Study of Two-Phase Metastable Flow

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Study of Two-Phase Metastable Flow

By Richard W. Bryers and William S. Hsieh, Foster-Wheeler Corporation, John Blizard Research Laboratory, Carteret, New Jersey, for Office of Saline Water; J. A. Hunter, Acting Director and Assistant Director, Engineering and Development; Everett N. Sieder, Chief, Distillation Division

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Frank C. Di Luzio, Assistant Secretary for Water Pollution Control

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FOREWORD

This is the two hundred and thirty-fourth of a series of reports designed to present accounts of progress on saline water conversion with the expectation that the exchange of such data will contribute to the long-range development of economical processes applicable to large scale, low cost demineralization plants of multi-million gallon per day capacity for conversion of sea and other saline waters.

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ABSTRACT

An experimental study was made to determine the flow rate of saturated water through short tubes of various lengths and diameters. Tubes of both rounded and sharp edge entrances were tested in the horizontal and vertical positions.

It was found that the fluid passed through the aperture in the metastable state. Critical flow rates existed for all test runs. The critical mass flow rates were dependent on both the length and the diameter of the tubes instead of the length to diameter ratio alone.

The critical mass flow rate was found to be proportional to the ratio of the specific volume of the vapor and liquid to the .630 power and the aperture volume to the .163 power.

Test results were analyzed and correlated. The flow patterns within the test tube were photographed by a high-speed movie camera to obtain a qualitative interpretation of the two-phase fluid flow.

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NOMENCLATURE

h -	Enthalpy	Btu/lb
P -	Absolute Pressure	Lb/ft^2
υ -	Specific Volume	Ft^3/lb
T -	Temperature	°F
C_p -	Specific Heat	Btu/lb-°F
g -	Gravitational Constant	Ft/sec^2
Z -	Height	Ft
L -	Length	Ft
A -	Area	Ft^2
V -	Volume	Ft^3
V -	Velocity	Ft/sec
W -	Mass Flow Rate	Lb/sec
G -	Mass Flow Rate Per Unit Area	$Lb/sec\text{-}ft^2$
Q -	Heat Per Unit Mass	Btu/lb
f -	Friction Factor	
C -	Discharge Coefficient	
Y -	Flow Passage Parameter	
Φ -	Mass Flow Rate Parameter, Defined in Text	
K -	Defined in Text	
ΔP_o -	Pressure Drop Due to Entrance Effect of the Tube	Lb/ft^2
$\Delta P_{o\text{-}e}$ -	Pressure Drop Due to Phase Change Through the Tube	Lb/ft^2
$\Delta P_{1\text{-}2}$ -	Measured Pressure Drop between Plenum Chambers	Lb/ft^2

NOMENCLATURE (Cont'd.)

Subscripts

f	Liquid
fg	Change From Liquid To Vapor
1	Upstream Plenum Chamber
e	Exit Plane Of The Tube
2	Downstream Plenum Chamber
0	Inlet plane of the tube

1. INTRODUCTION

The two-phase metastable flow program was begun to acquire a better understanding of the phenomena in the range of operating conditions encountered in multistage flash evaporators. By establishing a correlation for mass flow rate and pressure drop as a saturated fluid passes through apertures resembling short tubes, the design of interstage loop seals and flashing devices can be refined. By-passing of vapor through the interstage loop seal should be eliminated and multistage evaporators should be capable of operating over a wide range of flows or load conditions. This should also simplify start-up procedure.

As a result of a better understanding of the two-phase flow phenomena, it was hoped that the economy of flash evaporators could be improved by either reducing the size of the flash chamber or reducing the nonequilibrium losses in the brine. This question remains unresolved as it was found that the brine leaves the flashing device or short tube in this case with a considerable degree of metastability. Improvements in flash chamber economy can be achieved only if there is an increase in heat transfer rate or evaporation surface immediately downstream of the flashing device. This is beyond the scope of the original work.

The literature was briefly reviewed. It was found that characteristics of flashing fluid passing through various types of flow passages have been treated by a large number of investigators. Numerous experimental data has been collected (2, 7, 8, 9, 10, 15, 16) and some analytical relationships have been developed (6, 11, 14, 17, 20).

Although a considerable amount of work has been done in the field of two-phase fluid flow, the investigations have been confined to specific areas, and no experimental data have been uncovered for the two-phase fluid flow at low temperature levels.

Experimental work was done on several short tubes of various dimensions with both rounded and sharp edge entrances. Lengths were chosen to be compatible with evaporator design. The temperatures of the test program ranged from 150° to 250°F. Tubes were primarily tested in the horizontal position to attempt a better understanding of the phenomena. An additional test was run in the vertical position to give a qualitative comparison of the effect of hydrostatic head. Tests were run with city water as it was felt that slight impurities would not effect the flow at the levels of turbulance encountered.

Observation of the two-phase fluid flow pattern was accomplished with the help of a high speed movie camera. The motion pictures were used as a qualitative supplement to the experimental data.

2. THEORETICAL REVIEW

2.1 General Discussion

For fluid flowing through a passage of constant cross sectional area, the assumption of one-dimensional flow is applicable in most cases. If no transient condition is involved, the following fundamental relations hold.

Energy Equation

$$dh + d\left(\frac{V^2}{2g}\right) + dz - dQ = 0 \tag{1}$$

Momentum Equation

$$\upsilon dp + d\left(\frac{V^2}{2g}\right) + dz + \frac{fYV^2}{2Ag} dL = 0 \tag{2}$$

Continuity Equation

$$W = \frac{VA}{\upsilon} = \text{Constant} \tag{3}$$

For frictionless, adiabatic process, dh is equal to vdp, and the last terms of both equations (1) and (2) vanish. Then both energy and momentum equations become identical as

$$\upsilon dp + d\left(\frac{V^2}{2g}\right) = 0 \tag{4}$$

if the change of hydrostatic head is negligible. It becomes one expression of Euler's Equation for steady, continuous, frictionless and irrotational flow.

Combining equations (3) and (4), the mass flow rate of the fluid can be expressed by

$$\left(\frac{W}{A}\right)^2 = -g\left(\frac{dp}{d\upsilon}\right)_S \tag{5}$$

In order to solve these equations, an additional functional relationship of the state variable called an equation of state should be sought.

2.2 Single Phase Fluid

For the case of an incompressible fluid, the specific volume can be treated as constant. For compressible, single-phase fluids, the ideal gas flow can be applied as an approximation provided the pressure is not too high. Then the equations can be solved explicitly for both cases.

The mass flow rate of the single phase,compressible fluid keeps increasing as the pressure differential between both ends of the passage increases until the critical condition is reached, where no further increase of mass flow rate is possible no matter how much the back pressure in the downstream receiver is reduced. Such a phenomeon is also called "choking" and the fluid reaches its sonic velocity.

2.3 Equilibrium Two-Phase Fluid

When saturated liquid flows through a pipe to a receiver where the pressure is lower than the corresponding saturation pressure of the fluid, part of the liquid is transformed into vapor, and the two-phase mixture is accelerated by the mechanical work done from the expansion of the fluid. This is called the flashing process. Both the pressure and the specific volume of the mixture vary along the pipe, and the relationship between these two state variables in the two-phase fluid must be known in order to solve the problem.

Based on the assumption of thermodynamic equilibrium, several two-phase flow models have been proposed. These analytical relations give a substantially simplified solution to the problem, however, they have been verified only to a limited extent by experimental results.

The simplest one proposed is the homogeneous flow model (1, 18) where the two-phase fluid is treated as a homogeneous mixtures under thermodynamic equilibrium, and both phases travel with equal velocity. The predicted values of the mass flow rate based on this model are usually lower than those measured.

More recently, models have been proposed (7, 14, 17) based on the assumption of thermodynamic equilibrium of fluid with relative velocity, or slip, existing between phases. The results from this model exhibited good agreement with experimental data for long tubes where thermodynamic equilibrium state is possibly reached. Fauske (7) concluded that a tube length to diameter ratio of 12 or more is required to meet the prediction from this model.

2.4 Non-equilibrium Two-Phase Fluid

A model based on the idea of nucleation theory of evaporation has been developed (19, 20) where the vapor formation is limited by the heat transfer rate between the liquid-vapor interface, and thermodynamic equilibrium does not exist within the fluid.

Nucleation of the vapor bubbles is assumed to occur at a rate depending on the properties of the fluid including the surface tension, foreign bodies and dissolved gases within the liquid, the presence of the latter two effects can markedly increase the rate of nucleation. The nuclei are assumed to grow, and the bubble radius is assumed to be a function of time. The two factors provide the basis for an expression for the mean specific volume of the two-phase fluid. Since a certain amount of excess energy is needed to keep the vapor bubble growing, the liquid-vapor mixture cannot be in thermodynamic equilibrium.

The calculated mass flow rate based on this model leads to a result slightly greater than, but close to, the experimental result.

2.5 Semi-analytical Consideration

Due to the lack of a basic knowledge of the characteristics of the two-phase fluid flow, a general relationship derived from any flow model capable of giving a valid prediction of the experimental results still seems remote. Hence a great amount of experimental work has been performed, and correlations based on the experimental results were also developed in order to have a reliable design criterion.

The configurations of the flow passage and the working conditions of the two-phase fluid have been tested in a great variety of ways by different investigators. It is recognized by most investigators that due to the surface tension of the fluid, a certain amount of superheat of the liquid and a certain time interval after discharge from the tube inlet are needed for the vapor bubble growth within the flow passage.

For the case of saturated liquid passing through an orifice of zero length, it has been demonstrated and concluded by a number of investigators (3, 5, 7, 12, 16) that the fluid behaves as it were in a subcooled condition.

The relation

$$\frac{W}{A} = C\sqrt{2g(P_1 - P_2)\rho} \tag{6}$$

Where

$$C = \frac{\pi}{\pi+2}$$

solved analytically for potential flow (13), predicts the results of saturated liquid flow rate accurately. The contact time of the saturated liquid within the orifice where the fluid passes through is apparently too short to establish the evaporation process. No critical condition exists for this case.

When the saturated fluid passes through the short tubes, where the metastability of the fluid is still high, a modified incompressible fluid flow relation

$$\frac{W}{A} = C'C\sqrt{2g(P_1-P_2)\rho} \qquad (7)$$

was applied to predict the mass flow rate, where C is the discharge coefficient of the subcooled water, and C' is a modified coefficient for the two-phase fluid. Bailey (2) considered the contraction of the liquid core of the two-phase fluid due to evaporation in expressing C'. He defined the coefficient of evaporation as a function of L/D ratio, the initial pressure and the critical pressure. Based on his experimental data, he assumed the coefficient of evaporation to be constant. Fauske (7) justified that the coefficient should be proportional to the square root of the critical pressure instead of being constant.

With C' equal to unity and P_2 the critical pressure, both Isbin (12) and Fauske (7) predicted the critical mass flow rate for apertures and short tubes accurately, where test pressures were above 40 psig.

For two-phase fluid flowing through long tubes where the frictional effect is pronounced, friction factors were determined from experimental evaluations by Benjamin and Miller (4) and Bottomley (5). Since thermal equilibrium is generally attained in this condition, Fauske's Model (6) predicts the results accurately.

3. DESCRIPTION OF TEST FACILITY

3.1 Test Tube in the Horizontal Position

The test loop consisted of the test tube, two plenum chambers (one at each end of the tube), a circulating pump, a heating element, two condensers, the vacuum system, and the appropriate instrumentation and controlling devices. Since one of the objectives of the test was to observe the behavior of the flow pattern, all parts of the test unit were made of either stainless steel, brass or glass in order to prevent formation of rusty particles, which would interfere with the visibility through the fluid and might distort the experimental results.

A picture of the complete setup for this test program is shown in Figure 1. The corresponding flow diagram is shown in Figure 2, where the locations of the temperature, the pressure and the flow measuring devices are also indicated.

The two plenum chambers were standard dished head tanks, 24 inches in diameter and 36 inches long, made of Type 304 stainless steel. A water level gage was installed on the side of each tank. Figure 3 shows the detailed construction of both tanks.

The heating element was a conventional steam-water heater with water on the tube side. The tube bundle was made of Type 304 stainless steel, and provided enough surface area for the maximum heat load of 1,000,000 Btu/hr under the operating condition of the test.

The circulating pump was a single speed centrifugal type having a maximum capacity of 200 GPM at 6 feet NPSH. The pump was made of Type 316 stainless steel.

On the top of the downstream plenum chamber there were two condensers, where the vapor formed by the flashing process was condensed. The purpose of using two condensers was to attain a more accurate control of the evaporation rate at a desired operating condition. One condenser was isolated from the system when the heat load of the working fluid was small, otherwise both of them were used together. Both condensers were made of red brass and admiralty and had cooling water on the tube side.

A two-stage steam ejector comprised the vacuum system. Using available plant steam a minimum pressure of 2 inches Hg. absolute could be reached.

3.2 Test Tube in the Vertical Position

The construction of the test tube in the vertical position was almost the same as that in the horizontal except with minor modification of the test section assembly. This was accomplished by rotating the upstream chamber 90 degrees so that the opening holding the test tube faced upward. The downstream chamber was modified to receive the test tube by installing an 8 inch diameter, 15 inch long adapter section, which made it possible to maintain the exit section at desired pressure and visualize the major portion of the two-phase flow phenomena inside the tube. A picture of the setup of the vertical tube is shown in Figure 4.

3.3 Configuration and Assembly of Test Tube

The cylindrical test tubes were double-tough, Pyrex glass pipes. Seven different tubes were used for testing in the horizontal position and one in the vertical. A picture including all the cylindrical tubes tested is shown in Figure 5. One rectangular duct made of Type 304 stainless steel with an equivalent hydraulic diameter of 2 inches was tested in the vertical position also. Detailed dimensions of the tubes and duct tested are given in Table 1.

Figures 6 and 7 show the assembly of the test tubes in the horizontal and vertical positions respectively. The tube was held by the compression force from the reducing flanges at each end, which were pulled together carefully during assembly by the tie-rods, thus ensuring a uniform stress distrubtion in the glass tube. The continuous alignment of the inside surface of the tube with the openings of the flanges was checked during assembly.

Two different tube inlet configurations were tested, one a sharp edge entrance, and the other a rounded edge entrance having an arbitrarily selected quarter inch radius of curvature.

3.4 Instrumentation

The first attempt of the temperature measurement was made by using platinum resistance temperature bulbs connected to a multi-point temperature recorder. Each resistance bulb was calibrated together with the recorder, and an accuracy of ± .1 degree centigrade was expected within the range of operation.

A total of ten resistance bulbs were installed at different locations in the experimental unit. After a few hours operation, all three of the bulbs located at the exit of the test tube failed. When additional bulbs reinforced with a steel sheath were inserted at the same location, the bulbs failed again after a very short period of operation.

Since all the broken resistance bulbs were located in the two-phase fluid region, it was suspected that the fine platinum wire in the bulbs broke as a result of high frequency vibration induced by the turbulent two-phase flow stream. While the exact cause of breaking the resistance bulbs is still unknown, it was felt that the purchased resistance bulbs were not suitable for this application without further modification of the construction of the bulb itself.

All the resistance bulbs except two, which remained in the liquid phase in the two chambers, were replaced by the calibrated copper-constantan thermocouples. One thermocouple was located at the inlet of the test tube, two were located at the outlet. Figure 8 shows the detailed locations of thermocouples at both inlet and outlet. All other thermocouples were located in the position as their corresponding resistance bulbs shown in Figure 2. A potentiometer was used to record the temperature readings from the thermocouples. An overall accuracy of ± .25 degree fahrenheit was expected.

ASME coded concentric orifices were used to measure the mass flow rate of the test fluid, heating steam and cooling water. Mercury and Meriam fluids were used in the flow measuring manometers.

Conventional mercury manometers were installed to read the pressure in each chamber as well as the pressure differential between the two chambers. Figure 2 gives the location of the pressure taps on the test unit. The accuracy is within ± 0.25 cm.

3.5 Photographic Equipment

A high speed motion picture camera capable of exposures at a maximum rate of 5000 frames per second with 100-foot film capacity was used to take pictures of the fluid flowing inside the test tube. Diffused light of uniform intensity projected on the test tube gave a satisfactory illumination of the flow pattern.

4. DESCRIPTION OF TEST PROCEDURE

4.1 Start Up

City water was used as the test fluid in the system. No analyses were taken with respect to the air content and other chemicals in the water. Test fluid was circulated through the test loop by the centrifugal pump. Before the regular test procedure was started, the pressure in the system was pulled close to vacuum and maintained for a certain period. This can be relied on for checking leaks in the system and to carry on the deaeration of the water. When the sealing situation of the whole test unit was found to be satisfactory, it was assumed permissible to continue the test program.

The steam line leading to the heater was opened, the testing fluid was heated up very smoothly to avoid any ebullition within the heater. This was continued until the pressure in the system was higher than the atmosphere, then the vent line on the test unit was opened to bleed off the remaining noncondensable gas within the system. This can be checked by both readings of temperature and pressure of the vapor phase within the two plenum chambers. When both saturated pressure and temperature readings agreed satisfactorily, the vent was shut off, and the unit was ready for further testing.

4.2 Test Runs

For each set of data collected, the pressure in the upstream chamber was adjusted to a desired level and maintained constant. Desired working conditions were attained by manually regulating the flow rate of the heating steam, the cooling water and the test fluid by means of throttle valves.

During the test with tubes in the horizontal position, the water level in the upstream chamber was adjusted and maintained about 2 inches above the upper edge of the tube. This level was high enough to seal the tube entrance to eliminate any bypassing of steam through the tube from the upstream chamber and low enough to minimize any appreciable subcooling effect imposed on the fluid within the test tube.

The stability of the working conditions of the fluid was observed from the printed temperature readings on the recorder through those two resistance bulbs. When the condition of steady state of the fluid was found satisfactory, twenty minutes was maintained for the fluid running under each desired working condition, then the readings of temperature, pressure, flow rate as well as the water level measured from the centerline of the test tube were recorded manually at the same period.

Tests were run over a range of temperature from 150° to 250°F. Six different pressure levels in the upstream chamber were tested for most individual tubes. Table 1 gives complete information of the conditions of the test conducted for the two-phase metastable flow program.

Selected sets of test conditions were repeated to demonstrate the reproducibility of the experimental results. The repeated tests were performed by either steadily increasing or decreasing the pressure difference or taking random points. The results indicated that the same characteristics were imposed on the fluid for the same working conditions. Data of the test runs may refer to both Table 1 and the Appendix.

High speed motion pictures at a film speed of 2000 frames per second were taken. Complete information of the test condition of the fluid was recorded, this was based on interpreting the fluid phenomena observed in the pictures.

5. PRESENTATION AND DISCUSSION OF EXPERIMENTAL DATA

5.1 General Presentation

Experimental data of mass flow rate versus pressure drop for different tube configurations are shown in Figures 9 through Figures 18. The initial pressure marked on all figures are only the selected integers close to the experimental data recorded. All the results indicate the existence of the critical condition, where no further increase of the mass flow rate is possible for any reduction of the pressure in the downstream chamber. Results also indicate the general trend that the higher critical mass flow rates can be attained with a higher initial pressure for any specific tube configuration. The data collected and their calculations may be referred to in the appendix.

5.2 Residual Heat of Fluid at the Tube Exit

Temperatures were measured at the test tube exit for all runs of the test. Since both chambers at the ends of the tube were maintained under saturated condition, the information of the temperature measured at the tube exit gave the magnitude of the residual heat of the fluid, and also indicated the metastability of the liquid, which influenced the mass flow rate through the tube.

The experimental data of the residual temperature, which was defined as the temperature difference between the tube exit and the vapor phase in the downstream chamber, versus the available temperature difference between the chambers are shown in Figures 20 to 29. The results indicate that the relationship was approximately linear for all the tubes tested before the critical condition was reached. After the critical condition was reached, the temperature at the tube exit still kept decreasing with further reduction of back pressure, as a result of this, it demonstrated the nonequilibrium state of the fluid within the short tubes.

5.3 Tubes of the Same Diameter

Results of 2" I.D. tubes of three different lengths with rounded edge entrance are compared in Figure 20. It shows that the longer the tube is, the smaller the mass flow rate. This is because the residence time of the fluid within the shorter tube is smaller, and the evaporation process has less change to be carried out. A similar conclusion has been drawn and verified by a number of investigators (2, 7, 9, 16).

5.4 Tubes of the Same Length

Figure 31 shows the experimental results of 12" long tubes of three different diameters. It shows that the tube of smaller diameter gives higher mass flow rates, which contradicts what Fauske (7) prdicted and is close to Silver and Mitchell's data (19). This is possibly due to the surface effect of the tube which may retard the formation of the vapor bubbles or the relationship between tube diameter and mean diameter of the vapor bubbles.

5.5 Tubes of the Same L/D Ratio

Test results for L/D ratio equal to 8 for tubes of various diameters were plotted and compared in Figure 32. This shows clearly that different mass flow rates are attained even with the same L/D ratio for various diameters. Since most previous works of two-phase fluid flow relied on the L/D ratio as the sole parameter of the geometrical dependence on the mass flow rate, the results presented here give a strong evidence that instead of L/D ratio alone, both the diameter and the length of the tube influence the flow characteristics of the two-phase fluid.

5.6 Effect of Initial Pressure

Four to six different initial pressures were tested for each tube configuration. The results are shown in Figures 9 through 18. The higher initial pressure gives a higher mass flow rate with other conditions remaining the same. Similar results were reported in (9). To interpret this, the lower mass flow rate obtained at a lower initial pressure is due to the greater specific volume of the vapor phase, which increases the velocity of the two-phase mixture.

5.7 Effect of Entrance Condition

Most tubes in the horizontal position were tested with a rounded edge entrance of 1/4" radius of curvature. One selected tube of 2" I.D.- 16" long in the horizontal position was tested with sharp edge entrance. The discharge coefficients of the rounded entrance for cold water were calibrated for both 1.5" I.D. x 12" long and 3" I.D. x 24" long tubes and were found close to the average value 0.85. The calibrated data are presented in Table 2 and 3. Table 4 gives the calibration of discharge coefficient of cold water for 2" I.D. x 21" long tubes with sharp edge entrance.

A comparison of the data obtained on a 2" I.D.- 16" long tube in the horizontal position for both a rounded and a sharp edge entrance is shown in Figure 33. The results clearly show that slightly higher mass flow rates are achieved in the rounded edge entrance tube than in the sharp edge one, which experiences a greater Vena Contracta effect and reduces the mass flow rate. The flow patterns are therefore different for both cases.

Since results of only one specific tube geometry with different entrance conditions are compared, the authors have no guarantee that the results would be the same for tubes of different dimensions. It is expected that for shorter tubes, the effect of entrance condition will be more prominent and vanish for sufficiently long tubes. Similar discussion can be found in (7, 19).

5.8 Tube in the Vertical Position

One 2" I.D. x 21" long cylindrical tube having a sharp edge entrance with fluid flowing upward was tested in the vertical position. The odd tube length was due to some restriction caused by the construction of the test unit. The test results are shown in Figure 17. Since no tube of similar geometrical configuration was tested in the horizontal position, no direct comparison can be given here.

However, the results show a relatively smaller mass flow rate than obtained in tubes tested in the horizontal position. This is possibly due to two reasons: one is the longer length of the tube, the other is that a certain amount of pressure force will be spent to overcome the hydrostatic head of the fluid within the vertical tube.

5.9 Test Section of Rectangular Duct

A 21" long rectangular duct of 1.5" x 3" cross section (2" equivalent diameter) having a sharp edge entrance was tested in the vertical position. Compared with the 2" I.D. x 21" long cylindrical tube in the same position, the mass flow rate versus pressure drop is almost the same for most of the initial pressures. However, for the initial pressure of 60" Hg. the mass flow rate in the cylindrical tube is slightly higher than that in the rectangular duct. The reason for this is still unknown. A comparison of the results is shown in Figure 34.

5.10 Critical Mass Flow Rate

Since no pressure measuring device was located right at the exit of the test tube, the exact critical pressures were not known. But the critical mass flow rates, which approach a constant with any further decrease of back pressure, are clearly shown in the results. Figure 19 shows the experimental data of the critical mass flow rates versus initial pressures for all the tubes tested. It indicates that the critical mass flow rate is not dependent on the L/D ratio alone for a given initial pressure, contrary to what had been reported by most previous investigators (7, 9, 16), it depends on both diameter and length of the tube.

5.11 Observations

High speed photographic analysis and observations of the phenomena were used to supplement experimental data. Although this type of experimental evidence does not contribute directly to a quantitative solution to the problem, it is hoped that it will be of some assistance in selecting a suitable model.

Observations with the naked eye indicate a large quantity of steam by volume was generated immediately downstream from the entrance to the tube. This is illustrated in Figure 35. No separation of the fluid from the tube wall was noticed at the entrance for all tubes tested with a 1/4" rounded inlet. During tests of tubes with sharp edged entrance, a clearly defined Vena Contracta was formed extending 3 to 4 inches downstream of the entrance (See Figure 36). Upstream from the exit of the tube there appeared to be a slight change in steam void density suggesting fluid acceleration at this point.

Inspection of the flow phenomena through a sight glass located on the center line of the test section upstream from the tube entrance and in a plane perpendicular to the direction of flow indicated two vortices were formed rotating on and parallel to the centerline of the tube. The direction of rotation alternated from clockwise to counterclockwise and back in rapid sequence. The strength of the vortices appeared to increase with pressure and mass flow.

The significance of the presence of the vortices is uncertain at this time. From this vantage point, it could also be observed that boiling began just downstream of the entrance to the tube in the vicinity of the point at which the tube butts up against the metal adaptor. During tests of high metastability, thus low mass flow rates and pressure differentials, the core of the fluid flow path remained void of vapor.

Analysis of the high speed photography of the flow along its path indicated bubbles formed within the first several inches of tube length. The bubbles appeared to be undistorted and varied in size. The maximum bubble size did not appear to exceed 1/8" in diameter. There was no indication of a velocity profile across the tube nor a differential in linear velocity with size. In either case photographic limitations may have prohibited detecting these variations. Curvature of the tube could have prevented observation of the boundary layer, and the speed of the film could have prevented detection of relatively small differences in velocity.

Analysis of the motion pictures with a Kodak Optical Analyzer indicates bubble formation must take place in less than .0005 sec. The films were taken at a rate of 2000 frames per second for which film frame exposure time is 1/10,000 of a second. This is in agreement with the observation that all the bubbles appear to form at the entrance.

Motion pictures taken of flow in the vertical position indicate, at high pressure and relatively large pressure differentials, a portion of the bubbles form at the entrance to the tube and the surface of the Vena Contracta (See Figure 38). The core is clear and void of noticeable vapor generation for several inches upstream of the entrance after which bubbles begin to form. Although a film of water could be detected returning along the wall to the entrance of the tube, there still remains some uncertainty as to which phase occupies the void surrounding the Vena Contracta. Approximately eight inches from the exit to the 21 inch tube, additional bubbles began to form with a noticeable acceleration of the fluid. There was no indication of instability in flow.

Attempts were made to take pictures of the inlet to the horizontal tube in a plane perpendicular to the direction of flow. Considerable difficulty was encountered in focusing the camera on the entrance plane and in providing sufficient light to take high speed photographs. However, the pictures taken do indicate a change in phase of the fluid immediately downstream of the entrance without the formation of a discrete surface. There is evidence of highly turbulent local fluid motion with only an occasional bubble formation at a point removed from the surface.

From the qualitative data accumulated from observation and photographic analysis, it may be concluded that heat or mass is transferred at extremely high rates at the entrance and exit to the tube. The change in momentum takes place within a few inches downstream of the entrance and upstream of the exit. Although wall friction exists, its overall contribution to the change in momentum may be considered negligible. In view of the fact that undisturbed bubbles of different sizes appeared to be traveling at the same speed, it may be concluded that slip is negligible for the short tubes tested here.

6. DISCUSSION OF RESULTS AND CONCLUSIONS

Two-phase metastable flow is extremely complex. It involves many variables and includes some phenomena for which there is little understanding. As it was pointed out earlier in the report, the data available is sparse, particularly at low temperatures and pressures. The numerous models proposed, based on a restricted number of variables, fail to reveal a true understanding of the factors involved. Therefore, it appears pointless to attempt a correlation beyond that which is necessary to interpret the data.

The data is analyzed by applying the equation of motion. Since no boiling is evident upstream of the entrance, and since all prior experience indicates no boiling takes place at the throat of an aperture as the length approaches zero, it would seem reasonable to break up the equation of motion into two parts. The first part of the quation applies to the change in potential energy prior to the entrance plane of the tube. This can be simply expressed in terms of an entrance effect. Thus,

$$\frac{\Delta P_0\, g}{\left(\frac{W}{A}\right)^2 v_f} = C' \qquad \text{where} \quad C' = \frac{1}{2C^2} \qquad (8)$$

The second part of the equation must take into consideration the change in momentum due to the expansion of the fluid and the surface friction. For this particular case it is felt that friction can be neglected as the tubes were constructed of glass of small length-to-diameter ratios.

The momentum equation may be written as follows:

$$g\Delta P_{o-e} = -\left(\frac{V_o}{v_o}\right)^2 \left(v_o - v_e\right) \tag{9}$$

Where

$$\frac{v_f - v_e}{v_f} = -\frac{C_p \Delta T_{1-e}}{h_{fg}} \left(\frac{v_{fg,e}}{v_f}\right) \quad \text{AND} \quad \frac{W}{A} = \frac{V_o}{v_o} \; ; \; v_o = v_f \; ; \; T_1 \doteq T_o ; \tag{10}$$

thus,

$$\frac{g\Delta P_{o-e}}{v_f} = \frac{C_p \Delta T_{1-e}}{h_{fg}} \left(\frac{v_{fg,e}}{v_f}\right)\left(\frac{W}{A}\right)^2 \tag{11}$$

Evaluation of the change in momentum depends upon knowledge of the metastable state and the void fraction of the vapor. This still remains the weakest link in evaluating two-phase flow. Measurement of these factors is extremely difficult if possible at all.

For analysis purposes,this problem may be circumvented by relating the actual change in specific volume to the change in specific volume for the nonslip, equilibrium case by some factor K. The equation (11) becomes

$$\frac{g\Delta P_{o-2}}{v_f \left(\frac{W}{A}\right)^2} = \frac{C_p \Delta T_{1-2}}{h_{fg}} \left(\frac{v_{fg,1}}{v_f}\right) K \tag{12}$$

Where ΔT_{1-2} must represent the change in bulk liquid temperature between the tube inlet and exit

K must include such factors as change in specific volume of the vapor with temperature, deviations of the bulk fluid temperature from equilibrium and slip between the phases. Inspection of the data reveals that the temperature drops across the tube are small and, except for the very low temperature runs the deviation in specific volume of the vapor contributes little to the value of K. It has already been pointed out that slip is probably small by virtue of the fact that the fluid is comprised of small undistorted bubbles flowing at the same velocity. Therefore the major portion of K must be attributed to the existence of a metastable state.

Although the value of any temperature measurement at the exit of the tube is a source of contention, the thermocouple readings at this point indicate rather large fluid superheats that vary in direct proportion to the temperature differential across the tanks (See Figures 20 through 29). There also appears to be a consistent but small variation of the slope of the curves with temperature level and tube geometry. Data for the 3" diameter 24" long and 1.5" diameter 12" long tubes deviate from the general trend. These tests were run prior to relocating the exit temperature probes, which might explain the discrepancy. In general the thermocouples support the analysis of the other raw data as well as observations. Therefore it is felt that K is associated with the temperature differentials rather than the specific volume.

At this point the two equations of motion may be combined to form the general equation of motion for the entire aperture. Thus from equation (8) and (12), equation (13) is obtained.

$$\frac{g\,\Delta P_{1-2}}{v_f\left(\frac{W}{A}\right)^2} = \frac{C_P\,\Delta T_{1-2}}{h_{fg}}\left(\frac{v_{fg,1}}{v_f}\right) K + C' \qquad (13)$$

Here the effect of hydrostatic head is neglected

Inspection of this equation reveals that for small temperature differentials and small values of K, the mass rate of flow increases with pressure drops in practically the same manner as an incompressible fluid. However, as the temperature differentials, and consequently the pressure differentials continue to increase, the change in momentum resulting from the transfer of heat or mass within the tube becomes large compared to the change in momentum at the entrance to the tube. Eventually a point is reached beyond which the entrance effect contributes very little to the overall pressure drop. Practically the entire change in momentum is due to the phase change or transfer of mass. At this point a "critical mass flow" is reached and a further drop in pressure is accompanied by a proportional drop in tube exit temperature. "Critical mass flow" in this case should not be confused with the critical mass flow accompanied by sonic velocities.

Since the rate of change of pressure with temperature is inversely proportional to the change in specific volume, it is suggested that the critical mass flow should occur at approximately the same temperature differential for small changes in temperature level. This can be confirmed by rearranging the general equation of motion in the following manner.

$$g\Delta P_{1-2}\,\frac{1-\dfrac{\Delta P_o}{\Delta P_{1-2}}}{\dfrac{C_p\Delta T_{1-2}}{h_{fg}}\,v_f} = \left(\frac{W}{A}\right)^2\frac{v_{fg,1}}{v_f}\,K \qquad (14)$$

Where

$$\Delta P_o = \frac{C' v_f \left(\frac{W}{A}\right)^2}{g}$$

and substituting the mass flow parameter Φ such that

$$g\Delta P_{1-2}\,\frac{1-\dfrac{\Delta P_o}{\Delta P_{1-2}}}{\dfrac{C_p\Delta T_{1-2}}{h_{fg}}\,v_f} = \Phi^2 \qquad (15)$$

Where

$$\Phi = \left(\frac{W}{A}\right)\left(\frac{v_{fg_1}}{v_f}\right)^{0.5} K^{0.5} \qquad (16)$$

It is recalled that the temperature measurements indicate K is some function of pressure level and geometry. By evaluating the data at the critical mass flow rate, $\sqrt{K}$ is found to be directly proportional to the ratio of the specific volume to the .13 power and the tube volume to the .163 power. It is realized that volume defines a specific relationship between the length and diameter. However, until additional data is accumulated which will clearly define this relationship, tube volume appears to be a suitable choice. This expression for K is substituted into the mass flow rate parameter. Thus,

$$\Phi = \frac{W}{A}\left(\frac{v_{fg_1}}{v_f}\right)^{0.63}\left(\nabla\right)^{0.163}\cdot 10^{-4} \qquad (17)$$

A plot of the mass flow rate parameter versus the temperature drop between chambers indicates the critical mass flow is reached at a specific temperature differential between 8 to 10°F. for all geometries and pressure levels. See Figures 39 through 46. The manner in which the graphs are presented was selected to best illustrate the effects of pressure level and geometry.

In Figures 39 through 46 it is observed that the low pressure runs at 8" Hg Abs. and occassionally the runs at 16" Hg Abs. deviate from the tests performed at the higher pressure levels. It is believed that submergence or subcooling of the fluid at the entrance to the tube is the cause for these deviations. A similar experience was encountered during preliminary tests at high pressures. It was found by increasing the subcooling at the entrance to the tube, higher mass flows could be achieved for the same total pressure differential. However, the critical mass flow rate remained constant for the same degree of subcooling. The lower portion of the mass flow rate versus pressure drop curves may be interpreted in the same manner. It would be desirable to evaluate the submergence effect, however data for water levels in the upstream chamber are not accurate enough. Water levels were measured to an accuracy of ± 25 percent. In addition, evidence of occasional surface depressions at the entrance to the tube and occasional bubble formation may be sufficient to reduce the accuracy of measured water levels.

Summarizing:

1) A correlation for the data is offered which represents two-phase metastable flow within the limits of the parameters studied.

2) Extrapolation of the correlation requires further study of the effects of length, diameter, entrance conditions and frictional effects on two-phase flow. The present correlation appears suitable for extrapolation upon evaluation of these factors.

3) A critical mass rate of flow is reached which is dependent upon the distribution of the pressure drop between the entrance effect and the change in momentum within the aperture. The critical mass rate of flow occurrs at a constant temperature

differential, and it is proportional to the ratio of specific volume of the vapor and liquid, and the volume of the tube to appropriate powers.

4) The fluid appears to be flowing under metastable conditions. Since friction, although it may be present, appears to be negligible, there is a strong indication that the rate of transfer of heat and mass may be the governing phenomena of the mass flow rate.

5) Slight rounding of the tube at the entrance reduces separation of the fluid flow considerably. Yet, it is not certain about the exact effect of the radius of curvature of the rounded entrance.

6) Slightly lower mass flow rates were obtained in the vertical position which is probably due to the additional hydrostatic head.

7) Bubble flow is encountered through the range of variables tested.

8) Boiling does not occur prior to the entrance of the aperture.

9) Flow is stable for all operating conditions except for low pressure differentials at low pressure in the vertical position.

10) The data should provide a means for sizing flashing devices or interstage loop seals for multistage evaporators. However, further testing is desirable with regard to subcooling effects and hydrostatic head in the vertical position.

11) Operation of a multistage flash evaporator should be improved by using a metastable two-phase flow flashing device

in conjunction with a sharp edged orifice.

12) A controlled flashing device cannot improve the "thermal efficiency" within itself by virtue of the fact that a large degree of metastability must exist at the exit of the aperture. However, it may improve the "thermal efficiency" of the flash chamber if it can be shown that the rate of transfer of heat or the liquid surface exposed to the vapor has been increased in the stream immediately downstream of the flashing device.

7. RECOMMENDATIONS

The study of two-phase metastable flow or the flow of saturated fluid through short tube is in its infancy. A better understanding of the phenomena requires additional work to determine the effects of length, diameter, hydrostatic head, entrance conditions, and subcooling. To arrive at a suitable model for representing the phenomena, it is necessary to have an understanding of the fluid history with regard to pressure and temperature along the path of the operation. This, however, will require developing special techniques for determing the pressure, temperature or percent steam void fraction.

In support of multistage flash evaporation in particular, it would be desirable to obtain additional information with regard to subcooling effects, hydrostatic head, and the effects of length and diameter in the vertical position. It is recommended that additional work be done along these lines. In addition, it is recommended that the test facility used be properly instrumented to indicate any improvement in thermal efficiency that may be achieved immediately downstream of the controlled flashing device.

ACKNOWLEDGMENT

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TABLE 1

TESTS CONDUCTED FOR THE TWO-PHASE METASTABLE FLUID FLOW PROJECT

Run Number	Configuration Of Test Section	Dimensions	L/D Ratio	Position	Entrance Condition	Initial Pressure
031466	Cylindrical	1.5"I.D. x 6"L.	4	Horizontal	Rounded	8.3 Hg.
031166	"	"	"	"	"	8.4
030966	"	"	"	"	"	16.7
030866	"	"	"	"	"	23.5
030766B	"	"	"	"	"	30.8
030466	"	"	"	"	"	37.3
030766A	"	"	"	"	"	61.2
021066	"	1.5"I.D. x 12"L	8	"	"	8.3
020966	"	"	"	"	"	8.8
020866	"	"	"	"	"	16.6
020766A	"	"	"	"	"	16.6
020766B	"	"	"	"	"	23.5
021466A	"	"	"	"	"	23.1
021566	"	"	"	"	"	30.8
021466B	"	"	"	"	"	38.1
021666	"	"	"	"	"	61.7
032966	"	2"I.D. x 6" L	3	"	"	7.6
033166	"	"	"	"	"	15.5
040166B	"	"	"	"	"	22.2
033066B	"	"	"	"	"	30.1
033066A	"	"	"	"	"	37.1
040166A	"	"	"	"	"	59.3

TABLE 1 (Continued)

Run Number	Configuration Of Test Section	Dimensions	L/D Ratio	Position	Entrance Condition	Initial Pressure
032466B	Cylindrical	2"I.D. x 12"L	6	Horizontal	Rounded	7.9 Hg
032866B	"	"	"	"	"	15.8
032866A	"	"	"	"	"	22.7
032566	"	"	"	"	"	30.8
032366	"	"	"	"	"	37.6
032466A	"	"	"	"	"	60.2
041266A	"	2"I.D. x 16"L	8	"	"	8.1
041266B	"	"	"	"	"	16.3
041466A	"	"	"	"	"	23.2
041366	"	"	"	"	"	30.6
041166	"	"	"	"	"	37.7
041466B	"	"	"	"	"	59.9
032266A	"	3"I.D. x 12"L	4	"	"	8.2
032166	"	"	"	"	"	16.6
031766B	"	"	"	"	"	23.2
032266B	"	"	"	"	"	30.3
031666B	"	"	"	"	"	28.9
031666	"	"	"	"	"	37.9
031766A	"	"	"	"	"	61.6
030166	"	3"I.D. x 24" L	8	"	"	7.7
022866	"	"	"	"	"	16.5
022566	"	"	"	"	"	22.4
022366	"	"	"	"	"	31.1
022166	"	"	"	"	"	37.9
022266	"	"	"	"	"	60.8

TABLE 1 (Continued)

Run Number	Configuration Of Test Section	Dimensions	L/D Ratio	Position	Entrance Condition	Initial Pressure
042066	Cylindrical	2"I.D. x 16"L	8	Horizontal	Sharp	16.6 Hg.
041866B	"	"	"	"	"	23.1
041866A	"	"	"	"	"	37.6
041966	"	"	"	"	"	60.7
050966B	"	2"I.D. x 21"L	10.5	Vertical	"	8.3
050866B	"	"	"	"	"	16.5
050666C	"	"	"	"	"	21.9
050866A	"	"	"	"	"	29.9
050666B	"	"	"	"	"	37.4
050466	"	"	"	"	"	37.5
050966A	"	"	"	"	"	59.9
051766B	Rectangular	3" x 1.5" x 21"	10.5	"	"	16.4
051766A	"	"	"	"	"	22.1
051666A	"	"	"	"	"	37.2
051666B	"	"	"	"	"	60.1

SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

Table 2 Calibration of discharge coefficient of cold water for 1-1/2" I. D. x 12" tube with rounded entrance

Configuration of Test Section Cylindrical Entrance Condition Rounded Entrance

Position Horizontal Length 12 Inches Diameter 1.5 Inches I.D.

Test	1	2	3	4	5	6	7		
1 Pressure Tank #1 In Hg.	41.97	40.76	39.19	37.45	35.95	34.75	33.76		
2 Pressure Tank #2 In. Hg.	23.04	24.53	25.74	27.08	28.33	29.42	30.36		
3 Pressure Differential In. Hg.	18.93	16.23	13.45	10.37	7.62	5.33	3.4		
4 Flow Rate lb/sec-ft^2	1958.3	1769.5	1625.4	1448.6	1244.9	1041.4	848.8		
5 Water Level Tank #1 In. Water	4	3.5	3.5	3	2.5	2.5	2.5		
6 Water Level Tank #2 In. Water	2	1.5	1.5	1.3	1	1	1		
7 Discharge Coefficient	0.844	0.824	0.831	0.844	0.846	0.846	0.863		

SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

Table 3 Calibration of discharge coefficient of cold water for 3" I.D. x 24" tube with rounded entrance

Configuration of Test Section Cylindrical Entrance Condition Rounded Entrance

Position Horizontal Length 24 Inches Diameter 3 Inches I.D.

Test	1	2	3	4	5				
1 Pressure Tank #1 In. Hg.	29.9	29.9	29.9	29.9	29.9				
2 Pressur Tank #2 In. Hg.	29.5	29.3	29.0	28.5	28.1				
3 Pressure Differential In. Hg.	0.4	0.6	0.9	1.4	1.8				
4 Flow Rate lb/sec-ft^2	282	367	423	548	622				
5 Water Level Tank #1 In. Water	3	4	4	4.5	4.5				
6 Water Level Tank #2 In. Water	0.5	0	0	0.5	0.5				
7 Discharge Coefficient	0.836	0.888	0.836	0.868	0.869				

SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW
0-59-1135

Table 4 Calibration of discharge coefficient of cold water for 2" I.D. x 21" tube with sharp edge entrance

Configuration of Test Section Cylindrical Entrance Condition Sharp Edge Entrance

Position Vertical Length 21 Inches Diameter 2 Inches I. D.

Test	1	2	3	4	5	6	7	8	9
1 Pressure Tank #1 In. Hg.	31.0	31.5	32.2	32.6	33.4	34.2	35.0	35.8	36.9
2 Pressure Tank #2 In. Hg.	29.95	29.95	29.95	29.95	29.95	29.95	29.95	29.95	29.95
3 Pressure Differential In. Hg.	1.05	1.55	2.25	2.65	3.45	4.25	5.05	5.85	6.95
4 Flow Rate lb/sec-ft^2	420	500	595	660	760	830	890	960	1050
5 Water Level Tank #1 In. Water									
6 Water Level Tank #2 In. Water	0.766	0.752	0.743	0.759	0.766	0.755	0.742	0.744	0.746
7 Discharge Coefficient									

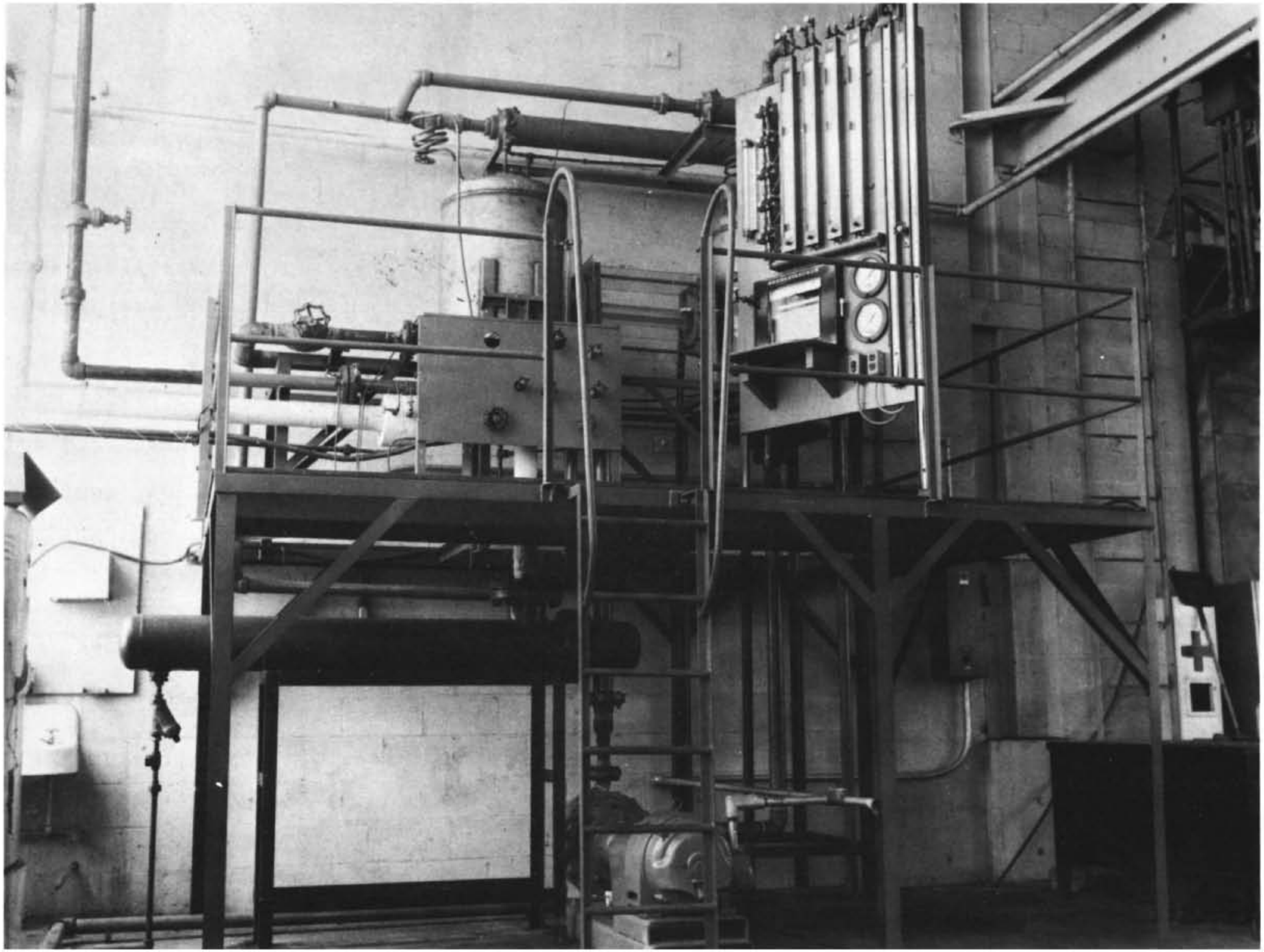
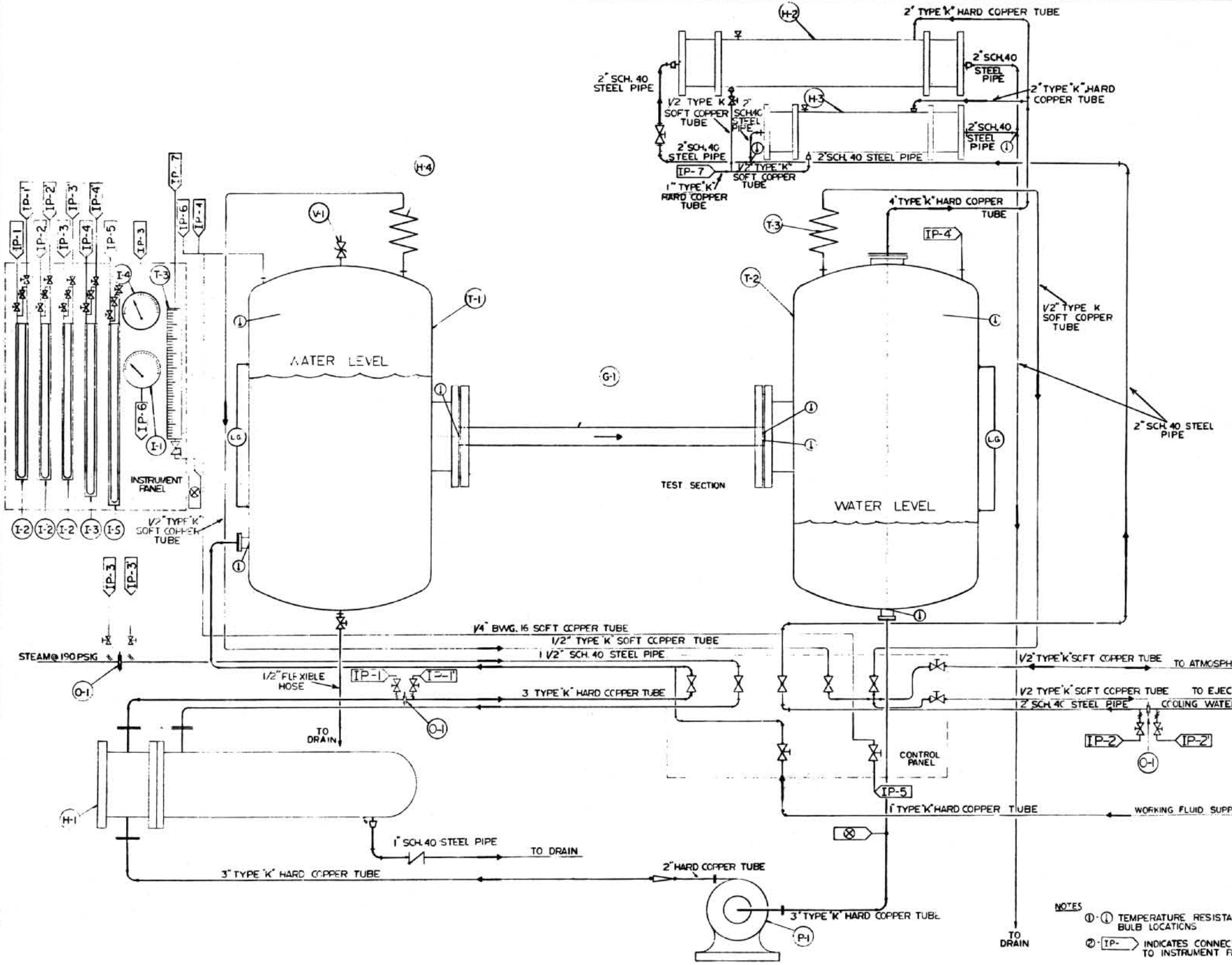


Figure 1. Construction of Test Unit



NOTES

① ① TEMPERATURE RESISTANCE BULB LOCATIONS

② IP- INDICATES CONNECTION TO INSTRUMENT PANEL

LIST OF MATERIALS

PART NO.	NAME	MATERIAL	QUANT.	DESCRIPTION
T-1	PLENUM CHAMBER	304 S.S.	1	2' DIA. × 3' HIGH — SEE DET. DWG. #RD-651-67
T-2	PLENUM CHAMBER	304 S.S.	1	2' DIA. × 3' HIGH — SEE DET. DWG. #RD-651-67
P-1	CENTRIFUGAL PUMP	316 S.S.	1	DEAN BROS. MODEL PH-20135
H-1	WATER HEATER	BRASS ON TUBE SIDE, STEEL ON SHELL SIDE	1	B&G. MODEL Q-SU 31612 86-2
H-2	CONDENSOR	ADMIRALTY ON TUBE SIDE, BRASS ON SHELL SIDE	1	YOUNG MODEL F-606 AR-1
H 3	CONDENSOR	ADMIRALTY ON TUBE SIDE, BRASS ON SHELL SIDE	1	YOUNG MODEL F-502 AR-1
G-1	TEST SECTION		4	SEE DET. DWG. #RD 651-68
T-3	CONDENSATE COLLECTOR	304 S.S.	1	2' HIGH, 4' NOM. DIA.
H-4	CONDENSING COIL	BRASS	2	3/8" TUBING, 3" COIL DIA.
O-1	CONCENTRIC ORIFACE	BRASS	3	3/32" PLATE
I-1	BOURDON PRESS. GAGE		1	B.C. MODEL P/N 1813 SPEC. NO. 80871
I-2	MANOMETER		3	MERIAM 400#, MODEL P/N 20DA40, 30"
I-3	MANOMETER		1	KING 60", MM. SCALE
V-1	SAFETY VALVE	BRASS	1	150 PSI
I-4	BOURDON PRESS GAGE		1	B.C. MODEL P/N 1813, SPEC. NO. 69060
I-5	MANOMETER		1	KING 100", MM. SCALE

FIG. 2

FLOW DIAGRAM OF TEST LOOP
AND THE
LOCATION OF INSTRUMENTATION

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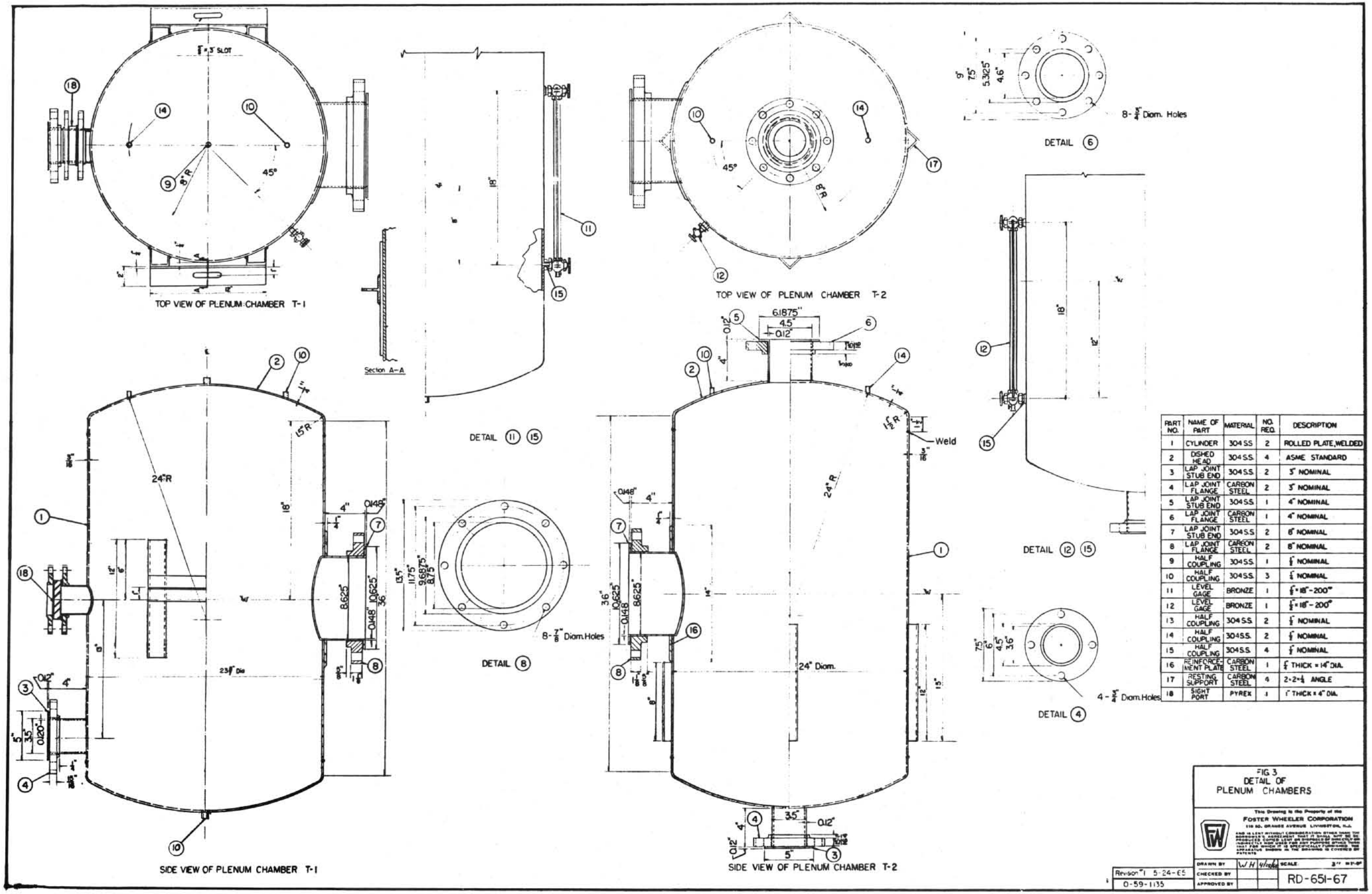
CHECKED BY			RD-651-66	
APPROVED BY				

Revision #1 5-26-65
0-59-1135

FORM 285 T5V



PART NO.	NAME OF PART	MATERIAL	NO. REQ.	DESCRIPTION
1	CYLINDER	304 S.S.	2	ROLLED PLATE, WELDED
2	DISHED HEAD	304 S.S.	4	ASME STANDARD
3	LAP JOINT STUB END	304 S.S.	2	3" NOMINAL
4	LAP JOINT FLANGE	CARBON STEEL	2	3" NOMINAL
5	LAP JOINT STUB END	304 S.S.	1	4" NOMINAL
6	LAP JOINT FLANGE	CARBON STEEL	1	4" NOMINAL
7	LAP JOINT STUB END	304 S.S.	2	8" NOMINAL
8	LAP JOINT FLANGE	CARBON STEEL	2	8" NOMINAL
9	HALF COUPLING	304 S.S.	1	½" NOMINAL
10	HALF COUPLING	304 S.S.	3	¼" NOMINAL
11	LEVEL GAGE	BRONZE	1	½" × 18" – 200°
12	LEVEL GAGE	BRONZE	1	½" × 18" – 200°
13	HALF COUPLING	304 S.S.	2	½" NOMINAL
14	HALF COUPLING	304 S.S.	2	½" NOMINAL
15	HALF COUPLING	304 S.S.	4	½" NOMINAL
16	REINFORCEMENT PLATE	CARBON STEEL	1	¼" THICK × 14" DIA.
17	RESTING SUPPORT	CARBON STEEL	4	2×2×¼ ANGLE
18	SIGHT PORT	PYREX	1	1" THICK × 4" DIA.

FIG 3
DETAIL OF
PLENUM CHAMBERS

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CHECKED BY			RD-651-67
APPROVED BY			

Revision #1 5-24-65
0-59-1135

FORM 385-7SV

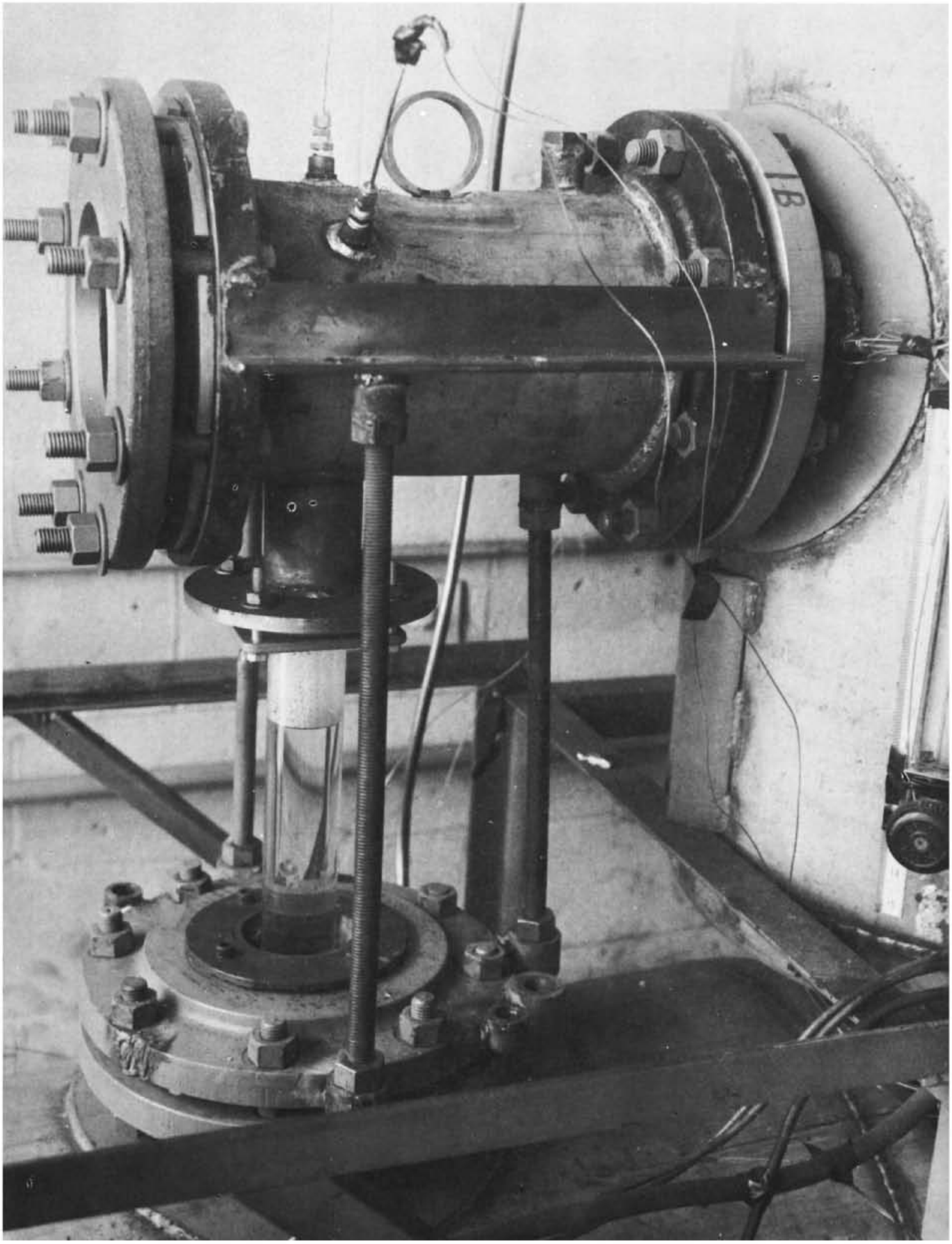
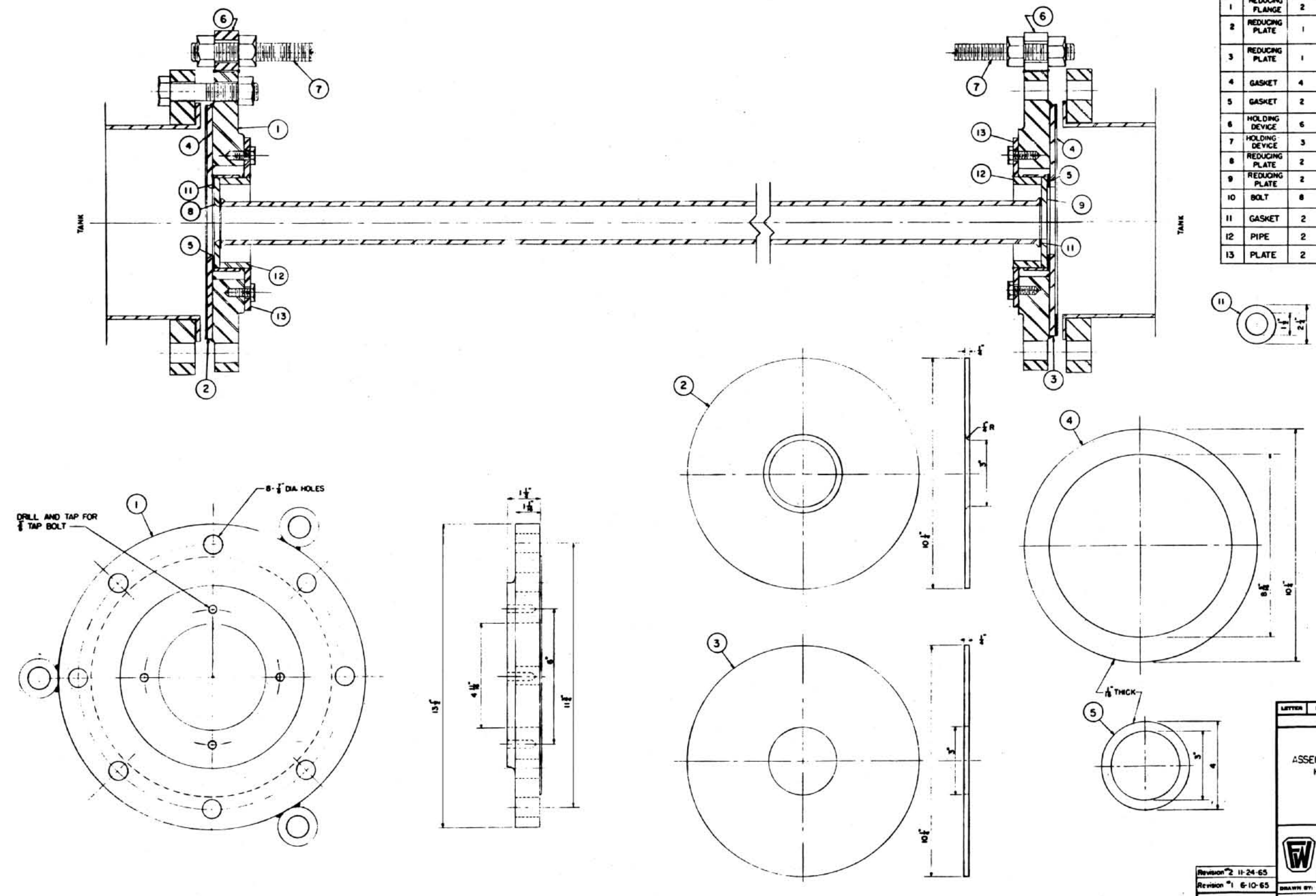


Figure 4. Test Section in the Vertical Position

Figure 5. Samples of Cylindrical Test Tubes



PART NO.	NAME OF PART	QUANTITY	MATERIAL	DESCRIPTION
1	REDUCING FLANGE	2	CARBON STEEL	4" × 13 1/2" REDUCING SLIP ON WELDING FLANGE
2	REDUCING PLATE	1	304 S.S.	CIRCULAR PLATE 3" DIA. CENTER HOLE, 1/8 R ROUNDED EDGE ONE FACE
3	REDUCING PLATE	1	304 S.S.	CIRCULAR PLATE 3" DIA. CENTER HOLE, SHARP EDGE BOTH FACES
4	GASKET	4	ASBESTOS	DIMENSIONS AS PER DWG, CUT FROM ASBESTOS SHEET
5	GASKET	2	ASBESTOS	SAME AS ABOVE
6	HOLDING DEVICE	6	CARBON STEEL	HEAVY WALL PIPE 1 1/4 LONG × 1" I.D.
7	HOLDING DEVICE	3	CARBON STEEL	3/4" THREADED ROUND
8	REDUCING PLATE	2	304 S.S.	SEE DWGS. RD-654-164, RD-654-165
9	REDUCING PLATE	2	304 S.S.	SAME AS ABOVE
10	BOLT	8	S.S.	1" × 5/8"
11	GASKET	2	ASBESTOS	SAME AS 4
12	PIPE	2	CARBON STEEL	3 1/2" NOM. PIPE, STD. WALL 4" O.D.
13	PLATE	2	CARBON STEEL	CIRCULAR – 7 1/2 O.D., 4" ID HOLE 6" BOLT CIRC. – 7/16" D. HOLES

LETTER	DATE	DESCRIPTION

REVISIONS

FIG 6

ASSEMBLY OF TEST TUBE IN THE
HORIZONTAL POSITION

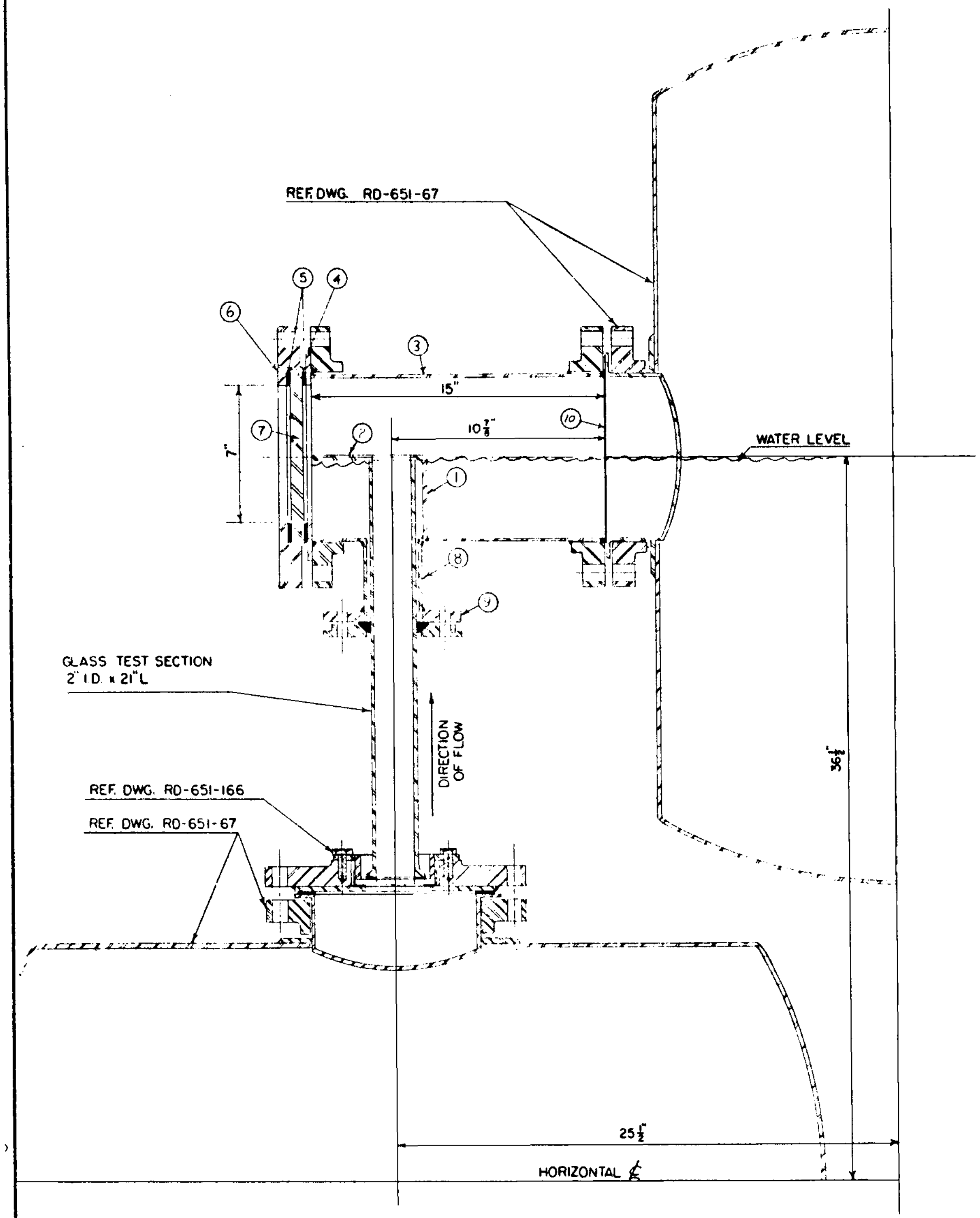
This Drawing is the Property of the
FOSTER WHEELER CORPORATION
110 SO. ORANGE AVE. LIVINGSTON, N.J.
AND IS LENT WITHOUT CONSIDERATION OTHER THAN THE BORROWER'S AGREEMENT THAT IT SHALL NOT BE REPRODUCED, COPIED, LENT, OR DISPOSED OF DIRECTLY OR INDIRECTLY NOR USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT IS SPECIFICALLY FURNISHED. THE APPARATUS SHOWN IN THE DRAWING IS COVERED BY PATENTS.

Revision #2 11-24-65
Revision #1 6-10-65
0-59-1135

DRAWN BY:	F Z	11 24 65	SCALE: 6" = 1'-0"
CHECKED BY:			RD-651-165
APPROVED BY:			

THIS DRAWING SUPERSEDES
THIS DRAWING SUPERSEDED BY

PART NO.	MATERIAL	DESCRIPTION
1	304 S.S.	SUPPORT LEG FOR SPLASH PLATE
2	304 S.S.	SPLASH PLATE
3	304 S.S.	8" NOMINAL SCHED. 10 PIPE 15" LONG
4	304 S.S.	END PLATE
5	ASBESTOS	GASKET
6	CARBON STEEL	MACHINED BLIND FLANGE
7	GLASS	SIGHT GLASS
8	304 S.S.	2½" NOMINAL SCHED. 10 PIPE 4" LONG
9	CARBON STEEL	CIRCULAR PLATE, 7½" DIA., 3" DIA. CENTER HOLE, 5½" BOLT CIRCLE
10	ASBESTOS	GASKET

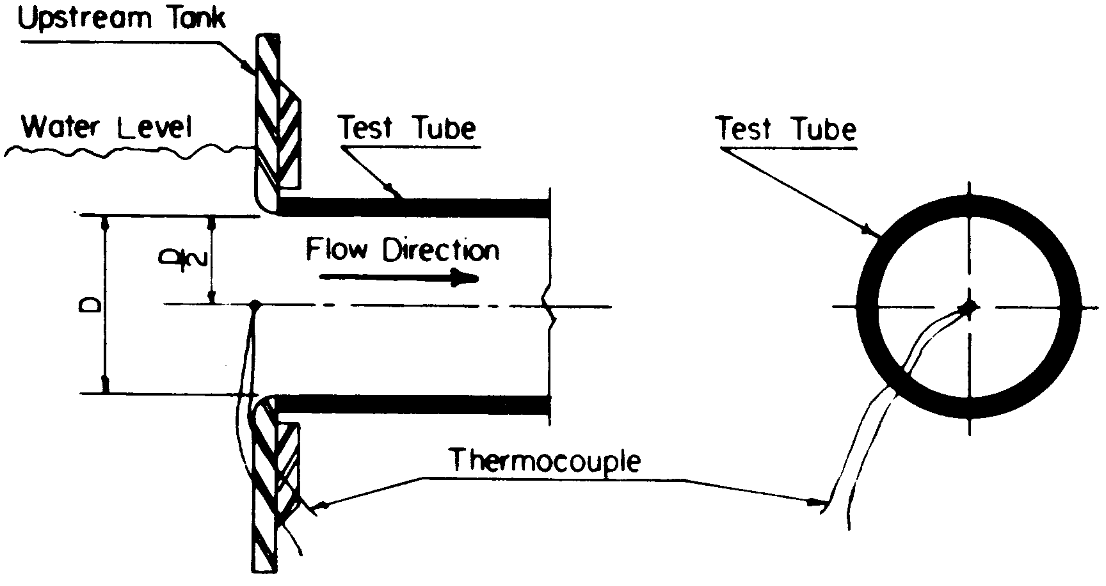


FOSTER WHEELER CORP.
FIG. 7
ASSEMBLY OF TEST TUBE
IN THE VERTICAL POSITION

SCALE 3 INCH = ONE FOOT
DRAW BY F.Z. DATE 11/1/61
CHECKED BY
APPROVED BY

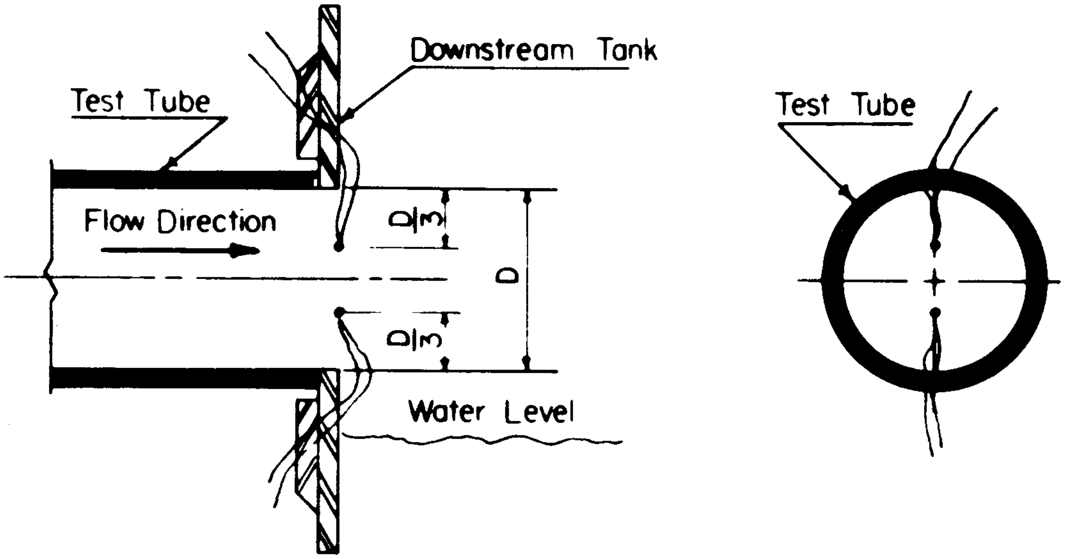
DRAWING NO.

LETTER	DATE	DESCRIPTION
REVISIONS		



SIDE VIEW SECTION VIEW

TEST TUBE INLET



SIDE VIEW SECTION VIEW

TEST TUBE OUTLET

Figure 8, DETAILED LOCATIONS OF THERMOCOUPLES AT TEST TUBE INLET AND OUTLET

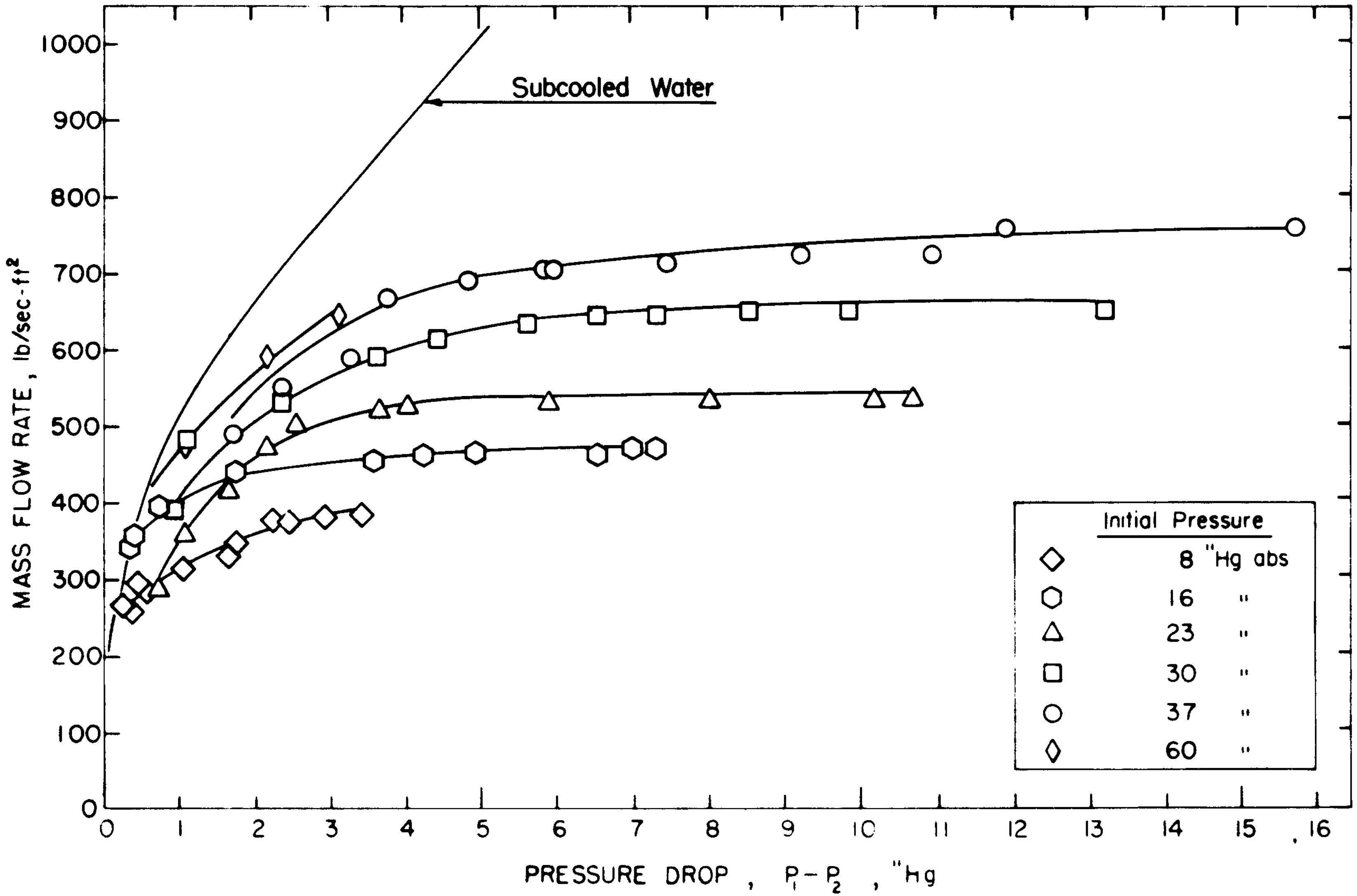


FIG. 9, MASS FLOW RATE FOR 1½" I.D. – 6" L. TUBE WITH ROUNDED ENTRANCE

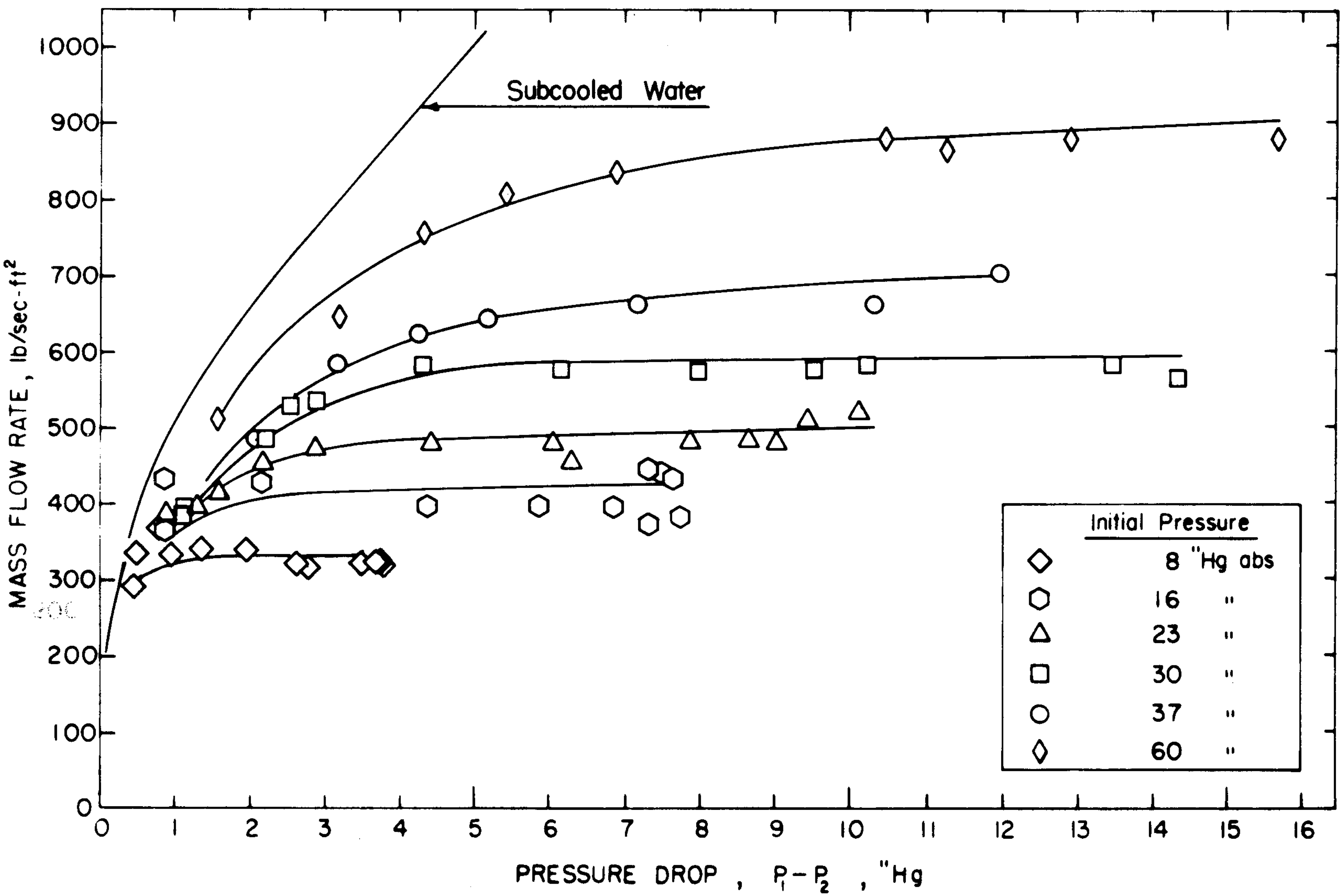


FIG. 10, MASS FLOW RATE FOR $1\frac{1}{2}$" I.D.-12" L. TUBE WITH ROUNDED ENTRANCE

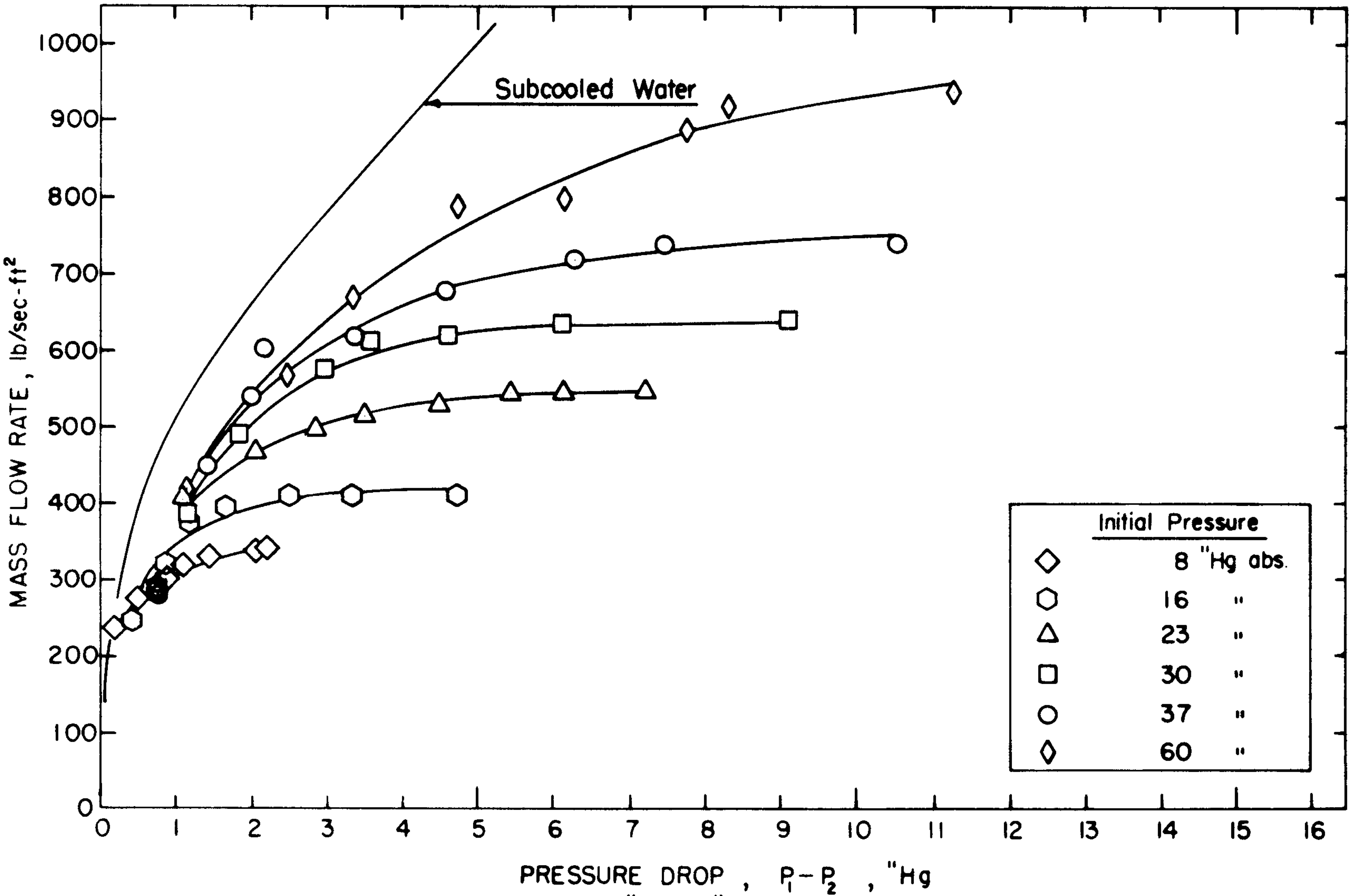


FIG. 11, MASS FLOW RATE FOR 2" I.D. - 6" L. TUBE WITH ROUNDED ENTRANCE

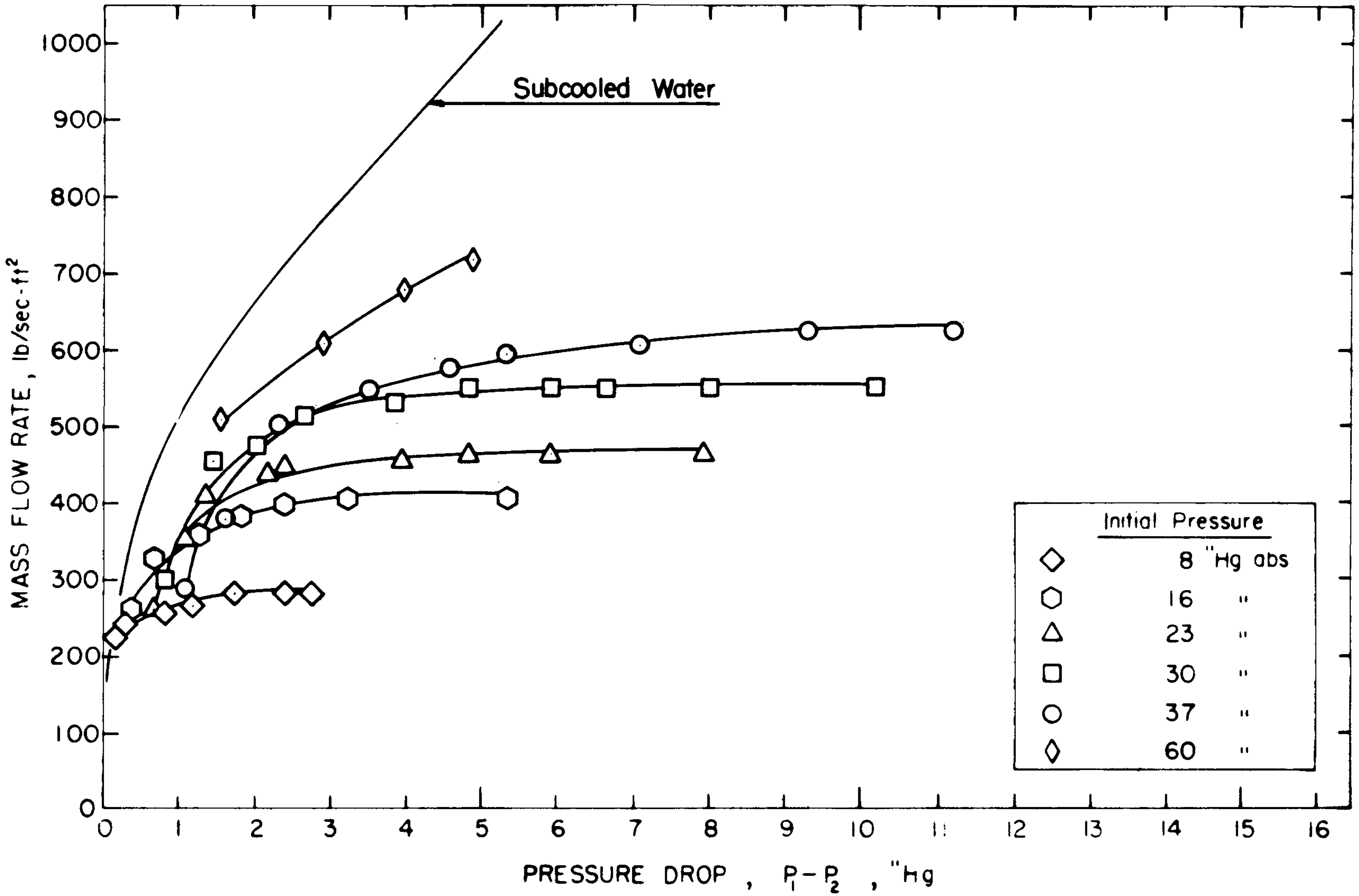


FIG. 12, MASS FLOW RATE FOR 2" I.D.-12" L. TUBE WITH ROUNDED ENTRANCE

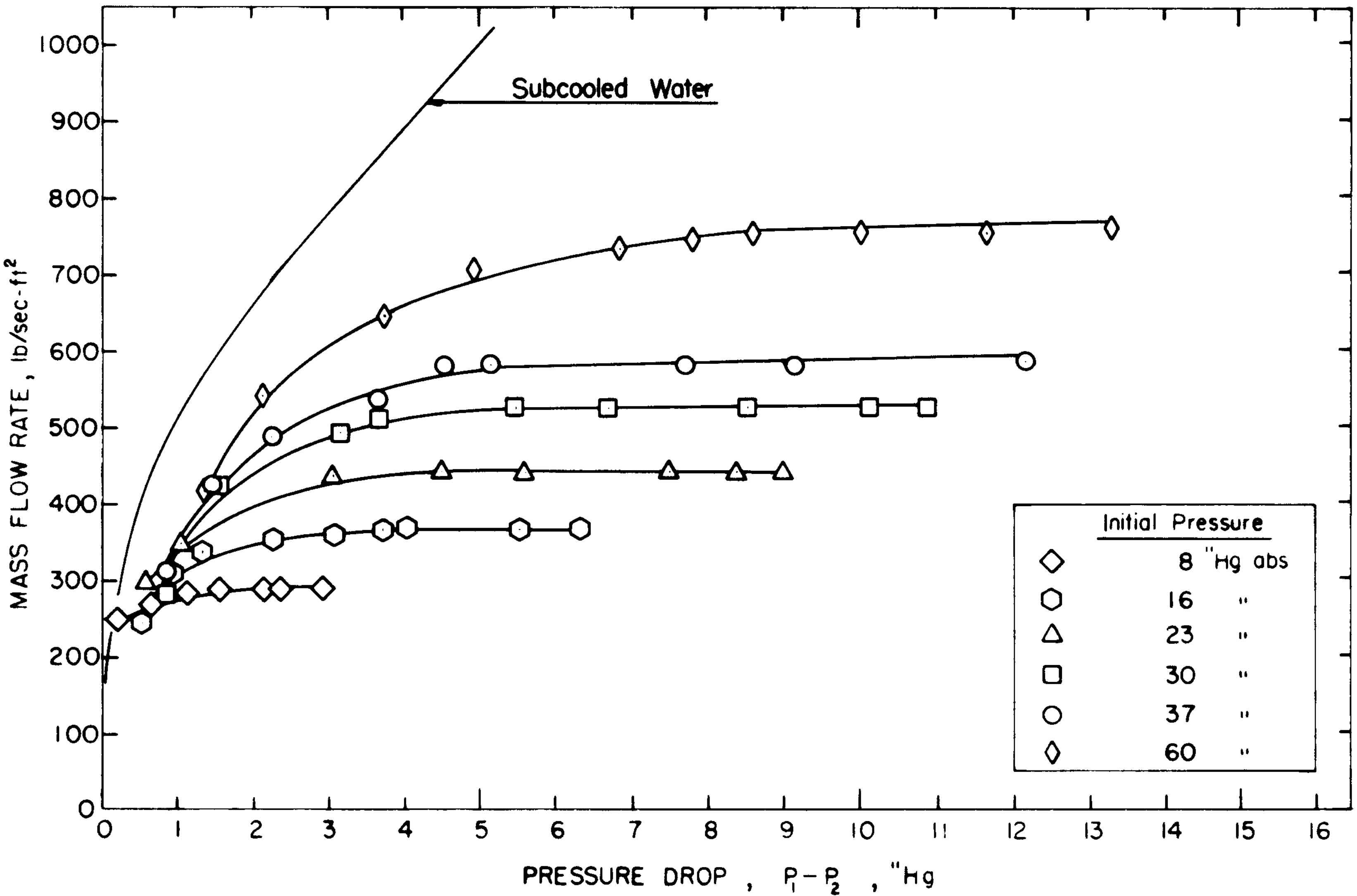


FIG. 13, MASS FLOW RATE FOR 2"I.D.-16"L. TUBE WITH ROUNDED ENTRANCE

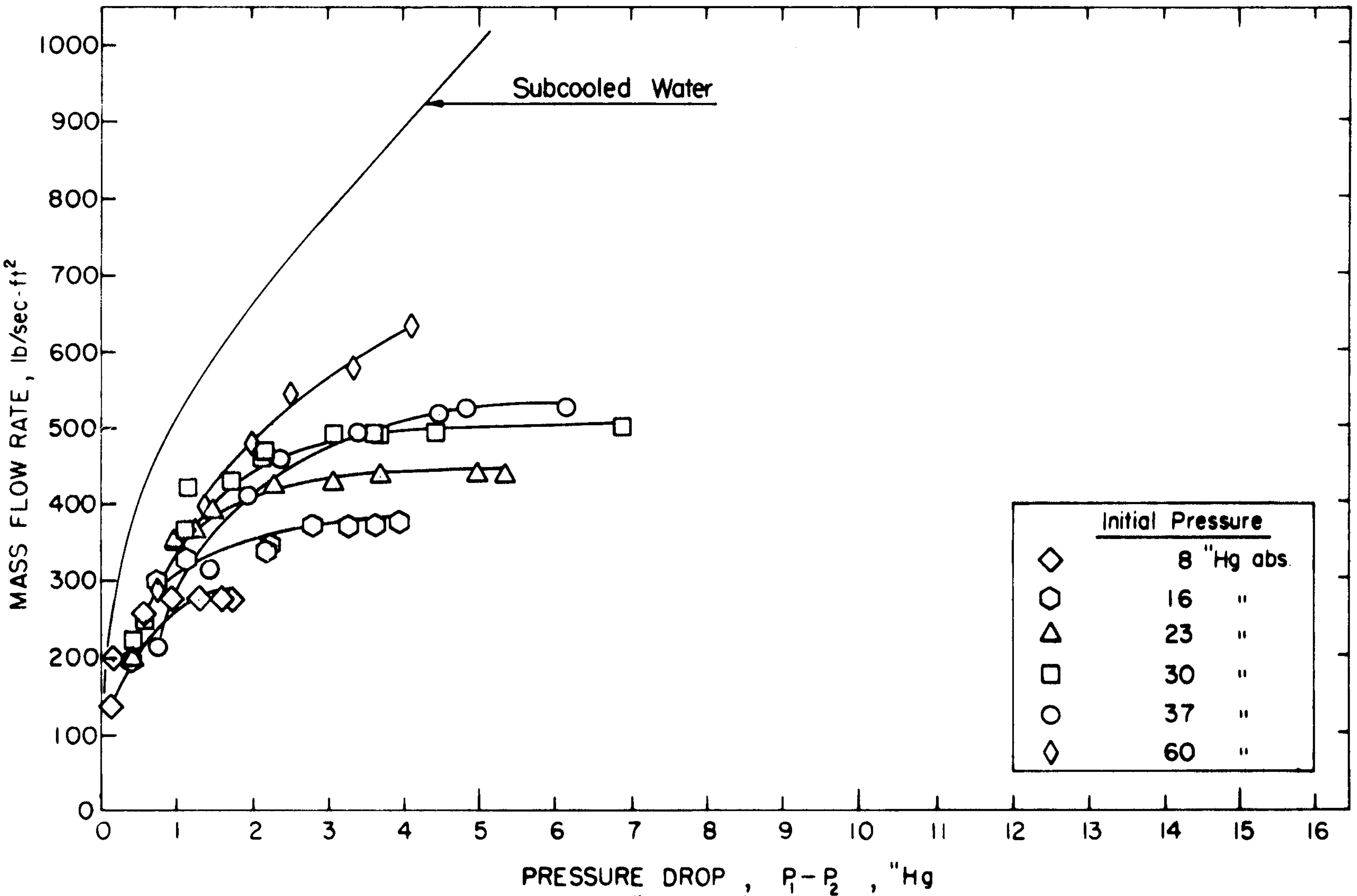


FIG. 14, MASS FLOW RATE FOR 3" I.D. - 12" L. TUBE WITH ROUNDED ENTRANCE

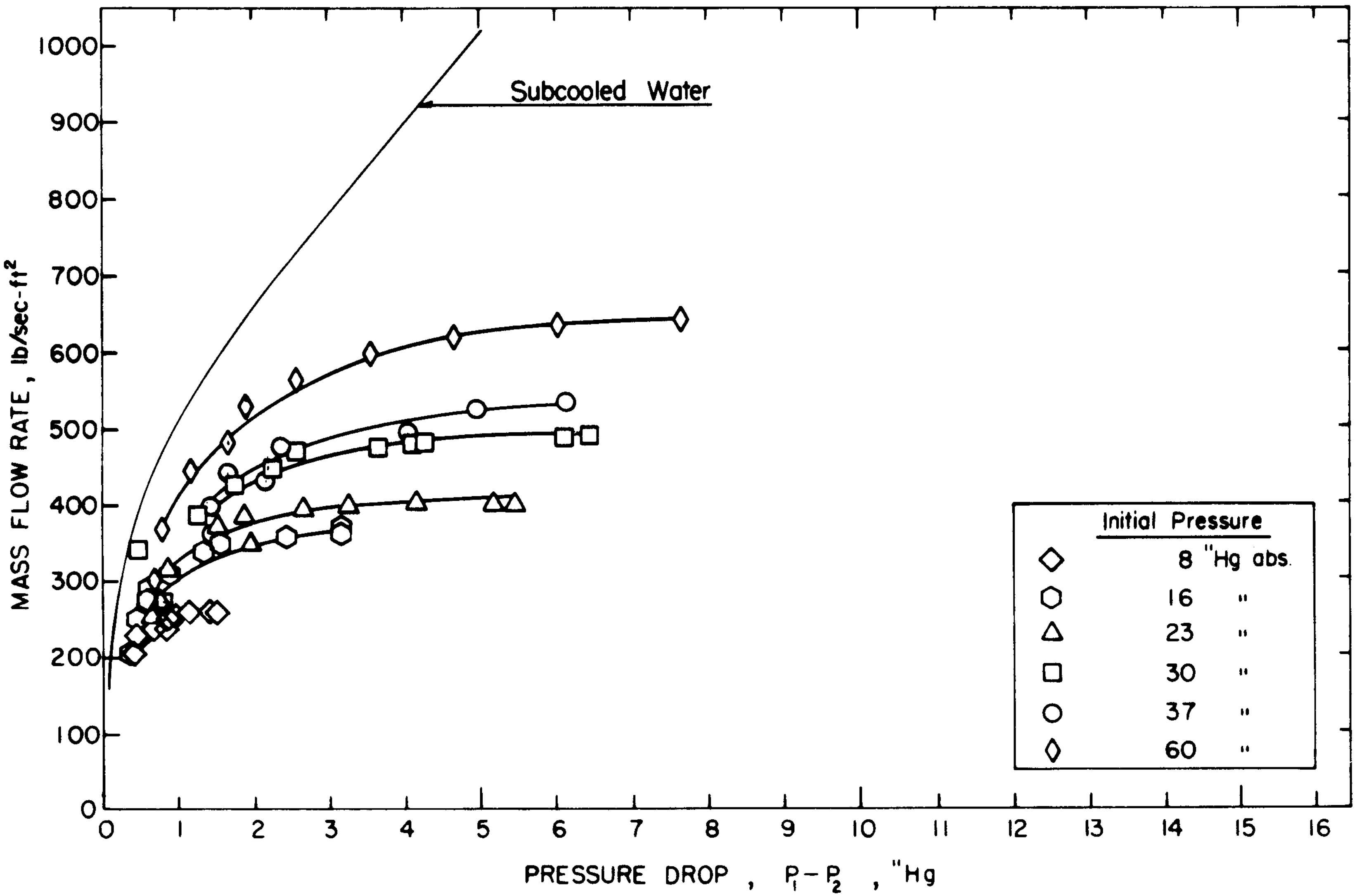


FIG. 15, MASS FLOW RATE FOR 3" I.D.-24" L. TUBE WITH ROUNDED ENTRANCE

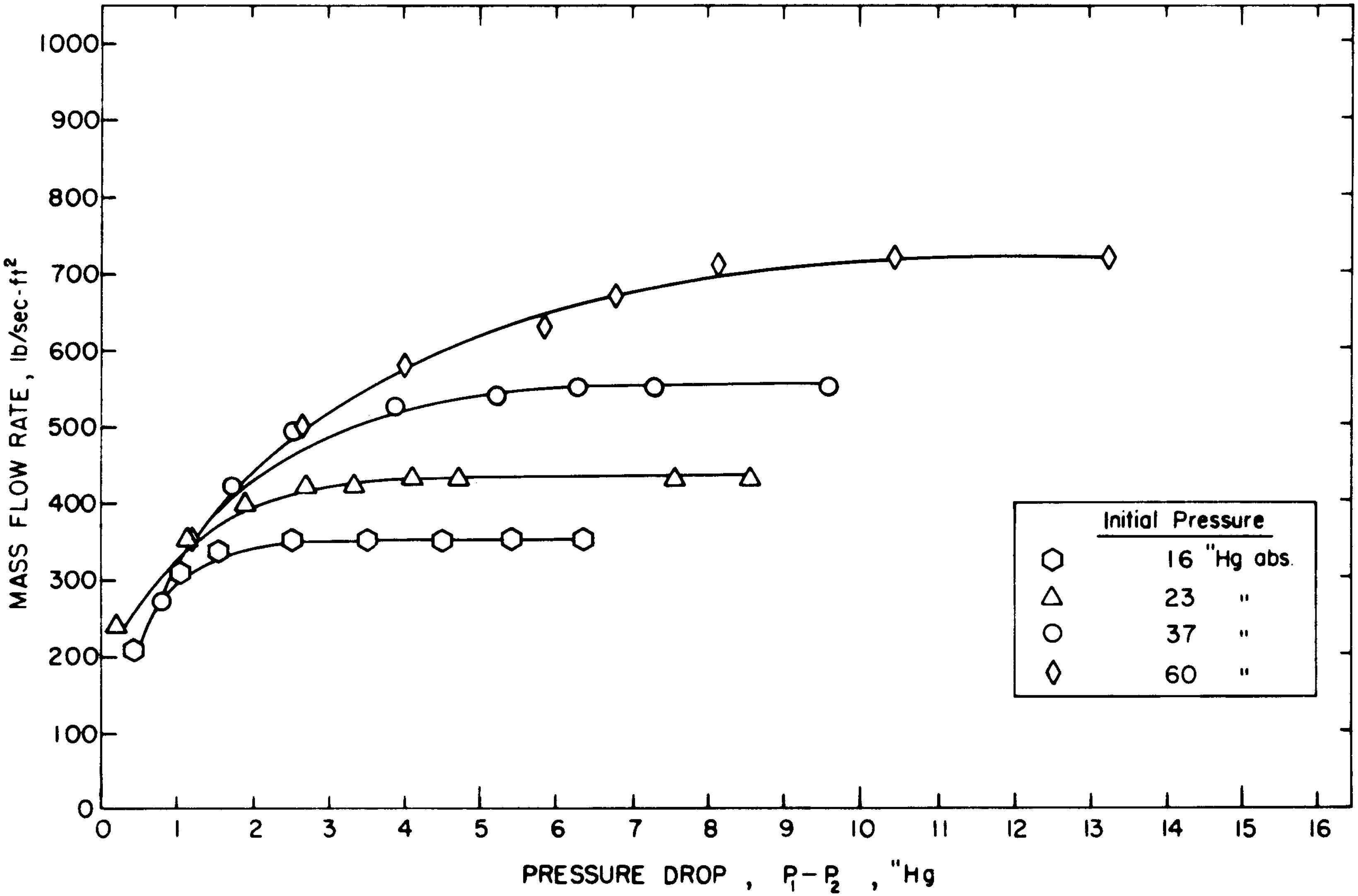


FIG. 16, MASS FLOW RATE FOR 2" I.D. - 16" L. TUBE WITH SHARP EDGE ENTRANCE

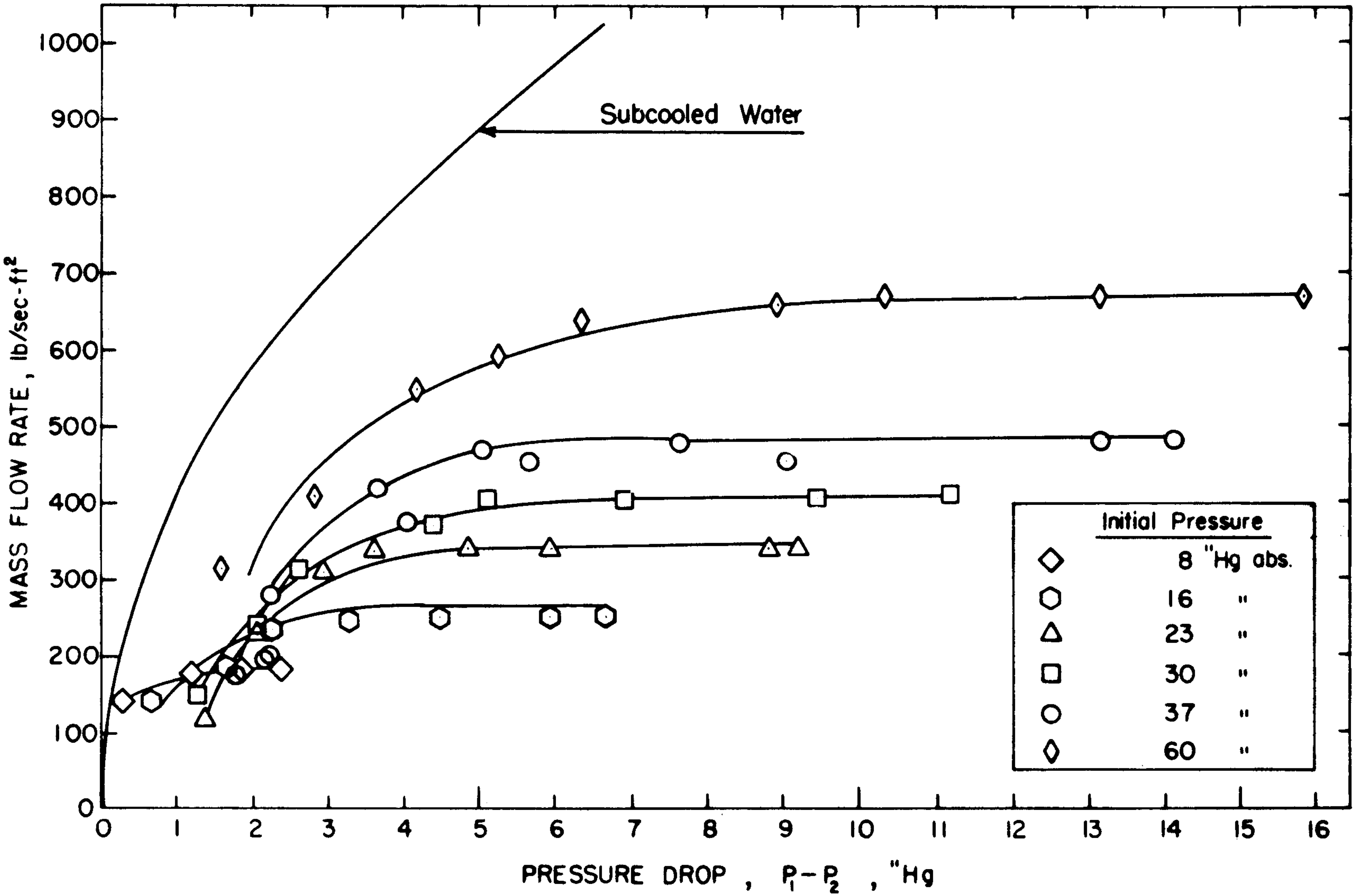


FIG. 17, MASS FLOW RATE FOR 2" I.D. - 21" L. TUBE WITH SHARP EDGE ENTRANCE

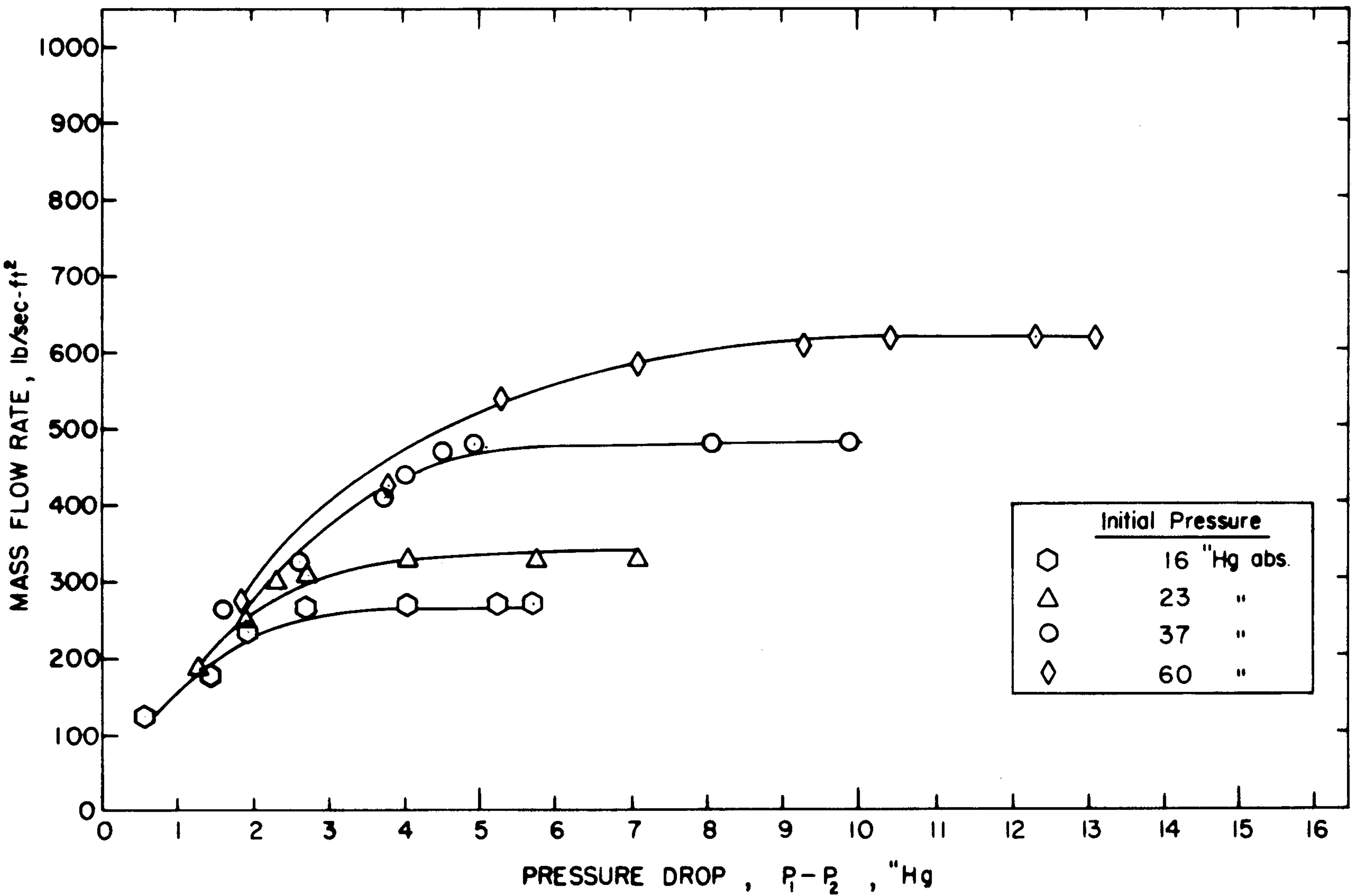


FIG. 18, MASS FLOW RATE FOR $1\frac{1}{2}$" x 3" – 21" L. DUCT WITH SHARP EDGE ENTRANCE

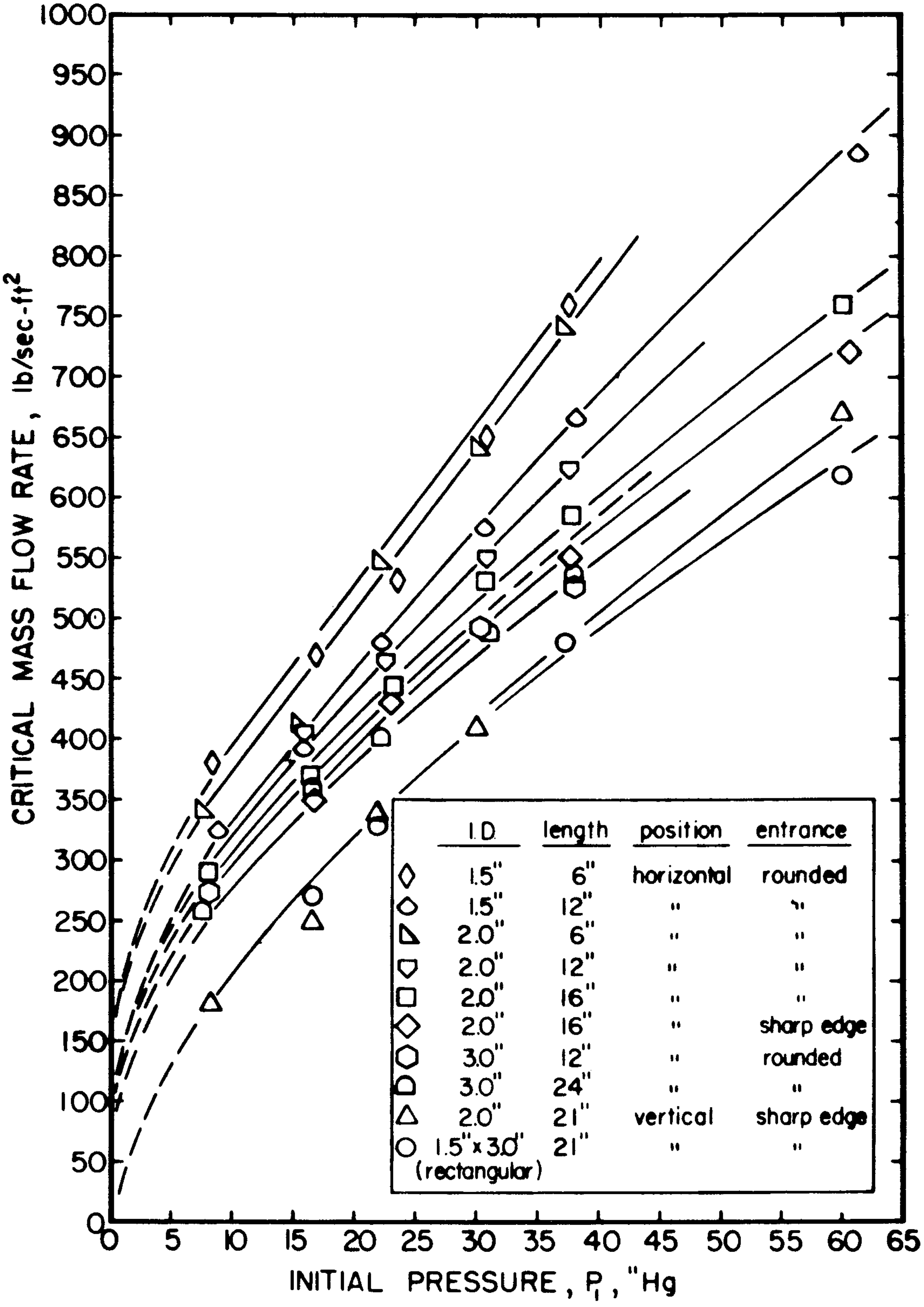


FIG. 19, CRITICAL MASS FLOW RATE OF TWO PHASE FLUID

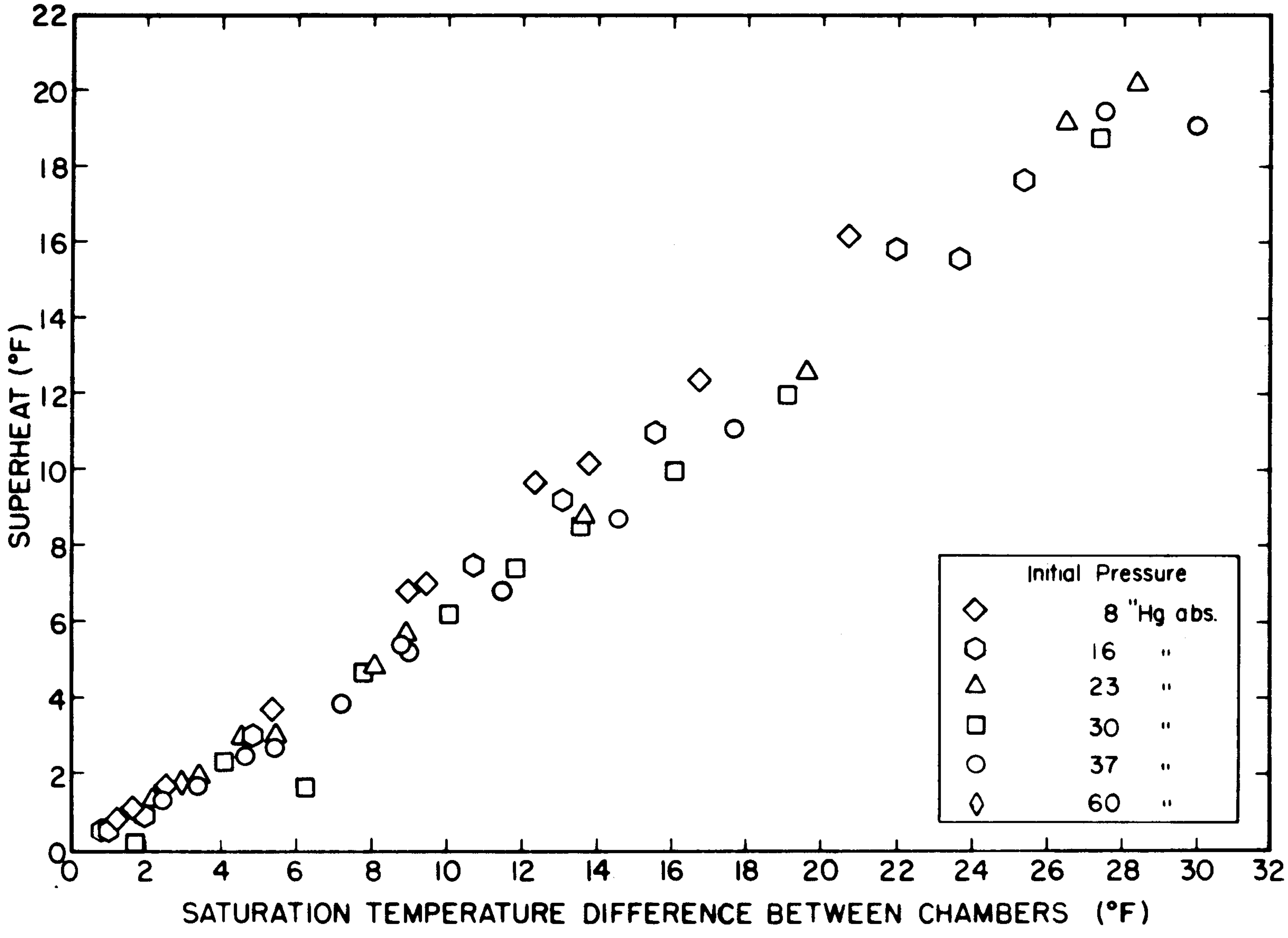


FIG. 20, RESIDUAL HEAT FOR 1.5" I.D.-6" L. TUBE WITH ROUNDED ENTRANCE

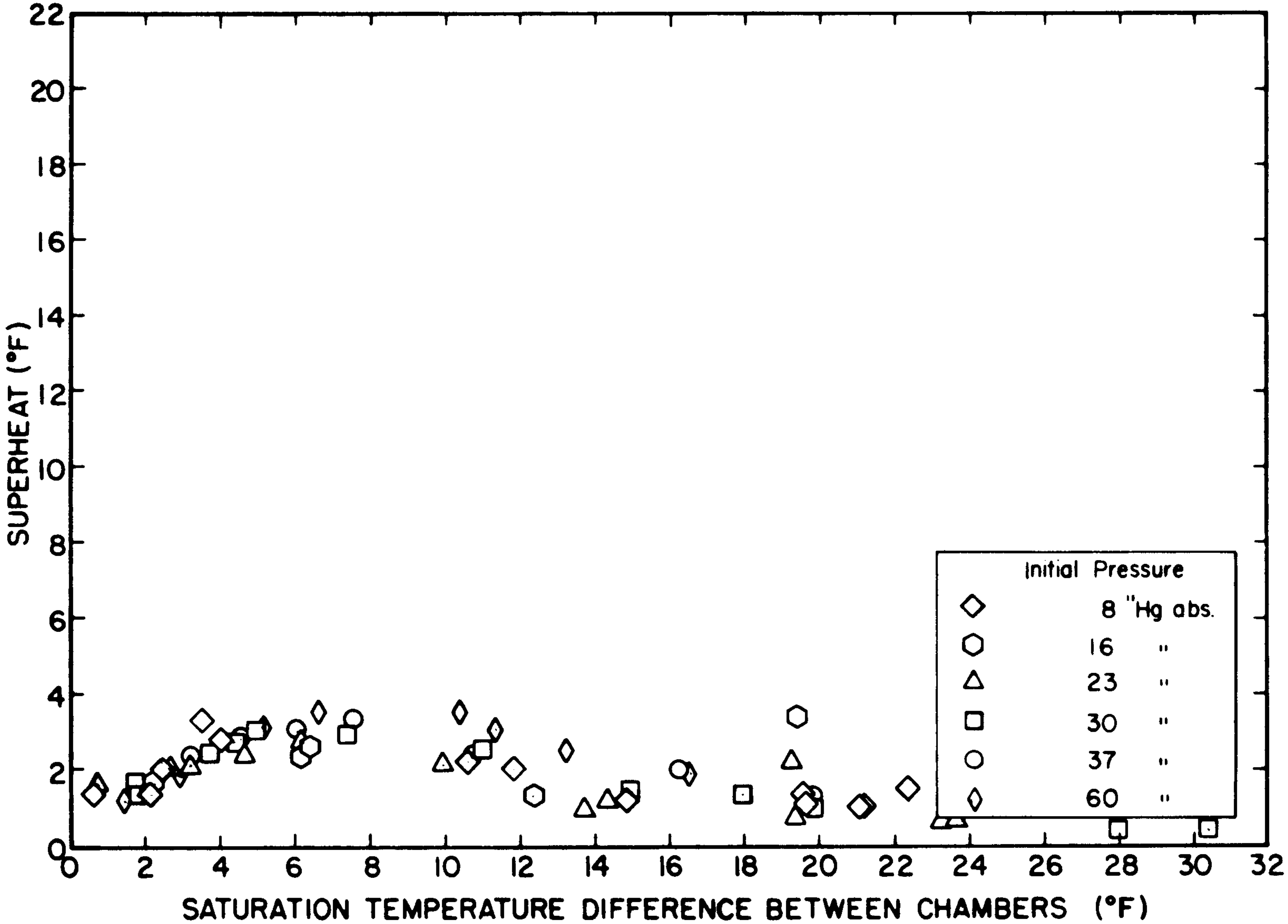


FIG. 21, RESIDUAL HEAT FOR 15" I.D.–12" L. TUBE WITH ROUNDED ENTRANCE

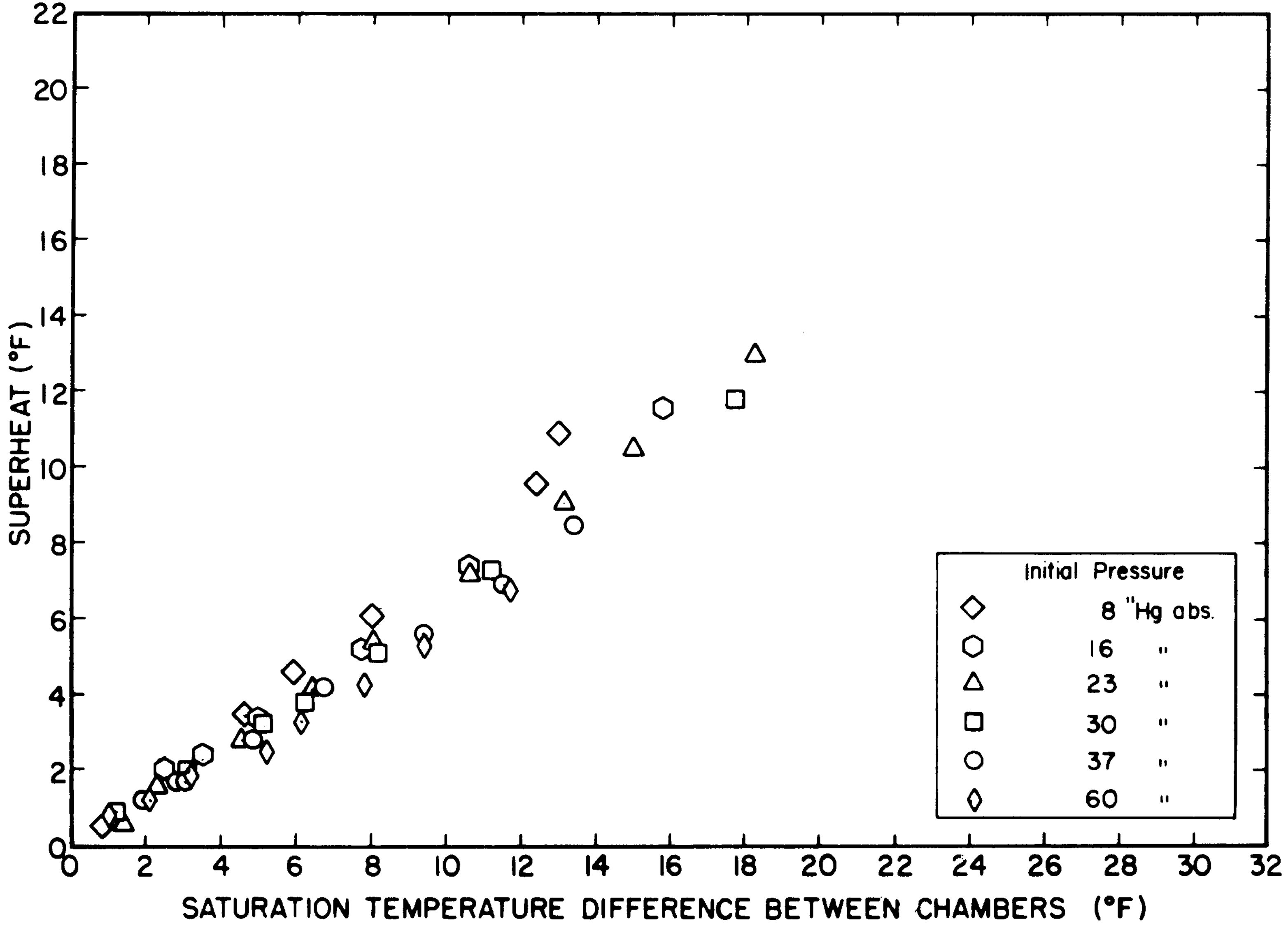


FIG. 22, RESIDUAL HEAT FOR 2" I.D.-6" L. TUBE WITH ROUNDED ENTRANCE

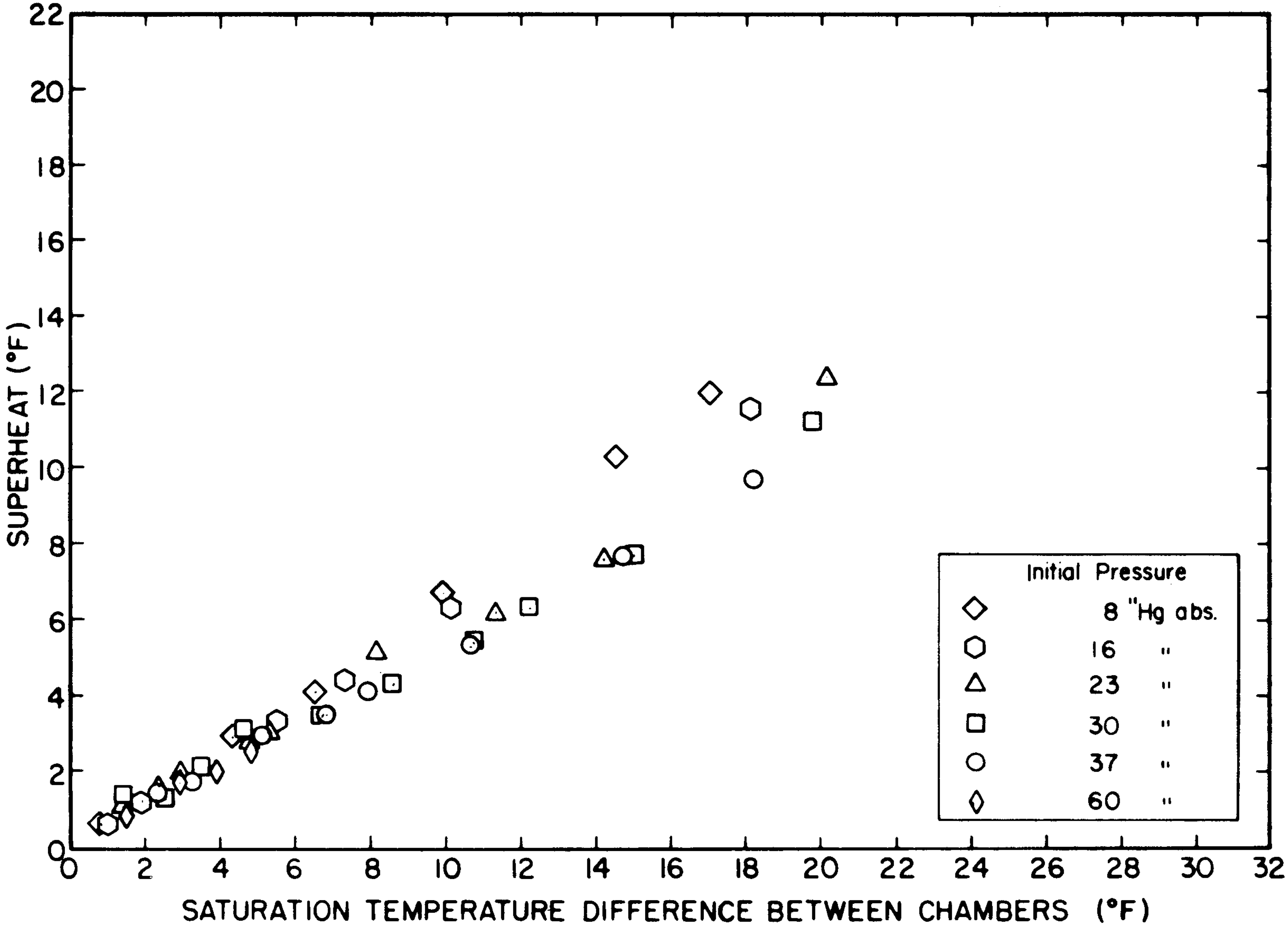


FIG. 23, RESIDUAL HEAT FOR 2" I.D.–12" L. TUBE WITH ROUNDED ENTRANCE

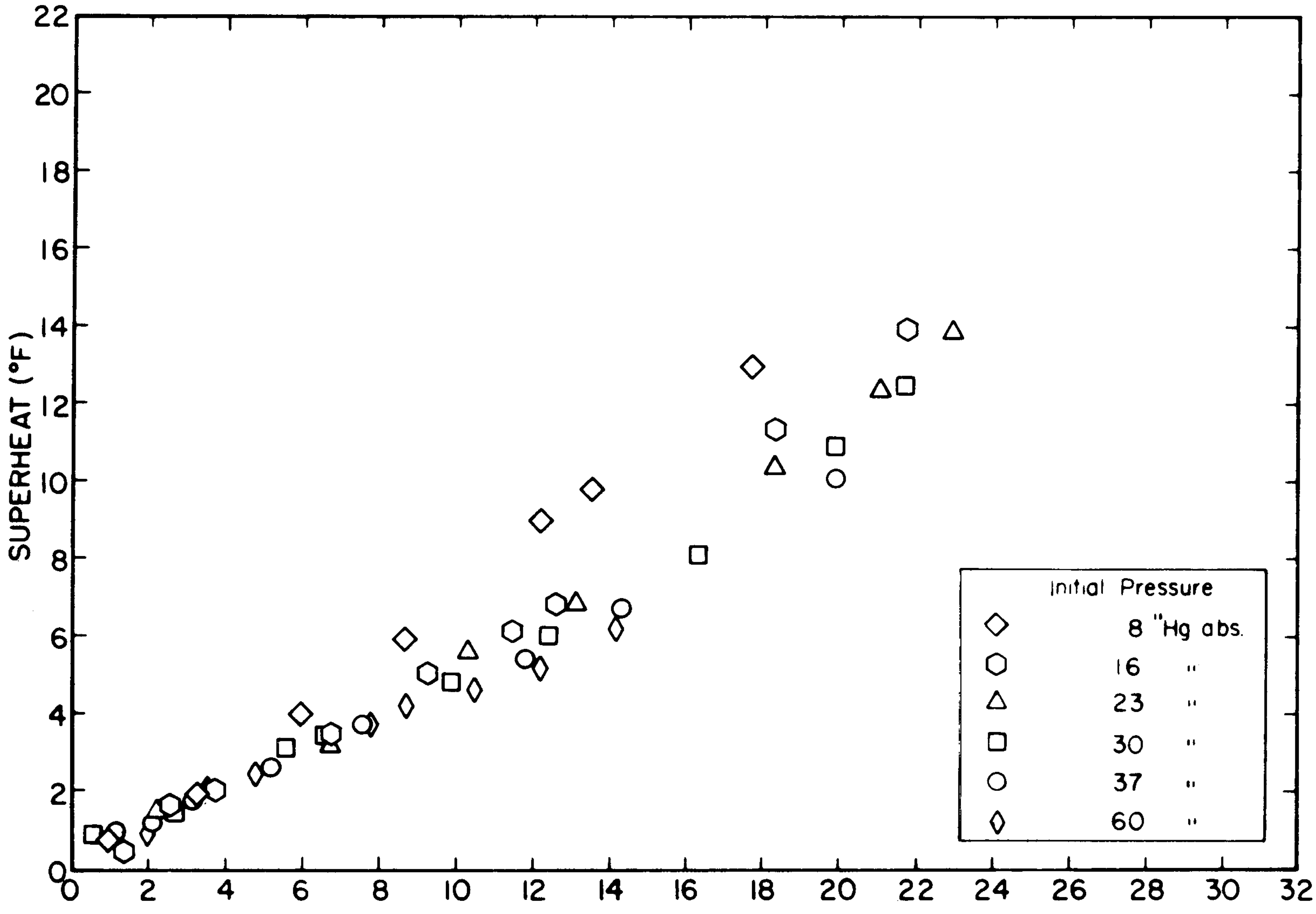


FIG. 24, RESIDUAL HEAT FOR 2" I.D.–16" L. TUBE WITH ROUNDED ENTRANCE

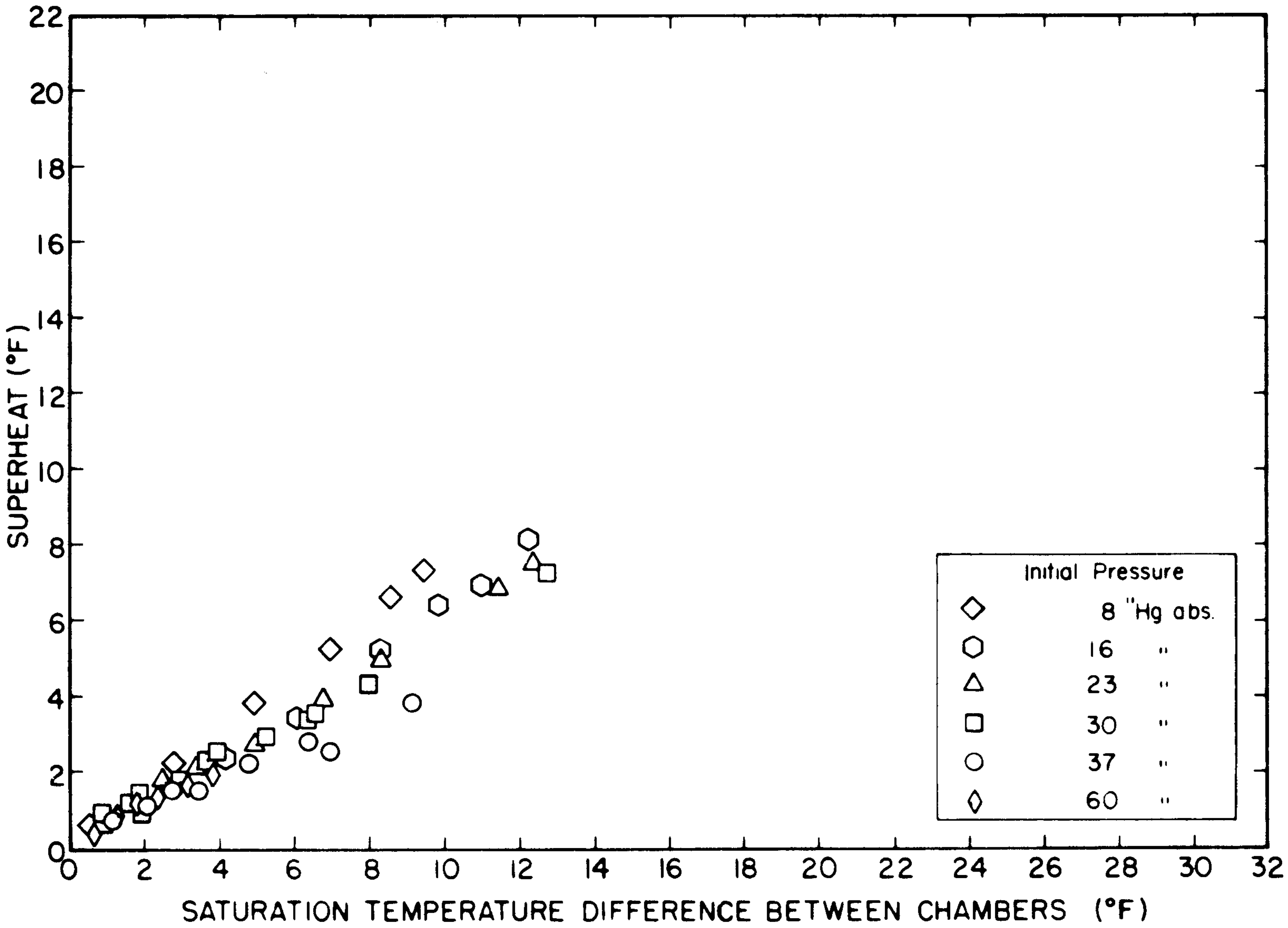


FIG. 25, RESIDUAL HEAT FOR 3" I.D.— 12" L. TUBE WITH ROUNDED ENTRANCE

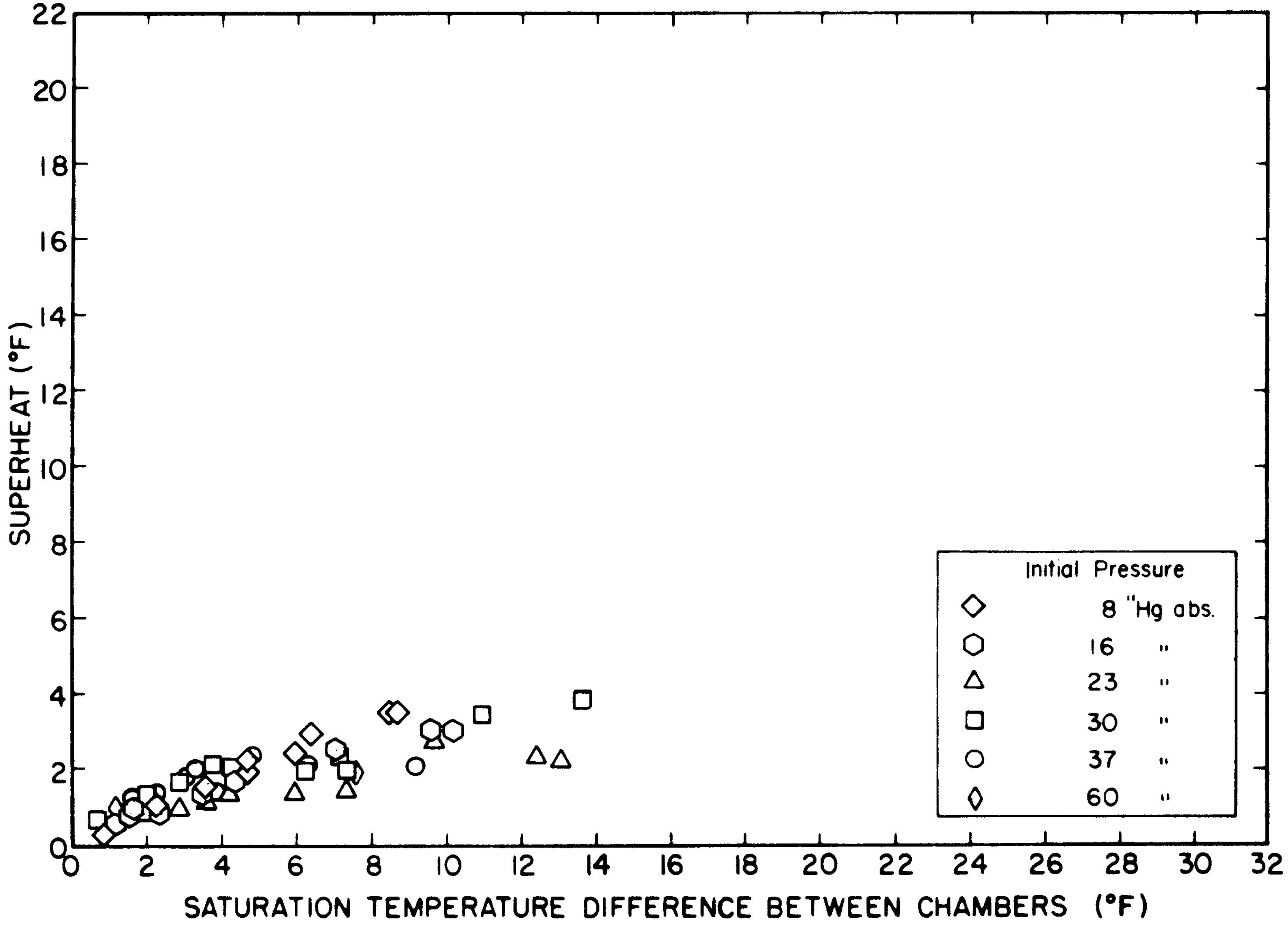


FIG. 26, RESIDUAL HEAT FOR 3" I.D.—24" L. TUBE WITH ROUNDED ENTRANCE

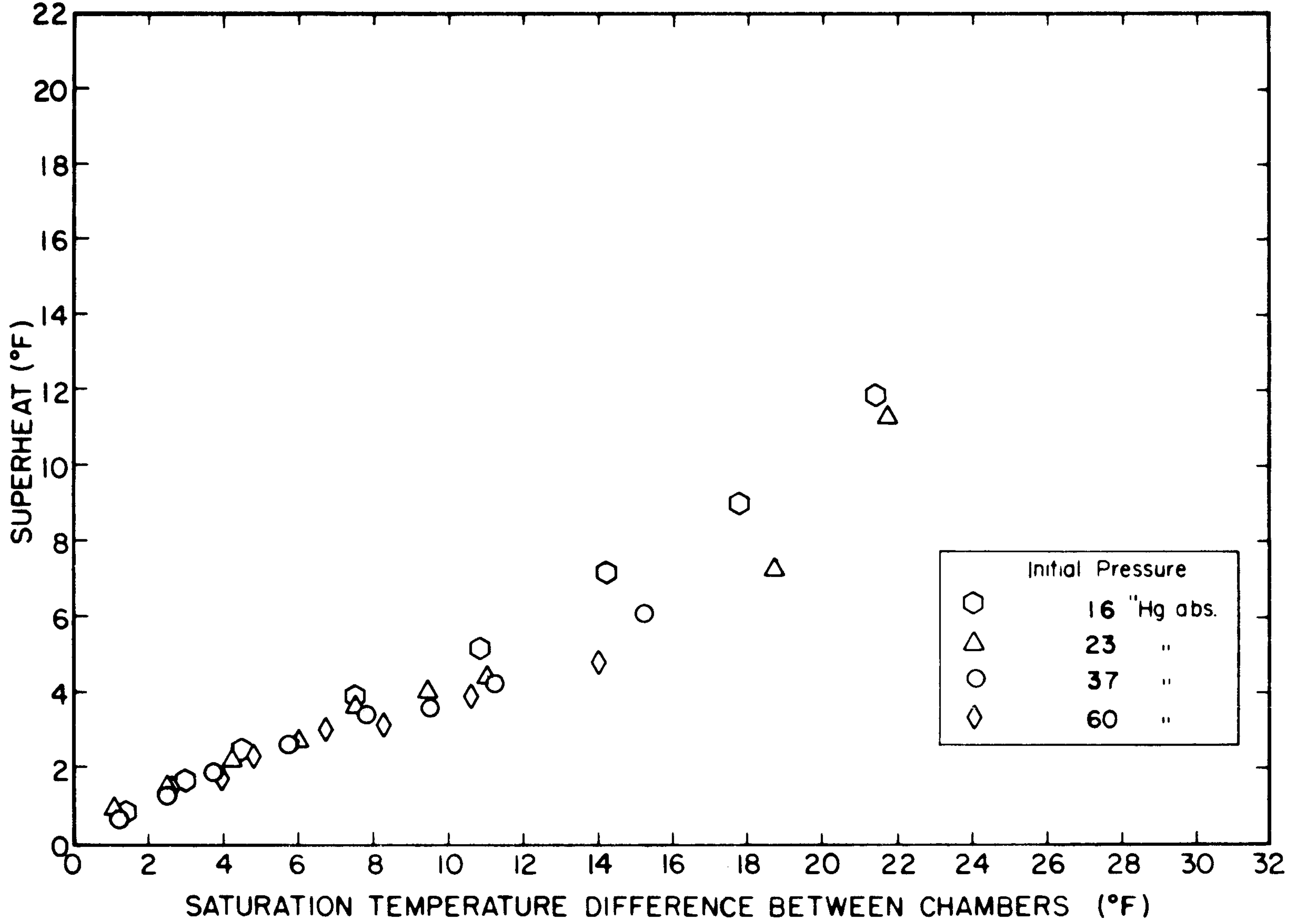


FIG. 27, RESIDUAL HEAT FOR 2" I.D.–16" L. TUBE WITH SHARP ENTRANCE

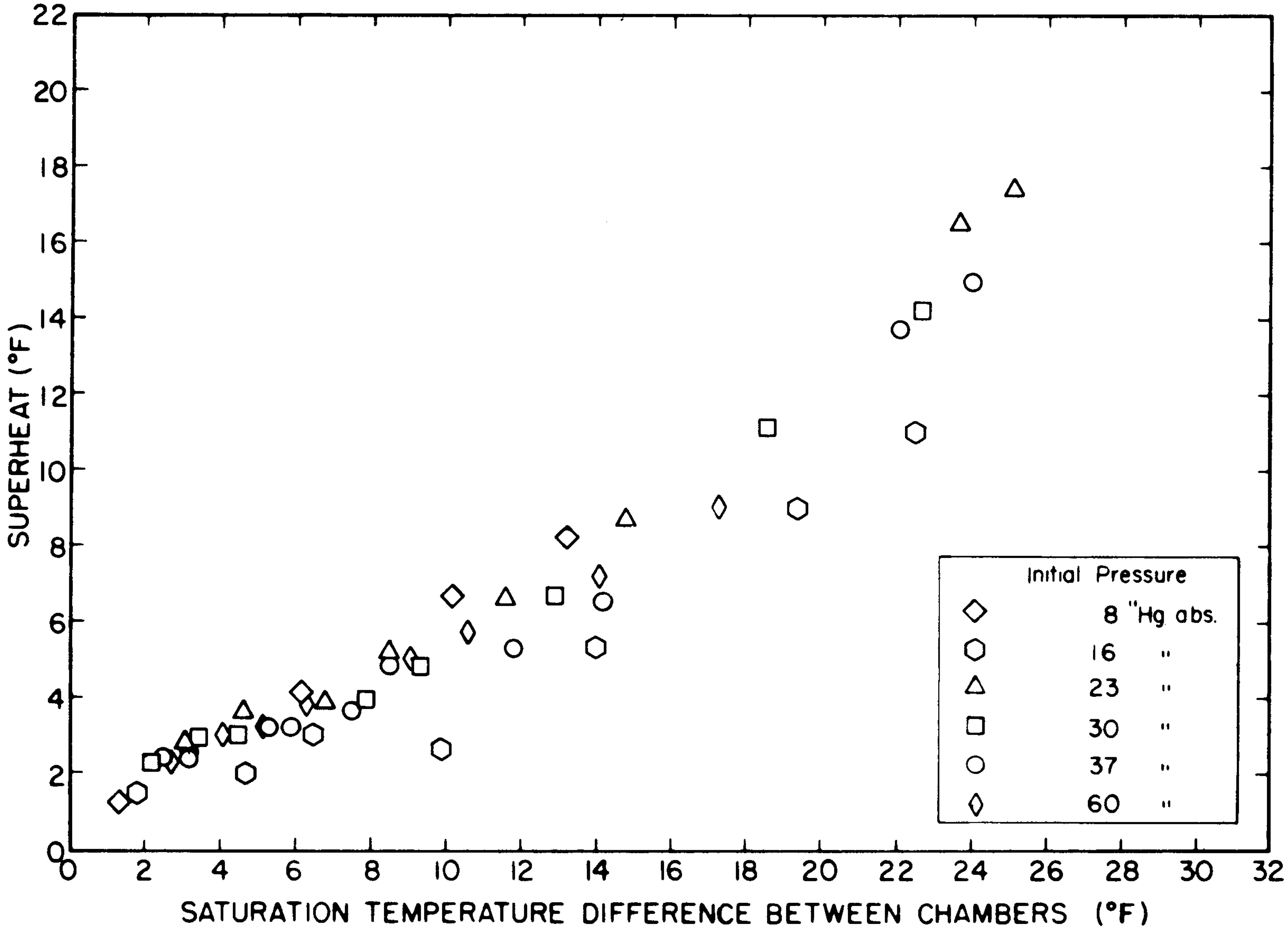


FIG. 28, RESIDUAL HEAT FOR 2" I.D.—21" L. TUBE WITH SHARP ENTRANCE

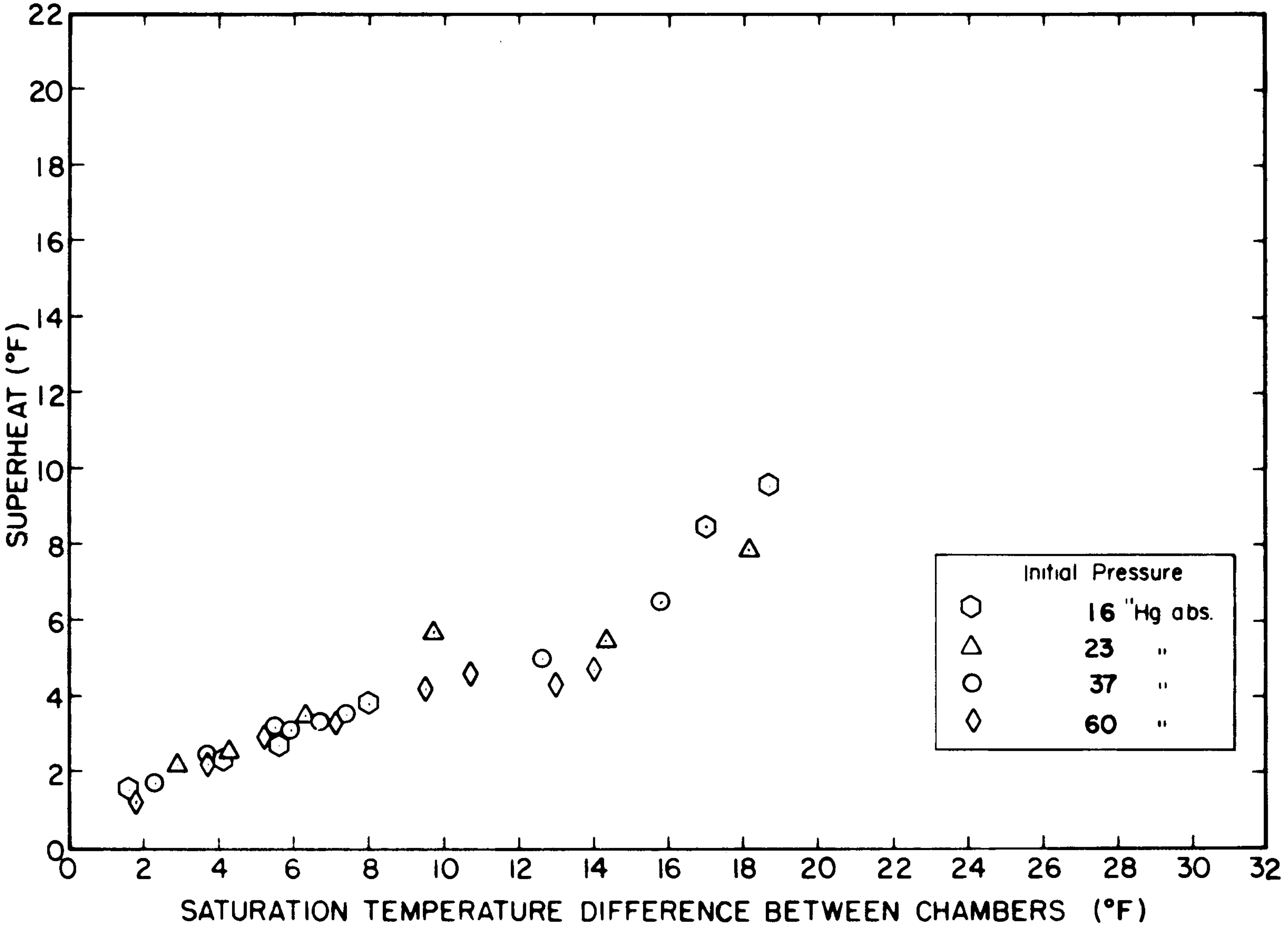


FIG. 29, RESIDUAL HEAT FOR 1.5"x3"—21" L. RECTANGULAR DUCT

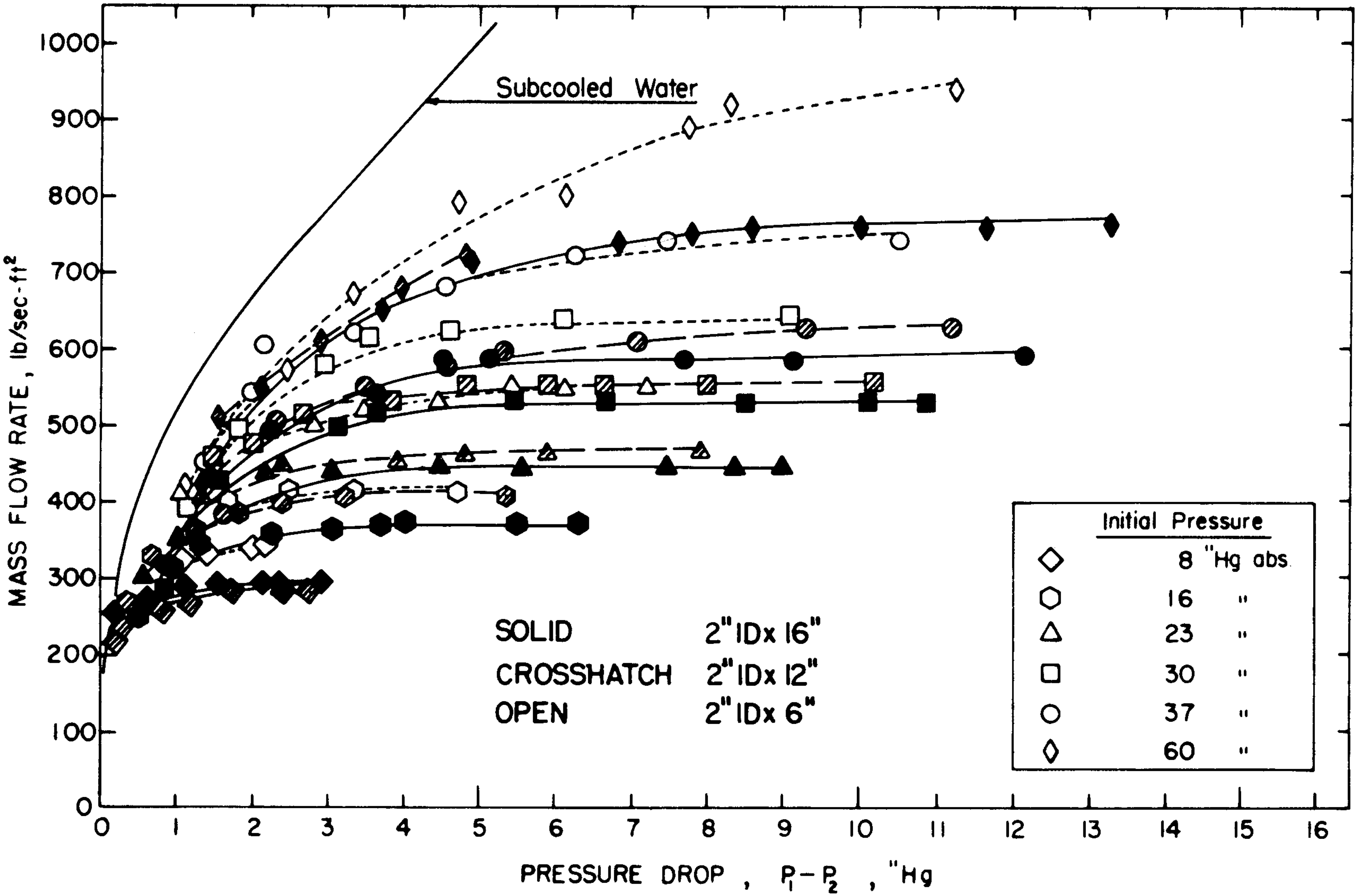


FIG. 30, COMPARISON OF MASS FLOW RATES FOR 2" I.D. TUBES

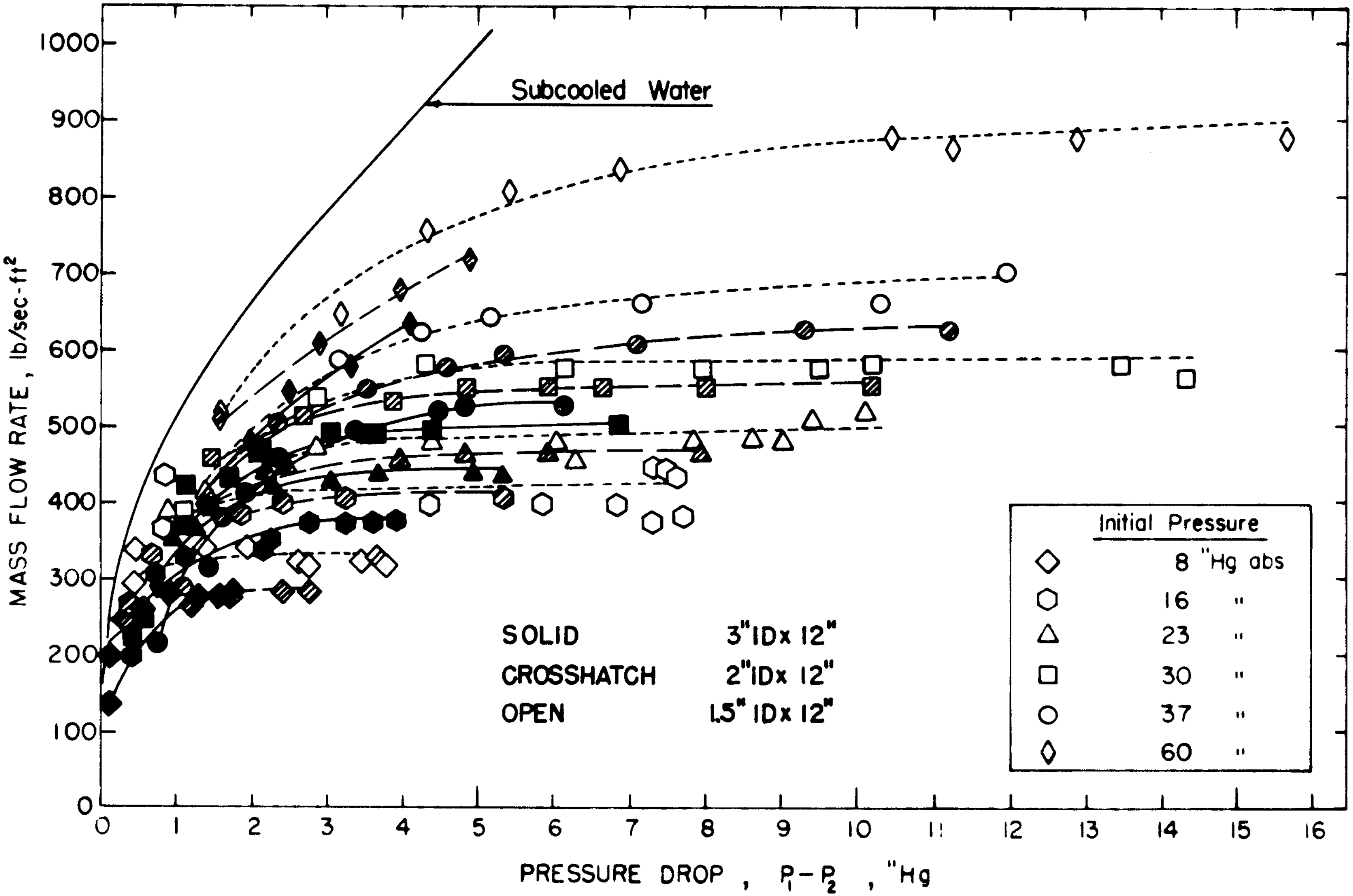


FIG. 31, COMPARISON OF MASS FLOW RATES FOR 12" LONG TUBES

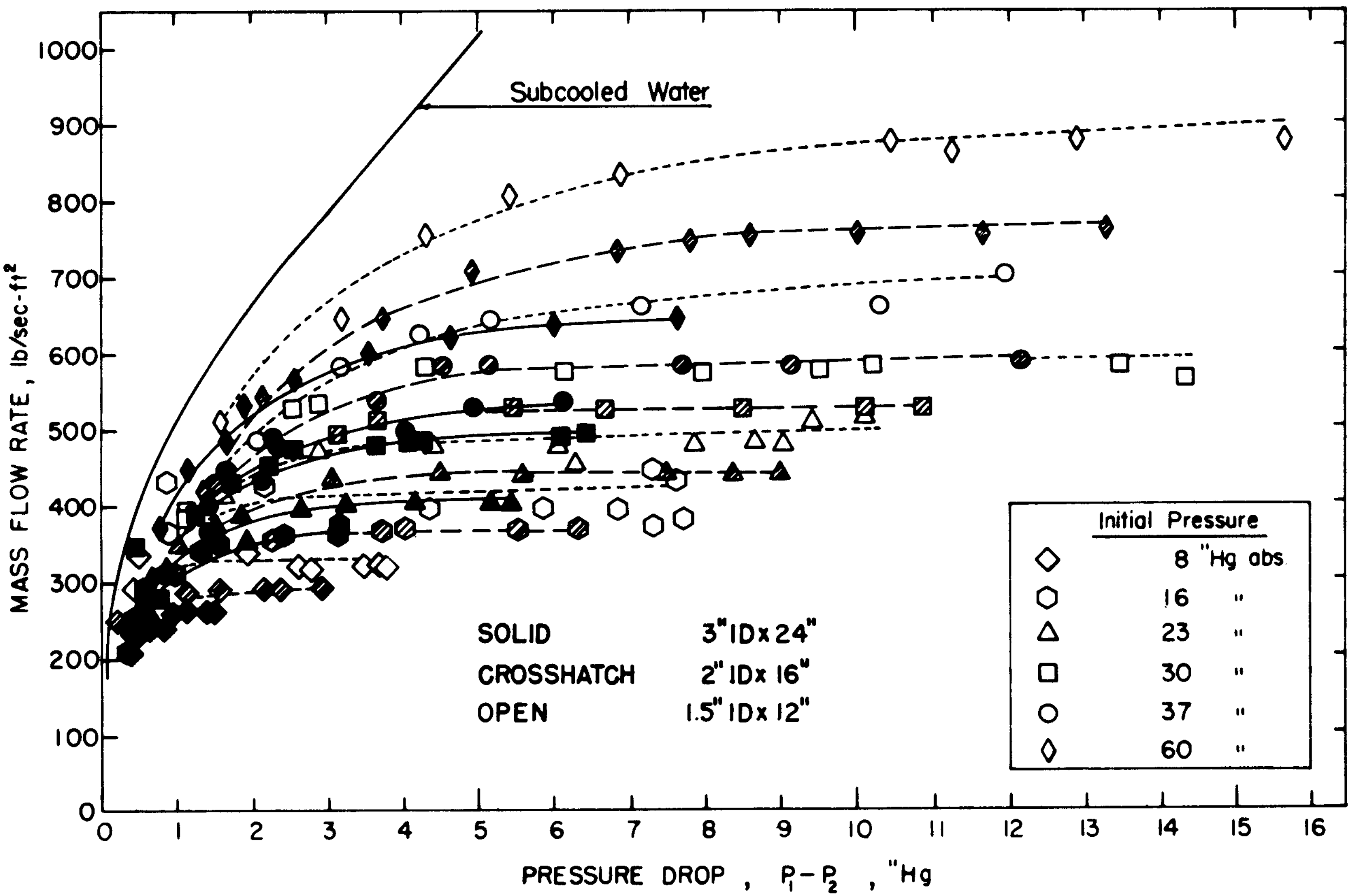


FIG. 32, COMPARISON OF MASS FLOW RATES FOR L/D = 8 TUBES

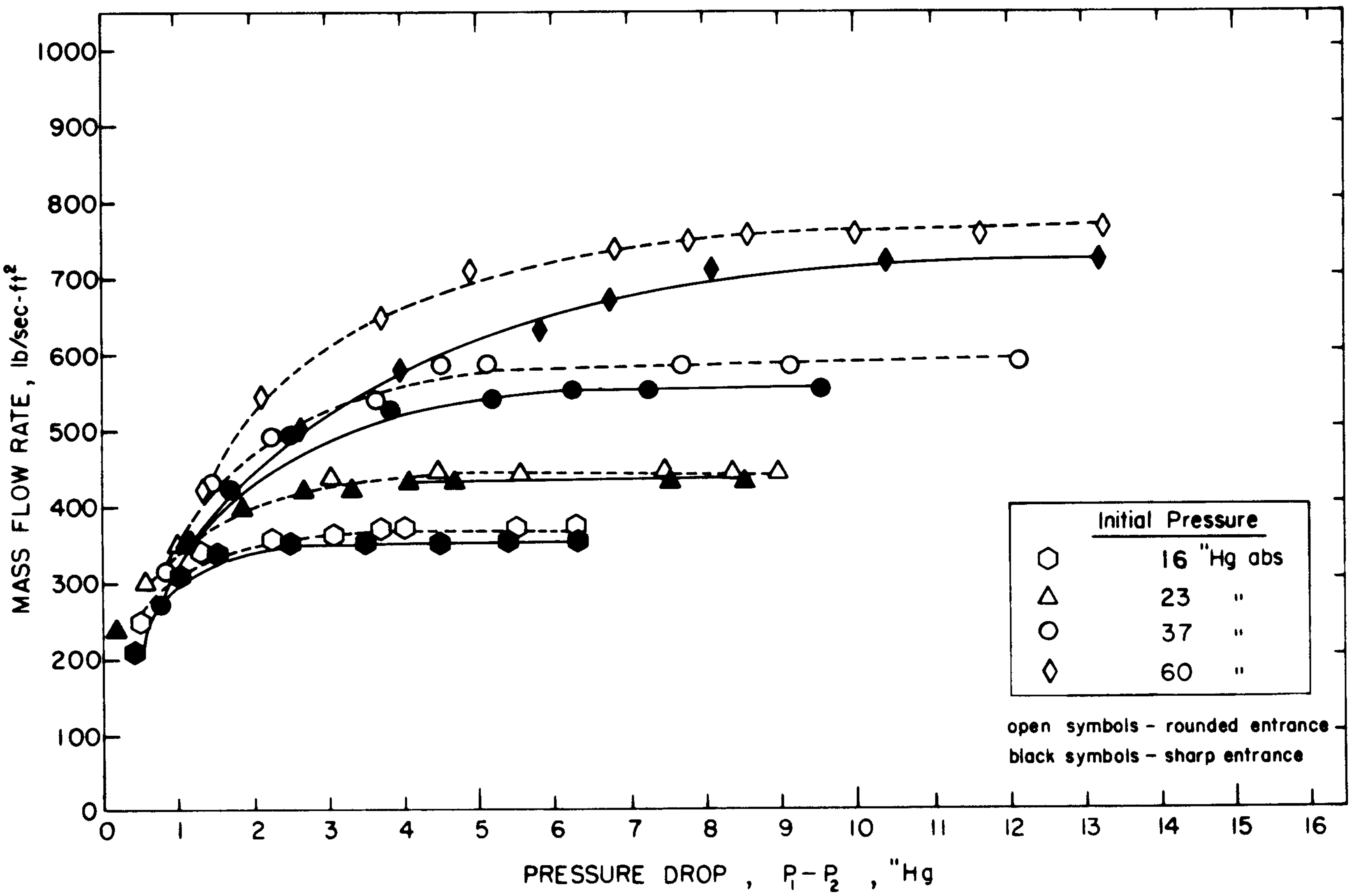


FIG. 33, COMPARISON OF MASS FLOW RATES FOR 2" ID x 16" TUBES WITH DIFFERENT ENTRANCES

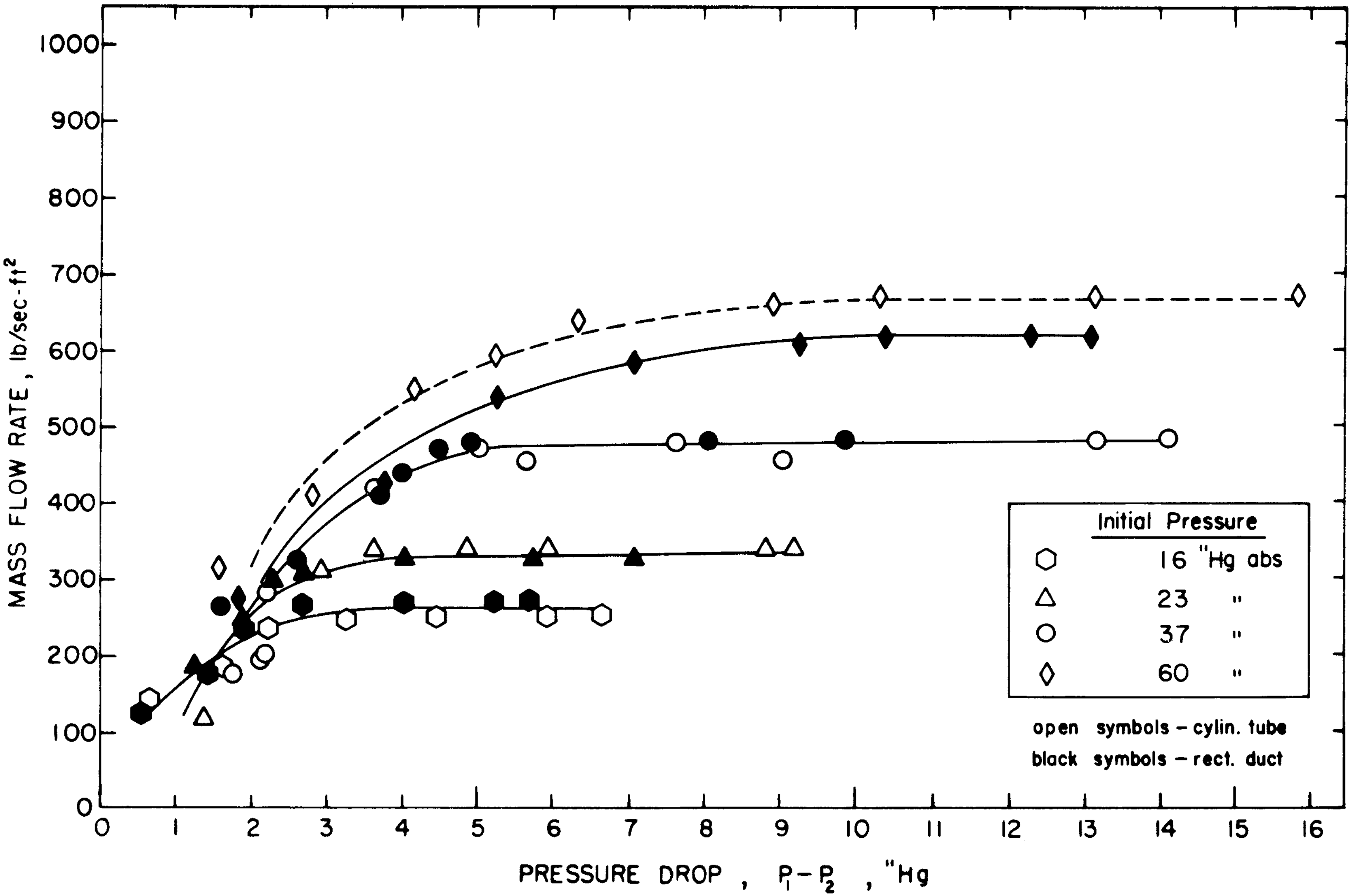
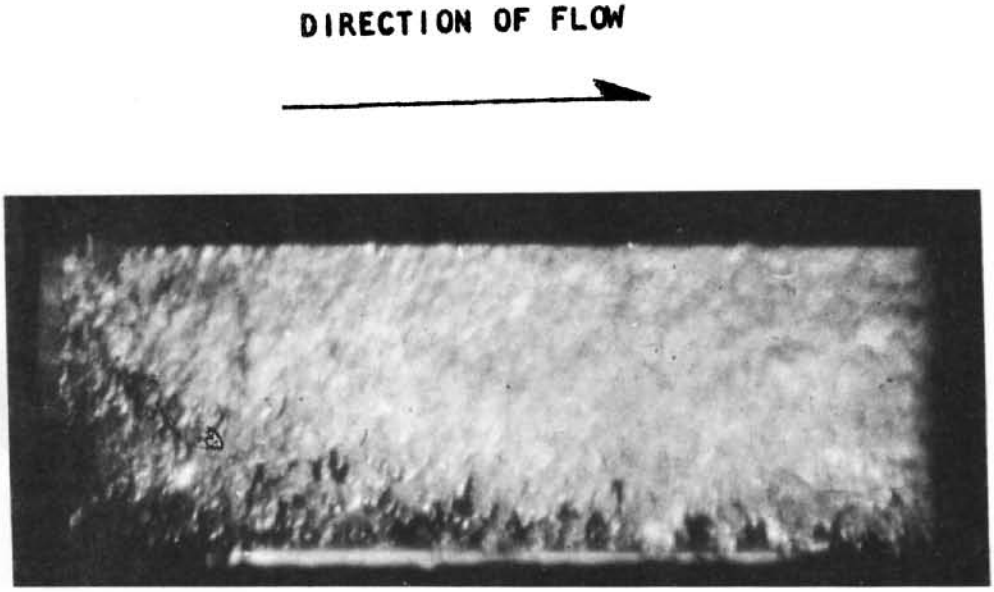


FIG. 34, COMPARISON OF MASS FLOW RATES OF CYLINDRICAL TUBE AND RECTANGULAR DUCT



Tube Dimension: 3" I.D. x 24" L

Position: Horizontal

Entrance Condition: 1/4" Rounded Edge

Location of Exposure: 3/4" From The Tube Entrance

Initial Pressure: 20.2" Hg.

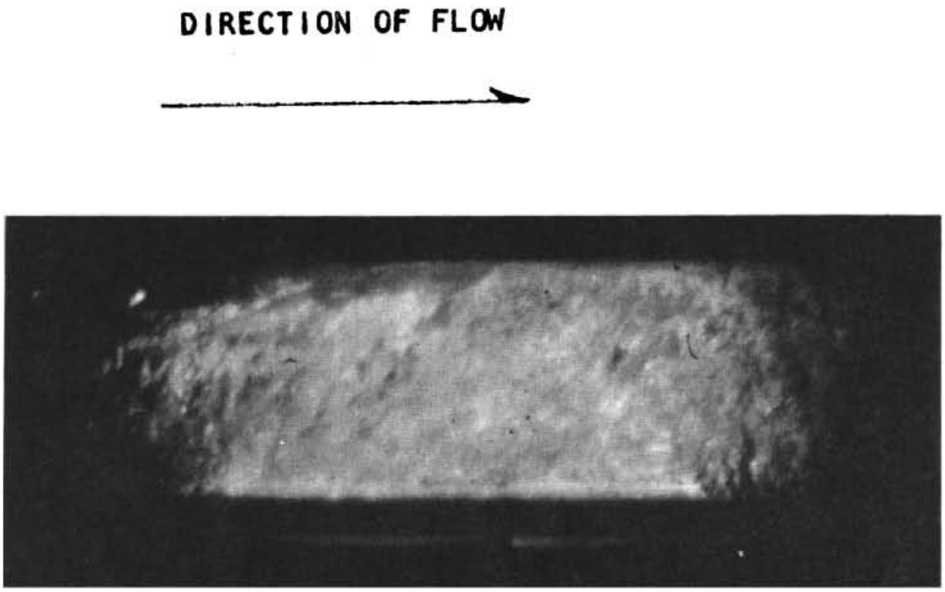
Pressure Differential: 8.1" Hg.

Temperature at Tube Inlet: 192.8°F

Mass Flow Rate: 400 lb/sec-ft.^{2}

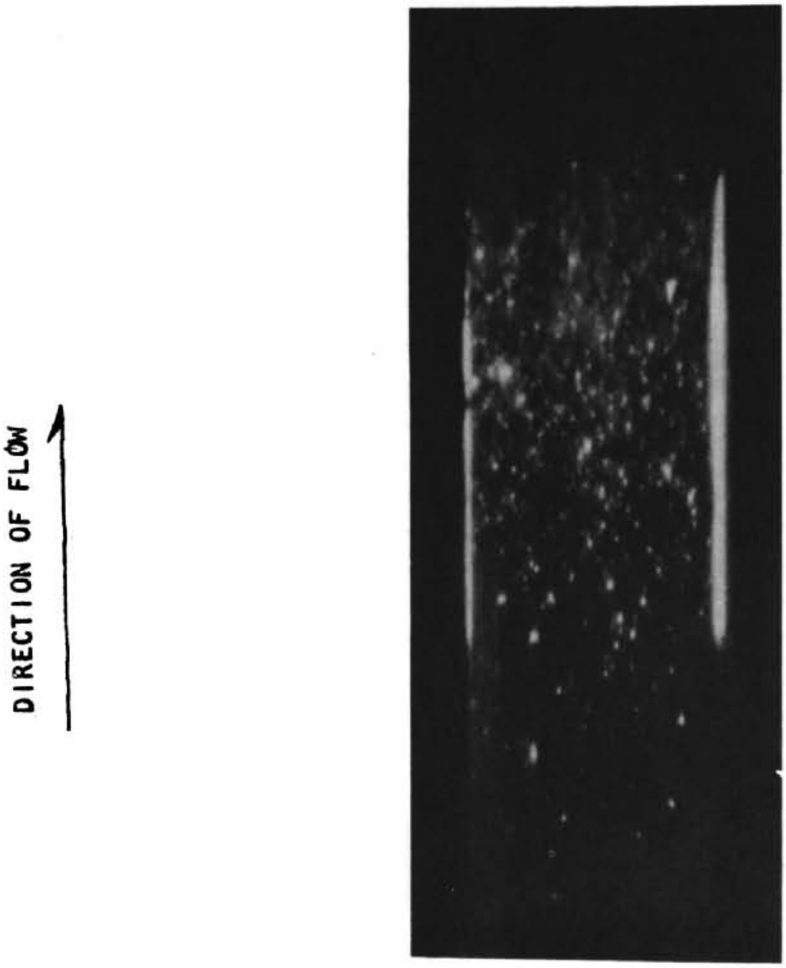
Rate of Exposure: 2000 Frames Per Second

FIGURE 35 - Flow Pattern Near Entrance Of 3" I.D. x 24" L Tube.



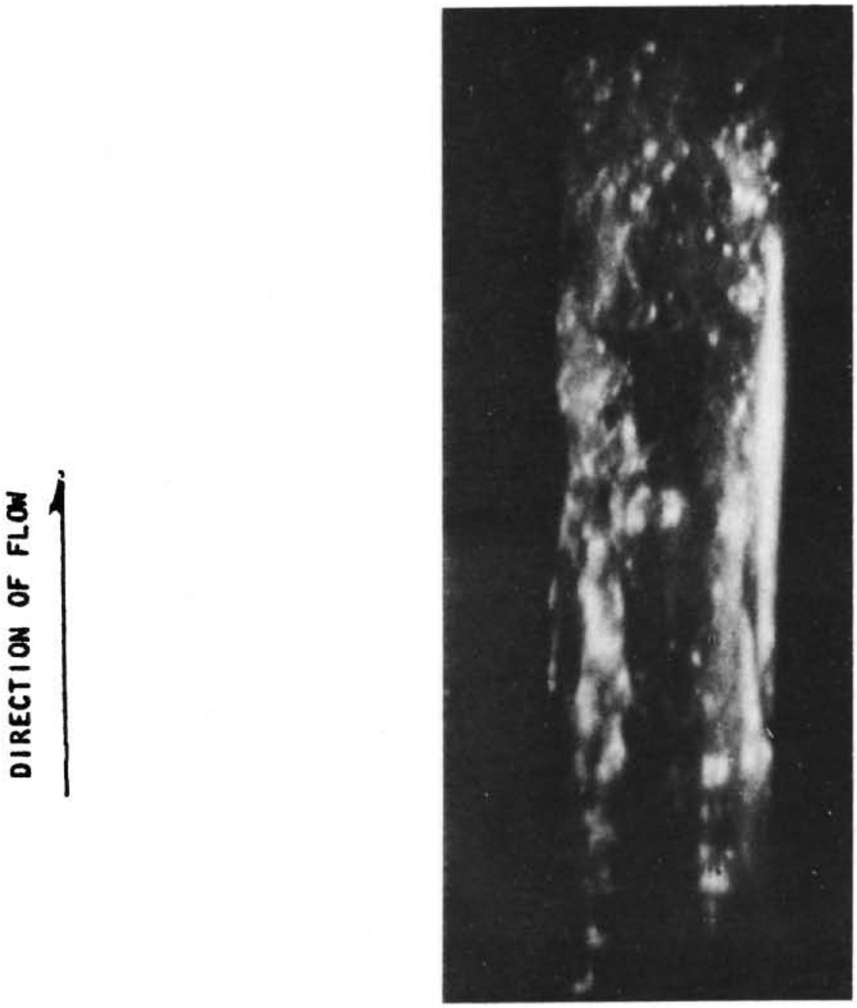
Tube Dimension:	2" I.D. x 16" L
Position:	Horizontal
Entrance Condition:	Sharp Edge
Location of Exposure:	3/4" From The Tube Entrance
Initial Pressure:	30.4" Hg.
Pressure Differential:	4.7" Hg.
Temperature at Tube Inlet:	212.5°F
Mass Flow Rate:	485 lb/sec.-ft.^{2}
Rate of Exposure:	2000 Frames Per Second

FIGURE 36 - Flow Pattern Near Entrance Of 2" I.D. x 16" L Tube.



Tube Dimension:	2" I.D. x 21" L
Position:	Vertical
Entrance Condition:	Sharp Edge
Location of Exposure:	3/4" From The Tube Entrance
Initial Pressure:	8.75" Hg.
Pressure Differential:	2.7"Hg.
Temperature at Tube Inlet:	155.9°F
Mass Flow Rate:	192 lb/sec.-ft.^{2}
Rate of Exposure:	2000 Frames Per Second

FIGURE 37 - Flow Pattern Near Entrance Of 2" I.D. x 21"L Tube Under Low Initial Pressure.



Tube Dimension:	2" I.D. x 21" L
Position:	Vertical
Entrance Condition:	Sharp Edge
Location of Exposure:	3/4" From The Tube Entrance
Initial Pressure:	59.8" Hg.
Pressure Differential:	3.51" Hg.
Temperature at Tube Inlet:	249.1°F
Mass Flow Rate:	475 lb/sec.-ft.^{2}
Rate of Exposure:	2000 Frames Per Second

FIGURE 38 - Flow Pattern Near Entrance Of 2" I.D. x 21" L Tube Under High Initial Pressure.

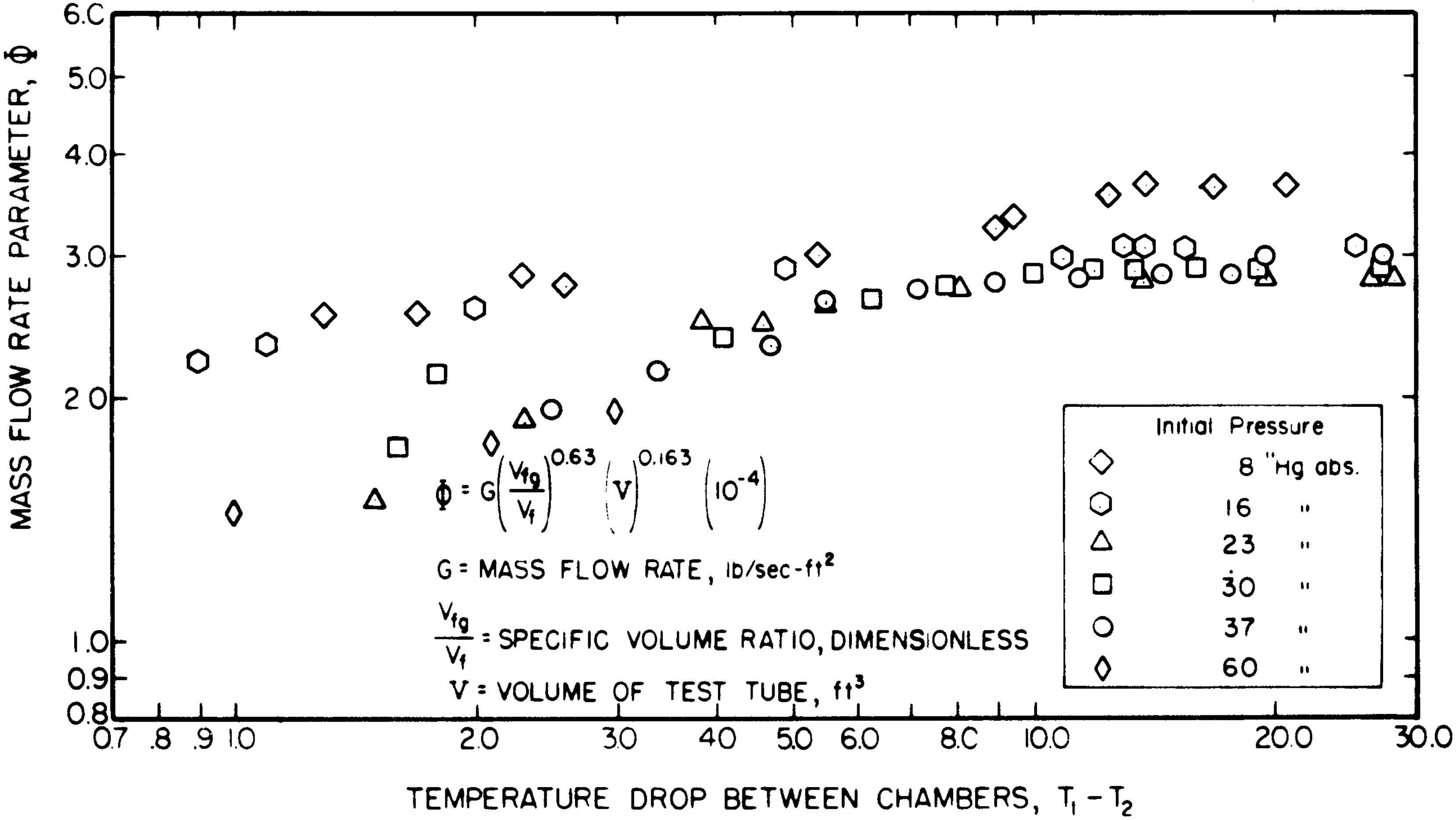


FIG. 39, CORRELATION OF RESULTS FOR $1\frac{1}{2}$" I.D. – 6" L. TUBE

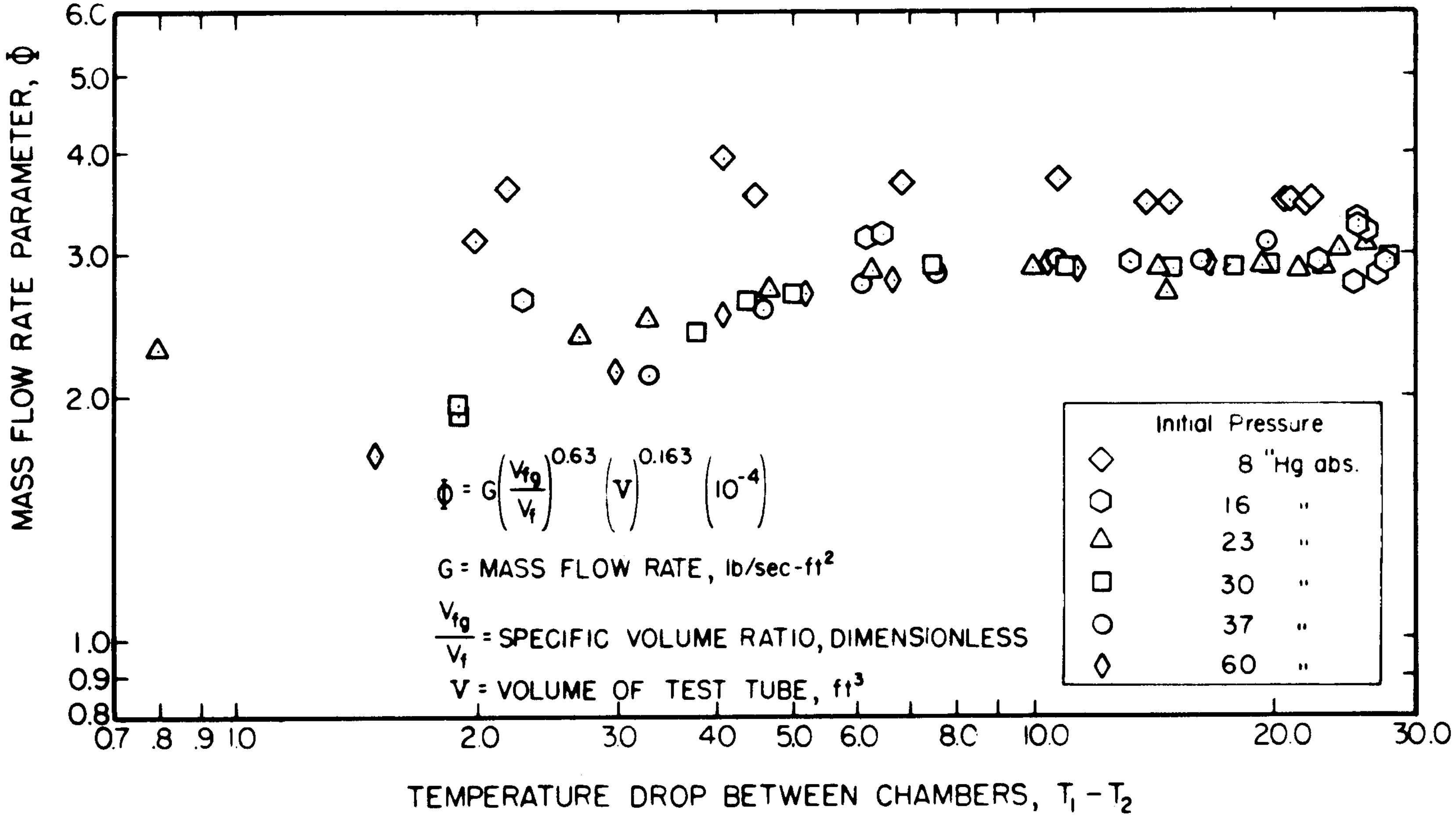


FIG. 40, CORRELATION OF RESULTS FOR $1\frac{1}{2}''$ I.D. – 12" L. TUBE

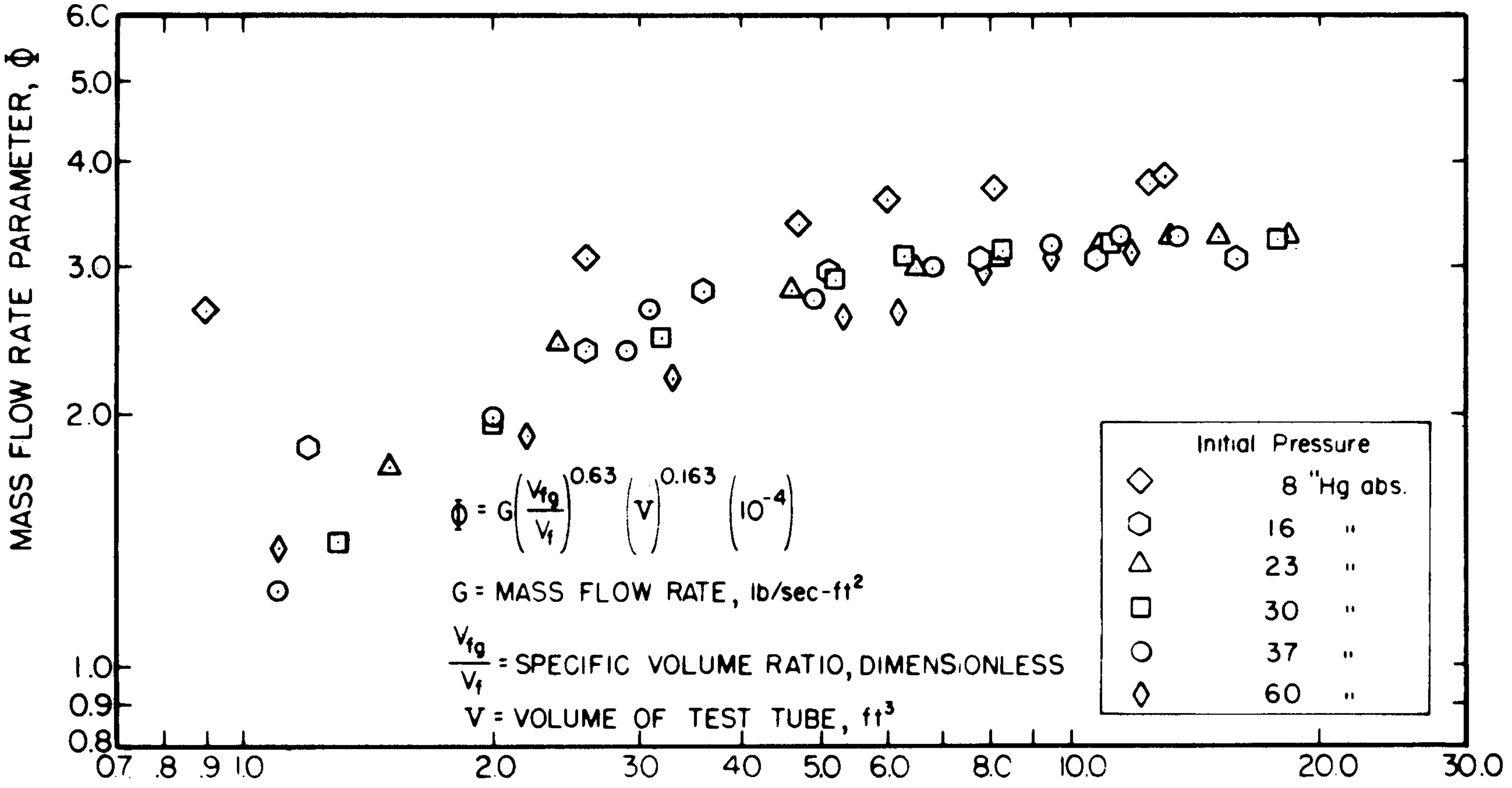


FIG.41, CORRELATION OF RESULTS FOR 2" I.D. – 6" L. TUBE

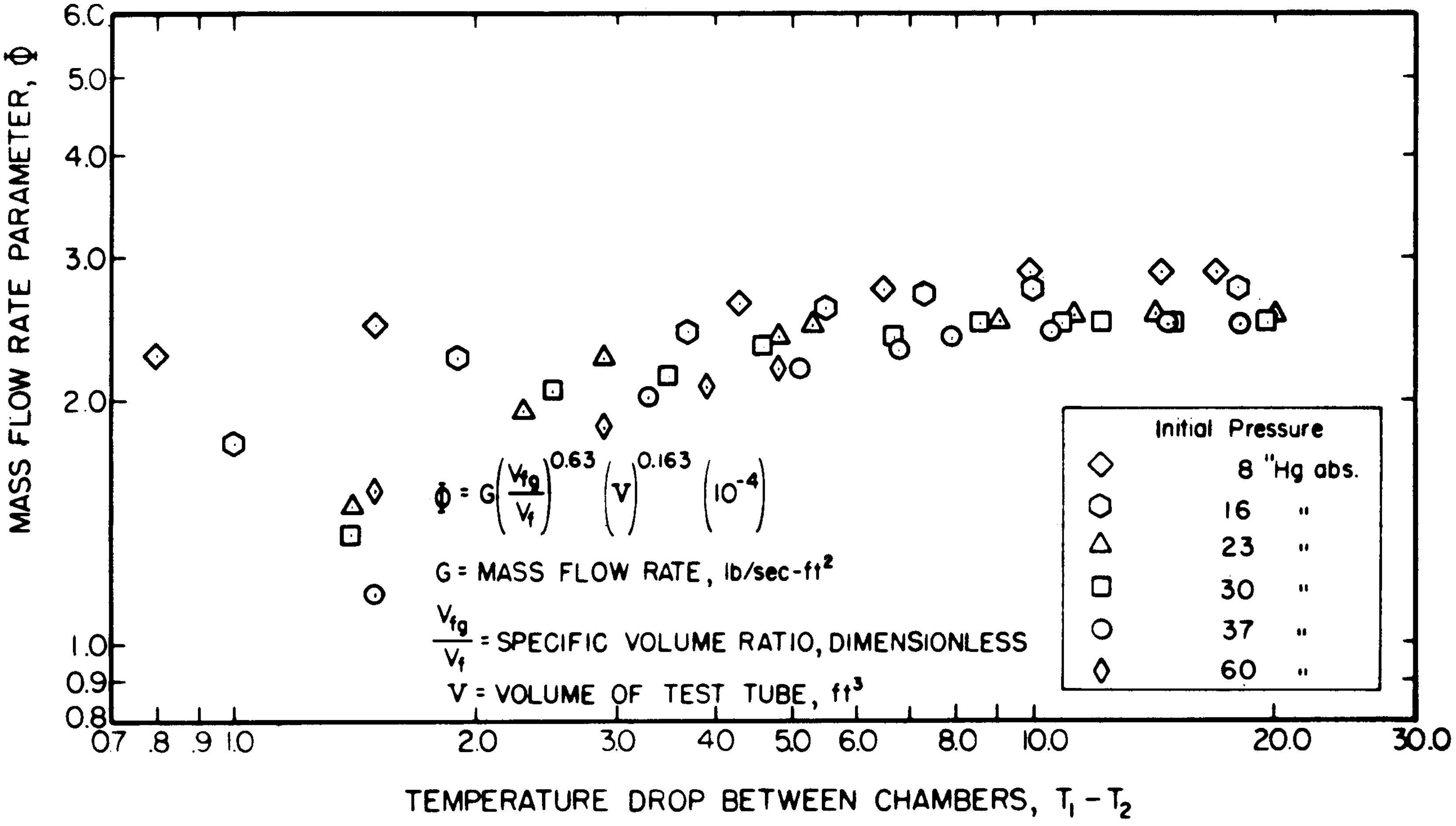


FIG. 42, CORRELATION OF RESULTS FOR 2" I.D. – 12" L. TUBE

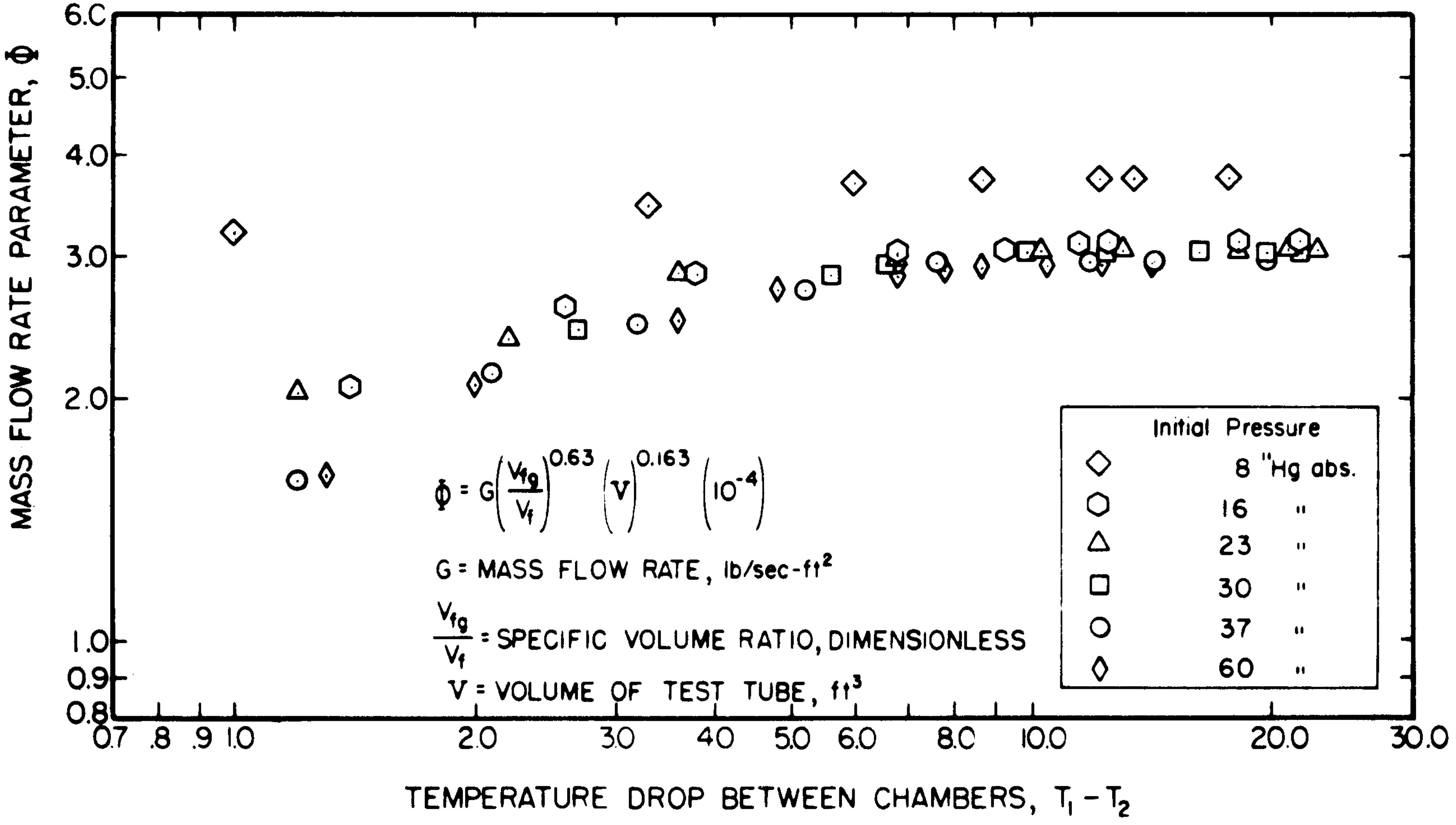


FIG. 43, CORRELATION OF RESULTS FOR 2" I.D.-16" L. TUBE

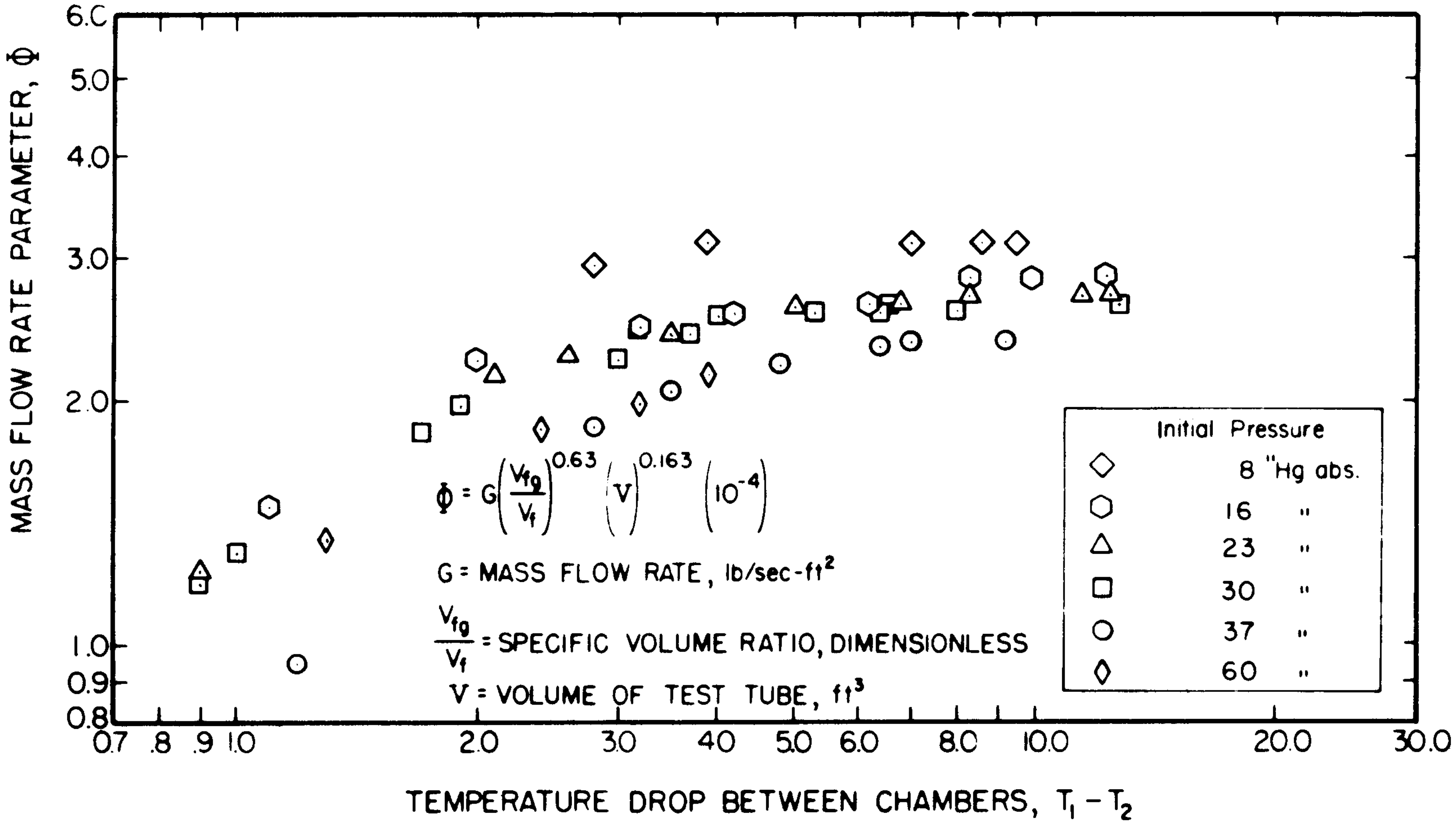


FIG. 44, CORRELATION OF RESULTS FOR 3"I.D.-12"L. TUBE

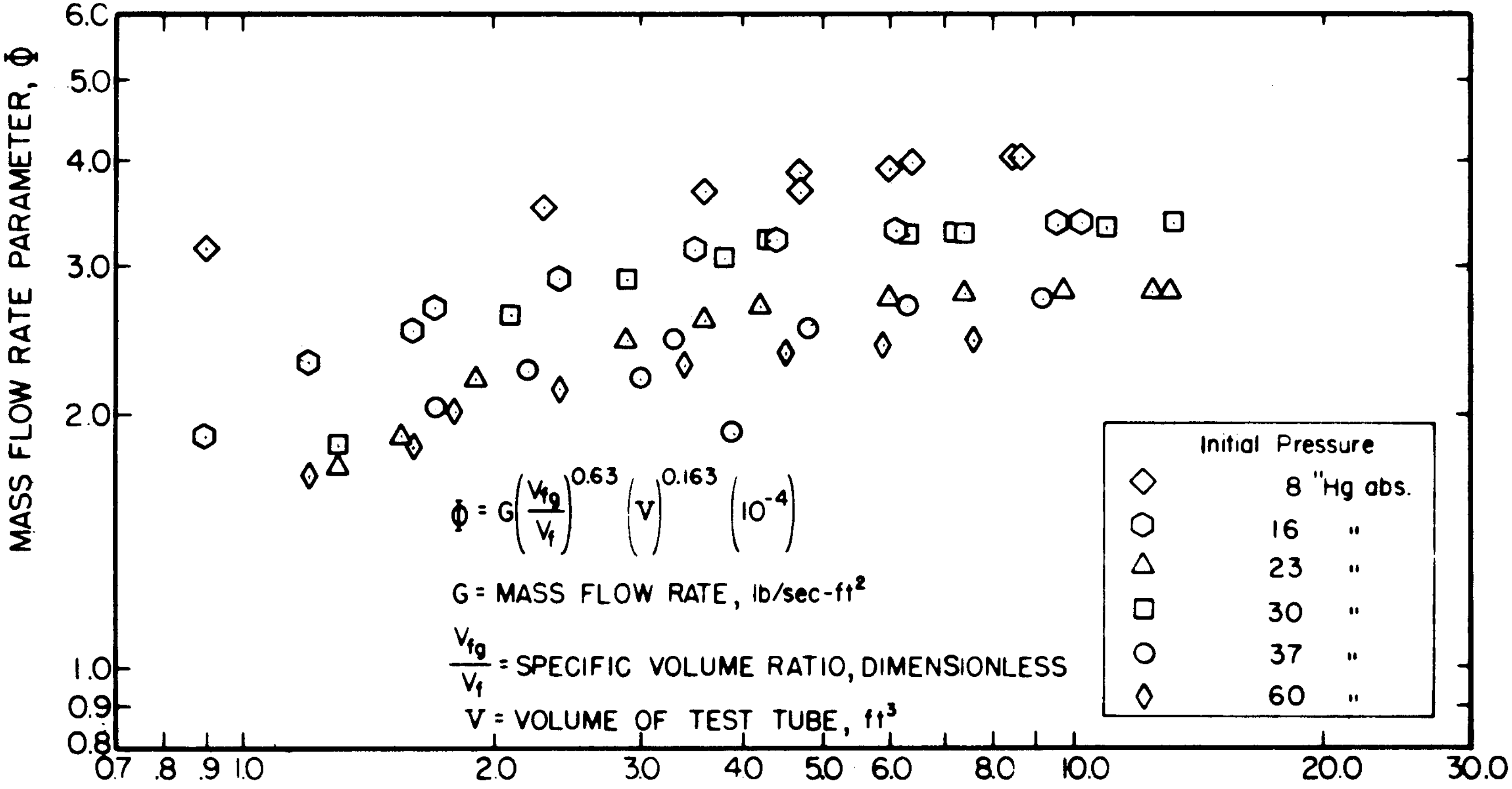


FIG. 45, CORRELATION OF RESULTS FOR 3" I.D. – 24" L. TUBE

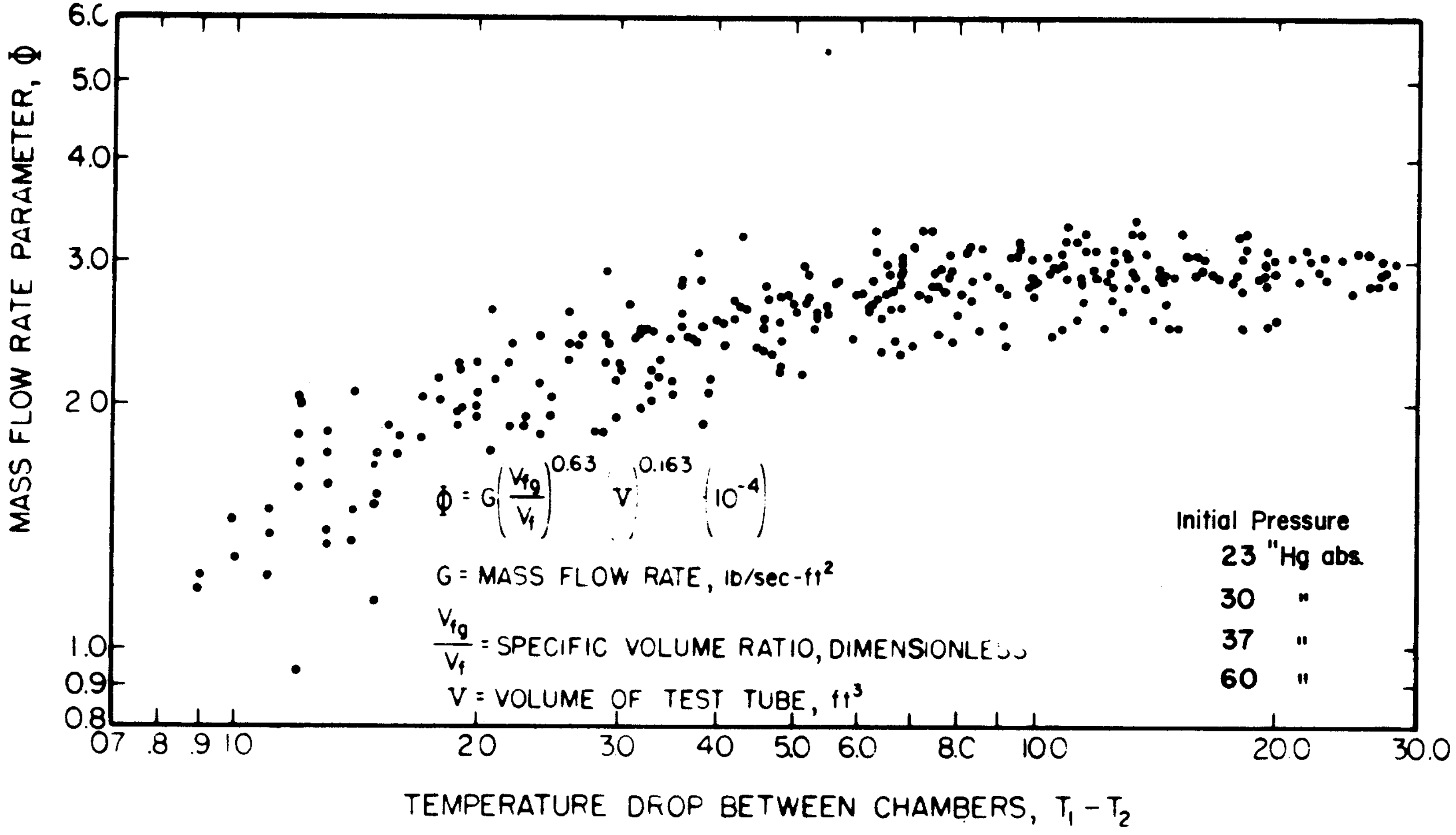


FIG. 46, CORRELATION OF RESULTS FOR HORIZONTAL TUBES WITH ROUNDED ENTRANCE

APPENDIX

SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 031466

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.08 Inches Hg

POSITION Horizontal LENGTH 6 Inches DIAMETER 1.5 Inches

TEST	1	2	3	4									
1 Pressure Tank #1 In. Hg	8.31	8.33	8.29	8.33									
2 Pressure Differential In. Hg	0.34	0.52	1.66	2.44									
3 Temperature Tank #1 °F	153.8	153.9	153.7	153.9									
4 Temperature Tank #2 °F	152.1	151.3	144.7	140.1									
5 Temp. Test Sec. Outlet °F	153.2	153.0	151.5	150.3									
6 Flow Rate lb/sec-ft^2	258	281	329	372									
7 Water Level Tank #1 In. Water	4	4	3	3									
8 Water Level Tank #2 In. Water	10	10	10	10									
9 Superheat (5-4) °F	1.1	1.7	6.8	10.2									
10 Metastability (5-4)÷(3-4)	65	65	75	74									
11													
12													
13													
14													
15													

SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 031166

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.37 Inches Hg

POSITION Horizontal LENGTH 6 Inches DIAMETER 1.5 Inches

TEST	1	2	3	4	5	6	7							
1 Pressure Tank #1 In. Hg	8.49	8.49	8.47	8.47	8.47	8.49	8.41							
2 Pressure Differential In. Hg	0.26	1.05	0.46	1.77	2.25	2.92	3.43							
3 Temperature Tank #1 °F	154.7	154.7	154.6	154.6	154.6	154.7	154.3							
4 Temperature Tank #2 °F	153.4	149.3	152.3	145.1	142.2	137.9	133.6							
5 Temp. Test Sec. Outlet °F	154.2	153.0	153.9	152.1	151.9	150.3	149.8							
6 Flow Rate lb/sec-ft^2	263	312	295	347	372	378	382							
7 Water Level Tank #1 In. Water	3.7	2.5	2.5	4	3.2	2.7	2.5							
8 Water Level Tank #2 In. Water	4	2.5	2.5	4.5	3.5	2.5	2.5							
9 Superheat (5-4) °F	.8	3.7	1.6	7.0	9.7	12.4	16.2							
10 Metastability (5-4)÷(3-4)	62	68	69	73	78	74	78							
11														
12														
13														
14														
15														

SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 030966

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.66 Inches Hg

POSITION Horizontal LENGTH 6 Inches DIAMETER 1.5 Inches

TEST	1	2	3	4	5	6	7	8	9	10			
1 Pressure Tank #1 In. Hg	16.81	16.88	16.77	16.70	16.70	16.70	16.66	16.70	16.81	16.66			
2 Pressure Differential In. Hg	0.33	0.40	0.72	1.72	3.58	4.95	4.23	6.58	7.02	7.35			
3 Temperature Tank #1 °F	184.3	184.5	184.2	184.0	184.0	184.0	183.9	184.0	184.3	183.9			
4 Temperature Tank #2 °F	183.4	183.4	182.2	179.1	173.2	168.4	170.8	162.0	160.6	158.5			
5 Temp. Test Sec. Outlet °F	183.9	183.9	183.1	182.1	180.7	179.4	180.0	177.9	176.2	176.2			
6 Flow Rate lb/sec-ft^2	340	355	395	440	454	465	460	460	470	470			
7 Water Level Tank #1 In. Water	3.2	4.5	3.0	3.5	2.5	3.0	2.5	2.5	2.5	2.5			
8 Water Level Tank #2 In. Water	3	5	2.5	3	1.5	2	1.5	1.5	1.5	.5			
9 Superheat (5-4) °F	.5	.5	.9	3.0	7.5	11.0	9.2	15.9	15.6	17.7			
10 Metastability (5-4)+(3-4)	55	45	45	61.3	69.5	70.9	70.9	72.0	60.9	69.5			
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 030866

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.22 Inches Hg

POSITION Herizontal LENGTH 6 Inches DIAMETER 1.5 Inches

TEST	1	2	3	4	5	6	7	8	9	10	11		
1 Pressure Tank #1 In. Hg	23.46	23.46	23.57	23.46	23.46	23.40	23.57	23.57	23.46	23.46	23.40		
2 Pressure Differential In. Hg	0.71	1.08	1.66	2.14	2.53	3.66	4.03	5.92	8.05	10.25	10.77		
3 Temperature Tank #1 °F	200.0	200.0	200.2	200.0	200.0	199.9	200.2	200.0	200.0	200.0	199.9		
4 Temperature Tank #2 °F	198.5	197.7	196.7	195.4	194.5	191.8	191.3	186.5	180.4	173.5	171.5		
5 Temp. Test Sec. Outlet °F	199.7	199.0	198.6	198.3	197.5	196.6	197.0	195.3	193.0	192.7	191.7		
6 Flow Rate lb/sec-ft^2	285	355	415	470	500	520	525	530	532	532	532		
7 Water Level Tank #1 In. Water	3.5	4.5	3	4.5	5	4	4.5	3.5	3.5	3	2.5		
8 Water Level Tank #2 In. Water	3.5	4.5	3	4.5	5	3	3.5	3	3	2.8	7		
9 Superheat (5-4) °F	1.2	1.3	1.9	2.9	3.0	4.8	5.7	8.8	12.6	19.2	20.2		
10 Metastability (5-4)÷(3-4)	80	56	54	52.5	54	59	64	64	64	72	71		
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 030766B

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.92 Inches Hg.

POSITION Horizontal LENGTH 6 Inches DIAMETER 1.5 Inches Diameter

TEST	1	2	3	4	5	6	7	8	9	10	11		
1 Pressure Tank #1 In. Hg	30.84	30.84	30.96	30.72	30.96	30.96	30.84	30.96	30.84	30.90	30.84		
2 Pressure Differential In. Hg	13.32	9.91	8.58	7.36	6.54	5.63	4.42	3.63	2.36	1.04	0.92		
3 Temperature Tank #1 °F	213.6	213.6	213.8	213.4	213.8	213.8	213.6	213.8	213.6	213.7	213.6		
4 Temperature Tank #2 °F	186.2	194.5	197.7	199.8	201.9	203.7	205.8	207.5	209.5	211.9	212.0		
5 Temp. Test Sec. Outlet °F	205.0	206.5	207.7	208.3	209.3	209.9	210.5	211.2	211.8	212.0	213.0		
6 Flow Rate lb/sec-ft^2	650	650	650	645	645	635	615	590	530	480	390		
7 Water Level Tank #1 In. Water	4.5	5	4.5	5	5	4	3.5	3.5	4.5	3.8	4		
8 Water Level Tank #2 In. Water	9	10	9	9	9	8.5	7.5	8	9	7.0	9		
9 Superheat (5-4) °F	18.8	12.0	10.0	8.5	7.4	6.2	4.7	1.7	2.3	0.1	1.0		
10 Metastability (5-4)+(3-4)	68.5	63	62	58.5	62	61	60	51	74	6	62.5		
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 030466

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.82 Inches Hg.

POSITION Horizontal LENGTH 6 Inches DIAMETER 1.5 Inches Diameter

TEST	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Pressure Tank #1 In. Hg	37.21	37.36	37.43	37.29	37.43	37.36	37.36	37.29	37.43	37.43	37.43	3.75	37.21
2 Pressure Differential In. Hg	1.72	2.36	3.29	3.77	4.85	5.98	7.49	9.27	11.01	12.0	15.84	16.9	5.82
3 Temperature Tank #1 °F	223.2	223.4	223.5	223.3	223.5	223.4	223.4	223.3	223.5	223.5	223.5	223.6	223.2
4 Temperature Tank #2 °F	220.7	220.0	218.8	217.8	216.3	214.4	211.9	208.7	205.8	203.9	196.0	193.6	214.4
5 Temp. Test Sec. Outlet °F	222.0	221.7	221.3	220.5	220.2	219.6	218.7	217.4	216.9	209.4	215.5	212.7	219.8
6 Flow Rate lb/sec-ft^2	490	550	590	670	690	705	715	724	724	760	760	760	705
7 Water Level Tank #1 In. Water	4	4.5	3.5	4.5	4	4.5	4.5	4.5	5.5	3	4	4	4.5
8 Water Level Tank #2 In. Water	4.2	6	5.5	8	8	8.5	9.5	10	10	9	10	10	10
9 Superheat (5-4) °F	1.3	1.7	2.5	2.7	3.9	5.2	6.8	8.7	11.1	5.5	19.5	19.1	5.4
10 Metastability (5-4)÷(3-4)	52	50.0	53	49	43	45	46	49	63	28	71	63.6	61.4
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 030766A

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.92 Inches Hg

POSITION Horizontal LENGTH 6 Inches DIAMETER 1.5 Inches Diameter

TEST	1	2	3										
1 Pressure Tank #1 In. Hg	61.15	61.35	61.26										
2 Pressure Differential In. Hg	1.05	2.18	3.12										
3 Temperature Tank #1 °F	250.4	250.6	250.5										
4 Temperature Tank #2 °F	249.4	248.5	247.5										
5 Temp. Test Sec. Outlet °F	250.2	249.6	249.3										
6 Flow Rate lb/sec-ft^2	480	590	645										
7 Water Level Tank #1 In. Water	4	5	3										
8 Water Level Tank #2 In. Water	2	5	4										
9 Superheat (5-4) °F	.8	1.1	1.8										
10 Metastability (5-4)÷(3-4)	80	52	60										
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12													
13													
14													
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 021066

CONFIGURATION OF TEST SECTION Cylindrieal BAROMETRIC PRESSURE 30.43 Inches Hg

POSITION Herisontal LENGTH 1 Foot DIAMETER 1.5 Inches

TEST	1	2	3	4	5	6							
1 Pressure Tank #1 In. Hg	8.83	8.37	8.43	8.33	8.23	8.19							
2 Pressure Differential In. Hg	2.74	3.47	3.66	1.95	0.44	0.79							
3 Temperature Tank #1 °F	156.3	154.1	154.4	153.9	153.4	153.2							
4 Temperature Tank #2 °F	141.4	133.0	132.0	143.2	151.2	149.1							
5 Temp. Test Sec. Outlet °F	142.6	134.0	133.5	145.4	152.5	151.7							
6 Flow Rate lb/sec-ft^2	317	320	322	341	333	364							
7 Water Level Tank #1 In. Water	6	5.5	6	4	4.5	4.5							
8 Water Level Tank #2 In. Water	6	5.5	7	5	6	6							
9 Superheat (5-4) °F	1.2	1.0	1.5	2.2	1.3	2.6							
10 Metastability (5-4)÷(3-4)	8.1	4.73	6.69	20.56	59.09	63.41							
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 020966

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.69 Inches Hg

POSITION Horizontal LENGTH 1 Foot DIAMETER 1.5 Inches

TEST	1	2	3	4	5	6	7						
1 Pressure Tank #1 In. Hg	9.11	8.77	8.77	8.90	8.37	8.70	8.87						
2 Pressure Differential In. Hg	3.71	3.58	3.77	2.60	1.31	.41	.92						
3 Temperature Tank #1 °F	157.6	156.0	156.0	156.6	154.1	155.7	156.5						
4 Temperature Tank #2 °F	136.7	135.2	133.8	142.7	147.2	153.7	152.0						
5 Temp. Test Sec. Outlet °F	138.0	136.3	134.8	144.7	150.5	155.0	154.0						
6 Flow Rate lb/sec-ft^2	326	326	320	322	341	292	332						
7 Water Level Tank #1 In. Water	7	6.5	7	5.5	5	3.5	4.5						
8 Water Level Tank #2 In. Water	7	6.5	7	5.5	5	4	3.5						
9 Superheat (5-4) °F	1.3	1.1	1.0	2.0	3.3	1.3	2.0						
10 Metastability (5-4)÷(3-4)	6.2	5.3	4.51	14.4	47.8	65.0	44.4						
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12													
13													
14													
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 020866

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.56 Inches Hg

POSITION Horizontal LENGTH 1 Foot DIAMETER 1.5 Inches

TEST	1	2	3	4	5	6	7	8					
1 Pressure Tank #1 In. Hg	16.77	16.70	16.85	16.92	16.63	16.59	16.63	16.63					
2 Pressure Differential In. Hg	7.44	7.72	4.34	6.88	5.86	2.12	.83	2.23					
3 Temperature Tank #1 °F	184.2	184.0	184.4	184.6	183.8	183.7	183.8	183.8					
4 Temperature Tank #2 °F	158.6	57.0	171.1	161.7	156.0	177.5	181.5	177.3					
5 Temp. Test Sec. Outlet °F	159.4	158.0	172.0	165.1	156.8	179.8	183.1	179.9					
6 Flow Rate lb/sec-ft^2	440	383	398	398	398	429	362	436					
7 Water Level Tank #1 In. Water	9	2.8	4	3.5	3	6.5	4.5	5					
8 Water Level Tank #2 In. Water	8	3.5	4	3.5	3	6	4.5	5					
9 Superheat (5-4) °F	.8	1.0	1.3	3.4	.8	2.3	1.6	2.6					
10 Metastability (5-4)÷(3-4)	3.1	3.7	9.7	14.8	28.7	37.1	69.5	40.0					
11													
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

C-59-1135

RUN NO. 020766A

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.37 Inches Hg

POSITION **Horizontal** LENGTH 1 Foot DIAMETER 1.5 Inches

TEST	1	2	3										
1 Pressure Tank #1 In. Hg	6.60	16.69	16.38										
2 Pressure Differential In. Hg	7.29	7.58	7.29										
3 Temperature Tank #1 °F	183.7	184.0	183.1										
4 Temperature Tank #2 °F	158.5	157.6	157.5										
5 Temp. Test Sec. Outlet °F	159.3	158.2	158.3										
6 Flow Rate lb/sec-ft^2	375	438	447										
7 Water Level Tank #1 In. Water	3	7	6										
8 Water Level Tank #2 In. Water	3	6.5	5										
9 Superheat (5-4) °F	.8	.6	2.86										
10 Metastability (5-4)+(3-4)	3.2	2.3	11.2										
11													
12													
13													
14													
15													

SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

C-59-1135

RUN NO. 020766B

CONFIGURATION OF TEST SECTION **Cylindrical** BAROMETRIC PRESSURE **30.37 Inches Hg**

POSITION **Herisontal** LENGT **1 Foot** DIAMETER **1.5 Inches**

TEST	1	2	3	4									
1 Pressure Tank #1 In. Hg	23.51	23.52	23.52	23.17									
2 Pressure Differential In. Hg	6.30	8.67	10.15	9.47									
3 Temperature Tank #1 °F	200.1	200.2	200.2	199.4									
4 Temperature Tank #2 °F	185.4	178.7	174.0	175.1									
5 Temp. Test Sec. Outlet °F	186.3	180.9	175.0	175.7									
6 Flow Rate lb/sec-ft^2	459	487	525	513									
7 Water Level Tank #1 In. Water	5	4.5	9	7									
8 Water Level Tank #2 In. Water	3.5	3.5	8.5	6.5									
9 Superheat (5-4) °F	.9	2.2	1.0	.6									
10 Metastability (5-4)+(3-4)	6.1	10.2	3.8	2.5									
11													
12													
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 021466A

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.97 Inches Hg

POSITION Horizontal LENGT 1 Foot DIAMETER 1.5 Inches

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	22.80	23.17	22.80	23.17	22.98	23.17	23.27	23.27	23.17				
2 Pressure Differential In. Hg	9.04	7.89	6.03	4.38	2.84	2.15	1.55	0.85	1.26				
3 Temperature Tank #1 °F	198.6	199.4	198.6	199.4	199.0	199.4	199.6	199.6	199.4				
4 Temperature Tank #2 °F	175.3	180.0	184.2	189.4	192.7	194.7	196.3	197.8	196.7				
5 Temp. Test Sec. Outlet °F	175.9	180.7	185.4	191.5	195.4	196.9	198.4	199.0	198.4				
6 Flow Rate lb/sec-ft^2	483	483	480	480	476	452	416	385	396				
7 Water Level Tank #1 In. Water	5	3.5	5.5	5	5	5	5	5	5				
8 Water Level Tank #2 In. Water	5	3.5	5	4.5	4.5	5	5	5	5				
9 Superheat (5-4) °F	0.6	0.7	1.2	2.1	2.7	2.2	2.1	1.2	1.7				
10 Metastability (5-4)÷(3-4)	2.57	3.61	8.33	21.0	42.85	46.81	63.64	66.66	62.96				
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 021566

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.32 Inches Hg

POSITION Horizontal LENGTH 1 Foot DIAMETER 1.5 Inches

TEST	1	2	3	4	5	6	7	8	9	10	11	12	
1 Pressure Tank #1 In. Hg	30.84	30.84	30.84	30.84	30.84	30.95	30.84	30.61	31.13	30.84	30.84	30.84	
2 Pressure Differential In. Hg	1.10	2.53	1.10	2.19	2.88	4.27	6.12	8.00	9.54	10.27	13.56	14.43	
3 Temperature Tank #1 °F	213.6	213.6	213.6	213.6	213.6	213.8	213.6	213.2	214.0	213.6	213.6	213.6	
4 Temperature Tank #2 °F	211.7	209.2	211.7	209.8	208.6	206.3	202.5	198.2	196.0	193.7	185.6	183.2	
5 Temp. Test Sec. Outlet °F	213.0	211.9	213.2	212.2	211.7	209.2	205.0	199.6	197.3	194.7	186.0	183.6	
6 Flow Rate lb/sec-ft^2	394	530	382	485	537	583	578	575	578	583	586	568	
7 Water Level Tank #1 In. Water	6	5	4.5	5	7	7	6	5	4	4	4	5	
8 Water Level Tank #2 In. Water	5	5	3.5	5	6	7	6	5	5	5	5	7	
9 Superheat (5-4) °F	1.3	2.7	1.5	2.4	3.1	2.9	2.5	1.4	1.3	1.0	0.4	0.4	
10 Metastability (5-4)÷(3-4)	68.4	61.4	78.9	63.2	62.0	38.7	22.5	9.3	7.2	5.0	1.4	1.3	
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 021466B

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.97 Inches Hg

POSITION Horizontal LENGTH 1 Foot DIAMETER 1.5 Inches

TEST	1	2	3	4	5	6	7						
1 Pressure Tank #1 In. Hg	38.13	38.26	38.13	37.98	38.13	37.98	37.02						
2 Pressure Differential In. Hg	2.03	3.14	4.23	5.15	7.18	10.37	12.01						
3 Temperature Tank #1 °F	224.5	224.7	224.5	224.3	224.5	224.3	222.9						
4 Temperature Tank #2 °F	212.2	220.1	218.4	216.7	213.8	208.0	203.1						
5 Temp. Test Sec. Outlet °F	223.5	222.9	221.4	220.0	216.1	210.0	204.4						
6 Flow Rate lb/sec-ft^2	486	585	626	646	665	665	705						
7 Water Level Tank #1 In. Water	7	5	4	7	6	6	8						
8 Water Level Tank #2 In. Water	8	6	5	8	7	8	9						
9 Superheat (5-4) °F	2.3	2.8	3.0	3.3	2.3	2.0	1.3						
10 Metastability (5-4)÷(3-4)	69.7	60.9	49.2	43.4	21.5	12.3	6.6						
11													
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 021666

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.08 Inches Hg

POSITION Horizontal LENGTH 1 Foot DIAMETER 1.5 Inches

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	61.25	61.70	61.49	61.70	61.70	61.70	61.70	61.25	61.25				
2 Pressure Differential In. Hg	1.55	3.15	4.29	5.40	6.88	10.50	11.30	12.99	15.73				
3 Temperature Tank #1 °F	250.5	250.9	250.7	250.9	250.9	250.9	250.9	250.5	250.5				
4 Temperature Tank #2 °F	249.0	247.9	246.6	245.7	244.2	240.4	239.5	237.2	233.9				
5 Temp. Test Sec. Outlet °F	250.1	249.7	249.2	248.8	247.7	243.9	242.5	239.7	235.8				
6 Flow Rate lb/sec-ft^2	513	650	760	810	840	885	870	885	885				
7 Water Level Tank #1 In. Water	6	4.5	5	7	7	6	7	6	5				
8 Water Level Tank #2 In. Water	8	7	9	9	9	9	9	9	9				
9 Superheat (5-4) °F	1.1	1.8	2.6	3.1	3.5	3.5	3.0	2.5	1.9				
10 Metastability (5-4)÷(3-4)	73.3	60.0	63.4	59.6	52.2	33.3	26.3	18.8	11.4				
11													
12													
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15													

SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 032966

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.91 Inches Hg.

POSITION Horizontal LENGTH 6 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7						
1 Pressure Tank #1 In. Hg	7.66	7.66	7.66	7.66	7.66	7.66	7.66						
2 Pressure Differential In. Hg	.17	.84	.47	1.07	1.41	2.08	2.17						
3 Temperature Tank #1 °F	150.5	150.5	150.5	150.5	150.5	150.5	150.5						
4 Temperature Tank #2 °F	149.6	145.8	147.9	144.5	142.4	138.0	137.4						
5 Temp. Test Sec. Outlet °F	150.1	149.3	149.8	149.1	148.5	147.6	148.3						
6 Flow Rate lb/sec-ft^2	237	300	275	320	330	335	340						
7 Water Level Tank #1 In. Water	4.5	4	5	4	4.5	4.5	4.5						
8 Water Level Tank #2 In. Water	7	7	8.0	7	8	8	8						
9 Superheat (5-4) °F	.5	3.5	1.9	4.6	6.1	9.6	10.9						
10 Metastability (5-4)÷(3-4)	55	75	73	77	75	77	83.2						
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12													
13													
14													
15													

SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 033166

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.61 Inches Hg

POSITION Horizontal LENGTH 6 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7						
1 Pressure Tank #1 In. Hg	15.58	15.51	15.55	15.55	15.55	15.55	15.55						
2 Pressure Differential In. Hg	0.40	0.85	1.18	1.67	2.49	3.32	4.72						
3 Temperature Tank #1 °F	180.9	180.7	180.8	180.8	180.8	180.8	180.8						
4 Temperature Tank #2 °F	179.7	178.1	177.2	175.7	173.0	170.1	164.9						
5 Temp. Test Sec. Outlet °F	180.4	180.1	179.6	179.0	178.2	177.4	176.5						
6 Flow Rate lb/sec-ft^2	245	320	375	395	410	410	410						
7 Water Level Tank #1 In. Water	5	4	5	5	4	4	4						
8 Water Level Tank #2 In. Water	6	5	6	6	5	5	5						
9 Superheat (5-4) °F	0.7	2.0	2.4	3.3	5.2	7.3	11.6						
10 Metastability (5-4)÷(3-4)	58.3	76.9	66.7	64.7	66.7	68.2	72.9						
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 040166B

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.53 Inches Hg.

POSITION Horizontal LENGTH 6 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	22.25	22.20	22.20	22.10	22.10	22.10	22.10	22.10	22.10				
2 Pressure Differential In. Hg	.72	1.10	2.06	2.83	3.50	4.50	5.44	6.13	7.22				
3 Temperature Tank #1 °F	197.4	197.3	197.3	197.1	197.1	197.1	197.1	197.1	197.1				
4 Temperature Tank #2 °F	195.9	194.9	192.7	190.6	188.9	186.4	183.9	182.0	178.8				
5 Temp. Test Sec. Outlet °F	196.7	196.5	195.5	194.7	194.3	193.6	193.0	192.5	191.8				
6 Flow Rate lb/sec-ft^2	290	405	470	500	515	530	545	545	545				
7 Water Level Tank #1 In. Water	5	5	5	5	5	5	5	5	4.5				
8 Water Level Tank #2 In. Water	8	8	8	8	8	8	8	8	8				
9 Superheat (5-4) °F	.6	1.6	2.8	4.1	5.4	7.2	9.1	10.5	13.0				
10 Metastability (5-4)÷(3-4)	40	66	60.8	63	66	67	69	69	71				
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 033066B

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.76 Inches Hg

POSITION Horizontal LENGTH 6 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8					
1 Pressure Tank #1 In. Hg	29.98	30.04	30.04	30.04	30.04	30.10	30.04	30.04					
2 Pressure Differential In. Hg	0.75	1.15	1.84	2.99	3.57	4.61	6.12	9.16					
3 Temperature Tank #1 °F	212.1	212.2	212.2	212.2	212.2	212.3	212.2	212.2					
4 Temperature Tank #2 °F	210.8	210.2	209.0	207.0	205.9	204.0	200.9	194.4					
5 Temp. Test Sec. Outlet °F	211.7	211.4	211.0	210.2	209.7	209.1	208.2	206.2					
6 Flow Rate lb/sec-ft^2	281	388	490	575	615	620	635	640					
7 Water Level Tank #1 In. Water	5	4.5	5	4.5	5	4.5	4.5	4.5					
8 Water Level Tank #2 In. Water	9	9	9	9	9	9	9	9					
9 Superheat (5-4) °F	0.9	1.2	2.0	3.2	3.8	5.1	7.3	11.8					
10 Metastability (5-4)÷(3-4)	69.2	60.0	62.5	61.5	60.3	61.4	64.6	66.3					
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 033066A

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.75 Inches Hg

POSITION Horizontal LENGTH 6 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	37.00	37.00	37.00	37.00	37.10	37.00	37.10	37.00	37.10				
2 Pressure Differential In. Hg	.75	1.40	2.00	2.14	3.38	4.59	6.30	7.50	10.6				
3 Temperature Tank #1 °F	222.9	222.9	222.9	222.9	223.0	222.9	223.0	222.9	223.0				
4 Temperature Tank #2 °F	221.8	220.9	220.0	219.8	218.1	216.1	213.5	211.3	209.5				
5 Temp. Test Sec. Outlet °F	222.6	222.1	221.7	221.5	220.9	220.3	219.1	218.4	218.0				
6 Flow Rate lb/sec-ft^2	280	450	540	605	620	680	720	740	740				
7 Water Level Tank #1 In. Water	5	5	4.5	4.5	5	4.5	4.5	4	4.5				
8 Water Level Tank #2 In. Water	5	5	6	6	6	8	9	8	8				
9 Superheat (5-4) °F	.8	1.2	1.7	1.7	2.8	4.2	5.6	6.9	8.5				
10 Metastability (5-4)÷(3-4)	47	60	58	55	57	62	59	54	63				
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 040166A

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.53 Inches Hg

POSITION Horizontal LENGTH 6 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8					
1 Pressure Tank #1 In. Hg	59.38	59.58	59.37	59.28	59.28	59.28	59.28	59.28					
2 Pressure Differential In. Hg	1.13	2.48	3.34	4.73	6.18	7.80	8.35	11.33					
3 Temperature Tank #1 °F	248.7	248.8	248.7	248.6	248.6	248.6	248.6	248.6					
4 Temperature Tank #2 °F	247.6	246.6	245.4	243.9	242.4	240.7	239.1	236.8					
5 Temp. Test Sec. Outlet °F	248.4	247.8	247.3	246.4	245.7	245.0	244.4	243.6					
6 Flow Rate lb/sec-ft^2	420	570	670	790	800	890	920	940					
7 Water Level Tank #1 In. Water	3.5	5	4	4	4.5	5	5	5					
8 Water Level Tank #2 In. Water	3	5	4	4	5	6	6	6					
9 Superheat (5-4) °F	.8	1.2	1.9	2.5	3.3	4.3	5.3	6.8					
10 Metastability (5-4)÷(3-4)	72	54	57	53.0	53.5	54.5	57.0	57.5					
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 032466B

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.93 Inches Hg.

POSITION Horizontal LENGTH 12 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7						
1 Pressure Tank #1 In. Hg	7.89	7.89	7.85	7.85	7.85	7.85	7.85						
2 Pressure Differential In. Hg	0.15	0.79	0.29	1.17	1.73	2.75	2.4						
3 Temperature Tank #1 °F	151.7	151.7	151.5	151.5	151.5	151.5	151.5						
4 Temperature Tank #2 °F	150.9	147.4	150.0	145.0	141.6	134.5	137.0						
5 Temp. Test Sec. Outlet °F	151.5	150.3	151.1	149.1	148.3	146.5	147.3						
6 Flow Rate lb/sec-ft^2	223	257	242	267	281	281	281						
7 Water Level Tank #1 In. Water	5	5	4.5	4.5	5	5	5						
8 Water Level Tank #2 In. Water	8	8	8	8	9	9	9						
9 Superheat (5-4) °F	.6	2.9	1.1	4.1	6.7	12.0	10.3						
10 Metastability (5-4)÷(3-4)	75	67.4	73.3	63.1	67.7	70.6	71.1						
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 032866B

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.08 Inches Hg

POSITION Herisontal LENGTH 12 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7						
1 Pressure Tank #1 In. Hg	15.87	15.87	15.87	15.87	15.94	15.91	15.91						
2 Pressure Differential In. Hg	0.36	0.66	1.24	1.82	2.39	3.23	5.38						
3 Temperature Tank #1 °F	181.7	181.7	181.7	181.7	181.9	181.8	181.8						
4 Temperature Tank #2 °F	180.7	179.8	178.0	176.2	174.6	171.7	163.7						
5 Temp. Test Sec. Outlet °F	181.3	181.0	180.1	179.5	179.0	178.0	175.3						
6 Flow Rate lb/sec-ft^2	261	327	359	382	398	405	405						
7 Water Level Tank #1 In. Water	4	4	4.5	4.8	4.5	4.5	4.0						
8 Water Level Tank #2 In. Water	8	8	8	8	8	8	8						
9 Superheat (5-4) °F	0.6	1.2	2.1	3.3	4.4	6.3	11.6						
10 Metastability (5-4)+(3-4)	60.0	63.2	56.7	60.0	60.3	62.4	64.1						
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 032866A

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.08 Inches Hg

POSITION Horizontal LENGTH 12 Inches DIAMETER 2.0 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	22.75	22.75	22.66	22.70	22.66	22.66	22.66	22.66	22.66				
2 Pressure Differential In. Hg	0.65	1.34	1.07	2.17	2.40	3.95	4.82	5.92	7.97				
3 Temperature Tank #1 °F	198.5	198.5	198.3	198.4	198.3	198.3	198.3	198.3	198.3				
4 Temperature Tank #2 °F	197.1	195.6	196.0	193.6	193.0	189.2	187.0	184.1	178.2				
5 Temp. Test Sec. Outlet °F	198.1	197.5	197.6	196.4	196.0	194.4	193.2	191.7	190.6				
6 Flow Rate lb/sec-ft^2	270	410	353	437	448	455	465	465	465				
7 Water Level Tank #1 In. Water	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5				
8 Water Level Tank #2 In. Water	7	7	7	7	7	7	7	7	7				
9 Superheat (5-4) °F	1.0	1.9	1.6	2.8	3.0	5.2	6.2	7.6	12.4				
10 Metastability (5-4)÷(3-4)	71.4	65.5	69.5	58.3	56.6	57.1	54.8	53.5	61.7				
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 032566

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.10 Inches Hg.

POSITION Horizontal LENGTH 12 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9	10			
1 Pressure Tank #1 In. Hg	30.72	30.78	30.78	30.72	30.84	30.84	30.84	30.84	30.84	30.84			
2 Pressure Differential In. Hg	0.8	1.43	2.01	2.64	3.84	4.84	5.93	6.67	8.04	10.22			
3 Temperature Tank #1 °F	213.4	213.5	213.5	213.4	213.6	213.6	213.6	213.6	213.6	213.6			
4 Temperature Tank #2 °F	212.0	211.0	210.0	208.8	206.9	205.0	202.9	201.4	198.6	193.8			
5 Temp. Test Sec. Outlet °F	213.4	212.3	212.1	211.9	210.4	209.3	208.3	207.7	206.3	205.0			
6 Flow Rate lb/sec-ft^2	300	455	472	515	530	550	550	550	550	550			
7 Water Level Tank #1 In. Water	0.4	0.4	4.5	4.5	4.5	4.5	5	5	4.5	4.5			
8 Water Level Tank #2 In. Water	0.3	0.3	3.5	3.5	3.5	4	4	4	5	10			
9 Superheat (5-4) °F	1.4	1.3	2.1	3.1	3.5	4.3	5.4	6.3	7.7	11.2			
10 Metastability (5-4)÷(3-4)	100	52	60	67.4	52.2	50	50.5	51.6	51.3	56.5			
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 032366

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.16 Inches Hg

POSITION Horizontal LENGTH 12 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	37.80	37.65	37.65	37.65	37.65	37.65	37.65	37.65	37.65				
2 Pressure Differential In. Hg	1.05	1.60	2.30	3.50	4.57	5.32	7.10	9.35	11.28				
3 Temperature Tank #1 °F	224.0	223.8	223.8	223.9	223.9	223.8	223.7	223.9	223.9				
4 Temperature Tank #2 °F	222.5	221.5	220.5	218.8	217.1	215.9	213.1	209.2	205.7				
5 Temp. Test Sec. Outlet °F	223.2	222.9	222.2	221.7	220.6	220.0	218.4	216.9	215.4				
6 Flow Rate lb/sec-ft^2	288	380	502	548	578	597	607	624	624				
7 Water Level Tank #1 In. Water	5	4.5	5	4.0	4	4.5	4.5	4.2	5				
8 Water Level Tank #2 In. Water	6	5.5	6	5.5	5.5	6	6	5.7	6				
9 Superheat (5-4) °F	.7	1.4	1.7	2.9	3.5	4.1	5.3	7.7	9.7				
10 Metastability (5-4)÷(3-4)	46	761	51	57	51	52	49	52	53				
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 032466A

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.93 Inches Hg.

POSITION Horizontal LENGTH 12 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4									
1 Pressure Tank #1 In. Hg	60.2	60.2	60.2	60.2									
2 Pressure Differential In. Hg	1.56	2.9	3.98	4.89									
3 Temperature Tank #1 °F	249.5	249.5	249.5	249.5									
4 Temperature Tank #2 °F	248.0	246.6	245.6	244.7									
5 Temp. Test Sec. Outlet °F	248.8	248.3	247.9	247.4									
6 Flow Rate lb/sec-ft^2	510	610	680	720									
7 Water Level Tank #1 In. Water	4	4.5	4	3.8									
8 Water Level Tank #2 In. Water	5	6	5	5									
9 Superheat (5-4) °F	0.8	1.7	2.0	2.5									
10 Metastability (5-4)+(3-4)	53.3	51.7	51.3	52.1									
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 041266A

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.46 Inches Hg

POSITION **Horizontal** LENGTH 16 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7						
1 Pressure Tank #1 In. Hg	8.09	8.11	8.09	8.09	8.09	8.13	8.09						
2 Pressure Differential In. Hg	0.2	0.63	1.12	1.56	2.13	2.34	2.92						
3 Temperature Tank #1 ^{o}F	152.7	152.8	152.7	152.7	152.7	152.9	152.7						
4 Temperature Tank #2 ^{o}F	151.7	149.5	146.7	144.1	140.5	139.4	135.0						
5 Temp. Test Sec. Outlet ^{o}F	152.4	151.8	150.7	150.0	149.5	149.2	148.0						
6 Flow Rate lb/sec-ft^2	250	270	287	290	290	290	290						
7 Water Level Tank #1 In. Water	4	4	4.5	4.5	4.5	4	4						
8 Water Level Tank #2 In. Water	3	3	3	4	4	4	4						
9 Superheat (5-4) ^{o}F	0.7	1.9	4.0	5.9	9.0	9.8	13.0						
10 Metastability (5-4)÷(3-4)	70.0	57.6	66.7	68.6	73.8	72.6	72.2						
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 041266B

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.46 Inches Hg.

POSITION Herisental LENGTH 16 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	16.38	16.23	16.26	16.26	16.38	16.38	16.30	16.26	16.23				
2 Pressure Differential In. Hg	0.51	0.92	1.31	2.28	3.08	3.72	4.02	5.53	6.35				
3 Temperature Tank #1 °F	183.1	182.7	[illegible].8	182.8	183.1	183.1	182.9	182.8	182.7				
4 Temperature Tank #2 °F	181.7	180.1	179.0	176.0	173.8	171.6	170.3	164.5	161.0				
5 Temp. Test Sec. Outlet °F	182.1	181.7	181.0	179.5	178.8	177.7	177.1	175.9	175.0				
6 Flow Rate lb/sec-ft^2	247	310	340	358	362	370	370	370	370				
7 Water Level Tank #1 In. Water	4	4.5	4.5	4	4	4	4	4	4				
8 Water Level Tank #2 In. Water	5	5	5	5	5	5	5	5	5				
9 Superheat (5-4) °F	0.4	1.6	2.0	3.5	5.0	6.1	6.8	11.4	14.0				
10 Metastability (5-4)+(3-4)	28.6	61.5	52.6	51.5	53.7	53.04	53.9	62.3	64.5				
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 041466A

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.36 Inches Hg

POSITION Horizontal LENGTH 16 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	23.13	23.17	23.13	23.17	23.17	23.13	23.17	23.13	23.17				
2 Pressure Differential In. Hg	0.57	1.02	1.68	3.07	4.5	5.61	7.51	8.41	9.03				
3 Temperature Tank #1 °F	199.3	199.4	199.3	199.4	199.4	199.3	199.4	199.3	199.4				
4 Temperature Tank #2 °F	198.1	197.2	195.7	192.6	189.1	186.2	181.1	178.3	176.5				
5 Temp. Test Sec. Outlet °F	198.8	198.6	197.6	195.8	194.7	193.0	191.5	190.7	190.4				
6 Flow Rate lb/sec-ft^2	300	350	420	440	445	445	445	445	445				
7 Water Level Tank #1 In. Water	4	4	5	5	5	5	5	5	5				
8 Water Level Tank #2 In. Water	3	3	4	4	4	4	4	4	4				
9 Superheat (5-4) °F	0.7	1.4	1.9	3.2	5.6	6.8	10.4	12.4	13.9				
10 Metastability (5-4)÷(3-4)	58.3	63.6	52.8	47.6	54.4	51.9	56.8	58.8	60.9				
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 041366

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.34 Inches Hg.

POSITION Horizontal LENGTH 16 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	30.61	30.61	30.69	30.69	30.66	30.67	30.67	30.67	30.67				
2 Pressure Differential In. Hg	0.86	1.55	3.14	3.69	5.49	6.71	8.57	10.18	10.97				
3 Temperature Tank #1 °F	213.2	213.2	213.5	213.5	213.3	213.4	213.4	213.4	213.4				
4 Temperature Tank #2 °F	211.8	210.5	207.9	206.9	203.4	201.0	197.1	193.5	191.7				
5 Temp. Test Sec. Outlet °F	212.6	211.9	211.0	210.3	208.2	207.0	205.2	204.4	204.2				
6 Flow Rate lb/sec-ft^2	285	428	497	515	530	530	530	530	530				
7 Water Level Tank #1 In. Water	5	5	4	5	5	5	5	5	5				
8 Water Level Tank #2 In. Water	6	6	5	6	6	6	6	6	6				
9 Superheat (5-4) °F	0.8	1.4	3.1	3.4	4.8	6.0	8.1	10.9	12.5				
10 Metastability (5-4)+(3-4)	57.1	51.8	55.4	51.5	48.5	48.4	49.7	54.8	57.6				
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 041166

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.11 Inches Hg.

POSITION Horizontal LENGTH 16 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	37.66	37.73	37.73	37.73	37.73	37.79	37.79	37.79	37.79				
2 Pressure Differential In. Hg	0.84	1.46	2.24	3.65	4.52	5.15	7.75	9.2	12.25				
3 Temperature Tank #1 °F	223.8	223.9	223.9	223.9	223.9	224.0	224.0	224.0	224.0				
4 Temperature Tank #2 °F	222.6	221.8	220.7	218.7	217.3	216.4	212.2	209.7	204.1				
5 Temp. Test Sec. Outlet °F	223.5	222.9	222.4	221.3	220.8	220.1	217.6	216.4	214.2				
6 Flow Rate lb/sec-ft^2	313	428	490	540	585	585	585	585	590				
7 Water Level Tank #1 In. Water	4.5	4.5	4.5	4	5	5	4	5	5				
8 Water Level Tank #2 In. Water	5	5	6	5	7	7	8	8	9				
9 Superheat (5-4) °F	0.9	1.1	1.7	2.6	3.5	3.7	5.4	6.7	10.1				
10 Metastability (5-4)÷(3-4)	75.0	52.4	53.1	50.0	53.0	48.7	45.7	46.8	50.7				
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 041466B

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.36 Inches Hg

POSITION Horizontal LENGTH 16 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9	10			
1 Pressure Tank #1 In. Hg	59.93	59.93	59.93	59.93	59.93	59.93	59.93	59.93	59.93	59.93			
2 Pressure Differential In: Hg	1.35	2.11	3.71	4.92	6.88	7.81	8.66	10.08	11.76	13.4			
3 Temperature Tank #1 °F	249.3	249.3	249.3	249.3	249.3	249.3	249.3	249.3	249.3	249.3			
4 Temperature Tank #2 °F	248.0	247.3	245.7	244.5	242.5	241.5	240.6	238.8	237.1	235.1			
5 Temp. Test Sec. Outlet °F	248.8	248.2	247.7	246.9	245.7	245.2	244.8	243.4	242.3	241.3			
6 Flow Rate lb/sec-ft^2	420	545	650	710	740	750	758	760	760	765			
7 Water Level Tank #1 In. Water	4	5	5	5	5	5	5	5	5	5			
8 Water Level Tank #2 In. Water	3	4	4	4	4	4	4	4	4	4			
9 Superheat (5-4) °F	0.8	0.9	2.0	2.4	3.2	3.7	4.2	4.6	5.2	6.2			
10 Metastability (5-4)÷(3-4)	61.5	45.0	55.6	50.0	47.1	47.4	48.3	43.8	42.6	43.7			
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 032266 A

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.08 Inches Hg

POSITION Horizontal LENGTH 12 Inches DIAMETER 3.0 Inches I.D.

TEST	1	2	3	4	5	6	7						
1 Pressure Tank #1 In. Hg	8.23	8.23	8.21	8.17	8.17	8.15	8.15						
2 Pressure Differential In. Hg	0.11	0.12	0.55	0.93	1.3	1.57	1.72						
3 Temperature Tank #1 °F	153.5	153.4	153.3	153.1	153.1	153.0	153.0						
4 Temperature Tank #2 °F	152.9	152.8	150.5	148.2	146.1	144.4	143.5						
5 Temp. Test Sec. Outlet °F	153.4	153.2	152.7	152.0	151.3	151.0	150.8						
6 Flow Rate lb/sec-ft^2	134	197	258	273	273	273	273						
7 Water Level Tank #1 In. Water	5	4.5	4.5	4.5	4.5	4.5	4.5						
8 Water Level Tank #2 In. Water	4	4.5	4.5	4.5	4.5	4.5	4.5						
9 Superheat (5-4) °F	0.5	0.4	2.2	3.8	5.2	6.6	7.3						
10 Metastability (5-4)÷(3-4)	83.3	66.66	78.57	77.55	74.28	76.74	76.84						
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 032166

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.08 Inches Hg

POSITION Horizontal LENGTH 12 Inches DIAMETER 3 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	16.63	16.55	16.55	16.55	16.55	16.55	16.55	16.55	16.55				
2 Pressure Differential In. Hg	.40	.71	1.13	2.25	2.80	3.28	3.62	3.98	2.20				
3 Temperature Tank #1 °F	183.8	183.6	183.6	183.6	183.6	183.6	183.6	183.6	183.6				
4 Temperature Tank #2 °F	182.7	181.6	180.4	177.4	175.3	173.7	172.6	171.3	179.4				
5 Temp. Test Sec. Outlet °F	183.6	183.0	182.1	180.8	180.4	180.1	179.5	179.4	181.8				
6 Flow Rate lb/sec-ft^2	193	295	324	345	370	370	370	375	337				
7 Water Level Tank #1 In. Water	4.5	4.5	4.5	4.5	4.5	5.0	4.5	4	4.5				
8 Water Level Tank #2 In. Water	4.5	4.5	4.5	4.5	4.5	5.5	5	6	6				
9 Superheat (5-4) °F	.9	1.4	1.7	3.4	5.1	6.4	6.9	8.1	2.4				
10 Metastability (5-4)÷(3-4)	82	70	53	55	61	64	63	66	61.6				
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 031766B

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.14 Inches Hg

POSITION Horizontal LENGTH 12 Inches DIAMETER 3.0 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	23.35	23.17	23.13	23.00	23.17	23.17	23.17	23.17	23.17				
2 Pressure Differential In. Hg	.40	.97	1.23	1.46	2.27	3.07	3.70	4.97	5.37				
3 Temperature Tank #1 °F	199.8	199.4	199.3	199.0	199.4	199.4	199.4	199.4	199.4				
4 Temperature Tank #2 °F	198.9	197.3	196.7	195.9	194.4	192.6	191.1	187.9	187.0				
5 Temp. Test Sec. Outlet °F	199.6	198.5	198.4	198.0	197.1	196.5	196.0	194.7	194.5				
6 Flow Rate lb/sec-ft^2	198	348	367	390	420	425	435	435	436				
7 Water Level Tank #1 In. Water	4.5	4.5	4.5	4	4	5	4.5	4.5	4				
8 Water Level Tank #2 In. Water	8	8	8	7	7	8	7	7	7				
9 Superheat (5-4) °F	.7	1.2	1.7	2.1	2.7	3.9	4.9	6.8	7.5				
10 Metastability (5-4)÷(3-4)	78	57	65	68	53	57	58	58	60.5				
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 032266 B

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.08 Inches Hg

POSITION Horizontal LENGTH 12 Inches DIAMETER 3.0 Inches I.D.

TEST	1	2	3	4	5	6	7	8					
1 Pressure Tank #1 In. Hg	30.43	30.43	30.43	30.31	30.31	30.31	30.31	30.31					
2 Pressure Differential In. Hg	0.57	0.97	1.72	2.12	3.05	3.63	4.46	6.91					
3 Temperature Tank #1 °F	212.9	212.9	212.9	212.7	212.7	212.7	212.7	212.7					
4 Temperature Tank #2 °F	211.9	211.2	209.9	209.0	207.4	206.3	204.7	199.9					
5 Temp. Test Sec. Outlet °F	212.6	212.3	211.6	211.3	210.3	209.7	209.0	207.1					
6 Flow Rate lb/sec-ft^2	248	350	430	462	490	491	492	500					
7 Water Level Tank #1 In. Water	4.5	4	4.5	4.5	4.5	4.2	4	4.5					
8 Water Level Tank #2 In. Water	2	1.5	2	2	2	2	4	8					
9 Superheat (5-4) °F	0.7	1.1	1.7	2.3	2.9	3.4	4.3	7.2					
10 Metastability (5-4)÷(3-4)	70.0	64.7	56.66	62.16	54.71	53.13	53.75	57.6					
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 031666B

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.08 Inches Hg

POSITION Horizontal LENGTH 12 Inches DIAMETER 3.0 Inches I.D.

TEST	1	2	3	4	5								
1 Pressure Tank #1 In. Hg	29.00	29.00	28.95	28.78	28.78								
2 Pressure Differential In. Hg	.42	1.10	1.16	2.19	3.68								
3 Temperature Tank #1 °F	210.4	210.4	210.3	209.9	209.9								
4 Temperature Tank #2 °F	209.5	208.5	208.3	205.9	203.3								
5 Temp. Test Sec. Outlet °F	210.4	209.9	209.2	208.9	206.8								
6 Flow Rate lb/sec-ft^2	220	365	420	470	490								
7 Water Level Tank #1 In. Water	4.5	4	3.5	4	4								
8 Water Level Tank #2 In. Water	10	10	10	10	10								
9 Superheat (5-4) °F	.9	1.4	.9	2.5	3.5								
10 Metastability (5-4)÷(3-4)	-	73	45	62	53								
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 031666

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.08

POSITION Horizontal LENGTH 12 Inches DIAMETER 3 Inches I.D.

TEST	1	2	3	4	5	6	7	8					
1 Pressure Tank #1 In. Hg	37.93	38.00	37.93	38.00	37.93	38.00	38.00	38.00					
2 Pressure Differential In. Hg	1.33	1.50	1.95	2.45	3.43	4.40	4.80	6.18					
3 Temperature Tank #1 °F	224.2	224.3	224.2	224.3	224.2	224.3	224.3	224.3					
4 Temperature Tank #2 °F	223.0	222.2	221.4	220.8	219.4	217.9	217.3	215.1					
5 Temp. Test Sec. Outlet °F	223.7	223.3	222.9	222.3	221.6	220.7	219.8	218.9					
6 Flow Rate lb/sec-ft^2	210	313	412	458	492	518	525	525					
7 Water Level Tank #1 In. Water	3	3	3	3	3.5	3.5	3.5	3.5					
8 Water Level Tank #2 In. Water	9	9	9	9	9.5	9.5	9.5	9.5					
9 Superheat (5-4) °F	.7	1.1	1.5	1.5	2.2	2.8	2.5	3.8					
10 Metastability (5-4)÷(3-4)	58.4	52.4	54.4	43.0	46.0	43.8	36.0	41.0					
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 031766A

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.14

POSITION Horizontal LENGTH 12 Inches DIAMETER 3 Inches I.D.

TEST	1	2	3	4	5	6							
1 Pressure Tank #1 In. Hg	61.60	61.70	61.70	61.70	61.70	61.70							
2 Pressure Differential In. Hg	.75	1.37	2.00	2.50	3.35	4.10							
3 Temperature Tank #1 °F	250.8	250.9	250.9	250.9	250.9	250.9							
4 Temperature Tank #2 °F	250.1	249.6	249.0	248.5	247.7	247.0							
5 Temp. Test Sec. Outlet °F	250.4	250.4	250.1	249.8	249.3	248.9							
6 Flow Rate lb/sec-ft^2	285	395	480	542	580	633							
7 Water Level Tank #1 In. Water	4	4.5	3.5	3.5	4	4							
8 Water Level Tank #2 In. Water	3	3	3	3	3	4							
9 Superheat (5-4) °F	.3	.8	1.1	1.3	1.6	1.9							
10 Metastability (5-4)÷(3-4)	43	61	58	54	50	48							
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 030166

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.40 Inches Hg.

POSITION Horizontal LENGTH 2 Feet DIAMETER 3 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	7.75	7.47	7.53	7.58	7.51	7.56	7.53	7.56	7.51				
2 Pressure Differential In. Hg	.37	.41	.66	.83	. 83	.92	1.12	1.49	1.45				
3 Temperature Tank #1 °F	149.9	149.5	149.8	150.1	149.7	150.0	149.8	150.0	149.7				
4 Temperature Tank #2 °F	149.6	147.2	146.2	145.4	145.0	144.0	143.4	141.3	141.2				
5 Temp. Test Sec. Outlet °F	149.0	148.2	147.7	147.3	147.2	147.2	146.3	144.8	144.7				
6 Flow Rate lb/sec-ft^2	201	225	235	235	248	250	255	258	258				
7 Water Level Tank #1 In. Water	3	3.5	4	3.5	3.5	3	3	3	3				
8 Water Level Tank #2 In. Water	3	3.5	4	3.5	3.5	3	3	3	3				
9 Superheat (5-4) °F	0.2	1.0	1.5	1.9	2.2	2.4	2.9	3.5	3.5				
10 Metastability (5-4)÷(3-4)	22.2	43.5	41.7	40.4	46.8	46.2	45.3	40.2	41.2				
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 022866

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.18 Inches Hg

POSITION Horizontal LENGTH 2 Feet DIAMETER 3 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9	10			
1 Pressure Tank #1 In. Hg	16.54	16.54	16.50	16.47	16.47	16.50	16.54	16.54	16.50	16.50			
2 Pressure Differential In. Hg	.31	.42	.55	.59	.84	1.31	1.52	2.41	3.16	3.16			
3 Temperature Tank #1 $^{\circ}$F	183.6	183.6	183.5	183.4	183.4	183.5	183.6	183.6	183.5	183.5			
4 Temperature Tank #2 $^{\circ}$F	182.7	182.4	181.9	181.7	181.0	180.0	179.2	176.5	173.9	173.3			
5 Temp. Test Sec. Outlet $^{\circ}$F	182.8	182.9	182.7	182.6	181.8	181.3	180.8	179.0	176.9	176.3			
6 Flow Rate lb/sec-ft^2	202	248	270	287	310	335	345	355	360	362			
7 Water Level Tank #1 In. Water	4	4	4	4	4	4	3.5	3.5	3.5	4			
8 Water Level Tank #2 In. Water	4	4	4	4	4	4	4	5	5	8			
9 Superheat (5-4) $^{\circ}$F	.1	.5	.8	.9	.8	1.3	1.6	2.5	3.0	3.0			
10 Metastability (5-4)÷(3-4)	11.1	41.6	50.0	52.9	33.3	37.1	36.4	35.2	31.3	29.4			
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 022566

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 29.57 Inches Hg

POSITION Horizontal LENGTH 2 Feet DIAMETER 3 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9	10	11		
1 Pressure Tank #1 In. Hg	22.37	22.33	22.42	22.47	22.47	22.37	22.37	22.37	22.33	22.37	22.37		
2 Pressure Differential In. Hg	1.49	1.94	.87	.74	.61	1.89	2.65	3.23	4.16	5.19	5.45		
3 Temperature Tank #1 °F	197.7	197.6	197.8	197.9	197.9	197.7	197.7	197.7	197.6	197.7	197.7		
4 Temperature Tank #2 °F	194.1	194.7	195.9	196.3	196.6	193.5	191.7	190.3	187.9	185.3	184.6		
5 Temp. Test Sec. Outlet °F	195.2	195.6	196.7	196.9	197.0	194.8	193.0	191.7	190.6	187.6	186.8		
6 Flow Rate lb/sec-ft^2	368	350	315	270	250	383	393	397	400	400	400		
7 Water Level Tank #1 In. Water	3	3.5	4	4	4	4	4	3.5	4	4	4		
8 Water Level Tank #2 In. Water	2.5	3	4	4	4.5	4.5	5	5	5.5	6	7		
9 Superheat (5-4) °F	1.1	0.9	0.8	0.6	0.4	1.3	1.3	1.4	2.7	2.3	2.2		
10 Metastability (5-4)÷(3-4)	30.6	31.0	42.1	37.5	30.8	31.0	21.7	18.9	27.8	18.6	16.8		
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 022366

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.64 Inches Hg

POSITION Horizontal LENGTH 2 Feet DIAMETER 3 Inch I.D.

TEST	1	2	3	4	5	6	7	8	9	10	11		
1 Pressure Tank #1 In. Hg	31.25	31.13	31.00	31.00	30.94	30.88	30.88	30.88	30.88	30.82	30.88		
2 Pressure Differential In. Hg	.79	.42	1.26	1.72	2.24	2.52	3.64	4.13	4.24	6.11	6.47		
3 Temperature Tank #1 °F	214.2	214.0	213.8	213.8	213.7	213.6	213.6	213.6	213.6	213.5	213.6		
4 Temperature Tank #2 °F	212.9	213.3	211.7	210.9	209.9	209.3	207.3	206.4	206.2	202.5	199.9		
5 Temp. Test Sec. Outlet °F	213.6	213.9	213.0	212.5	212.0	211.3	209.2	208.7	208.1	205.9	203.7		
6 Flow Rate lb/sec-ft^2	270	340	384	425	447	470	475	480	482	488	490		
7 Water Level Tank #1 In. Water	4	4	4	4	4	4	4	4	4	4	4		
8 Water Level Tank #2 In. Water	3	3.5	4	5	5	5	6	6	7	7	8		
9 Superheat (5-4) °F	0.7	0.6	1.3	1.6	2.1	2.0	1.9	2.3	1.9	3.4	3.8		
10 Metastability (5-4)÷(3-4)	53.84	85.71	61.9	55.2	55.3	46.5	30.2	31.9	25.7	30.9	27.7		
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 022166

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.25 Inches Hg

POSITION Horizontal LENGTH 2 Feet DIAMETER 3 Inches I.D.

TEST	1	2	3	4	5	6	7	8					
1 Pressure Tank #1 In. Hg	38.03	37.91	37.97	37.84	37.84	37.84	37.78	37.91					
2 Pressure Differential In. Hg	1.40	2.36	4.01	4.96	6.11	1.63	1.42	2.12					
3 Temperature Tank #1 °F	224.2	224.2	224.3	224.1	224.2	224.1	223.9	224.2					
4 Temperature Tank #2 °F	222.5	220.9	219.5	217.8	215.0	221.9	220.0	221.2					
5 Temp. Test Sec. Outlet °F	223.7	222.8	221.8	219.9	217.1	223.2	223.3	222.9					
6 Flow Rate lb/sec-ft^2	395	478	495	525	535	440	360	430					
7 Water Level Tank #1 In. Water	3	4	4	4	4	4	3	3.5					
8 Water Level Tank #2 In. Water	2	3	3.5	9	9	9	9	9					
9 Superheat (5-4) °F	1.2	1.95	2.3	2.05	2.05	1.30	1.30	1.7					
10 Metastability (5-4)÷(3-4)	63.2	58.2	47.9	32.5	22.4	57.8	66.7	56.7					
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 022266

CONFIGURATION OF TEST SECTION Cylindrical BAROMETRIC PRESSURE 30.38 Inches Hg

POSITION Horizontal LENGTH 2 Feet DIAMETER 3 Inch I.D.

TEST	1	2	3	4	5	6	7	8	9	10			
1 Pressure Tank #1 In. Hg	60.83	60.83	61.05	60.83	61.05	61.05	61.05	61.05	60.83	60.83			
2 Pressure Differential In. Hg	1.67	1.88	2.53	3.52	4.66	6.03	7.69	.69	.77	1.15			
3 Temperature Tank #1 °F	250.1	250.1	250.3	250.1	250.3	250.3	250.3	250.3	250.1	250.1			
4 Temperature Tank #2 °F	248.5	248.3	247.9	246.7	245.8	244.4	242.7	249.7	249.4	248.9			
5 Temp. Test Sec. Outlet °F	249.6	249.5	249.2	248.5	247.8	246.6	244.6	250.2	250.2	249.8			
6 Flow Rate lb/sec-ft^2	480	530	563	600	620	635	642	300	367	445			
7 Water Level Tank #1 In. Water	4	4	4	4	4	4	3.5	4	4	3.5			
8 Water Level Tank #2 In. Water	4	4	5	6	6	7	7	8	8	9			
9 Superheat (5-4) °F	1.05	1.15	1.30	1.85	1.95	2.25	1.90	0.45	0.65	0.95			
10 Metastability (5-4)÷(3-4)	67.7	63.9	54.2	53.6	43.8	37.8	25.0	75.0	86.7	76.0			
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 042066

CONFIGURATION OF TEST SECTION Cylin.; Sharp Edge Entrance BAROMETRIC PRESSURE 30.5 Inches Hg

POSITION Horizontal LENGTH 16 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8					
1 Pressure Tank #1 In. Hg	16.74	16.59	16.55	16.59	16.59	16.59	16.59	16.59					
2 Pressure Differential In. Hg	0.47	1.08	1.57	2.54	3.56	4.53	5.47	6.4					
3 Temperature Tank #1 °F	184.1	183.7	183.6	183.7	183.7	183.7	183.7	183.7					
4 Temperature Tank #2 °F	182.8	180.7	179.1	176.2	172.9	169.5	166.0	162.3					
5 Temp. Test Sec. Outlet °F	183.5	182.3	181.5	180.0	178.1	176.7	175.0	174.2					
6 Flow Rate lb/sec-ft^2	205	307	335	350	350	350	350	350					
7 Water Level Tank #1 In. Water	5	5	5	5	5	5	5	5					
8 Water Level Tank #2 In. Water	5	5	5	5	5	5	5	5					
9 Superheat (5-4) °F	0.7	1.6	2.4	3.8	5.2	7.2	9.0	11.9					
10 Metastability (5-4)÷(3-4)	53.8	53.3	53.3	50.7	48.1	50.7	50.8	55.5					
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 041866B

CONFIGURATION OF TEST SECTION Cylin.; Sharp Edge Entrance BAROMETRIC PRESSURE 30.37 Inches Hg.

POSITION Horizontal LENGTH 16 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	23.08	23.08	23.08	23.08	23.08	23.08	23.08	23.08	23.08				
2 Pressure Differential In. Hg	0.22	1.17	1.93	2.73	3.38	4.13	4.77	7.63	8.61				
3 Temperature Tank #1 °F	199.2	199.2	199.2	199.2	199.2	199.2	199.2	199.2	199.2				
4 Temperature Tank #2 °F	198.1	196.7	195.0	193.2	191.7	189.8	188.2	180.5	177.5				
5 Temp. Test Sec. Outlet °F	198.9	198.1	197.2	195.9	195.3	193.8	192.6	189.8	188.8				
6 Flow Rate lb/sec-ft^2	238	350	397	420	420	430	430	430	430				
7 Water Level Tank #1 In. Water	5	5	5	5	5	5	5	5	5				
8 Water Level Tank #2 In. Water	8	8	8	8	8	8	8	8	8				
9 Superheat (5-4) °F	0.8	1.4	2.2	2.7	3.6	4.0	4.4	9.3	11.3				
10 Metastability (5-4)÷(3-4)	72.7	56.0	52.4	45.0	48.0	42.6	40.0	49.7	52.1				
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 041866A

CONFIGURATION OF TEST SECTION Cylin.; Sharp Edge Entrance BAROMETRIC PRESSURE 30.37 Inches Hg

POSITION Horizontal LENGTH 16 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8					
1 Pressure Tank #1 In. Hg	37.63	37.71	37.57	37.63	37.78	37.57	37.57	37.57					
2 Pressure Differential In. Hg	0.82	1.74	2.57	3.92	5.27	6.31	7.37	9.67					
3 Temperature Tank #1 °F	223.8	223.9	223.7	223.8	224.0	223.7	223.7	223.7					
4 Temperature Tank #2 °F	222.6	221.4	220.0	218.1	216.2	214.2	212.5	208.5					
5 Temp. Test Sec. Outlet °F	223.2	222.6	221.8	220.7	219.6	217.8	216.7	214.6					
6 Flow Rate lb/sec-ft^2	270	420	490	525	540	550	550	550					
7 Water Level Tank #1 In. Water	4	5	5	5	5	5	5	5					
8 Water Level Tank #2 In. Water	4	5	5	5	5	5	5	5					
9 Superheat (5-4) °F	0.6	1.2	1.8	2.6	3.4	3.6	4.2	6.1					
10 Metastability (5-4)÷(3-4)	50.0	48.0	48.6	45.6	43.6	37.9	37.5	40.1					
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 041966

CONFIGURATION OF TEST SECTION Cylin.; Sharp Edge Entrance BAROMETRIC PRESSURE 30.4 Inches Hg

POSITION Horizontal LENGTH 16 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8					
1 Pressure Tank #1 In. Hg	60.41	60.52	60.75	60.52	60.52	60.52	60.52	60.75					
2 Pressure Differential In. Hg	1.21	2.69	4.03	4.89	6.82	8.2	10.53	13.39					
3 Temperature Tank #1 °F	249.8	249.9	250.1	249.9	249.9	249.9	249.9	250.1					
4 Temperature Tank #2 °F	248.6	247.3	246.2	245.1	243.2	241.7	239.3	236.1					
5 Temp. Test Sec. Outlet °F	249.3	248.7	247.9	247.4	246.2	244.8	243.2	240.9					
6 Flow Rate lb/sec-ft^2	350	500	580	630	670	710	720	720					
7 Water Level Tank #1 In. Water	5	5	5	5	5	5	5	5					
8 Water Level Tank #2 In. Water	5	5	5	5	5	5	5	5					
9 Superheat (5-4) °F	0.7	1.4	1.7	2.3	3.0	3.1	3.9	4.8					
10 Metastability (5-4)÷(3-4)	58.3	53.8	43.6	47.9	44.8	37.8	36.8	34.3					
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 050966B

CONFIGURATION OF TEST SECTION Cylindridal;Sharp Edge BAROMETRIC PRESSURE 30.28 Inches Hg.

POSITION Vertical LENGTH 21 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4									
1 Pressure Tank #1 In. Hg	8.33	8.31	8.31	8.31									
2 Pressure Differential In. Hg	0.26	1.18	1.86	2.34									
3 Temperature Tank #1 °F	153.9	153.8	153.8	153.8									
4 Temperature Tank #2 °F	152.6	147.6	143.6	140.6									
5 Temp. Test Sec. Outlet °F	153.8	151.7	150.3	148.8									
6 Flow Rate lb/sec-ft^2	140	174	181	181									
7 Water Level Tank #1 In. Water													
8 Water Level Tank #2 In. Water													
9 Superheat (5-4) °F	1.2	4.1	6.7	8.2									
10 Metastability (5-4)÷(3-4)	92.4	66.2	65.7	62.0									
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. **050866B**

CONFIGURATION OF TEST SECTION **Cylindrical;Sharp Edge** BAROMETRIC PRESSURE **29.85 Inches Hg.**

POSITION **Vertical** LENGTH **21 Inches** DIAMETER **2 Inches I.D.**

TEST	1	2	3	4	5	6	7						
1 Pressure Tank #1 In. Hg	16.55	16.59	16.63	16.59	16.59	16.66	16.66						
2 Pressure Differential In. Hg	0.65	1.64	2.23	3.29	4.48	5.92	6.69						
3 Temperature Tank #1 °F	183.6	183.7	183.8	183.7	183.7	183.9	183.9						
4 Temperature Tank #2 °F	181.8	179.0	177.3	173.8	169.7	164.5	161.4						
5 Temp. Test Sec. Outlet °F	183.3	181.0	180.3	176.4	175.0	173.5	172.4						
6 Flow Rate lb/sec-ft^2	140	185	233	244	250	250	250						
7 Water Level Tank #1 In. Water													
8 Water Level Tank #2 In. Water													
9 Superheat (5-4) °F	1.5	2.0	3.0	2.6	5.3	9.0	11.0						
10 Metastability (5-4)÷(3-4)	83.3	42.6	46.2	26.3	37.8	46.4	48.9						
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 050666C

CONFIGURATION OF TEST SECTION Cylindrical Sharp Edge BAROMETRIC PRESSURE 29.95 Inches Hg

POSITION Vertical LENGTH 21 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8					
1 Pressure Tank #1 In. Hg	21.77	21.87	21.91	21.91	21.96	21.91	21.91	21.91					
2 Pressure Differential In. Hg	1.37	2.03	2.92	3.6	4.84	5.97	8.85	9.25					
3 Temperature Tank #1 °F	196.4	196.6	196.7	196.7	196.8	196.7	196.7	196.7					
4 Temperature Tank #2 °F	193.3	192.0	189.9	188.2	185.2	181.9	173.0	171.6					
5 Temp. Test Sec. Outlet °F	196.1	195.6	193.8	193.4	191.8	190.6	189.5	189.0					
6 Flow Rate lb/sec-ft^2	117	230	310	337	340	340	340	340					
7 Water Level Tank #1 In. Water													
8 Water Level Tank #2 In. Water													
9 Superheat (5-4) °F	2.8	3.6	3.9	5.2	6.6	8.7	16.5	17.4					
10 Metastability (5-4)÷(3-4)	90.3	78.3	57.4	61.2	56.9	58.8	69.6	69.3					
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 050866A

CONFIGURATION OF TEST SECTION Cylindrical;Sharp Edge BAROMETRIC PRESSURE 29.85 Inches Hg

POSITION Vertical LENGTH 21 Inches DIAMETER 2 Inches I.D.

	TEST	1	2	3	4	5	6	7	8					
1	Pressure Tank #1 In. Hg	29.98	30.04	30.04	29.98	29.98	30.04	29.98	30.15					
2	Pressure Differential In. Hg	1.26	2.02	2.6	4.39	5.12	6.91	9.5	11.24					
3	Temperature Tank #1 °F	212.1	212.2	212.2	212.1	212.1	212.2	212.1	212.4					
4	Temperature Tank #2 °F	209.9	208.7	207.7	204.2	202.8	199.3	193.5	189.7					
5	Temp. Test Sec. Outlet °F	212.2	211.6	210.7	208.1	207.6	206.0	204.6	203.9					
6	Flow Rate lb/sec-ft^2	147	240	315	370	405	405	408	410					
7	Water Level Tank #1 In. Water													
8	Water Level Tank #2 In. Water													
9	Superheat (5-4) °F	2.3	2.9	3.0	3.9	4.8	6.7	11.1	14.2					
10	Metastability (5-4)÷(3-4)	-	82.8	66.7	49.4	51.6	51.9	59.7	62.6					
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 050666B

CONFIGURATION OF TEST SECTION Cylindrical;Sharp Edge BAROMETRIC PRESSURE 29.95 Inches Hg

POSITION Vertical LENGTH 21 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8					
1 Pressure Tank #1 In. Hg	37.57	37.57	37.37	37.43	37.43	37.43	37.43	37.43					
2 Pressure Differential In. Hg	2.22	2.22	1.75	3.65	5.03	7.68	8.26	6.61					
3 Temperature Tank #1 °F	223.7	223.7	223.4	223.5	223.5	223.5	223.5	223.5					
4 Temperature Tank #2 °F	220.5	220.5	220.9	218.2	216.0	211.7	201.4	199.5					
5 Temp. Test Sec. Outlet °F	222.9	223.0	223.3	221.4	219.6	217.0	215.1	214.4					
6 Flow Rate lb/sec-ft^2	280	200	175	420	470	480	480	480					
7 Water Level Tank #1 In. Water													
8 Water Level Tank #2 In. Water													
9 Superheat (5-4) °F	2.4	2.5	2.4	3.2	3.6	5.3	13.7	14.9					
10 Metastability (5-4)÷(3-4)	75.	78.	90.	60.	48.	45.	62.	62.					
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14													
15													

SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

C-59-1135

RUN NO. 050466

CONFIGURATION OF TEST SECTION Cylindrical/ Sharp Edge BAROMETRIC PRESSURE 30.44 Inches Hg

POSITION Vertical LENGTH 21 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4									
1 Pressure Tank #1 In. Hg	37.57	37.51	37.51	37.44									
2 Pressure Differential In. Hg	4.04	5.69	9.08	2.16									
3 Temperature Tank #1 °F	223.7	223.6	223.6	223.5									
4 Temperature Tank #2 °F	217.8	215.1	209.4	220.4									
5 Temp. Test Sec. Outlet °F	221.0	219.9	215.9	222.9									
6 Flow Rate lb/sec-ft^2	375	455	455	193									
7 Water Level Tank #1 In. Water													
8 Water Level Tank #2 In. Water													
9 Superheat (5-4) °F	3.2	4.8	6.5	2.5									
10 Metastability (5-4)÷(3-4)	54.2	56.5	45.7	80.6									
11													
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14													
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 050966A

CONFIGURATION OF TEST SECTION Cylindrical;Sharp Edge BAROMETRIC PRESSURE 30.28 Inches Hg.

POSITION Vertical LENGTH 21 Inches DIAMETER 2 Inches I.D.

TEST	1	2	3	4	5	6	7	8	9				
1 Pressure Tank #1 In. Hg	60.13	60.00	59.89	60.00	59.89	59.89	59.89	59.89	60.00				
2 Pressure Differential In. Hg	1.58	2.80	4.18	5.27	6.36	8.98	10.40	13.28	15.97				
3 Temperature Tank #1 °F	249.5	249.4	249.3	249.4	249.3	249.3	249.3	249.3	249.4				
4 Temperature Tank #2 °F	248.0	246.7	245.2	244.2	243.0	240.2	238.7	235.2	232.1				
5 Temp. Test Sec. Outlet °F	249.4	249.0	248.2	247.4	246.8	245.2	244.4	242.4	241.1				
6 Flow Rate lb/sec-ft^2	315	410	550	595	640	660	670	670	670				
7 Water Level Tank #1 In. Water													
8 Water Level Tank #2 In. Water													
9 Superheat (5-4) °F	1.4	2.3	3.0	3.2	3.8	5.0	5.7	7.2	9.0				
10 Metastability (5-4)÷(3-4)	93.4	85.2	73.2	61.5	60.4	55.0	53.8	51.1	52.0				
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14													
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SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. **051766B**

CONFIGURATION OF TEST SECTION **Rectangular** BAROMETRIC PRESSURE **29.95 Inches Hg**

POSITION **Vertical** LENGTH **21 Inches** DIAMETER **3 Inch by 1.5 Inch Inside**

TEST	1	2	3	4	5	6	7						
1 Pressure Tank #1 In. Hg	16.48	16.59	16.55	16.59	16.59	16.59	16.59						
2 Pressure Differential In. Hg	0.58	1.45	1.93	2.71	4.08	5.29	5.73						
3 Temperature Tank #1 °F	183.4	183.7	183.6	183.7	183.7	183.7	183.7						
4 Temperature Tank #2 °F	181.8	179.6	178.0	175.7	171.1	166.7	165.0						
5 Temp. Test Sec. Outlet °F	183.3	182.0	180.7	179.5	176.1	175.2	174.6						
6 Flow Rate $lb/sec\text{-}ft^2$	122	177	235	267	269	270	270						
7 Water Level Tank #1 In. Water													
8 Water Level Tank #2 In. Water													
9 Superheat (5-4) °F	1.5	2.4	2.7	3.8	5.0	8.5	9.6						
10 Metastability (5-4)÷(3-4)	93.7	58.5	48.2	47.5	39.7	50.0	51.3						
11													
12													
13													
14													
15													

SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 051766A

CONFIGURATION OF TEST SECTION **Rectangular** BAROMETRIC PRESSURE **29.95 Inches Hg**

POSITION **Vertical** LENGTH **21 Inches** DIAMETER **3 Inch by 1.5 Inch Inside**

TEST	1	2	3	4	5	6	7						
1 Pressure Tank #1 In. Hg	22.05	22.01	22.01	22.01	21.96	21.96	22.01						
2 Pressure Differential In. Hg	1.30	1.91	2.31	2.74	4.08	5.80	7.13						
3 Temperature Tank #1 °F	197.0	196.9	196.9	196.9	196.8	196.8	196.9						
4 Temperature Tank #2 °F	194.1	192.6	191.7	190.6	187.1	182.5	178.8						
5 Temp. Test Sec. Outlet °F	196.3	195.1	194.7	194.1	192.8	188.0	186.7						
6 Flow Rate lb/sec-ft^2	188	250	300	308	327	327	327						
7 Water Level Tank #1 In. Water													
8 Water Level Tank #2 In. Water													
9 Superheat (5-4) °F	2.2	2.5	3.0	3.5	5.7	5.5	7.9						
10 Metastability (5-4)÷(3-4)	75.8	58.1	57.7	55.6	58.7	38.5	43.6						
11													
12													
13													
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15													

SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 051666A

CONFIGURATION OF TEST SECTION **Rectangular** BAROMETRIC PRESSURE **30.27 Inches Hg**

POSITION **Vertical** LENGTH **21 Inches** DIAMETER **3 Inch by 1.5 Inch Inside**

TEST	1	2	3	4	5	6	7	8					
1 Pressure Tank #1 In. Hg	37.24	37.30	37.30	37.30	37.37	37.24	37.30	37.30					
2 Pressure Differential In. Hg	1.62	2.66	3.77	4.02	4.54	4.97	8.13	9.97					
3 Temperature Tank #1 °F	223.2	223.3	223.3	223.3	223.4	223.2	223.3	223.3					
4 Temperature Tank #2 °F	220.9	219.6	217.8	217.4	216.7	215.8	210.7	207.5					
5 Temp. Test Sec. Outlet °F	222.6	222.0	221.0	220.5	220.0	219.2	215.7	214.0					
6 Flow Rate lb/sec-ft^2	266	326	410	440	470	480	480	480					
7 Water Level Tank #1 In. Water													
8 Water Level Tank #2 In. Water													
9 Superheat (5-4) °F	1.7	2.4	3.2	3.1	3.3	3.5	5.0	6.5					
10 Metastability (5-4)÷(3-4)	73.9	64.8	58.2	52.5	49.3	46.7	39.7	41.1					
11													
12													
13													
14													
15													

SUMMARY OF RESULTS
TWO PHASE METASTABLE FLOW

0-59-1135

RUN NO. 051666B

CONFIGURATION OF TEST SECTION Rectangular BAROMETRIC PRESSURE 30.27 Inches Hg

POSITION Vertical LENGTH 21 Inches DIAMETER 3 Inch by 1.5 Inch Inside

TEST	1	2	3	4	5	6	7	8					
1 Pressure Tank #1 In. Hg	60.12	60.12	60.23	60.02	59.91	59.91	60.12	60.02					
2 Pressure Differential In. Hg	1.87	3.81	5.31	7.14	9.37	10.50	12.44	13.24					
3 Temperature Tank #1 °F	249.5	249.5	249.6	249.4	249.3	249.3	249.5	249.4					
4 Temperature Tank #2 °F	247.7	245.8	244.4	242.3	239.8	238.6	236.5	235.4					
5 Temp. Test Sec. Outlet °F	248.9	248.0	247.3	245.6	244.0	243.2	240.8	240.1					
6 Flow Rate lb/sec-ft^2	275	427	540	585	610	618	618	618					
7 Water Level Tank #1 In. Water													
8 Water Level Tank #2 In. Water													
9 Superheat (5-4) °F	1.2	2.2	2.9	3.3	4.2	4.6	4.3	4.7					
10 Metastability (5-4)÷(3-4)	66.7	59.5	55.8	46.5	44.2	42.9	33.1	33.6					
11													
12													
13													
14													
15													