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BURNOUT FOR FLOW INSIDE ROUND TUBES
WITH NONUNIFORM HEAT FLUXES

— Topical Report —

May 1966

PRELIMINARY REPORT
U.S.-EURATOM EXCHANGE

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Lynchburg, Virginia

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LIST OF PRINCIPAL INVESTIGATORS

ATOMIC ENERGY DIVISION

D. F. Judd
Technical Manager

R. H. Wilson
Analytical Program

ALLIANCE RESEARCH CENTER

C. P. Welch
R. A. Lee
J. W. Ackerman

Experimental Program

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 (departure from nucleate boiling). The experimental program is being conducted in the 1.8-MW heat transfer facility at B&W's Research Center, Alliance, Ohio. The analytical program is being 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 burn-out (critical heat flux). This program seeks to improve design correlations that will be suitable for direct use by reactor designers. Experimental work on tubular specimens with four axial power shapes was completed in December, 1964. Annular specimens with five power shapes are now being tested, and an effort to correlate the experimental data with empirical and analytical models is being made. The completion date of the program, with one extension, is June 30, 1966.

The data and results from the tubular 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:

<u>Axial flux shape</u>	<u>Pressure, psia</u>	<u>Mass velocity, lb/hr-ft² × 10⁶</u>	<u>Inlet subcooling, F</u>
1 Uniform	2000	0.5	20
3 Peak near inlet	1500	1.5	50
2 Peak near midpoint	1000	2.5	100
4 Peak near outlet			150

The 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 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.

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1. INTRODUCTION

Nuclear reactors and modern boilers require more and more knowledge about the limitations on the rates of heat transfer from channel walls to flowing liquids. Burnout (critical heat flux) is a very serious design problem still facing the reactor designer. From the design viewpoint, the result of this phenomenon is a considerable reduction in heat transfer conductance, which causes the metal and fuel temperatures to rise and initiate failure of the fuel element. From the laboratory viewpoint, the process is studied as a critical heat flux rather than as a burnout phenomenon. The nature of the process is still the subject of many inconclusive discussions; however, it is generally agreed that low heat transfer coefficients are associated with it. It is also known that the critical heat flux condition can exist on a surface without causing the surface to melt or "burn out", but the boundaries of such operation are ill-defined, and the heat fluxes are thought to be low. Moreover, the practicality of operating for long periods under critical heat flux must be proved from the corrosion standpoint. For these reasons, present practice in nuclear reactor design treats critical heat flux as burnout and seeks to avoid burnout by remaining on the safe side of the critical heat flux conditions as determined in heat transfer laboratories. Although considerable attention has been given to this problem in recent years, predicting the occurrence of burnout conditions is quite uncertain. In fact, there is still much disagreement on how channel geometry and operating conditions affect burnout.

In an effort to clarify some of the areas of disagreement, Babcock & Wilcox (B&W), as part of the Joint U.S.-Euratom Research and Development Program, began an experimental and analytical program on July 1, 1963, to determine the effects of nonuniform heat generation rates in tubular and annular flow channels on the operating conditions that cause burnout under experimental conditions representative of water reactor systems. The objective of the program is to seek improved design

correlations suitable for direct use by reactor designers. The technical approach to the work emphasizes the development of an improved understanding of the physical phenomena involved and their relation to design variables.

The experimental program is being conducted in a B&W heat transfer facility at its Research Center in Alliance, Ohio.¹ The controlled variables for the tests are pressure, inlet subcooling, and mass velocity; they are being investigated over ranges of 1000 to 2000 psia pressure, 0.5×10^6 to 2.5×10^6 lb/hr-ft² velocity, and 20 to 150 F subcooling. The tests are being performed in 6-foot-long tubular and annular test sections having both uniform and nonuniform axial heat flux distributions. The analytical program is being conducted by the Atomic Energy Division in Lynchburg, Virginia.

Since all the planned work on the tubular test sections has been completed, this topical report is prepared to collect this portion of the work in one volume and to present the complete analysis of data from the four tubular test sections. The final report will contain the annular data, analysis thereof, and any observed relationship to the tubular data. The annular tests will provide an opportunity to observe the effects on critical heat flux produced by three factors: a heated surface facing an unheated surface, two uniformly heated surfaces facing each other, and a uniformly heated surface facing an axially nonuniformly heated surface.

2. DESCRIPTION OF TEST APPARATUS

2.1. Experimental Loop

The experimental program is being conducted on a vertical test section in a closed loop through which water is circulated at a controlled rate. A 1.8-MW d-c power supply heats the test section. A photograph of the test site is shown in Figure 1, and Figure 2 is a schematic diagram of the test apparatus. The circuit consists of a Westinghouse 150-D canned rotor centrifugal circulating pump, an air-operated Annin flow control valve, flow measuring elements, a 60-kw immersion-type main loop heater, the tubular test section, a boiling water heat exchanger unit, and a loop pressurizer system. These components are joined with 3.25-inch-OD, 0.380-inch-wall SA-210 tubing to complete the closed loop. A burnout detector system is used for observing transition and film boiling in the test section. Feedwater is demineralized plant steam condensate with NH_4OH added for pH control.

Test section flow rates are measured with a calibrated flow nozzle assembly located ahead of the test section. A turbine-type flow meter is used in conjunction with the nozzle to detect and record variations in flow rates or hydraulic instability during test operation.

The boiling water heat exchanger and the main loop heater make up the heat removal and temperature control unit for the test loop. Since a boiling water heat exchanger alone provides rather sluggish control of heat removal rate, the exchanger is used only for coarse control of the heat removal rate. The main loop heaters are used for fine temperature control. In operation, the heat exchanger is adjusted to remove a little more heat from the system than is required to keep the system in thermal equilibrium. A small, controlled amount of heat is added to the system to adjust the overall heat removal rate to that required. This heat addition is made by the main loop heaters; the signal for the heater controls originates from a thermocouple used to measure the test section inlet fluid temperature.

Pressure is maintained with the pressurizer system by automatically controlling the rate of steam generation in the pressurizer vessel. Immersion-type electric heaters are used for heating.

The test apparatus is sufficiently automated to permit continuous standby operation without attending personnel; however, the d-c power supply is operated only during periods of obtaining test data. The only time the loop is to be completely shut down is for maintenance or for changing test sections.

The test sections are heated by passing direct current through the tube wall. The current is supplied from two d-c rectifier units, the input of each being 3-phase, 60-cycle, 4160-volt ac and the output being 100-volt dc at 9000 amperes. The two units can be operated in parallel and controlled with one controller, or operated independently with individual controllers.

The critical heat flux condition can be identified by an abrupt rise in the temperature of the test section heater wall. On the tubular test sections, a resistance-type, segmental, critical heat flux detector was used to detect transients in the heater wall temperature (Figure 3). The instrument operates on the principle that changes in temperature bring about changes in the electrical resistivity of the heater wall. Each of the tubes are divided into 12 or 15 segments by voltage taps. In the detector, the voltage drop across each segment is compared, using an Assembly Products differential voltmeter, with a portion of the total tube voltage drop (meter reference voltage). Each differential voltmeter contains two electrically isolated signal coils capable of reading ± 30 millivolts differential; the signal coils are connected so that their magnetic fields oppose each other. The meter is balanced by adjusting the meter reference voltage until it exactly cancels the voltage signal from the tube.

When a critical heat flux condition occurs in some segment of the tube, the electrical resistance of that segment increases, while the resistances of the other segments remain essentially unchanged. The rise in resistance of the critical heat flux segment causes the voltage drop across that segment to be more than the meter reference voltage. The resultant signal is picked up by the differential voltmeter across that segment, thereby providing visual evidence of the critical heat flux condition. The differential voltmeter is equipped with an automatic trip circuit which

shuts off the d-c power supply when the voltage differential exceeds a preset value.

2.2. Test Sections

The principal features of the test sections are the axial flux shapes that they are designed to produce. The general shapes are dictated by nuclear reactor considerations with simplifications to make fabrication more practical. It is thought that if exact flux shape is found to be a sensitive item with respect to burnout, then precise reactor flux shapes may be justified in future programs. One test section with uniform flux was run mainly for reference purposes. Following this, three nonuniform flux shapes were run with tubular flow channels. All channels had 72-inch heated lengths with a 50-inch unheated section at the inlet end.

2.2.1. Uniform Test Section

The uniform flux shape was the simplest to construct because it required no machining to vary the wall thickness, and a section of special drawn tubing was used for this purpose. The inside diameter was determined to be 0.445 inches. Figure 4 shows the physical arrangement of the test section.

2.2.2. Nonuniform Test Sections

The second test section was constructed according to the flux shape shown in Figure 5. The inside diameter was 0.448 inches, 2 mils over the design value of 0.446 inches. The outside diameter was varied by precision machining techniques to produce the desired wall thickness and heat flux shape. Table 1 compares the design values with the measured values of the finished test section. The voltage tap and thermocouple locations for this test section are shown in Figure 6.

The third test section was built to produce the flux shape shown in Figure 7; comparison of the designed and actual wall thickness is shown in Table 2. The inside diameter is 0.448 inches. Figure 8 shows the instrumentation for the third test section.

The flux shape for the fourth test section is shown in Figure 9, and the precision of manufacture is indicated in Table 3. The inside diameter is 0.448 inches. Voltage tap and thermocouple locations are given in Figure 10.

During the experimental work the actual flux profiles were determined by measuring the voltage drops across segments of the tubes. The results are shown as plotted points in Figures 5, 7, and 9.

Table 1. Geometry of Test Section 2-A (Chopped Cosine)

Distance from inlet end of heated length, in.	Required wall thickness, in.	Required tolerance, in.	Actual measured variation, in.
0	0.1645	± 0.002	+0.001
2	0.1314	± 0.002	+0.002
4	0.1071	± 0.002	+0.001
6	0.0928	± 0.002	+0.001
8	0.0810	± 0.001	+0.001
10	0.0731	± 0.001	+0.001
12	0.0656	± 0.001	± 0.001
14	0.0604	± 0.001	+0.001
16	0.0566	± 0.001	+0.001
18	0.0535	± 0.001	+0.001
20	0.0505	± 0.001	± 0.000
22	0.0482	± 0.001	+0.001
24	0.0467	± 0.001	± 0.000
26	0.0455	± 0.001	+0.001
28	0.0440	± 0.001	+0.000
30	0.0432	± 0.001	-0.001
32	0.0423	± 0.001	± 0.001
34	0.0423	± 0.001	± 0.000
36	0.0420	± 0.001	+0.000
38	0.0423	± 0.001	+0.001
40	0.0423	± 0.001	+0.001
42	0.0432	± 0.001	+0.001
44	0.0440	± 0.001	+0.001
46	0.0455	± 0.001	+0.001
48	0.0467	± 0.001	+0.001
50	0.0482	± 0.001	+0.001
52	0.0505	± 0.001	+0.001
54	0.0535	± 0.001	+0.001
56	0.0566	± 0.001	+0.001
58	0.0604	± 0.001	+0.001
60	0.0656	± 0.001	± 0.001
62	0.0731	± 0.001	+0.001
64	0.0810	± 0.001	+0.001
66	0.0928	± 0.002	+0.001
68	0.1071	± 0.002	+0.001
70	0.1314	± 0.002	+0.002
72	0.1645	± 0.002	-0.002

Table 2. Geometry of Test Section 3-A (Peak Near Inlet)

Distance from inlet end of heated length, in.	Required wall thickness, in.	Required tolerance, in.	Actual measured variation, in.
0	0.1752	±0.002	--
2	1.1172	±0.002	--
4	0.0868	±0.002	-0.001
6	0.0712	±0.001	-0.001
8	0.0605	±0.001	±0.000
10	0.0537	±0.001	+0.001
12	0.0493	±0.001	+0.001
14	0.0466	±0.001	+0.001
16	0.0447	±0.001	±0.000
18	0.0445	±0.001	-0.001
20	0.0447	±0.001	±0.000
22	0.0462	±0.001	+0.001
24	0.0475	±0.001	+0.001
26	0.0505	±0.001	+0.001
28	0.0537	±0.001	+0.001
30	0.0583	±0.001	+0.001
32	0.0655	±0.001	±0.000
34	0.0734	±0.001	+0.001
36	0.0823	±0.001	+0.001
38	0.0919	±0.001	±0.000
40	0.0997	±0.002	±0.000
42	0.1063	±0.002	+0.001
44	0.1172	±0.002	+0.001
46	0.1233	±0.002	+0.001
48	0.1341	±0.002	+0.002
50	0.1379	±0.002	+0.001
52	0.1467	±0.002	+0.002
54	0.1518	±0.003	±0.000
56	0.1570	±0.003	+0.002
58	0.1626	±0.003	+0.002
60	0.1686	±0.003	+0.001
62	0.1686	±0.003	+0.002
64	0.1699	±0.003	+0.002
66	0.1739	±0.003	-0.001
68	0.1752	±0.003	+0.002
70	0.1752	±0.003	+0.003
72	0.1752	±0.003	+0.003

Table 3. Geometry of Test Section 4 (Peak Near Exit)

Distance from outlet end of heated length, in.	Required wall thickness, in.	Required tolerance, in.	Actual measured variation, in.
72	0.1752	±0.003	+0.001
70	0.1752	±0.003	+0.001
68	0.1752	±0.003	±0.001
66	0.1739	±0.003	-0.001
64	0.1699	±0.003	±0.000
62	0.1686	±0.003	-0.001
60	0.1686	±0.003	-0.002
58	0.1626	±0.003	+0.001
56	0.1570	±0.003	+0.001
54	0.1518	±0.003	+0.000
52	0.1467	±0.002	-0.001
50	0.1379	±0.002	-0.001
48	0.1341	±0.002	+0.001
46	0.1233	±0.002	±0.000
44	0.1172	±0.002	±0.000
42	0.1063	±0.002	+0.001
40	0.0997	±0.002	±0.000
38	0.0919	±0.001	+0.001
36	0.0823	±0.001	+0.000
34	0.0734	±0.001	+0.001
32	0.0655	±0.001	-0.001
30	0.0583	±0.001	+0.000
28	0.0537	±0.001	±0.000
26	0.0505	±0.001	±0.000
24	0.0475	±0.001	±0.000
22	0.0462	±0.001	+0.001
20	0.0447	±0.001	-0.001
18	0.0445	±0.001	+0.000
16	0.0447	±0.001	+0.001
14	0.0466	±0.001	-0.001
12	0.0493	±0.001	+0.001
10	0.0537	±0.001	±0.000
8	0.0605	±0.001	-0.001
6	0.0712	±0.001	+0.001
4	0.0868	±0.002	±0.000
2	0.1172	±0.002	±0.000
0	0.1752	±0.002	±0.001

Figure 1. Test Site

Figure 2. Schematic Diagram of Test Apparatus

Figure 3. Schematic Diagram of Segmental Critical Heat Flux Detector

Figure 4. Arrangement of Tubular Test Sections

Figure 5. Heat Input Rate Distribution (chopped cosine;
maximum/average = 1.4)

Figure 6. Test Section No. 2 Instrumentation

Figure 7. Heat Input Rate Distribution (peak near inlet;
maximum/average = 1.94)

Figure 8. Test Section No. 3 Instrumentation

Figure 9. Heat Input Rate Distribution (peak near exit;
maximum/average = 1.94)

Figure 10. Test Section No. 4 Instrumentation

3. OPERATING PROCEDURE

3.1. Test Conditions

3.1.1. Experimental Parameters

Each of the test sections described in section 2.2 of this report was run under the following nominal experimental conditions in all combinations to yield a minimum of 144 data points:

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

During experimental operation, it was found that the pressure and mass velocity could be set reasonably close to the desired values; however, the dynamics of the loop were such that the time required to approach the specified inlet condition delayed considerably the achievement of each burnout data point. As a result, the inlet temperature specification was relaxed in the interest of saving time. For a given data point, the inlet temperature may vary as much as 10 F from nominal. Where analyses require more exact parametric inlet conditions, the experimental results are plotted versus the experimental inlet conditions. From these plots it is possible to make cross-plots that represent the parametric inlet conditions shown above.

3.1.2. Procedure for Obtaining a Data Point

Prior to the critical heat flux runs, calibration data were obtained for each test section. These data provided information for determining test section isothermal pressure drop and heat losses, for computing the heat balance between the measured power input to the test

section and the sensible heat acquired by single-phase water flowing through the test section, and for plotting the actual heat flux profile on the test section.

The critical heat flux data were obtained by the following procedure:

- a. A given mass velocity, inlet temperature, and outlet pressure were established.
- b. The test section heat flux was gradually increased until the critical heat flux was reached. This was indicated by thermocouple readings for the uniform tube and by the burnout detector for the non-uniform tubes. The criterion for the critical heat flux condition was a wall temperature rise of more than 10 F, as indicated by a thermocouple or by the segmental burnout detector when a step change in heat flux was made. The value of the heat flux at this point was noted. Depending on the severity of the test section metal temperature changes, the heat flux was reduced manually or cut off by automatic power trip.
- c. While maintaining the conditions in (a), the heat flux was again increased to a value within 5000 Btu/hr-ft² of that noted in (b); a complete set of data for this burnout point was recorded. After this, the heat flux was increased to the critical value to verify the previous burnout condition, and the power measurements at burnout were taken.

3.2. Burnout Detection

The burnout detector is a basic part of the instrumentation for this program; the following section is devoted to a discussion of this equipment and its principle of operation.

Thermocouples were used on the uniform test section; this is not unique, since they have been used for several years to detect burnout when the burnout location could be predicted. The thermocouples were attached to the test section as shown in Figure 6 and they were connected to a reference junction and a recorder.

For the nonuniform channels, a more sophisticated burnout detector was required because previous experience² had shown that the burnout location for nonuniformly heated channels was unpredictable. Furthermore, when a burnout trip occurred, we needed to know what portion of the channel experienced a critical heat flux condition. To meet

this need, a detector was developed to monitor several segments of the channel simultaneously. This detector operates on the principle that a segmental temperature rise, initiated by critical heat flux conditions, will produce a detectable change in the resistance of that segment.

Early in the experimental work, considerable difficulty was experienced with the segmental detector. The theory of operation had been proved, but one of the difficulties involved a mechanical switch, or chopper, that was used to compare test section incremental voltage drop with a reference voltage drop. Each of the choppers was replaced with a differential voltmeter system. This was judged a satisfactory solution, and the burnout detector was used during all testing subsequent to the tests on the uniform flux shape (No. 1), while thermocouples were used only for recording and not for power tripping.

3.3. Acquisition of Other Data

3.3.1. Pressure Drop

Test section pressure drop readings associated with critical conditions have been taken. Readings were made with both a Barton ΔP gauge and a mercury high pressure manometer.

3.3.2. Transient Records

In order to learn more about the loop and test section behavior at near-critical heat flux conditions, continuous recordings were made of some of the measured quantities. One type of measurement was made with a bridge circuit, wherein a test section was electrically divided in half and incorporated in a Wheatstone bridge circuit. The voltage unbalance in this circuit was recorded at near-critical conditions. In addition, flow meter signals, inlet pressure transducer signals, and wall temperatures from thermocouples on selected critical segments of the test section were recorded.

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4. DATA

4. 1. Channel Average Heat Flux

4. 1. 1. Effect of Flux Shape

Since the major parameter of this program is the flux shape, the data are presented to show the effect of changing the flux shape, with all other test parameters 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 critical heat flux or burnout point. Because the average heat flux is proportional to overall channel performance, the various data have been compared on that basis. In Figures 11, 12, and 13, the average heat flux over the length of the channel is shown versus inlet subcooling for nine combinations of mass velocity and pressure. 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 burnout occurs. Perhaps the most interesting behavior is exhibited by the inlet peak flux shape. In some cases, notably at 1500 psia and mass velocity of 2.5 million lb/hr-ft², it seems to run the gamut of power delivery. At low inlet subcooling, its average heat flux is very nearly the lowest; at high inlet subcooling, its average heat flux is the highest. It is seen that this flux shape can offer heat transfer advantages under some conditions. The outlet peak exhibited the lowest capability in all cases. The cosine appears to rank with the uniform cases except at the two conditions previously mentioned.

4. 1. 2. Effect of Inlet Subcooling

Many systems to which critical heat flux data are applied have constant inlet conditions or slowly changing inlet conditions. Therefore, it is important from one point of view to observe the effect of inlet condition, expressed as inlet subcooling, upon critical heat flux. The effect of inlet subcooling on the channel power is evident from Figures 11, 12, and 13. Increased inlet subcooling increases the channel power, and the increase is more pronounced at the higher mass velocities.

4. 1. 3. Effect of Mass Velocity

Because of the same application of the data as stated in section 4. 1. 2, it is important to observe the effects on critical heat flux of mass velocity at constant inlet conditions. With all other conditions constant, the general effect of increasing mass velocity is to increase the channel power. In some cases these increases are very small, if they exist at all—for example (in Figure 11), at 1000 psia and low subcoolings, where the mass velocity is increased from 1.5 to 2.5×10^6 lb/hr-ft² for the nonuniform shapes, changes in critical heat flux are so small that they are masked by the precision of the experiment.

4. 1. 4. Effect of Pressure

Increased pressure causes decreased burnout power. The conditions least sensitive to pressure occur at the high mass velocity and high inlet subcooling.

4. 1. 5. Exit Quality

From some points of view the exit quality is important. This is particularly true in boiling reactor applications, where it is desirable to have the highest possible quality. Lines of constant exit quality are shown on Figures 11, 12, and 13. It is interesting to note that at low mass velocity the quality lines are nearly parallel to the burnout lines, while at higher mass velocities the differences in direction between the quality lines and burnout lines are considerable.

4.2. Local Conditions

4.2.1. Local Heat Flux Vs Local Computed Quality

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

In most burnout work the chosen local fluid condition is usually expressed as quality; it is calculated as follows:

$$x = (H_{in} + \frac{q}{W} - H_f) / H_{fg},$$

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 great significance at the burnout location. The significance of the vapor fraction cannot be denied. The difficulty lies in the fact 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 the previous plots (Figures 11, 12, and 13) and note the appearance when the "local" conditions are plotted. Figures 14, 15, and 16 show a comparison of the uniform and cosine data on coordinates of local critical heat flux versus local steam quality.

The most significant conclusions to be drawn from this comparison are as follows:

1. For a given local steam quality, the uniform tube had considerably higher allowable local heat input rates than did the nonuniform tube.

2. In the lower range of mass velocity covered, an increase in the mass velocity causes a decrease in the local critical heat flux for a given local steam quality; with the higher mass velocity, at 2000 psia, an increase in mass velocity causes an increase in the local critical heat flux. This conclusion is true for both the uniform and nonuniform tubes.

3. For a given local steam quality, an increase in pressure causes a reduction in the local critical heat flux for both uniform and nonuniform tubes, and causes a reduction in the difference between the local critical heat fluxes for the two types of tubes.

4.2.2. Local Overheat Observed

After completing tests on flux shape 3, the test section was found to be damaged slightly, having a slight bulge and bend located about 25 inches from the inlet of the heated length. This area of the tube showed discoloration indicative of excessive metal temperature, and it is believed that the overheating occurred during run 270, which was the first run with an indication of burnout at that location. After this run, only two additional required runs (273 and 275) and five check runs (276-280) were made. Based on the results of the check runs, the damage to the tube apparently did not affect either the operating conditions or the location at which burnout occurred for any of the data obtained on the test section.

4.2.3. Evaluation of Data Points From Local Measurements

The significance of reported burnout data is closely associated with conditions corresponding to the reported heat flux during or just before the crisis. In essence, these conditions define or describe the reported critical heat flux, deal with the experimental approach to the data point, and justify the decision that critical heat flux has been achieved. As noted in the procedure section, certain measurements were described which help indicate what is meant by critical heat flux

(burnout or DNB). Examples of these measurements are shown in Figures 17 through 20.

The record of loop flow from the turbine meter is shown in Figure 17. With this and the three following figures at hand, it would be well to review the events leading up to a data point. A test run starts when the flow, pressure, and inlet temperature have reached steady state at the conditions desired. Test section power is then increased until some indication of near-critical condition is noted. The power is then set about 1% lower. When all conditions have stabilized at this power, data are taken. This corresponds to the chart location called Data Point in Figure 17. After the loop and test section conditions have been recorded, the power is increased until positive indications of critical heat flux are obtained. In some cases the test section wall temperature recordings show the onset of critical heat flux, while in others the burnout detector gives the indication. This point on Figure 17 is identified as DNB. When the burnout point has been reached, the power data are recorded, and the loop fluid conditions are checked. Fluid conditions generally show negligible change from the conditions at Data Point. For data reduction the critical heat flux is determined from the power at DNB, while the loop fluid conditions are those at Data Point. If the power at point DNB is 6% greater than the power at Data Point, a complete set of data is taken again at a higher power level. The test section is brought out of burnout conditions by manually reducing the power level, unless a power trip occurs. On run 253, shown in Figures 17 through 20, a power trip occurred. The heat flux numbers shown on these figures are average heat fluxes for the entire heated length of the test section, which in this case is test section 3 with the upstream peak.

Figure 18 shows a trace of the pressure at the test section inlet. After the start of the power increase, the pressure fluctuated over a 5 psi range only. This, together with the slight fluctuations in flow rate at the corresponding location on Figure 17, may cause concern regarding the stability of the system. Run 253 was considered stable, even though fluctuations seem to increase slightly after Power Increase; this is based on stability as a relative concept. When the pulsating regime (as studied in Russia and cited by CISE³) is considered, with its drastically reduced flow rate and pressure pulsations up to ± 400 psi, run 253 certainly appears

stable. On the present records, the pressure changed only 4 or 5 psi on Figure 18, and the small blips on the flow curve in Figure 17 represent flows above the normal value, rather than below.

Figure 19 shows the temperature trace from run 253. This particular thermocouple setup had such slow response that only the blip at critical heat flux shows.

Figure 20 is a trace from the bridge detector. The significance of this trace cannot be very detailed, since the device spans half of the test section. We can, however, see that the condition at DNB stands out from the previous conditions.

4.3. Data Tabulation

All the reduced data taken on the four tubular test sections are tabulated in Appendix A. These tables include several computed quantities of interest, as well as the essential experimental values.

4.4. Burnout Locations Reported by Various Observers

4.4.1. Observations From This Program

The burnout locations found in these experiments were many and varied, as shown in the data tables of Appendix A. For the most part, the burnout detector was relied upon to give the burnout location. Visual observations of the critical heat flux detector deflections revealed that (1) the crisis could occur upstream of the exit for nonuniformly heated tubes; (2) the detector at the exit segment did not always show a positive deflection when an upstream crisis occurred; and (3) when detectors at more than one segment showed a positive deflection, all of the deflections, not of equal magnitude, usually occurred within several seconds. Attempts to back up these observations with thermocouple recordings were not completely successful. The thermocouples were installed as shown in Figure 6, and it can be seen that the necessary electrical insulation also provided undesirable thermal insulation. Hence, the deflections provided by these thermocouples were slow and of low magnitude. However, one area of agreement with the burnout detector data is shown. For example, run 253 has a burnout detector indication at the exit, which is confirmed by a small blip on the thermocouple trace in Figure 19. In this sense the thermocouple data provide

support for the burnout detector. The cases that are not necessarily supported by thermocouple traces are those where burnout detector indications were given at various locations, but none at the exit—for example, run 254. In such cases, the thermocouple at the exit gave no indications of temperature perturbations. Because of the insulation and because of the thicker metal walls at the exit position, we cannot prove that no temperature perturbation occurred. However, it is presumed that there was absence of critical heat flux where no burnout was indicated. The burnout detector observations in this program appear to agree with those of other investigators, which are discussed in the following sections.

4.4.2. Observations From Reference 4

Many of the data reported in reference 4 were obtained with steam-water mixtures at the test section entrance. Under these conditions it is apparently possible to obtain very meaningful temperature records, because the boiling crisis does not produce excessively high wall temperatures. However, these same investigators also observed that at low and negative inlet qualities the slope of the temperature curve becomes so steep that a very slight increase of power may cause physical burnout. In this case the burnout detector indicates, practically without error, that the crisis has been reached. The latter observation agrees with those of the present program, since all of our inlet conditions were of negative quality, or subcooled. Because of this, the burnout detector results are believed to be quite reliable.

Reference 4 also reports that for the nonuniform axial flux shapes tested, the onset of crisis always occurred at the outlet of the heated section. The observations of the current program are contrary to this, especially in the case of the peak near the inlet. In view of this, it would be wise to examine the dissimilarities in the flux shapes tested. Reference 4 describes a chopped cosine flux shape, a linear increase flux shape, and a linear decrease flux shape; however, the maximum-to-average ratio for the chopped cosine is only 1.20, and for the linear increase and decrease it is 1.31. In the current program the chopped cosine has a ratio of 1.4, and the inlet and outlet peaks have a ratio of 1.94. This suggests that the higher maximum-to-average ratios

may cause the onset of crises to occur at a point away from the end of the heated channel.

4.4.3. Observations From Reference 5

The notion cited in 4.4.2 is supported by reference 5, in which the onset of the crisis usually occurred at some upstream location, and where temperatures permitted, it spread over a broader zone with time at constant power. The ratios for these test sections ranged from 1.27 to 1.43. The test section with the lower ratio seemed to have more crises begin near the end than the others had.

All the evidence cited here is indicative and is not positive proof. A program of testing all these ratios in all three rigs would perhaps give positive support to the observed possibility of burnout location being a function of the maximum-to-average ratio.

Figure 11. Channel Average Heat Flux Vs Inlet Subcooling With Flux Shape and Mass Velocity as Parameters; Pressure Constant at 1000 psia

Figure 12. Channel Average Heat Flux Vs Inlet Subcooling
With Flux Shape and Mass Velocity as Param-
eters; Pressure Constant at 1500 psia

Figure 13. Channel Average Heat Flux Vs Inlet Subcooling With Flux Shape and Mass Velocity as Parameters; Pressure Constant at 2000 psia

Figure 14. Local Critical Heat Flux Results

Figure 15. Local Critical Heat Flux Results

Figure 16. Local Critical Heat Flux Results

Figure 17. Primary Loop Flow Rate Time History -
Run No. 253

Figure 18. Test Section Inlet Pressure Time History -
Run No. 253

Figure 19. Test Section Metal Temperature Time History
1/2 Inch Before Exit - Run No. 253

Figure 20. Burnout Detector Bridge Voltage-Time History -
Run No. 253

5. DATA ANALYSIS

5.1. Empirical Correlation of the Variables

The data were studied to observe the effects of the various parameters on the critical heat flux and on the associated channel power. The pressures and mass velocities were considered constant at their nominal values. The inlet condition, on the other hand, varied sufficiently from run to run, so that it was decided to plot all the runs and interpolate to obtain parametric inlet conditions. The data appear consistent enough to justify this procedure, as can be seen in Figures 11, 12, and 13. 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, 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
3 Peak near inlet	1.5	1500	110
2 Peak near midpoint	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

$$\phi_0 = \frac{1}{L} \int_0^L \phi dZ$$

where

ϕ_0 = integrated average heat flux

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

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

Z = the variable distance along the channel

The relationship between the local heat flux and integrated average is shown in Figure 21 for flux shape 3. An example of the working analysis plots is shown in Figure 22. A decision had to be made regarding the burnout length to be considered, because most of the nonuniform runs exhibited multiple burnout locations. In this initial 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 assumption is based on the reasoning that for a given run this was the burnout occurring at the highest heat flux, and hence was the most significant, since high heat fluxes are more likely to be destructive under critical conditions. The heat flux information from the foregoing plots was condensed in tabular form (Table 4) in order to make further observations.

One may examine Table 4 for general hypotheses 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 on 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.

The question of correlating the local burnout heat flux naturally arises. A brief examination of the local values in Table 4 shows no consistent pattern of behavior such as that observed with the integrated average. Though it may be possible to correlate the local heat fluxes

at a later date, it appears more useful at present to pursue the correlation of integrated average heat fluxes.

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 burnout location. As previously mentioned, in the case of multiple burnout indications, the farthest upstream location is the one considered. Analysis of these data produced the following equation:

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

where

P = pressure, psia

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

ΔH_{si} = inlet subcooling, Btu/lb

G = mass velocity, lb/hr-ft²

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

It has been demonstrated that equation 1-a exhibited a correlation between the variables of the experimental work; however, if we desire to use this equation for predicting critical heat flux, we have difficulty

with the left-hand member. The significance of the left-hand member of the equation is more fully explained as follows:

$$\int_0^L \phi dZ = \int_0^L \phi_a \phi_N dZ = \phi_a \int_0^L \phi_N dZ$$

where

ϕ_a = average heat flux for the heated channel length

ϕ_N = normalized function describing the flux shape.

At a given location, Z , $\phi_N = \phi_{\text{local}} / \phi_a$.

Substitution in equation 1-a gives

$$\begin{aligned} \frac{\phi_a}{10^6} \int_0^L \phi_N dZ = 49.52 - 0.0218 P + \left(3.56 + 0.00352 P - 4.27 \frac{\phi_m}{\phi_a} \right. \\ \left. + 0.0504 \Delta H_{\text{si}} \right) \left(\frac{G}{10^6} + 0.372 \right) \quad (1-b) \end{aligned}$$

Two unknowns exist: ϕ_a and L ; one solution is to go back to the data and see if 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

$$\begin{aligned} \frac{\phi_a}{10^6} = 0.701 - 0.000305 P + \left(-0.0287 + 0.0000503 P \right. \\ \left. + 0.000981 \Delta H_{\text{si}} \right) \left(\frac{G}{10^6} + 0.256 \right) \quad (2) \end{aligned}$$

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

$$\begin{aligned} \frac{\phi_a}{10^6} = 0.660 - 0.000266 P + \left(-0.0933 + 0.0000663 P \right. \\ \left. + 0.000888 \Delta H_{\text{si}} \right) \left(\frac{G}{10^6} - 0.0576 \right) \quad (3) \end{aligned}$$

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ERRATA: BAW-3238-9,

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

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

to give a mean of 0.9996 and standard deviation of 0.0524. Thus, using equation 2 or 3 it is possible to calculate the average heat flux for a burnout condition, and, using equation 1-b, it is possible to study the behavior of burnout location with respect to the other variables.

A casual look at the burnout location data shows some scatter. However, it is possible that this scatter represents deviations from an empirical curve which shows trends in the data. Following this reasoning, it is believed that the preceding equations express trends in the data which 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 in Table 6. Several observations can be made from Table 6.

First, it appears that the integrated heat flux and the average heat flux can be computed more accurately than the length to burnout. This serves to support the observation that the burnout location is somewhat sensitive with respect to other variables.

About the only general statement to be made about the effect of flux shape on burnout location is that burnout occurs somewhere between the point of maximum heat flux and the outlet end of the heated channel. The other variables have considerable effect on the burnout location within this region, as will be shown.

The correlations show that increased pressure in the nonuniform cases causes the burnout location to move upstream. With some exceptions, this trend is supported by the experimental lengths to burnout.

The mass velocity has a mixed effect, depending on the ranges of the other parameters. At 40 Btu/lb inlet subcooling for the cosine shape, the calculated burnout location moves upstream as the mass velocity increases. At the same inlet subcooling and for the upstream peak flux shape, the burnout location also moves upstream with increased mass velocity. The downstream peak flux shape at 40 Btu/lb inlet subcooling shows both effects. At a pressure of 1000 psia, the burnout location moves downstream with increased mass velocity, while at 1500 and 2000 psia it moves upstream with increased mass velocity. Except for the uniform heat flux at 40 Btu/lb inlet subcooling, all the other cases in Table 6 show the burnout location moving upstream with increased mass velocity. The foregoing discussion presents a prime example of the

interactions of variables in the field of burnout studies. Conclusions drawn from a limited study cannot be generalized to the extent desired.

5.2. Comparison of Experimental Data With Various Predictions

Using the computer program written for this purpose, the data from the four tubular sections have been compared with the burnout correlations from references 6, 7, 8, 9, and 3 (Appendix B). The data have been grouped according to nominal pressure and axial heat flux shape within each pressure. For each group and correlation, the mean ratio of experimental-to-calculated heat flux and the standard deviation have been computed by

$$\bar{R} = \frac{\sum R}{N}$$

where

$$R = \frac{\text{experimental burnout heat flux}}{\text{predicted burnout heat flux}}$$

N = number of ratios

$\bar{R}$ = mean ratio

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

The results are shown in Figure 23. The agreement of a group of data with a specific correlation can be estimated by noting the proximity of the plotted point to the coordinates (1.0, 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 Figure 23, because the numbers were too divergent to appear on the same graph. The results for the equation from reference 8 and three flux shapes at 2000 psia are shown in Table 7. These wide deviations are the result of disagreement between the equation and certain individual points (for example, run 208) which exceed the ranges used to develop the equation. 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 burnout criteria that have been used, in order to see if the ranges of the correlations can be extended. Figure 23 shows which correlations agree with the tubular data of this experimental program:

One other burnout criterion, appearing as a set of design curves, has received considerable attention in the last few years.¹⁰ A set of data at one pressure and one mass velocity is compared with the corresponding burnout limit curve in Figure 24. It can be seen that this curve is very conservative for the uniform flux situation, but the conditions are not so favorable for other flux shapes.

5.3. Error Analysis

The objective of this error analysis is to estimate the effect of the uncertainties in the various experimental variables. In experiments like those reported here, the resultant error in the dependent variable is complicated by the number of independent variables and their uncertainties. One method of estimating the effect of deviations of variables is to study the propagation of precision indexes.¹¹ In order to use this method, a mathematical expression correlating the physical variables must be available; for this purpose the empirical correlation for average heat flux, equation 2, is used. Since mass velocity and heat flux are not measured, but are derived from the flow rate and power measurements, substitutions are made in equation 2 as follows:

$$G = \frac{4W}{\pi D^2} \quad \phi_a = \frac{Q}{\pi TD}$$

where

W = flow rate, lb/hr

Q = channel power, Btu/hr

D = channel ID, feet

T = total heated channel length, feet

This gives

$$Q = \pi TD \left(693,700 - 292 P + 228 \Delta H_{si} \right) + 4 \frac{TW}{D} \left(-0.0287 + 0.0000503 P + 0.000891 \Delta H_{si} \right) \quad (4)$$

The expression that gives the probable effect of errors in test section measurements and loop conditions is

$$S_Q^2 = \left(\frac{\partial Q}{\partial T}\right)^2 S_T^2 + \left(\frac{\partial Q}{\partial D}\right)^2 S_D^2 + \left(\frac{\partial Q}{\partial P}\right)^2 S_P^2 + \left(\frac{\partial Q}{\partial \Delta H}\right)^2 S_{\Delta H}^2 + \left(\frac{\partial Q}{\partial W}\right)^2 S_W^2 \quad (5)$$

The case of large flow, large inlet subcooling and greatest pressure was chosen; this gives the following parameters:

$$T = 6 \text{ feet} \quad P = 2000 \text{ psia}$$

$$D = 0.0373 \text{ feet} \quad \Delta H_{si} = 170 \text{ Btu/lb}$$

$$W = 2730 \text{ lb/hr}$$

The errors are estimated as follows:

$$S_T = \pm 0.01 \text{ feet} \quad S_P = \pm 10 \text{ psi}$$

$$S_D = \pm 0.0002 \text{ feet} \quad S_{\Delta H} = \pm 2 \text{ Btu/lb}$$

$$S_W = \pm 30 \text{ lb/hr } (\approx 1\%)$$

The values of the terms in equation 5 turn out to be as follows:

$$\left(\frac{\partial Q}{\partial T}\right)^2 S_T^2 = 0.69 \times 10^6$$

$$\left(\frac{\partial Q}{\partial D}\right)^2 S_D^2 = 2.37 \times 10^6$$

$$\left(\frac{\partial Q}{\partial P}\right)^2 S_P^2 = 1.37 \times 10^6$$

$$\left(\frac{\partial Q}{\partial \Delta H}\right)^2 S_{\Delta H}^2 = 11.90 \times 10^6$$

$$\left(\frac{\partial Q}{\partial W}\right)^2 S_W^2 = 18.60 \times 10^6$$

$$S_Q^2 = 34.93 \times 10^6$$

$$S_Q = 5910 \text{ Btu/hr}$$

From equation 4, $Q = 0.497 \times 10^6 \text{ Btu/hr}$. The percentage error that is expected in burnout power caused by errors in measuring test section geometry and fluid conditions is

$$\frac{S_Q}{Q} (100) = \frac{5910}{497,000} (100) = 1.19\%$$

It appears that improved accuracy of measurement would do little to improve the experiment. As a matter of further interest, the experimental power corresponding to this case study gives $Q_{\text{exp}} = 0.541 \times 10^6 \text{ Btu/hr}$. The experimental error in measuring the power itself is estimated at $\pm 3\%$. The conclusion is that correlation weaknesses are more likely to be due to lack of understanding of the basic physics of burnout than to errors in experimental measurements. The fundamental processes involved in critical heat flux are being examined as part of this program. Any useful results from this examination will be included in the final report.

5.4. List of Symbols

D	Diameter, ft
G	Mass velocity, lb/hr-ft ²
H _f	Enthalpy of saturated water, Btu/lb
H _{fg}	Latent heat of vaporization, Btu/lb
H _{in}	Enthalpy at inlet to heated length of test section, Btu/lb
L	Distance from inlet of heated channel to the point of interest, in.
N	Number of data points or ratios R
P	Pressure, psia
Q	Channel power, Btu/hr
R	Ratio of experimental to calculated burnout heat flux
$\bar{R}$	Mean of N values of R
S	Standard deviation
T	Total heated channel length, ft
W	Flow rate, lb/hr
Z	Variable distance along the channel, in.
q	Heat added to fluid between inlet and point under consideration, Btu/hr
x	Quality based on mass flow and heat input
ΔH_{si}	Inlet subcooling, Btu/lb
ΔT_{si}	Inlet subcooling, F
ϕ	Heat flux, Btu/hr-ft ²
ϕ_0	Integrated average heat flux, Btu/hr-ft ²
ϕ_a	Average heat flux for the heated channel length, Btu/hr-ft ²
ϕ_m	Maximum heat flux, Btu/hr-ft ²
ϕ_N	Normalized heat flux, ϕ / ϕ_a

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
110	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
	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

ΔH_{si} , Btu/lb	Flux shape No. (a)	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	1	1000	0.5	31.9	0.440	73	30	0.43	69
			1.5	36.7	.497	74	42	.61	69
			2.5	41.6	.554	75	45	.65	69
		1500	0.5	22.5	.306	74	19	.28	69
			1.5	29.1	.389	75	27	.39	69
			2.5	35.7	.471	76	29	.42	69
		2000	0.5	13.2	.173	76	13	.19	69
			1.5	21.5	.280	77	19	.27	69
			2.5	29.9	.388	77	28	.40	69
	3	1000	0.5	28.4	.440	54	30	.43	69
			1.5	29.2	.497	43	28	.50	42
			2.5	30.0	.554	37	28	.50	42
		1500	0.5	19.0	.306	48	19	.28	69
			1.5	21.6	.389	39	23	.34	61
			2.5	24.2	.471	35	23	.38	51
		2000	0.5	9.7	.173	39	11	.19	57
			1.5	14.0	.280	33	16	.27	50
			2.5	18.3	.388	31	18	.39	33
40	2	1000	0.5	30.4	.440	66	29	.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
	4	1000	0.5	28.4	.398	71	26	.39	67
			1.5	29.2	.406	72	31	.47	65
			2.5	30.0	.415	72	31	.46	67
		1500	0.5	19.0	.279	67	19	.27	70
			1.5	21.6	.321	66	22	.31	69
			2.5	24.2	.362	66	22	.33	68
		2000	0.5	9.7	.160	61	11	.16	63
			1.5	14.0	.235	61	14	.23	63
			2.5	18.3	0.310	60	20	0.31	63

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

Table 6. (Cont'd)

ΔH_{si} , Btu/lb	Flux shape No. (a)	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
110	1	1000	0.5	35.0	0.487	72	32	0.47	69
			1.5	43.3	.606	72	48	.69	69
			2.5	51.7	.726	71	52	.75	69
		1500	0.5	25.6	.353	73	23	.33	69
			1.5	35.7	.498	72	32	.47	69
			2.5	45.8	.643	71	39	.56	69
		2000	0.5	16.2	.220	74	16	.23	69
			1.5	28.1	.390	72	27	.39	69
			2.5	40.0	.560	72	40	.58	69
	3	1000	0.5	31.5	.487	54	32	.48	69
			1.5	35.8	.606	44	49	.58	65
			2.5	40.2	.726	39	36	.66	40
		1500	0.5	22.1	.353	50	22	.32	69
			1.5	28.2	.498	40	30	.47	57
			2.5	34.3	.643	36	35	.61	43
		2000	0.5	12.7	.220	42	12	.24	33
			1.5	20.6	.390	36	22	.41	38
			2.5	28.5	.560	34	27	.50	30
110	2	1000	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
	4	1000	0.5	31.5	.425	74	29	.43	67
			1.5	35.8	.496	72	35	.51	70
			2.5	40.2	.566	70	38	.55	67
		1500	0.5	22.1	.306	72	21	.29	70
			1.5	28.2	.410	67	27	.39	70
			2.5	34.3	.514	66	34	.49	68
		2000	0.5	12.7	.188	66	12	.19	63
			1.5	20.6	.325	63	21	.34	63
			2.5	28.5	0.462	62	30	0.47	63

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

Table 6. (Cont'd)

ΔH_{si} , Btu/lb	Flux shape No. (a)	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
170	1	1000	0.5	37.6	0.527	71	35	0.51	69
			1.5	49.0	.700	70	52	.76	69
			2.5	60.4	.873	69	58	.84	69
		1500	0.5	28.2	.394	72	25	.36	69
			1.5	41.4	.592	70	39	.57	69
			2.5	54.5	.790	69	51	.74	69
		2000	0.5	18.9	.260	73	17	.25	69
			1.5	33.8	.484	70	34	.49	69
			2.5	48.7	.707	69	51	.74	69
170	3	1000	0.5	34.1	.527	54	36	.52	69
			1.5	41.5	.700	44	37	.69	38
			2.5	48.9	.873	39	46	.85	39
		1500	0.5	24.7	.394	51	26	.37	69
			1.5	33.9	.592	41	32	.60	40
			2.5	43.0	.790	38	40	.81	34
		2000	0.5	15.4	.260	44	20	.29	63
			1.5	26.3	.484	38	26	.53	33
			2.5	37.1	.707	36	31	.77	27
170	2	1000	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	.707	57	50	.75	63
170	4	1000	0.5	34.1	.449	76	31	.46	67
			1.5	41.5	.573	73	38	.57	67
			2.5	48.9	.697	69	48	.69	67
		1500	0.5	24.7	.330	75	22	.33	68
			1.5	33.9	.487	68	33	.48	68
			2.5	43.0	.644	66	41	.64	64
		2000	0.5	15.4	.211	73	14	.22	63
			1.5	26.3	.402	65	26	.41	63
			2.5	37.1	0.592	63	39	0.61	63

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

Table 7. Burnout Equation Compared With Data

<u>Equation</u>	<u>Pressure, psia</u>	<u>Test section</u>	<u>Mean ratio</u>	<u>Standard deviation</u>
Ref 8	2000	Uniform	0.0821	2.269
		Inlet peak	0.3749	3.881
		Cosine	-1.7722	10.265

Figure 21. Heat Flux Distribution - 3

Figure 22. Critical Heat Fluxes and Location

Figure 23. Burnout Equations Compared With Data

Equation	Reference 6			Reference 7			Reference 8		
Pressure, psia	1000	1500	2000	1000	1500	2000	1000	1500	2000
Uniform	○	○	○	●	●	●	○	○	
Chopped Cosine	△	△	△	▲	▲	▲	△	△	
Peak Near Inlet	□	□	□	■	■	■	□	□	
Peak Near Exit	◇	◇	◇	◆	◆	◆	◇	◇	◇

Equation	Reference 9			Reference 3		
Pressure, psia	1000	1500	2000	1000	1500	2000
Uniform	○	○	○	○	○	○
Chopped Cosine	△	△	△	△	△	△
Peak Near Inlet	□	□	□	□	□	□
Peak Near Exit	◇	◇	◇	◇	◇	◇

Figure 24. Burnout Limit Curve From Reference 10 Compared With Data

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6. CONCLUSIONS

Within the limits of the variables in these experiments, the following conclusions can be drawn:

1. Changing from uniform to cosine and upstream peak flux shapes causes little or no penalty in channel power. Two possible exceptions to this appear at 1000 psia and mass velocities of 1.5 and 2.5×10^6 lb/hr-ft².

2. The outlet peak reduces channel power in all cases.

3. Equation 1-a shows that the integrated heat flux provides a reasonable basis for correlating the data with respect to flux shape, pressure, mass velocity, and inlet condition.

4. The average heat flux and system conditions for the nonuniformly heated channels can be correlated by equations 2 and 3.

5. The integrated heat flux and the average heat flux correlations as expressed by equations 1, 2, and 3 provide an opportunity for computing the burnout location.

6. In some cases, the computed burnout locations agree with the experimental locations; in general, the agreement is with respect to trends rather than actual values of length to burnout.

7. Correlation weaknesses are more likely to be due to lack of understanding of the basic physics of burnout than to errors in experimental measurements.

APPENDIX A
Tables A-1, A-2, A-3, and A-4
Tubular Test Section — Tabulation
of Results

List of Symbols for Appendix A

DNB	Departure from nucleate boiling (critical heat flux)—0 indicates the station number at which DNB occurred
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
$\phi_{1,0}$	Local average 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_0	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

Table A-1. Data From Flux Shape 1 (Uniform)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
1		5- 4-64	13:55	995	9.87	2.546	78.9	INLET	24.4	511.3	-4.66	14.7				
								12	.0	605.0	9.75	44.7	.378	.385		
								EXIT	.0	609.0	10.37	46.5		.385		
2		5- 4-64	14:29	1015	12.05	2.532	100.6	INLET	21.8	517.5	-4.20	14.7				
								12	.0	637.7	14.38	57.4	.488	.491		
								EXIT	.0	642.8	15.18	59.7		.491		
3		5- 4-64	15:01	1015	14.49	2.548	128.9	INLET	21.2	518.2	-4.10	14.8				
								1	15.8	524.8	-3.08	15.0	.621	.621		
								2	5.2	538.0	-1.03	15.2	.629	.625		
								3	.0	550.9	.97	18.2	.632	.619		
								4	.0	564.6	3.08	24.4	.631	.627		
								5	.0	577.6	5.10	30.4	.631	.624		
								6	.0	591.3	7.21	36.6	.628	.628		
								7	.0	604.6	9.27	42.7	.629	.629		
								8	.0	618.0	11.34	48.8	.631	.629		
								9	.0	631.3	13.40	54.8	.631	.629		
								10	.0	644.9	15.51	61.1	.634	.631		
								11	.0	658.3	17.57	67.2	.632	.631		
								12	.0	671.1	19.56	73.0	.623	.629		
								EXIT	.0	677.7	20.58	76.0		.628		
4	0	5- 4-64	15:26	1015	15.30	2.528	130.9	INLET	26.1	512.2	-5.02	14.7				
								12	.0	668.7	19.19	71.4	.638	.638		
								EXIT	.0	675.5	20.24	74.4		.638		
5	0	5- 4-64	15:36	1015	15.30	2.528	130.9	INLET	29.4	508.1	-5.66	14.6				
								12	.0	664.6	18.55	69.5	.638	.638		
								EXIT	.0	671.4	19.60	72.6		.638		
6		5- 5-64	10:20	1000	4.28	1.526	60.6	INLET	21.6	515.5	-4.14	8.9				
								12	.0	635.5	14.34	34.9	.294	.296		
								EXIT	.0	640.7	15.14	36.4		.296		
7		5- 5-64	11:01	1020	5.71	1.507	82.7	INLET	22.7	517.1	-4.39	8.8				
								12	.0	682.9	21.28	46.0	.402	.403		
								EXIT	.0	690.0	22.40	47.9		.403		
8		5- 5-64	11:32	1000	7.11	1.511	96.2	INLET	21.2	516.0	-4.06	8.8				
								12	.0	708.5	25.57	54.6	.464	.469		
								EXIT	.0	716.7	26.85	56.9		.469		
9		5- 5-64	11:47	1015	7.86	1.504	105.4	INLET	24.4	514.3	-4.70	8.7				
								12	.0	726.2	28.08	57.9	.507	.514		
								EXIT	.0	735.3	29.48	60.4		.514		
10		5- 5-64	12:04	1005	8.36	1.471	114.5	INLET	22.9	514.7	-4.39	8.5				
								12	.0	750.2	31.93	63.8	.552	.559		
								EXIT	.0	760.3	33.48	66.5		.559		
11		5- 5-64	12:11	1000	8.74	1.512	117.9	INLET	20.7	516.5	-3.98	8.8				
								12	.0	752.4	32.35	66.7	.565	.575		
								EXIT	.0	762.5	33.90	69.4		.575		

Table A-1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{10}}{10^6}$	$\frac{\phi_0}{10^6}$	$\frac{\phi_{11}}{10^6}$	$\frac{\phi_i}{10^6}$
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		
13		5- 5-64	15:17	1000	1.02	.504	72.3	INLET	28.5	507.1	-5.44	2.9				
								12	.0	940.5	61.30	39.4	.351	.352		
								EXIT	.0	959.2	64.18	41.1		.352		
14		5- 5-64	15:47	1000	1.20	.502	77.3	INLET	24.5	511.9	-4.69	2.9				
								12	.0	977.4	66.99	42.6	.377	.377		
								EXIT	.0	997.7	70.11	44.4		.377		
15		5- 5-64	15:58	995	1.25	.503	79.9	INLET	24.1	511.7	-4.59	2.9				
								12	.0	992.0	69.25	44.3	.382	.390		
								EXIT	.0	1012.5	72.40	46.2		.389		
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		
17		5- 6-64	13:00	1000	5.53	1,533	98.0	INLET	54.7	475.8	-10.25	8.6				
								12	.0	669.1	19.51	44.4	.474	.478		
								EXIT	.0	677.4	20.79	46.7		.478		
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		
19		5- 6-64	14:45	1025	9.56	2,494	121.8	INLET	58.1	475.4	-10.99	13.9				
								12	.0	623.1	11.92	49.1	.589	.594		
								EXIT	.0	629.4	12.91	51.9		.594		
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		
21		5- 7-64	10:23	1000	.29	.500	60.1	INLET	60.4	469.3	-11.26	2.8				
								12	.0	832.1	44.62	29.3	.294	.293		
								EXIT	.0	848.0	47.05	30.7		.293		
22		5- 7-64	10:52	1000	1.22	.512	85.4	INLET	60.9	468.8	-11.34	2.8				
								12	.0	972.5	66.23	43.0	.414	.416		
								EXIT	.0	994.3	69.58	45.0		.416		
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		
24		5- 7-64	13:22	1000	.66	.534	80.7	INLET	104.3	419.7	-18.89	2.8				
								12	.0	876.6	51.46	35.6	.389	.394		
								EXIT	.0	896.2	54.49	37.9		.393		
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		
26		5- 7-64	15:15	1000	5.30	1,509	121.8	INLET	99.5	425.0	-18.07	8.1				
								12	.0	669.2	19.53	43.8	.585	.595		
								EXIT	.0	679.7	21.14	46.6		.594		

Table A-1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
27		5-7-64	15:30	1000	6.79	1.510	142.9	INLET	97.9	426.8	-17.80	8.1				
								12	.0	712.9	26.26	55.8	.692	.697		
								EXIT	.0	725.3	28.16	59.1		.697		
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		
29		5-8-64	11:15	1000	8.15	2.419	147.5	INLET	99.5	425.1	-18.07	13.0				
								12	.0	609.4	10.31	43.9	.715	.719		
								EXIT	.0	617.3	11.54	47.4		.719		
30		5-8-64	15:15	1000	8.38	2.497	147.5	INLET	100.6	423.8	-18.27	13.4				
								12	.0	602.4	9.24	42.1	.713	.719		
								EXIT	.0	610.1	10.42	45.6		.719		
31		5-8-64	15:28	1000	8.79	2.499	153.2	INLET	98.9	425.7	-17.98	13.4				
								12	.0	611.1	10.58	46.1	.736	.748		
								EXIT	.0	619.1	11.80	49.7		.747		
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		
33		5-11-64	10:43	1000	3.31	1.438	121.6	INLET	148.9	371.2	-26.37	7.4				
								12	.0	626.8	13.00	30.6	.590	.593		
								EXIT	.0	637.9	14.70	33.5		.593		
34		5-11-64	11:12	1000	5.30	1.432	150.5	INLET	147.3	372.9	-26.10	7.4				
								12	.0	690.8	22.85	47.1	.726	.734		
								EXIT	.0	704.5	24.96	50.7		.734		
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		
36		5-11-64	14:15	980	4.94	2.455	147.5	INLET	143.5	374.3	-25.25	12.6				
								12	.0	555.9	2.54	22.2	.719	.719		
								EXIT	.0	563.8	3.75	25.8		.719		
37		5-11-64	15:01	995	5.73	2.392	156.3	INLET	143.0	376.8	-25.34	12.3				
								12	.0	574.3	5.03	28.6	.763	.762		
								EXIT	.0	582.9	6.35	32.3		.762		
38		5-11-64	15:23	1000	6.07	2.462	159.7	INLET	143.7	376.8	-25.51	12.7				
								12	.0	572.7	4.67	28.3	.779	.779		
								EXIT	.0	581.2	5.98	32.1		.779		
39		5-11-64	15:34	1000	6.21	2.466	161.9	INLET	143.3	377.2	-25.44	12.7				
								12	.0	575.6	5.12	29.7	.789	.790		
								EXIT	.0	584.2	6.44	33.5		.790		
40		5-11-64	15:47	1000	6.70	2.461	166.8	INLET	145.2	375.2	-25.74	12.7				
								12	.0	580.0	5.20	31.6	.814	.813		
								EXIT	.0	588.9	7.17	35.5		.813		
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		

Table A-1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
43		5-18-64	11:02	995	5.30	2.456	157.4	INLET	152.5	366.7	-26.90	12.4				
								12	.0	560.5	2.91	23.2	.755	.768		
								EXIT	.0	568.8	4.18	26.9		.768		
44		5-18-64	13:33	995	6.32	2.466	166.2	INLET	151.7	367.6	-26.76	12.6				
								12	.0	571.4	4.59	28.2	.793	.811		
								EXIT	.0	580.1	5.92	32.1		.810		
45		5-18-64	13:56	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	-8.58	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		
								12	.0	579.1	5.66	31.3	.824	.843		
								EXIT	.0	588.1	7.04	35.3		.842		
46		5-19-64	11:09	1000	1.20	.506	101.3	INLET	157.8	361.7	-27.82	2.6				
								12	.0	967.4	69.45	42.0	.485	.495		
								EXIT	.0	993.3	69.43	44.4		.494		
47		5-19-64	11:35	1002	1.29	.506	104.7	INLET	157.4	362.4	-27.78	2.6				
								12	.0	988.6	68.70	43.9	.500	.511		
								EXIT	.0	1015.2	72.80	46.3		.511		
48		5-19-64	11:45	1002	1.31	.506	105.9	INLET	158.0	361.7	-27.88	2.6				
								12	.0	994.7	69.64	44.4	.507	.517		
								EXIT	.0	1021.7	73.81	46.9		.516		
49		5-19-64	11:55	1002	1.31	.506	106.3	INLET	157.5	362.3	-27.80	2.6				
								12	.0	997.9	70.14	44.7	.509	.519		
								EXIT	.0	1025.0	74.31	47.2		.519		
50		5-19-64	14:23	1505		.504	73.2	INLET	157.5	418.7	-34.84	2.7				
								12	.0	898.2	44.30	18.9	.351	.357		
								EXIT	.0	877.0	47.68	20.1		.357		
51		5-19-64	14:37	1502		.505	75.6	INLET	156.5	419.6	-34.58	2.7				
								12	.0	872.6	46.91	19.9	.357	.369		
								EXIT	.0	891.6	50.33	21.1		.369		
52		5-19-64	14:49	1502		.505	76.1	INLET	155.6	420.6	-34.41	2.7				
								12	.0	875.8	47.47	20.1	.361	.371		
								EXIT	.0	895.0	50.94	21.4		.371		
53		5-20-64	10:26	1500	1.81	1.513	113.3	INLET	153.7	422.4	-34.00	8.0				
								12	.0	649.1	6.74	17.0	.541	.553		
								EXIT	.0	658.7	8.47	18.9		.553		

Table A-1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{11}}{10^6}$	$\frac{\phi_i}{10^6}$
94		5-20-64	11:00	1503	2.11	1.498	118.4	INLET	149.7	427.1	-33.26	8.0				
								12	.0	665.1	9.74	20.0	.568	.578		
								EXIT	.0	676.3	11.98	21.9		.577		
95		5-20-64	11:44	1502	2.17	1.511	121.3	INLET	153.0	423.4	-33.90	8.0				
								12	.0	666.2	9.77	20.2	.580	.592		
								EXIT	.0	676.5	11.63	22.2		.592		
96	0	5-20-64	11:52	1502	2.22	1.513	123.1	INLET	146.8	430.2	-32.68	8.1				
	0							12	.0	676.2	11.98	22.2	.590	.600		
								EXIT	.0	686.7	13.47	24.2		.600		
97		5-20-64	14:55	1493	3.10	2.510	138.9	INLET	152.2	423.4	-33.59	13.4				
								12	14.1	590.9	-3.55	15.9	.660	.678		
								EXIT	9.0	598.0	-2.28	16.1		.677		
98		5-20-64	15:17	1492	3.24	2.517	146.9	INLET	153.1	422.3	-33.75	13.4				
								12	8.2	599.0	-2.08	16.1	.697	.717		
								EXIT	3.1	606.4	-.75	16.3		.716		
99	0	5-20-64	15:49	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		
								EXIT	.0	627.2	2.91	21.5		.802		
60		5-21-64	12:56	1500	3.65	2.517	114.3	INLET	107.1	474.9	-24.57	14.0				
								12	.0	612.2	.11	16.6	.549	.558		
								EXIT	.0	618.1	1.17	18.5		.557		
61		5-21-64	13:20	1500	4.08	2.528	121.3	INLET	108.3	473.6	-24.81	14.0				
								12	.0	618.7	1.28	18.8	.583	.592		
								EXIT	.0	624.9	2.40	20.8		.592		
62		5-21-64	13:31	1500	4.39	2.517	126.8	INLET	106.6	475.5	-24.47	14.0				
								12	.0	627.8	2.91	21.6	.608	.619		
								EXIT	.0	634.3	4.08	23.7		.618		
63		5-21-64	13:48	1500	4.71	2.508	130.1	INLET	107.6	474.3	-24.69	13.9				
								12	.0	631.0	3.49	22.5	.630	.635		
								EXIT	.0	637.8	4.71	24.7		.634		
64	0	5-21-64	13:56	1500	4.85	2.506	133.6	INLET	111.9	469.4	-25.57	13.9				
	0							12	.0	630.6	3.41	22.4	.645	.652		
								EXIT	.0	637.5	4.66	24.6		.652		
65		5-22-64	10:22	1535		.521	67.6	INLET	115.2	469.1	-26.71	2.9				
								12	.0	861.2	44.60	19.3	.323	.330		
								EXIT	.0	877.9	47.63	20.3		.329		
66	0	5-22-64	10:36	1503		.503	69.8	INLET	111.1	470.6	-25.44	2.8				
	0							12	.0	889.8	50.00	20.9	.338	.340		
								EXIT	.0	907.9	53.25	22.1		.340		
67		5-22-64	12:55	1495	1.81	1.504	81.6	INLET	97.5	465.5	-22.52	8.4				
								12	.0	649.6	6.94	17.2	.395	.398		
								EXIT	.0	656.7	8.21	18.5		.398		
68		5-22-64	13:47	1505	2.33	1.523	97.5	INLET	106.3	476.3	-24.48	8.5				
								12	.0	669.8	10.37	21.0	.472	.476		
								EXIT	.0	678.2	11.88	22.6		.475		

Table A-1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	X	V_m	$\frac{\phi_{i,e}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
69		5-22-64	14108	1502	1.04	1.506	97.3	INLET	108.1	474.0	-24.80	8.4				
								12	.0	669.3	10.33	20.7	.469	.475		
								EXIT	.0	677.6	11.83	22.3		.474		
70		5-22-64	14116	1500	1.04	1.502	98.6	INLET	105.5	476.8	-24.24	8.4				
								12	.0	675.2	11.43	21.9	.479	.481		
								EXIT	.0	683.8	12.97	23.9		.481		
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		
72		5-25-64	10105	1495		.498	59.2	INLET	58.7	532.7	-14.04	2.9				
								12	.0	892.2	50.48	21.0	.285	.289		
								EXIT	.0	907.7	53.25	22.0		.289		
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		
74		5-25-64	12107	1503	2.54	1.494	77.1	INLET	54.5	538.9	-13.14	8.9				
								12	.0	695.0	14.94	25.4	.369	.376		
								EXIT	.0	701.6	16.13	26.6		.376		
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	29.8	.422	.430		
0								EXIT	.0	726.5	20.64	31.3		.429		
76		5-25-64	13126	1501	5.30	2.452	91.6	INLET	56.7	536.0	-13.62	14.6				
								12	.0	649.1	6.71	27.6	.436	.447		
								EXIT	.0	653.9	7.58	29.1		.447		
77		5-25-64	14122	1503	5.46	2.458	96.0	INLET	54.3	539.2	-13.09	14.6				
								12	.0	657.2	8.13	30.1	.471	.468		
								EXIT	.0	662.3	9.06	31.7		.468		
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		
79		5-26-64	10148	1503		.909	53.7	INLET	28.1	573.1	-6.99	3.1				
								12	.0	892.2	50.42	21.3	.258	.262		
								EXIT	.0	905.8	52.88	22.2		.262		
80		5-26-64	10159	1503		.508	56.8	INLET	29.0	572.0	-7.20	3.1				
								12	.0	910.0	53.63	22.4	.269	.277		
								EXIT	.0	924.3	56.20	23.3		.277		
81		5-26-64	11106	1502		.508	58.0	INLET	27.7	573.6	-6.87	3.1				
0								12	.0	919.1	55.27	23.0	.277	.283		
0								EXIT	.0	933.8	57.91	23.9		.283		
82		5-26-64	11156	1502	3.17	1.499	73.4	INLET	24.6	577.7	-6.14	9.3				
								12	.0	725.7	20.49	31.3	.352	.358		
								EXIT	.0	732.1	21.63	32.5		.358		
83		5-26-64	12116	1509	3.31	1.504	81.8	INLET	26.5	576.0	-6.63	9.3				
								12	.0	740.6	23.05	34.0	.391	.399		
								EXIT	.0	747.6	24.32	35.3		.399		

Table A-1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
84		5-26-64	12:25	1509	3.35	1.505	82.4	INLET	26.6	575.8	-6.65	9.4				
	0							12	.0	741.5	23.21	34.2	.395	.402		
	0							EXIT	.0	748.6	24.49	35.5		.402		
85		5-26-64	14:05	1503	6.32	2.467	80.4	INLET	24.1	578.6	-6.01	15.4				
								12	.0	677.2	11.73	36.4	.386	.393		
								EXIT	.0	681.4	12.49	37.7		.392		
86		5-26-64	14:20	1503	6.43	2.468	83.9	INLET	24.2	578.3	-6.05	15.4				
	0							12	.0	681.1	12.44	37.6	.406	.409		
	0							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				
	0							12	.0	663.7	9.08	31.3	.472	.474		
	0							EXIT	.0	669.0	10.02	32.9		.474		
88		5-28-64	11:20	2003		.501	36.2	INLET	27.8	626.8	-9.78	3.3				
								12	.0	844.8	37.32	12.0	.178	.176		
								EXIT	.0	854.3	39.39	12.4		.176		
89		5-28-64	11:37	2003		.507	38.5	INLET	27.1	627.8	-9.55	3.3				
	0							12	.0	857.6	40.08	12.7	.186	.188		
	0							EXIT	.0	867.4	42.22	13.2		.188		
90		5-28-64	13:14	2003		1.492	50.9	INLET	23.7	633.0	-8.43	9.9				
								12	.0	736.1	13.84	19.9	.246	.248		
								EXIT	.0	740.6	14.81	20.6		.248		
91		5-28-64	13:30	2003	1.77	1.504	53.1	INLET	23.5	633.2	-8.39	10.0				
								12	.0	740.1	14.70	20.7	.255	.259		
								EXIT	.0	744.6	15.68	21.3		.259		
92		5-28-64	13:36	2003	1.74	1.510	55.9	INLET	24.4	632.0	-8.65	10.0				
	0							12	.0	744.0	15.55	21.3	.267	.273		
	0							EXIT	.0	748.8	16.58	22.0		.273		
93		5-28-64	14:27	2003	5.16	2.482	58.6	INLET	22.6	634.7	-8.08	16.6				
								12	.0	706.1	7.37	25.9	.280	.286		
								EXIT	.0	709.2	8.02	26.7		.286		
94		5-28-64	14:47	2003	5.18	2.477	62.5	INLET	20.1	638.6	-7.23	16.6				
								12	.0	714.8	9.25	28.0	.302	.305		
								EXIT	.0	718.1	9.96	28.8		.305		
95		5-28-64	15:11	2003	5.30	2.520	67.0	INLET	25.2	630.7	-8.94	16.7				
								12	.0	711.0	8.41	27.5	.327	.327		
								EXIT	.0	714.5	9.17	28.4		.327		
96		5-28-64	15:22	2003	5.52	2.518	73.9	INLET	28.7	625.4	-10.08	16.6				
								12	.0	714.1	9.09	28.3	.360	.361		
								EXIT	.0	718.0	9.93	29.2		.361		
97		5-28-64	15:36	2003	5.86	2.495	79.4	INLET	28.3	626.1	-9.93	16.4				
								12	.0	722.3	10.86	30.0	.381	.387		
								EXIT	.0	726.4	11.75	31.0		.387		
98		5-28-64	15:51	2003	5.86	2.484	66.1	INLET	28.7	625.4	-10.07	16.4				
	0							12	.0	730.2	12.56	31.8	.418	.420		
	0							EXIT	.0	734.7	13.54	32.9		.420		

Table A-1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
99		6- 1-64	12:18	2000		.495	37.5	INLET	54.2	589.0	-17.85	3.1				
								12	.0	818.0	31.57	10.6	.187	.183		
								EXIT	.0	828.2	33.77	11.1		.183		
100		6- 2-64	9:24	2000	1.04	1.392	49.5	INLET	52.5	591.3	-17.35	8.7				
								12	.0	698.7	5.82	13.6	.244	.241		
								EXIT	.0	703.4	6.84	14.2		.241		
101		6- 2-64	9:51	2000	1.31	1.505	56.5	INLET	51.9	592.1	-17.18	9.5				
								12	.0	705.4	7.28	19.7	.279	.275		
								EXIT	.0	710.4	8.36	16.4		.275		
102		6- 2-64	10:08	2010	1.47	1.486	66.1	INLET	53.0	591.6	-17.60	9.3				
	0							12	.0	725.9	11.50	18.3	.328	.322		
	0							EXIT	.0	731.9	12.79	19.1		.322		
103		6- 2-64	12:18	2005	4.17	2.508	87.6	INLET	54.2	589.5	-17.90	15.7				
								12	.0	695.0	4.91	23.4	.428	.427		
								EXIT	.0	699.6	5.91	24.6		.427		
104		6- 2-64	13:13	2005	4.48	2.479	91.8	INLET	53.6	590.3	-17.73	15.5				
								12	.0	702.2	6.48	24.9	.447	.448		
								EXIT	.0	707.1	7.53	26.1		.448		
105		6- 2-64	13:28	2005	4.69	2.495	95.7	INLET	53.2	590.9	-17.60	15.7				
								12	.0	706.8	7.46	26.2	.467	.467		
								EXIT	.0	711.8	8.55	27.4		.467		
106		6- 2-64	14:05	2005	5.03	2.507	103.5	INLET	54.8	588.7	-18.07	15.7				
								12	.0	713.5	8.92	27.9	.503	.505		
								EXIT	.0	718.9	10.09	29.3		.505		
107		6- 2-64	14:20	2005	5.12	2.510	105.8	INLET	55.0	588.4	-18.15	15.7				
	0							12	.0	715.7	9.39	28.5	.516	.516		
	0							EXIT	.0	721.3	10.59	29.9		.516		
108		6- 2-64	15:50	2000		.506	37.4	INLET	57.7	584.2	-18.87	3.1				
								12	.0	807.5	29.31	10.3	.183	.182		
								EXIT	.0	817.3	31.41	10.8		.182		
109		6- 2-64	16:02	2000		.506	42.5	INLET	55.6	587.1	-18.26	3.2				
								12	.0	840.8	36.50	11.9	.207	.207		
								EXIT	.0	851.9	38.88	12.5		.207		
110		6- 2-64	16:09	2000		.503	44.7	INLET	55.4	587.4	-18.19	3.1				
	0							12	.0	856.1	39.79	12.6	.218	.218		
	0							EXIT	.0	867.8	42.32	13.2		.218		
111		6- 3-64	9:44	2005		.499	49.0	INLET	107.1	521.9	-32.51	2.9				
								12	.0	818.7	31.66	10.7	.236	.239		
								EXIT	.0	831.4	34.41	11.3		.239		
112		6- 3-64	10:02	2005		.497	50.7	INLET	106.8	522.3	-32.43	2.9				
	0							12	.0	831.2	34.36	11.2	.243	.248		
	0							EXIT	.0	844.3	37.20	11.8		.247		
113		6- 3-64	11:19	2005	1.25	1.501	82.2	INLET	99.1	531.7	-30.39	8.8				
								12	.0	657.4	5.43	14.4	.399	.401		
								EXIT	.0	704.6	6.98	15.4		.401		

Table A-1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	$-V_m$	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
114		6-3-64	11:45	2000	1.47	1.513	90.3	INLET	102.5	527.1	-31.20	8.8				
								12	.0	707.7	7.77	16.1	.433	.441		
								EXIT	.0	715.4	9.43	17.2		.440		
115		6-3-64	11:52	2000	1.52	1.513	94.0	INLET	105.8	523.1	-32.08	8.8				
	0							12	.0	710.3	8.33	16.5	.485	.457		
	0							EXIT	.0	718.9	10.20	17.7		.458		
116		6-3-64	13:24	2005	3.40	2.510	115.0	INLET	105.4	524.0	-32.06	14.6				
								12	9.7	662.5	-2.12	17.6	.556	.561		
								EXIT	2.2	668.5	-.83	17.8		.561		
117		6-3-64	13:44	2005	3.85	2.486	125.0	INLET	103.8	525.9	-31.65	14.5				
								12	.0	678.0	1.24	19.1	.603	.610		
								EXIT	.0	684.5	2.65	20.7		.610		
118		6-3-64	14:05	2000	4.08	2.491	129.5	INLET	104.8	524.3	-31.80	14.5				
								12	.0	681.6	2.13	20.2	.624	.632		
								EXIT	.0	688.3	3.59	21.8		.632		
119		6-3-64	14:21	2005	4.37	2.499	134.2	INLET	104.8	524.8	-31.90	14.5				
								12	.0	687.0	3.19	21.4	.649	.654		
								EXIT	.0	694.0	4.71	23.1		.654		
120		6-3-64	14:30	2000		2.498	139.4	INLET	104.2	525.1	-31.64	14.5				
	0							12	.0	693.6	4.73	23.1	.691	.679		
	0							EXIT	.0	701.1	6.34	25.0		.680		
121		6-04-64	11:00	2005	1.13	1.504	104.7	INLET	153.8	467.2	-44.35	8.3				
								12	.0	677.6	1.14	11.5	.509	.511		
								EXIT	.0	686.7	3.11	12.8		.510		
122		6-04-64	11:26	2003	1.31	1.507	112.1	INLET	153.8	467.1	-44.29	8.3				
								12	.0	691.9	4.30	13.7	.541	.547		
								EXIT	.0	701.6	6.39	19.1		.547		
123		6-04-64	11:35	2005	1.29	1.505	113.5	INLET	154.3	466.6	-44.48	8.3				
	0							12	.0	694.7	4.84	14.0	.547	.554		
	0							EXIT	.0	704.5	6.96	15.5		.554		
124		6-04-64	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		
125		6-04-64	15:36	2003	3.19	2.521	144.7	INLET	152.2	468.9	-43.90	13.9				
								12	17.6	642.5	-6.39	17.1	.701	.706		
								EXIT	13.0	650.0	-4.77	17.3		.706		
126		6-04-64	16:02	2005	3.31	2.520	149.9	INLET	153.3	467.7	-44.23	13.9				
								12	14.5	647.6	-5.35	17.2	.719	.731		
								EXIT	9.9	655.2	-3.68	17.5		.731		
127		6-04-64	16:14	2005	3.60	2.515	156.8	INLET	153.3	467.7	-44.23	13.8				
								12	9.4	656.2	-3.49	17.4	.767	.765		
								EXIT	4.6	664.4	-1.71	17.7		.765		
128		6-04-64	16:24	2005	3.80	2.519	161.9	INLET	155.2	465.6	-44.69	13.8				
								12	7.2	659.9	-2.69	17.6	.790	.789		
								EXIT	2.3	668.3	-.86	17.8		.789		

Table A-1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{i,j}}{10^6}$	$\frac{\phi_i}{10^6}$
129		6-04-64	16:32	2005	4.08	2.513	168.8	INLET	153.2	467.8	-44.21	13.8				
	0							12	.8	670.9	-1.30	17.9	.818	.823		
	0							EXIT	.0	679.7	1.60	19.8		.823		
130		6-10-64	11:45	1010	3.90	1.017	107.0	INLET	82.1	445.9	-15.14	5.5				
								12	.0	763.9	33.98	46.4	.515	.522		
								EXIT	.0	777.6	36.09	48.9		.522		
131		6-10-64	12:43	1007	4.55	1.005	120.6	INLET	82.9	444.5	-15.26	5.5				
								12	.0	807.6	40.76	53.9	.577	.589		
								EXIT	.0	823.1	43.15	56.7		.588		
132		6-10-64	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		
133		6-10-64	14:29	1015	8.65	1.997	140.5	INLET	82.5	446.1	-15.25	10.9				
								12	.0	658.9	17.67	52.9	.671	.686		
								EXIT	.0	668.0	19.07	56.1		.685		
134		6-10-64	14:41	1010	8.83	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		
135		6-11-64	10:33	1010	12.23	2.002	114.6	INLET	21.7	516.9	-4.18	11.6				
								12	.0	689.9	22.55	64.6	.550	.559		
								EXIT	.0	697.3	23.69	67.3		.559		
136		6-11-64	10:51	1010	11.78	1.979	121.8	INLET	20.9	517.8	-4.03	11.5				
								12	.0	704.0	24.72	68.9	.586	.595		
								EXIT	.0	712.0	25.96	71.7		.594		
137		6-11-64	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		
138		6-11-64	12:50	995	4.77	.986	95.6	INLET	21.6	514.8	-4.13	5.7				
								12	.0	807.8	40.92	53.7	.458	.466		
								EXIT	.0	820.3	42.84	56.0		.466		
139		6-11-64	13:14	995	4.91	.976	99.1	INLET	22.1	514.1	-4.23	5.7				
								12	.0	821.0	42.96	55.5	.476	.483		
								EXIT	.0	834.2	44.98	57.9		.483		
140		6-11-64	13:38	1000	5.25	.994	104.3	INLET	23.6	513.0	-4.52	5.8				
								12	.0	830.3	44.33	57.9	.500	.509		
								EXIT	.0	843.9	46.42	60.3		.508		
141		6-11-64	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	60.7	.515	.527		
	0							EXIT	.0	857.2	48.48	63.2		.526		
143		6-12-64	11:18	1500	3.48	1.500	72.8	INLET	13.2	593.0	-3.33	5.5				
								12	.0	739.8	23.04	34.1	.348	.355		
								EXIT	.0	746.1	24.17	35.3		.355		
144		6-12-64	11:31	1500	3.56	1.498	78.6	INLET	13.2	593.0	-3.34	5.5				
	0							12	.0	751.8	25.21	36.3	.379	.384		
	0							EXIT	.0	758.7	26.44	37.6		.383		

Table A-1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,e}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
145		6-12-64	12:44	1500	5.01	1.974	75.3	INLET	11.7	595.1	-2.97	12.6				
								12	.0	710.4	17.76	37.5	.363	.367		
								EXIT	.0	715.4	18.66	38.8		.367		
146		6-12-64	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	39.5	.380	.385		
	0							EXIT	.0	723.7	20.15	40.8		.384		
147		6-12-64	13:39	1500	6.91	2.460	76.9	INLET	16.2	588.9	-4.07	15.6				
								12	.0	683.4	12.91	38.4	.372	.375		
								EXIT	.0	687.5	13.64	39.6		.375		
148		6-12-64	13:51	1500	6.88	2.465	79.4	INLET	18.0	586.5	-4.52	15.5				
								12	.0	683.9	13.00	38.6	.383	.388		
								EXIT	.0	688.1	13.75	39.9		.387		
149		6-12-64	14:38	1500	6.77	2.494	84.7	INLET	21.8	581.3	-5.45	15.6				
	0							12	.0	684.0	13.01	39.1	.410	.413		
	0							EXIT	.0	688.4	13.80	40.5		.413		
150		6-15-64	11:28	1500	.86	1.000	92.3	INLET	153.3	422.9	-33.93	5.3				
								12	.0	701.8	16.21	17.9	.446	.450		
								EXIT	.0	713.8	18.37	19.4		.450		
151		6-15-64	11:50	1505	1.04	.999	97.9	INLET	152.2	424.5	-33.79	5.3				
								12	.0	720.9	19.57	20.2	.473	.478		
								EXIT	.0	733.7	21.87	21.8		.478		
152		6-15-64	13:10	1500	1.22	.997	102.0	INLET	152.9	423.4	-33.84	5.3				
								12	.0	732.7	21.76	21.8	.490	.498		
								EXIT	.0	745.9	24.15	23.4		.497		
153		6-15-64	13:25	1505	1.29	.997	105.4	INLET	152.6	424.1	-33.87	5.3				
								12	.0	743.7	23.67	23.0	.507	.514		
								EXIT	.0	757.4	26.13	24.7		.514		
154		6-15-64	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		
155		6-15-64	15:14	1510	3.49	1.500	76.3	INLET	20.7	583.9	-5.22	9.4				
								12	.0	737.7	22.52	33.3	.367	.372		
								EXIT	.0	744.3	23.71	34.6		.372		
156		6-15-64	15:24	1512	3.53	1.504	79.4	INLET	22.0	582.4	-5.55	9.4				
	0							12	.0	742.1	23.28	34.2	.383	.388		
	0							EXIT	.0	748.9	24.52	35.5		.387		
157		6-17-64	11:11	1992		.502	66.8	INLET	251.7	359.5	-66.95	2.5				
								12	.0	762.1	19.65	8.1	.318	.326		
								EXIT	.0	779.2	23.33	8.9		.326		
158		6-17-64	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		
159		6-17-64	13:40	1995	.23	1.005	105.4	INLET	250.8	360.8	-66.84	5.1				
								12	.0	677.8	1.43	7.8	.503	.514		
								EXIT	.0	691.3	4.34	9.1		.514		

Table A-1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
160		6-17-64	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 Flux Shape 2 (Chopped Cosine)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_0}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
161		08-26-64	11115	1015	.59	.496	84.7	INLET	22.4	516.2	-4.41	2.9				
								1	17.0	523.3	-3.31	2.9	.131	.131		
								2	1.8	542.5	-.34	3.0	.221	.142		
								3	.0	571.0	4.07	5.3	.304	.203		
								4	.0	606.6	9.58	8.5	.368	.239		
								5	.0	649.2	16.17	12.3	.410	.274		
								6	.0	694.6	23.18	16.3	.436	.300		
								7	.0	742.2	30.55	20.5	.437	.322		
								8	.0	787.6	37.57	24.6	.411	.335		
								9	.0	831.0	44.28	28.4	.370	.343		
								10	.0	867.3	49.89	31.7	.304	.342		
								11	.0	895.9	54.33	34.2	.222	.335		
								12	.0	915.8	57.41	36.0	.130	.322		
								EXIT	.0	922.9	58.49	36.6		.314		
162		08-26-64	11146	1020	1.22	.521	83.2	INLET	26.1	512.9	-5.04	3.0				
								12	.0	1002.4	70.77	45.6	.171	.414		
								EXIT	.0	1011.1	72.13	46.4		.403		
163	0	08-26-64	12133	1005	1.25	.506	86.2	INLET	24.9	512.2	-4.77	2.9				
								12	.0	1034.3	75.73	48.0	.174	.429		
								EXIT	.0	1043.4	77.15	48.8		.418		
164	0	08-26-64	13157	1010	7.20	1.477	112.2	INLET	20.0	518.9	-3.86	8.6				
								12	.0	751.7	32.09	64.1	.228	.558		
								EXIT	.0	755.8	32.73	65.2		.544		
165	0	08-26-64	15105	1010	12.75	2.504	115.3	INLET	17.7	521.8	-3.42	14.7				
								11	.0	656.5	17.38	65.7	.398	.599		
								12	.0	662.9	18.38	68.6	.234	.573		
166	0	08-26-64	15159	1025	8.97	2.535	119.2	EXIT	.0	665.4	18.76	69.8		.559		
								INLET	52.6	481.8	-9.99	14.2				
								11	.0	619.2	11.33	48.1	.411	.619		
167		08-27-64	12139	1025	5.01	2.513	120.3	12	.0	625.9	12.37	51.2	.243	.593		
								EXIT	.0	628.5	12.77	52.3		.578		
								INLET	100.5	427.2	-18.46	13.5				
								1	98.3	429.7	-18.07	13.5	.239	.239		
								2	92.0	436.6	-16.99	13.6	.407	.296		
								3	83.2	446.6	-15.44	13.7	.568	.365		
								4	71.1	460.4	-13.31	13.9	.687	.445		
								5	57.7	475.8	-10.92	14.0	.768	.507		
								6	43.5	492.6	-8.31	14.3	.814	.558		
								7	28.9	510.2	-5.59	14.5	.815	.599		
								8	15.2	527.0	-2.99	14.8	.767	.624		
								9	2.9	542.6	-.56	15.1	.689	.636		
								10	.0	555.9	1.50	19.5	.566	.635		
								11	.0	566.5	3.15	24.2	.416	.622		
								12	.0	573.8	4.29	27.5	.245	.598		
								EXIT	.0	576.4	4.69	28.6		.583		

Table A-2. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	X	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{II}}{10^6}$	$\frac{\phi_I}{10^6}$
168		08-27-64	13:04	1045	5.30	2.529	123.5	INLET	101.0	424.0	-18.38	13.5				
								12	.0	573.6	4.70	29.1	.251	.614		
								EXIT	.0	576.3	5.11	30.3		.599		
169		08-27-64	14:28	1020	5.93	2.494	128.6	INLET	97.4	430.0	-17.88	13.4				
								12	.0	587.9	6.58	33.9	.281	.639		
								EXIT	.0	590.7	7.01	35.2		.624		
170		08-27-64	14:56	1015	6.30	2.517	132.8	INLET	101.8	424.5	-18.59	13.4				
								12	.0	586.5	6.47	33.9	.270	.660		
								EXIT	.0	589.4	6.92	35.2		.644		
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	35.5	.286	.705		
0								EXIT	.0	602.5	8.84	40.9		.688		
172		08-28-64	11:12	1030	4.10	2.486	147.7	INLET	149.2	374.8	-26.75	12.8				
								12	.0	556.9	1.54	19.4	.300	.734		
								EXIT	.0	560.1	2.04	20.8		.716		
173		08-28-64	11:58	1003	4.46	2.484	152.9	INLET	149.2	371.3	-26.44	12.8				
								12	.0	559.9	2.63	22.6	.311	.760		
								EXIT	.0	563.3	3.15	24.1		.741		
174		08-28-64	12:10	1030	4.90	2.488	156.0	INLET	150.5	373.4	-26.96	12.8				
								12	.0	565.6	2.89	23.2	.318	.776		
								EXIT	.0	569.0	3.43	24.7		.757		
175		08-28-64	12:21	1000	5.44	2.472	160.2	INLET	147.9	372.3	-26.20	12.7				
								12	.0	570.8	4.37	27.6	.326	.796		
								EXIT	.0	574.3	4.92	29.2		.777		
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	33.0		.799		
177		08-28-64	13:13	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		
178		08-31-64	10:22	1010	4.69	1.534	118.5	INLET	101.1	424.6	-18.43	8.2				
								12	.0	661.3	18.12	41.6	.240	.589		
								EXIT	.0	665.5	18.77	42.8		.575		
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		
181		08-31-64	13:35	1005	1.11	.506	101.1	INLET	154.1	366.3	-27.28	2.6				
								12	.0	978.1	67.07	42.8	.205	.502		
								EXIT	.0	988.9	68.74	43.8		.490		
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		

Table A-2. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
183		09-31-64	14:50	1000	1.18	.504	101.1	INLET	105.1	418.8	-19.03	2.7				
	0							12	.0	1027.4	74.69	47.4	.203	.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	.364		
	0							EXIT	.0	735.5	22.04	32.8		.355		
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		
187		09-01-64	11:25	1510	2.08	1.752	98.5	INLET	98.5	465.9	-22.89	9.8				
	0							12	.0	658.2	8.18	21.4	.201	.490		
	0							EXIT	.0	661.3	8.74	22.1		.478		
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	1.504	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	894.7	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	928.0	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		

Table A-2. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
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	.388		
								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		
	0							12	.0	671.1	10.59	35.1	.158	.388		
	0							EXIT	.0	672.7	10.90	35.6		.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	.198	.464		
	0							EXIT	.0	665.0	9.60	33.3		.453		
196		09-02-64	15:06	1503	4.37	2.519	121.5	INLET	95.8	488.4	-22.24	14.2				
								12	.0	636.2	4.35	24.1	.247	.604		
								EXIT	.0	638.8	4.83	25.0		.589		
197		09-02-64	15:23	1503	4.44	2.537	125.1	INLET	99.3	484.2	-22.99	14.2				
								12	.0	635.4	4.21	24.1	.255	.622		
								EXIT	.0	638.0	4.69	24.9		.607		
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		
199		09-03-64	09:08	1505	3.37	2.539	154.2	INLET	149.2	427.9	-33.20	13.6				
								12	.0	614.0	.32	17.2	.314	.767		
								EXIT	.0	617.3	.91	18.2		.748		
200		09-03-64	09:42	1518	4.03	2.468	158.8	INLET	146.1	432.5	-32.79	13.2				
								12	.0	629.7	2.86	21.0	.323	.789		
								EXIT	.0	633.2	3.50	22.1		.770		
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		

Table A-2. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,j}}{10^6}$	$\frac{\phi_i}{10^6}$
204		09-03-64	15:18	2005	1.38	1.546	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		
206		09-04-64	13:16	2015		.509	29.8	INLET	31.7	622.2	-11.12	3.3				
								1	29.5	625.4	-10.43	3.3	.060	.060		
								2	23.8	634.1	-8.55	3.4	.102	.075		
								3	15.6	646.9	-5.76	3.5	.141	.094		
								4	5.7	663.5	-2.16	3.6	.172	.112		
								5	.0	681.8	1.82	4.1	.190	.126		
								6	.0	702.8	6.38	5.1	.202	.139		
								7	.0	724.4	11.07	6.1	.202	.149		
								8	.0	744.8	15.49	7.1	.190	.155		
								9	.0	764.3	19.73	8.1	.172	.159		
								10	.0	780.1	23.16	8.9	.140	.158		
								11	.0	793.8	26.13	9.6	.103	.155		
								12	.0	801.5	27.81	9.9	.060	.148		
								EXIT	.0	804.7	28.51	10.1		.144		
207		09-04-64	14:06	2003		.489	35.0	INLET	32.6	619.7	-11.32	3.2				
								12	.0	838.9	36.04	11.4	.071	.174		
								EXIT	.0	842.6	36.88	11.6		.170		
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	41.88	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		
212		09-08-64	14:50	1990	4.89	2.478	96.5	INLET	90.2	541.5	-27.74	14.7				
								11	9.0	655.1	-3.32	17.2	.332	.500		
								12	5.6	660.9	-2.08	17.3	.196	.480		
								EXIT	4.5	663.0	-1.62	17.4		.468		

Table A-2. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
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	2.489	78.9	INLET	22.2	635.5	-7.95	14.6				
	0							10	.0	721.1	10.55	29.6	.369	.418		
	0							11	.0	727.9	12.02	31.2	.268	.408		
								12	.0	732.7	13.07	32.4	.160	.392		
								EXIT	.0	734.4	13.44	32.8		.383		
215		09-09-64	09:57	2005	3.92	2.496	131.3	INLET	97.9	533.2	-30.08	14.7				
								11	.0	686.4	3.05	21.3	.454	.680		
								12	.0	694.4	4.78	23.2	.268	.653		
								EXIT	.0	697.3	5.40	23.9		.637		
216		09-09-64	13:10	2010	3.80	2.502	131.1	INLET	101.2	529.6	-31.05	14.6				
								11	.0	682.9	2.19	20.3	.454	.682		
								12	.0	690.1	3.74	22.1	.268	.652		
								EXIT	.0	693.0	4.37	22.8		.636		
217		09-09-64	13:28	1995	4.12	2.505	134.2	INLET	99.1	530.9	-30.21	14.7				
								11	.0	687.6	3.54	21.9	.462	.698		
								12	.0	695.1	5.16	23.7	.273	.668		
								EXIT	.0	698.0	5.79	24.4		.651		
218		09-09-64	13:40	2000	4.21	2.495	136.8	INLET	99.3	531.0	-30.36	14.6				
	0							11	.0	691.4	4.26	22.6	.472	.711		
								12	.0	699.1	5.90	24.4	.279	.680		
								EXIT	.0	702.1	6.55	25.2		.663		
219		09-09-64	15:21	2000	3.40	2.505	163.2	INLET	147.3	474.2	-42.62	13.9				
								11	4.4	664.2	-1.63	17.6	.561	.846		
								12	.0	673.8	.46	18.4	.330	.811		
								EXIT	.0	677.4	1.22	19.3		.791		
220		09-09-64	15:31	2000	3.71	2.484	167.6	INLET	146.7	474.9	-42.47	13.7				
								11	.1	671.5	-.04	17.7	.579	.868		
								12	.0	681.8	2.17	20.2	.341	.833		
								EXIT	.0	685.4	2.96	21.0		.813		
221		09-09-64	15:49	2010	3.94	2.504	172.4	INLET	147.6	474.6	-42.96	13.8				
	0							11	.0	675.3	.54	18.5	.595	.893		
								12	.0	685.6	2.77	21.0	.351	.857		
								EXIT	.0	689.4	3.58	21.9		.836		
222		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	10.98	18.2		.449		
223		09-10-64	12:23	1510		.478	57.1	INLET	29.4	572.3	-7.32	3.0				
	0							12	.0	538.7	58.76	22.7	.116	.284		
	0							EXIT	.0	945.2	59.94	23.1		.277		

Table A-2: (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,e}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,j}}{10^6}$	$\frac{\phi_i}{10^6}$
224		09-10-64	14143	1005	7.47	1.499	111.2	INLET	17.5	521.3	-3.38	8.2				
	0							12	.0	748.8	31.71	64.7	.221	.553		
	0							EXIT	.0	752.7	32.32	65.7		.539		
225		09-11-64	10121	995	12.37	2.484	116.9	INLET	17.9	519.3	-3.44	14.5				
	0							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 Flux Shape 3 (Peak Near Inlet)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
228		09-21-64	11:43	998	1.31	.493	81.7	INLET	25.1	510.9	-4.20	2.9				
								12	.0	1018.9	73.38	45.7	.153	.407		
								EXIT	.0	1027.2	74.66	46.5		.396		
229		09-21-64	12:07	998	1.49	.509	87.0	INLET	27.1	508.5	-5.17	2.9				
0								12	.0	1033.4	75.60	46.5	.162	.430		
0								EXIT	.0	1041.9	76.92	49.3		.422		
230		09-21-64	13:39	1005	6.66	1.503	101.1	INLET	22.0	515.7	-4.23	8.7				
0								7	.0	677.5	20.71	45.5	.403	.698		
0								8	.0	690.0	22.65	46.9	.301	.651		
0								9	.0	700.3	24.23	51.7	.247	.609		
0								10	.0	708.4	25.48	53.9	.211	.568		
0								11	.0	714.7	26.45	55.6	.196	.531		
0								12	.0	722.3	27.62	57.6	.188	.504		
0								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				
0								8	.0	667.8	19.13	42.3	.315	.685		
0								9	.0	678.9	20.84	45.2	.259	.640		
0								10	.0	687.7	22.21	47.6	.222	.599		
0								11	.0	695.2	23.36	49.6	.208	.562		
0								12	.0	702.6	24.50	51.6	.198	.531		
0								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				
0								8	.0	671.8	19.78	43.2	.318	.689		
0								9	.0	682.5	21.44	46.0	.261	.643		
0								10	.0	690.5	22.68	48.2	.222	.599		
0								11	.0	699.1	24.00	50.5	.207	.564		
0								12	.0	706.5	25.14	52.4	.199	.533		
0								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				
0								8	.0	632.9	13.64	33.6	.360	.779		
0								9	.0	645.2	15.73	36.9	.296	.728		
0								10	.0	654.5	17.18	39.5	.253	.679		
0								11	.0	664.0	18.63	42.1	.234	.640		
0								12	.0	672.2	19.90	44.3	.225	.604		
0								EXIT	.0	676.2	20.52	45.4		.589		
234		09-22-64	16:27	1003	4.60	1.510	140.8	INLET	146.5	374.2	-25.99	7.8				
0								7	.0	598.0	8.51	24.1	.560	.970		
0								8	.0	614.7	11.07	28.7	.419	.903		
0								9	.0	628.6	13.21	32.5	.343	.843		
0								10	.0	639.8	14.94	35.6	.291	.788		
0								11	.0	650.0	16.51	38.3	.271	.740		
0								12	.0	660.5	18.13	41.2	.262	.701		
0								EXIT	.0	665.1	18.64	42.5		.683		

Table A-3. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,j}}{10^6}$	$\frac{\phi_i}{10^6}$
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	99.5	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	.186	.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	.788		
	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		
241		09-24-64	16:47	1010	6.02	2.520	168.9	INLET	152.2	369.0	-27.01	12.9				
								7	11.0	530.0	-2.15	14.9	.675	1.164		
								8	1.2	542.5	-.22	15.1	.504	1.087		
								9	.0	552.3	1.30	19.0	.413	1.014		
								10	.0	560.8	2.61	22.8	.353	.949		
								11	.0	568.2	3.74	26.1	.329	.892		
								12	.0	574.7	4.75	29.1	.316	.841		
								EXIT	.0	578.1	5.27	30.6		.819		

Table A-3. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,j}}{10^6}$	$\frac{\phi_i}{10^6}$
242		09-24-64	14:06	1005	6.84	2.462	175.0	INLET	149.0	371.8	-26.43	12.7				
	0							7	1.0	541.9	-2.20	14.8	.695	1.202		
								8	.0	555.3	1.87	20.2	.519	1.124		
								9	.0	566.3	3.97	25.1	.427	1.051		
								10	.0	575.1	4.93	29.0	.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		
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	-2.40	9.9	.752	.945		
	0							7	.0	631.5	3.69	13.8	.520	.899		
	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	8.4				
	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	9.0				
	0							10	.0	696.6	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	9.3				
	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		

Table A-3. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
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	.146	.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		
252		09-29-64	12:03	1495	5.30	2.512	90.8	INLET	51.9	541.4	-12.48	15.0				
								9	.0	640.5	5.30	25.8	.223	.546		
								10	.0	644.5	6.02	27.1	.189	.509		
								11	.0	648.6	6.75	28.4	.177	.478		
								12	.0	652.3	7.42	29.6	.170	.452		
								EXIT	.0	654.1	7.75	30.1		.440		
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		
255		09-30-64	12:25	1490	4.26	2.563	164.2	INLET	150.5	425.0	-33.21	13.7				
								1	144.9	431.2	-32.10	13.7	.593	.593		
								2	128.4	449.5	-28.81	13.9	1.158	.784		
								3	104.3	477.1	-23.87	14.3	1.509	.997		
								4	77.4	509.2	-18.13	14.8	1.525	1.150		
								5	93.6	538.7	-12.84	15.3	1.296	1.208		
								6	35.0	562.5	-8.57	15.7	.953	1.196		
								7	22.4	579.3	-5.56	16.0	.657	1.135		
								8	13.6	591.3	-3.41	16.3	.490	1.061		
								9	7.0	600.4	-1.77	16.5	.403	.987		
								10	1.9	608.3	-.37	16.6	.342	.923		
								11	.0	615.3	.90	16.3	.321	.867		
								12	.0	621.6	2.03	20.4	.308	.818		
								EXIT	.0	624.8	2.60	21.4		.796		

Table A-3. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i1}}{10^6}$	$\frac{\phi_i}{10^6}$
296		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	595.9	-2.99	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		
297		10-01-64	09:46	1995	1.36	1,491	53.8	INLET	21.8	635.1	-7.75	10.0				
								4	.0	682.4	2.42	12.3	.498	.375		
								5	.0	699.1	6.03	14.7	.423	.396		
								6	.0	712.4	8.90	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		
298		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	-2.90	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	11.06	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	14.99	21.0		.336		
299		10-01-64	13:05	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	.497		
								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		
								6	1.3	669.5	-.48	10.7	.554	.693		
	0							7	.0	686.0	3.08	12.8	.383	.657		
	0							8	.0	698.5	5.78	14.7	.286	.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	.179	.478		
								EXIT	.0	732.7	13.17	19.7		.465		

Table A-3. (Cont'd)

RUN NO.	DNB	DATE	TIME	P.	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$
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	24.93	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		
	0							10	.0	842.5	36.87	11.9	.080	.212		
	0							11	.0	851.4	38.77	12.3	.074	.200		
	0							12	.0	859.2	40.46	12.7	.072	.189		
	0							EXIT	.0	863.0	41.28	12.9		.184		
262		10-02-64	11:42	2000		.503	45.2	INLET	54.7	588.4	-17.97	3.2				
								4	.0	705.4	7.27	5.2	.416	.314		
								5	.0	746.8	16.20	7.3	.353	.331		
	0							6	.0	779.6	23.29	8.9	.259	.327		
								7	.0	803.2	28.38	10.0	.181	.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	.237		
	0							12	.0	863.7	41.43	13.0	.085	.225		
	0							EXIT	.0	868.2	42.41	13.2		.219		
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		

Table A-3. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
264		10-02-64	15146	2000		.512	66.8	INLET	151.4	469.5	-43.64	2.8				
								4	17.7	642.0	-6.41	3.5	.617	.471		
								5	.0	700.1	6.12	5.1	.523	.490		
								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	36.91	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	10154	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	11157	1998	5.23	2.534	102.2	INLET	47.9	597.5	-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	.793		
	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		

Table A-3. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
267		10-05-64	14:48	1995	3.83	2.498	126.3	INLET	96.7	533.9	-29.55	14.7				
								1	92.7	538.8	-28.49	14.7	.460	.460		
								2	81.1	553.3	-25.37	15.0	.890	.684		
								3	64.4	575.0	-20.70	15.3	1.158	.766		
								4	45.9	600.0	-15.32	15.9	1.171	.879		
								5	29.2	623.9	-10.18	16.4	.992	.931		
								6	17.6	641.6	-6.36	16.9	.728	.912		
								7	9.5	654.8	-3.51	17.3	.503	.866		
								8	4.0	664.5	-1.42	17.6	.377	.811		
								9	.0	672.1	.20	18.0	.308	.757		
								10	.0	678.1	1.50	19.5	.263	.707		
								11	.0	683.5	2.67	20.8	.246	.664		
								12	.0	689.2	3.89	22.2	.236	.629		
268		10-05-64	15:10	1995	3.80	2.501	131.1	EXIT	.0	691.7	4.44	22.8		.613		
								INLET	103.2	525.8	-31.30	14.6				
								4	49.9	594.4	-16.52	15.8	1.218	.915		
								5	32.7	618.7	-11.29	16.3	1.033	.963		
								6	19.9	638.0	-7.14	16.8	.756	.952		
								7	11.3	651.8	-4.16	17.2	.521	.904		
								8	5.7	661.4	-2.10	17.5	.391	.843		
								9	1.3	669.3	-.39	17.8	.322	.788		
								10	.0	675.4	.93	18.9	.275	.735		
								11	.0	681.3	2.19	20.3	.256	.691		
								12	.0	686.7	3.36	21.6	.246	.653		
								EXIT	.0	689.4	3.93	22.3		.636		
269		10-05-64	15:25	1995	4.30	2.491	136.3	INLET	98.9	531.1	-30.15	14.6				
								4	43.6	603.0	-14.66	15.9	1.267	.955		
								5	26.3	628.3	-9.23	16.5	1.073	1.003		
								6	13.6	648.1	-4.96	17.0	.787	.988		
								7	5.0	662.6	-1.84	17.5	.544	.940		
								8	.0	673.1	.42	18.2	.406	.879		
								9	.0	681.2	2.17	20.2	.334	.821		
								10	.0	687.5	3.53	21.7	.285	.765		
								11	.0	693.5	4.82	23.2	.265	.719		
								12	.0	699.1	6.02	24.5	.255	.679		
								EXIT	.0	701.8	6.61	25.2		.661		

Table A-3. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	X	V_m	$\frac{\phi_{l,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{l,i}}{10^6}$	$\frac{\phi_i}{10^6}$
270		10-05-64	15:39	2000	4.60	2.505	141.3	INLET	98.0	932.7	-30.00	14.7				
	0							4	41.1	607.0	-13.96	16.0	1.310	.992		
	0							5	23.8	632.5	-8.46	16.7	1.113	1.037		
								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	24.8	.276	.745		
								12	.0	705.8	7.36	26.2	.265	.703		
								EXIT	.0	708.6	7.97	26.9		.685		
271		10-06-64	10:00	1995	3.24	2.525	159.6	INLET	148.6	472.3	-42.83	13.9				
								4	79.8	555.0	-25.01	15.2	1.482	1.114		
								5	57.4	584.2	-18.72	15.7	1.247	1.172		
								6	40.7	607.1	-13.78	16.2	.920	1.155		
								7	29.9	622.8	-10.41	16.6	.636	1.091		
								8	21.4	635.8	-7.62	16.9	.476	1.027		
								9	15.3	645.2	-5.58	17.2	.389	.959		
								10	10.8	652.6	-3.98	17.4	.333	.894		
								11	6.6	659.7	-2.46	17.6	.312	.841		
								12	3.0	666.3	-1.04	17.8	.299	.795		
								EXIT	1.2	669.5	-.35	18.0		.774		
272		10-06-64	10:17	1995	3.46	2.513	165.6	INLET	147.7	473.3	-42.60	13.9				
								4	76.1	559.7	-23.99	15.2	1.540	1.158		
								5	53.2	589.9	-17.49	15.8	1.299	1.215		
								6	35.9	613.8	-12.34	16.2	.958	1.198		
								7	24.5	631.0	-8.64	16.7	.660	1.137		
								8	16.5	643.2	-6.00	17.0	.495	1.062		
								9	10.6	652.9	-3.92	17.3	.406	.991		
								10	5.8	661.2	-2.13	17.6	.345	.928		
								11	2.0	668.1	-.65	17.8	.322	.870		
								12	.0	675.6	.96	19.0	.309	.825		
								EXIT	.0	678.9	1.67	19.8		.803		
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	1.235		
								5	48.0	597.3	-16.00	16.0	1.384	1.298		
								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	1.138		
								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		

Table A-3. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	X	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
274		10-06-64	12153	1995	1.11	1.506	110.3	INLET	149.1	471.7	-42.94	8.3				
								4	69.9	567.8	-22.26	9.2	1.025	.771		
								5	44.5	601.9	-14.92	9.6	.863	.812		
								6	26.5	627.9	-9.30	9.9	.638	.798		
								7	14.0	647.3	-5.13	10.3	.441	.759		
								8	5.8	661.2	-2.13	10.5	.330	.710		
								9	.0	671.9	.16	10.9	.271	.662		
								10	.0	680.7	2.07	12.1	.231	.618		
								11	.0	688.7	3.78	13.3	.215	.580		
								12	.0	696.5	5.46	14.5	.207	.549		
								EXIT	.0	700.1	6.25	15.0		.535		
275	0 0	10-06-64	14112	1995	1.34	1.514	123.1	INLET	148.9	472.0	-42.88	8.4				
								4	61.4	578.8	-19.87	9.4	1.146	.862		
								5	34.9	615.4	-12.00	9.8	.962	.900		
								6	15.1	645.6	-5.50	10.3	.711	.891		
								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	.738		
								10	.0	703.9	7.07	15.6	.259	.689		
								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	0 0	10-07-64	10145	1000	8.56	2.020	104.5	INLET	30.6	504.5	-5.84	11.6				
								4	.0	569.0	4.09	21.9	.972	.694		
								5	.0	591.9	7.62	30.2	.816	.732		
								6	.0	610.3	10.45	37.0	.603	.725		
								7	.0	628.3	13.22	43.6	.418	.718		
								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	.585		
								11	.0	657.6	17.73	54.3	.203	.549		
								12	.0	663.3	18.62	56.4	.195	.520		
								EXIT	.0	665.9	19.02	57.4		.507		
277	0 0	10-07-64	12138	1000	11.87	2.454	99.8	INLET	10.3	529.4	-2.00	14.5				
								4	.0	582.7	6.21	32.7	.928	.697		
								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	.208	.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		

Table A-3. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	X	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
278		10-07-64	15111	995	1.27	.516	119.2	INLET	219.0	296.9	-37.62	2.5				
								4	.0	558.9	8.81	8.5	1.108	.831		
								5	.0	706.7	25.38	18.6	.934	.677		
								6	.0	790.2	38.22	26.5	.688	.664		
								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	63.89	42.2	.249	.669		
								11	.0	981.6	67.65	44.5	.232	.628		
	0							12	.0	1005.6	71.34	46.7	.222	.593		
	0							EXIT	.0	1017.1	73.12	47.8		.578		
279		10-08-64	10144	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	26.17	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	14106	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	4.91	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	28.92	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 Flux Shape 4 (Peak Near Outlet)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_s}{10^6}$	$\frac{\phi_w}{10^6}$	$\frac{\phi_i}{10^6}$
281		10-26-64	15:45	1012	3.78	2.517	133.0	INLET	150.7	370.8	-26.80	12.9				
								12	12.4	528.5	-2.43	14.9	.616	.658		
								13	8.3	533.7	-1.63	19.0	.358	.651		
								EXIT	6.8	535.6	-1.33	19.0		.645		
282		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	-.20	19.0	.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	.297	.469		
0								EXIT	.0	600.7	8.77	40.3		.465		
285		10-27-64	15:14	997	9.47	2.489	86.3	INLET	22.0	514.5	-4.21	14.5				
								1	20.6	516.3	-3.94	14.5	.164	.164		
								2	17.6	519.9	-3.38	14.5	.171	.167		
								3	14.4	523.8	-2.79	14.6	.186	.172		
								4	11.0	528.1	-2.12	14.7	.215	.180		
								5	6.8	533.4	-1.31	14.8	.265	.195		
								6	1.7	540.0	-.30	14.9	.353	.215		
								7	.0	549.2	1.11	18.2	.512	.247		
								8	.0	562.3	3.14	24.1	.701	.296		
								9	.0	576.7	5.65	31.5	.815	.350		
								10	.0	596.4	8.37	39.6	.802	.400		
								11	.0	611.3	10.67	46.3	.627	.428		
								12	.0	620.4	12.07	50.4	.408	.437		
								13	.0	624.0	12.62	52.0	.237	.432		
								EXIT	.0	625.2	12.81	52.6		.428		
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		
								13	.0	631.8	13.77	55.4	.251	.459		
								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	367.3	-26.96	7.7				
0								12	.0	597.9	8.54	24.2	.539	.576		
0								13	.0	605.4	9.70	26.3	.313	.570		
0								EXIT	.0	608.2	10.13	27.0		.564		
288		10-29-64	15:31	1000	3.35	1.512	99.3	INLET	99.8	424.6	-18.13	8.1				
								12	.0	620.8	12.08	30.6	.458	.492		
								13	.0	627.2	13.06	32.3	.264	.486		
								EXIT	.0	629.5	13.42	33.0		.482		

Table A-4. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
289		10-29-64	15:49	1000	3.53	1.504	103.7	INLET	99.0	425.5	-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	1.983	96.5	INLET	47.7	485.1	-9.01	8.9				
	0							12	.0	667.1	19.08	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	8.6				
	0							11	.0	690.1	22.86	49.0	.658	.452		
	0							12	.0	706.4	25.37	53.4	.429	.462		
	0							13	.0	712.6	26.32	55.0	.248	.457		
	0							EXIT	.0	714.9	26.67	55.6		.453		
292		11-02-64	14:51	998	.84	.497	78.1	INLET	25.0	511.0	-4.78	2.9				
	0							12	.0	579.7	67.34	42.5	.357	.387		
	0							13	.0	995.0	69.70	43.9	.210	.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	2.8				
	0							12	.0	965.0	65.03	41.2	.375	.406		
	0							13	.0	980.6	67.45	42.6	.217	.401		
	0							EXIT	.0	986.4	68.34	43.1		.397		
294		11-03-64	11:50	998	.82	.507	83.2	INLET	101.1	422.9	-18.34	2.7				
	0							12	.0	913.1	57.10	37.2	.382	.412		
	0							13	.0	928.7	59.50	38.7	.223	.407		
	0							EXIT	.0	934.6	60.41	39.2		.404		
295		11-03-64	12:06	998	.88	.507	88.7	INLET	101.7	422.3	-18.44	2.7				
	0							12	.0	943.8	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		
296		11-03-64	13:20	995	.84	.505	93.9	INLET	150.0	369.4	-26.49	2.6				
	0							12	.0	924.7	58.90	38.3	.433	.465		
	0							13	.0	943.0	61.71	40.0	.252	.460		
	0							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				
	0							12	.0	834.0	39.98	17.3	.315	.341		
	0							13	.0	846.9	42.29	18.2	.183	.337		
	0							EXIT	.0	851.8	43.17	18.5		.333		
298		11-05-64	10:18	1505		.490	62.4	INLET	104.4	478.6	-24.07	2.7				
	0							12	.0	858.6	44.37	18.4	.285	.309		
	0							13	.0	871.0	46.59	19.2	.166	.306		
	0							EXIT	.0	875.5	47.40	19.5		.303		
299		11-05-64	12:39	1500		.494	57.4	INLET	55.6	537.3	-13.36	2.9				
	0							12	.0	883.7	48.91	20.2	.264	.284		
	0							13	.0	895.4	51.01	20.9	.154	.281		
	0							EXIT	.0	899.5	51.76	21.2		.278		

Table A-4. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_{i0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{ij}}{10^6}$	$\frac{\phi_i}{10^6}$
300		11-05-64	13:47	1498		.511	53.7	INLET	26.7	574.4	-4.63	3.2				
	0							12	.0	648.0	49.85	21.3	.246	.266		
	0							13	.0	698.7	51.61	21.9	.143	.263		
	0							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				
	0							12	.0	709.3	17.61	27.9	.293	.315		
	0							13	.0	713.5	18.35	28.7	.170	.312		
	0							EXIT	.0	715.1	18.63	29.0		.309		
302		11-06-64	10:37	1495	1.95	1.495	65.8	INLET	47.7	546.7	-11.54	9.0				
								1	46.0	548.8	-11.15	9.0	.120	.120		
								2	42.5	553.3	-10.35	9.0	.127	.123		
								3	38.8	558.2	-9.48	9.1	.139	.128		
								4	34.7	563.6	-8.51	9.2	.159	.135		
								5	29.8	570.0	-7.35	9.2	.199	.145		
								6	23.5	578.4	-5.84	9.3	.263	.161		
								7	15.2	589.6	-3.83	9.5	.381	.184		
								8	3.4	606.3	-.84	9.7	.522	.222		
								9	.0	626.3	2.75	12.7	.606	.261		
								10	.0	647.9	6.63	16.8	.600	.297		
								11	.0	667.2	10.08	20.4	.468	.320		
								12	.0	678.2	12.06	22.5	.304	.326		
								13	.0	682.4	12.82	23.3	.177	.322		
								EXIT	.0	684.0	13.10	23.6		.319		
303		11-06-64	10:54	1495	1.95	1.500	68.9	INLET	47.6	546.8	-11.51	9.0				
	0							12	.0	683.8	13.07	23.6	.319	.341		
	0							13	.0	688.5	13.91	24.5	.185	.337		
	0							EXIT	.0	690.1	14.21	24.8		.334		
304		11-06-64	12:59	1495	1.52	1.510	79.8	INLET	98.8	484.0	-22.79	8.5				
								12	.0	641.8	5.54	15.8	.368	.395		
								13	.0	646.9	6.45	16.7	.213	.391		
								EXIT	.0	648.8	6.79	17.1		.387		
305		11-06-64	13:25	1493	1.63	1.507	85.4	INLET	98.0	484.8	-22.58	8.4				
	0							12	.0	654.2	7.81	18.1	.393	.423		
	0							13	.0	659.6	8.77	19.2	.228	.418		
	0							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				
	0							12	.0	632.5	3.59	13.7	.472	.507		
	0							13	.0	638.9	4.74	14.9	.274	.501		
	0							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				
	0							12	.0	657.8	8.20	30.8	.298	.320		
	0							13	.0	660.3	8.75	31.6	.173	.316		
	0							EXIT	.0	661.2	8.92	31.9		.313		

Table A-4. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	X	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
308		11-09-64	11:32	1500	4.30	2.504	79.2	INLET	49.9	544.5	-12.07	15.0				
	0							12	.0	638.0	4.29	25.0	.364	.392		
	0							13	.0	641.9	5.44	26.0	.214	.348		
								EXIT	.0	643.0	5.64	26.3		.344		
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	.99	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		
313		11-10-64	13:40	2005	.86	1.523	71.3	INLET	100.9	529.6	-30.86	8.9				
								1	99.0	531.8	-30.37	8.9	.130	.130		
								2	95.2	536.5	-29.36	9.0	.136	.132		
								3	91.2	541.6	-28.26	9.0	.149	.137		
								4	86.7	547.2	-27.04	9.1	.172	.143		
								5	81.2	554.0	-25.57	9.1	.214	.155		
								6	74.4	562.8	-23.67	9.2	.286	.172		
								7	65.0	575.0	-21.03	9.4	.414	.199		
								8	52.2	592.2	-17.33	9.6	.568	.237		
								9	36.6	613.9	-12.62	9.8	.657	.282		
								10	21.2	637.0	-7.63	10.2	.649	.321		
								11	8.4	657.8	-3.14	10.6	.507	.347		
								12	1.8	669.2	-.66	10.8	.329	.353		
								13	.0	673.9	.36	11.1	.192	.349		
								EXIT	.0	675.6	.72	11.4		.346		
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		

Table A-4. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{11}}{10^6}$	$\frac{\phi_i}{10^6}$
315	0	11-10-64	15:01	2005	.75	1.514	92.4	INLET	150.4	471.0	-43.53	6.3				
								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	0	11-11-64	11:43	2005		.518	33.0	INLET	26.3	629.2	-9.31	3.4				
	0							11	.0	664.1	24.50	10.3	.233	.161		
	0							12	.0	619.3	31.78	11.1	.153	.163		
	0							13	.0	625.6	33.16	11.4	.089	.162		
	0							EXIT	.0	627.9	33.66	11.5		.160		
318	0	11-11-64	13:14	2005		.514	36.5	INLET	58.8	583.2	-19.26	3.2				
	0							11	.0	776.5	22.54	8.9	.259	.176		
	0							12	.0	755.6	26.67	9.8	.167	.181		
								13	.0	802.4	24.15	10.2	.097	.179		
								EXIT	.0	805.0	28.69	10.3		.177		
319	0	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		
320		11-11-64	16:11	2000		.506	44.6	INLET	154.9	465.6	-44.48	2.8				
								11	.0	706.1	7.41	5.3	.317	.216		
								12	.0	728.6	12.28	6.4	.206	.221		
								13	.0	737.4	14.18	6.8	.119	.219		
								EXIT	.0	740.5	14.86	7.0		.216		
321	0	11-11-64	16:30	2000		.503	49.5	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		
322		11-12-64	09:46	2010	4.19	2.491	56.5	INLET	23.0	634.8	-8.26	16.6				
								11	.0	696.6	5.14	23.5	.398	.274		
								12	.0	702.4	6.41	24.9	.259	.280		
								13	.0	704.7	6.90	25.5	.152	.277		
								EXIT	.0	705.5	7.08	25.7		.274		
323	0	11-12-64	10:03	2005	4.30	2.480	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		.295		
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		
	0							12	.0	692.3	4.32	23.0	.366	.395		
								13	.0	695.3	4.97	23.8	.214	.391		
								EXIT	.0	696.4	5.22	24.0		.387		

Table A-4. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_{o,0}}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_{o,i}}{10^6}$
325	0	11-12-64	13150	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	15105	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		
327		11-13-64	12158	1998	5.98	3.542	134.9	INLET	98.1	532.3	-30.00	20.8				
								11	21.0	636.7	-7.50	23.7	.961	.657		
								12	15.0	646.1	-5.47	24.1	.625	.668		
								13	12.7	649.8	-4.67	24.3	.359	.661		
								EXIT	11.9	651.1	-4.38	24.3		.654		
328	0	11-13-64	13117	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	.691		
								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	15107	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	10100	1495	6.05	3.497	138.6	INLET	99.9	482.8	-23.00	19.6				
	0							11	14.2	591.0	-3.58	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	12116	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		
332	0	11-16-64	13130	1500	5.64	2.481	61.0	INLET	8.7	599.3	-2.22	15.9				
	0							12	.0	672.7	10.96	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		
333		11-16-64	15102	1500	1.97	1.515	58.1	INLET	11.3	595.7	-2.86	9.7				
								12	.0	710.0	17.69	28.7	.265	.287		
								13	.0	713.8	18.37	29.5	.157	.284		
								EXIT	.0	715.2	18.62	29.7		.282		

Table A-4. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
334		11-16-64	15:21	1503	1.99	1.514	61.7	INLET	10.6	567.1	-2.69	9.7				
	0							12	.0	718.6	19.19	30.3	.283	.306		
	0							13	.0	722.6	19.60	31.0	.165	.302		
	0							EXIT	.0	724.0	20.16	31.3		.299		
342		11-20-64	11:48	2000	1.68	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	2.93	12.8	.360	.386		
								13	.0	690.9	4.02	13.6	.210	.384		
								EXIT	.0	692.7	4.42	13.8		.380		

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 6

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

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 7

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

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

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 8

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

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 9

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 3

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

where

q = critical heat transfer rate, 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.

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