NONUNIFORM HEAT GENERATION
EXPERIMENTAL PROGRAM

Quarterly Progress Report No. 5

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Lynchburg, Virginia

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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.

ABSTRACT

The Babcock & Wilcox Company, as part of the Joint U.S.-Euratom Research and Development Program, is conducting experimental and analytical investigations to determine the effects of irregular heat flow through reactor channels on the operating conditions that cause burnout (departure from nucleate boiling). This program seeks to improve design correlations that will be suitable for direct use by reactor designers. Tubular specimens having four axial power shapes and annular specimens having five power shapes will be used, and an effort to correlate the experimental data with empirical and analytical models will be made.

During the fifth quarter of this program, data were obtained from the test section having the chopped-cosine heat flux shape. Further progress has been made in modifying the facility and the test section instrumentation to provide more information than was obtained from the uniformly heated test section.

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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) is a very serious design problem still facing the reactor designer. The result of this phenomenon is that 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 on the effect of the channel geometry and operating conditions upon 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 report¹, is being conducted on a heat transfer facility at B&W's Research Center in Alliance, Ohio. 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 analytical program will be conducted by the Atomic Energy Division in Lynchburg, Virginia.

Problems that developed in the power supply have not been completely remedied; however, the power supply has operated satisfactorily for this test work. Solutions to the power supply problem have been recommended and are now being effected. During this quarter, data were obtained from Flux Shape No. 2 (chopped cosine) for the originally planned conditions, which include pressures of 2000, 1500, and 1000 psia; mass velocities of 0.5, 1.5, and 2.5 million lb/hr-ft²; and inlet subcoolings of 20, 50, 100, and 150 F.

A computer program for comparing uniform heat flux data from round geometries with existing published burnout correlations has been written. The uniform flux data from the experiment have been compared with some of the correlations.

2. PROGRAM

2.1. Test Facility Modifications

Burnout detector operation at the end of the fourth quarter (June 1964) was unreliable to the extent that it alone could not provide correct critical heat flux information and prevent test section failure. Because of this, thermocouples were used on the uniform flux test section to manually monitor wall temperature and detect critical conditions. Plans were made to use thermocouples on the second flux shape (chopped cosine). However, development work on the burnout detector continued (at Company expense) in parallel with the installation of the thermocouple monitoring system. The theory of operation of the detector had been proved, but one of the remaining difficulties involved a mechanical switch, or chopper, which was used to compare test section incremental voltage drop with a reference voltage. One of the more promising solutions to the problem was to replace the chopper with a differential voltmeter system, and this solution was pursued during the fifth quarter. Results from the differential voltmeter scheme were encouraging, so that the burnout detector was judged satisfactory for tests on Flux Shape No. 2. All testing subsequent to tests on Flux Shape No. 1 used the burnout detector for detecting critical heat flux, while thermocouples were used only for recording purposes and not for power tripping.

2.2. Test Sections

2.2.1. Tubular Test Sections

Flux Shape No. 2 was supplied with thermocouples and voltage taps, as shown in Figure 1. The thermocouples were electrically insulated from the test section with aluminum oxide because it was thought that direct contact between the thermocouple junction and the test section would result in a false temperature reading due to pickup of d-c voltage from the tube. Subsequent development work resulted in a method

for installing thermocouples directly on the test section in such a way that there is little or no d-c voltage interference. This direct attachment is more desirable since the measured temperature is more representative of actual test section wall temperature than is the temperature obtained from insulated thermocouples. Flux Shapes No. 3 and 4 will have thermocouples attached directly.

2.2.2. Annular Test Sections

Material is being received and fabrication is well under way on these test sections. It is expected that the first section (uniform heat input rate, inside tube heated) will be ready for installation by the time the tubular tests are completed near the end of this year. Some development work will have to be conducted to determine the acceptability of the spacer piece design and the present concepts of instrumentation of the inside tube. As with the tubular test sections, these annular sections are to be supplied with thermocouples—the outside tube with as many as required, and the inside tube with one at the outlet only.

Figure 1. Test Section No. 2 Instrumentation

3. TEST OPERATION

At the end of the fourth quarter, tests on Flux Shape No. 1 were completed. Testing was then discontinued to permit installation of the thermocouple monitoring system. The system was installed and checked out, and testing was resumed and completed on Flux Shape No. 2 (chopped cosine) during the fifth quarter. Flux Shape No. 3 (inlet peak) was being installed and checked out at the end of the quarter.

During all testing, total test section pressure drop readings have been taken. Readings are taken from both a Barton ΔP gage and a mercury manometer. The pressure drop measuring system is shown on Figure 2.

Figure 2. Pressure Drop System Schematic Diagram

4. TEST DATA

Test results from Flux Shape No. 1 were presented graphically in the last quarterly report², but there was insufficient time to include the tabulated data. These data are included in Table 1 in this report. In addition, the tabulated results of tests on Flux Shape No. 2 are in Table 2.

Test results for Flux Shape No. 2 are also presented graphically in Figures 3 through 5. These figures have coordinates of average test section heat input rate and test section inlet subcooling. Also shown on these curves are the results from Flux Shape No. 1. These figures show that, in general, the allowable average heat input rates (total power) for both the uniformly and nonuniformly heated tubes are equal for the same test section inlet temperatures. Exceptions to this agreement occur at 1000 psi at mass velocities of 1.5 and 2.5×10^6 lb/hr-ft², where the average rate is lower for the nonuniformly heated tube.

During the course of testing, other data concerning the stability of test section metal temperature, flow rate, and inlet pressure during periods of transition to film boiling were obtained.

There were no indications of fluctuating temperatures at DNB operating conditions. But, as described in the last quarterly report² for Flux Shape No. 1, the thermocouples were electrically insulated from the test section, and the insulation tended to reduce the amplitude of any temperature fluctuations which might have occurred. Thermocouples that are directly attached to the tube will be used for subsequent test sections, and more representative temperatures will be available.

Flow and inlet pressure data recorded so far indicate that no apparent instability of these variables is caused by burnout.

List of Symbols for Tables

DNB	Departure from Nucleate Boiling, "0" indicates location of DNB
P	Pressure, psia
ΔP	Test section pressure drop, psid
G	Mass velocity, lb/hr-ft ²
ΔT_s	Subcooling at test section inlet, F
h	Local fluid enthalpy, Btu/lb
x	Steam quality, wt %
V_m	Mixture velocity, ft/sec
$\phi_{l,o}$	Local heat flux (outside tube), Btu/hr-ft ²
ϕ_o	Integrated heat flux (outside tube), Btu/hr-ft ²
Run No.*	DNB condition, asterisk indicates data not taken during DNB but immediately prior to DNB

Table 1. Preliminary Report of Test Results From Flux Shape No. 1

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$
1		5-4-64	13:55	995	9.87	2.546	76.4	INLET	23.9	512.0	-4.55	14.8		
								12	.0	602.8	9.40	43.6	.366	.373
								EXIT	.0	606.7	10.00	45.4		.373
2		5-4-64	14:29	1015	12.05	2.532	97.9	INLET	21.2	518.2	-4.10	14.8		
								12	.0	635.0	13.98	56.2	.474	.477
								EXIT	.0	640.1	14.76	58.5		.477
3		5-4-64	15:01	1015	14.49	2.548	125.8	INLET	20.6	518.9	-3.99	14.9		
								1	15.4	525.3	-3.00	15.0	.606	.606
								2	5.1	538.2	-1.00	15.2	.614	.610
								3	.0	550.8	.95	18.1	.617	.604
								4	.0	564.2	3.01	24.2	.616	.612
								5	.0	576.9	4.98	30.0	.616	.609
								6	.0	590.2	7.05	36.1	.613	.613
								7	.0	603.3	9.06	42.1	.614	.614
								8	.0	616.3	11.07	48.0	.616	.614
								9	.0	629.3	13.09	53.9	.616	.614
								10	.0	642.6	15.15	60.0	.619	.616
								11	.0	655.6	17.16	65.9	.617	.616
								12	.0	668.1	19.10	71.7	.608	.614
4-0-0		5-4-64	15:26	1015	15.30	2.528	127.8	EXIT	.0	674.6	20.09	74.6		.613
								INLET	25.5	512.9	-4.91	14.7		
								12	.0	665.7	18.72	70.0	.623	.623
5-0-0		5-4-64	15:36	1015	15.30	2.528	127.8	EXIT	.0	672.3	19.74	73.0		.623
								INLET	28.9	508.8	-5.56	14.6		
								12	.0	661.6	18.08	68.1	.623	.623
6		5-5-64	10:20	1000	4.28	1.526	58.4	EXIT	.0	648.2	19.10	71.1		.623
								INLET	20.7	516.6	-3.97	8.9		
								12	.0	632.2	13.83	34.0	.283	.285
7		5-5-64	11:01	1020	5.71	1.507	80.2	EXIT	.0	637.2	14.60	35.4		.285
								INLET	21.8	518.2	-4.22	8.8		
								12	.0	678.9	20.68	45.0	.390	.391
8		5-5-64	11:32	1000	7.11	1.511	93.5	EXIT	.0	685.9	21.76	46.8		.391
								INLET	20.3	517.1	-3.89	8.8		
								12	.0	704.2	24.92	53.4	.451	.456
9		5-5-64	11:47	1015	7.86	1.504	102.6	EXIT	.0	712.3	26.16	55.6		.456
								INLET	23.5	515.4	-4.53	8.7		
								12	.0	721.8	27.39	56.7	.493	.501
10		5-5-64	12:04	1005	8.36	1.471	111.6	EXIT	.0	730.6	28.75	59.1		.500
								INLET	21.9	515.8	-4.21	8.6		
								12	.0	745.4	31.18	62.5	.537	.545
11		5-5-64	12:11	1000	8.74	1.512	115.0	EXIT	.0	755.2	32.70	65.2		.544
								INLET	19.8	517.7	-3.81	8.8		
								12	.0	747.7	31.61	65.4	.551	.561
								EXIT	.0	757.5	33.12	68.1		.561

Table 1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$
12		5- 5-64	12:17	1000		1.504	116.9	INLET	18.5	519.2	-3.57	8.8		
	0							12	.0	754.1	32.60	66.8	.570	.570
	0							EXIT	.0	764.3	34.18	69.6		.570
13		5- 5-64	12:17	1000	1.02	.504	69.9	INLET	25.8	510.4	-4.93	2.9		
								12	.0	929.4	59.59	38.4	.339	.341
								EXIT	.0	947.5	62.38	40.1		.341
14		5- 5-64	12:47	1000	1.20	.502	74.8	INLET	21.7	515.3	-4.17	2.9		
								12	.0	966.0	65.72	41.6	.365	.365
								EXIT	.0	985.6	68.24	43.3		.365
15		5- 5-64	12:58	995	1.25	.503	77.4	INLET	21.3	515.1	-4.07	2.9		
								12	.0	980.4	67.47	43.2	.370	.378
								EXIT	.0	1000.2	70.51	45.0		.377
16		5- 5-64	13:14	1000	1.27	.502	82.6	INLET	22.4	514.5	-4.29	2.9		
	0							12	.0	1012.5	72.39	45.8	.393	.403
	0							EXIT	.0	1033.6	75.64	47.7		.403
17		5- 6-64	13:00	1000	5.53	1.533	95.3	INLET	93.9	476.8	-10.10	8.6		
								12	.0	664.7	18.84	43.2	.461	.465
								EXIT	.0	672.8	20.09	45.5		.465
18		5- 6-64	13:30	1000	7.93	1.528	126.8	INLET	48.6	483.0	-9.14	8.6		
	0							12	.0	733.8	29.48	62.2	.617	.618
	0							EXIT	.0	744.7	31.15	65.2		.618
19		5- 6-64	14:45	1025	9.56	2.494	118.8	INLET	57.6	476.0	-10.90	13.9		
								12	.0	420.0	11.45	47.7	.574	.580
								EXIT	.0	626.2	12.42	50.5		.580
20		5- 6-64	15:22	1000	12.05	2.491	138.6	INLET	54.9	475.6	-10.29	13.9		
	0							12	.0	643.6	15.59	60.7	.690	.675
	0							EXIT	.0	651.1	16.74	64.1		.676
21		5- 7-64	10:23	1000	.29	.500	57.8	INLET	97.8	472.3	-10.80	2.8		
								12	.0	821.5	42.97	28.3	.283	.282
								EXIT	.0	836.7	45.32	29.7		.282
22		5- 7-64	10:52	1000	1.22	.512	82.8	INLET	98.3	471.7	-10.89	2.9		
								12	.0	980.3	64.35	41.9	.402	.404
								EXIT	.0	981.4	67.60	43.9		.404
23		5- 7-64	11:12	995	1.36	.513	90.8	INLET	57.1	472.3	-10.65	2.9		
	0							12	.0	1007.0	71.56	46.6	.435	.443
	0							EXIT	.0	1029.9	75.07	48.7		.443
24		5- 7-64	13:22	1000	.86	.534	78.2	INLET	102.2	422.1	-18.53	2.9		
								12	.0	864.8	49.45	34.4	.377	.381
								EXIT	.0	883.9	52.58	36.3		.381
25		5- 7-64	14:15	1000		.506	97.2	INLET	105.2	418.7	-19.85	2.7		
	0							12	.0	1000.0	70.47	45.0	.472	.474
	0							EXIT	.0	1025.2	74.34	47.3		.474
26		5- 7-64	15:15	1000	5.30	1.509	118.9	INLET	98.7	425.9	-17.94	8.1		
								12	.0	864.1	18.74	42.4	.571	.580
								EXIT	.0	874.3	20.31	45.1		.580

Table 1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	X	V_m	$\frac{\phi_{10}}{10^6}$	$\frac{\phi_0}{10^6}$
27		5-7-64	15:30	1000	6.79	1.510	139.7	INLET	97.1	427.7	-17.67	8.1		
								12	.0	707.4	25.40	54.2	.676	.681
								EXIT	.0	719.4	27.26	57.5		.681
28		5-7-64	15:43	1005		1.517	144.3	INLET	101.6	423.3	-18.48	8.1		
								12	.0	711.1	25.89	55.1	.698	.704
								EXIT	.0	723.5	27.81	58.5		.704
29		5-8-64	11:15	1000	8.15	2.419	144.2	INLET	99.0	425.6	-17.99	13.0		
								12	.0	605.8	9.77	42.3	.699	.704
								EXIT	.0	613.6	10.97	45.8		.703
30		5-8-64	15:15	1000	8.38	2.497	144.2	INLET	100.1	424.3	-18.19	13.4		
								12	.0	599.0	8.71	40.6	.697	.704
								EXIT	.0	606.5	9.87	44.0		.703
31		5-8-64	15:28	1000	8.79	2.499	149.9	INLET	98.5	426.2	-17.90	13.4		
								12	.0	607.6	10.04	44.6	.720	.732
								EXIT	.0	615.4	11.24	48.1		.731
32		5-8-64	15:41	1005	8.79	2.495	151.9	INLET	99.5	425.7	-18.12	13.4		
								12	.0	609.2	10.19	44.8	.777	.739
								EXIT	.0	617.6	11.48	48.5		.741
33		5-11-64	10:43	1000	3.31	1.438	118.7	INLET	148.3	371.9	-26.25	7.4		
								12	.0	621.4	12.16	29.2	.576	.579
								EXIT	.0	632.2	13.82	32.0		.579
34		5-11-64	11:12	1000	5.30	1.432	147.2	INLET	146.6	373.7	-25.98	7.4		
								12	.0	684.6	21.90	45.5	.710	.718
								EXIT	.0	698.0	23.95	49.0		.718
35		5-11-64	11:24	1010		1.428	150.2	INLET	145.5	376.1	-25.92	7.4		
								12	.0	694.1	23.19	47.2	.725	.733
								EXIT	.0	707.8	25.30	50.7		.733
36		5-11-64	14:15	980	4.94	2.455	144.3	INLET	143.1	374.8	-25.18	12.6		
								12	.0	552.3	2.00	20.6	.704	.703
								EXIT	.0	560.1	3.18	24.1		.703
37		5-11-64	15:01	995	5.73	2.392	153.0	INLET	142.6	377.3	-25.27	12.3		
								12	.0	570.6	4.46	27.0	.747	.746
								EXIT	.0	579.0	5.75	30.6		.746
38		5-11-64	15:23	1000	6.07	2.462	158.3	INLET	143.3	377.2	-25.44	12.7		
								12	.0	569.1	4.10	26.7	.763	.762
								EXIT	.0	577.4	5.39	30.4		.762
39		5-11-64	15:34	1000	6.21	2.466	158.5	INLET	142.9	377.6	-25.37	12.7		
								12	.0	571.9	4.54	28.0	.773	.773
								EXIT	.0	580.4	5.84	31.8		.773
40		5-11-64	15:47	1000	6.70	2.461	163.4	INLET	144.8	375.7	-25.68	12.7		
								12	.0	576.2	5.21	29.9	.797	.797
								EXIT	.0	585.0	6.56	33.8		.797
41		5-11-64	15:57	1000	6.98	2.461	170.1	INLET	144.8	375.7	-25.68	12.7		
								12	.0	584.5	6.48	33.8	.828	.829
								EXIT	.0	593.6	7.88	37.4		.829

Table 1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$
43		5-18-64	11:02	995	5.30	2.456	154.0	INLET	152.1	367.1	-26.84	12.6		
								12	.0	556.8	2.33	21.5	.738	.752
								EXIT	.0	564.9	3.57	25.1		.751
44		5-18-64	13:33	995	6.32	2.466	162.7	INLET	151.3	368.0	-26.69	12.6		
								12	.0	567.5	3.98	26.4	.776	.794
								EXIT	.0	576.0	5.29	30.2		.793
45		5-18-64	13:56	1000	6.64	2.468	169.0	INLET	151.9	368.0	-26.86	12.6		
								1	143.7	376.8	-25.50	12.7	.812	.812
								2	127.2	394.6	-22.76	12.9	.825	.814
								3	110.6	412.7	-19.97	13.1	.827	.820
								4	94.6	430.4	-17.24	13.2	.829	.817
								5	78.3	448.8	-14.41	13.5	.830	.823
								6	62.5	466.9	-11.62	13.7	.825	.824
								7	47.2	484.6	-8.90	13.9	.830	.822
								8	31.8	503.0	-6.06	14.2	.827	.825
								9	17.0	521.1	-3.27	14.5	.824	.825
								10	2.6	539.2	-.90	14.8	.827	.825
								11	.0	556.9	2.23	21.3	.825	.824
								12	.0	575.1	5.04	29.5	.807	.825
	0							EXIT	.0	583.9	6.40	33.4		.824
46		5-19-64	11:09	1000	1.20	.506	98.6	INLET	155.9	363.8	-27.51	2.6		
								12	.0	953.0	63.73	40.7	.471	.481
								EXIT	.0	978.1	67.10	43.0		.481
47		5-19-64	11:35	1002	1.29	.506	102.0	INLET	155.5	364.4	-27.47	2.6		
								12	.0	974.2	66.48	42.6	.486	.498
								EXIT	.0	1000.1	70.47	44.9		.497
48		5-19-64	11:45	1002	1.31	.506	103.1	INLET	156.1	363.8	-27.57	2.6		
								12	.0	980.2	67.40	43.1	.494	.503
								EXIT	.0	1006.4	71.45	45.5		.503
49		5-19-64	11:55	1002	1.31	.506	103.6	INLET	155.6	364.3	-27.48	2.6		
								12	.0	983.4	67.90	43.4	.495	.505
								EXIT	.0	1009.7	71.96	45.8		.505
50		5-19-64	14:23	1505		.504	70.5	INLET	155.3	421.2	-34.39	2.7		
								12	.0	844.2	41.76	18.0	.338	.344
								EXIT	.0	862.2	45.01	19.2		.344
51		5-19-64	14:37	1502		.505	72.9	INLET	154.2	422.1	-34.13	2.7		
								12	.0	858.4	44.35	19.0	.343	.356
								EXIT	.0	876.7	47.44	20.2		.355
52		5-19-64	14:49	1502		.505	73.3	INLET	153.3	423.1	-33.96	2.7		
								12	.0	861.6	44.92	19.2	.348	.358
								EXIT	.0	880.1	48.25	20.4		.357
53		5-20-64	10:26	1500	1.81	1.513	110.1	INLET	152.9	423.3	-33.85	8.1		
								12	.0	843.4	5.72	16.0	.525	.537
								EXIT	.0	852.8	7.40	17.7		.537

Table 1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{10}}{10^6}$	$\frac{\phi_o}{10^6}$
54		9-20-64	11:00	1503	2.11	1.498	115.1	INLET	148.9	428.0	-33.10	8.0		
								12	.0	660.3	8.69	18.9	.552	.562
								EXIT	.0	670.2	10.48	20.8		.561
55		9-20-64	11:44	1502	2.17	1.511	118.0	INLET	152.3	424.2	-33.75	8.1		
								12	.0	660.3	8.72	19.1	.563	.576
								EXIT	.0	670.4	10.52	21.0		.575
56		9-20-64	11:52	1502	2.22	1.513	119.7	INLET	146.1	431.1	-32.52	8.1		
	0							12	.0	670.3	10.52	21.0	.574	.584
	0							EXIT	.0	680.5	12.35	23.0		.584
57		9-20-64	14:55	1493	3.10	2.510	135.3	INLET	151.7	423.9	-33.50	13.4		
								12	16.9	587.1	-4.24	15.8	.642	.661
								EXIT	11.9	594.0	-3.00	16.0		.660
59		9-20-64	15:49	1495	4.40	2.513	160.8	INLET	154.3	421.3	-34.04	13.4		
	0							12	.0	614.8	.69	17.6	.764	.785
	0							EXIT	.0	623.0	2.16	20.2		.784
60		9-21-64	12:56	1500	3.65	2.517	111.0	INLET	106.5	475.5	-24.46	14.0		
								12	1.9	608.9	-.49	16.3	.533	.542
								EXIT	.0	614.6	.54	17.4		.541
61		9-21-64	13:20	1500	4.08	2.528	118.0	INLET	107.7	474.2	-24.71	14.0		
								12	.0	615.3	.67	17.7	.566	.576
								EXIT	.0	621.3	1.75	19.6		.575
62		9-21-64	13:31	1500	4.39	2.517	123.4	INLET	106.1	476.1	-24.36	14.0		
								12	.0	624.3	2.28	20.5	.591	.602
								EXIT	.0	630.6	3.42	22.5		.602
63		9-21-64	13:48	1500	4.71	2.508	126.6	INLET	107.1	474.9	-24.58	13.9		
								12	.0	627.5	2.85	21.4	.613	.618
								EXIT	.0	634.0	4.04	23.5		.617
64		9-21-64	13:56	1500	4.85	2.506	130.1	INLET	111.4	470.0	-25.46	13.9		
	0							12	.0	626.9	2.75	21.2	.628	.635
	0							EXIT	.0	633.7	3.97	23.3		.634
65		9-22-64	10:22	1535		.521	64.8	INLET	112.7	472.0	-26.18	2.9		
								12	.0	848.2	42.23	18.4	.310	.316
								EXIT	.0	864.2	45.14	19.4		.316
66		9-22-64	10:36	1503		.503	67.1	INLET	108.5	473.6	-24.90	2.8		
	0							12	.0	876.4	47.58	20.1	.325	.327
	0							EXIT	.0	893.8	50.71	21.2		.327
67		9-22-64	12:55	1495	1.81	1.504	78.8	INLET	96.6	486.5	-22.33	8.4		
								12	.0	644.9	6.09	16.3	.381	.384
								EXIT	.0	651.7	7.31	17.6		.384
68		9-22-64	13:47	1505	2.33	1.523	94.3	INLET	105.5	477.3	-24.30	8.5		
								12	.0	644.6	9.42	20.0	.457	.460
								EXIT	.0	672.6	10.88	21.5		.460
69		9-22-64	14:08	1502	1.04	1.506	94.1	INLET	107.2	475.0	-24.62	8.4		
								12	.0	663.8	9.35	19.7	.453	.459
								EXIT	.0	671.9	10.61	21.3		.459

Table 1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{1,0}}{10^6}$	$\frac{\phi_o}{10^6}$
70		5-22-64	14:16	1500	1.04	1.502	95.4	INLET	104.6	477.8	-24.06	8.4		
								12	.0	669.8	10.46	20.8	.463	.465
								EXIT	.0	678.1	11.95	22.4		.465
71		5-22-64	14:25	1495	1.09	1.496	99.9	INLET	104.6	477.3	-23.99	8.3		
0								12	.0	679.3	12.26	22.7	.481	.488
0								EXIT	.0	687.9	13.82	24.3		.487
72		5-25-64	10:05	1495		.498	56.5	INLET	55.8	536.4	-13.39	3.0		
								12	.0	879.9	48.26	20.2	.272	.276
								EXIT	.0	894.6	50.90	21.1		.276
73		5-25-64	10:16	1502		.502	58.6	INLET	56.2	536.7	-13.52	3.0		
0								12	.0	889.6	49.96	20.9	.284	.286
0								EXIT	.0	904.8	52.69	21.8		.286
74		5-25-64	12:07	1503	2.54	1.494	74.2	INLET	53.5	540.2	-12.92	8.9		
								12	.0	690.4	14.12	24.5	.355	.362
								EXIT	.0	696.8	15.27	25.7		.362
75		5-25-64	12:38	1501	2.90	1.487	85.0	INLET	52.7	541.0	-12.71	8.9		
0								12	.0	714.0	18.39	28.9	.407	.415
0								EXIT	.0	721.4	19.72	30.3		.415
76		5-25-64	13:26	1501	3.30	2.452	88.6	INLET	56.1	536.7	-13.48	14.6		
								12	.0	646.1	6.18	26.6	.422	.432
								EXIT	.0	650.7	7.01	28.1		.432
77		5-25-64	14:22	1503	3.46	2.458	92.9	INLET	53.7	539.9	-12.96	14.7		
								12	.0	654.1	7.99	29.1	.456	.453
								EXIT	.0	659.1	8.49	30.7		.453
78		5-25-64	15:01	1503	3.48	2.450	97.1	INLET	54.4	539.1	-13.12	14.6		
0								12	.0	658.8	8.43	30.5	.477	.473
0								EXIT	.0	664.1	9.37	32.1		.474
79		5-26-64	10:48	1503		.509	51.1	INLET	25.1	577.1	-6.27	3.2		
								12	.0	880.9	48.39	20.6	.245	.249
								EXIT	.0	893.9	50.73	21.4		.249
80		5-26-64	10:59	1503		.508	54.2	INLET	26.0	575.9	-6.48	3.2		
								12	.0	898.5	51.56	21.7	.257	.265
								EXIT	.0	912.1	54.01	22.6		.264
81		5-26-64	11:06	1502		.508	55.4	INLET	24.7	577.6	-6.15	3.2		
0								12	.0	907.5	53.18	22.3	.264	.270
0								EXIT	.0	921.5	55.69	23.2		.270
82		5-26-64	11:56	1502	3.17	1.499	70.6	INLET	23.6	579.1	-5.89	9.4		
								12	.0	721.5	19.72	30.5	.339	.344
								EXIT	.0	727.6	20.81	31.7		.344
83		5-26-64	12:16	1509	3.31	1.504	78.9	INLET	25.5	577.3	-6.39	9.4		
								12	.0	736.1	22.24	33.2	.377	.385
								EXIT	.0	742.9	23.46	34.4		.385
84		5-26-64	12:25	1509	3.35	1.505	79.5	INLET	25.6	577.2	-6.41	9.4		
0								12	.0	737.0	22.40	33.4	.381	.388
0								EXIT	.0	743.8	23.63	34.6		.388

Table 1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	X	V_m	$\frac{\phi_{10}}{10^6}$	$\frac{\phi_0}{10^6}$
85		5-26-64	14:05	1503	6.32	2.467	77.5	INLET	23.5	579.4	-5.86	15.4		
								12	.0	674.5	11.24	35.6	.372	.378
								EXIT	.0	678.5	11.77	36.8		.378
86		5-26-64	14:20	1503	6.43	2.468	80.9	INLET	23.6	579.2	-5.91	15.4		
0								12	.0	678.3	11.94	36.8	.391	.395
0								EXIT	.0	682.6	12.71	38.1		.395
87		5-26-64	15:42	1515	5.48	2.435	94.2	INLET	51.7	543.8	-12.60	14.6		
0								12	.0	660.7	8.52	30.3	.456	.459
0								EXIT	.0	665.7	9.44	31.9		.459
88		5-28-64	11:20	2003		.501	33.5	INLET	24.7	631.5	-8.77	3.3		
								12	.0	633.6	34.90	11.4	.165	.163
								EXIT	.0	642.4	36.81	11.9		.164
89		5-28-64	11:37	2003		.507	35.8	INLET	24.1	632.4	-8.56	3.4		
0								12	.0	646.3	37.65	12.2	.173	.175
0								EXIT	.0	655.5	39.64	12.6		.175
90		5-28-64	13:14	2003		1.492	48.1	INLET	22.7	634.6	-8.09	10.0		
								12	.0	732.0	12.95	19.3	.233	.234
								EXIT	.0	736.2	13.86	19.9		.234
91		5-28-64	13:30	2003	1.77	1.504	50.3	INLET	22.5	634.8	-8.05	10.0		
								12	.0	735.9	13.80	20.1	.241	.245
								EXIT	.0	740.2	14.73	20.7		.245
92		5-28-64	13:36	2003	1.74	1.510	53.1	INLET	23.4	633.5	-8.32	10.1		
0								12	.0	739.9	14.65	20.7	.253	.259
0								EXIT	.0	744.4	15.63	21.4		.259
93		5-28-64	14:27	2003	5.16	2.482	55.7	INLET	22.0	635.6	-7.87	16.6		
								12	.0	703.5	6.81	25.3	.266	.272
								EXIT	.0	706.4	7.43	26.0		.272
94		5-28-64	14:47	2003	5.18	2.477	59.5	INLET	19.5	639.5	-7.02	16.7		
								12	.0	712.2	8.67	27.3	.288	.290
								EXIT	.0	715.3	9.35	28.1		.290
95		5-28-64	15:11	2003	5.30	2.520	64.0	INLET	24.6	631.6	-8.74	16.7		
								12	.0	708.3	7.83	26.9	.312	.312
								EXIT	.0	711.6	8.56	27.7		.312
96		5-28-64	15:22	2003	5.52	2.518	70.8	INLET	28.1	626.3	-9.88	16.6		
								12	.0	711.3	8.49	27.6	.345	.345
								EXIT	.0	715.0	9.29	28.5		.345
97		5-28-64	15:36	2003	5.86	2.495	76.2	INLET	27.7	627.0	-9.73	16.5		
								12	.0	719.4	10.24	29.3	.366	.372
								EXIT	.0	723.4	11.79	30.3		.372
98		5-28-64	15:51	2003	5.86	2.486	82.9	INLET	28.1	626.4	-9.87	16.4		
0								12	.0	727.2	11.92	31.1	.403	.404
0								EXIT	.0	731.6	12.86	32.1		.404
99		6-1-64	12:18	2000		.495	34.9	INLET	51.1	593.3	-16.92	3.1		
								12	.0	806.1	29.01	10.0	.174	.170
								EXIT	.0	815.6	31.05	10.5		.170

Table 1. (Cont'd).

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	X	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$
100		6- 2-64	9:24	2000	1.04	1.392	46.7	INLET	51.4	592.8	-17.02	8.8		
								12	.0	604.2	4.86	13.0	.231	.228
								EXIT	.0	608.7	5.82	13.6		.228
101		6- 2-64	9:51	2000	1.31	1.505	53.6	INLET	50.9	593.5	-16.87	9.5		
								12	.0	701.1	6.35	15.0	.265	.261
								EXIT	.0	705.9	7.38	15.7		.261
102		6- 2-64	10:08	2010	1.47	1.486	63.2	INLET	51.9	593.1	-17.29	9.4		
0								12	.0	721.5	10.54	17.6	.314	.308
0								EXIT	.0	727.2	11.77	18.4		.308
103		6- 2-64	12:48	2005	4.17	2.508	84.3	INLET	53.6	590.3	-17.72	15.7		
								12	.0	692.0	4.25	22.7	.412	.411
								EXIT	.0	696.4	5.21	23.8		.411
104		6- 2-64	13:13	2005	4.48	2.479	88.5	INLET	53.0	591.2	-17.54	15.6		
								12	.0	699.1	5.79	24.1	.431	.432
								EXIT	.0	703.8	6.81	25.3		.432
105		6- 2-64	13:28	2005	4.69	2.495	92.3	INLET	52.5	591.7	-17.42	15.7		
								12	.0	703.6	6.77	25.4	.450	.450
								EXIT	.0	708.4	7.82	26.6		.450
106		6- 2-64	14:05	2005	5.03	2.507	100.1	INLET	54.1	589.6	-17.89	15.7		
								12	.0	710.2	8.20	27.1	.486	.488
								EXIT	.0	715.4	9.33	28.4		.488
107		6- 2-64	14:20	2005	5.12	2.510	102.3	INLET	54.4	589.2	-17.96	15.7		
0								12	.0	712.4	8.67	27.7	.499	.499
0								EXIT	.0	717.7	9.83	29.0		.499
108		6- 2-64	15:50	2000		.506	34.8	INLET	54.7	588.4	-17.98	3.2		
								12	.0	796.0	26.82	9.7	.170	.169
								EXIT	.0	805.0	28.78	10.2		.169
109		6- 2-64	16:02	2000		.506	39.8	INLET	52.5	591.3	-17.35	3.2		
								12	.0	829.0	33.94	11.3	.194	.194
								EXIT	.0	839.3	36.17	11.8		.194
110		6- 2-64	16:09	2000		.503	42.0	INLET	52.3	591.6	-17.28	3.2		
0								12	.0	844.0	37.19	12.0	.205	.205
0								EXIT	.0	855.0	39.56	12.5		.205
111		6- 3-64	9:44	2005		.499	46.2	INLET	104.2	525.5	-31.75	2.9		
								12	.0	805.5	28.81	10.0	.223	.226
								EXIT	.0	817.5	31.41	10.6		.225
112		6- 3-64	10:02	2005		.497	48.0	INLET	103.9	525.9	-31.66	2.9		
0								12	.0	817.9	31.48	10.6	.229	.234
0								EXIT	.0	830.3	34.17	11.2		.234
113		6- 3-64	11:19	2005	1.25	1.501	79.0	INLET	98.1	532.9	-30.13	8.8		
								12	.0	692.1	4.29	13.6	.384	.385
								EXIT	.0	699.0	5.78	14.6		.385
114		6- 3-64	11:45	2000	1.47	1.513	87.0	INLET	101.5	528.3	-30.95	8.8		
								12	.0	752.3	6.60	15.3	.417	.425
								EXIT	.0	709.7	8.21	16.4		.424

Table 1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{10}}{10^6}$	$\frac{\phi_o}{10^6}$
115		6-3-64	11:52	2000	1.52	1.513	90.7	INLET	104.9	524.2	-31.82	8.8		
	0							12	.0	704.9	7.16	15.7	.469	.441
	0							EXIT	.0	713.3	8.97	16.9		.442
116		6-3-64	13:24	2005	3.40	2.510	111.4	INLET	104.8	524.7	-31.91	14.6		
								12	7.8	658.8	-2.91	17.5	.538	.543
								EXIT	4.4	664.6	-1.66	17.7		.543
117		6-3-64	13:44	2005	3.85	2.486	121.3	INLET	103.2	526.6	-31.49	14.5		
								12	.0	674.2	.42	18.2	.585	.592
								EXIT	.0	680.5	1.79	19.8		.592
118		6-3-64	14:05	2000	4.08	2.491	125.7	INLET	104.2	525.0	-31.65	14.5		
								12	.0	677.7	1.28	19.2	.606	.613
								EXIT	.0	684.2	2.70	20.8		.613
119		6-3-64	14:21	2005	4.37	2.499	130.3	INLET	104.2	525.5	-31.75	14.5		
								12	.0	683.1	2.33	20.5	.630	.636
								EXIT	.0	689.9	3.80	22.1		.635
120		6-3-64	14:30	2000		2.498	135.5	INLET	103.6	525.8	-31.49	14.5		
	0							12	.0	689.6	3.87	22.2	.672	.660
	0							EXIT	.0	696.9	5.43	23.9		.661
121		6-04-64	11:00	2005	1.13	1.504	101.2	INLET	193.0	468.2	-44.14	8.3		
								12	.4	671.5	-.17	10.7	.492	.493
								EXIT	.0	680.3	1.74	11.9		.493
122		6-04-64	11:26	2003	1.31	1.507	108.5	INLET	192.9	468.1	-44.08	8.3		
								12	.0	685.7	2.94	12.8	.523	.529
								EXIT	.0	695.0	4.97	14.1		.529
123		6-04-64	11:35	2005	1.29	1.505	109.9	INLET	193.5	467.6	-44.27	8.3		
	0							12	.0	688.4	3.49	13.1	.530	.536
	0							EXIT	.0	697.9	5.54	14.5		.536
124		6-04-64	13:37	2005		.501	53.3	INLET	195.3	465.4	-44.73	2.7		
	0							12	.0	786.8	24.76	9.1	.258	.260
	0							EXIT	.0	800.7	27.76	9.8		.260
125		6-04-64	15:36	2003	3.19	2.521	140.7	INLET	191.7	469.5	-43.77	13.9		
								12	20.3	638.2	-7.31	16.9	.681	.686
								EXIT	15.6	645.5	-5.73	17.1		.686
126		6-04-64	16:02	2005	3.31	2.520	149.8	INLET	192.8	468.3	-44.11	13.9		
								12	17.2	643.2	-6.28	17.1	.699	.711
								EXIT	12.6	650.7	-4.66	17.3		.711
127		6-04-64	16:14	2005	3.60	2.515	152.6	INLET	192.8	468.3	-44.11	13.8		
								12	12.0	651.7	-4.45	17.3	.747	.744
								EXIT	7.3	659.7	-2.72	17.6		.744
128		6-04-64	16:24	2005	3.80	2.519	157.6	INLET	194.7	466.2	-44.56	13.8		
								12	9.9	655.3	-3.66	17.4	.769	.769
								EXIT	5.0	663.6	-1.88	17.7		.769
129		6-04-64	16:32	2005	4.08	2.513	164.5	INLET	192.7	468.4	-44.08	13.8		
	0							12	3.4	666.3	-1.29	17.7	.797	.802
	0							EXIT	.0	674.9	.56	18.6		.802

Table 1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$
130		6-10-64	11:45	1010	3.90	1.017	104.1	INLET	80.9	447.2	-14.94	5.5		
								12	.0	756.6	32.85	45.0	.501	.508
								EXIT	.0	769.9	34.90	47.5		.508
131		6-10-64	12:43	1007	4.55	1.005	117.5	INLET	81.7	445.9	-15.05	5.5		
								12	.0	799.7	39.54	52.5	.562	.574
								EXIT	.0	814.8	41.86	55.2		.573
132		6-10-64	12:55	1007	4.67	1.005	120.7	INLET	80.6	447.2	-14.86	5.5		
0								12	.0	810.4	41.19	54.4	.577	.589
0								EXIT	.0	825.9	43.98	57.2		.589
133		6-10-64	14:29	1015	8.65	1.997	137.2	INLET	81.9	446.8	-15.14	10.0		
								12	.0	654.5	16.99	51.3	.655	.669
								EXIT	.0	663.3	18.35	54.5		.669
134		6-10-64	14:41	1010	8.83	1.991	140.6	INLET	80.4	447.8	-14.85	10.0		
0								12	.0	661.5	18.15	54.1	.665	.686
0								EXIT	.0	670.5	19.54	57.3		.686
135		6-11-64	10:33	1010	12.23	2.002	111.6	INLET	21.0	517.7	-4.05	11.7		
								12	.0	686.3	21.99	63.3	.535	.544
								EXIT	.0	693.5	23.10	65.9		.544
136		6-11-64	10:51	1010	11.78	1.979	118.8	INLET	20.2	518.7	-3.90	11.5		
								12	.0	700.2	24.14	67.5	.571	.580
								EXIT	.0	708.0	25.34	70.3		.579
137		6-11-64	11:00	1005	11.73	1.977	122.5	INLET	21.3	516.5	-4.11	11.5		
0								12	.0	704.0	24.80	69.3	.586	.598
0								EXIT	.0	711.9	26.03	72.1		.597
138		6-11-64	12:50	995	4.77	.986	-2.9	INLET	20.2	516.5	-3.86	5.7		
								12	27.4	507.7	-5.22	5.7		
								EXIT	27.7	507.3	-5.28	5.7		
139		6-11-64	13:14	995	4.91	.976	96.3	INLET	20.7	515.9	-3.96	5.7		
								12	.0	814.2	41.91	54.3	.462	.470
								EXIT	.0	827.0	43.87	56.6		.470
140		6-11-64	13:38	1000	5.25	.994	101.2	INLET	22.2	514.7	-4.26	5.8		
								12	.0	822.9	43.19	56.5	.486	.494
								EXIT	.0	836.0	45.22	58.9		.494
141		6-11-64	13:50	1000	5.37	1.002	104.9	INLET	18.7	519.1	-3.59	5.8		
0								12	.0	835.8	45.18	59.3	.500	.512
0								EXIT	.0	849.2	47.25	61.8		.511
143		6-12-64	11:18	1500	3.48	1.500	69.9	INLET	12.2	594.5	-3.08	9.6		
								12	.0	735.5	27.27	33.3	.335	.341
								EXIT	.0	741.5	28.35	34.4		.341
144		6-12-64	11:31	1500	3.56	1.498	75.8	INLET	12.2	594.5	-3.08	9.5		
0								12	.0	747.5	24.43	35.5	.365	.370
0								EXIT	.0	754.1	25.61	36.7		.370
145		6-12-64	12:44	1500	5.01	1.974	72.5	INLET	11.0	596.1	-2.78	12.6		
								12	.0	707.2	17.18	36.7	.349	.354
								EXIT	.0	711.9	18.04	37.9		.353

Table 1. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	v_m	$\frac{\phi_{i,0}}{10^6}$	$\frac{\phi_o}{10^6}$
146		6-12-64	12:53	1500	5.14	1.970	76.0	INLET	9.2	598.6	-2.34	12.6		
	0							12	.0	715.2	18.62	38.6	.366	.371
	0							EXIT	.0	720.2	19.52	39.9		.370
147		6-12-64	13:39	1500	6.91	2.460	74.1	INLET	15.5	589.8	-3.92	15.6		
								12	.0	680.9	12.45	37.6	.358	.361
								EXIT	.0	684.8	13.15	38.8		.361
148		6-12-64	13:51	1500	6.88	2.465	76.6	INLET	17.4	587.3	-4.37	15.6		
								12	.0	681.3	12.53	37.8	.370	.374
								EXIT	.0	685.3	13.26	39.1		.374
149		6-12-64	14:38	1500	6.77	2.494	81.8	INLET	21.2	582.1	-5.30	15.6		
	0							12	.0	681.2	12.92	38.2	.396	.399
	0							EXIT	.0	685.5	13.28	39.6		.399
150		6-15-64	11:28	1500	.86	1.000	89.2	INLET	152.1	424.1	-33.70	5.3		
								12	.0	693.7	14.76	16.9	.431	.435
								EXIT	.0	705.3	16.85	18.4		.435
151		6-15-64	11:50	1505	1.04	.999	94.8	INLET	151.1	425.8	-33.56	5.3		
								12	.0	712.8	18.11	19.2	.457	.463
								EXIT	.0	725.1	20.33	20.7		.462
152		6-15-64	13:10	1500	1.22	.997	98.8	INLET	151.7	424.6	-33.61	5.3		
								12	.0	724.4	20.27	20.7	.475	.482
								EXIT	.0	737.2	22.98	22.3		.482
153		6-15-64	13:25	1505	1.29	.997	102.2	INLET	151.5	425.4	-33.64	5.3		
								12	.0	735.2	22.15	22.0	.491	.499
								EXIT	.0	748.5	24.54	23.6		.498
154		6-15-64	13:37	1500	1.29	.996	104.3	INLET	149.9	426.7	-33.25	5.3		
	0							12	.0	743.1	23.64	23.1	.500	.509
	0							EXIT	.0	756.6	26.07	24.8		.508
155		6-15-64	15:14	1510	3.49	1.500	73.4	INLET	19.7	585.3	-4.97	9.4		
								12	.0	733.3	21.73	32.5	.354	.358
								EXIT	.0	739.7	22.88	33.7		.358
156		6-15-64	15:24	1512	3.53	1.504	76.5	INLET	21.0	583.7	-5.30	9.4		
	0							12	.0	737.6	22.47	33.3	.369	.373
	0							EXIT	.0	744.2	23.67	34.6		.373
158		6-17-64	11:25	1990		.498	65.4	INLET	251.7	359.4	-66.87	2.9		
	0							12	.0	756.9	18.97	7.7	.314	.319
	0							EXIT	.0	774.0	22.23	8.6		.319
160		6-17-64	13:55	1995	.34	1.005	105.6	INLET	249.3	362.2	-66.52	5.1		
	0							12	.0	680.1	1.93	8.0	.505	.515
	0							EXIT	.0	693.6	4.84	9.4		.515

Table 2. Preliminary Report of Test Results From Flux Shape No. 2

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$
161		08-26-64	11:15	1015	.59	.496	62.7	INLET	20.0	519.6	-3.87	2.9		
								1	14.7	526.2	-2.86	2.9	.122	.122
								2	1.3	544.3	-.05	3.0	.211	.152
								3	.0	571.8	4.19	5.4	.296	.193
								4	.0	606.4	9.54	8.5	.358	.229
								5	.0	648.0	15.97	12.2	.400	.264
								6	.0	692.2	22.82	16.1	.427	.291
								7	.0	738.8	30.03	20.2	.428	.312
								8	.0	783.2	36.88	24.2	.402	.325
								9	.0	825.5	43.43	27.9	.360	.333
								10	.0	860.7	48.88	31.1	.294	.332
								11	.0	888.4	53.16	33.5	.213	.325
								12	.0	907.2	56.07	35.2	.121	.312
								EXIT	.0	913.7	57.08	35.8		.304
162		08-26-64	11:46	1020	1.22	.521	81.0	INLET	23.4	516.2	-4.53	3.0		
								12	.0	993.2	69.35	44.7	.160	.403
								EXIT	.0	1001.4	70.63	45.5		.393
163		08-26-64	12:33	1005	1.25	.506	84.1	INLET	22.1	515.6	-4.25	2.9		
0								12	.0	1024.8	74.77	47.1	.163	.418
0								EXIT	.0	1033.4	75.60	47.9		.408
164		08-26-64	13:57	1010	7.20	1.477	109.8	INLET	19.0	520.1	-3.68	8.6		
0								12	.0	748.0	31.52	63.1	.216	.546
0								EXIT	.0	751.9	32.12	64.1		.532
165		08-26-64	15:05	1010	12.75	2.504	112.9	INLET	17.1	522.5	-3.31	14.7		
0								11	.0	654.5	17.08	64.9	.386	.587
								12	.0	660.7	18.03	67.6	.223	.561
								EXIT	.0	663.1	18.40	68.7		.547
166		08-26-64	15:59	1025	8.97	2.535	116.4	INLET	52.1	482.4	-9.90	14.3		
0								11	.0	616.8	10.95	47.0	.397	.605
								12	.0	623.2	11.94	49.9	.229	.579
								EXIT	.0	625.6	12.32	51.0		.564
167		08-27-64	12:39	1025	5.01	2.513	117.8	INLET	100.1	427.7	-18.39	13.5		
								1	97.9	430.1	-18.01	13.5	.227	.227
								2	91.9	436.8	-18.98	13.6	.395	.284
								3	83.3	446.5	-15.47	13.7	.556	.353
								4	71.5	460.0	-13.37	13.9	.675	.433
								5	58.3	475.2	-11.02	14.0	.756	.495
								6	44.2	491.7	-8.45	14.2	.802	.546
								7	29.9	509.0	-5.77	14.5	.803	.586
								8	16.4	525.5	-3.21	14.8	.755	.612
								9	4.2	540.9	-.83	15.1	.677	.624
								10	.0	553.9	1.20	18.6	.554	.623
								11	.0	564.3	2.81	23.2	.403	.610
								12	.0	571.4	3.90	26.4	.233	.586
								EXIT	.0	573.8	4.29	27.5		.571

Table 2. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{i,o}}{10^6}$	$\frac{\phi_o}{10^6}$
168		08-27-64	13:04	1005	5.30	2.929	121.0	INLET	100.6	424.5	-18.30	13.5		
								12	.0	571.2	4.32	28.0	.239	.602
								EXIT	.0	573.7	4.71	29.1		.587
169		08-27-64	14:28	1020	5.93	2.496	126.0	INLET	97.0	430.5	-17.80	13.4		
								12	.0	585.3	6.18	32.8	.248	.627
								EXIT	.0	588.0	6.59	34.0		.611
170		08-27-64	14:56	1015	6.30	2.512	130.2	INLET	101.3	425.0	-18.51	13.4		
								12	.0	583.9	6.06	32.8	.257	.648
								EXIT	.0	586.6	6.49	34.0		.631
171		08-27-64	15:15	1020	6.93	2.524	139.1	INLET	99.4	427.8	-18.23	13.5		
								12	.0	596.8	7.95	38.3	.273	.692
								EXIT	.0	599.7	8.40	39.6		.675
172		08-28-64	11:12	1030	4.10	2.486	144.9	INLET	148.8	375.2	-26.68	12.8		
								12	.0	554.0	1.09	18.1	.287	.721
								EXIT	.0	557.1	1.57	19.4		.703
173		08-28-64	11:58	1003	4.46	2.484	150.1	INLET	148.8	371.7	-26.38	12.8		
								12	.0	557.0	2.18	21.3	.298	.747
								EXIT	.0	560.2	2.67	22.7		.728
174		08-28-64	12:10	1030	4.90	2.488	153.2	INLET	150.1	373.8	-26.90	12.8		
								12	.0	562.6	2.43	21.9	.304	.762
								EXIT	.0	565.9	2.94	23.3		.743
175		08-28-64	12:21	1000	5.44	2.472	157.3	INLET	147.5	372.7	-26.14	12.7		
								12	.0	567.8	3.91	26.2	.312	.783
								EXIT	.0	571.2	4.43	27.7		.763
176		08-28-64	12:42	1005	5.98	2.437	162.0	INLET	146.5	374.5	-26.02	12.5		
								12	.0	578.2	5.41	30.1	.321	.806
								EXIT	.0	581.7	5.95	31.6		.786
177		08-28-64	15:13	1025	5.89	1.467	115.2	INLET	55.4	478.5	-10.50	8.2		
								12	.0	719.3	26.86	53.9	.226	.573
								EXIT	.0	723.5	27.50	55.0		.559
178		08-31-64	10:22	1010	4.69	1.534	116.0	INLET	100.3	425.4	-18.30	8.2		
								12	.0	657.3	17.50	40.5	.228	.577
								EXIT	.0	661.2	18.12	41.6		.563
179		08-31-64	10:37	1015	5.30	1.520	127.3	INLET	100.0	426.4	-18.29	8.1		
								12	.0	683.2	21.42	46.9	.252	.633
								EXIT	.0	687.6	22.11	48.1		.617
180		08-31-64	11:55	1005	4.46	1.512	140.6	INLET	147.0	373.9	-26.10	7.8		
								12	.0	659.1	17.88	40.7	.278	.700
								EXIT	.0	664.0	18.64	42.1		.682
181		08-31-64	13:35	1005	1.11	.506	98.7	INLET	152.2	368.3	-26.96	2.6		
								12	.0	966.4	65.28	41.7	.194	.491
								EXIT	.0	976.7	66.86	42.7		.479
182		08-31-64	13:45	1005	1.16	.510	103.7	INLET	152.5	368.0	-27.01	2.6		
								12	.0	991.5	69.14	44.4	.205	.516
								EXIT	.0	1002.2	70.79	45.4		.503

Table 2. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{1,0}}{10^6}$	$\frac{\phi_o}{10^6}$
183		08-31-64	14:50	1000	1.18	.504	97.8	INLET	102.9	421.3	-18.65	2.7		
	0							12	.0	1016.3	72.97	46.4	.192	.487
	0							EXIT	.0	1026.4	74.54	47.3		.475
184		08-31-64	17:04	1005	1.16	.494	86.9	INLET	46.6	486.0	-8.82	2.8		
	0							12	.0	1026.1	74.48	46.0	.170	.433
	0							EXIT	.0	1035.3	75.90	46.8		.422
185		09-01-64	09:27	1515	2.69	1.502	70.8	INLET	20.4	584.9	+5.16	9.5		
	0							10	.0	712.4	17.88	28.5	.333	.376
	0							11	.0	723.1	19.81	30.5	.240	.369
	0							12	.0	729.4	20.94	31.7	.137	.352
	0							EXIT	.0	731.8	21.38	32.1		.343
186		09-01-64	10:23	1510	2.38	1.513	80.2	INLET	48.5	547.3	-11.81	9.1		
	0							12	.0	709.9	17.51	28.3	.155	.399
	0							EXIT	.0	712.7	18.00	28.0		.389
187		09-01-64	11:25	1510	2.08	1.752	95.9	INLET	97.7	486.8	-22.73	9.8		
	0							12	.0	654.6	7.53	20.6	.188	.477
	0							EXIT	.0	657.5	8.05	21.3		.465
188		09-01-64	11:45	1510	2.08	1.491	99.1	INLET	100.1	484.0	-23.23	8.4		
	0							12	.0	687.9	13.93	23.8	.194	.493
	0							EXIT	.0	691.4	14.16	24.5		.481
189		09-01-64	12:48	1505	2.02	1.506	119.0	INLET	146.6	430.7	-32.68	8.1		
	0							12	.0	673.0	10.95	21.4	.235	.502
	0							EXIT	.0	677.2	11.70	22.2		.577
190		09-01-64	14:43	1510		.487	73.4	INLET	156.5	420.3	-34.73	2.6		
	0							12	.0	882.2	48.59	19.7	.143	.365
	0							EXIT	.0	890.1	50.00	20.2		.356
191		09-01-64	16:02	1508		.509	68.3	INLET	106.7	476.2	-24.59	2.8		
	0							12	.0	888.1	49.65	20.9	.132	.340
	0							EXIT	.0	895.0	50.91	21.4		.331
192		09-02-64	10:34	1508		.494	61.0	INLET	54.1	539.9	-13.10	3.0		
	0							12	.0	917.5	54.96	22.3	.117	.304
	0							EXIT	.0	923.9	56.10	22.7		.296
193		09-02-64	11:05	1510		.489	54.6	INLET	30.4	570.9	-7.56	3.0		
	0							12	.0	926.2	56.51	22.4	.109	.282
	0							EXIT	.0	932.1	57.58	22.8		.275

Table 2. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_0	h	x	V_m	$\frac{\phi_{10}}{10^6}$	$\frac{\phi_0}{10^6}$
194		09-02-64	12:07	1505	5.30	2.519	75.6	INLET	25.6	576.8	-6.39	15.7		
								1	24.4	578.3	-6.11	15.7	.146	.146
								2	21.2	582.6	-5.33	15.8	.254	.183
								3	16.5	589.1	-4.17	15.9	.356	.232
								4	10.4	597.5	-2.65	16.1	.434	.279
								5	3.6	607.0	-.94	16.3	.484	.316
								6	.0	617.7	.99	16.2	.514	.350
								7	.0	628.7	2.97	21.7	.518	.376
								8	.0	639.7	4.95	25.2	.485	.394
								9	.0	649.5	6.71	28.3	.433	.402
								10	.0	658.0	8.23	31.0	.355	.401
								11	.0	664.2	9.35	32.9	.257	.391
								12	.0	668.9	10.21	34.4	.146	.376
								EXIT	.0	670.5	10.49	34.9		.367
195		09-02-64	13:47	1500	4.98	2.511	90.7	INLET	45.7	549.8	-11.10	15.2		
								12	.0	660.7	8.82	32.0	.177	.451
								EXIT	.0	662.6	9.16	32.6		.440
196		09-02-64	15:06	1503	4.37	2.519	118.6	INLET	95.3	489.0	-22.13	14.2		
								12	.0	633.4	3.86	23.3	.234	.590
								EXIT	.0	635.9	4.31	24.1		.575
197		09-02-64	15:23	1503	4.44	2.537	122.2	INLET	98.8	484.8	-22.88	14.2		
								12	.0	632.6	3.71	23.2	.241	.608
								EXIT	.0	635.1	4.16	24.0		.593
198		09-02-64	15:37	1510	4.73	2.545	126.9	INLET	95.7	489.2	-22.30	14.3		
								12	.0	642.1	5.28	26.0	.250	.631
								EXIT	.0	644.8	5.76	26.8		.616
199		09-03-64	09:08	1505	3.37	2.539	151.0	INLET	148.8	428.4	-33.11	13.6		
								12	1.0	610.8	-.26	16.5	.298	.751
								EXIT	.0	613.9	.31	17.1		.733
200		09-03-64	09:42	1518	4.03	2.468	155.6	INLET	145.7	433.0	-32.70	13.2		
								12	.0	626.4	2.26	20.0	.308	.774
								EXIT	.0	629.7	2.87	21.1		.755
201		09-03-64	09:53	1518	4.05	2.510	164.9	INLET	152.2	425.9	-34.00	13.4		
								12	.0	627.3	2.43	20.7	.327	.820
								EXIT	.0	630.8	3.06	21.8		.800
202		09-03-64	12:53	2005	1.27	1.484	51.9	INLET	23.1	634.1	-8.25	9.9		
								11	.0	736.2	13.83	19.8	.172	.269
								12	.0	741.4	14.95	20.6	.096	.258
								EXIT	.0	743.2	15.33	20.8		.252
203		09-03-64	14:19	2008	1.29	1.508	64.9	INLET	47.3	599.2	-15.91	9.6		
								11	.0	725.2	11.38	18.5	.220	.338
								12	.0	731.1	12.66	19.3	.124	.323
								EXIT	.0	733.3	13.13	19.6		.315

Table 2. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{10}}{10^6}$	$\frac{\phi_o}{10^6}$
204		09-03-64	15:18	2005	1.38	1.546	92.7	INLET	99.6	531.1	-30.53	9.0		
	0							11	.0	708.2	7.76	16.4	.319	.486
	0							12	.0	715.1	9.25	17.5	.182	.461
	0							EXIT	.0	718.2	9.94	17.9		.450
205		09-03-64	17:01	1970	1.40	1.565	114.4	INLET	142.5	477.2	-40.73	8.7		
	0							11	.0	690.8	4.81	14.6	.390	.504
	0							12	.0	701.4	7.07	16.2	.224	.569
	0							EXIT	.0	705.2	7.89	16.8		.555
206		09-04-64	13:16	2015		.509	27.4	INLET	28.6	626.7	-10.15	3.4		
								1	26.9	629.3	-9.59	3.4	.049	.049
								2	22.1	636.7	-7.98	3.4	.090	.063
								3	14.7	648.3	-5.45	3.5	.129	.082
								4	5.6	663.7	-2.12	3.6	.160	.100
								5	.0	680.8	1.60	4.0	.179	.114
								6	.0	700.6	5.89	5.0	.191	.127
								7	.0	721.0	10.32	6.0	.191	.138
								8	.0	740.1	14.48	6.9	.179	.144
								9	.0	758.4	18.44	7.8	.160	.147
								10	.0	773.0	21.61	8.5	.129	.146
								11	.0	785.4	24.32	9.1	.091	.143
								12	.0	791.9	25.73	9.5	.049	.136
								EXIT	.0	794.5	26.29	9.8		.133
207		09-04-64	14:06	2003		.489	32.5	INLET	29.5	624.3	-10.32	3.2		
								12	.0	828.6	33.82	10.9	.059	.162
								EXIT	.0	831.8	34.52	11.1		.158
208		09-04-64	14:33	2003		.478	35.3	INLET	26.4	628.9	-9.32	3.2		
	0							11	.0	845.9	37.56	11.5	.116	.184
	0							12	.0	855.5	39.64	11.9	.065	.176
	0							EXIT	.0	859.2	40.43	12.1		.171
209		09-08-64	10:39	2005		.504	58.0	INLET	153.2	467.9	-44.21	2.8		
	0							11	.0	805.6	28.83	10.1	.196	.303
	0							12	.0	821.2	32.19	10.9	.111	.289
	0							EXIT	.0	827.0	33.47	11.2		.281
210		09-08-64	11:58	1995		.508	48.8	INLET	100.9	528.6	-30.69	3.0		
	0							11	.0	805.6	28.96	10.3	.164	.250
	0							12	.0	820.1	32.09	11.0	.092	.240
	0							EXIT	.0	825.0	33.13	11.2		.234
211		09-08-64	13:11	1990		.491	38.0	INLET	49.0	595.2	-16.19	3.1		
	0							11	.0	826.0	33.42	11.0	.131	.202
	0							12	.0	838.4	36.08	11.6	.073	.194
	0							EXIT	.0	842.4	36.93	11.7		.189
212		09-08-64	14:50	1990	4.89	2.478	93.4	INLET	89.6	542.2	-27.58	14.7		
								11	-10.5	652.6	-3.85	17.1	.318	.486
								12	7.2	658.1	-2.68	17.2	.182	.466
								EXIT	6.1	660.1	-2.25	17.3		.454

Table 2. (Cont'd)

RUN NO.	DNS	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_s}{10^6}$	$\frac{\phi_o}{10^6}$
213		09-08-64	15:02	1995	4.87	2.475	97.0	INLET	49.9	594.4	-16.52	15.6		
	0							11	.0	709.0	8.16	26.8	.330	.504
	0							12	.0	714.6	9.36	28.1	.189	.483
	0							EXIT	.0	716.6	9.80	28.6		.470
214		09-08-64	16:05	2005	5.43	2.489	74.1	INLET	21.6	636.5	-7.75	16.7		
	0							10	.0	719.3	10.16	29.1	.356	.405
	0							11	.0	725.8	11.57	30.7	.254	.395
								12	.0	730.3	12.55	31.8	.146	.379
								EXIT	.0	731.9	12.89	32.2		.369
215		09-09-64	09:57	2005	3.92	2.496	128.1	INLET	97.4	533.9	-29.93	14.7		
								11	.0	683.6	2.45	20.6	.439	.664
								12	.0	691.3	4.10	22.4	.292	.637
								EXIT	.0	694.0	4.69	23.1		.621
216		09-09-64	13:10	2010	3.80	2.502	127.9	INLET	100.6	530.3	-30.89	14.6		
								11	.0	680.1	1.58	19.7	.438	.666
								12	.0	687.0	3.06	21.3	.252	.636
								EXIT	.0	689.7	3.65	22.0		.620
217		09-09-64	13:28	1995	4.12	2.505	131.0	INLET	98.5	531.6	-30.05	14.7		
								11	.0	684.7	2.93	21.2	.446	.682
								12	.0	691.9	4.48	22.9	.257	.652
								EXIT	.0	694.7	5.07	23.6		.635
218	0	09-09-64	13:40	2000	4.21	2.495	133.5	INLET	98.8	531.7	-30.21	14.6		
								11	.0	688.6	3.64	21.9	.456	.695
								12	.0	695.9	5.22	23.7	.264	.664
								EXIT	.0	698.7	5.83	24.4		.648
219		09-09-64	15:21	2000	3.40	2.505	159.7	INLET	146.7	474.8	-42.49	13.9		
								11	6.2	660.9	-2.32	17.5	.544	.829
								12	.9	670.3	-1.31	17.8	.313	.794
								EXIT	.0	673.6	.41	18.3		.774
220		09-09-64	15:31	2000	3.71	2.484	164.0	INLET	146.1	475.5	-42.34	13.7		
								11	2.0	668.2	-.75	17.6	.562	.850
								12	.0	678.1	1.37	19.3	.324	.816
								EXIT	.0	681.6	2.13	20.1		.796
221	0	09-09-64	15:49	2010	3.94	2.504	168.8	INLET	147.1	475.2	-42.83	13.9		
								11	.6	672.0	-.19	17.9	.577	.875
								12	.0	681.9	1.97	20.1	.334	.840
								EXIT	.0	685.5	2.74	21.0		.819
222		09-10-64	09:44	2000	1.31	1.503	89.7	INLET	98.9	531.5	-30.25	8.8		
	0							11	.0	706.0	7.40	15.7	.302	.466
	0							12	.0	714.7	9.29	17.0	.173	.447
	0							EXIT	.0	717.8	9.95	17.5		.435
223		09-10-64	12:23	1510		.478	54.8	INLET	26.2	576.5	-6.56	3.0		
	0							12	.0	628.3	56.90	22.1	.105	.273
	0							EXIT	.0	634.2	57.66	22.4		.266

Table 2. (Cont'd)

RUN NO.	DNB	DATE	TIME	P	ΔP	$G \times 10^{-6}$	KW	STA NO.	ΔT_s	h	x	V_m	$\frac{\phi_{10}}{10^6}$	$\frac{\phi_o}{10^6}$
224		09-10-64	14:43	1005	7.47	1.400	109.7	INLET	16.6	522.4	-3.20	8.8		
	0							12	.0	745.0	31.13	63.6	.200	.541
	0							EXIT	.0	748.7	31.70	64.7		.527
225		09-11-64	10:21	995	12.37	2.484	114.4	INLET	17.4	520.0	-3.33	14.5		
	0							11	.0	654.9	17.42	66.1	.390	.595
								12	.0	661.2	18.39	66.0	.220	.569
								EXIT	.0	663.6	18.75	70.1		.555

Figure 3. Critical Heat Flux Data for Chopped Cosine Distribution at 1000 psia

Figure 4. Critical Heat Flux Data for Chopped Cosine Distribution at 1500 psia

Figure 5. Critical Heat Flux Data for Chopped Cosine Distribution at 2000 psia

5. ANALYSIS

The computer program for comparing uniform heat flux data with correlations has been completed. This program has been used to compare the uniform flux data from this experiment with the equations from References 3, 4, and 5. The data have been grouped according to nominal pressure, and each group has been compared with the three equations. For each group and each equation the mean ratio of experimental-to-calculated heat flux and the standard deviation have been computed. The results are shown in Figure 6. The agreement of a group of data with a specific equation 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. The agreement of the data with the equations of References 4 and 5 appears to be somewhat mixed and superior to the agreement with the equation of Reference 3. In considering the equations of Reference 4 only the quality correlation was used because all of the burnout runs had exit quality.

Figure 6. Comparison of Burnout Equations With Uniform Heat Flux Data

6. PROGRAM SCHEDULE

The schedule in Figure 7 indicates the work expected to be done during the next two quarters.

Figure 7. Schedule of Nonuniform Heat Generation Experimental Program

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- ³ DeBortoli, R. A., et al., Forced Convection Heat Transfer Burnout Studies for Water in Rectangular Channels and Round Tubes at Pressures Above 500 psia, WAPD-188, October 1958.
- ⁴ Tong, L. S., et al., New DNB (Burnout) Correlations, WCAP-1997, May 1963.
- ⁵ Wilson, R. H. and Ferrell, J. K., Correlation of Critical Heat Flux for Boiling Water in Forced Circulation at Elevated Pressures, AIChE Symposium Series, Nuclear Engineering X. (Also appeared as BAW-168.)

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