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MASTER

Critical Heat Flux Experiments In a Circular Tube with Heavy Water and Light Water

(AWBA Development Program)

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May 1980

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DISCLAIMER

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FOREWORD

The Shippingport Atomic Power Station located in Shippingport, Pennsylvania was the first large-scale, central-station nuclear power plant in the United States and the first plant of such size in the world operated solely to produce electric power. This program was started in 1953 to confirm the practical application of nuclear power for large-scale electric power generation. It has provided much of the technology being used for design and operation of the commercial, central-station nuclear power plants now in use.

Subsequent to development and successful operation of the Pressurized Water Reactor in the Atomic Energy Commission (now Department of Energy, DOE) owned reactor plant at the Shippingport Atomic Power Station, the Atomic Energy Commission in 1965 undertook a research and development program to design and build a Light Water Breeder Reactor core for operation in the Shippingport Station.

The objective of the Light Water Breeder Reactor (LWBR) program has been to develop a technology that would significantly improve the utilization of the nation's nuclear fuel resources employing the well-established water reactor technology. To achieve this objective, work has been directed toward analysis, design, component tests, and fabrication of a water-cooled, thorium oxide-uranium oxide fuel cycle breeder reactor for installation and operation at the Shippingport Station. The LWBR core started operation in the Shippingport Station in the Fall of 1977 and is expected to be operated for about 4 to 5 years. At the end of this period, the core will be removed and the spent fuel shipped to the Naval Reactors Expended Core Facility for a detailed examination to verify core performance including an evaluation of breeding characteristics.

In 1976, with fabrication of the Shippingport LWBR core nearing completion, the Energy Research and Development Administration, now DOE, established the Advanced Water Breeder Applications (AWBA) program to develop and disseminate technical information which would assist U. S. industry in evaluating the LWBR concept for commercial-scale applications. The program is exploring some of the problems that would be faced by industry in adapting technology confirmed in the LWBR program. Information being developed includes concepts for commercial-scale prebreeder cores which would produce uranium-233 for light water breeder cores while producing electric power, improvements for breeder cores based on the technology developed to fabricate and operate the Shippingport LWBR core, and other information and technology to aid in evaluating commercial-scale application of the LWBR concept.

All three development programs (Pressurized Water Reactor, Light Water Breeder Reactor, and Advanced Water Breeder Applications) are under the technical direction of the Division of Naval Reactors of DOE. They have the goal of developing practical improvements in the utilization of nuclear fuel resources for generation of electrical energy using water-cooled nuclear reactors.

Technical information developed under the Shippingport, LWBR, and AWBA programs has been and will continue to be published in technical memoranda, one of which is this present report.

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Experiments were performed to establish the critical heat flux (CHF) characteristics of heavy water and light water. Testing was performed with the up-flow of heavy and of light water within a 0.3744 inch inside diameter circular tube with 72.3 inches of heated length. The parameter ranges tested were:

pressure: 400 to 2200 psia (2.76 to 15.2 MPa)

inlet temperature: 200 to 600°F (366 to 589°K)

mass velocity: 250,000 to 3,500,000 lb/hr-ft^2 (339 to 4750 Kg/m^2·s)

heat flux: up to 1,300,000 Btu/hr-ft^2 (4.1 MW/m^2)

Comparisons were made between heavy water and light water critical heat flux levels for the same local equilibrium quality at CHF, operating pressure, and nominal mass velocity. Results showed that heavy water CHF values were, on the average, 8 per cent below the light water CHF values.

Critical Heat Flux Experiments in a Circular Tube with Heavy Water and Light Water

(AWBA Development Program)

I. INTRODUCTION

This testing was performed to develop a basic understanding of the thermal and hydraulic characteristics of heavy water compared to those of light water over a range of fluid conditions of interest to pressurized water reactor studies.

A limited set of heavy water CHF data was reported by Savannah River Laboratory in Reference 1. These tests were performed at low pressure (150 psia, 1.03 MPa) in an internally heated annulus mounted vertically with 24 inches (61 cm) of heated length. The electrically heated center tubes tested had diameters of 0.50, 0.75, and 2.10 inches (1.27, 1.90, and 5.33 cm) with flow path equivalent diameters of 0.375 or 0.400 inches (0.95 or 1.01 cm). Tests were performed with exit conditions in the subcooled regime with water flowing downward at velocities ranging from 15 to 60 fps (4.6 to 18.3 m/s). The subcooled critical heat flux for heavy water was reported as 8% greater than for light water at constant inlet subcooling and mass velocity.

The test described herein was conducted at high pressure with water flowing upward inside a heated tube with exit conditions at saturation. The results indicate that CHF for heavy water was lower than that for light water. A qualitative comparison between these test results and the Savannah River data is discussed in Section V.B.

II. TEST EQUIPMENT

Testing was performed in a high pressure loop in the Bettis Thermal and Hydraulics Laboratory, as illustrated in Figures 1 and 2. Significant features of the stainless steel loop included air operated isolation valves and rupture discs venting into a large blowdown tank. The isolation valves and blowdown equipment were included as a precaution against losing the expensive heavy water. The loop and test section were designed for a pressure of 2500 psia (17.2 MPa) and a temperature of 680°F (633°K).

The test section consisted of an electrically-heated circular tube of 304 stainless steel providing for the vertical upflow of heavy or light water within the tube. Test section dimensions were 0.3744 inches (9.5 mm) inside diameter by 72.3 inches (1.84 m) heated length. These dimensions were based on pre-test measurements and corrections for thermal expansion. Uniform electrical resistance heating was provided by using direct current from a motor-generator set with maximum ranges of 100 volts and 25,000 amps. Silver plated copper terminals were positioned at both ends of the test section for electrical connections. The test section was insulated with Kaylo-10 (calcium silicate-fiberglass), to a nominal outside diameter of 5 inches.

III. INSTRUMENTATION

Test section instrumentation included pressure taps positioned at 3.25 inches beyond the heated length at both inlet and exit ends. Water temperatures were measured at both inlet and exit ends using sheathed Chromel-Alumel thermocouples. Six wall thermocouples for detection of critical heat flux were spot welded at 60-degree intervals around the outer surface of the tubes at a distance 1/4-inch upstream of the end of the heated length. Test section flow was measured using a pre-calibrated orifice flow assembly. The assembly consisted of duplicate orifices mounted in series in each of two parallel flow legs designed for high and low velocities. The test section pressure drop was measured using Rosemount differential pressure cells. Operating pressure was measured using a calibrated Bourdon-type gage.

Purity readings of heavy water were made by first measuring the density of samples extracted from the loop water using a density meter, Mettler/Paar Model DMA 46. This density was used to provide an indication of the molecular purity of a heavy water mixture defined as:

$$\text{Mole \% of } D_2O = 100 \times \left(\frac{\text{No. of Deuterium Atoms}}{\text{Total No. of Deuterium and Hydrogen Atoms}}\right)$$

The data acquisition system included a Honeywell 12-point recorder for test monitoring. A Hewlett-Packard integrating digital voltmeter (IDVM) was used to measure all thermocouple and pressure transducer signals. One second and ten second time intervals were used on thermocouple and pressure differential readings, respectively. A six-channel oscillograph was used to monitor the wall thermocouples for indications of critical heat flux by an excursion in wall temperature. Instrument signals on the IDVM were recorded on magnetic tape for later data processing.

IV. TEST PROCEDURE

During the testing, loop conditions were monitored to ensure that the oxygen content was less than 0.2 ppm and that the electrical resistivity of the makeup water was greater than 1.0 megohm-cm. The coolant was made slightly alkaline by use of a bypass ion exchange column filled with resin in the NH_4^+-OH form. Resin previously deuterated with heavy water was used for the heavy water runs in order to avoid light water contamination through the ion exchange column. For light water tests the pH was held at 9.0 $\pm$0.5; for heavy water tests the same alkalinity was maintained by controlling to an indicated reading of 9.5±0.5 on a pH meter calibrated for light water.*

There were four types of test runs performed, all at steady-state conditions after stabilizing the conditions in the loop for about 15 minutes. The types of runs were isothermal runs (ISO), heat balance runs (HTB), critical heat flux runs (CHF) and runs made at 98% of critical heat flux (98). Forty-five isothermal runs were made with no heat in the test section to obtain pressure drop data and establish the friction factors.

Twenty-one heat balance runs were made at subcooled conditions with low mass velocity to provide the basis for estimating the heat losses during all test runs and to provide heated pressure drop data. Heat losses were correlated with the difference between the test section wall temperature and the ambient.

The balance of the test consisted of dual test runs made at the experimentally determined critical heat flux and at a heat flux just below CHF. The pressure, mass velocity and inlet temperature for each run were established and the heat flux was slowly raised to 75% of an estimated CHF value based on light water CHF correlations. The heat flux was then increased in 5% increments until CHF was indicated by an observed rapid increase of any of the wall thermocouple readings, at which time, if possible, a complete line of data was recorded. Following a CHF run, the power was reset to approximately 98% of the CHF power level and a complete line of data was recorded. These 98% runs served as a backup indication of nominal test section conditions for the CHF runs where a rapid CHF prevented the recording of a full line of data on magnetic tape.

Several replication runs were made throughout the test. In addition to the automatic recording of all data, oscillograph charts were also saved and examined.

* An indicated pH of 9.5 for tests with heavy water was interpreted to provide equivalence between the concentration of OD^- ions and the OH^- ions used in light water tests with a pH of 9.0. This is the result of a correction of +0.4 for the meter being calibrated with H_2O solutions and -0.9 for the fact that pK_{D_2O} is 0.9 units greater than pK_{H_2O}. (pH is the negative $\log_{10}$ of hydrogen ion concentration, pK_{H_2O} is the negative $\log_{10}$ of the product of the concentration of hydrogen $[H^+]$ and hydroxyl $[OH^-]$ ions, and pK_{D_2O} is the negative $\log_{10}$ of the product of the concentration of $[D^+]$ and $[OD^-]$ ions.)

The sequence of testing was conducted as follows in three nominally identical test assemblies:

Phase 1 - Runs 1-152 were performed with light water in test section assembly no. 1.

Phase 2 - Runs 153-196 were performed with light water in test section assembly no. 2.

Phase 3 - Runs 197-252 were performed with heavy water (93.0 per cent pure) in test section assembly no. 2.

Phase 4 - Runs 253-546 were performed with heavy water (99.84 per cent pure) in test section assembly no. 2.

Phase 5 - Runs 547-634 were performed with light water in test section assembly no. 2.

Phase 6 - Runs 635-636 were performed with light water in test section assembly no. 3.

Test section assembly no. 1 represented the original test section tube with moderate structural support. This moderate support consisted of a pipe-support-hanger at the exit end and one spring loaded connection to the floor at the bottom of the test section.

Test section assembly no. 2 consisted of a new test section tube and additional structural support. The new tube was cut from the same stock as the original tube used in assembly no. 1. This new tube was used since small pits were found on the tube surface under the exit copper terminals after run 152. The additional structural support consisted of a rigid support at the test section exit and four connections spring-loaded to the floor. This additional structural support was used to reduce test section vibration and to help determine whether this would influence test results. The test conditions in Phase 2, runs 153-196 included replications of critical heat flux data with the additional structural support.

Test section assembly no. 3 used the same tube as assembly no. 2. The only difference was that a loose pipe-support was used at the exit and no support, other than piping, was used at the inlet (bottom).

This support change was made in order to perform an additional check on data replication and it showed that the manner of support had no influence on the CHF results.

The testing with heavy water of 93 per cent quality in test phase no. 3 was a result of incomplete draining of light water from the loop. While testing with heavy water of this purity was not originally intended, these 93 per cent putity runs provided data for indicating the sensitivity of test results to heavy water purity. Following run 252, the loop was completely drained and evacuated by a vacuum technique, and refilled with high purity (99.84 per cent) heavy water. This high purity was maintained and verified by daily purity checks using the previously described density meter. After run 546, the loop was completely drained and evacuated using the vacuum technique. The loop was then refilled with light water for the remainder of the test.

For data reduction, all light water properties were evaluated from Reference 2. Heavy water properties of saturation conditions, subcooled density and subcooled enthalpy were evaluated from curve-fits of the tabular data given in Reference 3. Heavy water viscosity was evaluated using the ratio correlation given in Reference 4. Table 1 shows the principal heavy water properties used in this study.

The test section mass velocity was calculated by dividing the measured flow rate by the tube inside flow area of 7.645×10^{-4} ft^2 (7.10×10^{-5} m^2). The power delivered to the test section water was evaluated as the supplied electrical power less heat loss. Heat losses were estimated for both light and heavy water using data from single phase unheated (ISO) runs and were determined to be typically less than 2 per cent of the supplied power. The average test section heat flux was evaluated by dividing the power delivered to the water by the heated area of 0.5906 ft^2 (0.055 m^2).

V. RESULTS AND DISCUSSION

A. Data Presentation

The experimental results of this test are shown in Tables 2-10. Tables 2-4 are for the light water base case. Tables 5-7 are for the high grade (99.84 per cent pure) heavy water. Tables 8-10 are for the low grade (93 per cent pure) heavy water. In each group, the three tables give the critical heat flux conditions, data at 98% CHF power, and data at single phase conditions, respectively.

The critical heat flux Tables 2, 5 and 8 include water type designations as light water, HOH, or heavy water, DOD. The operating conditions for each run include the operating pressure, the mass velocity calculated from the flow rate measurements and the average test section heat flux. The inlet enthalpy was calculated from subcooled fluid properties at the inlet temperature and pressure. The exit enthalpy was calculated by the expression

$$H_{exit} = H_{inlet} + \frac{\phi A}{W} \quad (1)$$

where

ϕ is the heat flux

A is the heated area, and

W is the flow rate.

The exit equilibrium quality was calculated by the expression

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

where

H_{exit} is the exit enthalpy

H_f is the saturated liquid enthalpy

H_g is the saturated vapor enthalpy

The data conditions at 98% of critical heat flux power level are presented in Tables 3, 6 and 9 and include the measured tap-to-tap pressure drop.

Test data for subcooled exit flow conditions are presented in Tables 4, 7 and 10 including two types of runs:

ISO - no power applied to the test section

HTB - heated run with subcooled exit conditions.

These tables include the Reynolds Number and the experimental value of the dimensionless friction factor (f) as calculated by the expression

$$f = \frac{\Delta P \, g_c}{\left(\frac{L}{D}\right)\left(\frac{G^2}{2\rho}\right)} \quad (3)$$

where

ΔP is the frictional pressure drop (total ΔP - elevation ΔP)

L is the length (tap-to-tap)

D is the tube inside diameter

G is the mass velocity, and

ρ is the fluid density.

B. Critical Heat Flux

The plots in Figures 3-15 were constructed as a means for the comparison of critical heat flux characteristics between heavy water (99.84 per cent pure) and light water. These plots show critical heat flux versus exit equilibrium quality (X) for fixed values of pressure and nominal mass velocity where $X < 0$ indicates subcooled exit conditions. The exit equilibrium quality was selected as the abscissa for the plots since it reflects local conditions at CHF. These plots show that, for a given value of exit equilibrium quality, the critical heat flux for heavy water is generally less than or equal to the corresponding light water value. The average decrement for all of the pure heavy water versus light water CHF data was found by observation to be approximately 8%. The uncertainty in CHF data of this nature is usually relatively high, on the order of ±10%. The uncertainty for the data reported is not accurately known, but from the few replications runs it can be inferred to be on the order of ± 2 to 3%.

The heavy water decrement trend was true for virtually all tested conditions except for two light water data points shown in Figure 15 at the following conditions:

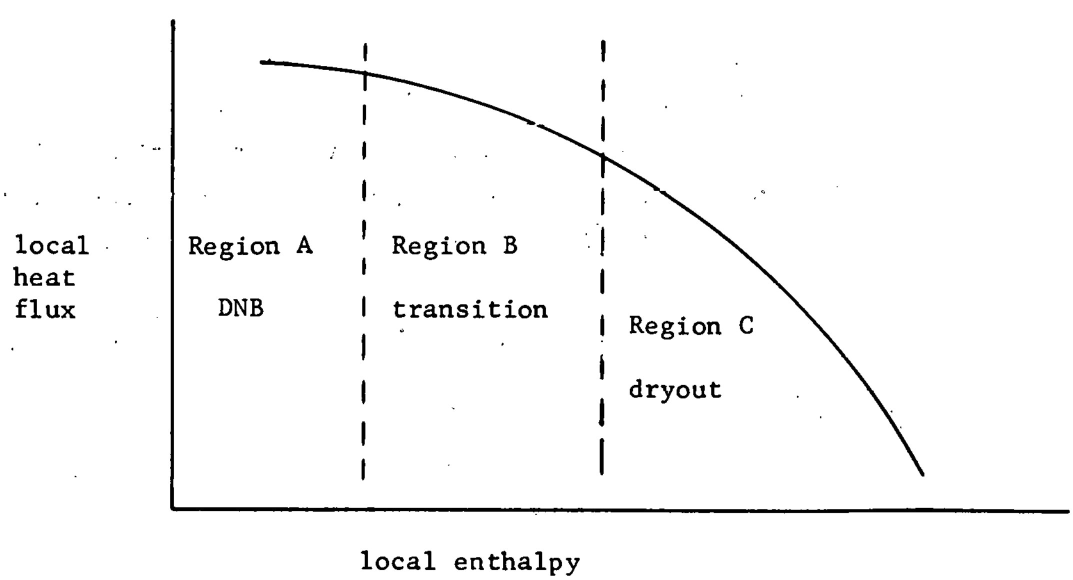
Run	Pressure (psia)	Inlet Temperature (°F)	Mass Velocity $\times 10^{-6}$ (lb/hr-ft^2)	Critical Heat Flux $\times 10^{-6}$ (Btu/hr-ft^2)
191	800	198	0.503	0.479
195	800	197	0.482	0.472

These runs at 800 psia (5.51 MPa) exhibited relatively low values of critical heat flux inconsistent with the trend of the other data. Three additional runs were made at these conditions, Runs 554, 631 and 635, and the results fall in line with the balance of the data. Although the cause of the discrepancy is not known, the two runs, 191 and 195, are judged to be in error and are not included in subsequent data analyses.

In order to interpret the variations of critical heat flux between heavy and light water, the critical heat flux ratios (heavy water/light water) taken from the curves in Figures 3-15 at equal values of exit equilibrium quality, were examined versus pressure and mass velocity. The trends exhibited were considered too weak and inconsistent to warrant any conclusion as to the variation of the CHF ratio with mass velocity or pressure. The only apparent trend was that as the quality increases and/or the mass velocity decreases the heavy water-to-light-water CHF ratio approaches 1.0. Plotting heat flux versus quality normalizes the characteristics of the two fluids with respect to latent heat of vaporization. Thus the above mentioned trend as seen in Figures 3-15 is not surprising since it is to be expected that the critical heat flux phenomena in the two fluids will be similar at high quality as the limit of total channel dryout is approached.

As mentioned in the Introduction, previous test data reported by Savannah River Laboratory in Reference 1 indicated that subcooled critical heat flux values for heavy water were on the average 8% greater than for light water when compared on a constant mass velocity basis. Examination of the CHF data for this test indicates that the critical heat flux values for heavy water are consistently lower than for light water with an average decrement of 8 per cent. This discrepancy between the results of the two experiments may be explainable on the basis of different mechanisms for critical heat flux and corresponding relevant fluid properties as discussed below. Although this qualitative portrayal of CHF mechanisms is an oversimplification of highly complex phenomena, it is judged to be appropriate for purposes of this discussion.

It is well known that critical heat flux phenomena may be generally characterizied using a plot, as illustrated below, of critical heat flux versus local enthalpy.



The critical heat flux phenomena may be categorized in three regions: A, B anc C. In the subcooled Region A, critical heat flux occurs at conditions of high heat flux, low enthalpy, and at bulk fluid conditions which are subcooled or at low quality. The mechanism of CHF in Region A is a departure from nucleate boiling (DNB) featuring a vapor patch of concentrated or coalesced bubbles at the heated surface. Region B is a transition zone. In Region C, the dryout zone, critical heat flux occurs at low heat flux levels and at high enthalpy. The bulk fluid conditions feature a two-phase mixture with high quality. The mechanism of CHF is dryout, that is, a depletion of a thin annular film of liquid on the wall.

All of the Savannah River test data were obtained with subcooled exit fluid conditions and hence the critical heat flux was most likely a departure from nucleate boiling, region A. Most of the Bettis test points are judged to have been perfomred in the dryout region (C) with some suspected operation in the transition region (B). It is, therefore, judged that the two test programs generally explored different mechanisms of critical heat flux.

In the subcooled Region A a parameter relevant to the critical heat flux phenomenon is the ratio of Weber number to Reynolds number

$$\frac{W_e}{R_e} = \frac{G\mu}{\rho\sigma} = \frac{\text{viscous forces}}{\text{surface tension forces}} \qquad (4)$$

where

ρ = density

μ = viscosity

σ = surface tension

G = mass velocity

The functional dependence on this parameter in Region A is such that increases in the W_e/R_e ratio result in increased values of critical heat flux. This follows since high viscous forces tend to strip away the vapor patch and hence exhibit a higher heat flux at DNB. Low surface tension forces permit the bubble to be easily removed, thus resulting in a higher heat flux at DNB. DNB results from the congestion of bubbles generated at the heated surface preventing the plentiful liquid from contacting the wall.

As related to heavy and light water, this dependence may be expressed as

$$\frac{\left(\phi_{CHF}\right)_{D_2O}}{\left(\phi_{CHF}\right)_{H_2O}} \simeq \frac{\left(\frac{G\mu}{\rho\sigma}\right)_{D_2O}}{\left(\frac{G\mu}{\rho\sigma}\right)_{H_2O}} \qquad (5)$$

For operation with equal mass velocities, pressures typical, of both test programs and a temperature of 200°F,* this relation is estimated at

$$\frac{\left(\phi_{CHF}\right)_{D_2O}}{\left(\phi_{CHF}\right)_{H_2O}} \simeq 1.05 \ . \qquad (6)$$

This trend of higher critical heat flux for heavy water as compared to light water is consistent with the Savannah River test results which reported an approximately 8 per cent increment in heavy water over light water on an equal mass velocity basis.

In region C, a parameter relevant to critical heat flux is the latent heat of vaporization (H_{fg}). Surface tension and viscious forces are judged to be of less importance to CHF in this region. The functional dependence for H_{fg} is that critical heat flux increases as the latent heat of vaporization increases. This follows since a fluid with a high value of H_{fg} would require more energy in order to dry out the liquid film than fluid with low heat of vaporization. This dependence may be expressed as

$$\frac{\left(\phi_{CHF}\right)_{D_2O}}{\left(\phi_{CHF}\right)_{H_2O}} \simeq \frac{\left(H_{fg}\right)_{D_2O}}{\left(H_{fg}\right)_{H_2O}} \ . \qquad (7)$$

For operation over a range of pressure from atmosphere up to 2200 psi, this relation is estimated at

$$\frac{\left(\phi_{CHF}\right)_{D_2O}}{\left(\phi_{CHF}\right)_{H_2O}} \simeq 0.90 \ . \qquad (8)$$

---

* 200°F corresponds approximately to the conditions of the Savannah River tests.

This trend of lower critical heat flux for heavy water as compared to light water agrees with the Bettis test results which indicate approximately an 8 per cent decrement in heavy water compared to light water. It is further noted that operating in the quality region corresponds to commercial reactor core CHF conditions for which this study is applicable.

The argument presented above suggesting the dominance of DNB or dryout phenomena in separate regions is qualitative in nature. It is put forward as a possible explanation of the apparent discrepancy between two sets of data and may only apply in the extreme cases of large subcooling on the one hand or at enthalpies near the vapor enthalpy on the other. In particular it would be a mistake to conclude that based on this argument any given set of fluid conditions will necessarily result in a higher performance rating for either light or heavy water. In fact, some of the data trends in this report indicate a decrease in the light water CHF performance margin with increasing quality, a trend which the above argument suggests would be more appropriate for the DNB region. It is concluded (1) that the Savannah River data and the data reported herein although divergent are not necessarily inconsistent, and (2) that data trends of heavy water versus light water are not readily amenable to interpolation or extrapolation.

C. Pressure Drop

Overall test section pressure drop data from the unheated (ISO) single phase runs were used to compute values of the isothermal friction factor. Figure 16 shows a plot of isothermal friction factors vs. Reynolds No. Also shown, for reference, is the Moody curve corresponding to a smooth wall. The data generally followed the smooth Moody curve with scatter. The scatter was somewhat greater than expected particularly for the light water data, but this was attributed primarily to the low values of frictional pressure drop for flow in a smooth pipe.

The test section pressure drop data acquired in this test during two-phase flow were primarily those measured at a power level of approximately 98 per cent of the critical heat flux power level. In general, these pressure drops were approximately equal for the two fluids. As illustrated in Figure 17, which is a plot of pressure drop at 98% CHF power level versus mass velocity for a given operating pressure and inlet temperature, the heavy water pressure drops were approximately the same as those for light water for an inlet temperature of 400°F. The heavy water pressure drops were approximately 7 per cent below the light water values for runs with a 600°F inlet temperature. These comparisons were made at different power levels but at similar exit quality conditions.

D. Low Purity Heavy Water

As previously discussed, this study included tests with low grade heavy water at a nominal purity of 93 per cent. These runs serve to indicate the sensitivity of critical heat flux performance relative to heavy water purity.

Inspection of the data confirms the general trend expressed as:

$$CHF_{H_2O} > CHF_{D_2O} \text{ (93\% pure)} \geq CHF_{D_2O} \text{ (99.84\%)}$$

for given values of operating pressure, inlet temperature and mass velocity. On the average, the decrement in CHF for heavy water compared to light water was proportional to the purity. The decrement for the 93% pure heavy water was found to be approximately 93% of that for the high purity heavy water based on a comparison of the average CHF decrement for high purity heavy water versus the average CHF decrement for low purity heavy water for all 23 cases in which comparable data were obtained. This trend can be seen from Tables 2, 5 and 8.

VI. CONCLUSIONS

From interpretations of the data taken in this study and for the ranges of parameters tested, the following conclusions are made:

1. Comparisons of the heavy water and light water critical heat flux results at equal values of equilibrium quality at CHF, operating pressure, and nominal mass velocity showed the critical heat flux of heavy water to be generally less than that for light water. The average decrement was approximately 8 per cent.
2. For critical heat flux, heavy water purity is moderately important in that slightly lower purities (i.e., 93 per cent) exhibit critical heat flux values between light water and the tested 99.84 per cent heavy water.
3. For pressure drop at approximately 98 per cent of critical heat flux power, heavy water exhibited approximately the same pressure drop to slightly less pressure drop than for light water at the same mass velocity and inlet temperature.

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TABLE 1. Heavy Water Properties Used in This Study

Pressure (psia)	400	800	1200	1600	2000	2200
T_{sat} (°F)	444.92	517.23	565.71	602.97	633.52	647.00
H_g (Btu/lb)	1117.80	1114.67	1102.12	1082.84	1057.02	1041.35
H_f (Btu/lb)	411.92	494.69	554.23	602.85	645.64	666.01

Subcooled Properties:	T	ρ	H	T	ρ	H	T	ρ	H	T	ρ	H	T	ρ	H	T	ρ	H
T (°F)	200	66.800	162.98	200	66.887	163.71	200	66.973	164.45	200	67.060	165.18	200	67.147	165.91	200	67.191	166.28
ρ (lb/ft³)	-	-	-	300	63.740	264.04	300	63.846	264.60	300	63.951	265.16	300	64.057	265.72	300	64.109	266.00
H (Btu/lb)	-	-	-	400	59.650	364.40	400	59.792	364.77	400	59.933	365.16	400	60.074	365.54	400	60.144	365.73
	-	-	-	-	-	-	500	54.410	470.73	500	54.695	469.56	500	54.946	469.17	500	55.064	469.07
	-	-	-	-	-	-	-	-	-	550	51.135	528.50	550	51.457	526.55	550	51.675	526.00
	-	-	-	-	-	-	-	-	-	-	-	-	600	47.414	593.07	600	47.705	591.45

Conversion Factors:

- Temperature: (°K) = (°F + 459.67)/1.8
- Enthalpy: (J/kg) = (2326.)(Btu/lbm)
- Density: (kg/m^3) = $(15.02)(lbm/ft^3)$
- Pressure: (Pa) = (6895)(psia)

TABLE 2. Light Water

CRITICAL HEAT FLUX CONDITIONS

RUN NO.	WATER TYPE	PRES- SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALCULATED EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY
558	HOH	400	197	166	0.245	0.296	1099	0.864
560	HOH	400	197	166	0.368	0.424	1057	0.810
562	HOH	400	196	165	0.491	0.527	994	0.730
568	HOH	400	196	165	0.489	0.510	971	0.700
564	HOH	400	197	166	0.737	0.674	871	0.573
566	HOH	400	196	165	0.982	0.790	787	0.465
193	HOH	800	197	167	0.243	0.277	1048	0.781
550	HOH	800	197	167	0.245	0.286	1070	0.813
552	HOH	800	197	167	0.362	0.419	1063	0.802
191	HOH	800	198	167	0.503	0.479	903	0.571
195	HOH	800	197	167	0.482	0.472	923	0.599
554	HOH	800	195	166	0.489	0.548	1031	0.756
631	HOH	800	197	167	0.494	0.552	1029	0.754
635	HOH	800	195	164	0.489	0.557	1046	0.778
556	HOH	800	196	166	0.742	0.720	915	0.587
633	HOH	800	195	166	0.982	0.836	824	0.455
117	HOH	800	398	373	0.252	0.251	1142	0.917
119	HOH	800	398	374	0.491	0.456	1091	0.843
121	HOH	800	398	374	1.003	0.663	884	0.543
185	HOH	800	397	373	1.007	0.648	870	0.522
123	HOH	800	398	374	2.013	0.861	704	0.282
127	HOH	800	398	374	1.976	0.847	705	0.283
125	HOH	800	398	374	2.955	0.930	617	0.156

Conversion Factors:

Pressure: (Pa) = (6895)(psia)

Temperature: (^{o}K) = (^{o}F + 459.67)/1.8

Enthalpy: (J/kg) = (2326.)(Btu/lbm)

Mass Velocity: (kg/m^2 . s) = (1.356x10^{-3})(lbm/ft^2-hr)

Heat Flux: (W/m^2) = (3.155)(Btu/hr-ft^2)

TABLE 2 (Continued)

CRITICAL HEAT FLUX CONDITIONS

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALCULATED EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY
147	HOH	1200	198	169	0.252	0.301	1090	0.846
151	HOH	1200	198	169	0.254	0.301	1082	0.834
149	HOH	1200	198	169	0.498	0.503	950	0.617
570	HOH	1200	196	167	0.735	0.657	858	0.467
572	HOH	1200	196	167	0.981	0.758	764	0.314
115	HOH	1200	398	374	0.257	0.241	1098	0.860
113	HOH	1200	398	374	0.497	0.415	1019	0.731
111	HOH	1200	398	375	0.998	0.584	826	0.416
183	HOH	1200	397	373	0.976	0.583	834	0.428
107	HOH	1200	398	374	1.998	0.734	658	0.141
105	HOH	1200	398	374	3.020	0.891	602	0.050
109	HOH	1200	398	374	2.976	0.882	603	0.052
63	HOH	1200	498	486	0.256	0.217	1140	0.929
65	HOH	1200	499	486	0.494	0.356	1044	0.770
67	HOH	1200	498	485	1.023	0.486	853	0.459
73	HOH	1200	498	486	1.026	0.487	852	0.458
175	HOH	1200	498	485	1.015	0.481	851	0.457
69	HOH	1200	498	486	2.005	0.594	714	0.233
71	HOH	1200	498	486	2.969	0.632	650	0.128
141	HOH	1600	198	170	0.250	0.270	1005	0.707
143	HOH	1600	198	170	0.493	0.453	880	0.476
574	HOH	1600	196	168	0.984	0.699	717	0.173

TABLE 2 (Continued)

CRITICAL HEAT FLUX CONDITIONS

RUN NO.	WATER TYPE	PRESSURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALCULATED EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY
93	HOH	1600	395	374	0.250	0.213	1035	0.762
95	HOH	1600	393	375	0.495	0.337	901	0.514
99	HOH	1600	398	375	0.498	0.343	907	0.525
97	HOH	1600	399	376	0.988	0.489	758	0.249
181	HOH	1600	397	374	1.025	0.505	754	0.241
101	HOH	1600	399	376	1.976	0.745	667	0.080
103	HOH	1600	400	377	3.017	1.004	634	0.018
173	HOH	1600	497	484	0.254	0.189	1059	0.807
171	HOH	1600	497	485	0.513	0.296	931	0.569
165	HOH	1600	497	484	0.985	0.419	813	0.350
167	HOH	1600	497	484	1.975	0.522	688	0.119
169	HOH	1600	497	484	2.989	0.679	660	0.066
35	HOH	1600	549	547	0.256	0.175	1075	0.837
37	HOH	1600	548	546	0.501	0.258	943	0.592
39	HOH	1600	548	547	1.025	0.357	815	0.355
163	HOH	1600	548	546	1.004	0.357	820	0.364
41	HOH	1600	548	546	2.008	0.414	705	0.151
45	HOH	1600	548	546	1.979	0.420	710	0.159
43	HOH	1600	548	545	3.002	0.506	676	0.096
137	HOH	2000	198	171	0.252	0.247	930	0.556
139	HOH	2000	197	170	0.494	0.404	801	0.279
145	HOH	2000	196	159	0.496	0.404	799	0.273
189	HOH	2000	197	170	0.497	0.415	814	0.306
576	HOH	2000	196	159	0.983	0.657	685	0.029

TABLE 2 (Continued)

CRITICAL HEAT FLUX CONDITIONS

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALCULATED EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY
129	HOH	2000	298	271	0.253	0.224	958	0.615
131	HOH	2000	299	272	0.500	0.357	823	0.326
133	HOH	2000	299	273	1.029	0.575	704	0.070
135	HOH	2000	298	272	1.994	1.003	660	-0.025
146	HOH	2000	299	272	1.991	1.035	674	0.005
187	HOH	2000	302	276	2.045	1.028	664	-0.016
91	HOH	2000	397	375	0.259	0.204	981	0.665
89	HOH	2000	398	375	0.497	0.305	850	0.383
75	HOH	2000	399	376	0.987	0.458	734	0.134
87	HOH	2000	398	375	1.002	0.468	736	0.138
77	HOH	2000	398	375	1.506	0.630	698	0.057
79	HOH	2000	398	375	1.966	0.790	685	0.029
179	HOH	2000	398	375	2.009	0.803	684	0.025
81	HOH	2000	399	376	2.510	0.967	673	0.004
83	HOH	2000	398	375	2.947	1.122	669	-0.005
85	HOH	2000	398	375	3.454	1.291	664	-0.016
61	HOH	2000	498	485	0.255	0.169	999	0.704
59	HOH	2000	499	486	0.499	0.246	867	0.421
57	HOH	2000	498	485	1.025	0.354	752	0.174
55	HOH	2000	498	486	2.006	0.577	708	0.077
177	HOH	2000	497	485	2.044	0.590	708	0.078
53	HOH	2000	499	486	2.995	0.811	695	0.051

TABLE 2 (Continued)

CRITICAL HEAT FLUX CONDITIONS

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALCULATED EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY
33	HOH	2000	548	545	0.264	0.152	990	0.686
31	HOH	2000	547	544	0.500	0.220	884	0.457
25	HOH	2000	548	546	1.031	0.300	771	0.213
27	HOH	2000	548	546	1.976	0.467	728	0.122
161	HOH	2000	546	542	1.989	0.468	724	0.113
29	HOH	2000	548	545	2.978	0.655	715	0.094
19	HOH	2000	598	612	0.256	0.128	997	0.701
21	HOH	2000	598	612	0.505	0.187	899	0.488
23	HOH	2000	597	611	1.041	0.247	795	0.264
47	HOH	2000	598	612	2.014	0.346	744	0.156
51	HOH	2000	598	612	2.026	0.346	743	0.154
159	HOH	2000	596	609	2.047	0.353	742	0.151
49	HOH	2000	598	612	3.003	0.497	740	0.146
578	HOH	2200	196	170	0.250	0.237	901	0.484
580	HOH	2200	197	170	0.494	0.389	778	0.194
582	HOH	2200	197	170	0.984	0.662	690	-0.013
587	HOH	2200	397	375	0.241	0.182	958	0.618
589	HOH	2200	398	375	0.491	0.295	839	0.339
584	HOH	2200	398	375	0.982	0.461	738	0.100
591	HOH	2200	397	375	1.973	0.824	698	0.006

TABLE 2 (Continued)

CRITICAL HEAT FLUX CONDITIONS

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALCULATED EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY
603	HOH	2200	496	483	0.240	0.155	981	0.672
601	HOH	2200	495	482	0.491	0.238	857	0.380
599	HOH	2200	496	483	0.992	0.352	757	0.146
595	HOH	2200	496	483	1.984	0.616	723	0.065
593	HOH	2200	497	485	3.000	0.882	712	0.040
597	HOH	2200	495	482	2.993	0.885	711	0.036
605	HOH	2200	547	544	0.241	0.139	988	0.688
607	HOH	2200	547	544	0.494	0.210	873	0.418
609	HOH	2200	548	545	0.988	0.296	776	0.190
611	HOH	2200	547	544	1.980	0.504	741	0.107
615	HOH	2200	546	543	1.990	0.502	738	0.100
613	HOH	2200	547	543	3.050	0.724	727	0.074
627	HOH	2200	597	610	0.248	0.123	992	0.698
625	HOH	2200	597	610	0.492	0.178	890	0.458
623	HOH	2200	597	610	0.985	0.236	795	0.234
617	HOH	2200	597	610	1.000	0.236	792	0.228
621	HOH	2200	600	613	1.962	0.389	767	0.168
619	HOH	2200	596	608	2.948	0.572	758	0.147

TABLE 3. Light Water

PRESSURE DROP CONDITIONS
AT 98 PER CENT CHF POWER

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY	TAP-TAP PRESSURE DROP (PSI)
559	HOH	400	197	166	0.245	0.285	1067	0.823	3.865
561	HOH	400	197	166	0.357	0.411	1056	0.809	6.706
563	HOH	400	196	165	0.493	0.515	973	0.702	9.311
569	HOH	400	196	165	0.490	0.499	951	0.675	8.928
565	HOH	400	196	165	0.735	0.658	857	0.554	13.441
567	HOH	400	196	165	0.983	0.775	774	0.448	17.643
194	HOH	800	197	167	0.265	0.269	952	0.642	2.507
551	HOH	800	197	167	0.241	0.279	1063	0.802	2.512
553	HOH	800	197	167	0.362	0.411	1046	0.778	3.822
192	HOH	800	198	168	0.495	0.467	895	0.559	4.644
196	HOH	800	197	167	0.482	0.454	894	0.557	4.548
555	HOH	800	195	166	0.485	0.535	1019	0.738	5.345
632	HOH	800	197	167	0.494	0.541	1013	0.729	5.470
636	HOH	800	195	165	0.488	0.544	1028	0.752	5.478
557	HOH	800	195	166	0.743	0.704	899	0.564	7.722
634	HOH	800	136	166	0.983	0.818	808	0.433	9.202
118	HOH	800	398	373	0.250	0.238	1108	0.868	2.427
120	HOH	800	398	374	0.493	0.439	1062	0.801	5.658
122	HOH	800	398	374	0.999	0.657	882	0.539	11.249
186	HOH	800	397	373	1.009	0.637	861	0.509	11.347
124	HOH	800	398	374	2.000	0.852	703	0.280	18.206
128	HOH	800	398	374	1.968	0.842	705	0.282	18.058
126	HOH	800	398	374	2.947	0.920	615	0.152	21.084

TABLE 3 (Continued)

PRESSURE DROP CONDITIONS
AT 98 PER CENT CHF POWER

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY	TAP-TAP PRESSURE DROP (PSI)
148	HOH	1200	198	169	0.251	0.280	1032	0.751	2.234
152	HOH	1200	198	169	0.253	0.287	1046	0.774	2.272
150	HOH	1200	198	169	0.501	0.491	925	0.577	3.534
571	HOH	1200	195	167	0.734	0.643	843	0.444	4.574
573	HOH	1200	196	167	0.981	0.742	751	0.293	5.317
116	HOH	1200	398	374	0.258	0.214	1017	0.727	2.003
114	HOH	1200	397	373	0.499	0.406	1001	0.701	3.268
112	HOH	1200	398	374	1.005	0.574	816	0.398	6.179
184	HOH	1200	397	374	0.972	0.571	827	0.417	6.152
108	HOH	1200	398	374	1.993	0.723	654	0.135	8.532
106	HOH	1200	398	374	2.986	0.881	602	0.049	11.086
110	HOH	1200	398	374	2.975	0.866	599	0.045	10.854
64	HOH	1200	499	486	0.256	0.206	1108	0.876	1.898
66	HOH	1200	498	486	0.494	0.348	1031	0.749	3.763
68	HOH	1200	498	486	1.022	0.480	849	0.452	6.821
74	HOH	1200	498	485	1.025	0.475	843	0.444	6.820
176	HOH	1200	498	485	1.015	0.473	845	0.447	6.833
70	HOH	1200	498	486	1.998	0.584	711	0.228	11.445
72	HOH	1200	498	485	2.981	0.621	646	0.122	14.108
142	HOH	1600	198	170	0.250	0.262	979	0.658	2.131
144	HOH	1600	198	170	0.492	0.438	859	0.436	2.883
575	HOH	1600	196	168	0.985	0.683	704	0.149	3.874

TABLE 3 (Continued)

PRESSURE DROP CONDITIONS
AT 98 PER CENT CHF POWER

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY	TAP-TAP PRESSURE DROP (PSI)
94	HOH	1600	398	375	0.249	0.207	1017	0.728	1.852
96	HOH	1600	398	375	0.495	0.331	893	0.498	2.719
100	HOH	1600	398	375	0.498	0.334	892	0.498	2.736
98	HOH	1600	399	376	0.987	0.482	753	0.240	4.067
182	HOH	1600	397	374	1.021	0.492	746	0.227	4.144
102	HOH	1600	399	376	1.986	0.735	662	0.070	6.311
104	HOH	1600	400	377	3.017	0.976	627	0.005	9.078
174	HOH	1600	497	484	0.252	0.184	1046	0.783	1.588
172	HOH	1600	498	485	0.513	0.291	923	0.556	2.739
166	HOH	1600	497	484	0.981	0.412	808	0.342	4.466
168	HOH	1600	497	484	1.972	0.513	684	0.112	6.849
170	HOH	1600	497	484	2.992	0.668	657	0.060	10.348
36	HOH	1600	548	546	0.259	0.169	1051	0.793	1.515
38	HOH	1600	548	546	0.502	0.254	937	0.580	2.522
40	HOH	1600	548	546	1.027	0.354	813	0.350	4.693
164	HOH	1600	548	546	1.003	0.350	815	0.355	4.504
42	HOH	1600	549	547	2.027	0.406	702	0.144	7.725
46	HOH	1600	549	547	1.989	0.415	708	0.156	7.599
44	HOH	1600	548	545	3.007	0.498	673	0.092	11.586
138	HOH	2000	198	171	0.253	0.243	912	0.518	2.178
140	HOH	2000	198	171	0.497	0.397	787	0.248	2.676
190	HOH	2000	197	170	0.495	0.406	803	0.282	2.637
577	HOH	2000	195	169	0.983	0.646	676	0.010	3.308

TABLE 3 (Continued)

PRESSURE DROP CONDITIONS
AT 98 PER CENT CHF POWER

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY	TAP-TAP PRESSURE DROP (PSI)
130	HOH	2000	298	271	0.251	0.220	948	0.594	2.043
132	HOH	2000	299	272	0.500	0.348	811	0.299	2.616
134	HOH	2000	299	273	1.033	0.565	695	0.050	3.593
135	HOH	2000	298	271	1.987	0.982	653	-0.040	5.592
188	HOH	2000	304	278	2.044	1.016	662	-0.021	5.373
92	HOH	2000	397	375	0.259	0.198	964	0.629	1.884
90	HOH	2000	398	375	0.496	0.298	839	0.361	2.465
76	HOH	2000	398	375	1.004	0.448	719	0.102	3.322
88	HOH	2000	398	375	0.999	0.462	732	0.130	3.378
78	HOH	2000	399	376	1.515	0.617	690	0.039	4.485
80	HOH	2000	398	375	1.974	0.777	679	0.015	5.544
180	HOH	2000	398	375	2.012	0.790	678	0.014	5.596
82	HOH	2000	398	375	2.472	0.950	672	0.000	7.044
84	HOH	2000	398	375	2.941	1.110	666	-0.012	8.582
86	HOH	2000	398	375	3.484	1.243	650	-0.046	9.767
62	HOH	2000	498	485	0.253	0.164	985	0.674	1.739
60	HOH	2000	498	486	0.499	0.241	859	0.403	2.400
58	HOH	2000	498	486	1.040	0.348	744	0.155	3.499
56	HOH	2000	498	486	2.006	0.566	704	0.069	6.340
178	HOH	2000	497	485	2.038	0.581	705	0.072	6.024
54	HOH	2000	499	487	2.980	0.802	694	0.049	9.752

TABLE 3 (Continued)

PRESSURE DROP CONDITIONS
AT 98 PER CENT CHF POWER

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY	TAP-TAP PRESSURE DROP (PSI)
34	HOH	2000	548	545	0.261	0.148	984	0.671	1.529
32	HOH	2000	547	544	0.501	0.215	876	0.439	2.292
26	HOH	2000	548	546	1.031	0.295	767	0.204	3.477
28	HOH	2000	549	546	2.008	0.461	723	0.111	6.050
162	HOH	2000	547	544	1.971	0.454	722	0.107	6.124
30	HOH	2000	548	546	3.004	0.646	712	0.086	10.455
20	HOH	2000	598	612	0.251	0.124	993	0.690	1.427
22	HOH	2000	598	612	0.505	0.184	894	0.478	2.235
24	HOH	2000	597	611	1.038	0.244	793	0.261	3.630
48	HOH	2000	598	511	2.016	0.338	741	0.149	6.889
52	HOH	2000	598	612	2.024	0.340	741	0.149	6.842
160	HOH	2000	595	608	2.036	0.347	740	0.146	6.766
50	HOH	2000	598	611	3.006	0.489	737	0.140	12.310
579	HOH	2200	195	170	0.250	0.232	885	0.447	2.171
581	HOH	2200	197	170	0.494	0.381	767	0.168	2.543
583	HOH	2200	197	170	0.984	0.653	682	-0.030	3.219
588	HOH	2200	397	375	0.240	0.178	946	0.590	1.888
590	HOH	2200	398	375	0.490	0.290	832	0.321	2.405
585	HOH	2200	397	375	0.981	0.449	729	0.079	3.183
592	HOH	2200	397	375	1.970	0.814	694	-0.003	5.517

TABLE 3 (Continued)

PRESSURE DROP CONDITIONS
AT 98 PER CENT CHF POWER

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY	TAP-TAP PRESSURE DROP (PSI)
604	HOH	2200	495	483	0.239	0.150	966	0.638	1.589
602	HOH	2200	495	482	0.491	0.232	846	0.356	2.313
600	HOH	2200	496	483	0.989	0.343	751	0.131	3.245
596	HOH	2200	497	484	1.982	0.610	722	0.062	6.267
598	HOH	2200	495	483	2.983	0.876	710	0.035	11.134
594	HOH	2200	499	486	2.994	0.877	713	0.041	11.044
606	HOH	2200	547	544	0.239	0.134	978	0.665	1.581
608	HOH	2200	548	545	0.492	0.206	868	0.407	2.236
610	HOH	2200	548	545	0.984	0.291	773	0.182	3.287
612	HOH	2200	548	545	1.982	0.499	739	0.104	6.804
616	HOH	2200	547	544	1.982	0.495	736	0.097	6.592
614	HOH	2200	549	546	2.998	0.709	729	0.079	12.479
628	HOH	2200	598	611	0.246	0.117	980	0.669	1.455
626	HOH	2200	597	610	0.490	0.174	884	0.445	2.110
624	HOH	2200	597	610	0.983	0.229	790	0.222	3.249
618	HOH	2200	597	609	1.002	0.230	786	0.214	3.318
622	HOH	2200	598	611	1.975	0.376	758	0.148	7.014
620	HOH	2200	595	607	2.972	0.557	752	0.134	13.221

TABLE 4. Light Water

SINGLE PHASE
PRESSURE DROP CONDITIONS

RUN NO.	WATER TYPE	RUN TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	TAP-TAP PRESSURE DROP (PSI)	REYNOLDS NUMBER	EXPER. FRICTION FACTOR
586	HOH	ISO	800	197	167	0.493	----	167	2.928	20500	.02507
120A	HOH	ISO	800	398	374	1.005	----	374	3.038	97700	.01769
9	HOH	ISO	1200	199	170	0.246	----	170	2.803	10400	.02779
10	HOH	ISO	1200	199	169	0.989	----	169	3.377	41900	.02202
547	HOH	ISO	1200	197	168	0.982	----	168	3.361	41100	.02172
8	HOH	ISO	1200	497	485	0.258	----	485	2.305	31600	.01908
7	HOH	ISO	1200	498	485	0.990	----	485	2.835	122000	.01682
38A	HOH	ISO	1500	548	546	1.034	----	546	2.759	140200	.01583
3	HOH	ISO	2000	198	171	0.258	----	171	2.826	10800	.03304
154A	HOH	ISO	2000	196	169	0.243	----	169	2.814	10100	.02886
549	HOH	ISO	2000	197	169	0.242	----	169	2.813	10000	.02923
154	HOH	ISO	2000	197	169	0.287	----	169	2.831	11900	.02846
2	HOH	ISO	2000	198	171	0.976	----	171	3.377	41100	.02241
1	HOH	ISO	2000	199	172	4.331	----	172	11.692	183900	.01651
153	HOH	ISO	2000	198	170	4.431	----	170	12.202	188500	.01631
548	HOH	ISO	2000	197	169	4.523	----	169	13.480	188800	.01818
4	HOH	ISO	2000	598	612	0.251	----	612	2.029	38500	.01906
18A	HOH	ISO	2000	599	614	0.257	----	614	2.030	37900	.02102
155	HOH	ISO	2000	597	611	0.242	----	611	2.044	35600	.02618
5	HOH	ISO	2000	598	613	1.021	----	613	2.816	151600	.02016
6	HOH	ISO	2000	598	612	3.477	----	612	8.977	516700	.01431
156	HOH	ISO	2000	597	610	3.604	----	610	8.805	533300	.01302

TABLE 4 (Continued)

SINGLE PHASE
PRESSURE DROP CONDITIONS

RUN NO.	WATER TYPE	RUN TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	TAP-TAP PRESSURE DROP (PSI)	REYNOLDS NUMBER	EXPER. FRICTION FACTOR
630	HOH	ISO	2200	196	169	2.958	----	169	7.691	123000	.01956
629	HOH	ISO	2200	597	610	2.991	----	610	10.105	441200	.02259
11	HOH	HTB	1200	198	168	2.964	0.296	245	6.791	-----	-----
12	HOH	HTB	1200	198	168	2.964	0.494	297	6.665	-----	-----
13	HOH	HTB	1200	198	168	2.962	0.691	349	6.602	-----	-----
14	HOH	HTB	1200	203	174	2.960	0.791	380	6.588	-----	-----
14C	HOH	HTB	1200	397	373	2.978	0.296	450	6.699	-----	-----
14B	HOH	HTB	1200	398	374	2.960	0.492	502	6.694	-----	-----
14A	HOH	HTB	1200	398	374	2.923	0.592	557	7.364	-----	-----
18	HOH	HTB	2000	398	375	2.978	0.095	400	6.693	-----	-----
15	HOH	HTB	2000	398	375	2.982	0.294	451	6.696	-----	-----
157	HOH	HTB	2000	397	374	3.002	0.298	450	6.759	-----	-----
15	HOH	HTB	2000	398	375	2.983	0.491	502	6.751	-----	-----
17	HOH	HTB	2000	398	376	2.984	0.694	555	6.781	-----	-----
158	HOH	HTB	2000	398	375	2.971	0.589	554	6.811	-----	-----

TABLE 5. Heavy Water (99.84%)

CRITICAL HEAT FLUX CONDITIONS

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALCULATED EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY
483	DOD	401	196	159	0.250	0.265	977	0.801
481	DOD	400	197	160	0.370	0.374	941	0.750
479	DOD	400	196	159	0.488	0.484	925	0.727
485	DOD	401	196	159	0.492	0.490	929	0.732
477	DOD	400	196	159	0.733	0.625	818	0.575
475	DOD	400	196	158	0.974	0.759	761	0.494
446	DOD	800	197	160	0.251	0.274	1031	0.817
450	DOD	800	197	160	0.248	0.258	954	0.756
465	DOD	800	195	159	0.241	0.258	935	0.790
467	DOD	800	196	160	0.360	0.376	957	0.761
448	DOD	800	196	160	0.490	0.512	958	0.763
452	DOD	800	197	161	0.490	0.505	958	0.748
469	DOD	800	196	159	0.488	0.503	957	0.745
471	DOD	800	196	160	0.738	0.675	856	0.599
473	DOD	800	196	160	0.975	0.787	783	0.466
419	DOD	800	297	261	0.257	0.257	1034	0.869
407	DOD	800	397	361	0.244	0.218	1050	0.896
409	DOD	800	397	361	0.495	0.412	1004	0.821
411	DOD	800	397	361	0.977	0.593	830	0.542
417	DOD	800	395	360	0.993	0.597	824	0.531
413	DOD	800	398	362	1.971	0.771	664	0.274
415	DOD	803	395	359	2.966	0.848	580	0.138

TABLE 5 (Continued)

CRITICAL HEAT FLUX CONDITIONS

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALCULATED EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY
439	DOD	1200	197	161	0.252	0.274	1002	0.818
444	DOD	1200	196	161	0.255	0.277	1000	0.814
458	DOD	1200	196	161	0.252	0.273	999	0.811
441	DOD	1200	196	161	0.488	0.460	890	0.612
487	DOD	1200	196	160	0.736	0.611	801	0.451
489	DOD	1200	197	161	0.983	0.703	714	0.292
405	DOD	1200	397	362	0.236	0.208	1042	0.891
403	DOD	1200	397	361	0.495	0.385	962	0.745
401	DOD	1200	397	362	0.957	0.535	794	0.438
397	DOD	1200	397	362	1.978	0.689	631	0.140
395	DOD	1200	397	362	2.946	0.824	578	0.043
399	DOD	1200	396	361	2.942	0.829	578	0.044
332	DOD	1200	496	466	0.251	0.191	1053	0.911
328	DOD	1200	496	467	0.477	0.319	983	0.783
326	DOD	1200	498	469	0.993	0.432	805	0.458
330	DOD	1200	497	467	0.992	0.432	804	0.455
379	DOD	1200	496	466	0.972	0.427	806	0.459
324	DOD	1200	497	467	1.970	0.545	680	0.230
322	DOD	1200	497	467	2.966	0.582	618	0.117
437	DOD	1600	197	162	0.243	0.250	958	0.741
454	DOD	1600	197	162	0.250	0.256	952	0.728
435	DOD	1600	197	162	0.492	0.420	821	0.455
456	DOD	1600	196	162	0.488	0.424	832	0.476
544	DOD	1600	197	162	0.974	0.651	679	0.158

TABLE 5 (Continued)

CRITICAL HEAT FLUX CONDITIONS

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALCULATED EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY
383	DOD	1600	398	363	0.247	0.198	982	0.789
385	DOD	1600	397	362	0.491	0.316	860	0.535
389	DOD	1600	397	362	0.489	0.312	856	0.527
387	DOD	1600	398	363	0.982	0.477	738	0.281
391	DOD	1600	398	363	1.948	0.677	632	0.060
393	DOD	1600	397	363	2.951	0.926	605	0.004
316	DOD	1600	496	465	0.249	0.171	996	0.820
370	DOD	1600	497	467	0.245	0.167	994	0.814
314	DOD	1600	496	465	0.488	0.261	877	0.572
368	DOD	1600	497	466	0.494	0.262	876	0.570
312	DOD	1600	498	467	0.977	0.381	769	0.345
366	DOD	1600	497	466	0.983	0.385	768	0.345
318	DOD	1600	497	466	1.973	0.486	657	0.112
372	DOD	1600	498	468	1.975	0.486	657	0.114
320	DOD	1600	497	466	2.941	0.617	628	0.053
374	DOD	1600	499	469	2.943	0.612	630	0.056
290	DOD	1600	547	524	0.246	0.155	1010	0.848
292	DOD	1600	546	524	0.487	0.232	892	0.603
294	DOD	1600	547	525	0.982	0.320	777	0.362
296	DOD	1600	545	524	1.993	0.395	577	0.155
300	DOD	1600	548	525	1.983	0.394	579	0.159
298	DOD	1600	548	526	2.949	0.464	647	0.093

TABLE 5 (Continued)

CRITICAL HEAT FLUX CONDITIONS

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALCULATED EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY
431	DOD	2000	197	163	0.253	0.236	883	0.577
429	DOD	2000	197	163	0.490	0.378	758	0.274
433	DOD	2000	197	162	0.491	0.378	757	0.270
542	DOD	2000	197	163	0.979	0.618	651	0.012
421	DOD	2000	297	263	0.252	0.212	912	0.647
423	DOD	2000	298	264	0.489	0.328	783	0.333
425	DOD	2000	298	263	0.980	0.521	674	0.069
427	DOD	2000	297	262	1.962	0.923	626	-0.048
334	DOD	2000	398	363	0.243	0.177	926	0.681
361	DOD	2000	397	363	0.243	0.179	931	0.694
336	DOD	2000	396	362	0.493	0.282	804	0.385
359	DOD	2000	397	363	0.493	0.282	805	0.388
338	DOD	2000	397	363	0.981	0.423	696	0.123
342	DOD	2000	397	363	0.992	0.428	696	0.122
357	DOD	2000	397	363	0.968	0.423	700	0.131
364	DOD	2000	397	362	0.979	0.425	698	0.127
340	DOD	2000	397	363	1.481	0.577	664	0.044
355	DOD	2000	397	363	1.469	0.573	664	0.045
344	DOD	2000	398	363	1.979	0.732	649	0.009
346	DOD	2000	400	366	1.962	0.724	651	0.012
349	DOD	2000	396	361	2.464	0.895	642	-0.009
351	DOD	2000	396	361	2.948	1.039	633	-0.030
353	DOD	2000	398	364	3.421	1.179	630	-0.038

TABLE 5 (Continued)

CRITICAL HEAT FLUX CONDITIONS

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALCULATED EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY
306	DOD	2000	496	465	0.237	0.147	944	0.726
308	DOD	2000	496	465	0.492	0.232	830	0.448
310	DOD	2000	497	466	0.975	0.327	726	0.194
302	DOD	2000	496	465	1.955	0.519	670	0.059
304	DOD	2000	496	465	2.929	0.739	660	0.034
288	DOD	2000	545	521	0.244	0.134	946	0.729
286	DOD	2000	545	521	0.486	0.204	846	0.486
284	DOD	2000	545	520	0.979	0.282	743	0.236
280	DOD	2000	545	520	1.986	0.429	687	0.101
282	DOD	2000	547	523	2.963	0.591	677	0.076
268	DOD	2000	595	585	0.238	0.111	945	0.729
270	DOD	2000	596	587	0.493	0.173	858	0.516
272	DOD	2000	598	591	0.996	0.230	769	0.300
274	DOD	2000	595	586	1.963	0.316	710	0.156
278	DOD	2000	597	588	1.968	0.308	710	0.156
276	DOD	2000	597	589	2.918	0.439	705	0.143
536	DOD	2200	197	163	0.244	0.220	859	0.515
538	DOD	2200	197	163	0.494	0.366	736	0.186
540	DOD	2200	197	164	0.981	0.619	651	-0.039
534	DOD	2200	397	363	0.237	0.167	907	0.642
532	DOD	2200	396	362	0.492	0.271	787	0.323
530	DOD	2200	396	361	0.977	0.425	697	0.084
528	DOD	2200	397	363	1.967	0.770	665	-0.003

TABLE 5 (Continued)

CRITICAL HEAT FLUX CONDITIONS

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALCULATED EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY
524	DOD	2200	498	467	0.238	0.141	923	0.685
522	DOD	2200	498	467	0.489	0.218	811	0.386
503	DOD	2200	497	466	0.987	0.326	721	0.148
499	DOD	2200	496	464	1.974	0.575	689	0.062
501	DOD	2200	495	464	2.953	0.817	678	0.031
526	DOD	2200	498	466	2.947	0.806	678	0.031
518	DOD	2200	547	522	0.243	0.128	928	0.697
520	DOD	2200	547	523	0.498	0.194	823	0.419
505	DOD	2200	547	523	0.979	0.271	736	0.187
491	DOD	2200	549	525	1.951	0.460	707	0.108
515	DOD	2200	548	523	1.971	0.464	705	0.104
493	DOD	2200	547	523	2.961	0.663	696	0.079
511	DOD	2200	597	587	0.235	0.106	935	0.717
509	DOD	2200	597	587	0.511	0.167	839	0.461
507	DOD	2200	598	588	0.976	0.216	760	0.249
513	DOD	2200	597	588	0.995	0.221	759	0.248
497	DOD	2200	598	589	1.982	0.359	729	0.167
495	DOD	2200	597	587	2.976	0.523	722	0.150

TABLE 6. Heavy Water (99.84%)

PRESSURE DROP CONDITIONS
AT 98 PER CENT CHF POWER

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY	TAP-TAP PRESSURE DROP (PSI)
484	DOD	400	196	159	0.248	0.256	955	0.769	3.602
482	DOD	400	197	160	0.370	0.364	919	0.718	5.837
480	DOD	400	196	159	0.489	0.474	908	0.703	8.477
486	DOD	400	196	159	0.491	0.479	912	0.708	8.573
478	DOD	400	196	159	0.737	0.613	801	0.551	12.728
476	DOD	400	195	159	0.977	0.747	749	0.478	17.319
447	DOD	800	197	161	0.251	0.266	980	0.782	2.649
451	DOD	800	197	161	0.247	0.247	932	0.706	2.562
466	DOD	800	195	159	0.241	0.248	954	0.741	2.568
468	DOD	800	197	161	0.360	0.365	944	0.724	3.575
449	DOD	800	197	160	0.491	0.503	952	0.737	5.111
453	DOD	800	197	161	0.490	0.492	937	0.713	4.986
470	DOD	800	196	160	0.488	0.491	936	0.712	4.981
472	DOD	800	196	159	0.740	0.656	845	0.565	7.129
474	DOD	800	196	160	0.975	0.774	773	0.449	8.522
420	DOD	800	297	261	0.255	0.248	1012	0.834	2.328
408	DOD	800	397	361	0.244	0.211	1029	0.863	2.287
410	DOD	800	397	361	0.495	0.403	991	0.800	5.476
412	DOD	800	397	361	0.977	0.582	821	0.527	10.314
418	DOD	800	395	359	0.995	0.587	815	0.517	10.370
414	DOD	800	396	360	1.973	0.755	656	0.261	16.444
416	DOD	800	395	360	2.969	0.833	577	0.132	19.273

TABLE 6 (Continued)

PRESSURE DROP CONDITIONS
AT 98 PER CENT CHF POWER

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY	TAP-TAP PRESSURE DROP (PSI)
440	DOD	1200	197	161	0.251	0.267	984	0.784	2.366
445	DOD	1200	196	161	0.256	0.272	982	0.781	2.389
459	DOD	1200	196	161	0.252	0.266	976	0.770	2.394
442	DOD	1200	196	161	0.486	0.453	880	0.595	3.498
490	DOD	1200	197	161	0.984	0.688	701	0.267	5.088
406	DOD	1200	397	362	0.236	0.202	1023	0.855	1.893
404	DOD	1200	397	361	0.494	0.372	944	0.712	3.552
402	DOD	1200	398	362	0.955	0.527	788	0.427	5.555
398	DOD	1200	397	361	1.979	0.676	625	0.130	8.452
396	DOD	1200	396	361	2.950	0.808	573	0.034	10.878
400	DOD	1200	395	360	2.945	0.812	573	0.035	10.924
382	DOD	1200	497	467	0.242	0.180	1042	0.890	1.770
381	DOD	1200	497	467	0.478	0.314	975	0.768	3.476
378	DOD	1200	497	467	0.981	0.426	802	0.453	6.371
380	DOD	1200	496	467	0.974	0.418	798	0.445	6.275
377	DOD	1200	498	468	1.945	0.536	681	0.232	10.695
376	DOD	1200	497	468	2.963	0.571	617	0.114	13.512
438	DOD	1500	197	162	0.243	0.244	938	0.698	2.230
455	DOD	1500	197	162	0.250	0.250	937	0.695	2.291
436	DOD	1500	197	162	0.492	0.414	811	0.433	2.957
457	DOD	1500	196	162	0.489	0.416	819	0.450	2.999
545	DOD	1500	197	162	0.973	0.637	668	0.136	3.902

TABLE 6 (Continued)

PRESSURE DROP CONDITIONS
AT 98 PER CENT CHF POWER

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY	TAP-TAP PRESSURE DROP (PSI)
384	DOD	1600	398	363	0.246	0.194	971	0.767	1.896
386	DOD	1600	397	363	0.490	0.310	851	0.517	2.762
390	DOD	1600	397	362	0.488	0.306	846	0.507	2.761
388	DOD	1600	398	363	0.983	0.470	732	0.270	4.207
392	DOD	1600	398	363	1.949	0.664	626	0.049	6.186
394	DOD	1600	396	361	2.954	0.906	598	-0.010	9.251
317	DOD	1600	496	466	0.248	0.167	987	0.799	1.783
371	DOD	1600	497	466	0.245	0.165	986	0.798	1.594
369	DOD	1600	497	467	0.494	0.259	872	0.560	2.655
313	DOD	1600	497	467	0.977	0.371	760	0.328	4.377
367	DOD	1600	497	466	0.983	0.379	764	0.336	4.433
373	DOD	1600	499	468	1.970	0.478	655	0.110	6.845
375	DOD	1600	500	470	2.926	0.599	628	0.053	10.093
291	DOD	1600	547	524	0.244	0.151	1003	0.834	1.578
293	DOD	1600	546	524	0.488	0.227	884	0.586	2.538
295	DOD	1600	547	525	0.983	0.314	772	0.352	4.432
297	DOD	1600	546	524	2.000	0.387	673	0.147	7.263
301	DOD	1600	548	525	1.996	0.387	675	0.150	7.286
299	DOD	1600	548	526	2.954	0.457	645	0.088	10.739
432	DOD	2000	197	163	0.253	0.230	865	0.533	2.264
430	DOD	2000	197	163	0.491	0.370	745	0.241	2.714
434	DOD	2000	197	163	0.490	0.371	747	0.247	2.715
543	DOD	2000	197	163	0.979	0.607	642	-0.008	3.447

TABLE 6 (Continued)

PRESSURE DROP CONDITIONS
AT 98 PER CENT CHF POWER

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY	TAP-TAP PRESSURE DROP (PSI)
422	DOD	2000	297	263	0.251	0.206	897	0.611	2.082
424	DOD	2000	297	263	0.488	0.323	774	0.312	2.527
428	DOD	2000	296	261	1.963	0.908	619	-0.066	5.435
362	DOD	2000	397	363	0.242	0.176	923	0.675	1.955
360	DOD	2000	397	363	0.491	0.278	800	0.375	2.587
358	DOD	2000	397	362	0.967	0.419	697	0.125	3.415
365	DOD	2000	396	362	0.981	0.413	688	0.102	3.396
356	DOD	2000	397	363	1.468	0.567	661	0.038	4.341
347	DOD	2000	401	366	1.959	0.712	647	0.003	5.502
350	DOD	2000	396	361	2.469	0.878	636	-0.024	6.858
352	DOD	2000	395	360	2.956	1.019	627	-0.046	8.424
354	DOD	2000	397	362	3.425	1.146	621	-0.060	10.219
307	DOD	2000	497	465	0.235	0.142	933	0.697	1.730
309	DOD	2000	496	465	0.492	0.227	821	0.425	2.435
311	DOD	2000	497	466	0.975	0.319	718	0.177	3.438
303	DOD	2000	496	465	1.950	0.511	667	0.052	5.629
305	DOD	2000	495	464	2.925	0.726	656	0.024	8.310
289	DOD	2000	545	521	0.244	0.130	933	0.700	1.629
287	DOD	2000	545	521	0.485	0.202	844	0.481	2.308
285	DOD	2000	545	520	0.978	0.276	738	0.225	3.504
281	DOD	2000	544	520	1.991	0.423	684	0.092	5.979
283	DOD	2000	547	523	2.964	0.583	675	0.071	9.728

TABLE 6 (Continued)

PRESSURE DROP CONDITIONS
AT 98 PER CENT CHF POWER

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY	TAP-TAP PRESSURE DROP (PSI)
269	DOD	2000	595	585	0.233	0.100	917	0.658	1.474
271	DOD	2000	596	587	0.491	0.170	854	0.507	2.232
273	DOD	2000	598	590	0.994	0.226	765	0.290	3.548
275	DOD	2000	594	585	1.968	0.309	706	0.147	6.308
279	DOD	2000	596	587	1.971	0.303	705	0.145	6.271
277	DOD	2000	596	588	2.927	0.432	702	0.137	10.899
537	DOD	2200	197	163	0.243	0.214	842	0.470	2.343
539	DOD	2200	197	163	0.494	0.363	730	0.171	2.741
541	DOD	2200	197	164	0.981	0.607	641	-0.066	3.353
535	DOD	2200	397	363	0.236	0.164	897	0.617	1.984
533	DOD	2200	396	362	0.492	0.264	776	0.294	2.515
531	DOD	2200	395	361	0.982	0.416	688	0.059	3.252
529	DOD	2200	396	362	1.967	0.755	658	-0.020	5.352
525	DOD	2200	493	467	0.238	0.137	913	0.659	1.781
523	DOD	2200	493	467	0.488	0.213	804	0.368	2.353
504	DOD	2200	497	466	0.983	0.318	716	0.132	3.263
500	DOD	2200	495	464	1.977	0.562	683	0.046	5.895
502	DOD	2200	494	462	2.962	0.799	671	0.013	9.981
527	DOD	2200	497	466	2.953	0.790	672	0.017	9.401

TABLE 6 (Continued)

PRESSURE DROP CONDITIONS
AT 98 PER CENT CHF POWER

RUN NO.	WATER TYPE	PRESSURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY	TAP-TAP PRESSURE DROP (PSI)
519	DOD	2200	547	522	0.242	0.125	921	0.678	1.663
521	DOD	2200	547	523	0.498	0.190	817	0.403	2.280
506	DOD	2200	547	522	0.979	0.264	730	0.170	3.231
492	DOD	2200	547	522	1.953	0.445	698	0.086	6.005
515	DOD	2200	548	523	1.973	0.454	701	0.093	6.273
494	DOD	2200	548	523	2.959	0.654	694	0.074	10.716
512	DOD	2200	597	587	0.234	0.102	925	0.689	1.506
510	DOD	2200	597	587	0.510	0.163	834	0.446	2.210
508	DOD	2200	597	588	0.979	0.211	754	0.234	3.223
514	DOD	2200	597	588	0.995	0.214	754	0.235	3.260
498	DOD	2200	598	589	1.982	0.355	727	0.162	6.556
496	DOD	2200	595	585	2.992	0.519	719	0.140	12.823

TABLE 7. Heavy Water (99.84%)

SINGLE PHASE
PRESSURE DROP CONDITIONS

RUN NO.	WATER TYPE	RUN TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	TAP-TAP PRESSURE DROP (PSI)	REYNOLDS NUMBER	EXPER. FRICTION FACTOR
464	DOD	ISO	800	197	161	0.248	----	161	3.107	8800	.03241
256	DOD	ISO	1200	196	161	0.235	----	161	3.109	8300	.03374
443	DOD	ISO	1200	196	161	0.242	----	161	3.112	8500	.03390
257	DOD	ISO	1200	196	161	0.981	----	161	3.640	35000	.02322
463	DOD	ISO	1200	196	160	2.953	----	160	7.326	105100	.01880
259	DOD	ISO	1200	497	468	0.237	----	468	2.547	25900	.02439
258	DOD	ISO	1200	496	465	0.987	----	466	3.061	108400	.01813
255	DOD	ISO	2000	196	162	0.259	----	162	3.127	9200	.03426
254	DOD	ISO	2000	197	163	0.986	----	163	3.651	35100	.02317
253	DOD	ISO	2000	197	163	4.783	----	163	12.872	171100	.01650
363	DOD	ISO	2000	396	362	0.983	----	362	3.290	82200	.01933
348	DOD	ISO	2000	396	361	2.447	----	361	5.733	204300	.01720
260	DOD	ISO	2000	596	588	0.234	----	588	2.239	31300	.01933
267	DOD	ISO	2000	595	585	1.012	----	585	2.791	136000	.01608
261	DOD	ISO	2000	595	588	3.491	----	588	8.366	472200	.01390
546	DOD	ISO	2200	196	162	2.951	----	162	7.308	104700	.01877
517	DOD	ISO	2200	547	523	0.490	----	523	2.540	59100	.02060

TABLE 7 (Continued)

SINGLE PHASE
PRESSURE DROP CONDITIONS

RUN NO.	WATER TYPE	RUN TYPE	PRESSURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	TAP-TAP PRESSURE DROP (PSI)	REYNOLDS NUMBER	EXPER. FRICTION FACTOR
266	DOD	HTB	1200	196	160	2.956	0.297	238	6.774	-----	-----
460	DOD	HTB	1200	197	161	2.951	0.496	291	7.277	-----	-----
461	DOD	HTB	1200	197	161	2.948	0.693	343	7.360	-----	-----
462	DOD	HTB	1200	198	162	2.953	0.890	395	7.489	-----	-----
262	DOD	HTB	2000	397	363	2.975	0.097	388	6.589	-----	-----
263	DOD	HTB	2000	397	362	2.999	0.295	438	6.631	-----	-----
264	DOD	HTB	2000	396	361	2.977	0.492	489	6.597	-----	-----
265	DOD	HTB	2000	398	363	2.957	0.690	544	6.808	-----	-----

TABLE 8. Heavy Water (93%)

CRITICAL HEAT FLUX CONDITIONS

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALCULATED EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY
251	DOD	800	294	258	0.243	0.244	1034	0.870
239	DOD	800	397	362	0.959	0.589	836	0.550
241	DOD	800	398	363	1.980	0.785	669	0.281
237	DOD	1200	398	362	0.998	0.541	784	0.420
219	DOD	1200	498	468	0.982	0.435	818	0.467
235	DOD	1600	397	362	0.997	0.483	736	0.277
243	DOD	1600	399	364	1.004	0.484	736	0.278
233	DOD	1600	398	363	1.963	0.681	631	0.059
221	DOD	1600	497	466	1.976	0.492	658	0.115
217	DOD	1600	544	521	0.972	0.324	779	0.367
215	DOD	1600	549	527	1.981	0.394	680	0.161
249	DOD	2000	295	261	0.239	0.206	927	0.684
247	DOD	2000	296	262	1.965	0.920	623	-0.054
200	DOD	2000	398	363	0.991	0.436	703	0.139
231	DOD	2000	397	362	1.978	0.732	648	0.006
229	DOD	2000	398	364	2.977	1.038	633	-0.030
223	DOD	2000	496	465	1.003	0.332	721	0.184
225	DOD	2000	497	466	1.984	0.529	672	0.064
227	DOD	2000	497	466	2.961	0.748	659	0.032

TABLE 8 (Continued)

CRITICAL HEAT FLUX CONDITIONS

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALCULATED EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY
208	DOD	2000	548	524	0.998	0.285	744	0.239
210	DOD	2000	546	522	1.984	0.431	690	0.108
212	DOD	2000	549	525	2.971	0.592	679	0.080
202	DOD	2000	597	588	1.016	0.236	768	0.298
204	DOD	2000	596	587	1.949	0.313	711	0.159
245	DOD	2000	598	591	1.932	0.303	712	0.161
206	DOD	2000	596	588	2.956	0.450	705	0.145

TABLE 9. Heavy Water (93%)

PRESSURE DROP CONDITIONS
AT 98 PER CENT CHF POWER

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY	TAP-TAP PRESSURE DROP (PSI)
252	DOD	800	297	261	0.243	0.239	1020	0.847	2.484
240	DOD	800	397	362	0.962	0.586	832	0.544	10.146
242	DOD	800	399	363	1.976	0.778	668	0.279	16.995
238	DOD	1200	397	362	0.990	0.528	774	0.402	5.925
220	DOD	1200	497	467	0.982	0.426	803	0.454	6.247
236	DOD	1600	397	362	0.993	0.472	729	0.264	4.231
244	DOD	1600	398	363	1.003	0.471	726	0.257	4.234
234	DOD	1600	397	363	1.963	0.670	626	0.049	6.047
222	DOD	1600	497	466	1.976	0.485	655	0.109	6.698
218	DOD	1600	548	525	0.967	0.315	777	0.363	4.304
216	DOD	1600	548	526	1.981	0.388	677	0.155	7.102
250	DOD	2000	295	261	0.240	0.200	986	0.632	2.167
248	DOD	2000	297	263	1.963	0.904	618	-0.066	5.103
201	DOD	2000	397	363	0.988	0.433	701	0.135	3.463
232	DOD	2000	397	362	1.977	0.725	646	-0.000	5.336
230	DOD	2000	398	363	2.983	1.016	626	-0.047	7.841
224	DOD	2000	496	465	1.000	0.328	719	0.177	3.492
226	DOD	2000	497	466	1.986	0.520	668	0.054	5.655
228	DOD	2000	497	466	2.963	0.725	655	0.022	8.598

TABLE 9 (Continued)

PRESSURE DROP CONDITIONS
AT 98 PER CENT CHF POWER

RUN NO.	WATER TYPE	PRES-SURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEAT FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	EXIT EQUILIBRIUM QUALITY	TAP-TAP PRESSURE DROP (PSI)
209	DOD	2000	548	524	0.993	0.280	741	0.232	3.553
211	DOD	2000	546	522	1.982	0.424	687	0.101	6.030
213	DOD	2000	547	523	2.972	0.587	675	0.072	9.589
203	DOD	2000	597	588	1.014	0.234	766	0.293	3.641
246	DOD	2000	598	590	1.930	0.296	709	0.154	6.137
297	DOD	2000	596	588	2.958	0.444	703	0.140	11.061

TABLE 10. Heavy Water (93%)

SINGLE PHASE
PRESSURE DROP CONDITIONS

RUN NO.	WATER TYPE	RUN TYPE	PRESSURE (PSIA)	INLET TEMP. (DEG.F)	INLET ENTHALPY (BTU/LB)	MASS VELOCITY X10-6 (LB/HR-FTSQ)	HEA. FLUX X10-6 (BTU/HR-FTSQ)	CALC. EXIT ENTHALPY (BTU/LB)	TAP-TAP PRESSURE DROP (PSI)	REYNOLDS NUMBER	EXPER. FRICTION FACTOR
214	DOD	ISO	1600	547	525	1.992	----	525	4.323	243800	.01469
197	DOD	ISO	2000	197	163	0.981	----	163	3.651	34900	.02336
198	DOD	ISO	2000	596	588	0.978	----	588	2.761	132000	.01653
199	DOD	HTB	2000	396	361	2.977	0.500	491	6.629	-----	-----

Heavy Water Loop Schematic Diagram

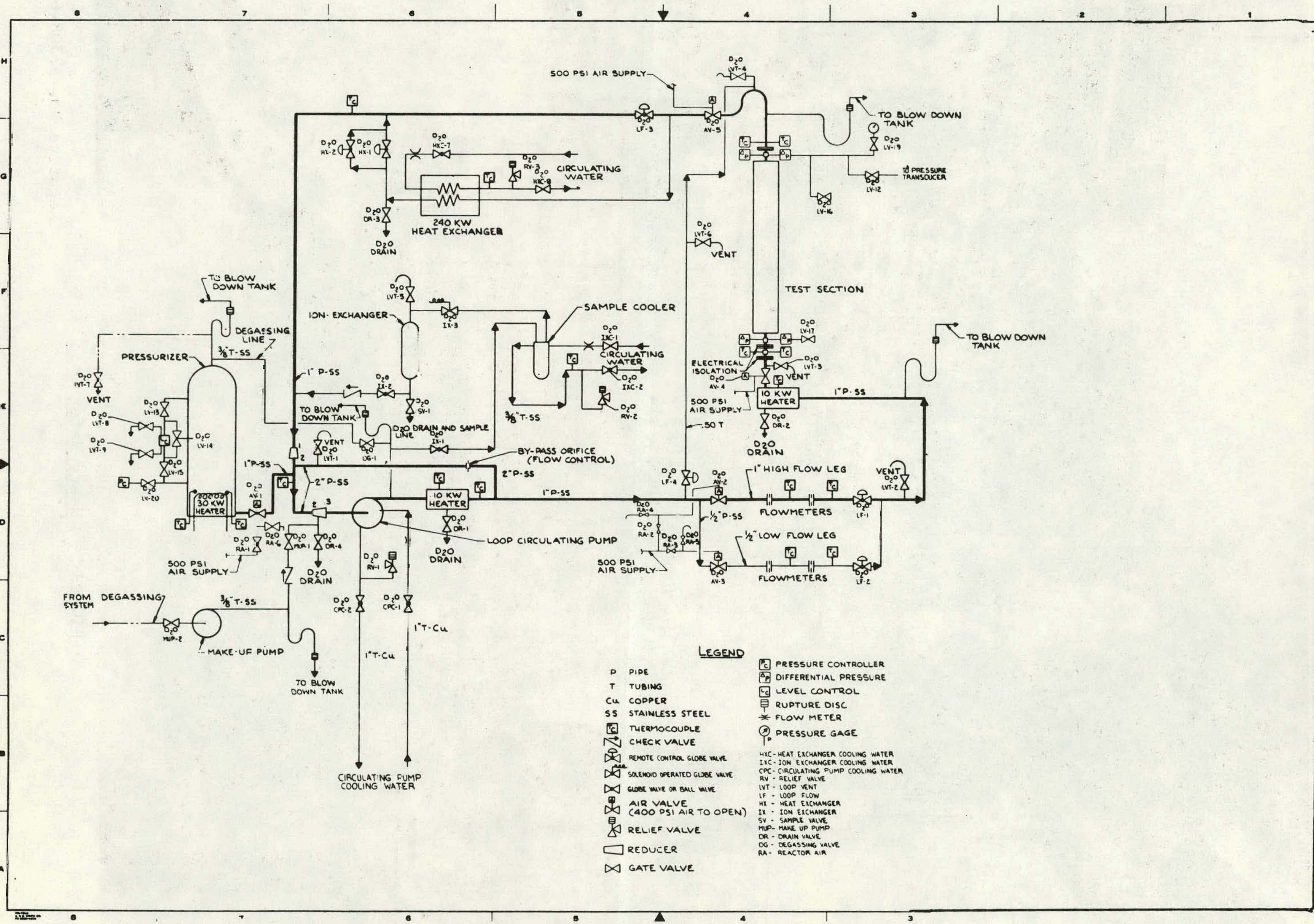


FIGURE 1

Negative No. 52965

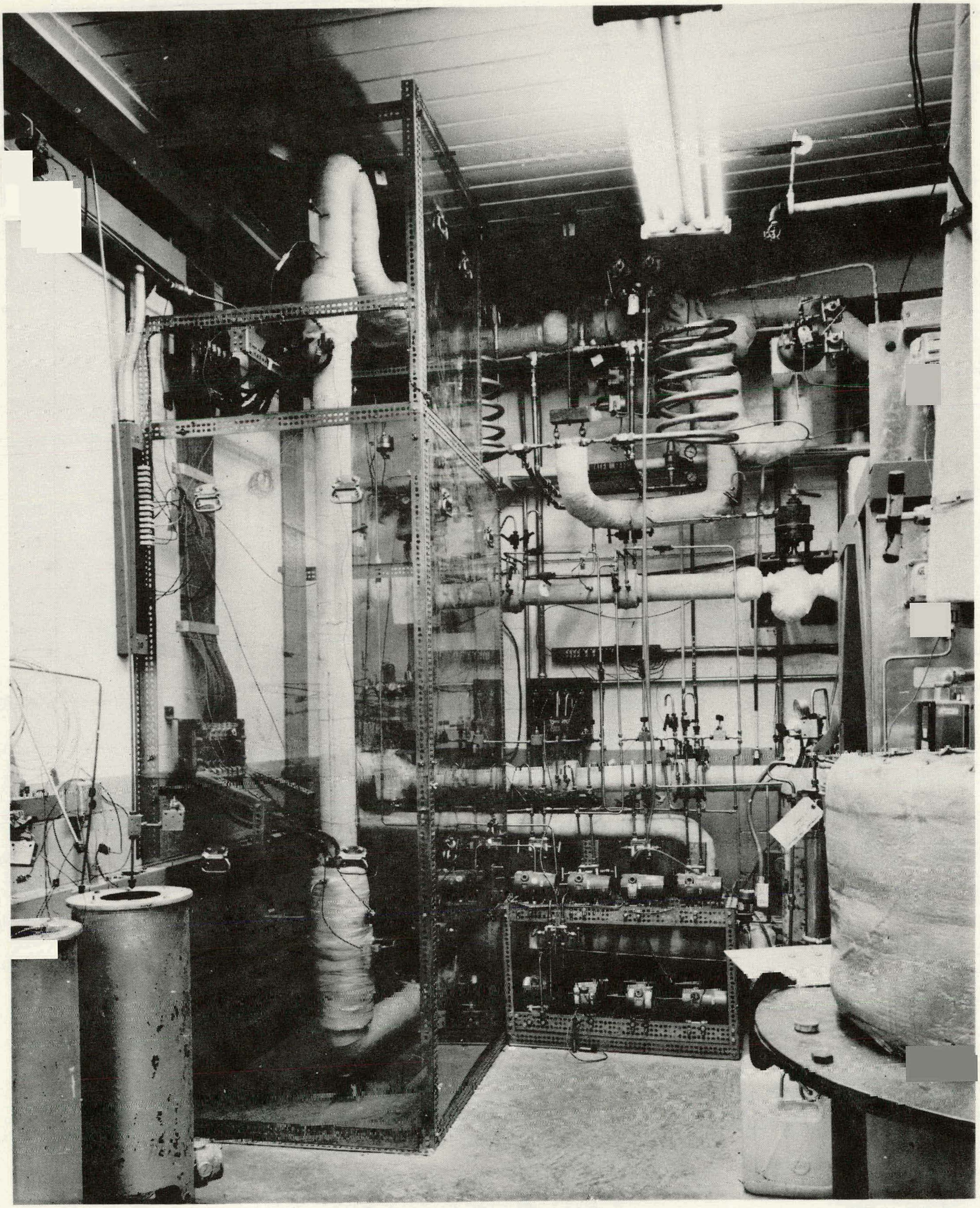
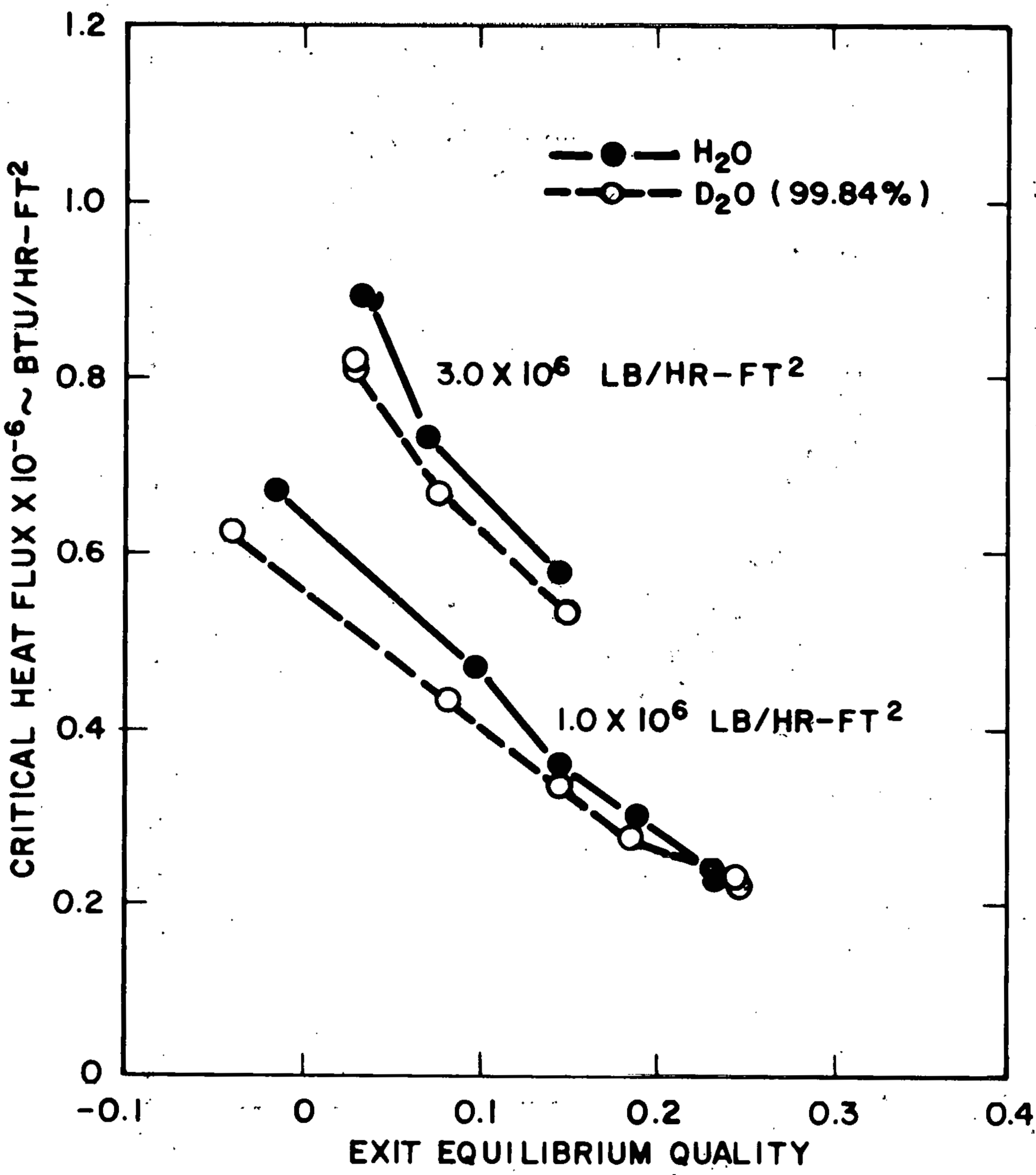


FIGURE 2. Heavy Water Loop

Negative No. 52308-6

CRITICAL HEAT FLUX VS EXIT EQUILIBRIUM QUALITY AT 2200 PSIA PRESSURE AND 1.0 X 10^6 AND 3.0 X 10^6 LB/HR-FT^2 MASS VELOCITIES



CONVERSION FACTORS:

PRESSURE: (Pa) = (6895) (PSIA)

MASS VELOCITY: (Kg/m^2·s) = (1.356 X 10^{-3}) (LBm/HR-FT^2)

HEAT FLUX: (W/m^2) = (3.155) (BTU/HR-FT^2)

FIGURE 3

CRITICAL HEAT FLUX VS EXIT EQUILIBRIUM QUALITY AT 2200 PSIA PRESSURE AND 2.0×10^6 LB/HR-FT^2 MASS VELOCITY

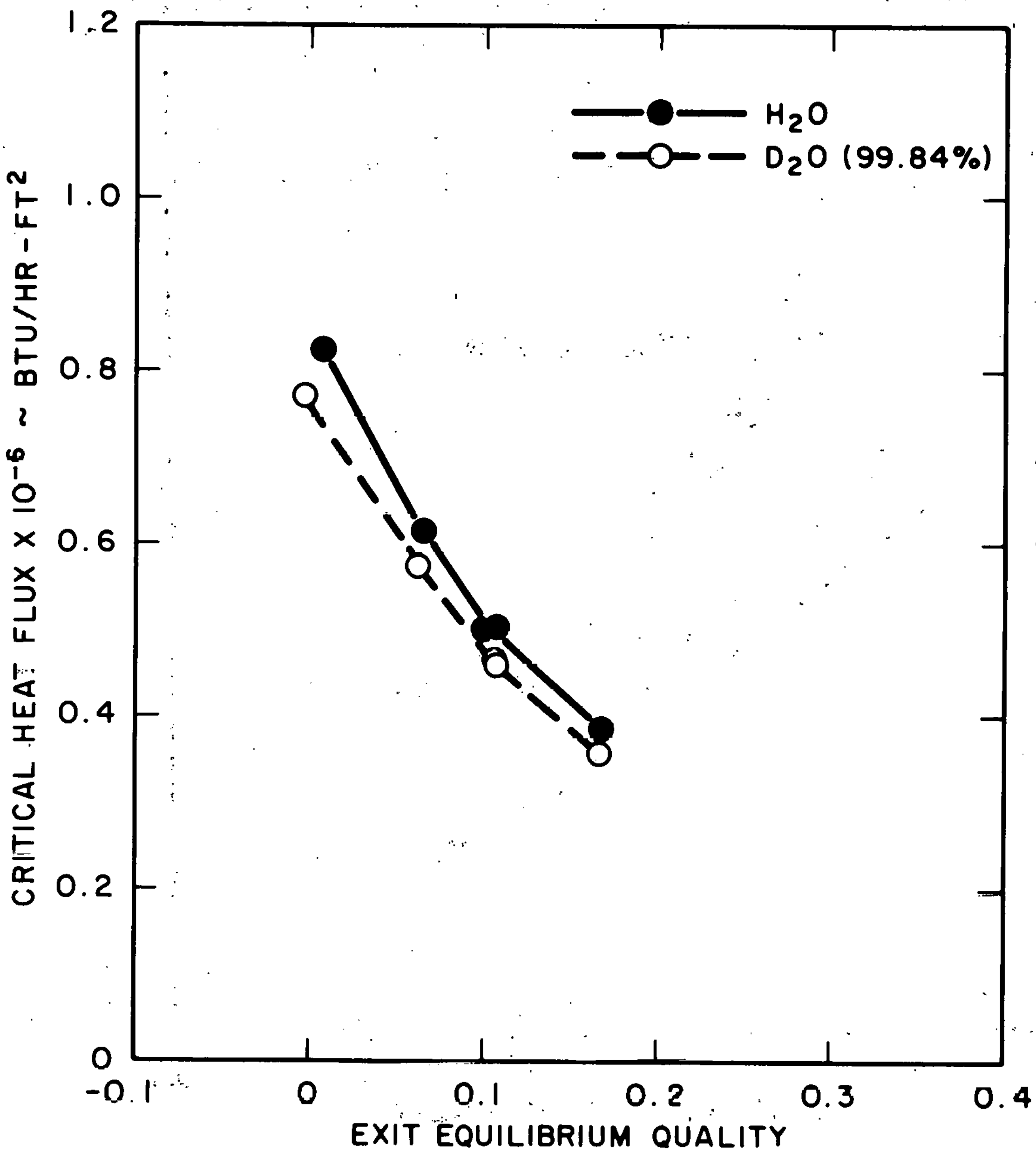


FIGURE 4

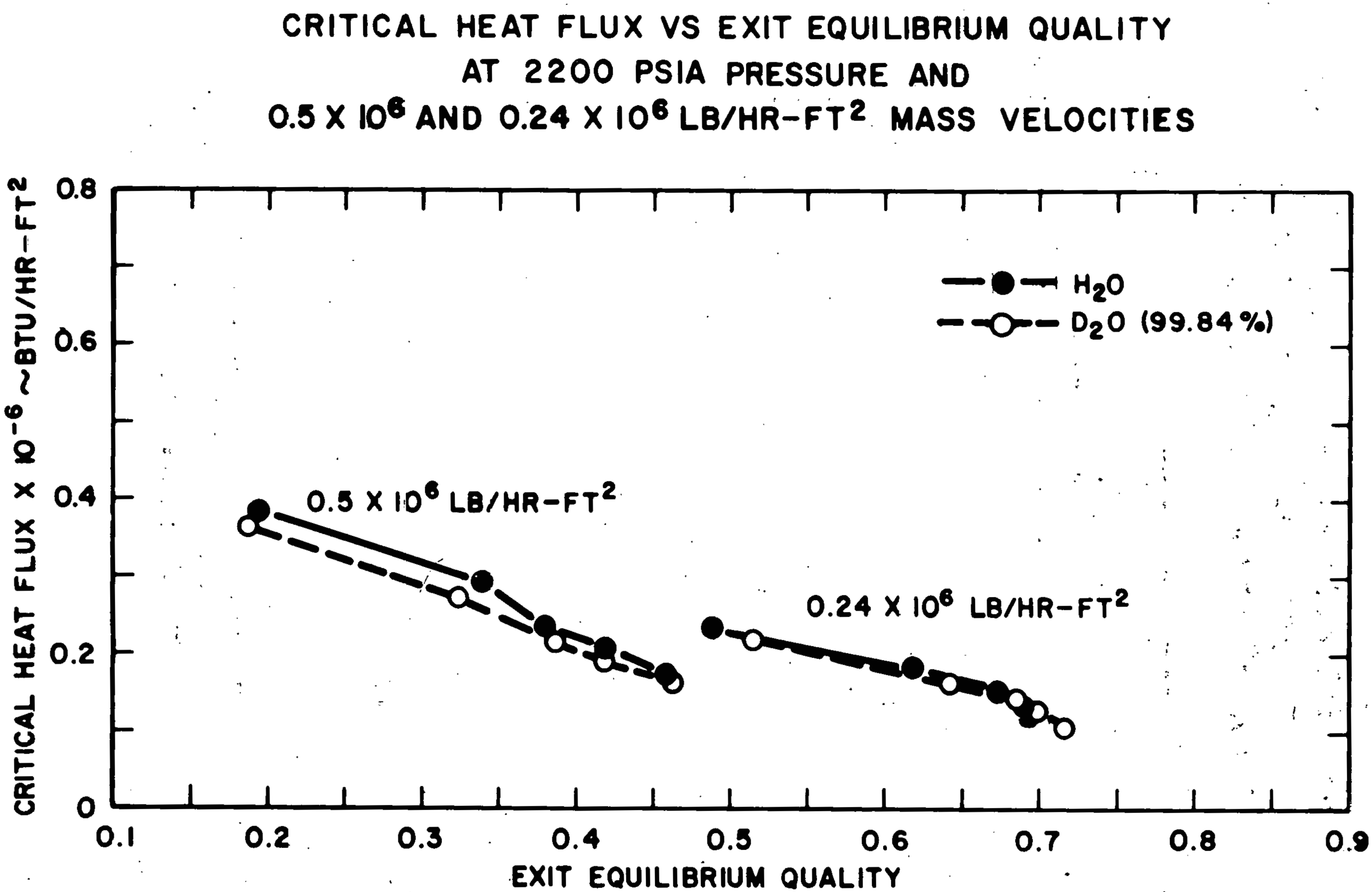

CRITICAL HEAT FLUX VS EXIT EQUILIBRIUM QUALITY
AT 2200 PSIA PRESSURE AND
0.5 X 10^6 AND 0.24 X 10^6 LB/HR-FT^2 MASS VELOCITIES
H2O
D2O (99.84%)
0.5 X 10^6 LB/HR-FT^2
0.24 X 10^6 LB/HR-FT^2
CRITICAL HEAT FLUX X 10^-6 ~BTU/HR-FT^2
EXIT EQUILIBRIUM QUALITY
0
0.2
0.4
0.6
0.8
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

FIGURE 5

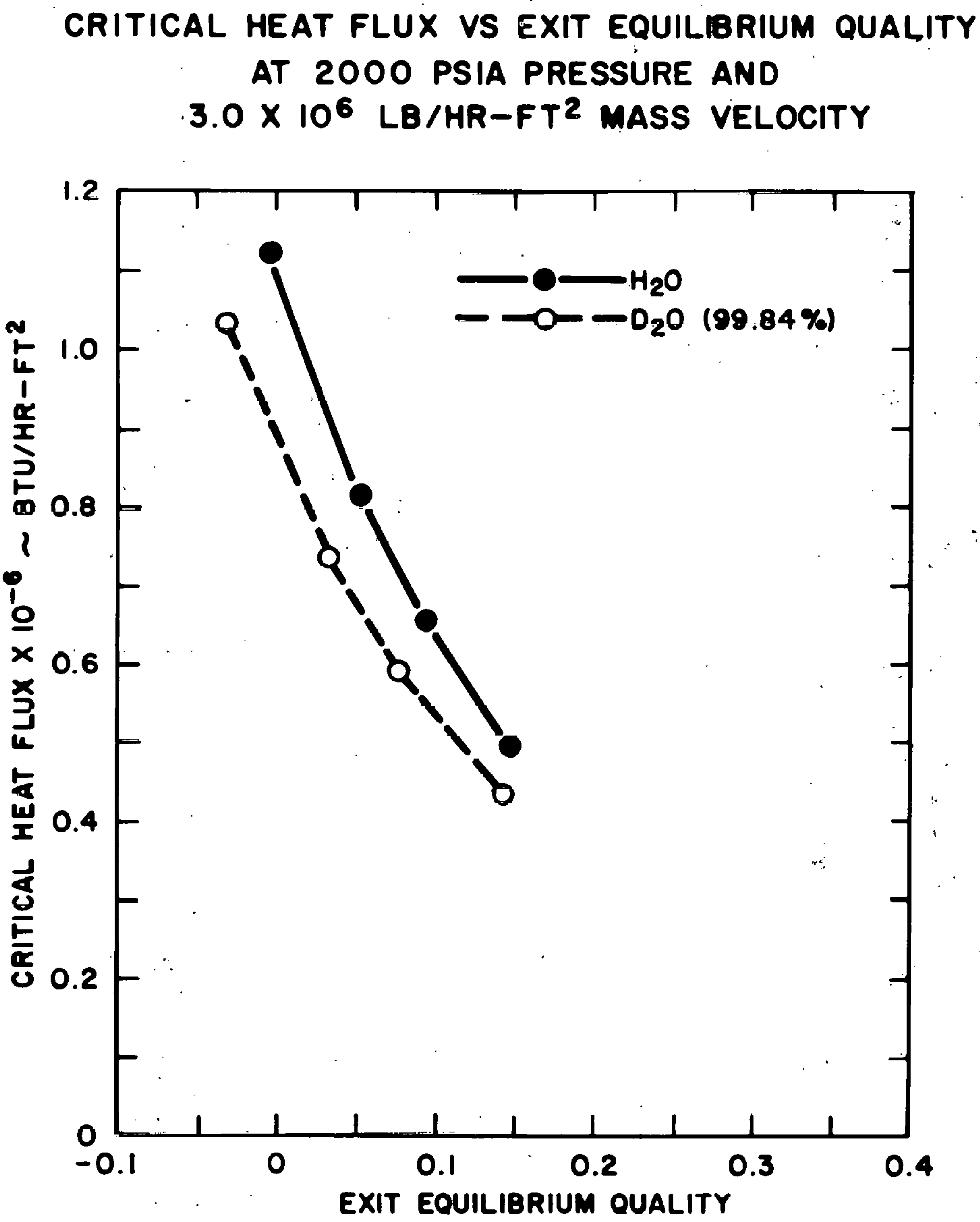

CRITICAL HEAT FLUX VS EXIT EQUILIBRIUM QUALITY
AT 2000 PSIA PRESSURE AND
3.0 X 10^6 LB/HR-FT^2 MASS VELOCITY
H2O
D2O (99.84%)
CRITICAL HEAT FLUX X 10^-6 ~ BTU/HR-FT^2
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.1
0
0.1
0.2
0.3
0.4
EXIT EQUILIBRIUM QUALITY

FIGURE 6

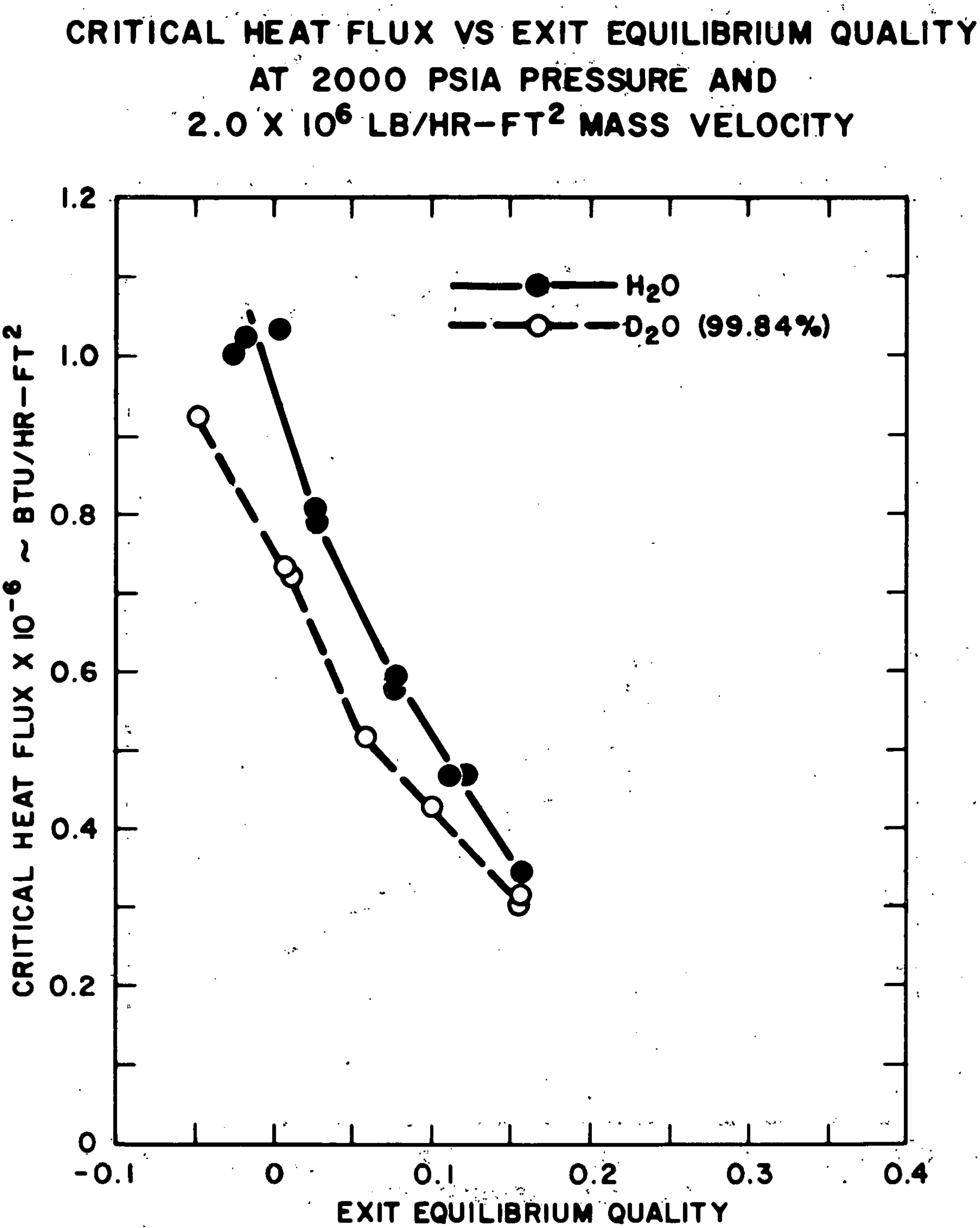

CRITICAL HEAT FLUX VS EXIT EQUILIBRIUM QUALITY
AT 2000 PSIA PRESSURE AND
2.0 X 10^6 LB/HR-FT^2 MASS VELOCITY
H2O
D2O (99.84%)
CRITICAL HEAT FLUX X 10^-6 ~ BTU/HR-FT^2
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.1
0
0.1
0.2
0.3
0.4
EXIT EQUILIBRIUM QUALITY

FIGURE 7

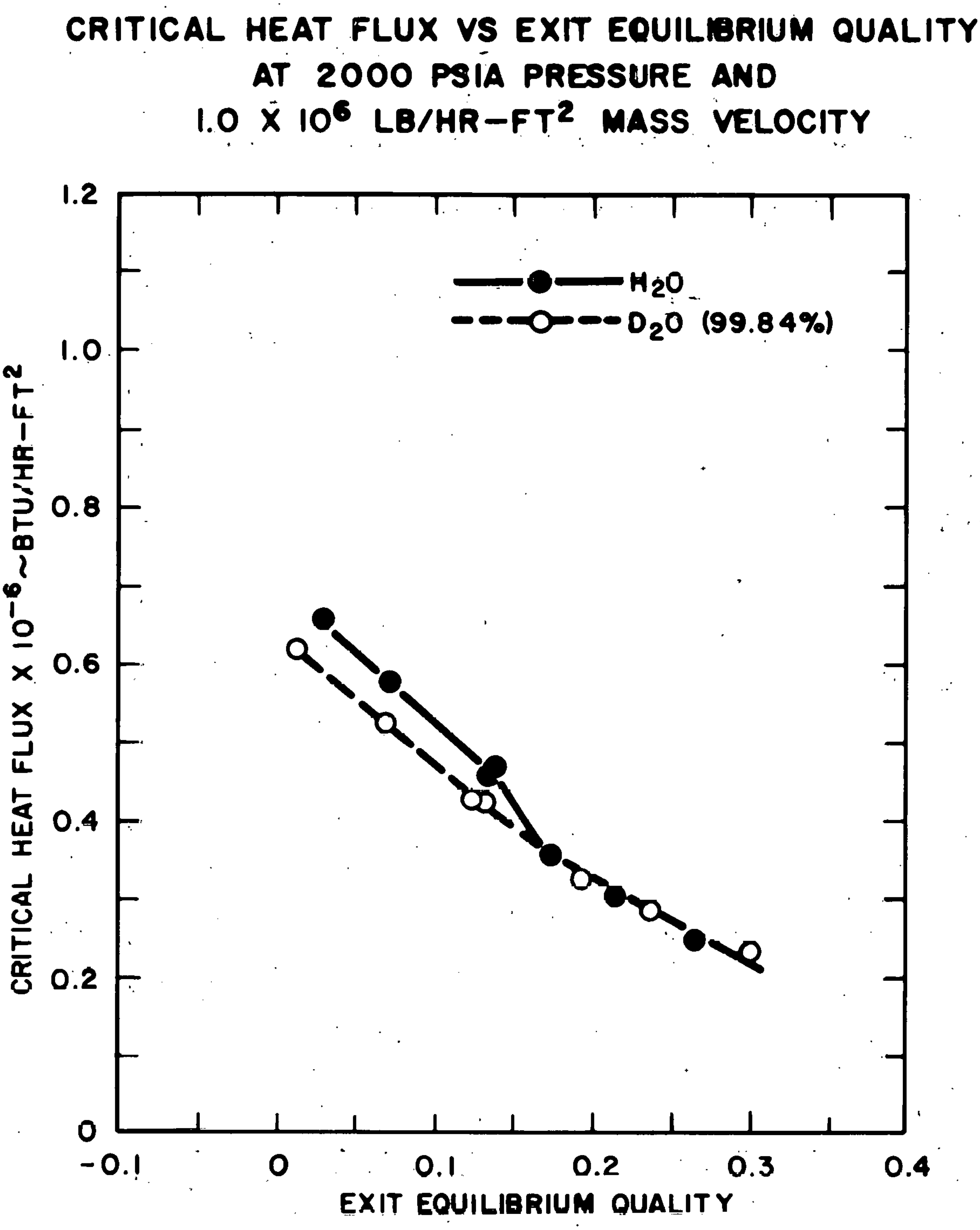

CRITICAL HEAT FLUX VS EXIT EQUILIBRIUM QUALITY
AT 2000 PSIA PRESSURE AND
1.0 X 10⁶ LB/HR-FT² MASS VELOCITY
H2O
D2O (99.84%)
CRITICAL HEAT FLUX X 10⁻⁶~BTU/HR-FT²
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.1
0
0.1
0.2
0.3
0.4
EXIT EQUILIBRIUM QUALITY

FIGURE 8

CRITICAL HEAT FLUX VS EXIT EQUILIBRIUM QUALITY AT 2000 PSIA PRESSURE AND 0.5×10^6 AND 0.24×10^6 LB/HR-FT^2 MASS VELOCITIES

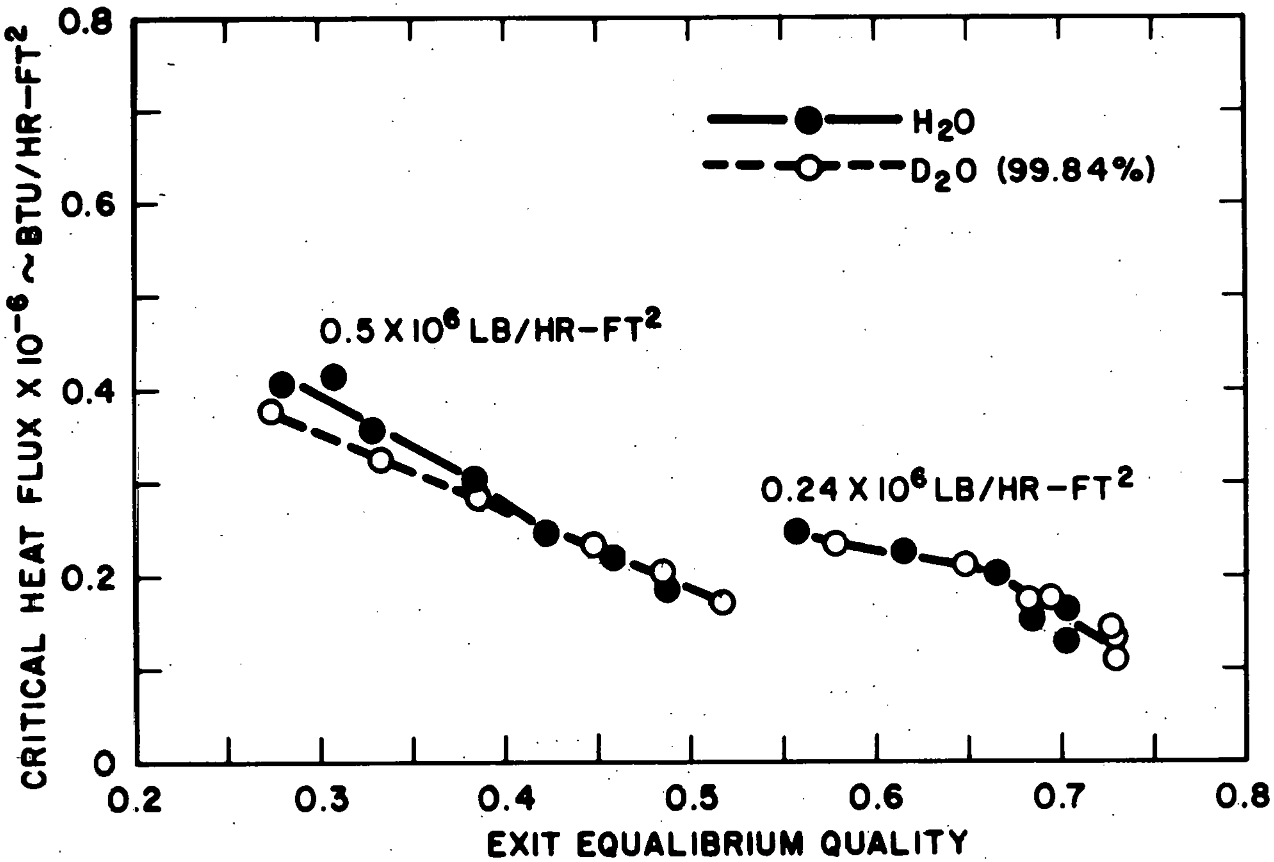


FIGURE 9

CRITICAL HEAT FLUX VS EXIT EQUILIBRIUM QUALITY AT 1600 PSIA PRESSURE AND 1.0 X 10^6 AND 3.0 X 10^6 LB/HR-FT^2 MASS VELOCITIES

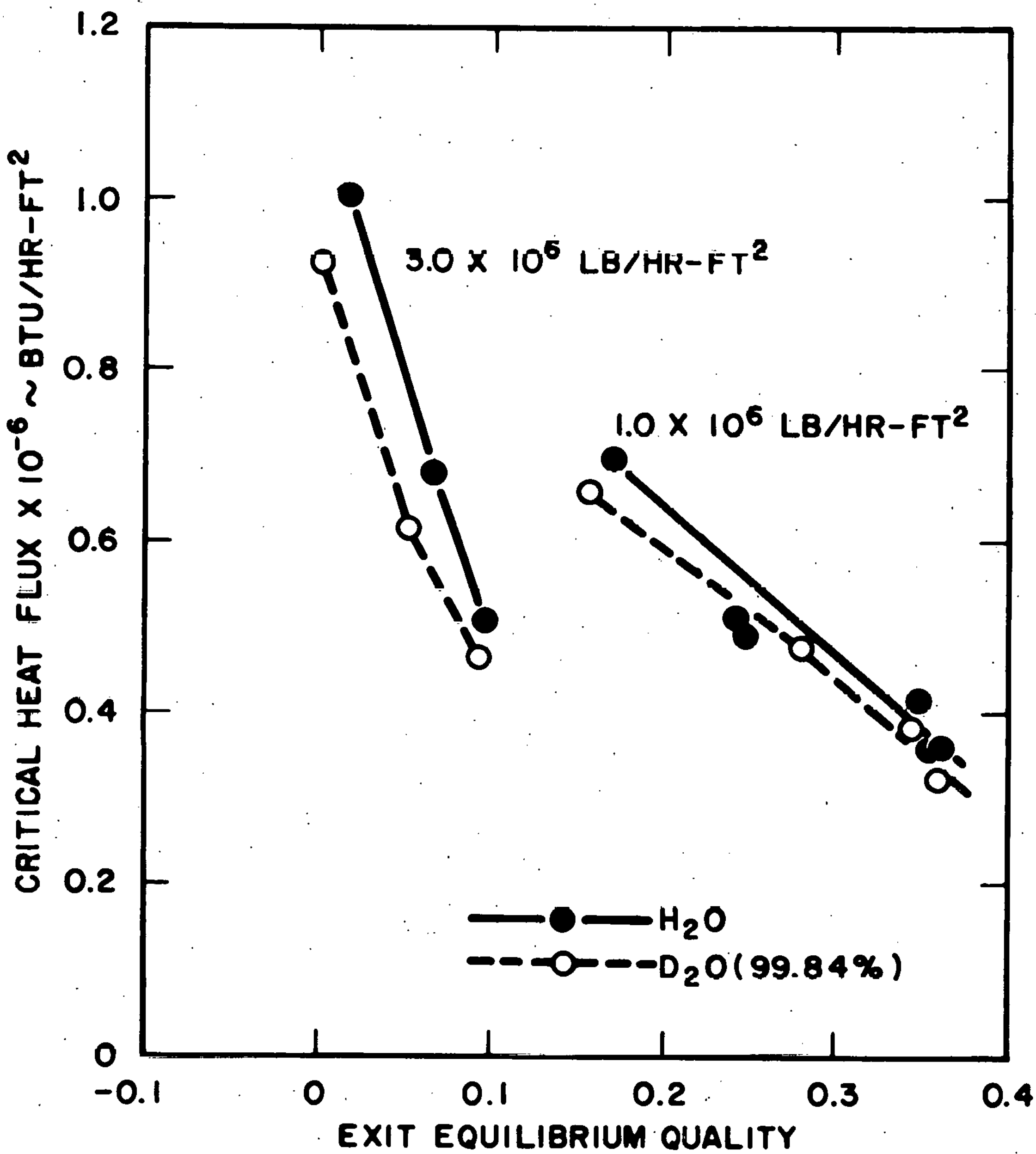


FIGURE 10

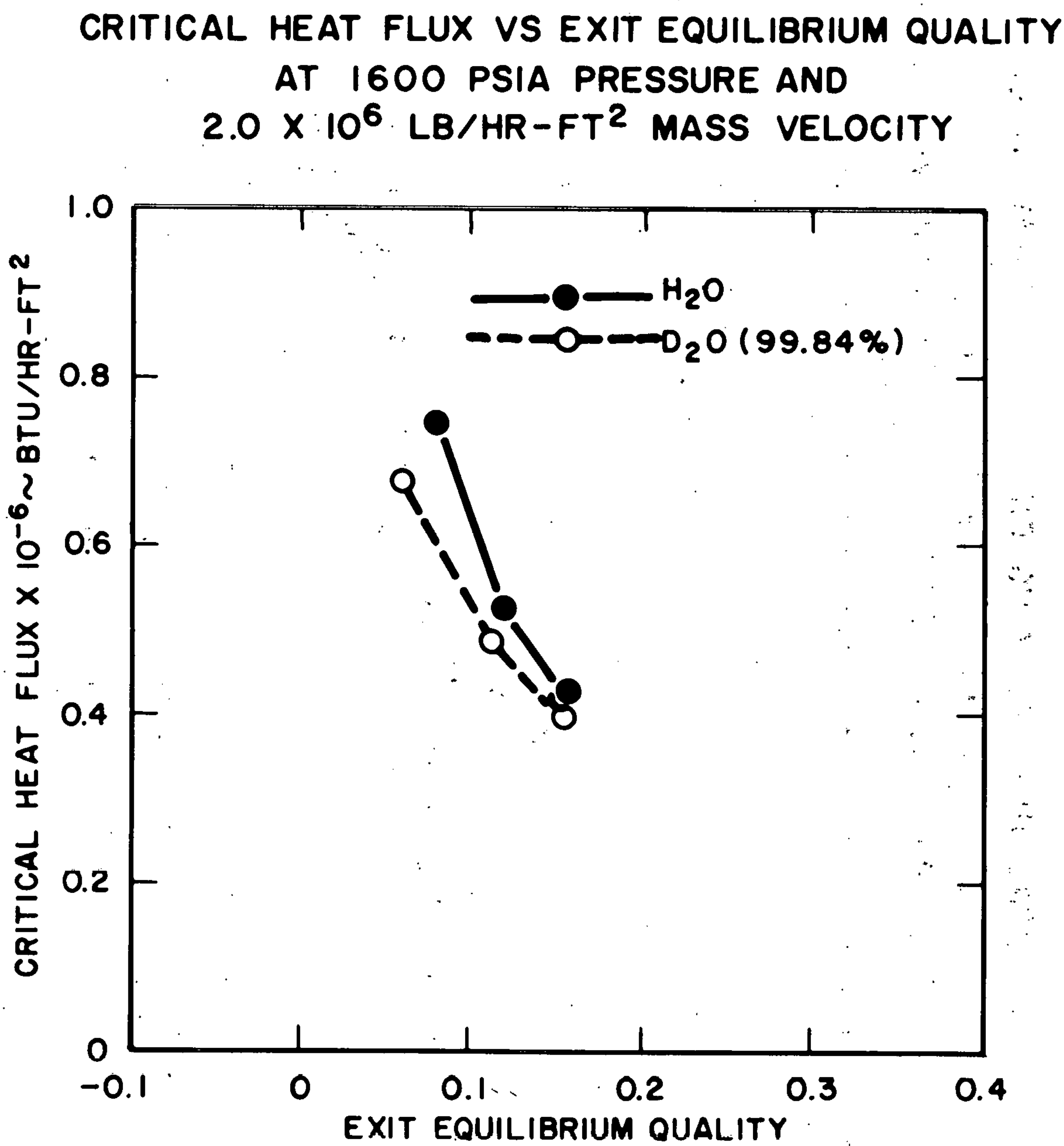

CRITICAL HEAT FLUX VS EXIT EQUILIBRIUM QUALITY
AT 1600 PSIA PRESSURE AND
2.0 X 10^6 LB/HR-FT^2 MASS VELOCITY
H2O
D2O (99.84%)
CRITICAL HEAT FLUX X 10^-6 ~ BTU/HR-FT^2
EXIT EQUILIBRIUM QUALITY
1.0
0.8
0.6
0.4
0.2
0
-0.1
0
0.1
0.2
0.3
0.4

FIGURE 11

CRITICAL HEAT FLUX VS EXIT EQUILIBRIUM QUALITY
AT 1600 PSIA PRESSURE AND
0.5 X 10^6 AND 0.25 X 10^6 LB/HR-FT^2 MASS VELOCITIES

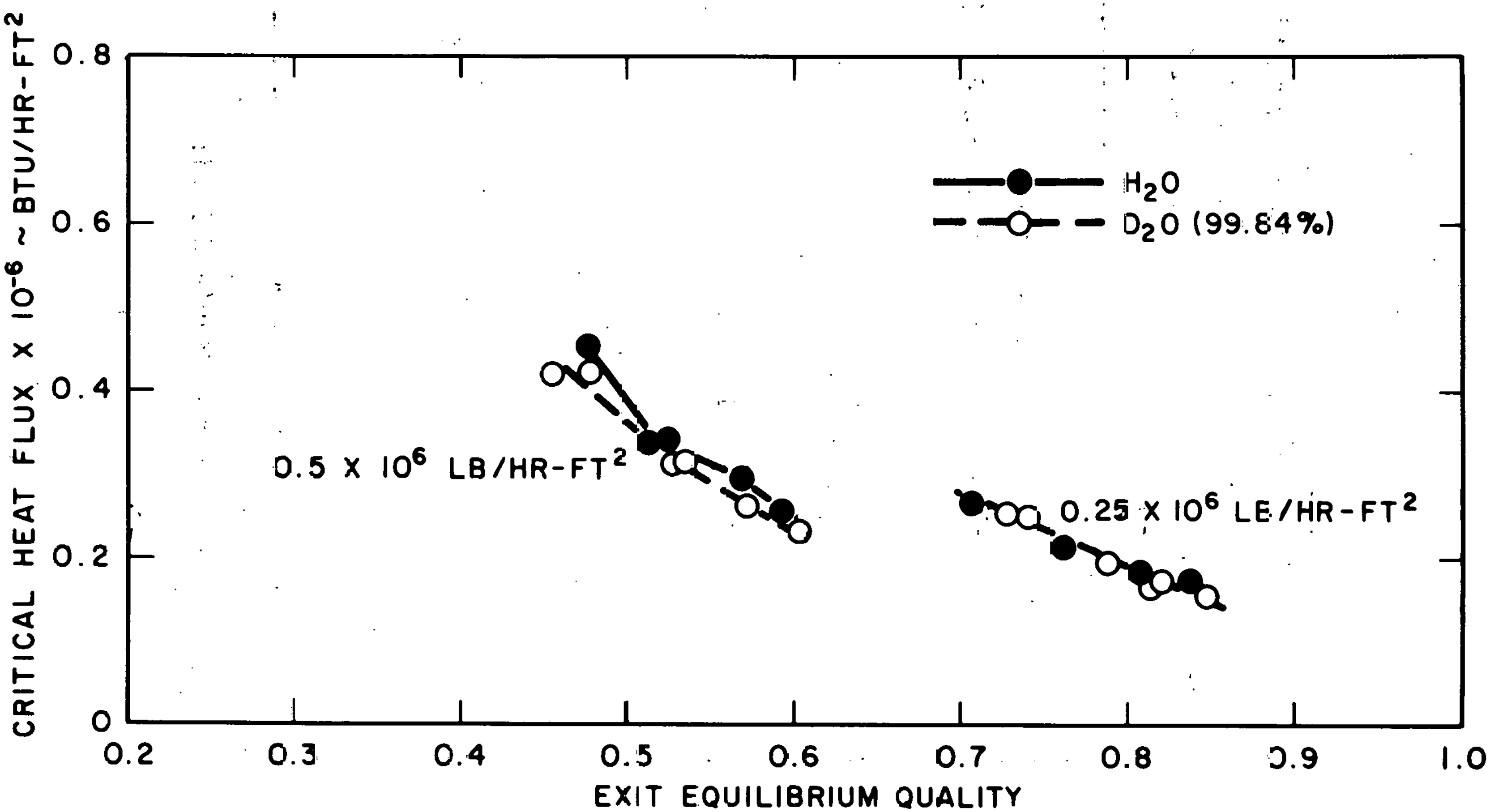


FIGURE 12

CRITICAL HEAT FLUX VS EXIT EQUILIBRIUM QUALITY AT 1200 PSIA PRESSURE AND 3.0×10^6, 2.0×10^6, AND 1.0×10^6 LB/HR-FT^2 MASS VELOCITIES

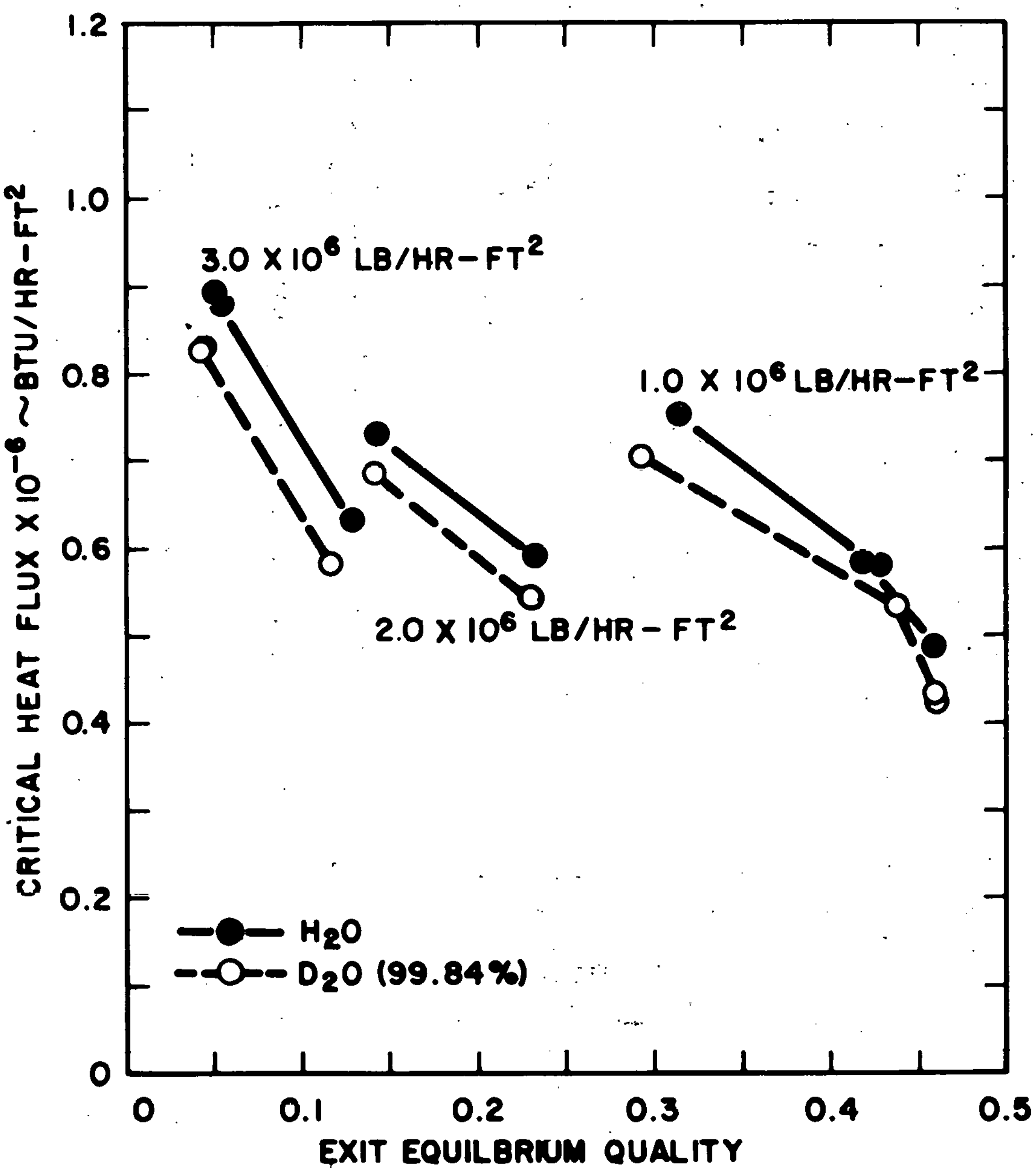


FIGURE 13

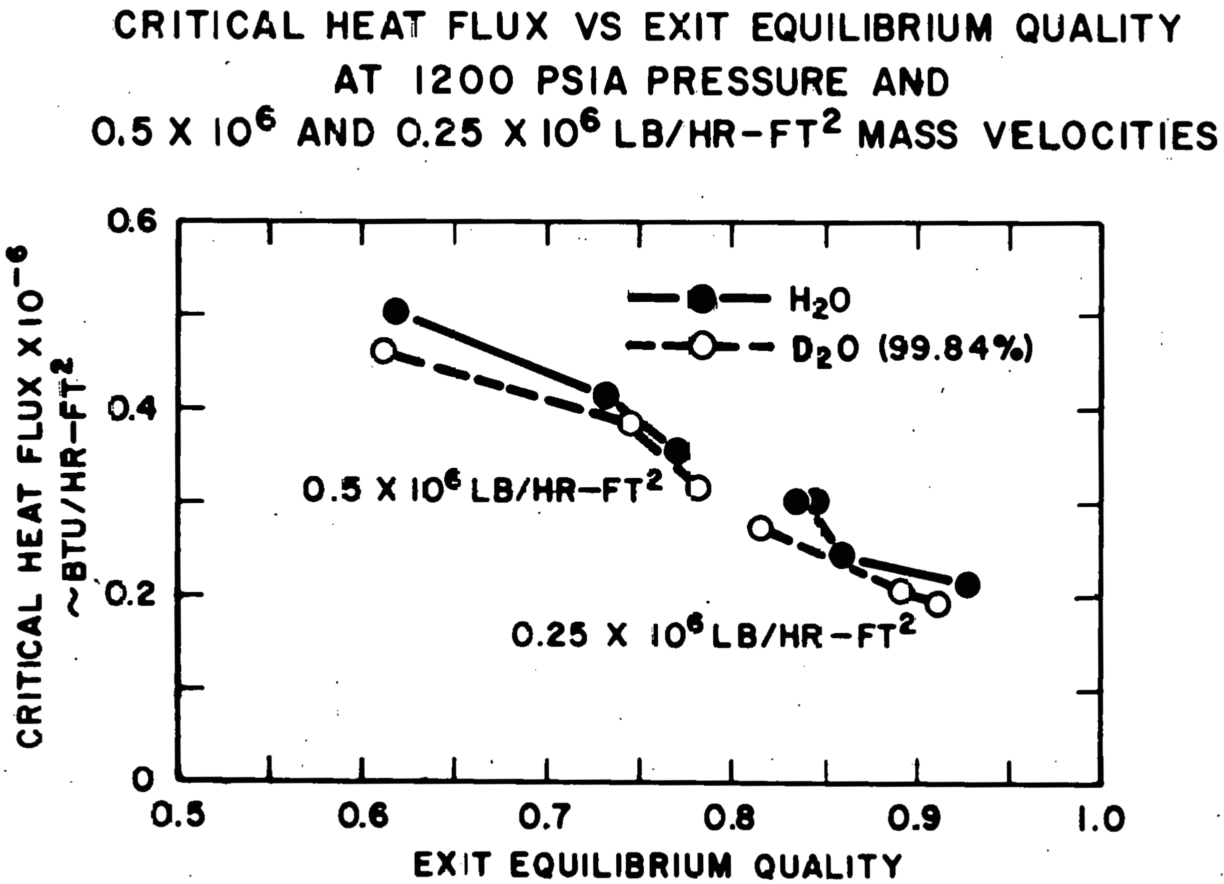

CRITICAL HEAT FLUX VS EXIT EQUILIBRIUM QUALITY
AT 1200 PSIA PRESSURE AND
0.5 X 10^6 AND 0.25 X 10^6 LB/HR-FT^2 MASS VELOCITIES
H2O
D2O (99.84%)
0.5 X 10^6 LB/HR-FT^2
0.25 X 10^6 LB/HR-FT^2
CRITICAL HEAT FLUX X 10^-6 ~BTU/HR-FT^2
EXIT EQUILIBRIUM QUALITY
0.6
0.4
0.2
0
0.5
0.6
0.7
0.8
0.9
1.0

FIGURE 14

CRITICAL HEAT FLUX VS EXIT EQUILIBRIUM QUALITY AT 800 PSIA PRESSURE AND 1.0 X 10^6, 0.5 X 10^6, AND 0.25 X 10^6 LB/HR-FT^2 MASS VELOCITIES

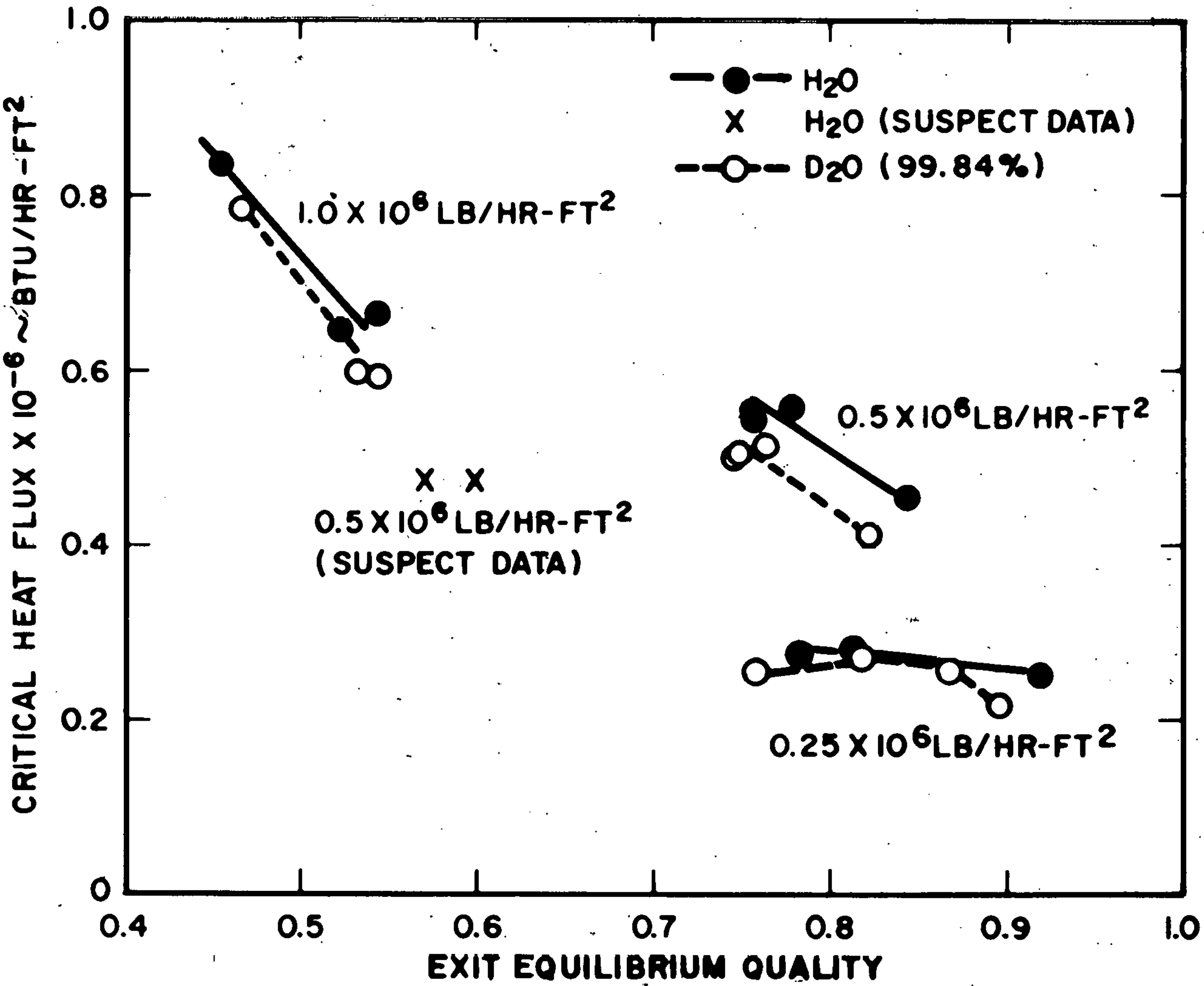
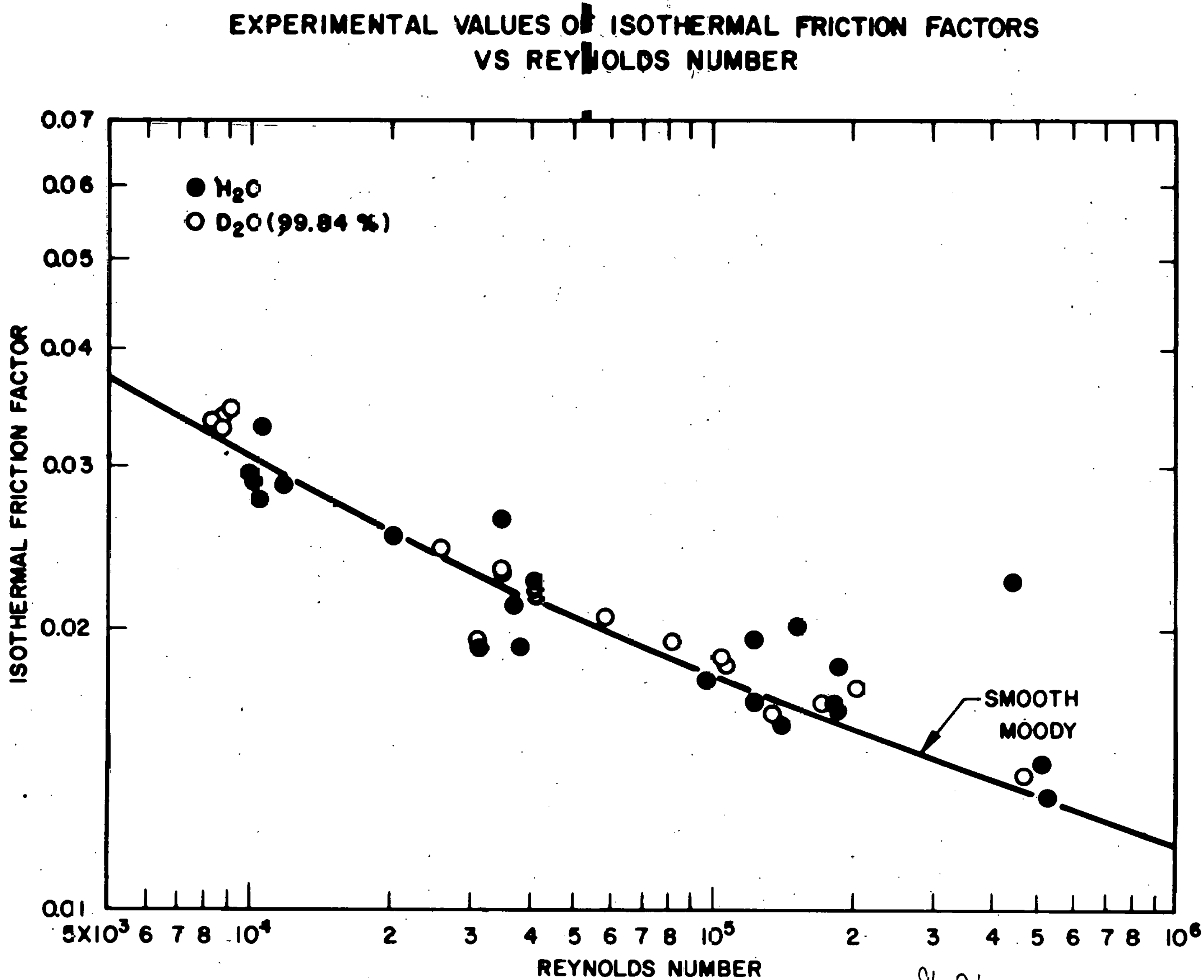


FIGURE 15


EXPERIMENTAL VALUES OF ISOTHERMAL FRICTION FACTORS
VS REYNOLDS NUMBER
H2O
D2O (99.84 %)
ISOTHERMAL FRICTION FACTOR
0.07
0.06
0.05
0.04
0.03
0.02
0.01
SMOOTH
MOODY
5X10³ 6 7 8 10⁴ 2 3 4 5 6 7 8 10⁵ 2 3 4 5 6 7 8 10⁶
REYNOLDS NUMBER
FIGURE 16

%06

PRESSURE DROP AT 98% CHF POWER VS MASS VELOCITY AT 2000 PSIA

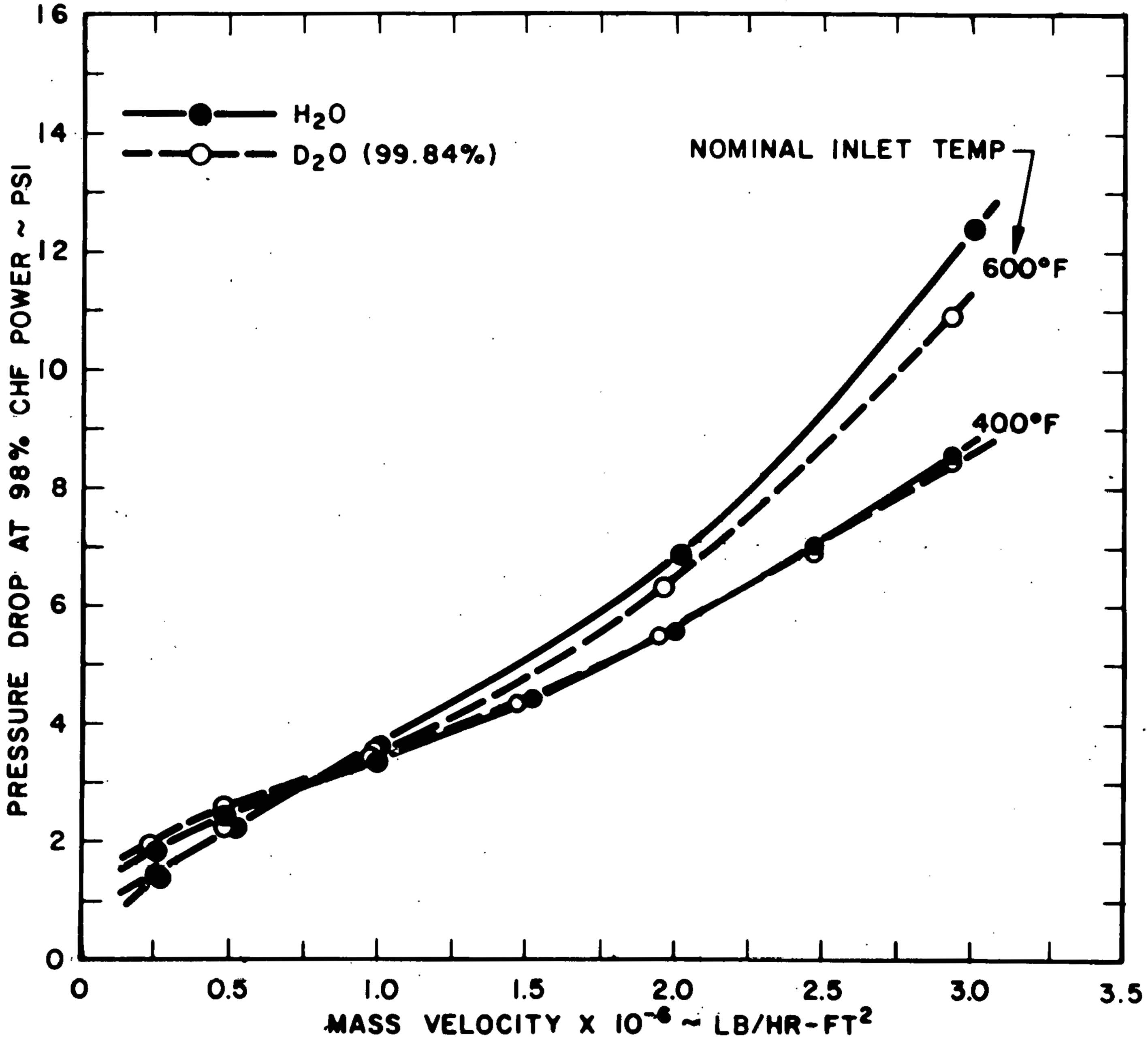


FIGURE 17