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**TWO-PHASE FLOW AND HEAT TRANSFER
IN MULTIROD GEOMETRIES
NINETEENTH
QUARTERLY PROGRESS REPORT
APRIL 1-JUNE 30, 1970**

U.S. ATOMIC ENERGY COMMISSION
CONTRACT AT(04-3)-189
PROJECT AGREEMENT 44

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**TWO-PHASE FLOW AND HEAT TRANSFER
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APRIL 1-JUNE 30, 1970**

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SUMMARY

Multirod critical heat flux data were obtained, using an array of nine uniformly heated rods held in their correct positions in a square channel by means of five grid-type spacers typical of modern water-cooled and moderated power reactors. Five combinations of axial position of heated length in relation to end of channel, and axial position of spacers with respect to end of heated length, were tested at various mass velocities and pressures. The effect on CHF of moving the end of the heated length from a position 2 inches before the end of the channel (test channel No. 4) to a position 3-1/2 feet before the end of the channel (test channel No. 2) was to reduce the CHF at low qualities. The effect on CHF of moving the last spacer from a position just past the end of the heated length (test channel No. 2) to a position just before the end of the heated length (test channel No. 1) was generally to raise the CHF, particularly at low qualities and high flows. The effect on the magnitude of CHF of adding a diversion plate 6 inches past the end of the heated length (test channel No. 2A) was insignificant, but the location of CHF moved from the corner rods to the center rod. The effect on CHF (relative to test channel No. 2) of removing the last spacer (test channel No. 3) was to raise the CHF at low qualities and lower the CHF at high qualities. The presence of the spacer just past the end of the heated length helped CHF at high qualities. At pressures greater than 1000 psia, the CHF decreases as the pressure is increased. This inverse pressure effect is stronger at higher flows. Sixteen-rod results were compared with nine-rod results (test channel No. 4) where, for both the sixteen-rod and the nine-rod channels, the rods were uniform, the ends of the heated lengths were even with the ends of the chamber, and the axial positions of the spacers were the same. The sixteen-rod points agree well with the nine-rod data at $G = 0.5 \times 10^6$ lb/h-ft², but lie above the nine-rod data at $G = 1.0 \times 10^6$ lb/h-ft².

1. INTRODUCTION

This is the nineteenth quarterly report on the work done under Contract AT(04-3)-189, Project Agreement No. 44, and covers the period from April 1 to June 30, 1970.

The objectives for Phase 1 of the program were as follows.

Task A

1. Obtain detailed measurements of flow structure (pressure drop, liquid film thickness, wall shear stress, local mass flux, local impact pressure) for air-water and steam-water mixtures.
2. Carry on an analytical effort in parallel with the air-water tests.

Task B

1. Measure the critical heat flux for a vertical nine-rod geometry, under forced convection conditions, with water at high pressure (600 to 1400 psia) and flow upward. Tests should be performed with a "clean" multirod geometry (as little disturbance as possible to the flow by the provisions for maintaining the rods in correct relative alignment).
2. Investigate the effect of certain parameters; specifically, quality, flow rate, heated length, pressure, and rod-wall spacing.
3. Use the results to evaluate one or more computer models as a basis for CHF prediction.

The work under Phase 1 has been reported in Quarterly Reports Numbers 1 through 10, plus certain topical reports and summary reports, either issued or to be issued soon.

The objectives for Phase 2 are as follows.

Task C

1. Make measurements of both fully-developed and developing two-phase flow (steam-water at 600 to 1400 psia, adiabatic and with heat addition, flow vertical upward) from which can be determined rates of mass and energy transfer in the transverse direction, such measurements to be made in a circular tube, eccentric annulus, and nine-rod channel. The nine-rod channel measurements should include representative measurements of subchannel flow and enthalpy from which can be deduced information concerning cross flow and mixing.
2. Determine the relationships between rate and driving potential, or potential gradient, and the effect of certain parameters (e.g., total flow, pressure, local void) on these relationships. In particular, determine the effect of grid-type spacers in the nine-rod channel.
3. Analyze the results to evaluate existing models of two-phase flow. Endeavor to develop an improved model in light of the results. Such a model should be useful in the prediction of flow structure, pressure drop, and critical heat flux in developing two-phase flow in multirod geometries, both "clean" and with grid-type spacers.

Task D

1. Measure critical heat flux in a nine-rod channel fitted with grid-type spacers characteristic of modern water-cooled reactors.
2. Determine, if possible, whether, and to what degree, the effect of spacers on the CHF is caused by a redistribution of the flow among the various subchannels, or by a highly localized disturbance which might, for example, disrupt the liquid film.
3. Modify the prediction methods developed in Task C as appropriate, and check them against the data obtained under Item 1.

The nine-rod test section used earlier for the Task C subchannel and flow structure measurements, was used during this reporting period for the Task D critical heat flux tests. A description of this test section was given in the Thirteenth Quarterly Report.¹ Some of the description is repeated, the particular five test channels and spacers for the CHF work are described, and the test results are given in the following sections.

2. DESCRIPTION OF NINE-ROD TEST SECTION

The test section described here was built specially for subchannel and flow structure measurements, but may also readily be used for critical heat flux tests. The test section as fitted for subchannel work and shown in Figure 1, was described in the Thirteenth Quarterly Report.¹ The only changes needed for CHF work are:

1. Omission of the flow splitters and sampling circuit and instrumentation.
2. Addition of thermocouples to the rods for CHF detection.

The salient geometrical features of the nine-rod test section are:

Number of Rods	Nine (3 X 3 array)
Rod Diameter	0.570 inch
Radius of Channel Corner	0.400 inch
Rod-Rod Clearance	0.168 inch
Rod-Wall Clearance	0.135 inch
Hydraulic Diameter	0.474 inch
Test Length	120 inches

Figure 1. Nine-Rod Test Section for Subchannel and Flow Structure Measurements,
Also Used for Critical Heat Flux Measurements

The rods are of a new type developed by GE. Each rod is clad with a nickel tube insulated from the electrical heater element so that the exterior of the rod may be at ground potential, thereby eliminating any shorting problems. The rods pass out the bottom end of the test section through water-cooled O-ring glands, to permit differential expansion and access to electrical power leads. The power supplied is three phase.

Each rod is lettered for identification purposes according to its position in the array. The lettering scheme, as viewed from above, is shown in Figure 2.

Tests can be run with all nine rods heated, or alternately with only six or only three of the nine rods heated. All the rods used for the tests reported here were heated. The heat flux was uniform, both axially and in the transverse direction. Two different sets of rods were used. The 6-foot heated length for the first set (used with test channel Nos. 1, 2, 2A, and 3), was located 3-1/2 feet before the end of the 10-foot test length. The 6-foot heated length for the second set (used with test channel No. 4) was located right at the end of the 10-foot test length.

For CHF detection, four 0.020-inch-o.d. sheathed chromel-alumel thermocouples with ungrounded junctions were placed on the outside of each of the rods by milling 0.025-inch-deep grooves in the nickel cladding, and then inserting the thermocouples and silver soldering in place (see Figure 3). Two of the thermocouple junctions were located 0.5 inch before the end of the heated length, and two were located 3.2 inches before the end of the heated length. All four thermocouples were located within a 65-degree sector, as shown in Figure 3. The thermocouples on the outside rods faced outward, and on the center rod faced one of the interior subchannels.

A set of critical heat flux runs was made for each of five test channels. All five of the channels used the same grid-type spacers (needed to maintain rod-rod and rod-wall clearances, and typical of modern water-cooled and moderated power reactors), and essentially the same rods. The principal features that differed between the various channels were: (1) the axial position of the 6-foot heated segment of the rods, and (2) the axial positions of the spacers, particularly with respect to the end of the heated length. The spacer and heated length positions, and certain other features of the five channels, are shown schematically in Figure 4. A close-up view of one of the spacers is shown in Figure 5.

The end of the heated length for test channel No. 4 is located 2 inches before the channel exit. This arrangement is typical for most out-of-core CHF test assemblies with which the results reported here can be compared. Test channel No. 4 is therefore the "reference" channel in the discussion of results which follows.

It has been observed that when the spacer at the end of the heated length is located with its leading (i.e., upstream) side 1/2 inch past the end of the heated length, the CHF is less than when this same spacer is located a few inches before the end of the heated length.² To investigate further the effect of axial position of this particular spacer, it has been placed so that its leading side is (1) 3 inches ahead of the end of the heated length (test channel No. 1), (2) 1/2 inch past the end (test channels Nos. 2, 2A, and 4), and (3) removed all together (test channel No. 3).

Because of the conjecture that the difference between the test channel No. 2 and the test channel No. 4 results might be due to flow diversion toward the outside of the bundle in the case of No. 4, a "diversion plate" was added to No. 2 in an effort to bring about a similar diversion. The plate is shown in Figure 4, test channel No. 2A. A detail of the plate appears in Figure 6.

Figure 2. Lettering Scheme for Rod Identification

Figure 3. Location of Thermocouples

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Figure 5. Grid-Type Spacer Details

Figure 6. Diversion Plate

3. TEST PROCEDURE

CHF was determined by means of the thermocouples already described, which were located near the end of the heated length. The CHF point was approached by holding pressure, flow, and subcooling constant, and gradually increasing power (in steps of 1% to 2%) until one or more thermocouples indicated a CHF condition.

The following quantities were measured and recorded at the onset of CHF:

- System pressure (at exit end of test section).
- Flow rate (just ahead of test section inlet).
- Inlet temperature.
- Power to test section.

The particular thermocouples indicating CHF were also noted and recorded.

The data were reduced, using the relationships given in Reference 3 for flow and quality, and dividing the power to test section by the total heat transfer area for heat flux.

4. RESULTS

The results are listed in Tables 1, 2, 3, 4, and 5, for test channels Nos. 1, 2, 2A, 3, and 4, respectively. Each table gives the location of CHF in terms of distance ahead of the end of the heated length at which the thermocouple that detected it was located. It will be noted that for test channel No. 1, CHF always occurred just before the last spacer on the heated length. For all the other test channels, CHF always occurred at the end of the heated length. In all plots of critical heat flux versus quality given in this report, the quality is always the average channel value at the CHF location.

For most runs, CHF occurred primarily on the corner rods. There is a notable exception in the case of test channel No. 2A, and this will be discussed in the text.

4.1 TEST CHANNEL NO. 4

Consider first test channel No. 4, the "Reference" channel. The critical heat flux at 1000 psia is plotted versus the quality $\bar{X}$ for mass velocities $G = 0.25 \times 10^6$, 0.5×10^6 , and 1.0×10^6 lb/h-ft², in Figures 7, 8, and 9, respectively. Superposed on Figures 8 and 9 are data from Reference 4 for the same channel cross section, but no grid-type spacers. (Pin spacers were used to minimize disturbance to the flow. This arrangement was called a "clean" channel in Reference 4, and will be so called here.)

The critical heat flux always occurred at the end of the heated length for test channel No. 4 (the same as for the clean channel) and hence just before the last spacer. Figures 7, 8, and 9 show the usual trend of critical heat flux with $\bar{X}$. The test channel No. 4 data can be fitted by straight lines, with scatter less than $\pm 10\%$.

Referring to Figure 8, the test channel No. 4 points are in good agreement with the clean channel data at $G = 0.5 \times 10^6$ lb/h-ft². In contrast to this, Figure 9 shows the test channel No. 4 points to be about 25% below the clean channel data at $G = 1.0 \times 10^6$ lb/h-ft². The arrangement of spacers for test channel No. 4 had an adverse effect on the critical heat flux (relative to the clean channel) at high flows, but not at low flows.

4.2 TEST CHANNEL NO. 1

The critical heat flux for test channel No. 1 at 1000 psia is plotted versus $\bar{X}$ for mass velocities 0.5×10^6 and 1.0×10^6 lb/h-ft² in Figure 10. Superposed are best-fit lines through the test channel No. 4 data of Figures 8 and 9.

Table 1
TEST CHANNEL NUMBER 1

Run Number	Pressure (psia)	Mass Velocity (Millions lb/h-ft ²)	Inlet Subcooling (Btu/lb)	Local Heat Flux at CHF (Millions Btu/h-ft ²)	Local Quality at CHF	Rod*	Location of CHF, Distance Before End of Heated Length (Inches)
1	1005.0	1.008	9.2	0.539	0.2966	H	3.2
2	775.0	0.998	20.1	0.635	0.3172	H	3.2
3	825.0	1.016	13.3	0.609	0.3115	H	3.2
4	1005.0	1.012	11.7	0.535	0.2897	H	3.2
5	1095.0	1.010	9.4	0.500	0.2804	H	3.2
6	1195.0	1.018	12.2	0.465	0.2609	H	3.2
7	1395.0	1.010	11.4	0.406	0.2430	H	3.2
8	1419.0	0.991	83.7	0.512	0.1943	H	3.2
10	811.0	1.013	58.4	0.672	0.2799	H	3.2
11	1005.0	1.007	59.0	0.603	0.2576	H	3.2
12	1105.0	1.012	61.5	0.576	0.2437	H	3.2
13	1197.0	1.016	64.6	0.540	0.2218	H	3.2
14	1411.0	1.011	74.7	0.497	0.1931	H	3.2
15	1005.0	1.009	93.6	0.648	0.2293	H	3.2
16	637.0	1.007	86.5	0.749	0.2697	H	3.2
17	801.0	1.008	83.2	0.721	0.2717	H	3.2
18	1095.0	1.011	91.7	0.621	0.2218	H	3.2
19	1185.0	1.012	97.1	0.589	0.1999	H	3.2
20	1403.0	1.014	106.8	0.544	0.1667	H	3.2
21	990.0	0.999	143.5	0.726	0.2008	H	3.2
22	610.0	1.005	123.3	0.816	0.2523	H	3.2
23	805.0	1.010	124.0	0.775	0.2415	H	3.2
24	1095.0	1.012	144.4	0.705	0.1880	H	3.2
25	1207.0	1.011	152.0	0.685	0.1699	H	3.2
26	1395.0	1.013	169.5	0.657	0.1306	H	3.2
27	1005.0	1.013	185.5	0.819	0.1853	H	3.2
28	797.0	1.007	170.1	0.861	0.2224	H	3.2
29	1105.0	1.012	193.3	0.794	0.1636	H	3.2
30	1195.0	1.013	197.6	0.764	0.1428	H,I	3.2
31	1407.0	1.012	208.2	0.714	0.1017	H,I	3.2
32	1207.0	1.006	213.6	0.770	0.1240	H	3.2
**33	1415.0	1.012	220.5	0.749	0.1036	H	3.2
34	995.0	1.007	8.9	0.517	0.2838	G	3.2
35	1000.0	0.499	17.8	0.441	0.4847	G,D	3.2
36	599.0	0.500	13.4	0.434	0.4296	G	3.2
37	805.0	0.500	18.2	0.435	0.4495	G	3.2
38	995.0	0.501	19.5	0.432	0.4693	G,D,A	3.2
39	1093.0	0.497	16.1	0.404	0.4586	G	3.2

* When more than one rod is shown for the same run, the strongest indication occurred on the first rod.

** Rod "G" lost at the end of this run.

Table 1 (Continued)

Run Number	Pressure (psia)	Mass Velocity (Millions lb/h-ft ²)	Inlet Subcooling (Btu/lb)	Local Heat Flux at CHF (Millions Btu/h-ft ²)	Local Quality at CHF	Rod*	Location of CHF,
							Distance Before End of Heated Length (Inches)
40	1197.0	0.504	24.8	0.404	0.4519	G	3.2
41	1400.0	0.502	23.7	0.353	0.4194	G	3.2
42	1403.0	0.503	21.4	0.361	0.4330	G,I	3.2
43	1009.0	0.500	41.2	0.465	0.4772	G	3.2
44	601.0	0.497	69.6	0.490	0.4136	G	3.2
45	803.0	0.501	77.9	0.503	0.4375	G	3.2
46	997.0	0.496	70.6	0.481	0.4535	G,I,D	3.2
47	1107.0	0.501	73.7	0.466	0.4397	G	3.2
48	1195.0	0.501	72.1	0.441	0.4228	G	3.2
49	1405.0	0.505	89.1	0.402	0.3674	G	3.2
50	995.0	1.013	12.0	0.537	0.2886	G,I	3.2
51	990.0	0.499	118.8	0.498	0.3944	G	3.2
52	605.0	0.495	99.8	0.498	0.3831	G,I	3.2
53	797.0	0.492	110.1	0.516	0.4139	A,D,G,I	3.2
54	1005.0	0.497	119.4	0.494	0.3936	I,G,D	3.2
55	1095.0	0.499	123.9	0.466	0.3615	I,G,D	3.2
56	1195.0	0.493	128.7	0.460	0.3632	G,D	3.2
57	1410.0	0.499	145.2	0.438	0.3226	G	3.2
58	1005.0	0.501	172.7	0.531	0.3499	G,I	3.2
59	593.0	0.498	143.2	0.533	0.3559	I,G,A	3.2
60	800.0	0.495	161.1	0.539	0.3628	G,I	3.2
61	1005.0	0.492	177.5	0.530	0.3526	G	3.2
62	1105.0	0.495	193.3	0.524	0.3269	G	3.2
63	1209.0	0.496	201.1	0.521	0.3201	G	3.2
64	1405.0	0.497	239.4	0.517	0.2671	G	3.2
65	601.0	0.496	182.3	0.558	0.3312	G	3.2
66	797.0	0.498	193.2	0.575	0.3511	G,I	3.2
67	1007.0	0.528	211.6	0.571	0.3030	G	3.2
68	1095.0	0.501	218.9	0.576	0.3407	G	3.2
69	1203.0	0.499	227.8	0.552	0.3097	G	3.2
70	1395.0	0.500	258.2	0.539	0.2581	G	3.2
71	998.0	0.499	256.0	0.609	0.3138	G	3.2
72	605.0	0.497	219.1	0.589	0.3120	G	3.2
73	805.0	0.499	241.6	0.619	0.3303	G	3.2
74	1095.0	0.499	264.6	0.609	0.3099	G	3.2
75	1199.0	0.500	288.1	0.610	0.2810	G	3.2
76	1397.0	0.500	313.4	0.584	0.2209	G	3.2
77	1008.0	0.500	19.6	0.444	0.4858	G	3.2
78	1000.0	0.744	11.5	0.500	0.3725	G	3.2
79	623.0	0.746	14.7	0.567	0.3753	G	3.2
80	803.0	0.739	9.5	0.546	0.3908	G	3.2

* When more than one rod is shown for the same run, the strongest indication occurred on the first rod.

Table 1 (Continued)

Run Number	Pressure (psia)	Mass Velocity (Millions lb/h-ft ²)	Inlet Subcooling (Btu/lb)	Local Heat Flux at CHF (Millions Btu/h-ft ²)	Local Quality at CHF	Location of CHF,	
						Rod*	Distance Before End of Heated Length (Inches)
81	1109.0	0.750	12.8	0.486	0.3682	G	3.2
82	1195.0	0.751	18.1	0.443	0.3337	G	3.2
83	1395.0	0.746	16.3	0.384	0.3083	G	3.2
84	1005.0	0.753	68.4	0.552	0.3211	G	3.2
85	1000.0	0.748	62.4	0.565	0.3422	I,G	3.2
86	610.0	0.756	57.0	0.603	0.3358	A,G	3.2
87	805.0	0.750	61.3	0.591	0.3428	G,A	3.2
88	1000.0	0.747	67.6	0.556	0.3282	I,G	3.2
89	1100.0	0.747	70.9	0.532	0.3138	G,I,A	3.2
90	1200.0	0.748	79.3	0.509	0.2897	G,I	3.2
91	1395.0	0.747	93.8	0.464	0.2437	G	3.2
92	995.0	0.750	117.9	0.618	0.2969	I,G,A	3.2
93	610.0	0.745	101.9	0.638	0.3045	I,A,G	3.2
94	805.0	0.750	109.3	0.629	0.3013	G	3.2
95	1005.0	0.743	113.3	0.596	0.2921	I,G,A	3.2
96	1105.0	0.746	117.5	0.591	0.2879	G,I,A	3.2
97	1195.0	0.750	119.1	0.571	0.2740	I,G	3.2
98	1415.0	0.747	136.2	0.529	0.2290	G	3.2
99	1000.0	0.751	176.2	0.669	0.2464	D,G	3.2
100	605.0	0.744	143.5	0.679	0.2759	G,A,I	3.2
101	795.0	0.744	159.7	0.674	0.2647	G,I,E	3.2
102	1000.0	0.736	170.9	0.675	0.2695	I,G,A	3.2
103	1095.0	0.747	176.9	0.665	0.2516	G,I,A,D	3.2
104	1195.0	0.743	184.7	0.632	0.2223	G	3.2
105	1405.0	0.740	193.9	0.585	0.1814	G	3.2
106	1000.0	0.747	247.9	0.751	0.2035	G	3.2
107	597.0	0.747	198.1	0.745	0.2445	G	3.2
108	798.0	0.746	219.8	0.751	0.2333	G	3.2
109	1099.0	0.743	239.8	0.744	0.2197	G	3.2
110	1207.0	0.749	251.4	0.720	0.1828	G	3.2
111	1401.0	0.753	259.5	0.694	0.1540	G	3.2
112	1005.0	0.763	261.7	0.778	0.1910	G	3.2
113	999.0	0.749	14.5	0.500	0.3655	G	3.2
114	997.0	0.246	32.1	0.294	0.6413	A,G,I	3.2
115	970.0	0.249	67.0	0.320	0.6340	G	3.2
116	1001.0	0.249	111.6	0.331	0.5974	G	3.2
118	997.0	0.249	208.5	0.385	0.5724	G	3.2
119	1003.0	0.250	254.7	0.408	0.5547	G	3.2
120	1007.0	0.249	300.2	0.428	0.5371	G	3.2
121	995.0	0.249	372.9	0.459	0.4935	I,G	3.2
122	999.0	0.247	436.3	0.488	0.4726	I,G	3.2

* When more than one rod is shown for the same run, the strongest indication occurred on the first rod.

Table 1 (Continued)

Run Number	Pressure (psia)	Mass Velocity (Millions lb/h-ft ²)	Inlet Subcooling (Btu/lb)	Local Heat Flux at CHF (Millions Btu/h-ft ²)	Local Quality at CHF	Rod*	Location of CHF, Distance Before End of Heated Length (Inches)
123	1000.0	0.250	162.3	0.353	0.5681	G	3.2
124	1000.0	0.249	45.2	0.299	0.6247	I,G	3.2
125	1005.0	1.248	7.9	0.544	0.2412	G,I	3.2
126	1005.0	1.245	55.5	0.618	0.2036	I,G	3.2
127	997.0	1.243	14.2	0.555	0.2374	I,G	3.2
128	1000.0	1.249	29.5	0.578	0.2234	G,I	3.2
129	993.0	1.247	72.9	0.650	0.1903	G	3.2
130	1005.0	1.248	104.4	0.697	0.1645	G	3.2
131	1000.0	1.248	170.3	0.821	0.1205	G	3.2
132	993.0	1.249	142.8	0.765	0.1363	G	3.2
133	1000.0	1.441	8.4	0.552	0.2097	A,I,G	3.2
134	1000.0	1.443	42.8	0.612	0.1806	G	3.2
135	995.0	1.430	79.0	0.680	0.1548	G	3.2
136	1000.0	1.506	102.5	0.723	0.1216	G	3.2
137	1000.0	1.518	143.9	0.842	0.1012	G	3.2
138	995.0	1.504	128.9	0.789	0.1066	G	3.2
139	997.0	1.472	56.0	0.639	0.1660	G	3.2
140	1005.0	1.473	26.6	0.586	0.1905	A,G,I	3.2
141	1005.0	1.019	44.2	0.573	0.2591	A,I,G	3.2
142	1000.0	1.010	78.0	0.638	0.2471	I,G,A	3.2
143	1003.0	1.009	110.8	0.665	0.2130	A,G,I	3.2
144	1002.0	1.011	8.7	0.525	0.2886	I,G	3.2

* When more than one rod is shown for the same run, the strongest indication occurred on the first rod.

Table 2
TEST CHANNEL NUMBER 2

Run Number	Pressure (psia)	Mass Velocity (Millions lb/h-ft ²)	Inlet Subcooling (Btu/lb)	Local Heat Flux at CHF (Millions Btu/h-ft ²)	Local Quality at CHF	Rod*	Location of CHF, Distance Before End of Heated Length (Inches)
145	1003.0	0.742	17.6	0.505	0.3857	G	0.50
146	998.0	0.748	49.7	0.544	0.3639	G	0.50
147	1000.0	0.746	80.3	0.586	0.3530	A,D,G	0.50
148	1001.0	0.748	110.5	0.631	0.3418	A,D,G	0.50
149	1003.0	0.751	142.7	0.641	0.2985	D,G	0.50
150	1003.0	0.750	174.0	0.648	0.2566	G	0.50
151	1001.0	0.742	202.9	0.651	0.2194	G,D	0.50
152	1005.0	0.747	234.8	0.671	0.1838	A,G,D,I	0.50
153	1000.0	0.753	15.3	0.518	0.3936	D,G	0.50
154	1001.0	0.750	48.3	0.554	0.3733	G	0.50
155	995.0	0.749	86.4	0.584	0.3393	D,G	0.50
156	1001.0	0.742	121.0	0.610	0.3124	D,G	0.50
157	1005.0	0.747	145.2	0.613	0.2749	D,G	0.50
158	1000.0	0.747	178.3	0.623	0.2314	D,G	0.50
159	995.0	0.737	229.1	0.661	0.1909	D,G	0.50
160	1000.0	0.748	255.8	0.698	0.1719	D,G	0.50
161	1000.0	0.749	133.0	0.631	0.3063	A,H,G	0.50
162	995.0	0.748	181.8	0.660	0.2549	G,H	0.50
163	1005.0	0.743	235.8	0.712	0.2192	G,H	0.50
164	993.0	1.247	12.3	0.562	0.2535	I,A	0.50
165	1000.0	1.248	46.4	0.612	0.2260	I,A	0.50
166	1005.0	1.242	75.9	0.672	0.2116	I,G	0.50
167	1000.0	1.242	97.4	0.710	0.1970	I,G,A	0.50
168	1003.0	1.248	135.6	0.760	0.1607	G,I	0.50
169	1003.0	1.246	159.5	0.788	0.1387	G,I	0.50
170	1000.0	1.250	188.4	0.819	0.1077	G	0.50
171	1001.0	1.245	194.4	0.822	0.1017	G	0.50
172	1000.0	1.249	136.8	0.748	0.1526	G,I	0.50
173	1000.0	1.246	117.0	0.719	0.1699	G,I	0.50
174	985.0	1.247	92.3	0.699	0.1970	A,G,I	0.50
175	1005.0	1.247	80.5	0.670	0.2019	I	0.50
176	1003.0	1.237	10.7	0.548	0.2522	I,A	0.50
177	1000.0	0.252	41.6	0.283	0.6115	A,G,I	0.50
178	1000.0	0.247	66.4	0.292	0.6113	A,G,I	0.50
179	1001.0	0.250	124.3	0.323	0.5880	A,G	0.50
180	1000.0	0.250	200.6	0.346	0.5282	G,I	0.50
181	1000.0	0.249	242.9	0.371	0.5258	G	0.50
182	992.0	0.248	288.3	0.392	0.5091	G,I	0.50

* When more than one rod is shown for the same run, the strongest indication occurred on the first rod.

Table 2 (Continued)

Run Number	Pressure (psia)	Mass Velocity (Millions lb/h-ft ²)	Inlet Subcooling (Btu/lb)	Local Heat Flux at CHF (Millions Btu/h-ft ²)	Local Quality at CHF	Rod*	Location of CHF, Distance Before End of Heated Length (Inches)
183	1005.0	0.249	341.7	0.421	0.4963	A,G,H	0.50
184	1003.0	0.250	402.7	0.449	0.4669	G,I	0.50
185	1000.0	0.251	428.2	0.472	0.4783	G,I	0.50
186	1001.0	0.248	166.7	0.334	0.5547	A,G	0.50
187	995.0	0.250	143.1	0.329	0.5732	A,G	0.50
188	1007.0	0.247	48.1	0.282	0.6148	A,G	0.50
189	1000.0	1.011	7.1	0.535	0.3095	I	0.50
190	671.0	1.000	19.9	0.645	0.3273	A,G	0.50
191	809.0	1.011	12.3	0.599	0.3220	A,G	0.50
192	1099.0	1.012	10.0	0.496	0.2901	I	0.50
193	1195.0	1.015	11.6	0.463	0.2739	A,I	0.50
194	1397.0	1.015	15.1	0.392	0.2374	A,G,I	0.50
195	1000.0	1.012	49.4	0.598	0.2825	A,G,I	0.50
196	675.0	1.010	42.5	0.683	0.3136	A,G,I	0.50
197	800.0	1.005	35.1	0.635	0.3105	A,G,I	0.50
198	1101.0	1.014	40.4	0.544	0.2708	A,I	0.50
199	1203.0	1.013	45.2	0.514	0.2527	A,I	0.50
200	1397.0	1.014	47.7	0.449	0.2193	I	0.50
201	1003.0	1.019	97.9	0.643	0.2323	G,I	0.50
202	671.0	1.008	84.8	0.722	0.2763	G,I	0.50
203	803.0	1.010	81.3	0.685	0.2705	G,I	0.50
204	1099.0	1.012	94.5	0.608	0.2251	G,I	0.50
205	1199.0	1.013	96.2	0.579	0.2106	I	0.50
206	1403.0	1.013	105.6	0.549	0.1877	A,G,I	0.50
207	997.0	1.015	145.6	0.689	0.1876	G	0.50
208	875.0	1.000	125.0	0.733	0.2268	G,H,I	0.50
209	803.0	1.005	129.6	0.713	0.2183	G,H,I	0.50
210	1101.0	1.008	149.6	0.661	0.1726	G	0.50
211	1203.0	1.011	151.5	0.649	0.1658	G	0.50
212	1399.0	1.012	160.6	0.603	0.1291	G	0.50
213	997.0	1.008	178.4	0.711	0.1536	G	0.50
214	677.0	1.009	158.8	0.749	0.1878	G,H	0.50
215	801.0	1.005	167.6	0.730	0.1723	G,H	0.50
216	1100.0	1.006	188.9	0.701	0.1368	G	0.50
217	1203.0	1.012	194.9	0.684	0.1172	G	0.50
218	1399.0	1.010	203.4	0.660	0.0938	G	0.50
219	1001.0	1.012	231.1	0.759	0.0997	G	0.50
220	673.0	1.007	206.4	0.770	0.1330	G,H	0.50
**221	795.0	1.008	217.8	0.760	0.1151	G	0.50
222	1000.0	0.742	11.5	0.525	0.4110	C,G	0.50

* When more than one rod is shown for the same run, the strongest indication occurred on the first rod.

** Rod "F" lost at end of this run.

Table 2 (Continued)

Run Number	Pressure (psia)	Mass Velocity (Millions lb/h-ft ²)	Inlet Subcooling (Btu/lb)	Local Heat Flux at CHF (Millions Btu/h-ft ²)	Local Quality at CHF	Rod*	Location of CHF, Distance Before End of Heated Length (Inches)
223	1001.0	0.749	183.8	0.672	0.2617	G	0.50
224	1000.0	0.741	209.5	0.706	0.2561	G	0.50
225	1030.0	0.743	257.2	0.731	0.2025	G	0.50
226	1000.0	0.751	226.2	0.628	0.1585	G	0.50
227	995.0	0.748	224.4	0.637	0.1703	G	0.50
228	1001.0	1.013	234.2	0.750	0.0889	G	0.50
229	1100.0	1.000	245.2	0.756	0.0839	G	0.50
230	1200.0	1.014	249.4	0.744	0.0654	G	0.50
231	1401.0	1.011	264.7	0.733	0.0364	G	0.50
232	998.0	0.498	21.2	0.437	0.4980	C	0.50
233	601.0	0.499	14.4	0.462	0.4785	C	0.50
234	799.0	0.498	19.0	0.456	0.4947	C	0.50
235	1105.0	0.497	20.5	0.424	0.5003	C	0.50
236	1200.0	0.500	22.7	0.407	0.4852	C	0.50
237	1398.0	0.497	22.8	0.360	0.4538	C	0.50
238	985.0	0.503	53.6	0.469	0.4798	C	0.50
239	598.0	0.492	13.8	0.449	0.4714	C,A,G	0.50
240	805.0	0.499	67.0	0.486	0.4593	C,G	0.50
241	605.0	0.499	50.4	0.477	0.4468	C	0.50
242	995.0	0.503	62.2	0.447	0.4416	C	0.50
243	1000.0	0.504	64.1	0.459	0.4523	C	0.50
244	1100.0	0.505	60.2	0.449	0.4595	C	0.50
245	1200.0	0.496	71.0	0.431	0.4429	C	0.50
246	1403.0	0.500	83.4	0.398	0.3996	C	0.50
247	1000.0	0.500	114.2	0.475	0.3997	C	0.50
248	601.0	0.492	95.2	0.421	0.3294	C,G,I	0.50
249	797.0	0.497	97.5	0.439	0.3624	C,G,I	0.50
250	1000.0	0.500	107.5	0.444	0.3717	C,G,I	0.50
251	1103.0	0.499	108.2	0.442	0.3800	C,G,I	0.50
252	1201.0	0.498	110.8	0.444	0.3914	C,G,I	0.50
253	1401.0	0.500	129.2	0.421	0.3499	C,G,I	0.50
254	1005.0	0.499	170.6	0.481	0.3207	C,G,F	0.50
255	601.0	0.498	138.5	0.442	0.2882	G,C	0.50
256	803.0	0.498	147.3	0.463	0.3175	C,G	0.50
257	1003.0	1.012	81.9	0.616	0.2436	C,G,F	0.50
258	1005.0	1.014	132.6	0.640	0.1789	C,G	0.50
259	1015.0	1.013	197.6	0.689	0.1089	C,G,I	0.50

* When more than one rod is shown for the same run, the strongest indication occurred on the first rod.

Table 3
TEST CHANNEL NUMBER 2A

Run Number	Pressure (psia)	Mass Velocity (Millions lb/h-ft ²)	Inlet Subcooling (Btu/lb)	Local Heat Flux at CHF (Millions Btu/h-ft ²)	Local Quality at CHF	Rod*	Location of CHF, Distance Before End of Heated Length (Inches)
260	1002.0	1.010	16.8	0.541	0.2987	E	0.50
261	1003.0	1.015	62.9	0.602	0.2631	E	0.50
262	1007.0	1.015	107.0	0.655	0.2270	E,I,G	0.50
263	1005.0	1.013	150.1	0.676	0.1738	G,E,I	0.50
264	1005.0	1.002	172.2	0.677	0.1453	G,I,E	0.50
265	1005.0	1.000	205.1	0.710	0.1153	C,F,E,I	0.50

* When more than one rod is shown for the same run, the strongest indication occurred on the first rod.

Table 4
TEST CHANNEL NUMBER 3

Run Number	Pressure (psia)	Mass Velocity (Millions lb/h-ft ²)	Inlet Subcooling (Btu/lb)	Local Heat Flux at CHF (Millions Btu/h-ft ²)	Local Quality at CHF	Rod*	Location of CHF, Distance Before End of Heated Length (Inches)
266	1005.0	1.008	7.1	0.510	0.2957	I	0.50
267	1005.0	1.001	53.1	0.561	0.2582	I	0.50
268	1015.0	1.004	96.5	0.633	0.2349	I	0.50
**269	1005.0	1.005	149.0	0.726	0.2091	G,I	0.50
270	1000.0	1.000	191.8	0.785	0.1815	G,I,E	0.50
271	1010.0	0.755	11.9	0.489	0.3749	I	0.50
272	995.0	0.755	48.7	0.533	0.3518	I	0.50
273	1000.0	0.752	80.2	0.566	0.3328	I	0.50
274	997.0	0.769	106.7	0.608	0.3142	I	0.50
275	1003.0	0.757	146.5	0.646	0.2927	I	0.50
276	997.0	0.759	170.4	0.680	0.2807	I	0.50
277	995.0	0.757	223.3	0.740	0.2490	I	0.50
278	1000.0	0.502	27.5	0.440	0.4885	C,G,I	0.50
279	1000.0	0.500	70.7	0.474	0.4640	C,G	0.50
280	995.0	0.500	133.8	0.521	0.4242	G	0.50
281	1000.0	0.497	175.4	0.552	0.4023	C,I	0.50
282	995.0	0.498	213.0	0.582	0.3799	C	0.50
283	995.0	0.497	245.3	0.599	0.3520	C	0.50
284	995.0	0.500	274.3	0.635	0.3473	C,I	0.50
285	995.0	0.494	326.1	0.661	0.3098	C,I	0.50
286	997.0	0.249	42.0	0.289	0.6334	C,G,I	0.50
287	999.0	0.249	74.4	0.299	0.6092	C,G,I	0.50
288	995.0	0.250	106.7	0.316	0.5978	C,G,I	0.50
289	1000.0	0.250	136.8	0.327	0.5786	C,G,I	0.50
290	1003.0	0.249	164.5	0.333	0.5540	C,G,I	0.50
291	1005.0	0.248	200.0	0.360	0.5697	C,G,I	0.50
292	1000.0	0.250	247.3	0.383	0.5457	C,G,I	0.50
293	997.0	0.251	301.8	0.408	0.5195	C,G,I	0.50
294	1001.0	0.246	344.5	0.427	0.5191	C,G,I	0.50
295	1000.0	0.248	419.3	0.465	0.4879	C,G,I	0.50
296	1000.0	1.248	12.8	0.522	0.2338	I	0.50
297	999.0	1.246	58.8	0.605	0.2038	I	0.50
298	997.0	1.247	110.4	0.716	0.1783	I	0.50
299	1000.0	1.244	149.9	0.782	0.1510	I	0.50
300	1000.0	1.243	186.6	0.850	0.1277	I,E	0.50

* When more than one rod is shown for the same run, the strongest indication occurred on the first rod.

** Rod lost at end of this run.

Table 5
TEST CHANNEL NUMBER 4

Run Number	System Pressure (psia)	Mass Flux (lb/h-ft ² X 10 ⁶)	Subcooling (Btu/lb)	Heat Flux (Btu/h-ft ² X 10 ⁶)	Exit Quality (%)
301	1019	1.051	29.4	0.518	25.54
302	1007	1.075	54.6	0.560	23.26
303	1018	1.134	110.2	0.665	18.77
304	1020	0.977	34.9	0.513	26.65
305	1038	0.936	13.1	0.460	28.16
306	1026	0.985	57.0	0.520	23.44
307	1001	1.033	97.1	0.602	20.49
308	1020	0.521	25.1	0.440	47.70
309	1022	0.538	57.0	0.478	45.50
310	1025	0.576	102.3	0.537	41.26
311	1020	0.598	155.6	0.587	35.97
312	1021	0.602	197.8	0.639	34.30
313	1025	0.508	66.7	0.459	44.89
314	1022	0.508	25.5	0.428	47.46
315	1045	0.495	104.8	0.484	43.92
316	1013	0.266	40.3	0.299	62.02
317	985	0.292	94.7	0.347	57.05
318	1011	0.286	76.0	0.327	57.80
319	988	0.296	148.8	0.376	54.10
320	1027	0.306	197.4	0.410	51.36
321	1011	0.269	211.7	0.386	54.62
322	1044	0.267	179.1	0.367	56.49
323	1038	0.251	107.3	0.323	62.17
324	1024	0.246	48.9	0.283	62.48
325	1031	0.244	38.2	0.271	61.84
326	781	0.934	221.7	0.820	18.11
327	783	0.490	12.3	0.458	51.23
328	798	0.508	66.2	0.495	46.19
329	775	0.495	164.3	0.533	37.76
330	773	0.500	254.0	0.601	31.86
331	786	0.266	26.0	0.315	63.75
332	765	0.288	86.3	0.367	59.99
333	792	0.250	180.4	0.379	60.75
334	755	0.252	235.6	0.408	57.76

Figure 7. Critical Heat Flux Versus Quality, Test Channel No. 4.
 $P = 1000 \text{ psia}$, $G = 0.25 \times 10^6 \text{ lb/h-ft}^2$

Figure 8. Critical Heat Flux Versus Quality, Test Channel No. 4.
 $P = 1000 \text{ psia}$, $G = 0.5 \times 10^6 \text{ lb/h-ft}^2$, Clean Channel Data Superposed

Figure 9. Critical Heat Flux Versus Quality, Test Channel No. 4.
 $P = 1000 \text{ psia}$, $G = 1.0 \times 10^6 \text{ lb/h-ft}^2$, Clean Channel Data Superposed

Figure 10. Critical Heat Flux Versus Quality, Test Channel No. 1.
 $P = 1000$ psia, $G = 0.5 \times 10^6$ and 1.0×10^6 lb/h-ft²

The critical heat flux always occurred just before the last spacer on the heated length for test channel No. 1 rather than at the end of the heated length as in the case of test channel No. 4. The $\bar{X}$ plotted in Figures 10, 11 and 12 is the average channel quality just before the last spacer. The test channel No. 1 data can be fitted by straight lines, with scatter less than $\pm 5\%$.

Referring to Figure 10, the test channel No. 1 points tend to lie below the test channel No. 4 data at $G = 0.5 \times 10^6$ lb/h-ft² and qualities less than about 0.45 but lie consistently above (by 12% to 28%) the test channel No. 4 data at $G = 1.0 \times 10^6$ lb/h-ft². The arrangement of spacers and position of heated length for test channel No. 1 has an adverse effect on CHF at low flows and a beneficial effect at high flows, relative to test channel No. 4.

The critical heat flux for test channel No. 1 at various pressures is plotted versus $\bar{X}$ for mass velocities 0.5×10^6 and 1.0×10^6 lb/h-ft² in Figures 11 and 12, respectively. Referring to both figures, for any given quality, as the pressure is *increased* in the range $1000 \leq P \leq 1400$ psia, the critical heat flux *decreases*. Conversely, as the pressure is *decreased* in the range $1000 \geq P \geq 800$ psia the critical heat flux *increases*. This is the well-known inverse pressure effect. Considering just Figure 11 ($G = 0.5 \times 10^6$ lb/h-ft²), however, a decrease in the pressure below 800 psia brings about a significant decrease in critical heat flux; i.e., the relationship between critical heat flux and pressure changes from inverse to direct. At 600 psia, the critical heat flux has decreased enough that it is equal to the critical heat flux at 1000 psia, within the scatter of the data.

Considering just Figure 12 ($G = 1.0 \times 10^6$ lb/h-ft²), on the other hand, a decrease in the pressure from 800 psia to 600 psia brings about no change in the critical heat flux, within the scatter of the data. Comparing Figure 12 with Figure 11 at $\bar{X} = 0.3$, an increase in pressure from 1000 psia to 1200 psia brings about a decrease in CHF of 0.04×10^6 Btu/h-ft² at $G = 0.5 \times 10^6$ lb/h-ft², but a decrease in CHF of 0.15×10^6 Btu/h-ft² at $G = 1.0 \times 10^6$ lb/h-ft²—nearly a fourfold difference. The inverse pressure effect is much stronger at higher flows.

4.3 TEST CHANNEL NO. 2

The critical heat flux for test channel No. 2 at 1000 psia is plotted versus $\bar{X}$ for $G = 0.5 \times 10^6$ and 1.0×10^6 lb/h-ft² in Figure 13. Best-fit lines through test channel No. 4 data are superposed.

There is a spacer just past the end of the heated length for test channel No. 2, the same as for test channel No. 4. The critical heat flux always occurred at the end of the heated length, the same as for test channel No. 4 (and hence just before the spacer). The quality against which the critical heat flux is plotted in Figures 13, 14, and 15 is therefore the exit quality. The test channel No. 2 data can be fitted by straight lines with scatter less than $\pm 5\%$.

Referring to Figure 13, the slope of the test channel No. 2 points, both flows, is much less than for test channel No. 4. Thus, at $G = 0.5 \times 10^6$ lb/h-ft², $\bar{X} < 0.45$, the points are below test channel No. 4, whereas at the same flow and $\bar{X} > 0.45$, the points are above test channel No. 4. Similarly, at $G = 1.0 \times 10^6$ lb/h-ft² $\bar{X} < 0.2$, the points are below test channel No. 4, but at $\bar{X} > 0.2$ the points are above. Comparing Figure 13 with Figure 10, at $G = 1.0 \times 10^6$ lb/h-ft², $\bar{X} > 0.27$, the test channel No. 2 points are even above test channel No. 1.

The critical heat flux for test channel No. 2 at various pressures is plotted versus $\bar{X}$ for mass velocities 0.5×10^6 and 1.0×10^6 lb/h-ft² in Figures 14 and 15, respectively. These two figures reveal essentially the same effect of pressure on CHF for test channel No. 2, which was shown in Figures 11 and 12 for test channel No. 1. It is an inverse effect for pressures in the range $1000 \leq P \leq 1400$, and is much stronger at the $G = 1.0 \times 10^6$ lb/h-ft² condition (Figure 15) than at $G = 0.5 \times 10^6$ lb/h-ft² (Figure 14). This reinforces the conclusion already made, that the inverse pressure effect is much stronger at higher flows.

Considering Figure 14, the change in CHF with pressure for pressures less than 1000 psia is less than the scatter in the data. The data for both Figures 14 and 15 are characterized by the fact that the slope is quite flat, particularly at the lower pressures.

Figure 11. Critical Heat Flux Versus Quality, Test Channel No. 1.
 $G = 0.5 \times 10^6 \text{ lb/h-ft}^2$, Various Pressures

Figure 12. Critical Heat Flux Versus Quality, Test Channel No. 1.
 $G = 1.0 \times 10^6 \text{ lb/h-ft}^2$, Various Pressures

Figure 13. Critical Heat Flux Versus Quality, Test Channel No. 2.
 $P = 1000 \text{ psia}$, $G = 0.5 \times 10^6$ and $1.0 \times 10^6 \text{ lb/h-ft}^2$

Figure 14. Critical Heat Flux Versus Quality, Test Channel No. 2.
 $G = 0.5 \times 10^6 \text{ lb/h-ft}^2$, Various Pressures

Figure 15. Critical Heat Flux Versus Quality, Test Channel No. 2.
 $G = 1.0 \times 10^6 \text{ lb/h-ft}^2$, Various Pressures

4.4 TEST CHANNEL NO. 2A

The critical heat flux for test channel No. 2A at 1000 psia is plotted versus $\bar{X}$ for $G = 1.0 \times 10^6$ lb/h-ft² in Figure 16. Test channel No. 2 data and the channel No. 4 best-fit line are superposed.

CHF always occurred at the end of the heated length, the same as for test channels Nos. 4 and 2, and hence occurred just before the spacer which was located immediately past the end of the heated length (see Figure 4). For qualities less than 20%, CHF occurred primarily on the corner rods, but there was some indication of CHF on the center rod. For qualities greater than 20%, CHF occurred primarily on the center rod. At the 30% quality point, CHF occurred *only* on the center rod. This is in contrast to the other test channels; for them there was no indication of CHF on the center rod at any time. The diversion plate, even though located 6 inches past the end of the heated length, brought about early dryout of the film on the center rod.

Referring to Figure 16, the test channel No. 2A points are seen to agree quite well with the test channel No. 2 data. There was at least indication of CHF on the corner rods for all the points except the one at 30% quality. The diversion plate evidently brought about no change in CHF on the corner rods, except possibly at the 30% quality point.

4.5 TEST CHANNEL NO. 3

The critical heat flux for test channel No. 3 at 1000 psia is plotted versus X for mass velocities 0.5×10^6 and 1.0×10^6 lb/h-ft² in Figure 17. Test channel No. 4 best-fit lines are superposed.

CHF always occurred at the end of the heated length, and always on the corner rods. The test channel No. 3 data can be fitted by straight lines with scatter less than $\pm 5\%$.

Referring to Figure 17, the test channel No. 3 points agree with the test channel No. 4 data at $G = 0.5 \times 10^6$ lb/h-ft², but lie consistently above (by 12% to 22%) at $G = 1.0 \times 10^6$ lb/h-ft². Comparing Figure 17 with Figure 10, the test channel No. 3 points agree well with the test channel No. 1 points at $G = 1.0 \times 10^6$ lb/h-ft².

4.6 COMPARISON WITH SIXTEEN-ROD RESULTS

The sixteen-rod test channel No. 3 configuration of Reference 2 corresponds to the nine-rod test channel No. 4 configuration reported here, in that:

1. The end of the heated length is close to the end of the channel. (The heated length is actually 5 inches before the end of the channel, and the underside of the grid plate is 3 inches past the end of the channel. These may be compared with the nine-rod dimensions given in Figure 4.)
2. The heat flux is uniform in both the axial and transverse directions.
3. The spacer at the end of the heated length is just 1/2 inch past the end of the heated length. The remainder of the spacers are located on 19-1/2-inch centers along the channel. (This latter dimension may be compared with the 18-inch centers for the nine-rod case.)

The 1000-psia, sixteen-rod and the 1000-psia, nine-rod data are compared at the two mass velocities, 0.5×10^6 and 1.0×10^6 lb/h-ft², in Figure 18.

CHF for the sixteen-rod channel always occurred at the end of the heated length and always on a corner rod, the same as for the nine-rod channel. Referring to Figure 18, the sixteen-rod points are seen to agree well with the nine-rod data at 0.5×10^6 lb/h-ft², but to lie above the nine-rod data at 1.0×10^6 lb/h-ft² by about 16% (except for two high points at the low end of the quality range which lie 27% and 35% above, respectively). At the higher flow, for the particular spacers tested, the nine-rod test channel No. 4 (i.e., the "Reference" channel) gives results which are low, compared with sixteen-rod results.

Figure 16. Critical Heat Flux Versus Quality, Test Channel No. 2A.
 P = 1000 psia, G = 1.0 X 10⁶ lb/h-ft², Test Channel No. 2 data superposed.

Figure 17. Critical Heat Flux Versus Quality, Test Channel No. 3.
 $P = 1000$ psia, $G = 0.5 \times 10^6$ and 1.0×10^6 lb/h-ft²

Figure 18. Critical Heat Flux Versus Quality, Test Channel No. 4.
 $P = 1900 \text{ psia}$, $G = 0.5 \times 10^6$ and $1.0 \times 10^6 \text{ lb/h-ft}^2$, 16-rod data superposed

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