	369.4	-26.49	2.6				
	n							12	.0	924.7	58.90	38.3	.433	.465		
	o							13	.0	943.0	61.71	40.0	.252	.460		
	o							EXIT	.0	949.7	62.74	40.6		.456		
297		11-03-64	14:55	1500		.501	68.7	INLET	152.4	423.8	-33.75	2.7				
	n							12	.0	834.0	39.98	17.3	.315	.341		
	o							13	.0	846.9	42.29	18.2	.183	.337		
	o							EXIT	.0	851.8	43.17	18.5		.333		
298		11-05-64	10:18	1505		.490	62.4	INLET	104.4	478.6	-24.97	2.7				
	n							12	.0	858.6	44.37	18.4	.285	.309		
	o							13	.0	871.0	46.59	19.2	.166	.306		
	o							EXIT	.0	875.5	47.40	19.5		.303		
299		11-05-64	12:39	1500		.494	57.4	INLET	95.6	537.3	-13.36	2.9				
	n							12	.0	883.7	48.91	20.2	.264	.284		
	o							13	.0	895.4	51.01	20.9	.154	.281		
	o							EXIT	.0	899.5	51.76	21.2		.278		
300		11-05-64	13:47	1498		.511	53.7	INLET	26.7	574.4	-6.63	3.2				
	n							12	.0	888.8	49.85	21.3	.246	.266		
	o							13	.0	898.7	51.61	21.9	.143	.263		
	o							EXIT	.0	902.4	52.29	22.1		.260		
301		11-05-64	15:26	1498	2.27	1.476	63.6	INLET	22.2	580.5	-5.54	9.2				
	n							12	.0	709.3	17.61	27.9	.293	.315		
	o							13	.0	713.5	18.35	28.7	.170	.312		
	o							EXIT	.0	715.1	18.63	29.0		.309		
303		11-06-64	10:54	1495	1.95	1.500	68.9	INLET	47.6	546.8	-11.51	9.0				
	n							12	.0	683.8	13.07	23.6	.319	.341		
	o							13	.0	688.5	13.91	24.5	.185	.337		
	o							EXIT	.0	690.1	14.21	24.8		.334		
305		11-06-64	13:25	1493	1.63	1.507	85.4	INLET	98.0	484.8	-22.58	8.4				
	n							12	.0	654.2	7.81	18.1	.393	.423		
	o							13	.0	659.6	8.77	19.2	.228	.418		
	o							EXIT	.0	661.6	9.13	19.6		.414		
306		11-06-64	15:16	1508	1.43	1.515	102.3	INLET	147.0	430.6	-32.81	8.1				
	n							12	.0	632.5	3.59	13.7	.472	.507		
	o							13	.0	638.9	4.74	14.9	.274	.501		
	o							EXIT	.0	641.3	5.18	15.4		.496		
307		11-09-64	10:01	1500	4.80	2.489	64.5	INLET	22.5	580.3	-5.62	15.6				
	n							12	.0	657.8	8.30	30.2	.298	.320		
	o							13	.0	660.3	8.75	31.6	.173	.316		
	o							EXIT	.0	661.2	8.92	31.9		.313		
308		11-09-64	11:32	1500	4.30	2.508	79.2	INLET	49.9	544.5	-12.07	15.0				
	n							12	.0	638.8	4.89	25.0	.366	.392		
	o							13	.0	641.9	5.44	26.0	.214	.386		
	o							EXIT	.0	643.0	5.64	26.3		.384		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_{l_0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{l_i}}{10^6}$	$\frac{\phi_i}{10^6}$
309		11-09-64	13:25	1493	3.65	2.497	112.0	INLET	100.0	482.4	-23.02	14.0				
	0							12	.0	616.2	.59	18.0	.516	.554		
	0							13	.0	620.6	1.78	19.4	.296	.548		
	0							EXIT	.0	622.2	2.06	19.9		.543		
310		11-09-64	14:45	1500	3.26	2.522	138.4	INLET	151.6	424.7	-33.60	13.4				
	0							11	26.9	574.5	-6.68	15.6	.986	.671		
	0							12	16.4	588.6	-4.13	15.9	.639	.686		
								13	12.6	593.9	-3.18	16.1	.369	.678		
								EXIT	11.2	595.9	-2.83	16.1		.671		
311		11-10-64	09:40	2005	1.31	1.513	46.8	INLET	22.7	634.7	-8.13	10.1				
	0							11	.0	719.2	10.15	17.7	.333	.227		
	0							12	.0	727.0	11.83	18.8	.217	.232		
								13	.0	730.0	12.49	19.3	.125	.229		
								EXIT	.0	731.2	12.73	19.4		.227		
312		11-10-64	10:46	2000	1.18	1.524	57.2	INLET	48.6	596.7	-16.18	9.6				
	0							11	.0	699.0	5.89	14.9	.405	.277		
	0							12	.0	708.7	7.99	16.4	.262	.283		
								13	.0	712.4	8.79	16.9	.155	.280		
								EXIT	.0	713.8	9.09	17.1		.277		
314		11-10-64	13:56	2000	1.02	1.513	78.2	INLET	98.6	532.0	-30.15	8.9				
	0							11	.0	673.6	.42	11.1	.555	.381		
	0							12	.0	686.4	3.17	13.0	.363	.387		
								13	.0	691.4	4.25	13.7	.212	.383		
								EXIT	.0	693.3	4.66	14.0		.379		
315		11-10-64	15:01	2005	.75	1.514	92.4	INLET	150.4	471.0	-43.53	8.3				
	0							11	21.5	636.5	-7.73	10.1	.655	.445		
								12	11.1	653.2	-4.12	10.4	.425	.458		
								13	7.6	659.2	-2.82	10.6	.247	.453		
								EXIT	6.3	661.4	-2.35	10.6		.448		
316		11-11-64	11:43	2005		.518	33.0	INLET	26.3	629.2	-9.31	3.4				
	0							11	.0	864.1	28.50	10.3	.233	.161		
	0							12	.0	819.3	31.78	11.1	.153	.163		
	0							13	.0	825.6	33.16	11.4	.089	.162		
	0							EXIT	.0	827.9	33.66	11.5		.160		
318		11-11-64	13:14	2005		.514	36.5	INLET	58.8	563.2	-14.26	3.2				
	0							11	.0	776.5	22.54	8.9	.259	.176		
	0							12	.0	795.6	26.67	9.8	.167	.181		
								13	.0	802.4	28.15	10.2	.097	.179		
								EXIT	.0	805.0	28.69	10.3		.177		
319		11-11-64	14:37	2007		.517	42.8	INLET	106.1	523.3	-32.29	3.0				
	0							11	.0	749.2	16.61	7.5	.302	.207		
	0							12	.0	770.5	21.21	8.6	.198	.212		
								13	.0	778.9	23.03	9.0	.115	.210		
								EXIT	.0	781.9	23.67	9.2		.208		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{l,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{l,i}}{10^6}$	$\frac{\phi_i}{10^6}$
321	0	11-11-64	14:30	2000		.503	40.5	INLET	155.0	465.5	-44.51	2.8				
								11	.0	735.8	13.84	6.7	.353	.242		
								12	.0	759.3	18.91	7.9	.229	.245		
								13	.0	768.8	20.95	8.3	.133	.242		
								EXIT	.0	772.3	21.71	8.5		.240		
323	0	11-12-64	10:03	2005	4.30	2.460	60.8	INLET	20.6	637.9	-7.43	16.7				
	0							11	.0	705.3	7.14	25.7	.432	.297		
	0							12	.0	711.1	8.40	27.1	.280	.301		
								13	.0	713.5	8.92	27.6	.163	.298		
								EXIT	.0	714.4	9.11	27.8		.245		
324	0	11-12-64	12:05	2005	3.74	2.534	79.8	INLET	47.9	598.2	-16.03	16.1				
	0							11	.0	684.5	2.64	21.1	.566	.389		
								12	.0	692.3	4.32	23.0	.366	.395		
								13	.0	695.3	4.67	23.8	.214	.391		
								EXIT	.0	696.4	5.22	24.0		.387		
325	0	11-12-64	13:50	2005	3.08	2.512	111.7	INLET	98.6	532.4	-30.26	14.7				
								11	10.7	653.8	-3.99	17.4	.794	.542		
								12	4.2	665.1	-1.56	17.7	.519	.553		
								13	1.6	669.5	-.61	17.8	.300	.547		
								EXIT	.7	671.1	-.27	17.9		.542		
326	0	11-12-64	15:05	2002	2.90	2.539	141.9	INLET	151.0	470.2	-43.58	14.0				
								11	30.4	622.9	-10.60	16.7	1.010	.689		
								12	20.9	637.1	-7.52	17.0	.658	.703		
								13	17.5	642.5	-6.37	17.2	.380	.695		
								EXIT	16.2	644.5	-5.53	17.2		.688		
328	0	11-13-64	13:17	1998	6.07	3.544	141.4	INLET	98.4	532.0	-30.07	20.8				
								11	17.7	641.7	-6.42	24.0	1.008	.641		
								12	11.9	651.2	-4.37	24.4	.656	.701		
								13	9.6	655.0	-3.55	24.5	.379	.692		
								EXIT	8.8	656.4	-3.24	24.6		.686		
329	0	11-13-64	15:07	2000	8.42	3.536	80.8	INLET	24.8	631.0	-8.79	23.5				
								11	.0	693.2	4.63	32.6	.568	.391		
								12	.0	699.3	5.95	34.7	.370	.400		
								13	.0	701.4	6.42	35.5	.218	.395		
								EXIT	.0	702.3	6.59	35.7		.392		
330	0	11-16-64	10:00	1495	6.05	3.497	138.6	INLET	99.9	482.8	-23.00	19.6				
	0							11	14.2	591.0	-3.56	22.2	.984	.673		
	0							12	6.9	601.2	-1.75	22.5	.642	.687		
								13	4.2	605.0	-1.06	22.6	.369	.679		
								EXIT	3.2	606.5	-.81	22.6		.672		
331	0	11-16-64	12:16	1500	8.65	3.507	71.3	INLET	20.4	583.2	-5.10	22.0				
	0							12	.0	643.9	5.80	37.2	.326	.353		
	0							13	.0	645.9	6.17	38.1	.191	.349		
	0							EXIT	.0	646.7	6.30	38.4		.346		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{l,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{l,i}}{10^6}$	$\frac{\phi_i}{10^6}$
332		11-16-64	13:30	1500	5.64	2.481	61.0	INLET	8.7	599.3	-2.22	15.9				
	0							12	.0	672.7	10.98	35.3	.280	.302		
	0							13	.0	675.1	11.41	36.1	.164	.299		
	0							EXIT	.0	676.0	11.57	36.4		.296		
334		11-16-64	15:21	1503	1.99	1.516	61.7	INLET	10.6	597.1	-2.69	9.7				
	0							12	.0	718.6	19.19	30.3	.283	.306		
	0							13	.0	722.6	19.90	31.0	.165	.302		
	0							EXIT	.0	724.0	20.16	31.3		.299		
342		11-20-64	11:48	2000	.68	1.495	89.1	INLET	147.5	473.9	-42.67	8.3				
	0							11	21.1	636.6	-7.57	10.0	.634	.432		
								12	11.6	651.8	-4.29	10.3	.413	.441		
								13	8.1	657.7	-3.02	10.4	.243	.436		
								EXIT	6.8	659.9	-2.55	10.4		.432		
343		11-20-64	13:20	2000	2.85	2.515	140.9	INLET	146.7	474.9	-42.48	13.9				
	0							11	26.8	627.9	-9.45	16.6	1.002	.684		
								12	17.5	642.2	-6.36	17.0	.653	.698		
								13	14.2	647.6	-5.20	17.2	.376	.690		
								EXIT	13.0	649.6	-4.77	17.2		.683		
344		11-20-64	15:28	1998	3.10	2.503	112.6	INLET	99.5	530.6	-30.37	14.6				
	0							11	10.2	653.9	-3.78	17.3	.800	.548		
								12	3.8	665.0	-1.40	17.6	.521	.558		
								13	1.3	669.4	-.45	17.8	.301	.551		
								EXIT	.4	671.0	-.10	17.8		.546		
345		11-23-64	11:12	2005	1.02	1.515	78.4	INLET	99.5	531.3	-30.49	8.9				
	0							11	.3	671.9	-.09	10.8	.555	.379		
	0							12	.0	685.8	2.63	12.8	.360	.386		
								13	.0	690.9	4.02	13.4	.210	.384		
								EXIT	.0	692.7	4.42	13.8		.380		

Table A-5. Data From Test Section 5
(Uniform Inside)

RUN NO.	CHF	DATE	TIME	P	ΔP	$Q \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{11}}{10^6}$	$\frac{\phi_{12}}{10^6}$
347	I	3-12-65	12:29	1010		.923	111.9	INLET	3.1	540.0	-6.60	3.1				
	I							12	.0	713.5	26.20	19.1			.393	.401
	I							EXIT	.0	720.9	27.34	19.8				.401
348	I	3-12-65	13:01	990		.499	111.2	INLET	1.7	538.8	-3.1	3.0				
	I							12	.0	719.4	27.41	19.3			.394	.399
	I							EXIT	.0	727.2	28.60	20.0				.399
349	I	3-12-65	13:05	1010		.513	131.2	INLET	30.4	506.2	-5.82	3.0				
	I							12	.0	713.7	26.23	18.7			.460	.470
	I							EXIT	.0	722.6	27.59	19.5				.470
351	I	3-15-65	11:33	995		.514	145.3	INLET	77.7	448.8	-14.27	2.8				
	I							12	.0	676.1	20.98	15.9			.508	.521
	I							EXIT	.0	687.8	22.48	16.8				.520
355	I	3-15-65	14:51	1000		.528	179.7	INLET	125.5	396.5	-22.47	2.8				
	I							12	.0	672.5	20.03	15.6			.622	.645
	I							EXIT	.0	684.1	21.82	16.7				.644
356	I	3-16-65	14:20	1085	4.67	1.477	200.5	INLET	11.3	528.9	-2.19	8.7				
	I							10	.0	620.0	11.85	29.4			.718	.720
	I							11	.0	629.3	13.28	31.8			.718	.717
	I							12	.0	639.1	14.80	34.5			.690	.719
	I							EXIT	.0	643.7	15.51	35.7				.718
357	I	3-16-65	15:23	1608	3.87	1.483	227.2	INLET	36.9	498.0	-7.03	8.5				
	I							12	.0	622.3	12.14	29.9			.784	.815
	I							EXIT	.0	627.5	12.94	31.3				.813
358	I	3-17-65	13:01	1005		.498	145.5	INLET	77.2	450.7	-14.26	2.7				
	I							12	.0	687.5	22.27	16.0			.502	.522
	I							EXIT	.0	697.4	23.79	16.9				.521
359	I	3-18-65	09:15	1495		.487	91.2	INLET	10.0	596.8	-2.54	3.1				
	I							12	.0	749.0	24.77	11.7			.316	.328
	I							EXIT	.0	755.3	25.91	12.1				.327
360	I	3-18-65	11:11	1500		.511	109.4	INLET	35.2	563.5	-8.64	3.1				
	I							12	.0	737.1	22.55	11.4			.378	.392
	I							EXIT	.0	744.3	23.86	11.9				.392
361	I	3-18-65	11:27	1490		.512	132.7	INLET	80.2	505.7	-18.75	2.9				
	I							12	.0	715.9	18.91	10.2			.457	.476
	I							EXIT	.0	724.6	20.48	10.8				.475
362	I	3-18-65	12:56	1500		.513	158.9	INLET	127.1	452.1	-28.68	2.8				
	I							12	.0	703.5	16.52	9.3			.548	.570
	I							EXIT	.0	714.0	18.41	10.0				.569
364	I	3-18-65	14:12	1495		1.509	158.9	INLET	17.1	587.0	-4.30	9.5				
	I							12	.0	666.1	10.26	20.8			.520	.541
	I							EXIT	.0	671.5	10.87	21.4				.540
365	I	3-19-65	10:29	1580	1.88	1.497	179.6	INLET	40.7	556.2	-9.56	9.1				
	I							12	.0	653.5	7.54	17.7			.620	.644
	I							EXIT	.0	657.6	8.27	18.5				.643

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
357		3-16-65	15:36	1500	1.31	1.478	229.8	INLET	90.8	494.1	-21.13	6.4				
	I							12	.0	620.2	1.55	11.3			.792	.824
	I							EXIT	.0	625.5	2.50	12.2				.823
358		3-20-65	9:44	1505	1.20	1.497	257.2	INLET	132.2	446.8	-29.79	8.1				
	I							12	18.6	566.2	-4.69	9.4			.884	.923
	I							EXIT	14.4	592.0	-3.64	9.5				.921
370		3-22-65	13:47	2005	1.45	1.486	125.8	INLET	16.6	643.9	-6.13	10.1				
	I							12	.0	712.0	8.73	16.4			.434	.452
	I							EXIT	.0	715.5	9.35	16.8				.451
371		3-22-65	14:54	1995	1.22	1.501	151.4	INLET	40.9	606.8	-13.85	9.6				
	I							12	.0	686.6	3.77	13.3			.523	.543
	I							EXIT	.0	692.0	4.51	13.8				.542
372		3-23-65	5:56	2000	1.03	1.514	169.2	INLET	87.5	545.7	-27.19	9.0				
	I							12	14.5	647.1	-5.31	10.3			.652	.679
	I							EXIT	11.9	651.3	-4.40	10.4				.678
373		3-23-65	15:41	2000	.96	1.467	234.4	INLET	135.0	466.4	-39.56	6.3				
	I							12	34.7	616.2	-11.97	9.6			.809	.841
	I							EXIT	31.1	621.6	-10.81	9.7				.840
374		3-23-65	13:34	2005		.508	79.4	INLET	12.1	651.5	-4.49	3.5				
	I							12	.0	776.5	22.96	6.9			.274	.285
	I							EXIT	.0	783.8	24.11	9.1				.285
375		3-25-65	10:31	2000		.502	82.4	INLET	19.4	639.4	-6.97	3.4				
	I							12	.0	772.5	21.76	8.5			.265	.296
	I							EXIT	.0	778.1	22.67	6.8				.295
376		3-25-65	11:41	2000		.495	96.8	INLET	45.6	600.8	-15.31	3.1				
	I							12	.0	759.5	18.94	7.8			.334	.347
	I							EXIT	.0	766.1	20.36	6.1				.347
377		3-25-65	12:49	2005		.494	117.1	INLET	97.7	533.4	-30.03	2.9				
	I							12	.0	725.6	11.53	6.1			.404	.420
	I							EXIT	.0	733.6	13.27	6.5				.419
378		3-25-65	14:56	2005		.508	141.2	INLET	149.0	472.6	-43.17	2.8				
	I							12	.0	698.3	5.62	4.9			.469	.507
	I							EXIT	.0	707.8	7.67	5.4				.506

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_0	h	X	V _m	$\frac{\phi}{10^6}$	$\frac{\phi}{10^6}$	$\frac{\phi}{10^6}$	$\frac{\phi}{10^6}$
379		5-26-65	10:15	2090	3.83	2.467	174.0	INLET	32.1	620.1	-11.14	16.1				
								1	30.5	622.5	-10.61	16.2			.621	.621
								2	27.1	627.6	-9.52	16.3			.627	.629
								3	23.8	632.5	-8.46	16.4			.631	.625
								4	20.6	637.5	-7.38	16.4			.624	.625
								5	17.3	642.6	-6.29	16.7			.625	.627
								6	14.2	647.5	-5.21	16.8			.621	.627
								7	11.2	652.5	-4.15	17.0			.623	.626
								8	8.2	657.5	-3.05	17.2			.623	.627
								9	5.3	662.5	-1.99	17.3			.625	.626
								10	2.5	667.5	-.92	17.4			.625	.626
								11	.0	672.4	.15	17.8			.625	.626
								12	.0	677.3	1.28	18.9			.600	.624
								EXIT	.0	679.7	1.72	19.9				.623
380		5-26-65	11:50	2095	4.26	2.394	153.4	INLET	18.8	640.8	-6.82	16.2				
								12	.0	642.8	4.43	21.9			.933	.552
								EXIT	.0	645.0	4.91	22.4				.551
381		5-26-65	12:59	1995	3.69	2.404	196.3	INLET	47.0	598.4	-15.66	15.6				
								12	4.8	603.0	-1.76	17.3			.678	.704
								EXIT	3.3	605.7	-1.18	17.4				.703
382		5-26-65	14:22	2000	3.71	2.522	286.4	INLET	47.7	533.0	-29.93	14.8				
								12	28.7	625.1	-10.05	16.6			.989	1.027
								EXIT	26.1	629.0	-9.22	16.7				1.025
383		5-26-65	15:56	1995	.93	1.505	248.2	INLET	159.5	460.0	-45.48	8.2				
								12	50.4	553.6	-16.66	9.5			.457	.890
								EXIT	46.3	559.4	-15.46	9.6				.889
384		5-24-65	11:56	1000	2.26	1.462	293.4	INLET	100.1	415.9	-19.57	7.9				
								12	.0	575.6	5.08	17.8			1.002	1.053
								EXIT	.0	572.5	6.10	19.6				1.051
385		5-24-65	12:25	1005		.505	177.9	INLET	152.2	368.3	-26.97	2.6				
								12	.0	655.5	17.33	18.2			.649	.639
								EXIT	.0	667.4	19.16	14.3				.637
388		6-21-65	14:32	1000	9.35	2.441	216.9	INLET	13.9	524.9	-2.69	14.4				
								8	.0	571.9	4.54	27.7			.780	.776
								9	.0	578.1	5.50	30.5			.780	.777
								10	.0	584.4	6.47	33.3			.777	.777
								11	.0	590.7	7.44	36.0			.777	.776
								12	.0	597.0	8.40	38.8			.767	.777
								EXIT	.0	600.0	8.87	40.2				.777
389		6-08-65	12:57	1010		.533	127.2	INLET	29.1	507.8	-5.58	3.1				
								12	.0	701.2	24.30	18.3			.451	.456
								EXIT	.0	709.6	25.58	19.1				.456
390		6-08-65	14:29	1005	.88	.816	171.2	INLET	35.9	498.8	-6.83	4.7				
								12	.0	668.9	19.38	23.4			.607	.613
								EXIT	.0	676.2	20.51	24.5				.613

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
391		6-08-65	15:34	995	1.90	1.021	200.5	INLET	41.4	490.8	-7.21	5.8				
	I							12	.0	649.9	16.65	26.3			.718	.718
	I							EXIT	.0	656.8	17.71	27.5				.718
392		6-08-65	16:44	995	4.17	1.493	221.2	INLET	31.7	502.5	-6.02	8.6				
	I							12	.0	622.6	12.45	31.0			.786	.792
	I							EXIT	.0	627.8	13.24	32.4				.792
394		6-09-65	11:44	1005		.529	137.3	INLET	55.3	475.8	-10.39	3.0				
	I							12	.0	685.9	22.02	16.8			.488	.492
	I							EXIT	.0	695.0	23.41	17.7				.492
395		6-09-65	13:01	1003	.72	.799	182.4	INLET	59.0	471.4	-11.02	4.4				
	I							12	.0	656.5	17.52	21.2			.448	.654
	I							EXIT	.0	664.5	18.75	22.4				.653
396		6-09-65	13:43	1015	1.36	.991	211.6	INLET	64.1	467.1	-12.00	5.5				
	I							12	.0	640.2	14.76	22.9			.732	.759
	I							EXIT	.0	647.5	15.90	24.2				.758
398		6-09-65	15:15	1013	3.13	1.479	248.3	INLET	61.9	469.3	-11.60	6.2				
	I							12	.0	605.5	9.45	25.1			.454	.891
	I							EXIT	.0	611.2	10.33	26.6				.890
399		6-09-65	16:02	995	4.64	1.971	268.4	INLET	60.0	469.0	-11.16	11.0				
	I							12	.0	579.5	5.82	25.4			.425	.963
	I							EXIT	.0	584.1	6.53	27.1				.961
400		6-09-65	17:20	995	6.52	2.419	263.3	INLET	46.2	485.0	-8.70	13.6				
	I							11	.0	565.7	3.70	25.1			.933	.945
								12	.0	573.4	4.88	28.5			.902	.945
								EXIT	.0	577.0	5.45	30.1				.943
402		05-10-65	14:33	1000		.522	157.5	INLET	95.7	429.2	-17.42	2.8				
	I							12	.0	674.2	20.30	15.8			.543	.565
	I							EXIT	.0	684.5	21.86	16.4				.564
403		06-11-65	09:25	1005	.43	.808	211.4	INLET	95.1	430.6	-17.36	4.3				
	I							12	.0	642.8	15.37	15.4			.734	.758
	I							EXIT	.0	651.8	16.75	26.7				.757
404		05-11-65	10:34	1005	1.18	1.007	241.8	INLET	98.6	426.6	-17.97	5.4				
	I							12	.0	621.5	12.66	20.3			.435	.667
	I							EXIT	.0	629.7	13.34	21.8				.666
405		05-11-65	13:12	993	3.01	1.930	297.2	INLET	95.2	426.9	-17.28	14.4				
	I							11	.0	543.0	.25	12.1			1.058	1.066
								12	.0	553.8	1.92	16.0			1.025	1.066
								EXIT	.0	559.0	2.72	17.8				1.064
406		05-11-65	14:38	990	4.14	2.480	318.7	INLET	161.2	421.8	-18.28	13.2				
	I							11	19.4	516.7	-3.70	14.4			1.147	1.140
								12	11.8	526.0	-2.28	14.6			1.111	1.143
								EXIT	8.3	530.4	-1.60	14.7				1.141
407		05-11-65	16:36	1000	2.45	1.480	282.5	INLET	100.6	423.8	-18.27	7.9				
	I							12	.0	578.5	5.55	15.6			1.000	1.012
	I							EXIT	.0	585.1	6.58	26.3				1.012

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
408	I	06-14-65	09:34	1502		.516	96.2	INLET	19.2	585.0	-4.82	3.2				
	I							12	.0	736.0	22.32	11.5			.340	.345
	I							EXIT	.0	742.4	23.49	11.9				.345
409	I	06-14-65	10:42	1502		.710	117.1	INLET	21.6	581.8	-5.41	4.4				
	I							12	.0	715.4	18.63	13.9			.416	.420
	I							EXIT	.0	721.2	19.66	14.4				.420
410	I	06-14-65	11:46	1510	.59	1.007	140.5	INLET	26.2	576.5	-6.55	6.3				
	I							12	.0	689.7	13.85	16.3			.492	.504
	I							EXIT	.0	694.5	14.72	16.9				.503
411	I	06-14-65	12:50	1502	.57	1.018	169.1	INLET	54.7	538.6	-13.17	6.1				
	I							12	.0	673.3	11.05	14.5			.601	.606
	I							EXIT	.0	679.1	12.09	15.3				.606
412	I	06-14-65	13:57	1500		.722	139.1	INLET	47.3	547.8	-11.47	4.3				
	I							12	.0	704.1	16.62	13.1			.493	.499
	I							EXIT	.0	710.8	17.83	13.8				.498
413	I	06-14-65	15:05	1498		.528	115.2	INLET	50.0	544.1	-12.08	3.2				
	I							12	.0	720.8	19.67	10.8			.410	.413
	I							EXIT	.0	728.5	21.04	11.3				.413
414	I	06-14-65	16:10	1500		.505	137.3	INLET	98.8	464.5	-22.84	2.8				
	I							12	.0	705.0	16.79	9.3			.485	.492
	I							EXIT	.0	714.4	18.49	9.9				.492
415	I	06-14-65	17:00	1515		.699	170.0	INLET	97.6	427.4	-22.77	3.9				
	I							12	.0	664.4	12.82	10.8			.604	.609
	I							EXIT	.0	692.9	14.35	11.5				.609
416	I	06-15-65	09:24	1497	3.53	1.975	163.7	INLET	18.4	585.6	-4.61	12.4				
	I							12	.0	652.7	7.45	23.3			.580	.587
	I							EXIT	.0	655.6	7.67	24.0				.586
417	I	06-15-65	10:34	1495	5.25	2.517	184.8	INLET	24.3	577.4	-6.03	15.7				
	I							12	.0	636.8	4.65	24.7			.656	.662
	I							EXIT	.0	639.4	5.11	25.5				.662
418	I	06-15-65	11:38	1510	4.37	2.498	228.5	INLET	49.8	545.7	-12.12	15.0				
	I							12	.0	619.7	1.24	18.5			.820	.818
	I							EXIT	.0	623.0	1.83	19.5				.818
419	I	06-15-65	14:46	1495	3.03	2.032	204.6	INLET	49.4	544.5	-11.53	12.2				
	I							12	.0	626.1	2.71	17.1			.732	.733
	I							EXIT	.0	629.6	3.34	18.0				.733
472	I	06-15-65	15:51	1492	2.38	2.023	262.2	INLET	97.9	464.7	-22.57	11.3				
	I							12	14.9	589.7	-3.75	12.8			.934	.939
	I							EXIT	11.6	594.2	-2.93	12.9				.939
473	I	06-15-65	16:47	1495	3.81	2.485	296.4	INLET	97.9	485.1	-22.59	13.9				
	I							12	21.0	581.7	-5.24	15.6			1.053	1.062
	I							EXIT	17.9	585.9	-4.49	15.7				1.061
475	I	06-16-65	13:27	1493		.501	179.1	INLET	143.8	432.7	-33.62	2.7				
	I							12	.0	722.5	20.05	10.4			.639	.642
	I							EXIT	.0	735.1	22.30	11.2				.641

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
476	I	05-16-65	14:39	1500		.691	204.3	INLET	147.4	429.4	-32.75	3.7				
	I							12	.0	669.0	10.32	9.5			.725	.732
	I							EXIT	.0	679.3	12.17	10.4				.732
477	I	06-16-65	16:29	1495	.38	1.026	240.7	INLET	152.5	423.2	-33.69	5.5				
	I							12	.0	613.4	.43	7.0			.852	.862
	I							EXIT	.0	621.5	1.90	8.1				.862
478	I	06-17-65	09:11	1490	1.19	1.480	268.4	INLET	141.1	435.3	-31.25	7.9				
	I							12	20.2	582.2	-5.03	9.3			.961	.961
	I							EXIT	15.5	588.6	-3.89	9.4				.961
479	I	06-17-65	09:44	1490	1.25	1.494	262.6	INLET	127.4	450.7	-28.59	8.1				
	I							12	12.3	593.1	-3.09	9.5			.937	.940
	I							EXIT	7.9	599.2	-1.58	9.6				.940
480	I	06-17-65	10:28	1508	2.23	2.010	300.6	INLET	128.5	451.3	-29.07	10.9				
	I							12	29.0	572.5	-7.23	12.4			1.068	1.077
	I							EXIT	25.1	577.7	-6.28	12.5				1.076
481	I	06-17-65	11:02	1505	3.53	2.485	337.2	INLET	131.9	447.2	-29.71	13.5				
	I							12	40.5	557.1	-9.92	15.1			1.199	1.208
	I							EXIT	36.8	561.9	-9.06	15.2				1.207
482	I	06-17-65	13:00	2005	.90	1.476	197.0	INLET	96.3	535.2	-29.64	8.7				
	I							12	17.1	643.4	-6.25	10.0			.701	.706
	I							EXIT	14.2	648.1	-5.24	10.1				.706
483	I	06-17-65	13:48	2007	.05	1.008	165.1	INLET	97.2	534.3	-29.91	9.9				
	I							11	10.0	655.3	-3.73	7.0			.596	.591
	I							12	3.2	667.0	-1.20	7.1			.590	.591
	I							EXIT	.0	672.7	.05	7.2				.591
484	I	06-17-65	14:53	1990		.697	145.7	INLET	93.2	537.8	-28.54	4.1				
	I							12	.0	707.0	7.85	7.5			.522	.522
	I							EXIT	.0	714.4	9.43	8.0				.522
485	I	06-17-65	16:20	1993		.701	117.8	INLET	49.3	595.1	-16.31	4.4				
	I							12	.0	731.3	12.99	9.1			.419	.422
	I							EXIT	.0	737.1	14.26	9.5				.422
486	I	06-17-65	17:11	2003		.991	137.6	INLET	50.6	594.1	-16.83	6.2				
	I							11	.0	696.6	5.30	9.4			.497	.492
	I							12	.0	706.6	7.47	10.4			.492	.493
	I							EXIT	.0	711.5	8.53	10.9				.493
487	I	06-18-65	09:38	2010		.701	99.0	INLET	23.5	634.1	-8.40	4.7				
	I							12	.0	748.5	16.38	10.1			.352	.355
	I							EXIT	.0	753.4	17.45	10.5				.355
488	I	06-18-65	10:21	2005	.16	1.011	113.5	INLET	24.0	632.8	-8.53	6.7				
	I							12	.0	723.8	11.14	12.3			.403	.407
	I							EXIT	.0	727.7	11.59	12.7				.407
489	I	06-18-65	11:54	2005	2.55	1.996	124.6	INLET	22.1	635.6	-7.92	13.3				
	I							12	.0	686.2	3.02	17.0			.444	.447
	I							EXIT	.0	688.4	3.49	17.4				.447

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i1}}{10^6}$	$\frac{\phi_i}{10^6}$
490		06-18-65	12:10	2013	2.68	1.983	150.0	INLET	24.2	633.3	-8.67	13.2				
	I							12	.0	694.6	4.64	18.3			.533	.538
	I							EXIT	.0	697.2	5.21	18.8				.538
491		06-18-65	13:40	2010	2.22	2.010	182.6	INLET	49.3	596.7	-16.51	12.7				
	I							11	5.2	663.8	-1.96	14.1			.654	.653
	I							12	1.5	670.3	-.55	14.3			.650	.654
	I							EXIT	.0	673.5	.13	14.5				.654
1058		06-22-65	12:49	2210		.500	80.7	INLET	25.1	650.9	-10.55	3.4				
								1	21.9	656.2	-0.30	3.4				.269
								2	15.3	667.2	-6.70	3.5				.276
								3	8.9	678.7	-4.00	3.6				.282
								4	2.7	690.2	-3.28	3.7				.285
								5	.0	701.7	1.44	4.0				.287
								6	.0	713.1	4.16	4.5				.288
								7	.0	724.5	6.85	5.0				.288
								8	.0	735.8	9.52	5.5				.288
								9	.0	747.2	12.20	6.0				.288
								10	.0	758.5	14.89	6.5				.288
								11	.0	769.9	17.59	7.0				.288
	I							12	.0	781.5	20.32	7.5				.289
	I							EXIT	.0	787.4	21.71	7.8				.289
1059		06-22-65	12:50	2206		.498	82.3	INLET	24.5	651.3	-10.39	3.4				
								1	21.2	656.7	-9.12	3.4				.273
								2	14.6	668.0	-6.46	3.5				.281
								3	8.0	679.7	-3.70	3.6				.287
								4	2.0	691.3	-.65	3.7				.290
								5	.0	702.9	1.60	4.0				.291
								6	.0	714.6	4.55	4.5				.291
								7	.0	726.2	7.31	5.1				.292
								8	.0	738.2	10.12	5.6				.293
								9	.0	750.0	12.92	6.1				.294
								10	.0	761.8	15.70	6.6				.295
								11	.0	773.7	18.52	7.2				.295
	I							12	.0	785.4	21.29	7.7				.296
	I							EXIT	.0	791.2	22.63	7.9				.295

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
1060		05-22-65	13:12	2192		.625	88.6	INLET	22.7	652.9	-9.60	4.3				
								1	19.9	657.5	-8.51	4.3				.295
								2	14.3	667.1	-6.27	4.4				.301
								3	8.7	677.0	-3.95	4.5				.307
								4	3.3	687.0	-1.60	4.6				.310
								5	.0	697.0	.75	4.8				.312
								6	.0	706.9	3.09	5.4				.313
								7	.0	717.1	5.48	5.9				.315
								8	.0	727.5	7.91	6.5				.317
								9	.0	737.6	10.29	7.1				.317
								10	.0	747.6	12.62	7.6				.317
								11	.0	757.6	14.98	8.2				.317
								12	.0	767.6	17.32	8.7				.317
								EXIT	.0	772.6	18.49	9.0				.318
1061		05-22-65	13:29	2218		.692	92.4	INLET	25.6	651.1	-10.87	4.7				
								1	22.9	655.4	-9.84	4.8				.306
								2	17.5	664.4	-7.70	4.8				.314
								3	12.2	673.8	-5.46	4.9				.320
								4	7.1	683.2	-3.25	5.0				.323
								5	2.2	692.6	-1.00	5.1				.325
								6	.0	702.1	1.25	5.5				.327
								7	.0	711.6	3.51	6.1				.328
								8	.0	721.1	5.78	6.6				.329
								9	.0	730.3	7.96	7.2				.329
								10	.0	739.8	10.21	7.8				.329
								11	.0	749.5	12.51	8.4				.330
								12	.0	759.0	14.76	8.9				.331
								EXIT	.0	763.8	15.92	9.2				.331
1062		05-22-65	14:00	2201		.810	96.2	INLET	21.2	656.2	-9.12	5.6				
								1	18.9	660.0	-8.22	5.6				.314
								2	14.2	668.1	-6.32	5.7				.326
								3	9.5	676.5	-4.33	5.8				.335
								4	5.0	684.9	-2.35	5.9				.339
								5	.8	693.4	-.36	6.0				.340
								6	.0	701.9	1.66	6.5				.343
								7	.0	710.4	3.64	7.1				.343
								8	.0	718.6	5.59	7.7				.343
								9	.0	727.0	7.57	8.3				.343
								10	.0	735.5	9.56	8.9				.344
								11	.0	743.9	11.55	9.5				.344
								12	.0	752.3	13.54	10.1				.345
								EXIT	.0	756.6	14.54	10.4				.345

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,j}}{10^6}$	$\frac{\phi_i}{10^6}$
1063	I I	05-22-65	14: 9	2181		.812	94.5	INLET	21.0	654.5	-8.78	5.6				.316
								1	18.7	658.4	-7.88	5.6				.327
								2	13.9	666.4	-6.00	5.7				.337
								3	9.1	674.9	-4.02	5.8				.341
								4	4.5	683.4	-2.04	5.9				.342
								5	.1	691.8	-.07	6.0				.344
								6	.0	700.3	1.50	6.6				.345
								7	.0	708.8	3.29	7.2				.347
								8	.0	717.4	5.50	7.8				.347
								9	.0	725.9	7.89	8.5				.347
								10	.0	734.4	9.85	9.1				.347
								11	.0	742.8	11.82	9.7				.346
								12	.0	751.0	13.72	10.3				.346
1064	I I	05-22-65	14: 9	2182		.812	97.2	EXIT	.0	755.0	14.66	10.6				
								INLET	21.2	654.6	-8.90	5.6				.317
								1	18.9	658.4	-8.00	5.6				.327
								2	14.2	666.4	-6.13	5.7				.336
								3	9.4	674.9	-4.15	5.8				.340
								4	4.8	683.3	-2.17	5.9				.342
								5	.5	691.8	-.20	6.0				.344
								6	.0	700.3	1.78	6.6				.344
								7	.0	708.7	3.76	7.2				.346
								8	.0	717.3	5.76	7.8				.347
								9	.0	726.0	7.79	8.4				.348
								10	.0	734.5	9.79	9.0				.349
								11	.0	743.1	11.79	9.7				.349
								12	.0	751.5	13.76	10.3				.349
1065	I I	05-22-65	14:24	2203		.902	98.7	EXIT	.0	755.8	14.74	10.6				
								INLET	21.9	655.0	-9.47	6.2				.323
								1	19.8	658.5	-8.65	6.2				.324
								2	15.5	665.9	-6.50	6.3				.344
								3	11.1	673.7	-5.06	6.4				.348
								4	6.8	681.5	-3.22	6.5				.350
								5	2.8	689.3	-1.36	6.6				.352
								6	.0	697.2	.47	6.6				.353
								7	.0	705.0	2.32	7.5				.354
								8	.0	712.8	4.16	8.1				.355
								9	.0	720.6	6.01	8.7				.355
								10	.0	728.4	7.85	9.4				.355
								11	.0	736.1	9.65	10.0				.354
								12	.0	743.7	11.44	10.6				.354
								EXIT	.0	747.5	12.34	10.9				

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,j}}{10^6}$	$\frac{\phi_i}{10^6}$
1066		05-22-65	14:39	2180		.986	102.4	INLET	18.3	658.5	-7.93	6.8				
								1	16.3	661.9	-7.15	6.9				.338
								2	12.2	668.9	-5.50	7.0				.349
								3	8.2	676.3	-3.77	7.1				.358
								4	4.2	683.8	-2.03	7.2				.362
								5	.5	691.2	-.29	7.3				.365
								6	.0	698.6	1.43	7.8				.366
								7	.0	706.0	3.15	8.5				.367
								8	.0	713.3	4.87	9.1				.367
								9	.0	720.7	6.60	9.8				.368
								10	.0	728.1	8.32	10.4				.368
								11	.0	735.4	10.03	11.1				.368
	I							12	.0	742.7	11.72	11.7				.367
	I							EXIT	.0	746.3	12.56	12.0				.367
1067		06-22-65	15:02	2174		1.222	112.8	INLET	18.1	658.3	-7.76	8.5				
								1	16.4	661.3	-7.07	8.5				.371
								2	12.7	667.5	-5.61	8.6				.383
								3	9.0	674.1	-4.09	8.7				.393
								4	5.5	680.6	-2.56	8.8				.397
								5	2.1	687.1	-1.05	8.9				.399
								6	.0	693.6	.46	9.2				.399
								7	.0	700.2	1.99	10.0				.401
								8	.0	706.9	3.54	10.7				.403
								9	.0	713.5	5.07	11.4				.404
								10	.0	720.0	6.60	12.1				.404
								11	.0	726.6	8.14	12.9				.405
	I							12	.0	733.1	9.65	13.6				.405
	I							EXIT	.0	736.3	10.39	13.9				.404
1068		06-22-65	15:23	2240		1.482	124.3	INLET	19.4	663.2	-8.76	10.3				
								1	17.8	665.9	-8.10	10.4				.409
								2	14.5	671.6	-6.74	10.5				.421
								3	11.3	677.5	-5.32	10.6				.432
								4	8.1	683.4	-3.90	10.7				.436
								5	5.0	689.4	-2.45	10.8				.440
								6	2.0	695.5	-.69	11.0				.443
								7	.0	701.6	.46	11.3				.445
								8	.0	707.6	1.91	12.1				.446
								9	.0	713.5	3.33	12.9				.446
								10	.0	719.4	4.76	13.7				.447
								11	.0	725.4	6.18	14.4				.447
	I							12	.0	731.2	7.58	15.2				.446
	I							EXIT	.0	734.0	8.27	15.5				.445

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_s}{10^6}$	$\frac{\phi_{LI}}{10^6}$	$\frac{\phi_i}{10^6}$
1069		06-22-65	15:46	2217		1.712	139.1	INLET	21.9	656.6	-9.54	11.8				
								1	20.3	659.2	-8.91	11.8				.462
								2	17.1	664.8	-7.60	12.0				.475
								3	13.8	670.5	-6.24	12.1				.485
								4	10.5	676.3	-4.86	12.2				.491
								5	7.4	682.1	-3.49	12.4				.494
								6	4.4	687.8	-2.12	12.5				.495
								7	1.5	693.5	-.77	12.7				.495
								8	.0	699.3	.61	13.1				.497
								9	.0	705.2	2.00	14.0				.498
								10	.0	710.9	3.36	14.9				.498
								11	.0	716.7	4.74	15.8				.499
	I							12	.0	722.5	6.11	16.6				.499
	I							EXIT	.0	725.2	6.76	17.1				.499
1070		06-22-65	16: 6	2209		1.977	147.9	INLET	19.0	661.2	-8.23	13.7				
								1	17.5	663.6	-7.65	13.8				.495
								2	14.6	668.8	-6.44	13.9				.508
								3	11.6	674.1	-5.19	14.0				.518
								4	8.7	679.4	-3.93	14.2				.523
								5	5.9	684.6	-2.68	14.3				.524
								6	3.1	689.9	-1.43	14.5				.526
								7	.4	695.3	-.17	14.7				.527
								8	.0	700.5	1.08	15.5				.528
								9	.0	705.8	2.32	16.4				.528
								10	.0	711.1	3.57	17.3				.528
								11	.0	716.5	4.85	18.3				.530
	I							12	.0	721.8	6.12	19.2				.530
	I							EXIT	.0	724.4	6.73	19.7				.530
1071		06-22-65	16:18	2201		2.238	154.9	INLET	17.0	663.2	-7.47	15.6				
								1	15.7	665.5	-6.93	15.7				.518
								2	13.0	670.2	-5.82	15.8				.531
								3	10.2	675.1	-4.66	15.9				.543
								4	7.6	680.0	-3.50	16.1				.548
								5	5.0	684.9	-2.35	16.3				.550
								6	2.5	689.8	-1.19	16.4				.552
								7	.1	694.8	-.02	16.6				.554
								8	.0	699.7	1.14	17.6				.555
								9	.0	704.7	2.31	18.6				.556
								10	.0	709.6	3.47	19.5				.556
								11	.0	714.5	4.63	20.5				.557
	I							12	.0	719.4	5.77	21.5				.556
	I							EXIT	.0	721.7	6.32	21.9				.555

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
1072		06-22-65	16:29	2219		2.464	164.6	INLET	16.5	666.3	-7.29	17.2				
								1	15.3	668.5	-6.77	17.3				.550
								2	12.7	673.1	-5.69	17.5				.564
								3	10.1	677.8	-4.56	17.6				.576
								4	7.5	682.6	-3.43	17.8				.581
								5	5.1	687.3	-2.31	18.0				.584
								6	2.7	692.0	-1.20	18.1				.584
								7	.4	696.7	-.08	18.3				.585
								8	.0	701.4	1.04	19.3				.586
								9	.0	706.1	2.17	20.3				.587
								10	.0	710.9	3.31	21.4				.588
								11	.0	715.7	4.45	22.4				.590
	I							12	.0	720.4	5.57	23.4				.590
	I							EXIT	.0	722.8	6.15	24.0				.590
1073		06-22-65	16:42	2235		2.691	175.9	INLET	17.3	666.1	-7.52	18.8				
								1	16.0	668.2	-7.40	18.9				.586
								2	13.5	672.7	-6.34	19.1				.601
								3	11.0	677.3	-5.23	19.2				.614
								4	8.5	681.9	-4.12	19.4				.620
								5	6.1	686.6	-3.00	19.6				.624
								6	3.7	691.2	-1.89	19.9				.626
								7	1.4	695.9	-.77	20.0				.628
								8	.0	700.6	.35	20.5				.629
								9	.0	705.2	1.46	21.6				.630
								10	.0	709.8	2.57	22.6				.630
								11	.0	714.4	3.67	23.7				.630
	I							12	.0	719.0	4.78	24.8				.630
	I							EXIT	.0	721.3	5.33	25.4				.630
1074		06-23-65	9:17	2206		.499	97.3	INLET	50.7	612.1	-19.73	3.2				
								EXIT	.0	776.9	19.23	7.3				.349
1075		06-23-65	9:37	2203		.614	109.2	INLET	53.0	608.3	-20.45	3.9				
								EXIT	.0	758.7	15.02	6.0				.392
1076		06-23-65	9:56	2208		.700	116.6	INLET	55.2	605.7	-21.33	4.5				
								EXIT	.0	746.4	11.97	8.3				.418
1077		06-23-65	10:11	2209		.804	123.1	INLET	57.1	603.3	-21.93	5.1				
								EXIT	.0	732.8	8.71	8.6				.441
1078		06-23-65	10:35	2197		.900	127.0	INLET	53.8	607.0	-20.62	5.7				
								EXIT	.0	726.3	7.46	9.2				.455
1079		06-23-65	10:38	2206		.904	125.6	INLET	52.4	609.4	-20.35	5.8				
								EXIT	.0	726.8	7.40	9.2				.450
1080		06-23-65	10:57	2206		1.010	131.9	INLET	54.9	606.1	-21.10	6.4				
								EXIT	.0	716.5	4.97	9.4				.473
1081		06-23-65	11:28	2189		1.247	140.7	INLET	50.7	610.1	-19.61	8.0				
								EXIT	.0	705.5	2.75	10.5				.504

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
1082	I	06-23-65	12: 4	2212		1.493	161.7	INLET	56.1	604.6	-21.67	9.5				
								EXIT	.0	696.1	.01	11.1				.580
1083	I	06-23-65	12:20	2186		1.777	183.6	INLET	56.4	602.3	-21.20	11.3				
								EXIT	1.8	689.7	-.77	13.0				.658
1084	I	06-23-65	13: 4	2192		2.012	198.8	INLET	55.7	603.9	-21.13	12.8				
								EXIT	3.4	687.4	-1.53	14.7				.712
1085	I	06-23-65	13:29	2192		2.260	211.4	INLET	53.3	607.1	-20.38	14.4				
								EXIT	4.0	686.1	-1.82	16.5				.757
1086	I	06-23-65	13:43	2190		2.500	228.1	INLET	52.8	607.5	-20.15	14.0				
								EXIT	4.7	684.6	-2.08	18.1				.817
1087	I	06-23-65	14: 3	2194		3.023	261.7	INLET	51.1	610.1	-19.65	19.4				
								EXIT	5.4	683.2	-2.48	21.9				.937
1088	I	06-24-65	9:50	2197		.511	123.0	INLET	97.9	548.7	-34.39	3.0				
								1	91.6	556.5	-32.54	3.1				.410
								2	78.7	573.0	-28.67	3.1				.421
								3	65.8	590.1	-24.64	3.2				.431
								4	53.4	607.2	-20.59	3.3				.435
								5	41.4	624.5	-16.53	3.3				.438
								6	30.2	641.7	-12.48	3.4				.440
								7	19.6	659.0	-8.42	3.5				.441
								8	9.7	676.2	-4.36	3.4				.442
								9	.6	693.4	-.32	3.8				.443
								10	.0	710.3	3.67	4.5				.443
								11	.0	727.1	7.62	5.3				.442
								12	.0	743.8	11.55	6.0				.441
	I							EXIT	.0	752.1	13.52	6.4				.441
1089	I	06-24-65	10:10	2238		.610	131.8	INLET	98.5	551.3	-35.43	3.6				
								1	92.8	558.4	-33.73	3.7				.441
								2	81.3	573.2	-30.18	3.7				.453
								3	69.6	588.5	-26.51	3.8				.462
								4	58.4	603.8	-22.84	3.9				.466
								5	47.5	619.2	-19.16	4.0				.468
								6	37.1	634.5	-15.48	4.1				.470
								7	27.3	649.8	-11.81	4.2				.471
								8	18.1	665.0	-8.16	4.3				.471
								9	9.6	680.2	-4.52	4.4				.471
								10	1.7	695.5	-.86	4.5				.471
								11	.0	711.0	2.86	5.2				.472
	I							12	.0	726.3	6.54	6.0				.473
	I							EXIT	.0	733.9	8.35	6.4				.472

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i1}}{10^6}$	$\frac{\phi_i}{10^6}$
1090	I	05-24-65	10:47	2217		.706	143.9	INLET	102.4	545.0	-36.11	4.2				
								1	97.0	551.7	-34.51	4.2				.485
								2	86.0	565.6	-31.20	4.3				.495
								3	74.9	580.0	-27.76	4.3				.504
								4	64.0	594.5	-24.34	4.4				.508
								5	53.4	609.1	-20.88	4.5				.511
								6	43.3	623.7	-17.41	4.6				.514
								7	33.6	638.2	-13.97	4.7				.515
								8	24.5	652.7	-10.52	4.8				.516
								9	15.9	667.1	-7.08	4.9				.516
								10	8.0	681.3	-3.71	5.1				.515
								11	.8	695.5	-.34	5.2				.515
								12	.0	710.0	3.11	6.1				.515
1091	I	05-24-65	11:22	2196		.804	151.3	EXIT	.0	717.4	4.85	6.5				.516
								INLET	98.3	548.0	-34.49	4.8				
								1	93.4	554.3	-32.93	4.8				.511
								2	83.3	567.1	-29.91	4.9				.521
								3	73.1	580.5	-26.77	5.0				.531
								4	63.1	593.9	-23.61	5.0				.536
								5	53.3	607.4	-20.45	5.1				.539
								6	43.9	620.7	-17.30	5.2				.541
								7	34.9	634.1	-14.17	5.3				.541
								8	26.4	647.4	-11.04	5.5				.542
								9	18.2	660.7	-7.90	5.6				.542
								10	10.5	674.1	-4.75	5.7				.543
								11	3.3	687.5	-1.60	5.9				.543
								12	.0	700.7	1.50	6.4				.543
1092	I	05-24-65	11:40	2212		.913	159.1	EXIT	.0	707.1	3.01	6.9				.542
								INLET	101.7	545.2	-35.75	5.4				
								1	97.1	551.0	-34.36	5.4				.539
								2	87.6	563.0	-31.59	5.5				.550
								3	78.0	575.3	-28.62	5.6				.559
								4	68.6	587.7	-25.69	5.7				.564
								5	59.5	600.0	-22.76	5.8				.566
								6	50.7	612.3	-19.87	5.9				.566
								7	42.2	624.5	-16.96	6.0				.567
								8	33.9	637.0	-14.02	6.1				.568
								9	26.0	649.4	-11.07	6.2				.569
								10	18.5	661.7	-8.15	6.3				.569
								11	11.4	674.0	-5.23	6.5				.570
								12	4.7	686.4	-2.29	6.7				.570
								EXIT	1.6	692.6	-.84	6.7				.570

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
1093		05-24-65	11:47	2211		.915	157.8	INLET	101.9	545.1	-35.71	5.4				
								1	97.3	550.9	-34.35	5.4				.536
								2	87.9	562.7	-31.54	5.5				.547
								3	78.4	574.9	-28.65	5.6				.555
								4	69.1	587.1	-25.76	5.7				.559
								5	60.1	599.3	-22.88	5.8				.561
								6	51.3	611.6	-19.97	5.9				.563
								7	42.7	623.9	-17.06	6.0				.564
								8	34.5	636.1	-14.16	6.1				.565
								9	26.7	648.4	-11.26	6.2				.566
								10	19.3	660.4	-8.41	6.3				.569
	I							11	12.3	672.6	-5.52	6.5				.565
								12	5.7	684.8	-2.63	6.6				.566
								EXIT	2.6	690.8	-1.21	6.7				.565
1094		06-24-65	12:25	2187		1.008	165.0	INLET	100.0	545.3	-34.65	6.0				
								1	95.6	550.2	-33.36	6.0				.565
								2	86.6	562.1	-30.72	6.1				.575
								3	77.5	573.7	-28.00	6.2				.583
								4	68.7	585.3	-25.29	6.3				.586
								5	60.1	596.9	-22.57	6.4				.588
								6	51.7	608.5	-19.85	6.5				.589
								7	43.7	620.1	-17.14	6.6				.590
								8	35.9	631.6	-14.45	6.7				.590
								9	28.5	643.1	-11.76	6.8				.590
								10	21.3	654.7	-9.04	6.9				.590
	I							11	14.4	666.4	-6.30	7.1				.591
	I							12	7.9	678.0	-3.59	7.2				.592
	I							EXIT	4.8	683.7	-2.25	7.3				.591
1095		06-24-65	12:53	2193		1.260	183.4	INLET	100.7	544.9	-35.03	7.5				
								1	96.9	549.6	-33.52	7.5				.601
								2	89.1	559.5	-31.61	7.6				.622
								3	81.0	569.8	-29.18	7.7				.638
								4	73.0	580.3	-26.73	7.8				.647
								5	65.2	590.7	-24.28	7.9				.652
								6	57.6	601.0	-21.85	8.0				.654
								7	50.2	611.3	-19.43	8.1				.655
								8	43.0	621.7	-17.00	8.2				.656
								9	35.9	632.1	-14.56	8.3				.657
								10	29.2	642.4	-12.13	8.5				.658
								11	22.7	652.7	-9.70	8.6				.658
	I							12	16.6	662.9	-7.31	8.8				.658
	I							EXIT	13.7	668.0	-6.13	8.9				.657

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_{i_o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i_l}}{10^6}$	$\frac{\phi_l}{10^6}$
1096		06-24-65	13:23	2194		1.494	201.2	INLET	97.1	549.6	-33.91	8.9				.658
								1	93.7	554.0	-32.89	8.9				.681
								2	86.6	563.1	-30.75	9.0				.699
								3	79.2	572.6	-28.51	9.1				.707
								4	71.9	582.2	-26.26	9.2				.712
								5	64.7	591.8	-24.01	9.3				.715
								6	57.6	601.4	-21.76	9.5				.717
								7	50.7	611.0	-19.51	9.6				.719
								8	43.9	620.6	-17.24	9.7				.721
								9	37.4	630.3	-14.97	9.9				.722
								10	31.0	639.9	-12.71	10.0				.722
								11	24.9	649.5	-10.46	10.2				.721
	I							12	19.2	658.8	-8.26	10.3				.721
	I							EXIT	16.4	663.5	-7.17	10.4				
1097		06-24-65	13:55	2187		1.771	234.9	INLET	97.6	548.3	-33.99	10.5				.769
								1	94.2	552.6	-32.99	10.6				.795
								2	87.1	561.5	-30.89	10.7				.816
								3	79.7	570.9	-28.66	10.8				.826
								4	72.5	580.4	-26.47	10.9				.832
								5	65.4	589.8	-24.26	11.1				.835
								6	58.4	599.3	-22.05	11.2				.838
								7	51.7	608.7	-19.83	11.3				.839
								8	45.1	618.1	-17.63	11.5				.839
								9	38.7	627.5	-15.44	11.6				.840
								10	32.5	636.8	-13.24	11.8				.842
								11	26.4	646.4	-11.00	12.0				.843
	I							12	20.7	655.8	-8.80	12.2				.841
	I							EXIT	18.0	660.4	-7.74	12.3				
1098		06-24-65	14:15	2197		2.007	259.8	INLET	98.4	547.9	-34.49	11.9				.894
								1	95.1	552.1	-33.51	12.0				.883
								2	88.2	560.9	-31.44	12.1				.906
								3	81.0	570.1	-29.27	12.2				.916
								4	73.9	579.3	-27.10	12.4				.921
								5	67.0	588.5	-24.93	12.5				.925
								6	60.2	597.7	-22.76	12.7				.928
								7	53.5	607.0	-20.58	12.8				.930
								8	47.0	616.3	-18.41	13.0				.931
								9	40.7	625.5	-16.24	13.2				.933
								10	34.5	634.7	-14.07	13.3				.934
								11	28.5	644.0	-11.89	13.5				.932
	I							12	22.9	653.0	-9.77	13.7				.931
	I							EXIT	20.3	657.3	-8.74	13.8				

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{L_0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{L_1}}{10^6}$	$\frac{\phi_i}{10^6}$
1099		06-24-65	14:43	2192		2.259	287.0	INLET	99.2	546.9	-34.51	13.4				
								1	95.8	551.0	-33.53	13.5				.980
								2	89.0	559.7	-31.50	13.6				.984
								3	82.0	568.7	-29.39	13.7				1.002
								4	75.0	577.7	-27.28	13.9				1.011
								5	68.2	586.7	-25.16	14.0				1.018
								6	61.5	595.8	-23.03	14.2				1.022
								7	54.9	604.8	-20.91	14.4				1.024
								8	48.5	613.9	-18.78	14.4				1.026
								9	42.2	622.9	-16.65	14.7				1.028
								10	36.2	632.0	-14.54	14.9				1.029
								11	30.3	641.0	-12.42	15.2				1.030
	I							12	24.7	649.9	-10.33	15.4				1.029
	I							EXIT	22.1	654.2	-9.30	15.5				1.028
1100		06-24-65	15: 9	2195		2.525	317.2	INLET	101.5	544.2	-35.23	14.9				
								1	98.1	548.4	-34.22	15.0				1.094
								2	91.1	557.1	-32.18	15.1				1.110
								3	84.1	566.0	-30.09	15.3				1.122
								4	77.2	574.9	-28.00	15.5				1.128
								5	70.4	583.8	-25.92	15.6				1.131
								6	63.8	592.7	-23.83	15.8				1.132
								7	57.4	601.5	-21.76	16.0				1.133
								8	51.0	610.4	-19.66	16.2				1.134
								9	44.8	619.4	-17.56	16.4				1.136
								10	38.8	628.2	-15.48	16.6				1.136
								11	33.0	637.1	-13.39	16.8				1.137
	I							12	27.4	646.0	-11.31	17.1				1.137
	I							EXIT	24.6	650.3	-10.26	17.2				1.136
1101		06-24-65	15:48	2189		2.754	329.3	INLET	100.6	544.7	-34.88	16.3				
								1	97.5	548.7	-33.66	16.4				1.099
								2	91.0	556.8	-32.04	16.5				1.128
								3	84.4	565.3	-30.06	16.7				1.151
								4	77.8	573.8	-28.07	16.8				1.162
								5	71.3	582.3	-26.08	17.0				1.168
								6	65.0	590.8	-24.09	17.2				1.172
								7	58.7	599.2	-22.11	17.4				1.174
								8	52.6	607.7	-20.11	17.6				1.176
								9	46.6	616.2	-18.13	17.8				1.177
								10	40.7	624.7	-16.14	18.0				1.179
								11	35.0	633.2	-14.14	18.3				1.180
								12	29.5	641.6	-12.17	18.5				1.180
								EXIT	26.9	645.8	-11.19	18.6				1.179

Table A-6. Data From Test Section 6
(Uniform Outside)

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
421		4-26-65	12:10	1000	.68	.904	232.6	INLET	26.9	509.0	-5.15	2.9				
	0							12	.0	883.1	52.47	34.2	.407	.441		
	0							EXIT	.0	898.9	54.90	35.6		.440		
422		4-26-65	13:18	1000	.59	.494	243.0	INLET	48.1	483.6	-9.05	2.8				
	0							12	.0	882.1	52.31	33.4	.488	.502		
	0							EXIT	.0	898.9	54.90	34.9		.501		
423		4-26-65	14:14	1000	.66	.517	278.1	INLET	102.5	421.7	-18.59	2.8				
	0							12	.0	858.8	48.89	32.7	.554	.575		
	0							EXIT	.0	876.3	51.41	34.4		.574		
424		4-27-65	11:00	1010	6.75	1.479	324.9	INLET	24.7	513.2	-4.75	8.6				
								1	18.6	520.6	-3.60	8.7	.644	.644		
								2	6.4	535.8	-1.20	8.8	.656	.652		
								3	.0	551.0	1.10	10.4	.680	.656		
								4	.0	567.2	3.60	15.1	.601	.669		
								5	.0	582.4	5.95	15.1	.644	.667		
								6	.0	597.8	8.32	23.2	.601	.667		
								7	.0	613.9	10.81	27.5	.689	.671		
								8	.0	628.8	13.11	31.5	.646	.668		
								9	.0	644.9	15.60	35.8	.606	.671		
								10	.0	660.0	17.93	39.8	.688	.670		
								11	.0	675.5	20.33	43.9	.652	.670		
	0							12	.0	691.4	22.77	48.1	.652	.671		
	0							EXIT	.0	698.9	23.93	50.1		.671		
425		4-27-65	11:54	1005	5.82	1.454	346.0	INLET	46.4	486.3	-8.77	8.2				
	0							12	.0	479.3	21.04	44.5	.688	.715		
	0							EXIT	.0	687.5	22.25	46.6		.714		
426		4-27-65	12:58	995	4.71	1.472	405.0	INLET	94.9	429.5	-17.24	7.9				
	0							12	.0	652.6	17.06	38.6	.814	.637		
	0							EXIT	.0	662.0	18.51	41.1		.636		
427		4-27-65	14:09	1000	3.91	1.476	454.5	INLET	145.6	374.8	-25.81	7.6				
	0							12	.0	624.5	12.64	30.8	.916	.934		
	0							EXIT	.0	635.1	14.27	33.7		.940		
428		4-27-65	14:41	995	3.67	1.480	456.5	INLET	143.1	376.8	-25.34	7.6				
	0							12	.0	626.9	13.11	31.9	.918	.943		
	0							EXIT	.0	637.4	14.73	34.7		.942		
429		4-27-65	16:21	995	.27	.506	266.6	INLET	146.5	373.1	-25.91	2.6				
	0							12	.0	400.7	39.84	26.9	.537	.551		
	0							EXIT	.0	818.8	42.62	28.6		.550		
430		4-28-65	10:07	1010	11.26	2.362	357.3	INLET	27.4	509.9	-5.25	13.7				
	0							12	.0	632.6	13.69	51.9	.717	.730		
	0							EXIT	.0	637.8	14.49	54.1		.737		
431		4-28-65	11:00	1005	9.92	2.450	396.2	INLET	51.0	480.9	-9.61	13.8				
	0							12	.0	612.0	10.61	45.2	.798	.618		
	0							EXIT	.0	617.5	11.47	47.6		.617		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{11}}{10^6}$	$\frac{\phi_i}{10^6}$
432		4-28-65	14:25	1000	6.39	2.424	458.0	INLET	99.9	424.6	-18.14	13.0				
	0							12	.0	577.7	5.44	30.1	.924	.946		
	0							EXIT	.0	584.2	6.44	32.9		.945		
433		4-28-65	15:25	993	4.89	2.510	515.5	INLET	145.2	374.2	-25.68	12.9				
	0							12	.9	540.8	-1.09	15.0	1.039	1.065		
	0							EXIT	.0	547.8	1.00	18.0		1.064		
454		5-11-65	15:42	1995		.497	112.5	INLET	24.6	630.8	-8.66	3.3				
	0							12	.0	814.6	30.69	10.5	.225	.232		
	0							EXIT	.0	822.3	32.56	10.9		.232		
456		5-11-65	13:00	2005	1.95	1.500	199.1	INLET	24.7	631.6	-8.79	10.0				
	0							12	.0	739.3	14.49	20.5	.395	.411		
	0							EXIT	.0	743.8	15.47	21.1		.411		
457		5-11-65	14:14	2005	1.76	1.507	230.3	INLET	48.6	597.2	-16.24	5.5				
	0							12	.0	721.1	10.55	17.9	.463	.476		
	0							EXIT	.0	726.3	11.68	18.7		.475		
458		5-13-65	09:33	2000	1.22	1.508	287.8	INLET	98.6	531.9	-30.17	8.8				
	0							12	.0	686.7	3.24	13.0	.570	.595		
	0							EXIT	.0	693.2	4.63	13.9		.594		
459		5-13-65	10:36	2000	1.11	1.496	336.6	INLET	147.3	474.1	-42.63	8.3				
	0							12	8.8	656.5	-3.27	10.4	.683	.695		
	0							EXIT	4.3	664.3	-1.59	10.9		.695		
460		5-13-65	12:16	1997	3.51	2.474	489.1	INLET	147.6	473.6	-42.63	13.7				
	0							12	22.7	633.9	-8.08	16.5	.987	1.010		
	0							EXIT	18.3	640.7	-6.61	16.7		1.009		
461		5-13-65	14:22	2000	4.01	2.503	408.2	INLET	101.0	529.0	-30.80	14.6				
	0							11	12.7	650.0	-4.66	17.2	.820	.845		
	0							12	6.1	661.2	-2.26	17.5	.823	.843		
	0							EXIT	2.8	666.8	-1.05	17.7		.842		
462		5-13-65	16:11	2005	4.66	2.476	307.5	INLET	49.2	596.4	-16.42	15.7				
	0							11	.0	688.7	3.54	21.6	.613	.636		
	0							12	.0	697.1	5.37	23.7	.616	.635		
	0							EXIT	.0	701.4	6.29	24.7		.635		
463		05-14-65	09:35	2000	5.34	2.411	246.9	INLET	21.1	636.7	-7.55	16.2				
	0							12	.0	719.8	10.38	26.5	.494	.510		
	0							EXIT	.0	723.3	11.13	26.3		.510		
464		5-14-65	14:36	1005	9.63	2.417	391.6	INLET	48.8	483.4	-9.21	12.6				
	0							11	.0	603.8	9.35	41.0	.782	.812		
	0							12	.0	614.6	11.05	45.8	.787	.809		
	0							EXIT	.0	620.4	11.90	48.2		.808		
465		5-17-65	10:09	1010	.43	.505	269.3	INLET	99.1	426.8	-18.08	2.7				
	0							10	.0	783.3	36.57	24.8	.567	.555		
	0							11	.0	822.9	43.09	26.4	.536	.558		
	0							12	.0	859.5	48.73	31.7	.537	.556		
	0							EXIT	.0	877.6	51.53	33.3		.556		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$
466		5-17-65	11:21	1000	.59	.509	282.9	INLET	118.6	404.0	-21.31	2.7				
	0							12	.0	854.6	48.07	31.9	.572	.584		
	0							EXIT	.0	873.8	51.03	33.6		.584		
467		5-17-65	12:23	1000	.20	.486	266.6	INLET	146.6	373.7	-25.98	2.5				
	0							12	.0	818.2	42.48	27.3	.534	.551		
	0							EXIT	.0	837.0	45.36	28.9		.550		
468		5-17-65	13:44	1000	.27	.508	282.4	INLET	175.0	343.5	-30.64	2.6				
	0							12	.0	794.0	38.75	26.3	.559	.584		
	0							EXIT	.0	812.8	41.64	28.0		.583		
469		5-18-65	09:24	997	.86	.600	310.3	INLET	148.5	371.3	-26.26	3.1				
	0							12	.0	790.3	38.21	30.7	.625	.641		
	0							EXIT	.0	808.0	40.94	32.7		.640		
470		5-18-65	11:14	993	1.81	.795	363.9	INLET	145.7	373.7	-25.76	4.1				
	0							12	.0	745.0	31.29	34.3	.727	.752		
	0							EXIT	.0	760.6	33.69	36.6		.751		
471		5-18-65	11:59	990	2.70	.998	403.8	INLET	146.5	372.4	-25.85	5.1				
	0							12	.0	701.5	24.67	35.3	.752	.837		
	0							EXIT	.0	714.4	26.64	37.7		.833		
492		5-19-65	10:20	1000	4.24	1.003	304.8	INLET	26.0	510.1	-4.97	5.8				
	0							12	.0	756.6	32.98	45.0	.616	.629		
	0							EXIT	.0	767.1	34.60	46.9		.629		
493		5-19-65	11:59	1005	2.81	.797	282.9	INLET	22.9	514.6	-4.41	4.6				
	0							12	.0	802.4	39.98	42.1	.571	.584		
	0							EXIT	.0	814.7	41.87	43.9		.584		
494		5-19-65	12:29	1005	2.54	.801	304.8	INLET	48.6	483.6	-9.18	4.5				
	0							12	.0	792.4	38.43	40.9	.605	.630		
	0							EXIT	.0	805.3	40.42	42.7		.629		
495		5-19-65	13:17	1005	3.44	1.000	325.2	INLET	50.5	481.4	-9.52	5.6				
	0							12	.0	745.0	31.12	42.5	.657	.672		
	0							EXIT	.0	756.2	32.85	44.5		.671		
496		5-19-65	14:17	1005	3.19	.988	363.9	INLET	97.9	427.5	-17.84	5.3				
	0							12	.0	726.0	28.19	38.6	.735	.752		
	0							EXIT	.0	738.7	30.15	40.8		.751		
497		5-19-65	15:18	1000	2.31	.806	337.2	INLET	97.9	426.8	-17.80	4.3				
	0							12	.0	766.0	34.43	37.5	.691	.696		
	0							EXIT	.0	780.6	36.68	39.6		.696		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,j}}{10^6}$	$\frac{\phi_i}{10^6}$
498		5-20-65	09:19	1495	1.38	.994	216.3	INLET	23.4	578.5	-5.82	6.2				
								1	18.0	585.8	-4.51	6.3	.426	.426		
								2	7.3	600.6	-1.86	6.4	.436	.428		
								3	.0	615.0	.73	7.0	.451	.425		
								4	.0	630.8	3.56	9.0	.450	.435		
								5	.0	645.7	6.24	10.9	.423	.435		
								6	.0	660.6	8.90	12.7	.451	.434		
								7	.0	676.8	11.81	14.8	.450	.440		
								8	.0	692.1	14.56	16.7	.426	.441		
								9	.0	707.5	17.33	18.6	.448	.442		
								10	.0	721.8	19.88	20.4	.459	.439		
								11	.0	738.5	22.90	22.5	.426	.444		
	0							12	.0	755.1	25.87	24.6	.431	.447		
	0							EXIT	.0	762.5	27.20	25.6		.446		
499		5-20-65	10:48	1493	.25	.707	194.1	INLET	27.8	572.5	-6.86	4.4				
	0							12	.0	795.0	33.05	21.2	.389	.401		
	0							EXIT	.0	804.3	34.73	22.0		.400		
500		5-20-65	11:41	1500		.512	172.6	INLET	28.8	571.9	-7.14	3.2				
	0							12	.0	845.3	42.01	18.4	.352	.356		
	0							EXIT	.0	857.0	44.12	19.2		.356		
501		5-20-65	12:23	1509		.509	182.8	INLET	53.6	540.7	-12.98	3.0				
	0							12	.0	832.0	39.53	17.4	.366	.378		
	0							EXIT	.0	844.2	41.74	18.1		.377		
502		5-20-65	13:15	1492	.27	.716	214.4	INLET	52.2	540.7	-12.54	4.3				
	0							12	.0	783.5	31.01	20.4	.434	.443		
	0							EXIT	.0	793.9	32.87	21.3		.442		
503		5-20-65	14:34	1503	1.17	1.004	241.7	INLET	55.1	538.1	-13.29	6.0				
	0							12	.0	733.4	21.85	21.9	.485	.499		
	0							EXIT	.0	741.7	23.34	23.0		.499		
504		5-20-65	16:06	1488	2.94	1.486	281.2	INLET	49.9	543.1	-11.99	8.9				
	0							12	.0	696.6	15.49	26.0	.562	.581		
	0							EXIT	.0	703.0	16.64	27.3		.580		
505		5-21-65	08:36	1495	3.25	1.476	251.7	INLET	26.2	574.7	-6.51	9.2				
	0							12	.0	713.0	18.31	28.7	.504	.520		
	0							EXIT	.0	718.8	19.35	29.8		.519		
506		5-21-65	10:01	1505	6.84	2.335	289.8	INLET	25.0	577.6	-6.24	14.5				
	0							11	.0	669.7	10.34	32.1	.583	.600		
								12	.0	678.2	11.88	34.7	.586	.598		
								EXIT	.0	682.5	12.65	35.9		.598		
507		5-21-65	10:33	1500	5.07	1.986	278.5	INLET	26.3	575.3	-6.53	12.3				
	0							11	.0	679.3	12.17	30.0	.560	.577		
								12	.0	688.9	13.90	32.4	.561	.575		
								EXIT	.0	693.8	14.77	33.6		.575		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^6$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
508		5-21-65	11:25	1500	4.44	1.985	315.2	INLET	52.1	541.7	-12.56	11.9				
	0							12	.0	670.4	10.58	27.7	.633	.651		
	0							EXIT	.0	675.9	11.56	29.1		.650		
509		5-21-65	11:55	1505	6.34	2.490	347.4	INLET	52.6	541.6	-12.71	14.9				
	0							11	.0	645.6	6.01	26.7	.691	.722		
								12	.0	654.8	7.66	29.6	.697	.718		
								EXIT	.0	659.5	8.52	31.1		.717		
510		5-21-65	13:25	1515	4.80	2.427	430.1	INLET	100.4	484.2	-23.35	13.6				
	0							12	.0	627.9	2.60	20.3	.867	.888		
	0							EXIT	.0	634.0	3.71	22.1		.887		
511		5-21-65	14:53	1498	3.46	1.947	373.4	INLET	94.1	489.8	-21.83	11.0				
	0							12	.0	645.3	6.11	21.1	.753	.771		
	0							EXIT	.0	651.9	7.29	22.7		.770		
512		5-21-65	15:35	1490	2.06	1.487	322.0	INLET	97.5	485.0	-22.46	8.3				
	0							12	.0	660.5	9.00	19.2	.648	.665		
	0							EXIT	.0	668.0	10.33	20.6		.664		
513		07-20-65	12:54	1480		.546	222.5	INLET	99.6	481.5	-22.74	3.1				
	0							EXIT	.0	825.5	38.68	18.7		.459		
514		07-20-65	13:28	1507		.695	242.4	INLET	100.7	482.7	-23.25	3.9				
	0							EXIT	.0	777.6	29.82	19.0		.500		
515		07-20-65	14:10	1498		.978	277.0	INLET	99.4	483.4	-22.51	5.5				
	0							EXIT	.0	722.7	20.05	20.2		.572		
516		07-20-65	15:08	1522		.552	242.3	INLET	148.9	429.8	-33.34	3.0				
	0							EXIT	.0	800.9	33.82	16.5		.500		
517		07-20-65	15:35	1506		.712	274.1	INLET	146.3	431.2	-32.57	3.8				
	0							EXIT	.0	756.4	25.58	17.6		.566		
518		07-20-65	16:00	1524		.973	314.9	INLET	147.9	430.9	-33.26	5.2				
	0							EXIT	.0	704.3	16.26	17.2		.650		
519		07-20-65	16:38	1485		1.470	372.6	INLET	143.5	432.3	-31.68	7.9				
	0							EXIT	.0	646.4	6.61	16.5		.769		
520		07-20-65	17:01	1505		2.014	435.6	INLET	145.3	432.2	-32.33	10.8				
	0							EXIT	.0	615.0	.56	13.9		.899		
521		07-20-65	17:27	1518		2.474	490.9	INLET	143.0	436.0	-32.09	13.3				
	0							EXIT	6.6	603.7	-1.78	15.9		1.013		
522		07-20-65	17:47	1490		2.943	555.4	INLET	141.8	434.8	-31.41	15.8				
	0							EXIT	11.1	554.3	-2.85	18.7		1.146		
524		07-21-65	10:14	1992		.494	120.0	INLET	25.1	629.3	-8.86	3.3				
	0							EXIT	.0	834.7	35.31	11.4		.248		
525		07-21-65	10:51	1987		.662	138.7	INLET	26.2	627.6	-9.09	4.4				
	0							EXIT	.0	804.7	28.93	13.4		.286		
526		07-21-65	12:07	1984		.994	165.6	INLET	18.6	638.2	-6.71	6.7				
	0							EXIT	.0	778.9	23.45	17.7		.342		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^6$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
927		07-21-65	12:58	1995		1.952	230.8	INLET	21.9	634.8	-7.76	13.0				
	0							11	.0	722.5	11.12	23.7		.478		
								12	.0	730.6	12.86	25.2		.476		
								EXIT	.0	734.7	13.75	26.0		.476		
928		07-21-65	13:15	1998		1.997	268.3	INLET	44.9	600.9	-15.19	12.7				
	0							11	.0	700.5	6.30	19.9		.555		
								12	.0	709.7	8.27	21.7		.554		
								EXIT	.0	714.4	9.29	22.6		.554		
929		07-21-65	13:48	2019		1.461	233.0	INLET	47.1	600.0	-16.08	9.3				
	0							11	.0	718.1	9.61	16.7		.481		
	0							12	.0	729.2	12.01	18.2		.481		
	0							EXIT	.0	734.8	13.24	19.0		.481		
930		07-21-65	14:23	2017		.982	199.3	INLET	53.8	590.5	-18.00	6.2				
	0							11	.0	741.2	14.73	13.4		.413		
	0							12	.0	755.1	17.76	14.8		.412		
	0							EXIT	.0	761.9	19.24	15.4		.411		
931		07-21-65	14:52	1983		.714	167.0	INLET	51.0	590.9	-16.81	4.5				
	0							EXIT	.0	788.5	25.51	13.4		.345		
932		07-21-65	15:20	2002		.529	139.2	INLET	50.9	592.9	-16.99	3.3				
	0							EXIT	.0	815.2	30.99	11.1		.287		
933		07-21-65	15:54	2061		.518	164.5	INLET	101.4	533.3	-32.12	3.0				
	0							EXIT	.0	801.5	27.23	9.8		.339		
934		07-22-65	9:26	2034		.697	199.2	INLET	104.8	526.8	-32.65	4.1				
	0							EXIT	.0	768.2	20.22	11.2		.411		
935		07-22-65	9:36	1995		.700	202.2	INLET	104.5	524.0	-31.57	4.1				
	0							EXIT	.0	768.2	20.99	11.6		.417		
936		07-22-65	10:31	2027		.999	243.1	INLET	103.3	528.1	-32.04	9.8				
	0							11	.0	707.9	7.20	10.3		.501		
								12	.0	725.0	10.54	12.0		.501		
								EXIT	.0	733.7	12.83	12.8		.502		
937		07-22-65	11:02	2039		1.493	300.7	INLET	103.1	529.2	-32.25	8.7				
	0							11	.0	678.2	.46	11.0		.621		
								12	.0	692.3	3.54	13.0		.620		
								EXIT	.0	699.4	5.10	14.0		.620		
938		07-22-65	11:25	2027		1.984	356.6	INLET	99.4	533.1	-30.56	11.6				
	0							11	4.6	666.6	-1.81	14.0		.739		
								12	.0	678.8	.85	14.9		.737		
								EXIT	.0	684.9	2.19	16.1		.736		
939		07-22-65	12:04	1999		1.996	419.5	INLET	144.8	476.8	-42.00	11.1				
	0							11	23.8	632.2	-8.47	13.3		.866		
	0							12	14.4	647.0	-5.29	13.6		.865		
	0							EXIT	9.9	694.4	-3.69	13.8		.866		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,j}}{10^6}$	$\frac{\phi_i}{10^6}$
540		07-22-65	12:35	1980		1.502	354.2	INLET	150.7	468.7	-42.84	8.3				
0								11	15.6	643.1	-5.53	10.2		.731		
0								12	5.5	659.6	-2.01	10.5		.731		
0								EXIT	.6	667.9	-.23	10.6		.731		
541		07-22-65	13:09	2039		.995	279.7	INLET	161.1	461.4	-47.11	5.4				
0								11	3.8	669.4	-1.48	7.0		.577		
0								12	.0	689.1	2.83	8.4		.577		
0								EXIT	.0	699.1	5.03	9.3		.577		
542		07-22-65	14:30	1999		.703	235.5	INLET	151.2	469.6	-43.56	3.9				
0								EXIT	.0	752.5	17.48	10.5		.486		
543		07-22-65	14:37	2021		.721	233.8	INLET	149.3	473.5	-43.67	4.0				
0								EXIT	.0	747.4	15.97	10.2		.482		
544		07-22-65	15:26	2027		.716	232.5	INLET	150.7	472.5	-44.14	4.0				
0								EXIT	.0	747.0	15.77	10.1		.480		
545		07-22-65	16:02	2033		.505	189.7	INLET	152.3	471.2	-44.65	2.8				
0								EXIT	.0	788.8	24.83	9.1		.391		
546		07-23-65	9:50	2213		.547	113.5	INLET	19.5	660.2	-8.50	3.8				
0								EXIT	.0	835.7	33.08	10.8		.234		
547		07-23-65	10:00	2204		.519	127.9	INLET	45.5	619.0	-17.94	3.4				
0								EXIT	.0	827.4	31.24	9.9		.264		
548		07-23-65	10:22	2212		.524	142.9	INLET	72.9	582.2	-26.99	3.2				
0								EXIT	.0	812.8	27.64	9.3		.295		
549		07-23-65	10:31	2230		.696	169.2	INLET	71.4	585.5	-26.98	4.3				
0								EXIT	.0	791.1	22.16	10.9		.349		
550		07-23-65	10:45	2223		.690	153.0	INLET	48.8	616.2	-19.32	4.5				
0								EXIT	.0	803.7	25.33	11.6		.316		
551		07-23-65	11:06	2197		.704	131.1	INLET	17.8	661.9	-7.67	4.9				
0								EXIT	.0	819.3	29.39	13.0		.271		
552		07-23-65	11:17	2214		.982	157.6	INLET	19.8	659.9	-8.64	6.8				
0								11	.0	778.6	19.51	14.4		.326		
0								12	.0	789.7	22.15	19.4		.325		
0								EXIT	.0	795.5	23.51	15.9		.325		
553		07-23-65	11:29	2196		.997	183.9	INLET	43.0	621.9	-17.05	6.5				
0								11	.0	758.3	15.05	13.1		.380		
0								12	.0	771.5	18.13	14.2		.380		
0								EXIT	.0	777.8	19.62	14.8		.379		
554		07-23-65	11:44	2194		1.014	206.7	INLET	68.6	586.2	-25.28	6.3				
0								11	.0	736.6	10.04	11.4		.426		
0								12	.0	751.0	13.40	12.7		.426		
0								EXIT	.0	758.5	15.17	13.3		.426		
555		07-23-65	12:04	2245		1.480	253.7	INLET	73.1	584.6	-27.77	9.2				
0								11	.0	711.7	2.82	12.6		.525		
								12	.0	723.6	5.68	14.1		.524		
								EXIT	.0	729.5	7.09	14.9		.523		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
556		07-23-65	12:30	2135		1.488	220.1	INLET	36.2	626.5	-13.79	6.8				
	0							11	.0	736.4	11.33	17.6		.456		
								12	.0	746.6	13.65	19.0		.455		
								EXIT	.0	751.5	14.77	19.7		.454		
557		07-23-65	12:37	2225		1.514	227.7	INLET	48.0	617.4	-19.14	6.8				
	0							11	.0	728.6	7.36	15.4		.470		
								12	.0	739.1	9.86	16.8		.469		
								EXIT	.0	744.5	11.17	17.5		.470		
558		07-23-65	13:09	2218		1.506	196.3	INLET	22.6	655.9	-9.72	10.3				
	0							11	.0	751.3	12.94	18.4		.481		
								12	.0	761.1	15.26	19.7		.483		
								EXIT	.0	766.0	16.45	20.4		.485		
559		07-23-65	13:21	2218		1.970	227.7	INLET	20.8	659.0	-8.99	13.6				
	0							11	.0	744.8	11.39	23.0		.472		
								12	.0	752.6	13.26	24.4		.470		
								EXIT	.0	756.7	14.22	25.1		.470		
560		07-23-65	13:34	2218		2.006	276.9	INLET	50.3	613.8	-19.73	12.9				
	0							11	.0	715.9	4.52	18.3		.571		
								12	.0	725.8	6.88	20.1		.572		
								EXIT	.0	730.4	7.98	20.9		.571		
561		07-23-65	14:06	2240		2.014	335.8	INLET	84.7	569.3	-31.32	12.2				
	0							11	3.4	692.7	-1.66	14.8		.694		
								12	.0	704.3	1.11	15.9		.693		
								EXIT	.0	710.1	2.52	16.9		.693		
562		07-23-65	14:12	2202		1.989	316.1	INLET	74.3	579.6	-27.26	12.3				
	0							11	.0	697.2	.50	15.1		.653		
								12	.0	708.2	3.09	17.1		.652		
								EXIT	.0	713.9	4.41	18.1		.652		
563		07-23-65	14:26	2191		2.486	368.2	INLET	74.8	578.0	-27.14	15.3				
	0							11	2.9	687.5	-1.44	18.2		.760		
								12	.0	697.8	.57	19.3		.759		
								EXIT	.0	703.1	2.21	20.5		.760		
564		07-23-65	14:44	2196		2.477	316.6	INLET	48.0	614.7	-18.74	16.0				
	0							11	.0	709.1	3.46	21.6		.652		
								12	.0	718.0	5.57	23.6		.652		
								EXIT	.0	722.7	6.66	24.6		.653		
565		07-23-65	15:09	2244		2.427	277.6	INLET	31.4	643.9	-13.52	16.4				
	0							11	.0	728.8	6.92	24.3		.575		
								12	.0	736.6	8.80	25.9		.573		
								EXIT	.0	740.6	9.75	26.8		.573		
566		07-23-65	15:12	2193		2.378	261.3	INLET	22.2	653.7	-9.46	16.3				
	0							11	.0	734.9	9.60	26.3		.538		
								12	.0	742.6	11.42	27.9		.539		
								EXIT	.0	746.6	12.35	28.8		.539		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
567		07-23-65	15:16	2220		2.476	266.0	INLET	22.5	655.9	-9.81	17.0				
0								11	.0	735.6	9.15	26.8		.551		
								12	.0	743.0	10.91	28.5		.550		
								EXIT	.0	746.7	11.79	29.3		.549		
568		07-23-65	15:30	2210		2.646	277.5	INLET	22.6	654.9	-9.61	18.2				
0								11	.0	732.6	8.75	28.3		.573		
								12	.0	739.9	10.49	30.0		.573		
								EXIT	.0	743.5	11.35	30.9		.573		
569		07-23-65	15:37	2139		2.841	331.6	INLET	40.7	619.9	-15.53	18.5				
0								11	.0	706.4	4.29	29.7		.686		
								12	.0	714.6	6.15	27.8		.685		
								EXIT	.0	718.6	7.07	28.8		.684		
570		07-23-65	15:46	2207		2.866	345.2	INLET	46.2	618.4	-18.20	18.6				
0								11	.0	707.7	2.90	24.4		.714		
								12	.0	716.0	4.86	26.5		.713		
								EXIT	.0	720.2	5.86	27.6		.712		
571		07-23-65	16:03	2202		3.046	415.6	INLET	67.1	589.2	-25.00	19.0				
0								11	2.6	690.2	-1.16	22.3		.859		
								12	.0	699.6	1.06	23.8		.857		
								EXIT	.0	704.5	2.20	25.1		.858		

Table A-7. Data From Test Section 7
(Uniform Both Sides)

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$
579		11-15-65	16:36	990	2.89	.691	445.0	INLET	152.6	366.1	-26.83	3.5				
	0							6	.0	842.6	46.32	42.3		.583		.582
	0 1							7	.0	887.6	53.23	48.0		.583		.582
	0 1							EXIT	.0	910.2	56.71	50.8		.583		.582
580		11-15-65	16:53	978	3.00	.694	428.5	INLET	123.8	395.3	-22.02	3.6				
	0 1							7	.0	894.8	54.43	49.8		.566		.552
	0 1							EXIT	.0	916.7	57.78	52.6		.566		.552
581		11-15-65	17:13	977	3.21	.713	409.3	INLET	100.8	420.3	-18.11	3.8				
	1							7	.0	885.4	53.01	50.0		.537		.534
	1							EXIT	.0	905.6	56.10	52.6		.537		.534
582		11-15-65	17:33	976	3.28	.708	393.5	INLET	81.3	441.8	-14.83	3.8				
	1							7	.0	891.9	53.99	50.5		.514		.516
	1							EXIT	.0	911.6	57.00	53.1		.514		.517
583		11-15-65	17:57	986	2.95	.710	356.3	INLET	59.3	468.3	-11.04	3.9				
	0							6	.0	839.6	45.90	43.3		.465		.470
	0 1							7	.0	874.7	51.28	47.8		.464		.470
	0 1							EXIT	.0	892.4	54.01	50.2		.464		.470
584		11-15-65	18:11	982	3.05	.714	327.9	INLET	33.2	498.8	-6.26	4.1				
	1							7	.0	870.2	50.63	47.8		.424		.437
	1							EXIT	.0	886.7	53.16	49.9		.424		.437
585		11-15-65	18:29	987	3.14	.723	309.4	INLET	9.5	528.3	-1.88	4.3				
	1							7	.0	874.7	51.28	48.6		.398		.416
	1							EXIT	.0	890.0	53.63	50.6		.399		.416
590		11-17-65	13:02	986	5.48	1.013	477.8	INLET	98.5	424.2	-17.79	5.4				
	1							7	.0	806.1	40.78	55.5		.626		.625
	1							EXIT	.0	822.7	43.31	58.6		.626		.624
591		11-17-65	13:46	995	4.94	1.023	495.0	INLET	126.8	394.4	-22.68	5.3				
	1							7	.0	786.4	37.62	51.7		.642		.659
	1							EXIT	.0	803.1	40.19	54.8		.642		.659
592		11-17-65	14:32	998	4.54	1.010	509.3	INLET	145.8	374.1	-25.89	5.2				
	1							7	.0	781.7	36.85	50.0		.658		.679
	1							EXIT	.0	800.1	39.70	53.4		.660		.679
593		11-17-65	15:18	998	5.76	1.248	565.1	INLET	150.4	369.3	-26.62	6.4				
	0 1							7	.0	736.3	29.87	51.9		.734		.750
	0 1							EXIT	.0	752.0	32.29	55.0		.734		.749
594		11-17-65	15:41	1003	6.01	1.230	541.8	INLET	130.3	391.6	-23.31	6.4				
	1							7	.0	748.2	31.65	53.0		.702		.721
	1							EXIT	.0	763.7	34.04	56.5		.703		.721
596		11-18-65	10:35	986	7.00	1.262	482.9	INLET	75.8	449.4	-13.90	6.9				
	1							7	.0	759.1	33.58	58.2		.625		.643
	1							EXIT	.0	772.9	35.69	61.4		.626		.643

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
997		11-18-65	11:06	996	7.15	1.271	444.7	INLET	51.4	479.1	-9.66	7.1				
	I							7	.0	762.6	33.95	58.6		.572		.600
	I							EXIT	.0	774.8	35.83	61.5		.572		.600
998		11-18-65	11:34	1002	7.43	1.268	393.7	INLET	20.6	516.8	-4.03	7.4				
	I							7	.0	768.3	34.74	59.3		.507		.530
	I							EXIT	.0	779.1	36.40	61.8		.507		.531
999		11-18-65	12:06	993	7.84	1.258	373.5	INLET	5.6	534.2	-1.09	7.5				
	I							7	.0	775.0	35.91	61.2		.480		.507
	I							EXIT	.0	785.1	37.47	63.5		.479		.506
600		11-18-65	12:39	998	9.49	1.497	413.3	INLET	17.3	520.1	-3.37	8.8				
	I							7	.0	743.5	31.01	63.8		.534		.552
	I							EXIT	.0	753.4	32.52	66.5		.534		.552
601		11-18-65	12:53	994	9.74	1.508	407.6	INLET	12.6	525.6	-2.44	8.9				
	I							7	.0	744.8	31.26	64.9		.528		.545
	I							EXIT	.0	754.1	32.68	67.4		.527		.545
602		11-18-65	13:17	991	9.16	1.505	478.2	INLET	49.8	480.3	-9.37	8.5				
	I							7	.0	737.5	30.15	63.0		.622		.631
	I							EXIT	.0	748.8	31.90	66.1		.623		.631
603		11-18-65	13:32	987	8.64	1.499	510.8	INLET	73.0	452.8	-13.42	8.2				
	I							7	.0	728.7	28.89	60.8		.667		.672
	I							EXIT	.0	740.7	30.74	64.1		.667		.672
604		11-18-65	13:54	993	7.91	1.489	545.5	INLET	99.2	424.4	-17.97	8.0				
	I							7	.0	720.9	27.60	57.7		.713		.716
	I							EXIT	.0	733.9	29.60	61.2		.713		.716
605		11-18-65	14:09	989	7.68	1.492	589.5	INLET	124.7	395.8	-22.22	7.8				
	I							7	.0	715.8	26.88	56.8		.775		.766
	I							EXIT	.0	729.7	29.02	60.6		.775		.767
606		11-18-65	14:28	984	7.37	1.496	615.0	INLET	147.0	371.2	-25.87	7.7				
	I							7	.0	703.8	25.11	54.0		.798		.815
	I							EXIT	.0	718.6	27.37	58.1		.799		.815
607		11-18-65	15:05	993	9.29	1.984	696.6	INLET	147.2	372.1	-26.01	10.2				
	O							7	.0	656.4	17.68	53.5		.910		.914
	O							EXIT	.0	668.9	19.60	58.0		.911		.914
608		11-18-65	15:16	995	9.15	2.000	702.1	INLET	150.4	369.1	-26.55	10.3				
	O							7	.0	653.2	17.15	52.6		.918		.928
	O							EXIT	.0	665.7	19.07	57.1		.919		.919
609		11-18-65	15:48	992	10.06	1.961	659.7	INLET	121.9	399.3	-21.81	10.3				
	O I							7	.0	671.9	20.07	58.5		.857		.876
	O I							EXIT	.0	683.7	21.88	62.7		.856		.876

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{h_0}}{10^6}$	$\frac{\phi_0}{10^6}$	$\frac{\phi_{h_1}}{10^6}$	$\frac{\phi_1}{10^6}$
611	I	11-19-65	10:05	998	11.09	2.005	622.1	INLET	95.9	428.6	-17.45	10.8				
	I							7	.0	680.0	21.23	62.2		.813		.817
	I							EXIT	.0	690.9	22.91	66.2		.813		.817
612	I	11-19-65	10:38	1000	11.70	2.000	578.9	INLET	75.8	451.7	-13.95	10.9				
	I							7	.0	686.0	22.14	64.1		.756		.761
	I							EXIT	.0	696.3	23.71	67.8		.756		.760
613	I	11-19-65	11:06	999	12.51	1.978	514.0	INLET	45.5	486.4	-8.62	11.2				
	I							7	.0	696.6	23.75	67.2		.663		.688
	I							EXIT	.0	706.0	25.20	70.6		.664		.689
614	I	11-19-65	11:33	1003	13.80	1.977	440.2	INLET	12.3	527.2	-2.38	11.7				
	I							7	.0	707.5	25.40	70.8		.567		.592
	I							EXIT	.0	715.4	26.61	73.6		.567		.592
615	0	11-19-65	11:58	1003	13.80	2.033	470.7	INLET	22.2	515.1	-4.25	11.8				
	0							7	.0	702.6	24.64	71.0		.609		.628
	0							EXIT	.0	710.8	25.89	74.0		.609		.629
623	0	11-19-65	15:37	991	10.63	2.514	766.0	INLET	149.5	369.5	-26.38	12.9				
	0							6	.0	595.0	8.26	39.7		1.005		1.001
	0							7	.0	616.2	11.52	49.5		1.003		1.002
	0							EXIT	.0	627.0	13.18	54.5		1.003		1.002
624	0	11-19-65	15:42	983	10.61	2.523	769.7	INLET	149.8	367.9	-26.31	12.9				
	0							6	.0	593.6	8.27	40.1		1.010		1.005
	0							7	.0	615.0	11.54	50.0		1.009		1.005
	0							EXIT	.0	625.8	13.20	55.1		1.009		1.005
633	0	11-30-65	13:47	1479	.91	.721	355.3	INLET	148.0	426.6	-32.92	3.8				
	0							7	.0	826.2	38.81	24.7		.466		.466
	0							EXIT	.0	842.8	41.78	26.3		.465		.466
634	0	11-30-65	13:51	1485	.88	.720	355.3	INLET	147.7	427.5	-32.58	3.8				
	0							7	.0	827.4	38.95	24.7		.465		.466
	0							EXIT	.0	844.5	42.02	26.2		.465		.466
635	0	11-30-65	14:11	1467	.96	.716	342.6	INLET	125.3	450.5	-27.82	3.9				
	0							7	.0	837.6	40.98	25.9		.444		.455
	0							EXIT	.0	854.9	44.05	27.5		.444		.455
636	0	11-30-65	14:29	1485	.96	.705	332.5	INLET	102.6	478.3	-23.48	3.9				
	0							7	.0	860.4	44.86	27.1		.431		.443
	0							EXIT	.0	877.0	47.83	28.6		.431		.443
637	0	11-30-65	14:46	1499	1.02	.722	315.3	INLET	73.0	514.7	-17.37	4.2				
	0							7	.0	868.1	46.13	28.1		.405		.425
	0							EXIT	.0	883.7	48.54	29.6		.406		.425

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	X	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
638		11-30-65	15:05	1486	1.10	.728	295.8	INLET	50.6	541.2	-12.25	4.3				
	0							7	.0	270.7	46.71	28.9		.383		.396
	0							EXIT	.0	284.7	49.21	30.2		.382		.396
639		11-30-65	15:10	1502	1.06	.723	297.9	INLET	49.9	543.8	-12.16	4.3				
	0							7	.0	276.8	47.69	28.9		.384		.398
	0							EXIT	.0	291.9	50.40	30.3		.385		.398
640		11-30-65	15:28	1495	1.03	.715	271.2	INLET	20.3	581.9	-5.21	4.5				
	0							7	.0	289.0	49.91	29.8		.350		.363
	0							EXIT	.0	302.5	52.33	31.1		.350		.363
641		11-30-65	15:53	1487	1.08	.714	246.0	INLET	.0	610.5	.16	4.7				
	1							7	.0	289.1	50.00	30.0		.315		.333
	1							EXIT	.0	301.6	52.23	31.2		.315		.333
642		11-30-65	16:19	1479	.06	.473	217.3	INLET	.0	618.2	1.69	3.6				
	1							7	.0	590.4	62.12	26.1		.283		.287
	1							EXIT	.0	1006.8	71.04	27.1		.283		.287
643		12-01-65	10:06	1482	2.53	1.035	321.3	INLET	29.4	568.1	-7.35	6.4				
	1							7	.0	219.5	37.57	34.5		.416		.428
	1							EXIT	.0	230.5	39.54	35.9		.416		.428
644		12-01-65	10:28	1488	2.57	1.038	289.8	INLET	11.3	593.4	-2.50	6.6				
	1							7	.0	219.3	37.52	34.4		.372		.392
	1							EXIT	.0	229.3	39.30	35.7		.372		.392
645		12-01-65	10:47	1480	2.41	1.032	337.2	INLET	50.3	540.8	-12.15	6.1				
	0							7	.0	205.3	35.07	32.6		.437		.449
	0							EXIT	.0	216.9	37.14	34.1		.437		.449
646		12-01-65	11:02	1480	2.26	1.024	355.5	INLET	70.0	516.3	-16.51	5.9				
	0							6	.0	773.4	29.40	28.2		.462		.474
	0							7	.0	757.4	33.69	31.3		.461		.473
	0							EXIT	.0	809.7	35.26	32.9		.461		.473
647		12-01-65	11:20	1491	2.08	1.027	375.2	INLET	96.2	486.7	-22.13	5.2				
	0							7	.0	782.5	30.28	29.1		.485		.502
	0							EXIT	.0	755.4	33.18	30.2		.485		.501
648		12-01-65	11:39	1507	1.90	1.024	402.6	INLET	128.5	451.1	-29.02	5.6				
	0							7	.0	769.4	28.31	26.9		.523		.534
	0							EXIT	.0	783.3	30.21	22.7		.523		.534
649		12-01-65	11:54	1501	1.82	1.028	416.8	INLET	147.9	429.0	-32.77	5.5				
	0							7	.0	757.7	26.30	25.7		.541		.555
	0							EXIT	.0	771.8	28.23	27.5		.540		.556
650		12-01-65	12:11	1479	2.65	1.266	464.0	INLET	146.6	428.2	-32.22	6.2				
	0							7	.0	725.3	20.20	27.1		.606		.611
	0							EXIT	.0	738.0	23.07	29.1		.606		.611
651		12-01-65	12:36	1489	2.84	1.274	446.3	INLET	129.1	448.8	-22.29	6.9				
	0							7	.0	732.8	21.99	22.1		.583		.588
	0							EXIT	.0	744.9	24.15	30.1		.582		.588

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,e}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
652		12-01-65	13:12	1470	3.01	1.264	414.0	INLET	95.9	484.7	-21.26	7.1				
	0							7	.0	749.9	25.33	31.3		.537		.549
	0							EXIT	.0	761.6	27.41	33.2		.538		.549
653		12-01-65	13:31	1496	3.11	1.266	387.3	INLET	74.3	512.9	-17.57	7.3				
	0							7	.0	760.9	26.94	32.3		.498		.524
	0							EXIT	.0	771.4	28.23	34.0		.497		.524
654		12-01-65	13:44	1480	3.49	1.273	368.9	INLET	51.7	539.0	-12.44	7.6				
	0							7	.0	773.4	29.40	35.0		.480		.486
	0							EXIT	.0	783.9	31.28	36.8		.481		.487
655		12-01-65	14:02	1495	3.58	1.243	336.8	INLET	26.5	573.5	-6.68	7.7				
	I							7	.0	792.8	32.67	36.8		.437		.447
	I							EXIT	.0	802.4	34.39	38.3		.437		.448
656		12-01-65	14:29	1495	3.84	1.265	300.9	INLET	5.2	603.3	-1.34	8.1				
	0							6	.0	779.8	30.33	35.3		.394		.398
	I							7	.0	796.2	33.26	37.9		.393		.397
	I							EXIT	.0	804.3	34.72	39.2		.392		.397
657		12-01-65	14:51	1488	5.09	1.487	314.1	INLET	2.5	606.2	-.66	9.6				
	I							7	.0	777.3	29.97	41.3		.407		.418
	I							EXIT	.0	784.7	31.30	42.7		.407		.418
658		12-01-65	15:02	1497	4.80	1.495	345.5	INLET	21.1	581.4	-5.35	9.3				
	0							6	.0	752.5	25.38	36.9		.451		.456
								7	.0	768.7	28.28	39.5		.450		.457
								EXIT	.0	776.7	29.73	41.0		.450		.457
659		12-01-65	15:23	1481	4.60	1.514	392.5	INLET	49.9	541.6	-12.01	9.0				
	0 I							7	.0	751.6	25.48	37.4		.510		.521
	0 I							EXIT	.0	760.7	27.11	39.2		.510		.521
660		12-01-65	15:38	1496	4.12	1.515	423.5	INLET	75.8	511.3	-17.24	8.7				
	0							7	.0	737.7	22.79	34.2		.553		.558
	0							EXIT	.0	747.5	24.94	36.1		.552		.558
661		12-01-65	16:04	1503	3.75	1.507	450.1	INLET	99.9	483.5	-23.08	8.4				
	0							7	.0	725.3	20.43	31.4		.587		.592
	0							EXIT	.0	735.9	22.33	33.4		.587		.592
662		12-01-65	16:25	1513	3.42	1.506	480.1	INLET	128.1	452.0	-29.02	8.2				
	0							7	.0	710.1	17.54	28.2		.628		.628
	0							EXIT	.0	721.4	19.58	30.3		.628		.629
663		12-01-65	16:40	1499	3.07	1.504	516.2	INLET	151.4	425.0	-33.51	8.0				
	0							7	.0	702.8	16.42	27.2		.678		.672
	0							EXIT	.0	715.0	18.61	29.5		.678		.672
664		12-01-65	16:50	1502	3.11	1.499	507.4	INLET	152.6	423.7	-33.76	8.0				
	0							7	.0	697.5	15.47	26.0		.664		.663
	0							EXIT	.0	709.6	17.65	28.3		.665		.663
665		12-02-65	11:08	1486	4.73	2.016	604.7	INLET	150.5	424.5	-33.06	10.7				
	0							7	.0	667.6	10.41	22.0		.787		.800
	0							EXIT	.0	678.1	12.28	30.7		.787		.800

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
666		12-02-65	11:42	1508	5.04	2.017	571.1	INLET	130.6	448.8	-29.43	11.0				
	0							7	.0	678.1	11.87	29.8		.743		.755
	0							EXIT	.0	688.1	13.67	32.4		.743		.755
667		12-02-65	12:06	1493	5.58	1.996	520.2	INLET	100.7	481.5	-23.10	11.2				
	0							7	.0	692.4	14.70	33.7		.672		.695
	0							EXIT	.0	701.7	16.37	36.1		.673		.695
668		12-02-65	12:38	1489	6.19	2.022	483.9	INLET	75.6	511.0	-17.72	11.6				
	0							6	.0	688.1	14.00	33.2		.634		.635
								7	.0	704.8	16.69	37.5		.632		.636
								EXIT	.0	713.2	18.49	39.7		.632		.636
669		12-02-65	12:59	1497	6.76	2.021	445.4	INLET	54.4	537.8	-13.14	12.0				
	0							6	.0	701.0	16.16	36.2		.580		.591
								7	.0	716.4	18.62	40.1		.579		.590
								EXIT	.0	724.0	20.29	42.0		.579		.590
670		12-02-65	13:27	1488	7.56	1.978	385.0	INLET	20.9	580.1	-5.30	12.3				
	0							6	.0	724.2	20.49	41.6		.502		.508
								7	.0	737.8	22.62	45.1		.501		.508
								EXIT	.0	744.6	24.14	46.8		.501		.509
671		12-02-65	13:50	1501	7.79	1.989	365.5	INLET	12.0	594.2	-3.13	12.6				
	0							6	.0	730.2	21.33	42.7		.477		.483
	0							7	.0	743.1	23.65	45.9		.476		.483
	0							EXIT	.0	749.5	24.80	47.6		.475		.484
672		12-02-65	14:14	1502	10.97	2.470	391.4	INLET	9.1	598.2	-2.42	15.8				
	0							6	.0	715.4	18.66	48.4		.512		.513
								7	.0	726.5	20.66	51.9		.512		.513
								EXIT	.0	732.1	21.66	53.6		.512		.513
673		12-02-65	14:31	1484	10.46	2.493	423.5	INLET	23.8	575.8	-6.01	15.5				
	0							6	.0	701.7	16.51	45.5		.553		.560
								7	.0	713.5	18.61	49.3		.552		.560
								EXIT	.0	719.3	19.65	51.1		.551		.560
674		12-02-65	14:49	1501	8.71	2.485	471.8	INLET	54.7	537.7	-13.29	14.7				
	0							6	.0	678.3	11.99	37.1		.618		.620
								7	.0	691.5	14.36	41.2		.616		.621
								EXIT	.0	698.1	15.56	43.3		.615		.622
675		12-02-65	15:05	1492	8.03	2.493	514.7	INLET	74.9	511.8	-17.70	14.4				
	0							6	.0	664.7	9.71	33.3		.675		.675
								7	.0	679.1	12.29	37.9		.674		.674
								EXIT	.0	686.3	13.59	40.2		.674		.674
676		12-02-65	15:25	1500	7.17	2.484	565.6	INLET	99.8	483.4	-23.04	13.9				
	0							6	.0	651.9	7.26	28.8		.741		.742
								7	.0	667.8	10.12	33.8		.739		.742
								EXIT	.0	675.8	11.56	36.3		.739		.743

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
677		12-02-65	15:51	1527	6.33	2.473	617.5	INLET	126.0	455.9	-28.85	13.5				
	0							6	.0	640.5	4.64	24.0		.804		.815
								7	.0	658.0	7.81	29.4		.803		.816
								EXIT	.0	666.9	9.42	32.1		.803		.817
678		12-02-65	15:58	1498	6.56	2.478	613.8	INLET	122.6	456.9	-27.68	13.6				
	0							6	.0	640.2	5.23	25.3		.799		.813
								7	.0	657.5	8.33	30.7		.798		.814
								EXIT	.0	666.2	9.90	33.4		.797		.814
679		12-02-65	16:57	1495	6.12	2.499	671.4	INLET	147.9	428.3	-32.70	13.4				
	0							6	.0	627.0	2.94	21.5		.876		.884
	0							7	.0	645.9	6.32	27.4		.875		.884
	0							EXIT	.0	655.4	8.03	30.4		.876		.885
680		12-02-65	17:34	1522	7.36	2.959	751.5	INLET	151.1	427.3	-33.83	15.8				
	0							7	.0	633.1	3.44	26.3		.985		.983
	0							EXIT	.0	641.9	5.03	29.6		.984		.983
681		12-02-65	17:54	1509	8.01	2.954	705.4	INLET	130.3	449.4	-29.41	16.1				
	0							6	.0	626.2	2.45	24.3		.919		.934
								7	.0	642.8	5.46	30.9		.918		.934
								EXIT	.0	651.2	6.96	33.6		.917		.934
682		12-02-65	18:16	1495	8.65	2.962	640.1	INLET	108.4	472.8	-24.79	16.4				
	0							6	.0	632.7	3.91	27.4		.841		.833
								7	.0	647.9	6.63	32.1		.840		.834
								EXIT	.0	655.5	7.99	36.0		.840		.834
683		12-02-65	18:36	1488	9.65	2.976	567.6	INLET	79.5	506.1	-18.56	17.0				
	0							6	.0	647.3	6.72	33.5		.741		.749
								7	.0	660.7	9.11	38.6		.740		.750
								EXIT	.0	667.3	10.29	41.1		.739		.750
684		12-02-65	18:49	1491	11.30	2.982	509.4	INLET	53.6	537.6	-13.00	17.7				
	0							6	.0	664.1	9.66	39.8		.662		.679
								7	.0	676.0	11.79	44.3		.661		.678
								EXIT	.0	682.0	12.86	46.6		.661		.678
685		12-02-65	19:09	1489	13.45	2.975	446.1	INLET	22.8	577.9	-5.76	18.5				
	0							6	.0	689.0	14.15	49.2		.586		.584
								7	.0	699.4	16.01	53.1		.585		.584
								EXIT	.0	704.6	16.93	55.1		.584		.583
686		12-08-65	12:50	983	1.13	.517	246.9	INLET	1.0	538.5	-1.19	3.1				
	I							7	.0	925.6	59.12	39.8		.317		.334
	I							EXIT	.0	942.4	61.70	41.4		.317		.334
687		12-08-65	13:08	986	1.01	.508	251.5	INLET	19.8	515.4	-3.81	3.0				
	I							7	.0	916.6	57.72	38.1		.323		.341
	I							EXIT	.0	933.7	60.34	39.7		.323		.341
688		12-08-65	13:28	985	1.02	.512	271.8	INLET	37.2	494.2	-7.01	2.9				
	I							7	.0	924.6	58.97	39.2		.351		.365
	I							EXIT	.0	943.0	61.78	40.9		.350		.365

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
689		12-08-65	13:48	986	1.03	.511	279.9	INLET	48.6	480.9	-9.12	2.9				
	I							7	.0	924.4	58.92	39.1		.360		.377
	I							EXIT	.0	943.8	61.89	40.9		.360		.377
690		12-08-65	14:11	984	1.02	.504	294.4	INLET	70.6	455.1	-12.97	2.8				
	I							7	.0	928.2	59.51	39.0		.380		.394
	I							EXIT	.0	949.0	62.70	40.9		.380		.395
691		12-08-65	14:29	984	1.05	.503	311.8	INLET	96.6	425.8	-17.46	2.7				
	I							7	.0	928.0	59.48	38.9		.403		.417
	I							EXIT	.0	950.1	62.88	40.9		.403		.417
692		12-08-65	14:55	985	1.18	.500	335.8	INLET	118.9	401.7	-21.19	2.6				
	I							7	.0	945.7	62.19	40.2		.436		.446
	I							EXIT	.0	969.5	65.84	42.4		.436		.446
693		12-08-65	15:10	983	1.13	.507	348.2	INLET	143.8	374.5	-25.30	2.6				
	I							7	.0	931.0	59.94	39.6		.453		.462
	I							EXIT	.0	954.5	63.55	41.8		.452		.462
694		12-08-65	15:23	983	1.06	.497	345.5	INLET	157.9	359.5	-27.58	2.5				
	O							6	.0	873.1	51.09	33.5		.448		.459
	O I							7	.0	921.5	58.49	37.9		.447		.460
	O I							EXIT	.0	946.5	62.32	40.2		.448		.460
695		12-08-65	15:49	984	2.79	.695	438.2	INLET	146.4	371.9	-25.80	3.6				
	I							7	.0	882.5	52.49	47.9		.570		.579
	I							EXIT	.0	905.0	55.94	50.7		.571		.579
696		12-08-65	16:08	984	2.96	.695	426.7	INLET	125.1	394.6	-22.24	3.6				
	I							7	.0	891.9	53.95	49.2		.559		.558
	I							EXIT	.0	913.4	57.25	51.9		.559		.558
697		12-08-65	16:15	983	2.97	.695	421.9	INLET	124.4	395.4	-22.07	3.6				
	O I							7	.0	887.3	53.26	48.6		.550		.558
	O I							EXIT	.0	908.3	56.48	51.3		.549		.558
698		12-08-65	16:32	983	3.04	.697	406.2	INLET	101.3	420.7	-18.24	3.7				
	O I							7	.0	892.6	54.07	49.4		.524		.545
	O I							EXIT	.0	913.1	57.21	52.0		.524		.545
699		12-08-65	16:51	984	3.05	.702	386.3	INLET	79.4	445.2	-14.49	3.8				
	I							7	.0	891.5	53.89	49.6		.504		.510
	I							EXIT	.0	910.6	56.81	52.0		.503		.510
700		12-08-65	17:14	986	3.01	.705	358.2	INLET	53.8	474.8	-10.07	3.9				
	I							7	.0	886.5	53.09	49.0		.468		.471
	I							EXIT	.0	904.3	55.22	51.3		.467		.472
701		12-08-65	17:38	983	2.94	.698	320.7	INLET	20.9	513.7	-3.98	4.1				
	I							7	.0	885.6	52.99	48.6		.416		.426
	I							EXIT	.0	902.0	55.51	50.7		.416		.427
702		12-08-65	18:01	982	3.12	.700	304.3	INLET	.5	539.1	-.08	4.2				
	I							7	.0	891.0	53.22	49.5		.393		.406
	I							EXIT	.0	906.6	56.21	51.5		.394		.406

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{i1}}{10^6}$	$\frac{\phi_{i2}}{10^6}$
703		12-08-65	18:04	981	3.03	.710	291.1	INLET	.0	545.2	.91	5.0				
	I							7	.0	277.4	51.76	42.5		.376		.391
	I							EXIT	.0	291.6	53.93	50.4		.376		.390
704		12-09-65	10:08	979	2.95	.699	302.3	INLET	3.0	535.5	-1.57	4.2				
	I							7	.0	225.4	52.99	42.9		.392		.402
	I							EXIT	.0	900.9	55.36	50.9		.392		.402
705		12-09-65	10:20	983	2.48	.653	290.8	INLET	5.2	533.1	-1.01	3.9				
	I							7	.0	293.9	54.27	46.5		.376		.389
	I							EXIT	.0	909.4	56.63	48.3		.376		.389
706		12-09-65	10:30	983	1.90	.599	276.5	INLET	7.2	530.3	-1.42	3.9				
	I							7	.0	904.3	55.26	43.8		.356		.372
	I							EXIT	.0	920.7	58.37	45.6		.356		.372
707		12-09-65	10:39	987	3.58	.771	320.5	INLET	6.3	532.3	-1.22	4.6				
	I							7	.0	269.0	50.42	51.1		.417		.424
	I							EXIT	.0	283.4	52.62	53.1		.417		.424
708		12-09-65	10:45	988	4.14	.820	339.1	INLET	6.5	532.3	-1.26	4.9				
	I							7	.0	267.1	50.11	54.0		.443		.445
	I							EXIT	.0	281.7	52.35	56.2		.443		.445
709		12-09-65	10:51	986	4.78	.899	352.5	INLET	11.7	525.7	-2.26	5.3				
	I							7	.0	243.3	46.47	55.3		.460		.463
	I							EXIT	.0	257.2	48.59	57.6		.460		.463
710		12-09-65	11:20	983	5.80	.997	364.1	INLET	6.8	531.1	-1.32	5.9				
	I							7	.0	226.8	43.98	52.6		.473		.482
	I							EXIT	.0	239.6	45.95	61.0		.473		.482
711		12-09-65	11:28	982	5.88	1.001	356.7	INLET	3.8	534.7	-.72	5.9				
	I							7	.0	223.5	43.50	52.3		.462		.475
	I							EXIT	.0	236.0	45.41	60.6		.462		.476
712		12-09-65	11:43	989	5.54	.996	381.7	INLET	23.3	511.4	-4.53	5.8				
	I							7	.0	221.8	43.13	57.2		.496		.506
	I							EXIT	.0	235.3	45.20	59.7		.496		.506
713		12-09-65	11:59	996	5.40	.997	416.0	INLET	48.2	422.6	-9.11	5.6				
	I							7	.0	220.4	42.25	56.9		.541		.550
	I							EXIT	.0	235.2	45.12	59.2		.541		.550
714		12-09-65	12:07	1002	5.32	.999	416.1	INLET	54.3	476.7	-10.18	5.6				
	I							7	.0	214.1	41.21	55.1		.541		.552
	I							EXIT	.0	228.6	44.05	57.7		.541		.552
715		12-09-65	12:32	985	5.36	.999	442.4	INLET	69.7	456.2	-12.27	5.5				
	I							7	.0	215.0	42.14	56.9		.577		.585
	I							EXIT	.0	230.3	44.49	59.3		.576		.584
716		12-09-65	13:04	957	5.40	1.008	476.4	INLET	97.5	421.1	-17.40	5.4				
	O I							7	.0	203.8	40.77	56.9		.620		.629
	O I							EXIT	.0	220.6	43.33	60.1		.621		.629

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
717		12-09-65	13:33	981	5.22	1.015	479.2	INLET	102.7	419.0	-18.43	5.4				
	O I							7	.0	801.4	40.12	55.1		.623		.634
	O I							EXIT	.0	818.1	42.67	58.2		.623		.635
718		12-09-65	13:41	988	5.00	1.013	479.0	INLET	103.8	418.4	-18.71	5.4				
	O I							7	.0	801.7	40.09	54.5		.625		.631
	O I							EXIT	.0	818.1	42.61	57.6		.624		.631
719		12-09-65	13:59	990	4.79	1.004	502.1	INLET	129.4	391.1	-23.04	5.2				
	O I							7	.0	795.5	39.08	52.8		.654		.662
	O I							EXIT	.0	813.5	41.84	56.1		.654		.662
720		12-09-65	14:15	987	4.41	1.004	500.4	INLET	148.9	369.5	-26.22	5.2				
	I							7	.0	773.1	35.70	48.8		.649		.667
	I							EXIT	.0	790.6	38.37	52.1		.648		.667
721		12-09-65	14:20	986	4.54	1.008	514.8	INLET	148.0	370.3	-26.02	5.2				
	I							7	.0	784.0	37.40	51.1		.670		.681
	I							EXIT	.0	802.0	40.15	54.5		.670		.681
722		12-09-65	14:59	981	7.43	1.488	627.4	INLET	147.0	370.7	-25.83	7.6				
	I							7	.0	712.0	26.43	56.3		.824		.816
	I							EXIT	.0	727.0	28.72	60.4		.824		.817
723		12-09-65	15:28	982	7.59	1.489	576.9	INLET	121.5	398.3	-21.68	7.8				
	I							7	.0	712.4	26.45	56.2		.750		.766
	I							EXIT	.0	725.8	28.50	59.9		.749		.766
724		12-09-65	15:52	987	8.38	1.498	546.1	INLET	94.5	428.7	-17.10	8.0				
	I							7	.0	724.0	28.19	55.4		.712		.721
	I							EXIT	.0	736.7	30.13	62.9		.712		.720
725		12-09-65	16:18	999	7.88	1.496	548.5	INLET	100.3	423.8	-18.22	8.0				
	I							7	.0	720.4	27.44	57.3		.712		.727
	I							EXIT	.0	733.6	29.47	60.9		.712		.727
726		12-09-65	16:37	991	8.61	1.502	525.0	INLET	77.2	448.6	-14.23	8.2				
	I							7	.0	731.5	29.24	61.2		.686		.688
	I							EXIT	.0	744.0	31.15	64.6		.687		.688
727		12-09-65	17:29	990	9.17	1.488	492.1	INLET	50.5	479.1	-9.45	8.4				
	I							7	.0	746.8	31.63	65.0		.646		.640
	I							EXIT	.0	758.6	33.44	68.2		.646		.641
728		12-09-65	18:01	981	9.77	1.496	438.5	INLET	23.3	510.4	-4.45	8.7				
	I							7	.0	747.8	31.90	66.4		.570		.581
	I							EXIT	.0	758.2	33.48	69.2		.569		.582
729		12-10-65	9:19	987	9.73	1.487	412.5	INLET	12.6	524.4	-2.44	8.7				
	I							7	.0	748.9	32.00	65.8		.531		.554
	I							EXIT	.0	758.8	33.51	68.5		.532		.554
730		12-10-65	9:34	986	13.79	1.962	421.9	INLET	6.4	531.8	-1.26	11.6				
	I							7	.0	706.0	25.45	71.5		.542		.571
	I							EXIT	.0	713.5	26.60	74.2		.541		.571

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
731		12-10-65	9:50	987	13.59	1.978	475.9	INLET	24.0	510.3	-4.63	11.5				
	I							7	.0	705.1	25.26	71.6		.620		.627
	I							EXIT	.0	713.6	26.56	74.7		.621		.627
732		12-10-65	10:06	987	12.82	2.001	532.4	INLET	50.1	479.1	-9.41	11.2				
	I							7	.0	694.4	23.62	68.5		.698		.694
	I							EXIT	.0	703.9	25.08	72.0		.698		.695
733		12-10-65	10:27	989	11.17	2.008	573.7	INLET	80.3	445.0	-14.64	10.9				
	I							7	.0	676.1	20.83	61.9		.748		.754
	I							EXIT	.0	686.5	22.41	65.7		.749		.755
734		12-10-65	10:52	1002	10.67	1.989	605.4	INLET	96.3	428.7	-17.54	10.7				
	I							7	.0	675.5	20.48	59.8		.792		.796
	I							EXIT	.0	686.0	22.09	63.5		.791		.795
735		12-10-65	11:09	987	10.36	2.004	635.4	INLET	109.9	411.7	-19.75	10.6				
	I							7	.0	668.2	19.61	59.0		.831		.832
	I							EXIT	.0	679.6	21.36	63.2		.832		.832
737		12-10-65	11:33	984	9.82	1.984	660.2	INLET	128.0	391.4	-22.76	10.3				
	I							7	.0	661.1	18.57	56.1		.863		.868
	I							EXIT	.0	672.6	20.34	60.3		.862		.868
738		12-10-65	11:51	985	9.46	1.968	693.8	INLET	145.3	373.1	-25.60	10.1				
	I							7	.0	658.8	18.20	54.7		.905		.915
	I							EXIT	.0	671.1	20.08	59.1		.904		.915
739		12-10-65	12:04	984	9.16	1.977	696.9	INLET	150.9	367.0	-26.53	10.1				
	I							7	.0	652.8	17.28	52.8		.909		.920
	I							EXIT	.0	664.9	19.14	57.2		.908		.920
740		12-10-65	12:39	984	10.23	2.474	759.7	INLET	153.6	364.2	-26.97	12.6				
	0							7	.0	612.9	11.15	47.9		.991		.999
	0							EXIT	.0	623.8	12.22	52.8		.991		.000
741		12-10-65	13:49	987	12.27	2.455	711.9	INLET	118.1	402.9	-21.15	12.9				
	0							7	.0	637.8	14.90	58.4		.932		.931
	0							EXIT	.0	647.9	16.46	63.0		.932		.931
742		12-10-65	14:04	985	9.87	1.980	648.6	INLET	125.6	394.4	-22.33	10.3				
	I							7	.0	659.7	18.34	55.3		.846		.855
	I							EXIT	.0	671.3	20.11	59.6		.846		.854
743		12-10-65	14:35	993	13.53	2.471	672.5	INLET	96.8	426.9	-17.58	13.2				
	0 I							7	.0	647.2	16.27	62.5		.881		.877
	0 I							EXIT	.0	656.9	17.76	66.9		.882		.878
744		12-10-65	15:03	996	14.49	2.471	609.8	INLET	70.8	456.6	-13.08	13.6				
	I							7	.0	656.5	17.65	64.4		.793		.807
	I							EXIT	.0	665.2	19.00	70.3		.793		.807
745		12-10-65	15:19	992	16.25	2.480	551.0	INLET	44.4	486.8	-8.39	14.0				
	I							7	.0	666.9	19.29	71.7		.718		.728
	I							EXIT	.0	674.5	20.47	75.1		.717		.728

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{ij}}{10^6}$	$\frac{\phi_i}{10^6}$
746	I	12-10-65	15:33	994	17.39	2.496	509.0	INLET	27.5	507.1	-5.25	14.4				
	I							7	.0	672.3	20.12	74.5		.660		.678
	I							EXIT	.0	679.5	21.23	77.6		.660		.678
747	I	12-10-65	15:42	990	18.33	2.464	471.2	INLET	10.6	527.5	-2.04	14.5				
	I							7	.0	682.3	21.73	78.5		.609		.630
	I							EXIT	.0	689.1	22.77	81.6		.609		.630
748	I	12-10-65	15:44	989	18.70	2.515	465.0	INLET	9.8	528.4	-1.87	14.8				
	I							7	.0	678.1	21.10	78.4		.602		.621
	I							EXIT	.0	684.6	22.10	81.4		.601		.621
749	I	12-10-65	15:56	990	23.29	2.981	518.0	INLET	14.0	523.3	-2.71	17.5				
	I							7	.0	664.2	18.91	85.0		.674		.687
	I							EXIT	.0	670.2	19.84	88.3		.673		.687
750	I	12-10-65	16:11	987	21.27	2.962	589.6	INLET	36.3	495.5	-6.89	16.9				
	I							7	.0	656.7	17.85	80.9		.774		.769
	I							EXIT	.0	663.7	18.92	84.7		.773		.769
751	I	12-10-65	16:26	985	18.08	2.958	668.6	INLET	71.5	454.3	-13.13	16.2				
	O							6	.0	621.6	12.52	62.1		.886		.859
	O							7	.0	637.3	14.92	70.6		.884		.859
	O							EXIT	.0	645.3	16.15	74.9		.885		.859
752	I	12-10-65	16:55	986	15.41	2.957	721.1	INLET	99.1	423.7	-17.86	15.8				
	O							6	.0	604.3	9.23	52.5		.949		.939
	O							7	.0	621.3	12.44	61.7		.947		.940
	O							EXIT	.0	629.7	13.74	66.3		.946		.940
753	I	12-11-65	9:41	1482	.02	.504	221.2	INLET	.0	609.3	.04	3.3				
	O							7	.0	964.6	63.52	26.1		.286		.295
	O							EXIT	.0	980.2	66.30	27.1		.286		.295
754	I	12-11-65	9:57	1489	.05	.512	238.1	INLET	21.6	579.4	-5.47	3.2				
	O							7	.0	956.2	61.99	25.8		.305		.322
	O							EXIT	.0	972.7	64.94	26.9		.305		.322
755	I	12-11-65	10:10	1491	-.01	.504	248.4	INLET	52.1	539.7	-12.61	3.0				
	I							7	.0	938.1	58.75	24.3		.319		.335
	I							EXIT	.0	955.9	61.95	25.4		.319		.336
756	I	12-11-65	10:19	1491	-.05	.498	239.0	INLET	46.4	546.9	-11.33	3.0				
	I							7	.0	935.4	58.27	23.8		.306		.325
	I							EXIT	.0	952.2	61.29	24.9		.306		.325
757	I	12-11-65	10:31	1489	.04	.500	249.5	INLET	81.2	504.1	-18.91	2.9				
	O							7	.0	908.1	53.40	22.2		.321		.337
	O							EXIT	.0	925.4	56.49	23.3		.321		.336
758	I	12-11-65	10:40	1497	.00	.511	248.5	INLET	69.6	518.9	-16.49	3.0				
	O							7	.0	912.9	54.22	22.8		.319		.336
	O							EXIT	.0	929.9	57.26	23.9		.319		.336
759	I	12-11-65	10:57	1495	.03	.507	247.3	INLET	63.9	525.6	-15.29	3.0				
	O							7	.0	920.7	55.61	23.2		.318		.335
	O							EXIT	.0	937.5	58.63	24.3		.317		.335

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	X	V_m	$\frac{\phi_{i0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i1}}{10^6}$	$\frac{\phi_i}{10^6}$
760		12-11-65	11:16	1493	.24	.514	263.2	INLET	100.3	481.8	-23.13	2.9				
0								7	.0	897.4	51.42	22.0		.339		.356
0								EXIT	.0	914.6	54.51	23.2		.339		.355
761		12-11-65	11:32	1489	.31	.506	276.0	INLET	118.5	460.5	-26.73	2.8				
0								7	.0	901.7	52.25	22.1		.356		.370
0								EXIT	.0	921.1	55.72	23.3		.356		.370
762		12-11-65	11:49	1487	.46	.505	279.6	INLET	141.9	434.1	-31.36	2.7				
0								7	.0	882.2	48.79	20.8		.361		.375
0								EXIT	.0	901.8	52.28	22.1		.360		.376
763		12-11-65	12:13	1482	.74	.454	268.6	INLET	148.5	426.4	-32.65	2.4				
0								7	.0	905.8	53.00	20.1		.344		.364
0								EXIT	.0	926.8	56.76	21.3		.344		.364
764		12-11-65	12:26	1488		.405	248.9	INLET	145.2	430.4	-32.06	2.2				
0								7	.0	928.7	57.10	19.1		.317		.342
0								EXIT	.0	950.0	60.91	20.1		.317		.342
765		12-11-65	12:38	1500	.47	.378	225.3	INLET	147.7	429.0	-32.74	2.0				
0								7	.0	911.6	53.96	16.8		.288		.307
0								EXIT	.0	933.0	57.81	17.8		.288		.307
766		12-11-65	12:49	1488	.46	.382	238.7	INLET	149.0	426.5	-32.89	2.0				
0								7	.0	933.0	57.82	18.2		.308		.320
0								EXIT	.0	954.9	61.75	19.2		.308		.320
767		12-11-65	13:03	1488		.344	220.0	INLET	148.1	427.4	-32.63	1.8				
0								7	.0	945.7	60.13	16.9		.284		.295
0								EXIT	.0	968.0	64.12	17.9		.284		.295
768		12-11-65	14:02	1993	-.49	.506	216.2	INLET	149.9	470.7	-43.07	2.8				
0								7	.0	816.9	31.44	10.8		.278		.292
0								EXIT	.0	831.8	34.64	11.5		.278		.292
769		12-11-65	14:19	2000	-.52	.504	202.2	INLET	120.4	505.4	-35.81	2.9				
0								7	.0	830.0	34.21	11.4		.260		.273
0								EXIT	.0	844.3	37.29	12.1		.260		.273
770		12-11-65	14:33	1986	-.52	.505	192.6	INLET	98.8	530.0	-30.04	2.9				
0								7	.0	839.0	36.26	11.9		.247		.262
0								EXIT	.0	852.3	39.11	12.6		.247		.262
771		12-11-65	14:50	1997	-.56	.511	181.6	INLET	78.1	557.0	-24.50	3.1				
0								7	.0	845.1	37.55	12.3		.232		.249
0								EXIT	.0	857.4	40.20	12.9		.231		.249
772		12-11-65	15:08	2006	-.64	.517	160.8	INLET	46.3	600.2	-15.56	3.3				
0								7	.0	852.1	38.61	12.7		.204		.223
0								EXIT	.0	862.8	41.24	13.2		.203		.223
773		12-11-65	15:11	1989	-.64	.510	159.6	INLET	48.5	595.1	-16.08	3.2				
0								7	.0	848.7	38.27	12.5		.202		.221
0								EXIT	.0	859.7	40.73	13.1		.202		.221

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
774		12-13-65	9:35	2005	2.73	1.500	249.9	INLET	13.3	649.0	-4.58	10.3				
	0							6	.0	772.4	21.70	25.3		.324		.335
								7	.0	784.0	24.22	27.0		.323		.335
								EXIT	.0	789.7	25.45	27.8		.323		.335
775		12-13-65	9:56	1997	2.59	1.494	266.5	INLET	24.5	630.4	-8.76	9.9				
	0							6	.0	763.0	19.80	24.0		.347		.358
	I							7	.0	775.0	22.39	25.7		.345		.357
	I							EXIT	.0	781.1	23.71	26.6		.344		.357
776		12-13-65	10:19	2002	2.38	1.486	302.8	INLET	47.8	597.5	-16.10	9.4				
	0							6	.0	748.4	16.51	21.6		.396		.400
	I							7	.0	762.5	19.57	23.7		.395		.400
	I							EXIT	.0	769.6	21.09	24.7		.395		.399
777		12-13-65	10:35	1998	2.22	1.522	338.8	INLET	72.1	564.8	-22.93	9.2				
	0							6	.0	729.6	12.59	19.5		.443		.446
								7	.0	745.1	15.92	21.8		.442		.446
								EXIT	.0	753.0	17.62	22.9		.442		.446
778		12-13-65	10:52	2007	1.82	1.514	366.3	INLET	102.4	527.4	-31.37	8.8				
	0							6	.0	706.4	7.35	15.8		.478		.482
	0							7	.0	723.3	11.01	18.3		.477		.483
	0							EXIT	.0	731.8	12.86	19.5		.477		.483
779		12-13-65	11:02	1997	1.59	1.512	376.7	INLET	122.5	502.7	-36.29	8.6				
	0							7	.0	704.7	7.22	15.7		.490		.500
	0							EXIT	.0	713.2	9.07	17.0		.489		.500
780		12-13-65	11:18	2000	1.47	1.509	411.1	INLET	149.8	471.1	-43.28	8.3				
	0							7	.0	691.8	4.35	13.7		.537		.541
	0							EXIT	.0	701.4	6.41	15.1		.536		.541
781		12-13-65	11:36	1996	2.68	1.994	490.8	INLET	147.9	473.2	-42.61	11.0				
	0							7	.0	672.6	.33	14.5		.641		.644
	0							EXIT	.0	681.3	2.20	16.2		.642		.644
782		12-13-65	11:54	1992	2.89	2.001	453.8	INLET	123.4	500.8	-36.44	11.3				
	0							7	.0	684.5	3.03	17.0		.590		.602
	0							EXIT	.0	692.5	4.75	18.5		.589		.602
783		12-13-65	12:11	1986	3.30	2.004	413.0	INLET	94.7	535.2	-28.88	11.8				
	0							7	.0	702.2	6.94	20.6		.538		.546
	0							EXIT	.0	709.4	8.48	22.0		.537		.546
784		12-13-65	12:24	1995	3.74	2.001	383.8	INLET	71.7	564.7	-22.87	12.1				
	0							6	.0	706.5	7.66	21.2		.497		.512
								7	.0	720.1	10.58	23.8		.496		.513
								EXIT	.0	726.8	12.03	25.1		.496		.513
785		12-13-65	12:52	1997	4.21	2.003	345.4	INLET	47.5	597.6	-15.87	12.7				
	0							6	.0	725.4	11.68	24.8		.450		.498
	I							7	.0	737.4	14.26	27.1		.449		.499
	I							EXIT	.0	743.3	15.54	28.3		.448		.499

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
786	0	12-13-65	13:13	1991	4.73	2.011	319.5	INLET	29.6	622.6	-10.30	13.2				
								6	.0	740.0	14.94	27.9		.412		.427
								7	.0	751.1	17.33	30.1		.412		.427
								EXIT	.0	756.8	18.56	31.2		.413		.427
787	0	12-13-65	13:31	2000	4.81	1.987	309.1	INLET	25.6	629.0	-9.08	13.2				
								6	.0	744.0	15.72	28.2		.403		.408
								7	.0	754.9	18.06	30.3		.402		.408
								EXIT	.0	760.5	19.26	31.4		.402		.409
788	0	12-13-65	13:36	1989	4.97	1.981	285.9	INLET	14.2	645.9	-5.20	13.5				
								6	.0	752.6	17.72	30.0		.371		.380
								7	.0	762.7	19.88	32.0		.370		.380
								EXIT	.0	767.9	20.99	33.0		.371		.381
789	0	12-13-65	14:02	1998	7.69	2.468	316.6	INLET	13.4	648.1	-4.58	16.8				
								6	.0	743.3	15.54	34.9		.412		.423
								7	.0	752.1	17.45	37.0		.410		.423
								EXIT	.0	756.5	18.39	38.0		.410		.423
790	0	12-13-65	14:11	1985	6.97	2.493	348.2	INLET	30.0	620.9	-10.45	16.3				
								6	.0	724.5	11.75	31.1		.457		.457
								7	.0	734.1	13.82	33.4		.456		.457
								EXIT	.0	738.9	14.85	34.6		.455		.457
791	0	12-13-65	14:34	2014	5.84	2.478	390.4	INLET	54.4	589.5	-18.20	15.5				
								6	.0	706.0	7.11	25.5		.510		.514
								7	.0	717.1	9.51	28.2		.509		.514
								EXIT	.0	722.6	10.71	29.5		.509		.514
792	I	12-13-65	14:45	1993	5.91	2.497	392.5	INLET	53.4	588.6	-17.66	15.6				
	I							7	.0	715.9	9.72	28.7		.509		.522
	I							EXIT	.0	721.4	10.92	30.1		.509		.522
793	I	12-13-65	15:07	2010	5.10	2.492	417.8	INLET	73.7	563.9	-23.58	15.1				
	I							7	.0	699.8	5.86	24.3		.540		.559
	I							EXIT	.0	705.6	7.12	25.7		.540		.559
794	I	12-13-65	15:31	1993	4.71	2.499	470.2	INLET	95.7	534.7	-29.20	14.7				
	I							7	.0	687.1	3.57	21.8		.613		.619
	I							EXIT	.0	693.8	5.00	23.4		.613		.620
796	0	12-13-65	16:07	1995	4.29	2.469	566.6	INLET	138.6	483.8	-40.26	13.8				
	0							6	10.0	653.6	-3.71	17.0		.744		.738
	0							7	.6	669.7	-.24	17.5		.744		.738
	0							EXIT	.0	677.7	1.48	19.2		.744		.737
797	0	12-13-65	16:20	1985	4.25	2.499	612.6	INLET	157.4	461.6	-44.65	13.7				
	0							7	5.6	660.1	-2.09	17.4		.803		.799
	0							EXIT	.6	668.8	-.23	17.7		.803		.800

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{l,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{l,i}}{10^6}$	$\frac{\phi_i}{10^6}$
798		12-13-65	16:31	1995	4.36	2.495	600.7	INLET	149.6	471.2	-42.98	13.8				
	0							6	12.9	649.2	-4.66	17.0		.783		.792
	0							7	2.7	666.1	-1.02	17.6		.782		.793
	0							EXIT	.0	674.6	.82	18.7		.782		.793
799		12-13-65	16:43	2005	4.50	2.496	556.9	INLET	131.5	492.8	-38.75	14.0				
	0							6	7.9	658.2	-3.00	17.3		.728		.736
	0 1							7	.0	673.6	.32	18.2		.725		.736
	0 1							EXIT	.0	681.3	2.01	20.0		.725		.737
800		12-13-65	16:54	2025	4.60	2.473	925.0	INLET	115.5	513.4	-35.14	14.2				
	0							6	2.1	670.7	-.85	17.6		.687		.689
	0 1							7	.0	685.4	2.37	20.3		.686		.689
	0 1							EXIT	.0	692.9	4.00	22.0		.687		.688

Table A-8. Data From Test Section 8
(Cosine Outside)

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
962		02-07-66	11:54	971	.96	.930	248.8	INLET	39.7	489.4	-7.42	3.0				
								6	.0	860.3	49.21	34.9		.548		
	0							7	.0	879.2	52.10	36.8		.526		
	0							EXIT	.0	886.3	53.19	37.5		.513		
963		02-07-66	12:47	986	.65	.504	270.6	INLET	95.0	428.0	-17.20	2.7				
	0							6	.0	852.3	47.86	31.9		.596		
	0							7	.0	874.1	51.21	33.9		.573		
	0							EXIT	.0	882.0	52.42	34.6		.558		
964		02-07-66	13:13	976	.52	.497	287.3	INLET	142.3	375.0	-24.99	2.6				
	0							6	.0	830.0	44.56	29.8		.630		
	0							7	.0	853.8	48.19	31.9		.606		
	0							EXIT	.0	863.8	49.73	32.9		.593		
965		02-07-66	14:39	993	3.49	1.482	419.3	INLET	140.8	379.0	-24.53	7.7				
	0							6	.0	602.3	9.38	25.4		.923		
								7	.0	613.7	11.14	28.5		.886		
								EXIT	.0	618.1	11.82	29.7		.865		
966		02-07-66	15:19	991	4.55	1.490	374.9	INLET	95.2	428.4	-17.31	8.0				
	0							6	.0	627.1	13.21	32.3		.826		
								7	.0	637.2	14.75	35.1		.793		
								EXIT	.0	641.0	15.34	36.1		.774		
967		02-07-66	15:52	1000	5.66	1.494	324.3	INLET	45.1	486.9	-8.51	8.4				
	0							6	.0	658.1	17.84	40.3		.714		
								7	.0	666.9	19.20	42.7		.685		
								EXIT	.0	670.3	19.72	43.6		.669		
968		02-07-66	16:24	988	6.61	1.481	289.9	INLET	14.2	522.5	-2.74	8.7				
	0							6	.0	677.2	20.99	46.0		.640		
								7	.0	684.9	22.17	48.1		.613		
								EXIT	.0	687.9	22.62	48.9		.598		
969		02-07-66	16:55	990	11.84	2.446	322.7	INLET	19.4	516.5	-3.73	14.3				
	0							6	.0	620.4	12.21	50.2		.709		
								7	.0	625.8	13.04	52.6		.681		
								EXIT	.0	628.0	13.39	53.6		.666		
970		02-07-66	17:19	1001	9.80	2.441	360.0	INLET	43.0	489.6	-8.16	13.8				
	0							3	.0	573.5	4.76	28.3		.799		
								4	.0	586.5	6.76	34.0		.815		
								5	.0	597.8	8.50	39.0		.814		
								6	.0	606.5	9.85	42.9		.796		
								7	.0	612.3	10.74	49.4		.763		
								EXIT	.0	614.3	11.04	46.3		.743		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
971		02-08-66	9:00	1499	-.41	.507	168.0	INLET	23.7	578.1	-5.96	3.2				
	0							6	.0	839.1	40.93	17.9		.369		
								7	.0	852.4	43.33	18.8		.355		
								EXIT	.0	857.9	44.32	19.1		.347		
972		02-08-66	9:14	1507	-.42	.503	180.8	INLET	51.7	542.2	-12.61	3.0				
	0							6	.0	826.8	38.64	16.8		.399		
	0							7	.0	841.0	41.21	17.7		.383		
	0							EXIT	.0	846.0	42.10	18.1		.373		
973		02-08-66	9:33	1475	-.39	.502	203.0	INLET	99.6	480.9	-22.73	2.8				
	0							6	.0	800.6	34.28	15.6		.448		
	0							7	.0	817.1	37.21	16.7		.430		
	0							EXIT	.0	822.6	38.21	17.0		.419		
974		02-08-66	9:51	1489	-.34	.499	225.9	INLET	147.5	428.2	-32.50	2.7				
	0							6	.0	786.5	31.63	14.4		.499		
	0							7	.0	804.1	34.79	15.6		.478		
	0							EXIT	.0	810.6	35.95	16.0		.466		
975		02-08-66	10:46	1496	1.74	1.504	378.1	INLET	149.2	427.1	-32.89	8.0				
	0							4	13.5	591.3	-3.44	9.5		.851		
								5	.0	610.7	.04	9.8		.852		
								6	.0	625.8	2.74	12.7		.834		
								7	.0	635.9	4.55	14.6		.800		
								EXIT	.0	639.6	5.22	15.3		.780		
976		02-08-66	10:54	1532	1.55	1.471	368.5	INLET	152.7	426.8	-34.26	7.8				
	0							3	33.8	568.1	-8.59	9.0		.812		
	0							4	17.5	590.3	-4.57	9.3		.829		
								5	3.9	609.6	-1.06	9.5		.829		
								6	.0	624.7	1.69	11.3		.812		
								7	.0	634.9	3.53	13.2		.780		
								EXIT	.0	638.5	4.19	13.8		.760		
977		02-08-66	11:03	1497	1.75	1.500	374.4	INLET	147.9	428.4	-32.75	8.0				
	0							6	.0	625.4	2.62	12.5		.825		
								7	.0	635.6	4.45	14.5		.792		
								EXIT	.0	639.3	5.11	15.2		.772		
978		02-08-66	11:30	1486	2.22	1.498	317.0	INLET	94.3	488.2	-21.68	8.4				
	0							6	.0	655.4	8.21	18.5		.699		
								7	.0	663.8	9.73	20.1		.670		
								EXIT	.0	667.0	10.20	20.7		.654		
979		02-08-66	11:59	1478	2.77	1.499	263.6	INLET	49.1	542.0	-11.93	8.9				
	0							6	.0	680.6	12.82	23.5		.580		
								7	.0	687.9	14.12	24.9		.557		
								EXIT	.0	690.6	14.60	25.4		.544		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
980	0	02-08-66	12:25	1491	3.06	1.510	217.3	INLET	20.0	581.6	-5.07	9.4				
								6	.0	695.2	15.28	26.2		.479		
								7	.0	701.1	16.34	27.3		.460		
								EXIT	.0	703.2	16.70	27.7		.448		
981	0	02-08-66	12:59	1493	7.06	2.487	264.9	INLET	24.7	575.9	-6.24	15.4				
								3	.0	636.1	4.55	24.2		.585		
								4	.0	645.6	6.24	27.2		.597		
								5	.0	653.9	7.73	29.8		.598		
								6	.0	660.1	8.85	31.7		.584		
								7	.0	664.2	9.59	33.0		.560		
								EXIT	.0	666.0	9.90	33.6		.547		
982	0	02-08-66	13:03	1489	7.09	2.486	262.4	INLET	24.1	576.2	-6.02	15.4				
								3	.0	636.3	4.74	24.5		.584		
								4	.0	645.5	6.39	27.4		.594		
								5	.0	653.5	7.82	30.0		.593		
								6	.0	659.7	8.54	31.9		.580		
								7	.0	664.0	9.69	33.3		.556		
								EXIT	.0	665.4	9.95	33.7		.542		
983	0	02-08-66	13:40	1491	5.79	2.467	313.5	INLET	50.5	541.5	-12.30	14.7				
								3	.0	613.6	.61	17.1		.694		
								4	.0	624.8	2.61	20.6		.708		
								5	.0	634.5	4.36	23.7		.707		
								6	.0	642.0	5.70	26.0		.692		
								7	.0	647.0	6.60	27.6		.663		
								EXIT	.0	648.9	6.95	28.2		.647		
984	0	02-08-66	14:11	1492	4.63	2.483	406.6	INLET	96.5	486.2	-22.28	14.0				
								3	22.2	578.8	-5.68	15.5		.898		
								4	11.9	593.2	-3.10	15.8		.916		
								5	3.3	605.7	-.86	16.0		.915		
								6	.0	615.3	.86	17.7		.894		
								7	.0	621.9	2.05	19.7		.859		
								EXIT	.0	624.6	2.53	20.6		.839		
985	0	02-08-66	14:36	1485	3.95	2.462	497.1	INLET	146.4	429.0	-32.28	13.2				
	0							3	48.8	543.1	-11.88	14.7		1.097		
	0							4	35.1	560.7	-8.74	15.0		1.117		
								5	23.6	576.0	-5.98	15.3		1.116		
								6	14.8	588.1	-3.62	15.5		1.093		
								7	8.9	596.4	-2.34	15.7		1.050		
								EXIT	6.7	599.6	-1.76	15.8		1.026		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{LI}}{10^6}$	$\frac{\phi_i}{10^6}$
986		02-09-66	9:24	1978	-.83	.906	115.1	INLET	19.4	636.9	-6.88	3.4				
0								6	.0	816.8	31.60	10.9		.254		
								7	.0	825.7	33.51	11.4		.244		
								EXIT	.0	828.9	34.18	11.5		.237		
987		02-09-66	9:47	1979	-.79	.499	137.6	INLET	47.7	594.8	-15.71	3.1				
0								6	.0	810.2	30.28	10.5		.300		
								7	.0	822.4	32.88	11.1		.290		
								EXIT	.0	827.7	34.00	11.4		.284		
988		02-09-66	10:15	1984	-.68	.907	172.1	INLET	101.2	526.9	-30.55	3.0				
0								6	.0	795.8	27.07	9.9		.381		
								7	.0	809.1	29.91	10.5		.365		
								EXIT	.0	813.5	30.87	10.7		.355		
989		02-09-66	10:33	1979	-.61	.900	197.1	INLET	152.7	466.3	-43.27	2.7				
0								6	.0	777.3	23.22	8.9		.434		
								7	.0	793.3	26.63	9.6		.416		
								EXIT	.0	799.6	27.97	10.0		.407		
990		02-09-66	11:36	1983	1.13	1.499	338.7	INLET	149.6	470.1	-42.69	8.3				
0								3	45.7	598.3	-15.23	9.5		.751		
								4	31.8	618.1	-10.99	9.8		.765		
								5	20.4	635.4	-7.28	10.0		.764		
								6	12.1	648.8	-4.43	10.2		.747		
								7	6.7	657.7	-2.51	10.4		.716		
								EXIT	4.7	661.1	-1.78	10.5		.699		
991		02-09-66	12:03	1989	3.63	2.450	474.8	INLET	144.9	476.0	-41.68	13.6				
0								4	42.8	603.0	-14.41	15.6		1.072		
0								5	32.6	617.7	-11.26	15.9		1.070		
								6	24.9	629.2	-8.79	16.2		1.047		
								7	19.8	637.0	-7.12	16.4		1.005		
								EXIT	18.0	639.8	-6.51	16.5		.980		
992		02-09-66	12:36	1993	3.98	2.479	393.8	INLET	97.8	532.0	-29.80	14.5				
0								3	30.1	621.8	-10.49	16.2		.870		
								4	21.0	635.6	-7.51	16.6		.886		
								5	13.4	647.7	-4.91	16.9		.885		
								6	7.7	657.2	-2.86	17.2		.866		
								7	3.9	663.8	-1.46	17.4		.832		
								EXIT	2.5	666.2	-.93	17.5		.813		
993		02-09-66	13:00	1987	1.24	1.903	272.8	INLET	97.8	531.4	-29.74	8.8				
0								3	21.1	634.7	-7.58	10.0		.607		
								4	11.2	650.4	-4.20	10.3		.617		
								5	3.2	664.2	-1.25	10.6		.616		
								6	.0	675.3	1.14	11.5		.604		
								7	.0	682.4	2.67	12.5		.578		
								EXIT	.0	684.8	3.17	12.8		.563		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_{i,e}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
994		02-09-66	13:46	1992	1.58	1.517	212.4	INLET	47.1	597.4	-15.76	9.6				
	0							3	.0	676.6	1.28	11.7		.469		
								4	.0	688.9	3.93	13.5		.479		
								5	.0	699.6	6.22	15.1		.478		
								6	.0	708.0	8.02	16.3		.468		
								7	.0	713.7	9.24	17.1		.449		
								EXIT	.0	715.7	9.69	17.5		.438		
995		02-09-66	14:12	1984	2.03	1.505	176.3	INLET	15.5	643.8	-5.55	10.2				
	0							3	.0	709.7	8.57	16.6		.387		
								4	.0	719.8	10.74	18.1		.394		
								5	.0	729.0	12.71	19.4		.395		
								6	.0	736.1	14.23	20.5		.388		
								7	.0	740.8	15.25	21.2		.372		
								EXIT	.0	742.8	15.67	21.5		.364		
996		02-09-66	14:50	1994	5.59	2.490	239.9	INLET	24.5	630.3	-8.66	16.5				
	0							3	.0	684.8	3.05	21.2		.530		
								4	.0	693.1	4.84	23.2		.539		
								5	.0	700.4	6.42	24.9		.538		
								6	.0	706.2	7.65	26.3		.527		
								7	.0	710.2	8.51	27.3		.507		
								EXIT	.0	711.8	8.85	27.7		.495		
997		02-09-66	15:08	1979	4.82	2.503	288.6	INLET	47.3	595.8	-15.66	15.8				
	0							3	4.3	661.3	-1.65	17.5		.640		
								4	.0	671.4	.52	18.3		.652		
								5	.0	680.1	2.38	20.5		.651		
								6	.0	686.9	3.83	22.1		.636		
								7	.0	691.5	4.82	23.3		.610		
								EXIT	.0	693.2	5.19	23.7		.596		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{11}}{10^6}$	$\frac{\phi_i}{10^6}$
998		02-09-66	17:15	982	11.87	2.512	330.5	INLET	22.1	511.9	-4.24	14.6				
	0							6	.0	615.7	11.65	50.2		.727		
								7	.0	621.0	12.47	52.7		.698		
								EXIT	.0	623.1	12.79	53.6		.682		
999		02-09-66	17:34	1000	9.47	2.449	358.0	INLET	45.3	486.7	-8.59	13.8				
								1	19.7	517.7	-3.82	14.3		.741		
	0							2	.0	556.0	2.08	20.7		.765		
	0							3	.0	570.0	4.23	26.9		.797		
								4	.0	582.6	6.19	32.5		.810		
								5	.0	593.6	7.87	37.4		.807		
								6	.0	602.1	9.18	41.2		.789		
								7	.0	608.0	10.09	43.8		.757		
								EXIT	.0	610.2	10.43	44.8		.739		
1000		02-09-66	18:03	994	6.88	2.467	428.4	INLET	91.0	433.6	-16.61	13.3				
								1	58.5	470.3	-10.98	13.7		.883		
	0							2	20.7	515.4	-4.04	14.4		.909		
	0							3	7.6	531.8	-1.51	14.6		.946		
								4	.0	546.9	.80	17.1		.963		
								5	.0	560.3	2.86	23.1		.963		
								6	.0	570.8	4.47	27.9		.944		
								7	.0	577.7	5.54	31.0		.906		
								EXIT	.0	580.4	5.95	32.2		.884		
1001		02-09-66	18:43	989	4.90	2.439	507.5	INLET	142.5	376.6	-25.18	12.6				
	0							3	37.4	494.4	-7.10	13.9		1.123		
								4	22.3	512.7	-4.30	14.2		1.144		
								5	9.6	528.4	-1.88	14.4		1.142		
								6	.0	540.9	.03	14.7		1.118		
								7	.0	549.3	1.33	18.5		1.073		
								EXIT	.0	552.5	1.81	19.9		1.047		
1002		02-10-66	8:43	980	.76	.509	238.3	INLET	16.7	518.4	-3.22	3.0				
	0							6	.0	888.1	53.39	35.8		.525		
	0							7	.0	907.1	56.30	37.6		.504		
	0							EXIT	.0	914.4	57.42	38.2		.492		
1003		02-10-66	8:57	977	.72	.506	249.2	INLET	47.0	481.4	-8.80	2.8				
	0							6	.0	870.3	50.69	34.0		.549		
	0							7	.0	889.9	53.69	35.9		.527		
	0							EXIT	.0	897.7	54.88	36.6		.514		

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{i1}}{10^6}$	$\frac{\phi_i}{10^6}$
1051		02-12-66	14:54	1999	-.63	.903	196.2	INLET	150.8	470.0	-43.41	2.8				
	0							6	.0	777.6	22.93	8.8		.432		
								7	.0	793.4	26.33	9.5		.415		
								EXIT	.0	799.5	27.65	9.8		.405		
1052		02-12-66	16:50	1493	1.70	1.495	374.6	INLET	146.2	429.9	-32.44	8.0				
	0							3	27.4	572.2	-6.92	9.2		.831		
								4	11.6	594.0	-3.01	9.5		.846		
								5	.0	613.1	.42	10.2		.845		
								6	.0	627.9	3.08	13.0		.826		
								7	.0	637.9	4.27	14.9		.792		
								EXIT	.0	641.7	5.54	15.6		.773		
1053		02-12-66	17:14	1496	.79	1.012	313.6	INLET	147.7	428.6	-32.68	5.4				
	0							6	.0	673.9	11.33	14.7		.692		
								7	.0	686.1	13.53	16.2		.664		
								EXIT	.0	690.6	14.33	16.8		.647		
1054		02-12-66	17:48	1493	-.31	.506	228.1	INLET	149.3	426.4	-33.05	2.7				
	0							7	.0	800.4	34.05	15.5		.483		
	0							EXIT	.0	807.0	35.22	15.9		.471		
1055		02-12-66	18:41	982	.48	.509	277.2	INLET	139.3	379.4	-24.59	2.6				
	0							7	.0	831.1	44.64	30.4		.586		
	0							EXIT	.0	839.5	45.91	31.1		.572		
1056		02-12-66	18:50	982	.42	.503	277.5	INLET	144.3	373.8	-25.43	2.6				
	0							6	.0	808.6	41.19	27.9		.610		
	0							7	.0	831.2	44.66	30.0		.586		
	0							EXIT	.0	840.0	46.00	30.8		.573		

Table A-9. Data From Test Section 9 (Cosine Outside, Uniform Inside)

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
1004		02-10-66	10:57	980	1.10	.900	258.5	INLET	13.2	522.7	-2.54	2.9				
	I							7	.0	948.8	62.69	40.8		.350		.335
	I							EXIT	.0	959.7	64.36	41.8		.340		.336
1005		02-10-66	11:21	981	1.22	.499	290.2	INLET	47.8	481.2	-8.93	2.8				
	I							7	.0	958.4	64.15	41.6		.391		.375
	I							EXIT	.0	972.2	66.27	42.8		.382		.376
1006		02-10-66	11:39	982	1.35	.501	328.2	INLET	98.6	423.4	-17.87	2.7				
	I							7	.0	962.7	64.79	42.0		.444		.425
	I							EXIT	.0	976.8	66.95	43.3		.432		.426
1007		02-10-66	12:07	980	1.45	.503	370.1	INLET	145.7	372.0	-25.57	2.6				
	0							7	.0	976.3	66.91	43.6		.497		.482
	0							EXIT	.0	993.6	69.55	45.2		.486		.483
1008		02-10-66	13:14	972	6.81	1.491	595.2	INLET	150.4	366.2	-26.24	7.6				
	0							6	.0	674.2	20.79	46.6		.836		.773
								7	.0	694.5	23.90	52.2		.802		.773
								EXIT	.0	703.5	25.27	54.7		.782		.774
1009		02-10-66	14:12	982	7.76	1.507	527.1	INLET	99.7	422.3	-17.97	8.0				
	0							6	.0	692.3	23.39	51.4		.734		.697
								7	.0	710.0	26.10	56.3		.703		.697
								EXIT	.0	717.9	27.30	58.5		.685		.698
1010		02-10-66	14:45	981	8.68	1.490	454.3	INLET	46.1	483.4	-8.64	8.4				
	0							6	.0	718.5	27.38	58.0		.640		.586
								7	.0	734.1	29.78	62.3		.615		.585
								EXIT	.0	741.0	30.84	64.2		.600		.586
1011		02-10-66	15:11	984	9.63	1.495	416.9	INLET	16.5	519.4	-3.17	8.7				
	0							6	.0	733.9	29.71	62.3		.582		.543
	I							7	.0	748.6	31.97	66.3		.560		.543
	I							EXIT	.0	755.0	32.95	68.1		.547		.544
1012		02-10-66	15:37	985	16.64	2.481	467.2	INLET	20.6	514.5	-3.92	14.4				
	0							6	.0	660.0	18.38	69.5		.656		.610
								7	.0	669.6	19.85	73.8		.628		.610
								EXIT	.0	673.6	20.47	75.7		.612		.612
1013		02-10-66	15:54	988	14.66	2.459	503.3	INLET	42.5	488.1	-8.03	13.9				
	0							6	.0	645.8	16.16	62.2		.704		.655
								7	.0	656.3	17.78	67.0		.676		.656
								EXIT	.0	661.0	18.50	69.1		.660		.657
1014		02-10-66	16:01	984	14.15	2.461	514.8	INLET	50.0	479.1	-9.34	13.8				
	0							6	.0	640.4	15.39	60.1		.723		.668
								7	.0	651.2	17.04	69.0		.695		.666
								EXIT	.0	655.9	17.76	67.1		.678		.666
1015		02-10-66	16:20	984	11.43	2.467	581.9	INLET	92.2	430.9	-16.71	13.3				
	0							6	.0	612.9	11.19	47.9		.822		.748
								7	.0	624.9	13.02	53.3		.788		.749
								EXIT	.0	630.2	13.84	55.7		.769		.749

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
1016	0	02-10-66	16:42	983	9.04	2.469	676.4	INLET	142.1	376.1	-25.07	12.7				
								6	.0	587.2	7.27	36.3		.949		.877
								7	.0	601.3	9.43	42.7		.911		.878
								EXIT	.0	607.6	10.40	45.6		.889		.879
1017	0	02-10-66	16:45	987	8.80	2.475	680.6	INLET	144.3	374.5	-25.51	12.7				
								6	.0	586.6	7.04	35.6		.956		.882
								7	.0	600.6	9.20	42.0		.917		.883
								EXIT	.0	606.9	10.16	44.9		.895		.884
1018	0	02-11-66	9:29	1481	.13	.931	243.3	INLET	21.9	578.6	-5.43	3.3				
								6	.0	932.3	57.75	25.4		.340		.319
								7	.0	955.9	61.95	27.0		.326		.319
								EXIT	.0	965.8	63.73	27.6		.318		.320
1019	0	02-11-66	9:58	1477	.05	.906	247.4	INLET	46.4	545.7	-11.17	3.0				
								6	.0	923.2	56.15	23.7		.344		.329
								7	.0	947.9	60.56	25.3		.329		.329
								EXIT	.0	958.6	62.47	26.0		.321		.329
1020	0	02-11-66	10:25	1484	.08	.911	269.8	INLET	98.3	483.2	-22.55	2.9				
								6	.0	889.2	50.02	21.5		.376		.351
								7	.0	916.9	54.59	23.3		.362		.352
								EXIT	.0	929.3	57.21	24.2		.353		.353
1021	0	02-11-66	10:43	1481	.05	.906	285.2	INLET	143.9	431.3	-31.71	2.7				
								6	.0	866.2	45.55	19.9		.400		.372
								7	.0	894.9	51.08	21.8		.384		.372
								EXIT	.0	907.4	53.31	22.6		.374		.372
1022	0	02-11-66	11:39	1486	2.99	1.511	481.4	INLET	145.4	430.2	-32.07	8.1				
								6	.0	676.3	11.54	22.7		.672		.634
								7	.0	692.4	14.22	25.8		.644		.634
								EXIT	.0	699.5	16.10	27.1		.628		.634
1023	0	02-11-66	11:47	1480	3.06	1.510	497.1	INLET	148.7	425.9	-32.66	8.1				
								6	.0	680.1	12.73	23.6		.700		.643
								7	.0	696.9	15.72	26.8		.672		.642
								EXIT	.0	704.2	17.02	28.2		.656		.642
1024	0	02-11-66	12:17	1483	3.48	1.492	418.2	INLET	95.6	486.2	-22.01	8.4				
								6	.0	702.3	16.62	27.4		.581		.552
								7	.0	716.8	19.20	30.1		.557		.553
								EXIT	.0	723.2	20.34	31.3		.544		.553
1025	0	02-11-66	12:21	1488	3.51	1.495	417.0	INLET	93.5	489.3	-21.65	8.4				
								6	.0	704.2	16.84	27.6		.581		.547
								7	.0	718.6	19.42	30.3		.558		.548
								EXIT	.0	725.0	20.58	31.6		.544		.548
1026	0	02-11-66	12:47	1482	4.11	1.507	341.5	INLET	44.3	548.8	-10.75	9.0				
								6	.0	723.7	20.48	31.8		.474		.453
								7	.0	735.2	27.54	34.0		.455		.453
								EXIT	.0	740.4	23.46	35.0		.444		.453

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_0	h	x	V_m	$\frac{\phi_{10}}{10^6}$	$\frac{\phi_0}{10^6}$	$\frac{\phi_{11}}{10^6}$	$\frac{\phi_1}{10^6}$
1027		02-11-66	12:52	1484	4.00	1.509	352.0	INLET	51.5	540.0	-12.33	9.0				
	0							6	.0	719.6	19.76	31.1		.494		.455
								7	.0	731.7	21.92	32.4		.474		.456
								EXIT	.0	737.1	22.89	34.4		.463		.456
1028		02-11-66	13:15	1500	4.15	1.508	296.4	INLET	21.5	580.7	-5.53	9.4				
	0							6	.0	731.9	21.64	32.7		.412		.390
								7	.0	742.3	23.51	34.7		.396		.390
								EXIT	.0	746.8	24.32	35.6		.387		.390
1029		02-11-66	13:56	1490	9.29	2.480	360.9	INLET	20.8	580.6	-5.29	15.5				
	0							6	.0	692.7	14.79	42.1		.508		.466
								7	.0	700.2	16.14	44.5		.487		.466
								EXIT	.0	703.5	16.74	45.5		.476		.467
1030		02-11-66	14:12	1495	8.18	2.455	419.6	INLET	47.0	546.7	-11.55	14.7				
	0							6	.0	678.5	12.11	36.9		.587		.548
								7	.0	687.2	13.68	35.7		.563		.549
								EXIT	.0	691.1	14.37	40.9		.549		.549
1031		02-11-66	14:35	1492	6.71	2.477	520.1	INLET	95.1	488.1	-21.29	13.9				
	0							6	.0	650.3	7.17	28.7		.729		.679
								7	.0	661.0	9.08	32.0		.699		.680
								EXIT	.0	665.6	9.91	33.5		.681		.681
1032		02-11-66	15:04	1495	5.25	2.479	625.4	INLET	147.9	428.4	-32.69	12.2				
	0							6	.0	623.0	2.21	20.0		.879		.810
								7	.0	636.0	4.54	24.1		.844		.810
								EXIT	.0	641.6	5.55	25.8		.823		.811
1033		02-11-66	16:01	1996	4.25	2.483	589.3	INLET	143.1	478.6	-41.45	13.8				
	0							6	5.3	661.8	-2.00	17.4		.830		.763
								7	.0	673.8	.60	18.3		.796		.762
								EXIT	.0	679.1	1.74	19.6		.777		.762
1034		02-11-66	16:29	1983	1.87	1.495	435.9	INLET	142.3	478.7	-40.83	8.3				
	I							7	.0	718.5	10.53	17.8		.585		.570
	I							EXIT	.0	725.1	11.95	18.8		.570		.571
1035		02-11-66	17:15	1994	2.20	1.517	385.0	INLET	99.5	529.9	-30.29	8.9				
	0							4	.0	690.6	4.29	13.7		.554		.496
	0							5	.0	709.5	8.34	16.5		.554		.497
	0							6	.0	725.4	11.77	18.9		.541		.497
								7	.0	738.5	14.58	20.8		.519		.497
								EXIT	.0	744.4	15.86	21.7		.507		.498
1036		02-11-66	17:22	1995	2.15	1.508	398.1	INLET	108.0	519.6	-32.59	8.7				
	0							4	.0	686.7	3.38	13.0		.569		.520
	0							5	.0	706.6	7.68	16.0		.570		.521
	0							6	.0	723.4	11.29	18.4		.557		.521
								7	.0	736.7	14.16	20.4		.534		.522
								EXIT	.0	742.6	15.43	21.3		.521		.522

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
1037		02-11-66	17:48	1977	5.16	2.524	530.1	INLET	105.5	521.4	-31.54	14.6				
	0							6	.0	683.1	3.03	21.4		.742		.689
	I							7	.0	694.1	5.37	24.1		.713		.690
	I							EXIT	.0	698.9	6.41	25.3		.695		.691
1038		02-11-66	17:55	1993	5.15	2.510	523.5	INLET	103.4	525.2	-31.29	14.6				
	0							6	.0	686.0	3.30	21.6		.732		.684
	I							7	.0	696.7	5.61	24.2		.702		.685
	I							EXIT	.0	701.5	6.63	25.4		.685		.685
1039		02-12-66	9:52	1994	2.58	1.509	318.9	INLET	47.9	596.2	-16.02	6.5				
	0							3	.0	713.0	9.10	16.9		.445		.421
								4	.0	730.0	12.77	19.5		.453		.421
								5	.0	745.6	14.13	21.7		.453		.421
								6	.0	759.1	19.03	23.7		.443		.421
								7	.0	770.0	21.38	25.3		.425		.421
								EXIT	.0	774.8	22.41	26.0		.415		.422
1040		02-12-66	10:10	1985	2.62	1.514	317.1	INLET	50.0	592.8	-16.51	6.5				
	0							3	.0	708.3	8.26	16.5		.439		.424
	0							4	.0	725.4	11.91	19.0		.448		.424
	0							5	.0	740.9	15.24	21.3		.447		.424
	0							6	.0	754.2	18.09	23.2		.437		.424
	I							7	.0	765.0	20.41	24.8		.420		.424
	I							EXIT	.0	769.8	21.44	25.6		.410		.425
1041		02-12-66	10:39	1998	2.87	1.521	282.9	INLET	24.3	631.0	-8.70	10.1				
	0							3	.0	733.8	13.46	20.1		.399		.367
								4	.0	748.9	16.71	22.3		.407		.367
								5	.0	762.6	19.67	24.3		.406		.367
								6	.0	774.4	22.21	26.1		.397		.367
	I							7	.0	783.9	24.27	27.5		.381		.367
	I							EXIT	.0	788.1	25.18	28.1		.372		.367
1042		02-12-66	10:44	1996	2.81	1.517	283.2	INLET	26.2	627.9	-9.28	10.0				
	I							7	.0	781.6	23.83	27.1		.383		.366
	I							EXIT	.0	785.7	24.71	27.7		.373		.367
1043		02-12-66	11:07	1992	7.46	2.489	365.4	INLET	25.8	628.2	-9.13	16.4				
	I							7	.0	748.8	16.82	36.7		.487		.482
	I							EXIT	.0	752.2	17.55	37.5		.476		.483
1044		02-12-66	11:27	1980	6.86	2.491	403.7	INLET	44.5	600.1	-14.72	15.8				
	I							7	.0	733.4	13.80	33.4		.539		.533
	I							EXIT	.0	737.0	14.57	34.3		.526		.533
1045		02-12-66	11:37	2013	6.42	2.500	434.5	INLET	57.3	585.4	-12.99	15.6				
	I							7	.0	728.4	12.02	31.2		.582		.570
	I							EXIT	.0	732.3	12.87	32.2		.568		.570
1046		02-12-66	13:12	1995	-7.75	.503	156.0	INLET	18.0	640.6	-6.51	3.4				
	0							6	.0	879.6	44.54	13.8		.217		.205
								7	.0	895.7	48.41	14.6		.209		.205
								EXIT	.0	902.8	49.54	14.9		.203		.206

RUN NO.	CHF	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{l,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{l,i}}{10^6}$	$\frac{\phi_i}{10^6}$
1047		02-12-66	13:33	2007	-.67	.512	175.8	INLET	45.0	601.8	-15.24	3.3				
	0							7	.0	884.1	45.84	14.2		.235		.231
	0							EXIT	.0	891.8	47.50	14.5		.229		.231
1048		02-12-66	13:39	1996	-.64	.509	180.0	INLET	50.5	593.3	-16.70	3.2				
	0							7	.0	884.6	46.02	14.2		.242		.234
	0							EXIT	.0	892.6	47.74	14.6		.236		.234
1049		02-12-66	13:52	2002	-.58	.500	209.2	INLET	96.5	534.2	-29.66	2.9				
	0							7	.0	878.1	44.59	13.6		.280		.274
	0							EXIT	.0	888.0	46.72	14.0		.273		.275
1050		02-12-66	14:07	1997	-.48	.514	240.2	INLET	144.9	476.8	-41.78	2.8				
	0							6	.0	836.6	35.69	11.9		.334		.315
	0							7	.0	860.9	40.62	13.2		.321		.316
	0							EXIT	.0	871.7	43.25	13.7		.314		.316
1057		02-12-66	19:26	979	1.49	.507	377.5	INLET	151.9	365.3	-26.62	2.6				
	0							7	.0	978.3	67.20	44.1		.506		.494
	0							EXIT	.0	955.2	69.79	45.7		.494		.495

APPENDIX B
Burnout Equations From References

List of Symbols for Appendix B

A_f	Cross sectional area of flow channel, ft ²
A'	Empirical constant
C	Empirical function (inch) ⁻¹
C'	Empirical constant
D_e	Equivalent diameter, in.
F	Empirical factor
H	Enthalpy, Btu/lb
L_S	Boiling length, in.
P_{cr}	Critical pressure of fluid, psia
Y_0	Empirical constant
Y_1	Empirical constant
Y_2	Empirical constant
Y_3	Empirical constant
Y_4	Empirical constant
Y_5	Empirical constant
Y_6	Empirical constant
Y_7	Empirical constant
Y_8	Empirical constant
Y_9	Empirical constant
Y_{10}	Empirical constant
Y_{11}	Empirical constant
l_{DNB}	Length from inlet of heated channel to critical heat flux location, in.
n	Empirical function
p	Pressure, psia
q''	Heat flux, Btu/hr-ft ²
$q''_{DNB,EU}$	Critical heat flux for equivalent uniform distribution, Btu/hr-ft ²
x_{DNB}	Quality at critical heat flux location
z	Axial distance along channel, in.
ϕ_{BO}	Burnout or critical heat flux, Btu/hr-ft ²

Burnout Equation From Reference 5

$$\frac{\phi_{BO}}{10^6} = \frac{0.28 \left(1 + \frac{G}{10^7}\right)^2}{\left(\frac{H}{1000}\right)^{2.5} \exp(0.0012 L/D)}$$

Applicable ranges:

Enthalpy at burnout point, Btu/lb	$500 \leq H \leq 1000$
Mass velocity, lb/hr-ft ²	$0.2 \leq G/10^6 \leq 8.0$
Pressure, psia	$1850 \leq p \leq 2150$
Length-to-diameter ratio	$21 \leq L/D \leq 365$

Burnout Equation From Reference 17

$$\frac{\phi_{BO}}{10^6} = (1.83 - 0.000415 P) 0.090 \left(\frac{G}{240} \frac{D}{L}\right)^n$$

$$n = 0.3987 + 0.001036(\Delta T_{si}) - 1.027 \times 10^{-6}(\Delta T_{si})^2$$

Ranges of data used to develop equation:

Length, in.	$3 \leq L \leq 27.4$
Diameter, in.	$0.075 \leq D \leq 0.44$
Mass velocity, lb/hr-ft ²	$0.02 \leq G/10^6 \leq 7.8$
Inlet subcooling, F	$0 \leq \Delta T_{si} \leq 564$
Pressure, psia	$1000 \leq p \leq 2000$
Flux shape	Uniform

Burnout Equation From Reference 18

$$\begin{aligned} \frac{q''_{DNB,EU}}{10^6} = & [(2.022 - 0.0004302 p) + (0.1722 - 0.0000984 p) \exp(18.177 \\ & - 0.004129 p)(x)] \times [(0.1484 - 1.596 x + 0.1729 x|x|) G/10^6 \\ & + 1.037] \times (1.157 - 0.869 x) \times \left(0.2664 + 0.8357 e^{-3.151 De}\right) \\ & \times [0.8258 + 0.000794(H_f - H_{in})] \end{aligned}$$

Ranges of data used to develop equation:

System pressure, $p = 800$ to 2000 psia

Mass velocity, $G = 0.5 \times 10^6$ to 5.0×10^6 lb/hr-ft²

Equivalent diameter, $D_e = 0.2$ to 0.7 inch

Quality, $x_{loc} = -0.15$ to $+0.15$

Inlet enthalpy, $H_{in} \geq 400$ Btu/lb

Length, $L = 10$ to 79 inches

$\frac{\text{Heated perimeter}}{\text{Wetted perimeter}} = 0.88$ to 1.00

Geometries = circular tube and rectangular channel

Flux = uniform and equivalent uniform flux converted from non-uniform data by using F factor

The local nonuniform $q''_{DNB,N}$ is calculated as

$$q''_{DNB,N} = \frac{q''_{DNB,EU}}{F}$$

where

$$F = \frac{C}{q''_{local \text{ measured}} \times \left(1 - e^{-Cl_{DNB}}\right)} \int_0^{l_{DNB}} q''(z) e^{-C(l_{DNB} - z)} dz$$

$$C = 0.44 \frac{(1 - x_{DNB})^{7.9}}{(G/10^6)^{1.72}}, \quad C = (\text{inch})^{-1}$$

In use of data, $q''_{local \text{ measured}}$ is measured at $z = l_{DNB}$.

Burnout Equation From Reference 11

High-velocity regime

$$\frac{\phi}{10^6} = \frac{A' + \frac{1}{4} D(G/10^6) \Delta H_{si}}{C' + L}$$

$$A' = Y_0 D^{Y_1} (G/10^6)^{Y_2} [1 + Y_3 D + Y_4 (G/10^6) + Y_5 D (G/10^6)]$$

$$C' = Y_6 D^{Y_7} (G/10^6)^{Y_8} [1 + Y_9 D + Y_{10} (G/10^6) + Y_{11} D (G/10^6)]$$

Table B-1. Optimum Y Values for High-Velocity Regime
Burnout Data

System pressure, psia	560	1000	1550	2000
Y_0	237	114	36.0	65.5
Y_1	1.20	0.811	0.509	1.19
Y_2	0.425	0.221	-0.109	0.376
Y_3	-0.940	-0.128	-0.190	-0.577
Y_4	-0.0324	0.0274	0.0240	0.220
Y_5	0.111	-0.0667	0.463	-0.373
Y_6	19.3	127	41.7	17.1
Y_7	0.959	1.32	0.953	1.18
Y_8	0.831	0.411	0.0109	-0.456
Y_9	2.61	-0.274	0.231	-1.53
Y_{10}	-0.0578	-0.0397	0.0767	2.75
Y_{11}	0.124	-0.0221	0.117	2.24

Low-velocity regime

$$\frac{\phi}{10^6} = \frac{(G/10^6)(H_{fg} + \Delta H_{si})}{158 D^{0.1} (G/10^6)^{0.49} + 4 L/D}$$

When velocity regime is in doubt, the lower of the two values given by the two equations should be used.

Burnout Equation From Reference 9

$$q_S = \frac{GA_f H_{fg} \left[1 - \left(\frac{P}{P_{cr}} \right) \right] L_S P_i}{1.10691 \left(\frac{G}{10^6} \right)^{1/3} \left[L_S + 61.977 \left(\frac{P_{cr}}{P} - 1 \right)^{0.4} D^{1.4} \left(\frac{G}{10^6} \right) \right] P_{tot}}$$

where

q_S = critical power or heat transfer rate over the length L_S , Btu/hr

G = mass velocity, lb/hr-ft²

A_f = cross-sectional area of flow channel, ft²

H_{fg} = latent heat of vaporization, Btu/lb

P = system pressure, psia

P_{cr} = critical pressure of fluid, psia

L_S = boiling length, in.

D = diameter, in.

P_i = perimeter of heated surface bearing CHF, in.

P_{tot} = channel perimeter, in.

REFERENCES

- ¹ Jacket, H. S., Roarty, J. D., and Zerbe, J. E., Trans. Am. Soc. Mech. Engrs. 80, p 391 (1958).
- ² Weatherhead, R. J., Nucleate Boiling Characteristics and the Critical Heat Flux Occurrence in Subcooled Axial-Flow Water Systems, ANL-6675, Argonne (1963).
- ³ Matzner, B. and Griffel, J., Basic Experimental Studies of Boiling Fluid Flow and Heat Transfer at Elevated Pressures, MRP-XIII-6-63, Columbia University, June 1963.
- ⁴ Swenson, H. S., Carver, J. R., and Kakarala, C. R., The Influence of Axial Heat Flux Distribution on the Departure From Nucleate Boiling in a Water-Cooled Tube, ASME Paper No. 62-WA-297.
- ⁵ DeBortoli, R. A., et al., Forced Convection Heat Transfer Burnout Studies for Water in Rectangular Channels and Round Tubes at Pressures Above 500 psia, WAPD-188, Bettis Laboratory, Pittsburgh, Pennsylvania, October 1958.
- ⁶ Judd, D. F., et al., Burnout for Flow Inside Round Tubes With Non-uniform Heat Fluxes, Topical Report, The Babcock & Wilcox Company, BAW-3238-9, Lynchburg, Virginia, May 1966.
- ⁷ Jansen, E. and Kervinen, J. A., Burnout Conditions for Single Rod in Annular Geometry, Water at 600 to 1400 psia, GEAP-3899, San Jose, February 1963.
- ⁸ Biancone, F., et al., Forced Convection Burnout and Hydrodynamic Instability Experiments for Water at High Pressure, Part I: Presentation of Data for Round Tubes with Uniform and Nonuniform Power Distribution, EUR 2490.e, Genova, May 1965.

- ⁹ Bertoletti, S., et al., Heat Transfer Crisis With Steam-Water Mixtures, CISE Report R-99, Segrate (Milano), Italy, September 1964.
- ¹⁰ Oberjohn, W. J. and Wilson, R. H., The Effect of Nonuniform Axial Flux Shapes on the Critical Heat Flux, ASME Paper No. 66-WA/ HT-60.
- ¹¹ Thompson, B. and MacBeth, R. V., Boiling Water Heat Transfer Burnout in Uniformly Heated Round Tubes: A Compilation of World Data with Accurate Correlations, AEEW-R356, Winfrith, Dorchester, Dorset, England, July 1964.
- ¹² Lee, D. H. and Obertelli, J. D., An Experimental Investigation of Forced Convection Burnout in High Pressure Water. Part I, Round Tubes With Uniform Flux Distribution, AEEW-R213, Winfrith, August 1963.
- ¹³ Griffel, J., Bonilla, C. F., "Forced Convection Boiling Burnout for Water in Uniformly Heated Tubular Test Sections", Nuclear Structural Engineering, 2, pp. 1-35 (1965).
- ¹⁴ Macbeth, R. V., Burnout Analysis, Part 4: Forced Convection Burnout in Simple Uniformly Heated Channels - A Detailed Analysis of World Data, AEEW-R267, September 1963.
- ¹⁵ Lee, D. H., An Experimental Investigation of Forced Convection Burnout in High Pressure Water, Part III: Long Tubes with Uniform and Nonuniform Axial Heating, AEEW-R355, March 1965.
- ¹⁶ Matzner, B., et al., Critical Heat Flux in Long Tubes at 1000 psi With and Without Swirl Promoters, ASME Paper No. 65-WA/HT-30.
- ¹⁷ Wilson, R. H. and Ferrell, J. K., "Correlation of Critical Heat Flux for Boiling Water in Forced Circulation at Elevated Pressures", AIChE Symposium Series, Nuclear Engineering, Vol X (1964).
- ¹⁸ Rochester Gas and Electric Corporation Brookwood Nuclear Station Unit No. 1, Preliminary Description and Safety Analysis Report, USAEC Exhibit D, Volume 1, Washington, D. C., 1965.
- ¹⁹ Adorni, N., et al., Heat Transfer Crisis With Steam-Water Mixtures in Complex Geometries: Experimental Data in Annuli and Clusters, CISE-R123, Segrate, December 1964.

- ²⁰ Nukiyama, S., "The Maximum and Minimum Values of Heat q Transmitted from Metal Surface to Boiling Water under Atmospheric Pressure", Journal of Society of Mechanical Engineers (Japan) 37, pp 367 and 553 (1934).
- ²¹ Roberts, H. A., A Review of Net Boiling Heat Transfer and Pressure Drop from the Literature, AERE ED/M 22, London, 1955.
- ²² Lacey, P. M. C., Hewitt, G. F., and Collier, J. G., Climbing Film Flow, AERE-R-3962, Paper No. 1, Symposium on Two-Phase Fluid Flow, Institution of Mechanical Engineers, London, February 7, 1962.
- ²³ Lee, D. H. and Obertelli, J. D., An Experimental Investigation of Forced Convection Burnout in High Pressure Water. Part II. Preliminary Results for Round Tubes with Non-Uniform Axial Heat Flux Distribution, AEW-R309, Winfrith, 1963.
- ²⁴ Davies, J. T. and Rideal, E. K., Interfacial Phenomena, 2nd ed., Academic Press, New York, 1963.
- ²⁵ Harkins, W. D., The Physical Chemistry of Surface Films, Reinhold Publishing Corp., New York, 1957.
- ²⁶ Gilliland, R. G., Investigation of the Wettability of Various Pure Metals and Alloys on Beryllium, ORNL-3438, Oak Ridge, 1963.
- ²⁷ Taylor, J. W., "Wetting by Liquid Metals", Progr. Nuclear Energy Ser. V 2, pp 398 - 416 (1959).
- ²⁸ Gottfried, B. S. and Bell, K. J., The Evaporation of Small Drops on a Flat Plate in the Film Boiling Regime, AIChE 54th Annual Meeting, Preprint 52, New York, 1961.
- ²⁹ Poppendiek, H. F., et al., High Acceleration Field Heat Transfer for Auxiliary Space Nuclear Power Systems, GLR-27, La Jolla, 1964.
- ³⁰ Borishansky, V. M., Heat Transfer to a Liquid Freely Flowing over a Surface Heated to a Temperature Above the Boiling Point, AEC-tr-3405, Oak Ridge, 1953.
- ³¹ McAdams, W. H., Heat Transmission, 3rd ed., McGraw Hill, New York, 1954.

BIBLIOGRAPHY OF PROGRAM REPORTS

1. Judd, D. F., et al., Non-Uniform Heat Generation Experimental Program, Quarterly Technical Report No. 1, The Babcock & Wilcox Company, BAW-1287, Lynchburg, Virginia, September 1963.
2. Judd, D. F., et al., Non-Uniform Heat Generation Experimental Program, Quarterly Progress Report No. 2, The Babcock & Wilcox Company, BAW-1291, Lynchburg, Virginia, December 1963.
3. Judd, D. F., et al., Non-Uniform Heat Generation Experimental Program, Quarterly Progress Report No. 3, The Babcock & Wilcox Company, BAW-3238-3, Lynchburg, Virginia, March 1964.
4. Judd, D. F., et al., Non-Uniform Heat Generation Experimental Program, Quarterly Progress Report No. 4, The Babcock & Wilcox Company, BAW-3238-4, Lynchburg, Virginia, June 1964.
5. Judd, D. F., et al., Nonuniform Heat Generation Experimental Program, Quarterly Progress Report No. 5, The Babcock & Wilcox Company, BAW-3238-5, Lynchburg, Virginia, September 1964.
6. Judd, D. F., et al., Nonuniform Heat Generation Experimental Program, Quarterly Progress Report No. 6, The Babcock & Wilcox Company, BAW-3238-6, Lynchburg, Virginia, December 1964.
7. Judd, D. F., et al., Nonuniform Heat Generation Experimental Program, Quarterly Progress Report No. 7, The Babcock & Wilcox Company, BAW-3238-7, Lynchburg, Virginia, March 1965.
8. Judd, D. F., et al., Nonuniform Heat Generation Experimental Program, Quarterly Progress Report No. 8, The Babcock & Wilcox Company, BAW-3238-8, Lynchburg, Virginia, June 1965.
9. Judd, D. F., et al., Burnout for Flow Inside Round Tubes with Nonuniform Heat Fluxes, Topical Report, The Babcock & Wilcox Company, BAW-3238-9, Lynchburg, Virginia, May 1966.
10. Judd, D. F., et al., Nonuniform Heat Generation Experimental Program, Quarterly Progress Report No. 9, The Babcock & Wilcox Company, BAW-3238-10, Lynchburg, Virginia, September 1965.

11. Judd, D. F., et al., Nonuniform Heat Generation Experimental Program, Quarterly Progress Report No. 10, The Babcock & Wilcox Company, BAW-3238-11, Lynchburg, Virginia, December 1965.
12. Judd, D. F., et al., Nonuniform Heat Generation Experimental Program, Quarterly Progress Report No. 11, The Babcock & Wilcox Company, BAW-3238-12, Lynchburg, Virginia, March 1966.

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