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EXPERIMENTAL PROGRAM

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U.S.-EURATOM EXCHANGE

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Atomic Energy Division
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

Experimental Program

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PREFACE

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

The program includes experimental and analytical investigations to determine how nonuniformly distributed heat flux along lengths of tubular and annular channels affects the onset of burnout (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.

SUMMARY

Since the beginning of the program, complete sets of data have been obtained on four tubular test sections. One had uniform flux to serve as a reference condition, and three had nonuniform axial heat flux to show the effect of flux distribution on critical heat flux conditions. These data were compared with those of other investigators where comparable data were available. Empirical correlations were developed to express mathematically the effects of the various operating variables on critical heat flux. Comparison of the data with published burnout correlations revealed the need for improved correlations.

The work during the previous report period included initial sets of data from two annular test sections. In the first case the inside surface was heated, and in the second case the outside surface was heated. During this quarter the data from these two annular test sections have been completed; they are tabulated in this report. These data have been reviewed, and a preliminary analysis is presented. For the same conditions of pressure, mass velocity, and inlet temperature, the annular test sections with one surface heated produce critical heat fluxes that are higher than those in the tubular test sections.

SCOPE

A serious design problem still facing the reactor designer is the phenomenon called burnout (critical heat flux). Although considerable attention has been given to this problem in recent years, the predictability of the occurrence of burnout conditions is still quite uncertain. In fact, there is still much disagreement as to how the channel geometry and operating conditions affect burnout.

In an effort to clarify some of the areas of disagreement, Babcock & Wilcox, as part of the Joint U. S. - Euratom Research and Development Program, is conducting an experimental and analytical program to determine how nonuniform heat generation rates in tubular and annular flow channels affect the operating conditions causing 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 scope of the experimental program includes data taken on tubular test sections with these conditions:

<u>Axial flux shape</u>	<u>Pressure, psia</u>	<u>Mass velocity, lb./hr-ft² × 10⁻⁶</u>	<u>Inlet subcooling, F</u>
Uniform	2000	0.5	20
Peak near inlet	1500	1.5	50
Peak near midpoint	1000	2.5	100
Peak near outlet	--	--	150

In addition, corresponding data will be taken on five annular test sections involving uniform and cosine axial flux shapes.

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1. INTRODUCTION

Nuclear reactors and modern boilers require more and more knowledge about the limitations on the transfer rates of heat from channel walls to flowing liquids. Burnout (departure from nucleate boiling, or critical heat flux) is a serious design problem still facing the reactor designer. As a result of this phenomenon, the heat transfer conductance is reduced considerably, causing the metal and fuel temperatures to rise and initiate failure of the fuel element. Although considerable attention has been given to this problem in recent years, the predictability of the occurrence of burnout conditions is quite uncertain. In fact, there is still much disagreement as to how the 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, is conducting an experimental and analytical program to determine the effects of nonuniform heat generation rates in tubular and annular flow channels on the operating conditions causing 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, which was discussed in the first quarterly report, is being conducted on a heat transfer facility at B&W's Research Center in Alliance, Ohio.¹ The controlled variables for the tests are pressure, inlet subcooling, and mass velocity. The tests are being performed in 6-foot-long tubular and annular test sections having both uniform and nonuniform axial heat flux distributions. The Atomic Energy Division in Lynchburg, Virginia, is conducting the analytical program.

Fabrication progress on both tubular and annular test sections, along with experimental work and data analysis on the tubular test sections, has been reported previously.²⁻⁸ Here the annular data, a review of these data, and a discussion of the annular experimental work are presented.

Because the original contract period had ended, and funds for its extension were not available before the start of the tenth quarter, the work level in this period was reduced considerably. Work during the ninth quarter was limited to completion and brief analysis of the data on test sections 5 and 6 and fabrication of parts of test sections 8 and 9.

2. EXPERIMENTAL EQUIPMENT

The principal geometric features of the uniform annular test sections are measured as follows:

OD (inside tube), inches	0.607
ID (outside tube), inches	1.053
Heated length, inches	72

Reference 8, the previous quarterly report, includes design and instrumentation details.

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3. EXPERIMENTAL OPERATION

3.1. Test Sections 5 and 6

The previous quarterly report includes descriptions of the experimental procedures used to obtain data from test sections 5 and 6.⁸

3.2. Test Section 7

3.2.1. Power Control Tests

The results of these tests have proved that one power control unit can heat both the inner and outer tubes. The method is illustrated below.

Power Control System

The schematic shows variable resistances (R_1 and R_2) in series with the control windings of saturable reactors No. 1 (SR-1) and No. 2 (SR-2), respectively. The control currents to both saturable reactors can be varied by changing the values of R_1 and R_2 ; a previous method used only one resistance (R_2) in changing the control current to SR-2. The values of R_2 and R_1 ultimately control the voltage (power) being supplied independently to the inner and outer tubes through two d-c power supplies (saturable reactor-transformer sets).

3.2.2. Heating Tests

The results of these tests are illustrated graphically in Figure 1, which shows how the heat input rate for both tubes can be varied over the control range at test section pressures of 1000 and 2000 psia. The control adjustments shown in the figure were accomplished by changing the values of resistances R_1 and R_2 .

1. Three control adjustments were made at 45, 55, and 75% of the control range in order to match the inner and outer tube heat input rates.
2. Further control adjustments could improve the agreement between the inner and outer heat input rates, but the agreement is considered adequate with those indicated.
3. Both the inner and outer tube heat rates depart from linearity at values below 25% of the control range; this indicates that good automatic control can be achieved to minimum heat input rates of 50,000 Btu/hr-sq ft. If these low heat fluxes are required, a control adjustment would be required at 25% to match the inner and outer tubes at both pressures.

Figure 1. Heat Input Rate Characteristics, Test Section 7

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4. EXPERIMENTAL DATA

4.1. Data Evaluation

The inner tube of the annulus is centered by eight sets of three spacer pins located at 18-inch intervals along the length of the test section. The pins are spaced at 120-degree intervals around the circumference of the tube. Figure 36 in the eighth quarterly report is a detailed drawing showing the installation of the pins.⁸ It was noted in that report that we were in the process of changing from "Al-Si-Mag" to "Lucalox" spacer pins. The "Lucalox" pins were installed on June 21, 1965, and inspected at various times during test runs on test sections 5 and 6. The results of these inspections showed little evidence of steam erosion; however, on three occasions (June 28, July 12, and July 26) as many as 3 pins out of 24 were found to be broken. Since most of the broken pins were near the test section inlet (one broken pin was discovered at a point 27 inches from the outlet), it is assumed that the broken pins did not affect the data presented in Tables 1 through 18. All of the data have been plotted to check their consistency, and those suspected of error have been rerun.

The results from test sections 5 and 6 are given in Tables 1 through 8 and 9 through 18, respectively. The tabular format is consistent with that presented in the eighth quarterly report.

The data tabulated in Tables 1 through 8 (test section 5) have been plotted at pressures of 1000, 1500, and 2000 psia in Figures 2 through 7. The data tabulated in Tables 9 through 18 (test section 6) have been plotted at pressures of 1000, 1500, 2000, and 2200 psia in Figures 8 through 15.

Run numbers 434 through 453 (test section 6) were included in the eighth quarterly report; however, they have been deleted from the tables herein because they are suspect to error from spacer pin failures. These

run numbers have been replaced with new data and run numbers as shown in the tabulation below:

<u>Eighth Quarterly Report</u>	<u>Ninth Quarterly Report</u>
<u>Old run numbers</u>	<u>New run numbers</u>
434, 435, 436, 437	500, 501, 513, ---
438, 439, 440, 441	516, 519, ---, 505
442, 443, 444, 445	504, 512, 506, 509
446, 447, 448, 449	---, 510, 521, 460
450, 451, 452, 453	524, 532, 533, 545

4.2. Parametric Effects

4.2.1. Effects of Subcooling

Figures 2, 3, and 4 (test section 5) and Figures 8, 9, and 10 (test section 6) show the effect of inlet subcooling on the average heat input rate at pressures of 1000, 1500, and 2000 psia. Additional (check) data were obtained for test section 6 at 2200 psia (Figure 11). The figures are plots of the data at mass velocities ranging from 0.5×10^6 to 2.5×10^6 lb/hr-sq ft. The lines shown on the plots were obtained from a modified form of the BAW-168 equation:^{9,10}

$$\phi = C_1 \left(\frac{G}{C_2} \right)^{C_3 + C_4 \Delta T_{sc} + C_5 (\Delta T_{sc})^2}$$

where

ϕ = the average heat input rate
 ΔT_{sc} = the inlet subcooled temperature

The constants for the equation were determined from the data by regression analysis and are tabulated in Table 19. As shown in Table 19, two sets of constants were required to correlate the data presented in Figures 2, 9, and 11; single sets of constants were required to correlate the data presented in Figures 3, 4, 8, and 10. The following observations can be made in Figures 2, 3, and 8:

1. The data lies below the line predicted by the equation (above) in Figures 3 and 8 at 0.5×10^6 lb/hr-sq ft.^{9,10}
2. Unexplained scatter exists in Figures 2 and 8 at the same mass velocity.

A possible explanation for both observations is that the data lies in a transition region between two flow regimes; this subject is treated more fully in sections 4.2.2 and 4.2.3.

4.2.2. Effects of Mass Velocity

Figures 5, 6, and 7 (test section 5) and Figures 12 through 15 (test section 6) show the effect of mass velocity on the average heat input rate at the same pressures and at inlet subcooled temperatures ranging from 0 to 150 F. The modified form of the BAW-168 equation that was used to correlate the data for the effects of inlet subcooling was also used to correlate the data for the figures that show the effects of mass velocity.^{9,10} As shown in Table 19, two flow regimes (two ranges of mass velocity) have been identified for Figures 5, 13, and 15; a single flow regime (one range of mass velocity) has been identified for Figures 6, 7, 12, and 14. The flow regimes are arbitrarily called "low", "middle", or "high" for the range of mass velocity tabulated. In most cases the "transition" region between flow regimes is difficult to identify. For example, the tabulation in Table 19 for Figure 12 shows the existence of one flow regime (the middle); however, an examination of the figure itself reveals the apparent existence of two flow regimes at a break point in mass velocity of 1×10^6 lb/hr-sq ft. The data plotted at mass velocities less than 1×10^6 lb/hr-sq ft are assumed to lie in the transition region of the middle flow regime. The transition region has not been identified in Table 19; it has been assumed to exist as shown by the dashed lines on all the figures except Figures 14 and 15.

The data shown in all the figures of this mass velocity study have been corrected for deviations from nominal inlet subcoolings; the following equation was used in these corrections:

$$\phi(\text{corrected}) = \phi_E - (\phi_{EC} - \phi_{TC})$$

where

- ϕ_E = experimental average heat input rate
- ϕ_{EC} = average heat input rate computed from the modified form of the BAW-168 equation^{9,10} at the actual G and actual ΔT_{sc} (See Table 19.)
- ϕ_{TC} = same computation as above except average heat input rate is computed at actual G and nominal ΔT_{sc}

4.2.3. Effect of Pressure

Figures 16 and 17 (for test sections 5 and 6) show the effect of pressure when it is plotted on the basis of mass velocity at a constant inlet temperature. A constant inlet temperature of 540 F was chosen because of the availability of the data at pressures of 1000, 1500, and 2000 psia. Both pressure and flow regimes appear to affect the trends of the data as shown in the two figures. General conclusions cannot be drawn from the figures because the transition region between the flow regimes is not readily distinguishable. However, the curves do show some trends which could serve as the basis for future study at other constant inlet temperatures. The conclusions drawn depend heavily on the way the data is plotted:

1. In Figure 16 (test section 5), it appears that the data at mass velocities greater than 1.5×10^6 lie in the transition region. The effect of the flow regimes becomes significant as evidenced by the divergence in the lines of constant pressure. The data at constant pressures of 1500 and 2000 psi appear to be colinear at mass velocities less than 1×10^6 lb/hr-sq.ft.
2. In Figure 17 (test section 6), it is difficult to identify the transition regions because the lines of constant pressure show little evidence of abrupt changes in slope.

NOMENCLATURE

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

Table 1. Data Summary Sheet, Test Section 5

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^6$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_{i0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{ij}}{10^6}$	$\frac{\phi_i}{10^6}$
346		03-12-65	11:12	1005		.514	95.5	INLET	7.5	533.7	-1.46	3.1				
								1	2.3	540.3	-.44	3.1			.347	.347
								2	.0	553.6	1.60	4.1			.344	.347
								3	.0	566.5	3.60	5.3			.345	.344
								4	.0	579.5	5.61	6.5			.345	.343
								5	.0	592.6	7.63	7.7			.342	.343
								6	.0	605.7	9.64	8.9			.341	.342
								7	.0	619.1	11.71	10.1			.340	.344
								8	.0	632.1	13.71	11.3			.341	.343
								9	.0	645.8	15.84	12.6			.340	.345
								10	.0	659.2	17.90	13.9			.341	.346
								11	.0	671.5	19.79	15.0			.342	.343
								12	.0	684.3	21.76	16.2			.336	.343
								EXIT	.0	690.7	22.75	16.8				.342
347		3-12-65	12:29	1010		.523	111.9	INLET	3.1	540.0	-.60	3.1				
	I							12	.0	713.5	26.20	19.1			.393	.401
	I							EXIT	.0	720.9	27.34	19.8				.401
348		3-12-65	13:01	990		.499	111.2	INLET	1.7	538.8	-.31	3.0				
	I							12	.0	719.4	27.41	19.3			.394	.399
	I							EXIT	.0	727.2	28.60	20.0				.399
349		3-12-65	14:40	1026		.504	114.1	INLET	35.9	501.9	-6.60	2.9				
								12	.0	685.3	21.57	15.5			.401	.409
								EXIT	.0	693.2	22.78	16.2				.409
350		3-12-65	15:05	1010		.513	131.2	INLET	30.4	506.2	-5.82	3.0				
	I							12	.0	713.7	26.23	18.7			.460	.470
	I							EXIT	.0	722.6	27.59	19.5				.470
351		3-15-65	11:33	995		.514	145.3	INLET	77.7	448.8	-14.27	2.8				
	I							12	.0	676.1	20.98	15.9			.508	.521
	I							EXIT	.0	687.8	22.48	16.8				.520
352		3-15-65	13:26	998		.522	158.4	INLET	125.4	396.3	-22.44	2.7				
								12	.0	642.6	15.47	12.7			.547	.568
								EXIT	.0	652.9	17.06	13.6				.567
353		3-15-65	14:21	1000		.534	164.6	INLET	125.8	396.1	-22.53	2.8				
								12	.0	646.1	15.68	13.2			.569	.590
								EXIT	.0	656.6	17.59	14.3				.589
354		3-15-65	14:36	1000		.535	170.9	INLET	125.9	396.0	-22.54	2.8				
								12	.0	654.9	17.33	14.1			.591	.613
								EXIT	.0	665.6	19.00	15.2				.612
355		3-15-65	14:51	1000		.528	179.7	INLET	125.5	396.5	-22.47	2.8				
	I							12	.0	672.5	20.03	15.6			.622	.645
	I							EXIT	.0	684.1	21.82	16.7				.644

Table 2. Data Summary Sheet, Test Section 5

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
356		3-16-65	14120	1005	4.67	1.477	200.5	INLET	11.3	528.9	-2.19	8.7				
	I							10	.0	620.0	11.85	26.4			.718	.720
	I							11	.0	629.3	13.28	31.8			.718	.717
	I							12	.0	639.1	14.80	34.5			.690	.719
	I							EXIT	.0	643.7	15.51	35.7				.718
357		3-16-65	15123	1008	3.87	1.483	227.2	INLET	36.9	496.0	-7.03	8.5				
	I							12	.0	622.3	12.14	29.9			.784	.815
	I							EXIT	.0	627.5	12.94	31.3				.813
358		3-17-65	13101	1005		.498	145.5	INLET	77.2	450.7	-14.26	2.7				
	I							12	.0	667.5	22.27	16.0			.502	.922
	I							EXIT	.0	697.4	23.79	16.9				.921
359		3-18-64	09115	1495		.487	91.2	INLET	10.0	596.8	-2.54	3.1				
	I							12	.0	749.0	24.77	11.7			.316	.328
	I							EXIT	.0	755.3	25.91	12.1				.327
360		3-18-65	10117	1500		.511	109.4	INLET	35.2	563.5	-8.64	3.1				
	I							12	.0	737.1	22.55	11.4			.378	.392
	I							EXIT	.0	744.3	23.86	11.9				.392
361		3-18-64	11127	1490		.512	132.7	INLET	80.2	505.7	-18.75	2.9				
	I							12	.0	715.9	18.91	10.2			.457	.476
	I							EXIT	.0	724.6	20.48	10.8				.475
362		3-18-65	12158	1500		.513	158.9	INLET	127.1	452.1	-28.68	2.8				
	I							12	.0	703.5	16.52	9.3			.548	.570
	I							EXIT	.0	714.0	18.41	10.0				.569
363		3-18-65	14156	1500	2.22	1.512	142.0	INLET	18.5	585.7	-4.66	9.5				
	I							12	.0	661.9	9.04	19.5			.488	.510
	I							EXIT	.0	665.1	9.61	20.1				.509
364		3-18-65	15112	1495		1.509	150.9	INLET	17.1	587.0	-4.30	9.5				
	I							12	.0	668.1	10.26	20.8			.520	.541
	I							EXIT	.0	671.5	10.87	21.4				.540
365		3-19-65	10129	1500	1.88	1.497	179.6	INLET	40.7	556.2	-9.96	9.1				
	I							12	.0	653.5	7.54	17.7			.620	.644
	I							EXIT	.0	657.6	8.27	18.5				.643
366		3-19-65	13122	1503	1.31	1.490	216.8	INLET	89.8	495.5	-20.96	8.4				
	I							12	.0	613.5	.28	10.0			.749	.778
	I							EXIT	.0	618.5	1.17	11.0				.776
367		3-19-65	15136	1500	1.31	1.478	229.8	INLET	90.8	494.1	-21.13	8.4				
	I							12	.0	620.2	1.55	11.3			.792	.824
	I							EXIT	.0	625.5	2.50	12.2				.823
368		3-20-65	9144	1505	1.20	1.497	257.2	INLET	132.2	446.8	-29.79	8.1				
	I							12	18.6	566.2	-4.69	5.4			.884	.923
	I							EXIT	14.4	592.0	-3.64	9.5				.921
369		3-20-65	13135	2005	1.36	1.504	118.0	INLET	21.1	637.1	-7.60	10.1				
	I							12	.0	740.8	6.17	14.9			.407	.424
	I							EXIT	.0	703.5	6.74	15.3				.423

Table 3. Data Summary Sheet, Test Section 5

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$
370		3-22-65	13:47	2005	1.45	1.486	125.8	INLET	16.8	643.9	-6.13	10.1				
	I							12	.0	712.0	8.73	16.4			.434	.492
	I							EXIT	.0	715.5	9.35	16.8				.451
371		3-22-65	14:54	1995	1.22	1.501	151.4	INLET	40.9	606.8	-13.25	9.6				
	I							12	.0	608.6	3.77	13.3			.523	.543
	I							EXIT	.0	692.0	4.51	13.8				.542
372		3-23-65	8:56	2000	1.03	1.514	189.2	INLET	87.5	545.7	-27.19	9.0				
	I							12	14.5	647.1	-5.31	10.3			.652	.679
	I							EXIT	11.9	651.3	-4.40	10.4				.678
373		3-23-65	10:41	2000	.96	1.487	234.4	INLET	135.0	488.4	-39.56	8.3				
	I							12	34.7	616.2	-11.97	9.6			.809	.841
	I							EXIT	31.1	621.6	-10.81	9.7				.840
374		3-23-65	13:39	2005		.508	79.4	INLET	12.1	651.5	-4.49	3.5				
	I							12	.0	778.5	22.96	8.9			.274	.285
	I							EXIT	.0	783.8	24.11	9.1				.285
375		3-25-65	10:31	2000		.502	82.4	INLET	19.4	639.4	-6.97	3.4				
	I							12	.0	772.5	21.76	8.5			.285	.296
	I							EXIT	.0	778.1	22.97	8.8				.295
376		3-25-65	11:41	2000		.495	96.8	INLET	45.6	600.8	-15.31	3.1				
	I							12	.0	759.5	18.94	7.8			.334	.347
	I							EXIT	.0	766.1	20.38	8.1				.347
377		3-25-65	12:49	2005		.494	117.1	INLET	97.7	533.4	-30.03	2.9				
	I							12	.0	725.6	11.53	6.1			.404	.420
	I							EXIT	.0	733.6	13.27	6.5				.419
378		3-25-65	14:56	2005		.508	141.2	INLET	149.0	472.6	-43.17	2.8				
	I							12	.0	696.3	5.62	4.9			.489	.507
	I							EXIT	.0	707.8	7.67	5.4				.506
379		3-26-65	10:16	2000	3.83	2.467	174.0	INLET	32.1	620.1	-11.14	16.1				
								1	30.5	622.5	-10.61	16.2			.621	.621
								2	27.1	627.6	-9.52	16.3			.627	.629
								3	23.8	632.5	-8.46	16.4			.631	.625
								4	20.6	637.5	-7.38	16.6			.626	.625
								5	17.3	642.6	-6.29	16.7			.625	.627
								6	14.2	647.5	-5.21	16.8			.621	.627
								7	11.2	652.5	-4.15	17.0			.623	.626
								8	8.2	657.5	-3.05	17.2			.623	.627
								9	5.3	662.5	-1.99	17.3			.625	.626
								10	2.5	667.5	-.92	17.4			.625	.626
								11	.0	672.4	.15	17.8			.625	.626
	I							12	.0	677.3	1.20	18.9			.600	.624
	I							EXIT	.0	679.7	1.72	19.5				.623
380		3-26-65	11:50	2005	4.26	2.399	153.8	INLET	18.8	640.8	-6.82	16.2				
	I							12	.0	692.6	4.43	21.9			.533	.552
	I							EXIT	.0	695.0	4.91	22.4				.551

Table 4. Data Summary Sheet, Test Section 5

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	X	V_m	$\frac{\phi_{10}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{11}}{10^6}$	$\frac{\phi_i}{10^6}$
381		3-26-65	12:59	1995	3.69	2.464	196.3	INLET	47.0	598.4	-15.66	15.6				
	I							12	4.8	663.0	-1.76	17.3			.678	.704
	I							EXIT	3.3	665.7	-1.18	17.4				.703
382		3-26-65	14:22	2000	3.71	2.522	286.4	INLET	97.7	533.0	-29.93	14.8				
	I							12	28.7	625.1	-10.05	16.6			.989	1.027
	I							EXIT	26.1	629.0	-9.22	16.7				1.025
383		3-26-65	15:36	1995	.93	1.505	248.2	INLET	159.5	460.0	-45.48	8.2				
	I							12	50.4	593.6	-16.66	9.5			.857	.890
	I							EXIT	46.3	599.4	-15.46	9.6				.889
384		3-29-65	11:58	1003	2.26	1.489	293.4	INLET	106.1	415.9	-19.57	7.9				
	I							12	.0	575.8	5.08	17.8			1.002	1.053
	I							EXIT	.0	582.5	6.10	19.6				1.051
385		3-29-65	15:25	1005		.503	177.9	INLET	152.2	368.3	-26.97	2.6				
	I							12	.0	655.5	17.33	13.2			.609	.636
	I							EXIT	.0	667.4	19.16	14.3				.637
386		4-21-65	13:53	1015	8.30	2.450	197.7	INLET	16.8	523.5	-3.27	14.4				
								1	14.5	526.4	-2.83	14.4			.699	.699
								2	10.1	532.0	-1.97	14.5			.706	.698
								3	5.7	537.5	-1.11	14.6			.706	.697
								4	1.6	543.3	-.21	14.7			.706	.703
								5	.0	549.0	.66	16.6			.708	.704
								6	.0	554.5	1.51	19.0			.704	.700
								7	.0	560.3	2.42	21.6			.706	.705
								8	.0	565.9	3.28	24.0			.707	.703
								9	.0	571.5	4.14	26.5			.706	.702
								10	.0	577.4	5.06	29.1			.704	.706
								11	.0	583.0	5.93	31.6			.706	.706
								12	.0	589.0	6.85	34.2			.691	.709
								EXIT	.0	591.8	7.28	35.4				.708
387		4-21-65	14:09	1000	8.86	2.419	205.0	INLET	15.5	522.9	-3.00	14.2				
								12	.0	591.6	7.58	36.1			.719	.735
								EXIT	.0	594.5	8.03	37.4				.734
388		4-21-65	14:32	1000	9.35	2.441	216.9	INLET	13.9	524.9	-2.69	14.4				
	I							8	.0	571.9	4.54	27.7			.780	.776
								9	.0	578.1	5.50	30.5			.780	.777
								10	.0	584.4	6.47	33.3			.777	.777
								11	.0	590.7	7.44	36.0			.777	.778
								12	.0	597.0	8.40	38.8			.762	.777
								EXIT	.0	600.0	8.87	40.2				.777
389		6-08-65	12:57	1010		.533	127.2	INLET	29.1	507.8	-5.58	3.1				
	I							12	.0	701.2	24.30	18.3			.451	.456
	I							EXIT	.0	709.6	25.58	19.1				.456
390		6-08-65	14:29	1005	.88	.816	171.2	INLET	35.9	498.8	-6.83	4.7				
	I							12	.0	668.9	19.38	23.4			.607	.613
	I							EXIT	.0	676.2	20.51	24.5				.613

Table 5. Data Summary Sheet, Test Section 5

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,i}}{10^6}$	$\frac{\phi_i}{10^6}$
391		6-08-65	15:34	995	1.90	1.021	200.5	INLET	41.4	490.8	-7.81	5.8				
	I							12	.0	649.9	16.65	26.3			.718	.718
	I							EXIT	.0	656.8	17.71	27.5				.718
392		6-08-65	16:44	995	4.17	1.493	221.2	INLET	31.7	502.5	-6.02	8.6				
	I							12	.0	622.6	12.45	31.0			.786	.792
	I							EXIT	.0	627.8	13.24	32.4				.792
393		6-09-65	11:26	997		.517	128.6	INLET	55.5	474.5	-10.37	2.9				
								1	48.1	483.1	-9.05	2.9			.451	.451
								2	33.4	500.7	-6.34	3.0			.462	.460
								3	19.1	518.1	-3.67	3.0			.462	.458
								4	5.0	535.6	-.98	3.1			.461	.459
								5	.0	553.5	1.78	4.2			.460	.461
								6	.0	570.5	4.39	5.8			.464	.459
								7	.0	588.4	7.14	7.5			.462	.461
								8	.0	606.2	9.90	9.1			.462	.462
								9	.0	623.7	12.58	10.8			.462	.462
								10	.0	642.4	15.46	12.5			.461	.465
								11	.0	660.3	18.21	14.2			.464	.465
								12	.0	676.2	20.66	15.7			.455	.461
								EXIT	.0	684.9	21.99	16.5				.461
394		6-09-65	11:44	1005		.529	137.3	INLET	55.3	475.8	-10.39	3.0				
	I							12	.0	685.9	22.02	16.4			.484	.492
	I							EXIT	.0	695.0	23.41	17.7				.492
395		6-09-65	13:01	1003	.72	.798	182.4	INLET	59.0	471.4	-11.02	4.4				
	I							12	.0	656.5	17.52	21.2			.644	.654
	I							EXIT	.0	664.5	18.75	22.4				.653
396		6-09-65	13:43	1015	1.36	.991	211.6	INLET	64.1	467.1	-12.00	5.5				
	I							12	.0	640.2	14.78	22.9			.732	.759
	I							EXIT	.0	647.5	15.90	24.2				.758
397		6-09-65	14:56	1005	2.70	1.483	227.7	INLET	64.1	465.8	-11.93	8.2				
								12	.0	590.4	7.29	21.6			.782	.817
								EXIT	.0	595.6	8.09	22.9				.816
398		6-09-65	15:15	1013	3.13	1.479	248.3	INLET	61.9	469.3	-11.60	8.2				
	I							12	.0	605.5	9.45	25.1			.856	.891
	I							EXIT	.0	611.2	10.33	26.6				.890
399		6-09-65	16:02	995	4.64	1.971	268.4	INLET	60.0	469.0	-11.16	11.0				
	I							12	.0	579.5	5.82	25.4			.923	.963
	I							EXIT	.0	584.1	6.53	27.1				.961
400		6-09-65	17:20	995	6.52	2.419	263.3	INLET	46.2	485.0	-8.70	13.4				
	I							11	.0	565.7	3.70	25.1			.933	.945
								12	.0	573.4	4.68	28.5			.902	.945
								EXIT	.0	577.0	5.45	30.1				.943
401		06-10-65	14:18	1000		.531	128.4	INLET	101.8	422.5	-18.47	2.8				
								12	.0	618.6	11.74	10.5			.441	.461
								EXIT	.0	626.8	12.59	11.3				.460

Table 6. Data Summary Sheet, Test Section 5

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
402		06-10-65	14:33	1000		.522	157.5	INLET	95.7	429.2	-17.42	2.8				
	I							12	.0	674.2	20.30	15.6			.543	.565
	I							EXIT	.0	684.5	21.88	16.4				.564
403		06-11-65	09:25	1005	.43	.808	211.4	INLET	95.1	430.6	-17.36	4.3				
	I							12	.0	642.8	15.37	15.4			.734	.758
	I							EXIT	.0	651.8	16.75	20.7				.757
404		06-11-65	10:34	1005	1.18	1.007	241.8	INLET	98.6	426.6	-17.97	5.4				
	I							12	.0	621.5	12.08	20.3			.834	.867
	I							EXIT	.0	629.7	13.34	21.8				.866
405		06-11-65	13:12	993	3.01	1.930	297.2	INLET	95.2	428.9	-17.28	10.4				
	I							11	.0	543.0	.25	12.1			1.056	1.066
								12	.0	553.8	1.92	16.0			1.025	1.066
								EXIT	.0	559.0	2.72	17.8				1.064
406		06-11-65	14:38	990	4.14	2.480	318.7	INLET	101.2	421.8	-18.28	13.7				
	I							11	19.4	516.7	-3.70	14.4			1.147	1.140
								12	11.8	526.0	-2.28	14.6			1.111	1.143
								EXIT	8.3	530.4	-1.60	14.7				1.141
407		06-11-65	16:36	1000	2.45	1.480	282.5	INLET	100.6	423.8	-18.27	7.9				
	I							12	.0	578.5	5.55	18.6			1.000	1.012
	I							EXIT	.0	585.1	6.98	20.3				1.012
408		06-14-65	09:34	1502		.516	96.2	INLET	19.2	585.0	-4.82	3.2				
	I							12	.0	736.0	22.32	11.5			.340	.345
	I							EXIT	.0	742.4	23.49	11.9				.345
409		06-14-65	10:42	1502		.710	117.1	INLET	21.6	581.8	-5.41	4.4				
	I							12	.0	715.4	18.63	13.9			.416	.420
	I							EXIT	.0	721.2	19.66	14.4				.420
410		06-14-65	11:46	1510	.59	1.007	140.5	INLET	26.2	576.5	-6.55	6.3				
	I							12	.0	689.7	13.85	16.3			.492	.504
	I							EXIT	.0	694.5	14.72	16.9				.503
411		06-14-65	12:50	1502	.57	1.018	169.1	INLET	54.7	538.6	-13.17	6.1				
	I							12	.0	673.3	11.05	14.5			.601	.606
	I							EXIT	.0	679.1	12.09	15.3				.606
412		06-14-65	13:57	1500		.722	139.1	INLET	47.3	547.8	-11.47	4.3				
	I							12	.0	704.1	16.62	13.1			.493	.499
	I							EXIT	.0	710.8	17.83	13.8				.498
413		06-14-65	15:05	1498		.528	115.2	INLET	50.0	544.1	-12.08	3.2				
	I							12	.0	720.8	19.67	10.8			.410	.413
	I							EXIT	.0	728.5	21.04	11.3				.413
414		06-14-65	16:10	1500		.505	137.3	INLET	98.8	484.5	-22.84	2.8				
	I							12	.0	705.0	14.79	9.3			.485	.492
	I							EXIT	.0	714.4	16.49	9.9				.492
415		06-14-65	17:00	1515		.699	170.0	INLET	97.6	487.4	-22.77	3.9				
	I							12	.0	684.4	17.82	10.8			.404	.609
	I							EXIT	.0	692.9	14.35	11.5				.609

Table 7. Data Summary Sheet, Test Section 5

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i1}}{10^6}$	$\frac{\phi_i}{10^6}$
416		06-15-65	09:24	1497	3.53	1.975	163.7	INLET	18.4	585.6	-4.61	12.4				
	I							12	.0	652.7	7.45	23.3			.580	.587
	I							EXIT	.0	655.6	7.57	24.0				.586
417		06-15-65	10:34	1495	5.25	2.517	184.8	INLET	24.3	577.4	-6.03	15.7				
	I							12	.0	636.8	4.65	24.7			.656	.662
	I							EXIT	.0	639.4	5.11	25.5				.662
418		06-15-65	11:38	1510	4.37	2.498	228.5	INLET	49.8	545.7	-12.12	15.0				
	I							12	.0	619.7	1.24	18.5			.820	.818
	I							EXIT	.0	623.0	1.83	19.5				.818
419		06-15-65	14:46	1495	3.03	2.032	204.6	INLET	49.4	544.5	-11.53	12.2				
	I							12	.0	626.1	2.71	17.1			.732	.733
	I							EXIT	.0	629.6	3.34	18.0				.733
472		06-15-65	15:51	1492	2.38	2.023	262.2	INLET	97.9	484.7	-22.57	11.3				
	I							12	14.9	589.7	-3.75	12.8			.934	.939
	I							EXIT	11.6	594.2	-2.93	12.9				.939
473		06-15-65	16:47	1495	3.81	2.485	296.4	INLET	97.9	485.1	-22.59	13.9				
	I							12	21.0	581.7	-5.24	15.6			1.053	1.062
	I							EXIT	17.9	585.9	-4.49	15.7				1.061
475		06-16-65	13:27	1493		.501	179.1	INLET	143.8	432.7	-31.92	2.7				
	I							12	.0	722.5	20.05	10.4			.639	.642
	I							EXIT	.0	735.1	22.30	11.2				.641
476		06-16-65	14:39	1500		.691	204.3	INLET	147.4	429.4	-32.75	3.7				
	I							12	.0	669.0	10.32	9.5			.725	.732
	I							EXIT	.0	679.3	12.17	10.4				.732
477		06-16-65	16:29	1495	.38	1.026	240.7	INLET	152.5	423.2	-33.69	5.5				
	I							12	.0	613.4	.43	7.0			.852	.862
	I							EXIT	.0	621.5	1.90	8.1				.862
478		06-17-65	09:11	1490	1.19	1.480	268.4	INLET	141.1	435.3	-31.25	7.9				
	I							12	20.2	582.2	-5.03	9.3			.961	.961
	I							EXIT	15.5	588.6	-3.89	9.4				.961
479		06-17-65	09:44	1490	1.25	1.494	262.6	INLET	127.4	450.7	-28.59	8.1				
	I							12	12.3	593.1	-3.09	9.5			.937	.940
	I							EXIT	7.9	599.2	-1.98	9.6				.940
480		06-17-65	10:28	1508	2.23	2.010	300.6	INLET	128.5	451.3	-29.07	10.9				
	I							12	29.0	572.5	-7.23	12.4			1.068	1.077
	I							EXIT	25.1	577.7	-6.28	12.5				1.076
481		06-17-65	11:02	1505	3.53	2.485	337.2	INLET	131.9	447.2	-29.71	13.5				
	I							12	40.5	557.1	-9.92	15.1			1.199	1.208
	I							EXIT	36.8	561.9	-9.06	15.2				1.207
482		06-17-65	13:00	2005	.90	1.476	197.0	INLET	96.3	535.2	-29.64	8.7				
	I							12	17.1	643.4	-6.25	10.0			.701	.706
	I							EXIT	14.2	648.1	-5.24	10.1				.706

Table 8. Data Summary Sheet, Test Section 5

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_{o,o}}{10^6}$	$\frac{\phi_{i,l}}{10^6}$	$\frac{\phi_{o,l}}{10^6}$
483		06-17-65	13:48	2007	.05	1.008	165.1	INLET	97.2	534.3	-29.91	9.9				
	I							11	10.0	695.3	-3.73	7.0			.596	.591
								12	3.2	667.0	-1.20	7.1			.590	.591
								EXIT	.0	672.7	.05	7.2				.591
484		06-17-65	14:53	1990		.697	145.7	INLET	93.2	537.8	-28.54	4.1				
	I							12	.0	707.0	7.85	7.5			.522	.522
	I							EXIT	.0	714.4	9.43	8.0				.522
485		06-17-65	16:20	1993		.701	117.8	INLET	49.3	595.1	-16.31	4.4				
	I							12	.0	731.3	12.99	9.1			.419	.422
	I							EXIT	.0	737.1	14.26	9.5				.422
486		06-17-65	17:11	2003		.991	137.6	INLET	50.6	594.1	-16.83	6.2				
	I							11	.0	696.6	5.30	9.4			.497	.492
	I							12	.0	706.6	7.47	10.4			.492	.493
	I							EXIT	.0	711.5	8.53	10.9				.493
487		06-18-65	09:38	2010		.701	99.0	INLET	23.5	634.1	-8.40	4.7				
	I							12	.0	748.5	16.38	10.1			.352	.355
	I							EXIT	.0	753.4	17.45	10.5				.355
488		06-18-65	10:21	2005	.16	1.011	113.5	INLET	24.0	632.8	-8.53	6.7				
	I							12	.0	723.8	11.14	12.3			.403	.407
	I							EXIT	.0	727.7	11.99	12.7				.407
489		06-18-65	11:54	2005	2.55	1.996	124.6	INLET	22.1	635.6	-7.92	13.3				
								12	.0	686.2	3.02	17.0			.444	.447
								EXIT	.0	688.4	3.49	17.4				.447
490		06-18-65	12:10	2013	2.68	1.983	150.0	INLET	24.2	633.3	-8.67	13.2				
	I							12	.0	694.6	4.64	18.3			.533	.538
	I							EXIT	.0	697.2	5.21	18.8				.538
491		06-18-65	13:40	2010	2.22	2.010	182.6	INLET	49.3	596.7	-16.51	12.7				
	I							11	5.2	663.8	-1.96	14.1			.654	.653
	I							12	1.5	670.3	-.55	14.3			.650	.654
	I							EXIT	.0	673.5	.13	14.5				.654

Table 9. Data Summary Sheet, Test Section 6

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	X	V_m	$\frac{\phi_{i0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i1}}{10^6}$	$\frac{\phi_{i2}}{10^6}$
420		4-26-65	10:23	1000	.75	.513	224.0	INLET	24.4	512.1	-4.67	3.0				
								1	12.4	526.8	-2.40	3.0	.444	.444		
								2	.0	556.9	2.24	4.4	.450	.449		
								3	.0	567.7	6.98	7.3	.467	.465		
								4	.0	618.9	11.79	10.2	.470	.459		
								5	.0	648.5	16.34	12.9	.444	.455		
								6	.0	678.8	21.01	15.8	.472	.455		
								7	.0	710.9	25.95	18.7	.474	.460		
								8	.0	741.4	30.64	21.6	.446	.459		
								9	.0	772.7	35.47	24.5	.470	.461		
								10	.0	805.7	40.54	27.6	.472	.444		
								11	.0	835.2	45.09	30.3	.446	.462		
								12	.0	866.5	49.90	33.2	.448	.463		
								EXIT	.0	881.4	52.20	34.6		.462		
421		4-26-65	12:10	1000	.68	.504	232.6	INLET	26.9	509.0	-5.15	2.9				
0								12	.0	883.1	52.47	34.2	.467	.481		
0								EXIT	.0	898.9	54.90	35.6		.480		
422		4-26-65	13:18	1000	.59	.494	243.0	INLET	48.1	483.6	-9.05	2.8				
0								12	.0	882.1	52.31	33.4	.488	.502		
0								EXIT	.0	898.9	54.90	34.9		.501		
423		4-26-65	14:14	1000	.66	.517	278.1	INLET	102.5	421.7	-18.59	2.8				
0								12	.0	858.0	48.49	32.7	.554	.575		
0								EXIT	.0	876.3	51.41	34.4		.574		
424		4-27-65	11:00	1010	6.75	1.479	324.9	INLET	24.7	513.2	-4.75	8.6				
								1	18.6	520.6	-3.60	8.7	.644	.644		
								2	6.4	535.8	-1.26	8.8	.656	.652		
								3	.0	551.0	1.10	10.8	.680	.656		
								4	.0	567.2	3.60	15.1	.681	.669		
								5	.0	582.4	5.95	19.1	.644	.667		
								6	.0	597.8	8.32	23.2	.681	.667		
								7	.0	613.9	10.81	27.5	.689	.671		
								8	.0	628.8	13.11	31.9	.646	.668		
								9	.0	644.9	15.60	35.8	.686	.671		
								10	.0	660.0	17.93	39.8	.688	.670		
								11	.0	675.5	20.33	43.9	.652	.670		
								12	.0	691.4	22.77	48.1	.652	.671		
								EXIT	.0	698.9	23.63	50.1		.671		
425		4-27-65	11:54	1005	5.82	1.454	346.0	INLET	46.4	486.3	-8.77	8.2				
0								12	.0	679.3	21.00	44.5	.695	.715		
0								EXIT	.0	687.5	22.25	46.6		.714		
426		4-27-65	12:58	995	4.71	1.472	405.0	INLET	94.9	429.5	-17.24	7.9				
0								12	.0	652.6	17.06	38.6	.814	.837		
0								EXIT	.0	662.0	18.51	41.1		.836		

Table 10. Data Summary Sheet, Test Section 6

RUN NO.	DNS	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_{i,2}}{10^6}$
427		4-27-65	14:09	1000	3.91	1.476	454.5	INLET	145.6	374.8	-25.81	7.6				
	0							12	.0	624.5	12.64	30.8	.916	.934		
	0							EXIT	.0	635.1	14.27	33.7		.938		
428		4-27-65	14:41	995	3.67	1.480	456.5	INLET	143.1	376.8	-25.34	7.4				
	0							12	.0	626.9	13.11	31.9	.918	.943		
	0							EXIT	.0	637.4	14.73	34.7		.942		
429		4-27-65	16:21	995	.27	.506	266.6	INLET	146.5	373.1	-25.51	2.6				
	0							12	.0	800.7	39.84	26.9	.537	.551		
	0							EXIT	.0	818.8	42.62	28.6		.550		
430		4-28-65	10:07	1010	11.26	2.362	357.3	INLET	27.4	509.9	-5.25	13.7				
	0							12	.0	632.6	13.69	51.9	.717	.738		
	0							EXIT	.0	637.8	14.49	54.1		.737		
431		4-28-65	11:00	1005	9.92	2.450	396.2	INLET	51.0	480.9	-9.61	13.8				
	0							12	.0	612.0	10.61	45.2	.798	.818		
	0							EXIT	.0	617.5	11.47	47.6		.817		
432		4-28-65	14:25	1000	6.39	2.424	458.0	INLET	99.9	424.6	-18.14	13.0				
	0							12	.0	577.7	5.44	30.1	.924	.946		
	0							EXIT	.0	584.2	6.44	32.9		.945		
433		4-28-65	15:25	993	4.89	2.510	515.5	INLET	145.2	374.2	-25.68	12.9				
	0							12	.9	540.8	-1.09	15.0	1.039	1.065		
	0							EXIT	.0	547.8	1.00	18.0		1.064		
434		5-11-65	15:42	1995		.497	112.5	INLET	24.6	630.8	-8.68	3.3				
	0							12	.0	614.6	30.89	10.5	.225	.232		
	0							EXIT	.0	622.3	32.56	10.9		.232		
435		5-11-65	12:41	2005	1.83	1.511	177.4	INLET	25.9	629.8	-9.19	10.0				
								1	23.4	633.7	-8.34	10.1	.350	.350		
								2	16.0	642.0	-6.54	10.2	.357	.362		
								3	13.0	650.1	-4.80	10.4	.379	.360		
								4	7.9	658.7	-2.94	10.5	.377	.366		
								5	3.2	666.8	-1.19	10.7	.352	.364		
								6	.0	674.3	.55	11.2	.378	.363		
								7	.0	683.5	2.42	12.4	.376	.366		
								8	.0	692.6	4.40	13.8	.351	.371		
								9	.0	700.2	6.03	14.9	.376	.367		
								10	.0	708.0	7.72	16.0	.377	.365		
								11	.0	717.9	9.86	17.5	.357	.372		
								12	.0	724.9	11.34	18.5	.358	.366		
								EXIT	.0	729.0	12.26	19.1		.366		
436		5-11-65	13:00	2005	1.95	1.500	199.1	INLET	24.7	631.5	-8.79	10.0				
	0							12	.0	739.3	14.49	20.5	.395	.411		
	0							EXIT	.0	743.8	15.47	21.1		.411		

Table 11. Data Summary Sheet, Test Section 6

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{10}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{11}}{10^6}$	$\frac{\phi_i}{10^6}$
457		5-11-65	14:14	2005	1.76	1.507	230.3	INLET	48.6	597.2	-34.24	5.5				
	0							12	.0	721.1	10.55	17.9	.463	.476		
	0							EXIT	.0	726.3	11.68	18.7		.475		
458		5-13-65	09:33	2000	1.22	1.508	287.8	INLET	98.6	531.9	-30.17	8.8				
	0							12	.0	686.7	3.24	13.1	.570	.595		
	0							EXIT	.0	693.2	4.63	13.9		.594		
459		5-13-65	10:36	2000	1.11	1.496	336.6	INLET	147.3	474.1	-42.63	8.3				
	0							12	8.8	656.5	-3.27	10.4	.683	.695		
	0							EXIT	4.3	664.3	-1.59	10.5		.695		
460		5-13-65	12:16	1997	3.51	2.474	489.1	INLET	147.6	473.6	-42.63	13.7				
	0							12	22.7	633.9	-8.08	16.5	.987	1.010		
	0							EXIT	18.3	640.7	-6.61	16.7		1.009		
461		5-13-65	14:22	2000	4.01	2.503	408.2	INLET	101.0	529.0	-30.80	14.4				
	0							11	12.7	650.0	-4.68	17.2	.820	.845		
	0							12	6.1	661.2	-2.26	17.5	.823	.843		
	0							EXIT	2.8	666.8	-1.05	17.7		.842		
462		5-13-65	16:11	2005	4.66	2.476	307.5	INLET	49.2	596.4	-16.42	15.7				
	0							11	.0	688.7	3.54	21.6	.613	.638		
								12	.0	697.1	5.37	23.7	.616	.635		
								EXIT	.0	701.4	6.29	24.7		.635		
463		05-14-65	09:35	2000	5.34	2.411	246.9	INLET	21.1	636.7	-7.95	16.2				
	0							12	.0	719.8	10.38	28.5	.494	.510		
	0							EXIT	.0	723.3	11.13	29.3		.510		
464		5-14-65	14:36	1005	9.63	2.417	391.6	INLET	48.8	483.4	-9.21	13.8				
	0							11	.0	603.8	9.35	41.0	.782	.812		
								12	.0	614.8	11.05	45.8	.787	.809		
								EXIT	.0	620.4	11.90	48.2		.808		
465		5-17-65	10:09	1010	.43	.505	269.3	INLET	99.1	426.8	-18.08	2.7				
								1	82.9	444.9	-15.29	2.7	.534	.534		
								2	51.4	481.1	-9.70	2.8	.543	.535		
								3	21.1	517.6	-4.07	2.9	.564	.537		
								4	.0	556.0	1.87	4.1	.566	.546		
								5	.0	593.7	7.68	7.6	.536	.548		
								6	.0	630.1	13.20	10.9	.570	.547		
								7	.0	669.6	19.41	14.4	.568	.552		
								8	.0	705.3	24.52	17.7	.539	.549		
								9	.0	744.9	31.04	21.3	.564	.553		
								10	.0	783.3	36.57	24.8	.567	.555		
								11	.0	822.9	43.09	28.4	.534	.558		
	0							12	.0	859.5	48.73	31.7	.537	.556		
	0							EXIT	.0	877.6	51.53	33.3		.556		

Table 12. Data Summary Sheet, Test Section 6

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_i}{10^6}$
466		5-17-65	11:21	1000	.59	.509	282.9	INLET	118.6	404.0	-21.31	2.7				
	0							12	.0	854.6	48.07	31.9	.972	.584		
	0							EXIT	.0	873.8	51.03	33.6		.584		
467		5-17-65	12:23	1000	.20	.486	266.6	INLET	146.6	373.7	-25.96	2.5				
	0							12	.0	818.2	42.48	27.3	.534	.551		
	0							EXIT	.0	837.0	45.36	28.9		.550		
468		5-17-65	13:44	1000	.27	.508	282.4	INLET	175.0	343.5	-30.64	2.6				
	0							12	.0	794.0	38.75	24.3	.559	.584		
	0							EXIT	.0	812.8	41.64	28.0		.583		
469		5-18-65	09:24	997	.86	.600	310.3	INLET	148.5	371.3	-26.26	3.1				
	0							12	.0	790.3	38.21	30.7	.625	.641		
	0							EXIT	.0	808.0	40.94	32.7		.640		
470		5-18-65	11:14	993	1.81	.795	363.9	INLET	145.7	373.7	-25.76	4.1				
	0							12	.0	745.0	31.29	34.3	.727	.752		
	0							EXIT	.0	760.6	33.69	36.6		.751		
471		5-18-65	11:59	990	2.70	.998	403.8	INLET	146.5	372.4	-25.85	9.1				
	0							12	.0	701.5	24.67	39.3	.752	.837		
	0							EXIT	.0	714.4	26.64	37.7		.833		
492		5-19-65	10:20	1000	4.24	1.003	304.8	INLET	26.0	510.1	-4.67	5.8				
	0							12	.0	756.6	32.98	49.0	.616	.629		
	0							EXIT	.0	767.1	34.60	46.9		.629		
493		5-19-65	11:59	1005	2.81	.797	282.9	INLET	22.9	514.6	-4.41	4.6				
	0							12	.0	802.4	39.98	42.1	.571	.584		
	0							EXIT	.0	814.7	41.27	43.9		.584		
494		5-19-65	12:29	1005	2.54	.801	304.8	INLET	48.6	483.6	-9.18	4.5				
	0							12	.0	792.4	38.43	40.9	.605	.630		
	0							EXIT	.0	805.3	40.42	42.7		.629		
495		5-19-65	13:17	1005	3.44	1.000	325.2	INLET	50.5	481.4	-9.52	5.6				
	0							12	.0	745.0	31.12	42.5	.657	.672		
	0							EXIT	.0	756.2	32.85	44.5		.671		
496		5-19-65	14:17	1005	3.19	.988	363.9	INLET	97.9	427.5	-17.84	9.3				
	0							12	.0	726.0	28.19	38.6	.735	.752		
	0							EXIT	.0	738.7	30.15	40.8		.751		
497		5-19-65	15:18	1000	2.31	.806	337.2	INLET	97.9	426.8	-17.80	4.3				
	0							12	.0	766.0	34.43	37.5	.691	.696		
	0							EXIT	.0	780.6	36.68	39.6		.696		

Table 13. Data Summary Sheet, Test Section 6

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_o}{10^6}$	$\frac{\phi_i}{10^6}$	$\frac{\phi_w}{10^6}$	$\frac{\phi_l}{10^6}$
498		9-20-65	09:19	1495	1.38	.994	216.3	INLET	23.4	578.5	-5.82	6.2				
								1	18.0	585.8	-4.51	6.3	.426	.426		
								2	7.3	600.6	-1.86	6.4	.436	.428		
								3	.0	615.0	.73	7.0	.451	.425		
								4	.0	630.8	3.56	9.0	.450	.435		
								5	.0	645.7	6.24	10.9	.423	.435		
								6	.0	660.6	8.90	12.7	.451	.434		
								7	.0	676.8	11.81	14.8	.450	.440		
								8	.0	692.1	14.56	16.7	.426	.441		
								9	.0	707.5	17.33	18.6	.448	.442		
								10	.0	721.8	19.88	20.4	.459	.439		
								11	.0	738.5	22.90	22.5	.426	.444		
								12	.0	755.1	25.87	24.6	.431	.447		
								EXIT	.0	762.5	27.20	25.6		.446		
499		9-20-65	10:48	1493	.25	.707	194.1	INLET	27.8	572.5	-6.86	4.4				
								12	.0	795.0	33.05	21.2	.389	.401		
								EXIT	.0	804.3	34.73	22.0		.400		
500		9-20-65	11:41	1500		.512	172.6	INLET	28.8	571.9	-7.14	3.2				
								12	.0	845.3	42.01	18.4	.352	.356		
								EXIT	.0	857.0	44.12	19.2		.356		
501		9-20-65	12:23	1509		.509	182.8	INLET	53.6	540.7	-12.98	3.0				
								12	.0	832.0	39.53	17.4	.366	.378		
								EXIT	.0	844.2	41.74	18.1		.377		
502		9-20-65	13:15	1492	.27	.716	214.4	INLET	52.2	540.7	-12.54	4.3				
								12	.0	783.5	31.01	20.4	.434	.443		
								EXIT	.0	793.9	32.87	21.3		.442		
503		9-20-65	14:34	1503	1.17	1.004	241.7	INLET	55.1	538.1	-13.29	6.0				
								12	.0	733.4	21.85	21.9	.485	.499		
								EXIT	.0	741.7	23.34	23.0		.499		
504		9-20-65	16:06	1488	2.94	1.486	281.2	INLET	49.9	543.1	-11.99	8.9				
								12	.0	696.6	15.49	26.0	.562	.581		
								EXIT	.0	703.0	16.64	27.3		.580		
505		9-21-65	08:36	1495	3.25	1.476	251.7	INLET	26.2	574.7	-6.51	9.2				
								12	.0	713.0	18.31	28.7	.504	.520		
								EXIT	.0	718.8	19.35	29.8		.519		
506		9-21-65	10:01	1505	6.84	2.335	289.8	INLET	25.0	577.6	-6.24	14.5				
								11	.0	669.7	10.34	32.1	.583	.600		
								12	.0	678.2	11.88	34.7	.586	.598		
								EXIT	.0	682.5	12.65	35.9		.598		
507		9-21-65	10:33	1500	5.07	1.986	278.5	INLET	26.3	575.3	-6.53	12.3				
								11	.0	679.3	12.17	30.0	.560	.577		
								12	.0	688.9	13.60	32.4	.561	.575		
								EXIT	.0	693.8	14.77	33.6		.575		

Table 14. Data Summary Sheet, Test Section 6

RUN NO.	DNS	DATE	TIME	P	ΔP	$Q \times 10^{-6}$	KW	STA NO.	ΔT_0	h	x	V_m	$\frac{V_{10}}{10^6}$	$\frac{V_0}{10^6}$	$\frac{V_{11}}{10^6}$	$\frac{V_i}{10^6}$
508		5-21-65	11:25	1500	4.44	1.985	315.2	INLET	52.1	541.7	-12.56	11.9				
	0							12	.0	670.4	10.58	27.7	.633	.651		
	0							EXIT	.0	675.9	11.56	29.1		.650		
509		5-21-65	11:55	1505	6.34	2.490	347.4	INLET	52.6	541.6	-12.71	14.9				
	0							11	.0	645.6	6.01	26.7	.691	.722		
								12	.0	654.8	7.66	29.6	.697	.718		
								EXIT	.0	659.5	8.52	31.1		.717		
510		5-21-65	13:25	1515	4.80	2.427	430.1	INLET	100.4	484.2	-23.35	13.6				
	0							12	.0	627.9	2.60	20.3	.867	.888		
	0							EXIT	.0	634.0	3.71	22.1		.887		
511		5-21-65	14:53	1498	3.46	1.947	373.4	INLET	94.1	489.8	-21.83	11.0				
	0							12	.0	645.3	6.11	21.1	.753	.771		
	0							EXIT	.0	651.9	7.29	22.7		.770		
512		5-21-65	15:35	1490	2.06	1.487	322.0	INLET	97.5	485.0	-22.46	8.3				
	0							12	.0	660.5	9.00	19.2	.648	.665		
	0							EXIT	.0	668.0	10.33	20.6		.664		
513		07-20-65	12:54	1480	.00	.546	222.5	INLET	99.6	481.5	-22.74	3.1				
	0							EXIT	.0	825.5	38.68	18.7		.459		
514		07-20-65	13:28	1507	.00	.695	242.4	INLET	100.7	482.7	-23.25	3.9				
	0							EXIT	.0	777.6	29.82	19.0		.500		
515		07-20-65	14:10	1498	.00	.978	277.0	INLET	99.4	483.4	-22.91	5.5				
	0							EXIT	.0	722.7	20.05	20.2		.572		
516		07-20-65	15: 8	1522	.00	.552	242.3	INLET	148.9	429.8	-33.34	3.0				
	0							EXIT	.0	800.9	33.82	16.5		.500		
517		07-20-65	15:35	1506	.00	.712	274.1	INLET	146.3	431.2	-32.57	3.8				
	0							EXIT	.0	756.4	25.98	17.6		.566		
518		07-20-65	16: 0	1524	.00	.973	314.9	INLET	147.9	430.9	-33.26	5.2				
	0							EXIT	.0	704.3	16.26	17.2		.650		
519		07-20-65	16:38	1485	.00	1.470	372.6	INLET	143.5	432.3	-31.68	7.9				
	0							EXIT	.0	646.4	6.61	16.5		.769		
520		07-20-65	17: 1	1505	.00	2.014	435.6	INLET	145.3	432.2	-32.33	10.8				
	0							EXIT	.0	615.0	.56	13.9		.899		
521		07-20-65	17:27	1518	.00	2.474	490.9	INLET	143.0	436.0	-32.09	13.3				
	0							EXIT	6.6	603.7	-1.78	15.9		1.013		
522		07-20-65	17:47	1490	.00	2.943	555.4	INLET	141.8	434.8	-31.41	15.8				
	0							EXIT	11.1	594.3	-2.85	18.7		1.146		
523		07-20-65	18:10	1511	.00	3.530	605.2	INLET	141.0	437.7	-31.53	19.0				
								EXIT	21.2	582.6	-5.41	22.1		1.249		
524		07-21-65	10:14	1992	.00	.494	120.0	INLET	25.1	629.3	-8.86	3.3				
	0							EXIT	.0	834.7	35.31	11.4		.248		
525		07-21-65	10:51	1987	.00	.662	138.7	INLET	26.2	627.6	-9.09	4.4				
	0							EXIT	.0	804.7	28.53	13.4		.288		
526		07-21-65	12: 7	1984	.00	.994	165.6	INLET	18.6	638.2	-6.71	6.7				
	0							EXIT	.0	778.9	23.45	17.7		.342		

Table 15. Data Summary Sheet, Test Section 6

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{1e}}{10^6}$	$\frac{\phi_s}{10^6}$	$\frac{\phi_{1i}}{10^6}$	$\frac{\phi_i}{10^6}$
927		07-21-65	12:58	1995	.00	1.952	230.8	INLET	21.9	634.8	-7.76	13.0				
	0							11	.0	722.5	11.12	23.7	.450	.478		
								12	.0	730.6	12.66	25.2	.472	.476		
								EXIT	.0	734.7	13.75	26.0		.476		
928		07-21-65	13:15	1998	.00	1.997	268.3	INLET	44.9	600.9	-15.19	12.7				
	0							11	.0	700.5	6.30	19.9	.519	.555		
								12	.0	709.7	8.27	21.7	.554	.554		
								EXIT	.0	714.4	9.29	22.6		.554		
929		07-21-65	13:48	2019	.00	1.461	233.0	INLET	47.1	600.0	-16.08	9.3				
	0							11	.0	718.1	9.61	16.7	.465	.481		
	0							12	.0	729.2	12.01	18.2	.483	.481		
	0							EXIT	.0	734.8	13.24	19.0		.481		
930		07-21-65	14:23	2017	.00	.982	199.3	INLET	53.8	590.5	-18.00	6.2				
	0							11	.0	741.2	14.73	13.4	.410	.413		
	0							12	.0	755.1	17.76	14.8	.393	.412		
	0							EXIT	.0	761.9	19.24	15.4		.411		
931		07-21-65	14:52	1983	.00	.714	167.0	INLET	51.0	590.9	-16.81	4.5				
	0							EXIT	.0	788.5	25.51	13.4		.345		
932		07-21-65	15:20	2002	.00	.529	139.2	INLET	50.9	592.9	-16.99	3.3				
	0							EXIT	.0	815.2	30.99	11.1		.287		
933		07-21-65	15:54	2061	.00	.518	164.5	INLET	101.4	533.3	-32.12	3.0				
	0							EXIT	.0	801.5	27.23	9.8		.339		
934		07-22-65	9:26	2034	.00	.697	199.2	INLET	104.8	526.8	-32.65	4.1				
	0							EXIT	.0	768.2	20.22	11.2		.411		
935		07-22-65	9:36	1995	.00	.700	202.2	INLET	104.5	524.0	-31.57	4.1				
	0							EXIT	.0	768.2	20.99	11.6		.417		
936		07-22-65	10:31	2027	.00	.999	243.1	INLET	103.3	528.1	-32.04	5.8				
	0							11	.0	707.9	7.20	10.3	.495	.501		
								12	.0	725.0	10.94	12.0	.507	.501		
								EXIT	.0	733.7	12.83	12.8		.502		
937		07-22-65	11: 2	2039	.00	1.493	300.7	INLET	103.1	529.2	-32.25	8.7				
	0							11	.0	678.2	.46	11.0	.604	.621		
								12	.0	692.3	3.54	13.0	.623	.620		
								EXIT	.0	699.4	5.10	14.0		.620		
938		07-22-65	11:25	2027	.00	1.984	356.6	INLET	99.4	533.1	-30.96	11.6				
	0							11	4.6	666.6	-1.81	14.0	.701	.739		
								12	.0	678.8	.85	14.9	.716	.737		
								EXIT	.0	684.9	2.19	16.1		.736		
939		07-22-65	12: 4	1999	.00	1.996	419.5	INLET	144.8	476.8	-42.00	11.1				
	0							11	23.8	632.2	-8.47	13.3	.852	.866		
	0							12	14.4	647.0	-5.29	13.6	.870	.865		
	0							EXIT	9.9	654.4	-3.69	13.8		.866		

Table 16. Data Summary Sheet, Test Section 6

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{f_{10}}{10^6}$	$\frac{f_o}{10^6}$	$\frac{f_{11}}{10^6}$	$\frac{f_i}{10^6}$
940		07-22-65	12:35	1980	.00	1.502	354.2	INLET	150.7	468.7	-42.84	8.3				
0								11	15.6	643.1	-5.53	10.2	.713	.731		
0								12	5.5	659.6	-2.01	10.5	.734	.731		
0								EXIT	.6	667.9	-.23	10.6		.731		
941		07-22-65	13: 9	2039	.00	.995	279.7	INLET	161.1	461.4	-47.11	9.4				
0								11	3.8	669.4	-1.48	7.0	.563	.577		
0								12	.0	689.1	2.23	8.4	.583	.577		
0								EXIT	.0	699.1	5.03	9.3		.577		
942		07-22-65	14:30	1999	.00	.703	235.5	INLET	151.2	469.6	-43.56	3.9				
0								EXIT	.0	752.5	17.48	10.5		.486		
943		07-22-65	14:37	2021	.00	.721	233.8	INLET	149.3	473.5	-43.67	4.0				
0								EXIT	.0	747.4	15.97	10.2		.482		
944		07-22-65	15:26	2027	.00	.716	232.5	INLET	150.7	472.5	-44.14	4.0				
0								EXIT	.0	747.0	15.77	10.1		.480		
945		07-22-65	16: 2	2033	.00	.505	189.7	INLET	152.3	471.2	-44.65	2.8				
0								EXIT	.0	788.8	24.83	9.1		.391		
946		07-23-65	9:50	2213	.00	.547	113.5	INLET	19.5	660.2	-8.50	3.8				
0								EXIT	.0	839.7	33.08	10.8		.234		
947		07-23-65	10: 0	2204	.00	.519	127.9	INLET	45.5	619.0	-17.94	3.4				
0								EXIT	.0	827.4	31.24	9.9		.264		
948		07-23-65	10:22	2212	.00	.524	142.9	INLET	72.9	582.2	-26.99	3.2				
0								EXIT	.0	812.8	27.64	9.3		.295		
949		07-23-65	10:31	2230	.00	.696	169.2	INLET	71.4	585.5	-26.98	4.3				
0								EXIT	.0	791.1	22.16	10.9		.349		
950		07-23-65	10:45	2223	.00	.690	153.0	INLET	48.8	616.2	-19.32	4.5				
0								EXIT	.0	803.7	25.33	11.6		.316		
951		07-23-65	11: 6	2197	.00	.704	131.1	INLET	17.8	661.9	-7.67	4.9				
0								EXIT	.0	819.3	29.39	13.0		.271		
952		07-23-65	11:17	2214	.00	.982	157.6	INLET	19.8	659.9	-8.64	6.8				
0								11	.0	778.6	19.51	14.4	.310	.326		
0								12	.0	789.7	22.15	19.4	.330	.325		
0								EXIT	.0	795.5	23.51	15.9		.325		
953		07-23-65	11:29	2196	.00	.997	183.9	INLET	43.0	621.9	-17.05	6.5				
0								11	.0	758.3	15.05	13.1	.398	.380		
0								12	.0	771.5	18.13	14.2	.369	.380		
0								EXIT	.0	777.8	19.62	14.8		.379		
954		07-23-65	11:44	2194	.00	1.014	206.7	INLET	68.6	586.2	-25.28	6.3				
0								11	.0	736.6	10.04	11.4	.403	.426		
0								12	.0	751.0	13.40	12.7	.447	.426		
0								EXIT	.0	758.5	15.17	13.3		.426		
955		07-23-65	12: 4	2245	.00	1.480	253.7	INLET	73.1	584.6	-27.77	9.2				
0								11	.0	711.7	-2.82	12.6	.519	.525		
								12	.0	723.6	5.68	14.1	.511	.524		
								EXIT	.0	729.5	7.09	14.9		.523		

Table 17. Data Summary Sheet, Test Section 6

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_{i,1}}{10^6}$	$\frac{\phi_{i,2}}{10^6}$	$\frac{\phi_{i,3}}{10^6}$
956	0	07-23-65	12:30	2135	.00	1.488	220.1	INLET	36.2	626.5	-13.79	9.8				
								11	.0	736.4	11.33	17.6	.457	.456		
								12	.0	746.6	13.65	19.0	.429	.455		
								EXIT	.0	751.5	14.77	19.7		.454		
957	0	07-23-65	12:37	2225	.00	1.514	227.7	INLET	48.0	617.4	-19.14	9.8				
								11	.0	728.6	7.36	15.4	.447	.470		
								12	.0	739.1	9.86	16.8	.485	.469		
								EXIT	.0	744.5	11.17	17.5		.470		
958	0	07-23-65	13: 9	2218	.00	1.506	196.3	INLET	22.6	655.9	-9.72	10.3				
								11	.0	751.3	12.94	18.4	.424	.401		
								12	.0	761.1	15.26	19.7	.439	.403		
								EXIT	.0	766.0	16.45	20.4		.405		
959	0	07-23-65	13:21	2218	.00	1.970	227.7	INLET	20.8	659.0	-8.99	13.6				
								11	.0	744.8	11.39	23.0	.442	.472		
								12	.0	752.6	13.26	24.4	.465	.470		
								EXIT	.0	756.7	14.22	25.1		.470		
960	0	07-23-65	13:34	2218	.00	2.006	278.9	INLET	50.3	613.8	-19.73	12.9				
								11	.0	715.9	4.52	18.3	.617	.571		
								12	.0	725.8	6.88	20.1	.548	.572		
								EXIT	.0	730.4	7.98	20.9		.571		
961	0	07-23-65	14: 6	2240	.00	2.014	335.8	INLET	84.7	569.3	-31.32	12.2				
								11	3.4	692.7	-1.66	14.8	.673	.694		
								12	.0	704.3	1.11	15.9	.692	.693		
								EXIT	.0	710.1	2.52	16.9		.693		
962	0	07-23-65	14:12	2202	.00	1.989	316.1	INLET	74.3	579.6	-27.26	12.3				
								11	.0	697.2	.50	15.1	.626	.653		
								12	.0	708.2	3.09	17.1	.655	.652		
								EXIT	.0	713.9	4.41	18.1		.652		
963	0	07-23-65	14:26	2191	.00	2.486	368.2	INLET	74.8	578.0	-27.14	15.3				
								11	2.9	687.5	-1.44	18.2	.724	.760		
								12	.0	697.8	.57	19.3	.771	.759		
								EXIT	.0	703.1	2.21	20.5		.760		
964	0	07-23-65	14:44	2196	.00	2.477	316.6	INLET	48.0	614.7	-18.74	16.0				
								11	.0	709.1	3.46	21.6	.624	.652		
								12	.0	718.0	5.57	23.6	.676	.652		
								EXIT	.0	722.7	6.66	24.6		.653		
965	0	07-23-65	15: 9	2244	.00	2.427	277.6	INLET	31.4	643.9	-13.52	16.4				
								11	.0	728.8	6.92	24.3	.552	.575		
								12	.0	736.6	8.80	25.9	.562	.573		
								EXIT	.0	740.6	9.75	26.8		.573		
966	0	07-23-65	15:12	2193	.00	2.378	261.3	INLET	22.2	653.7	-9.46	16.3				
								11	.0	734.9	9.60	26.3	.527	.538		
								12	.0	742.6	11.42	27.9	.557	.539		
								EXIT	.0	746.6	12.35	28.8		.539		

Table 18. Data Summary Sheet, Test Section 6

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i0}}{10^6}$	$\frac{\phi_o}{10^6}$	$\frac{\phi_{i1}}{10^6}$	$\frac{\phi_i}{10^6}$
967		07-23-69	15:16	2220	.00	2.476	266.0	INLET	22.5	655.9	-9.81	17.0				
	0							11	.0	735.6	9.15	26.8	.545	.551		
								12	.0	743.0	10.61	28.5	.531	.550		
								EXIT	.0	746.7	11.79	29.3		.549		
968		07-23-69	15:30	2210	.00	2.646	277.9	INLET	22.6	654.9	-9.61	18.2				
	0							11	.0	732.6	8.75	28.3	.572	.573		
								12	.0	739.9	10.49	30.0	.565	.573		
								EXIT	.0	743.5	11.35	30.9		.573		
969		07-23-69	15:37	2139	.00	2.841	331.6	INLET	40.7	619.9	-15.53	18.5				
	0							11	.0	706.4	4.29	25.7	.686	.686		
								12	.0	714.6	6.15	27.8	.668	.685		
								EXIT	.0	718.6	7.07	28.8		.684		
970		07-23-69	15:46	2207	.00	2.866	345.2	INLET	46.2	618.4	-18.20	18.6				
	0							11	.0	707.7	2.90	24.4	.687	.714		
								12	.0	716.0	4.86	26.5	.706	.718		
								EXIT	.0	720.2	5.86	27.6		.712		
971		07-23-69	16:13	2202	.00	3.046	415.6	INLET	67.1	589.2	-25.00	19.0				
	0							11	2.6	690.2	-1.16	22.3	.813	.859		
								12	.0	699.6	1.06	23.8	.863	.857		
								EXIT	.0	704.5	2.20	25.1		.858		

Table 19. Constants for Evaluating the BAW-168 Equation¹⁰

Figure No.	Pressure, psia	Flow regime	Mass velocity range, lb/hr-sq ft	Constant ^(a)					Error rms/%
				C ₁	C ₂	C ₃	C ₄	C ₅	
2, 5	1000	Low	$0.5 \times 10^6 \leq G \leq 1.5 \times 10^6$	175,468	95,619	0.49558	0.002286	-0.264×10^{-5}	1.97
		Middle	$1.5 \times 10^6 \leq G \leq 2.5 \times 10^6$	598,743	196,739	0.06449	0.002750	-0.805×10^{-5}	1.20
3, 6	1500	Middle	$0.5 \times 10^6 \leq G \leq 2.5 \times 10^6$	188,571	39,500	0.25569	0.002097	-0.486×10^{-5}	1.30
4, 7	2000	Middle	$0.5 \times 10^6 \leq G \leq 2.5 \times 10^6$	67,263	10,223	0.35847	0.001576	-0.363×10^{-5}	2.08
8, 12	1000	Middle	$0.5 \times 10^6 \leq G \leq 2.5 \times 10^6$	415,209	80,396	0.13576	0.001275	-0.208×10^{-5}	0.90
9, 13	1500	Middle	$0.5 \times 10^6 \leq G \leq 2.5 \times 10^6$	220,101	79,012	0.25071	0.001288	-0.463×10^{-6}	1.01
		High	$1.25 \times 10^6 \leq G \leq 2.5 \times 10^6$	179,141	118,893	0.36135	0.002115	-0.439×10^{-5}	1.45
10, 14	2000	Middle	$0.5 \times 10^6 \leq G \leq 2.5 \times 10^6$	63,007	24,326	0.42743	0.001570	-0.296×10^{-5}	1.82
11, 15	2200	Middle	$0.5 \times 10^6 \leq G \leq 1.0 \times 10^6$	47,237	24,456	0.48015	0.002274	-0.931×10^{-5}	0.78
		High	$1.5 \times 10^6 \leq G \leq 2.5 \times 10^6$	120,897	205,231	0.53920	0.003186	-0.638×10^{-5}	0.53

(a) Constants for evaluating $\phi = C_1 \left(\frac{G}{C_2} \right)^{C_3} + C_4 \Delta T + C_5 (\Delta T_{sc})^2$

Figure 2. DNB Points for Annular Geometry With Inner Tube Heated at 1000 psia, Test Section 5

Figure 3. DNB Points for Annular Geometry With Inner Tube Heated at 1500 psia, Test Section 5

Figure 4. DNB Points for Annular Geometry With Inner Tube Heated at 2000 psia, Test Section 5

Figure 5. DNB Points for Annular Geometry With Inner Tube Heated at 1000 psia, Test Section 5

Figure 6. DNB Points for Annular Geometry With Inner Tube Heated at 1500 psia, Test Section 5

Figure 7. DNB Points for Annular Geometry With Inner Tube Heated at 2000 psia, Test Section 5

Figure 8. DNB Points for Annular Geometry With Outer Tube Heated at 1000 psia, Test Section 6

Figure 9. DNB Points for Annular Geometry With Outer Tube Heated at 1500 psia, Test Section 6

Figure 10. DNB Points for Annular Geometry With Outer Tube Heated at 2000 psia, Test Section 6

Figure 11. DNB Points for Annular Geometry With Outer Tube Heated at 2200 psia, Test Section 6

Figure 12. DNB Points for Annular Geometry With Outer Tube Heated at 1000 psia, Test Section 6

Figure 13. DNB Points for Annular Geometry With Outer Tube Heated at 1500 psia, Test Section 6

Figure 14. DNB Points for Annular Geometry With Outer Tube Heated at 2000 psia, Test Section 6

Figure 15. DNB Points for Annular Geometry With Outer Tube Heated at 2200 psia, Test Section 6

Figure 16. Average Heat Flux Vs Mass Velocity at Inlet Temperature of 540 F, Test Section 5

Figure 17. Average Heat Flux Vs Mass Velocity at Inlet Temperature of 540 F, Test Section 6

5. ANALYSIS

5.1. Experimental Data Compared With Predictions

The available data from the two annular test sections were compared with burnout correlations from references 10, 11, and 12 in the previous quarterly report.⁸ This work has been repeated with the revised data reported in Tables 1 through 18. Each of these correlations contains a diameter term. In the case of annular channels, an equivalent diameter term must be evaluated to serve as the diameter term in computations. Two kinds of equivalent diameter have been evaluated, and comparison with the data has used each. First there is the usual hydraulic equivalent diameter based on the wetted perimeter:

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

An equivalent diameter can also be defined based on the heated perimeter:

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

Consideration of these two equivalent diameters increases the number of correlations from three to six. For each group and correlation, the mean ratio of experimental-to-calculated heat flux has 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

The standard deviation is computed by

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

where S = the standard deviation of the ratios. Figure 18 shows the results; the agreement of a group of data with a specific correlation can be estimated by noting the proximity of the plotted points 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. Figure 18 shows that the choice of equivalent diameter has considerable influence. When the heated perimeter is used, the points are reduced to a smaller area of the graph, and the general agreement of the equations with the data appears better.

This heated perimeter concept is worthy of further study. This view is supported in section 5.2, where individual data points are considered.

5.2. Effects of Heated Perimeter

Reference 13 presents a correlation for the burnout heat flux that considers the power added to the test section over the length of the heated surface in the quality region. For test sections that have equivalent hydraulic diameters, the following parameters are believed to hold:

$$x(P_t/P_h) = \text{modified exit quality}$$

$$L_s = \text{boiling length}$$

where P_t/P_h = ratio of the total to the heated perimeter. The correlating parameters were derived for uniformly- and nonuniformly-heated tubular, annular, and rod bundle test sections.

Figures 19 (1000 psia), 20 (1500 psia), and 21 (2000 psia) are plots of the data from test sections 1 (tubular) and 5 and 6 (annular) on the basis of the CISE parameters.¹³ Although the lines of constant mass velocity are omitted, an examination of all the figures reveals an excellent agreement between test sections 5 and 6 at mass velocities of 1×10^6 lb/hr-sq ft or greater. In other words, the parameters correlate the data from test sections 5 and 6 at all pressures and at $G \geq 1 \times 10^6$ lb/hr-sq ft. Examination of all the figures also indicates a fair agreement between test sections 1 (tubular) and 5 and 6 (annular) at all mass velocities. Use of the parameters warrants additional study as we proceed with testing annular test sections 7, 8, and 9.

Figure 18. Comparison of Burnout Equations With Annular Data

Figure 19. Modified Exit Quality Vs Boiling Length at 1000 psia for Test Sections 1 (Tubular), 5 (Annular - IS Heated), and 6 (Annular - OS Heated)

Figure 20. Modified Exit Quality Vs Boiling Length at 1500 psia for Test Sections 1 (Tubular), 5 (Annular - IS Heated), and 6 (Annular - OS Heated)

Figure 21. Modified Exit Quality Vs Boiling Length at 2000 psia for Test Sections 1 (Tubular), 5 (Annular - IS Heated), and 6 (Annular - OS Heated)

6. CONCLUSIONS

6.1. Effects of Subcooling

Figures 2, 3, 4 (test section 5) and 8 through 11 (test section 6) show the effect of inlet subcooling on the average heat input rate (burn-out heat flux). The following conclusions are drawn from these figures:

1. The average heat input rate is increased as the degree of subcooling at constant mass velocity is increased.
2. The average heat input rate is more sensitive to the degree of subcooling at high mass velocities than at low mass velocities.
3. No inverse effect of mass velocity is observed when the results are plotted using the parameter of inlet subcooling.
4. A modified form of the BAW-168 equation represents the data within the expected experimental accuracy with few exceptions (low mass velocity).^{9,10}

6.2. Effect of Mass Velocity

Figures 5, 6, and 7 (test section 5) and 12 through 15 (test section 6) show how mass velocity affects the average heat input rate. From these figures we draw certain preliminary conclusions:

1. It has been tentatively concluded that three flow regimes can be identified as affecting the average heat input rate. The exact velocity ranges that define these three regimes have not been completely specified. It is also evident that the transition region from one flow regime to the other may cause considerable difficulty in finally defining the mass velocity ranges that specify each regime.
2. All the results from test sections 5 and 6 show that the average heat input rate increases with increasing mass velocity for constant inlet subcooling.

6.3. Effect of Pressure

Figures 16 (test section 5) and 17 (test section 6) show the effect of pressure when it is plotted on the basis of mass velocity at a constant

inlet temperature. The following conclusions are drawn from Figures 16 and 17:

1. On test section 5, pressure has practically no effect on the average heat input rate at mass velocities below 1.5×10^6 lb/hr-sq ft. Above 1.5×10^6 lb/hr-sq ft, higher average heat input rates are obtainable with increased pressure.
2. On test section 6 at mass velocities below 1.5×10^6 lb/hr-sq ft, lower pressures provide higher allowable heat input rates (burnout heat fluxes), and above that mass velocity the burnout flux level is improved with higher operating pressures.

6.4. Effect of Heated Perimeter

Figures 18 through 21 show that we must consider the effect of heated versus wetted perimeter in correlating the data.

1. The modified equivalent diameter based on heated perimeter improves some of the older correlations.
2. A modified quality concept that involves the heated perimeter shows promise as a method of correlation.¹³

7. FUTURE WORK

Under the contract extension that begins with the tenth quarter, work is expected to resume a normal level of effort. The data runs on test sections 7 and 8 and the manufacture of test section 9 should be completed. Work will be resumed on the analytical model and on the correlation of uniform, nonuniform, tubular, and annular data.

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