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ALKALI METALS BOILING AND CONDENSING INVESTIGATIONS

Quarterly Progress Report 13

Edited by
D. R. FERGUSON
and
F. E. TIPPETS

prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CONTRACT NAS 3-2528

SPACE POWER AND PROPULSION SECTION
MISSILE AND SPACE DIVISION
GENERAL ELECTRIC
CINCINNATI, OHIO 45215

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QUARTERLY PROGRESS REPORT 13

Covering the Period
July 1, 1965 through September 30, 1965

Edited by

D.R. Ferguson
and
F.E. Tippets

October 29, 1965

prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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NOMENCLATURE

Simple Latin Letter Symbols

Symbol	Quantity	Units
A	Area	ft^2
D	Diameter	ft
E	Error	dimensionless
f	Darcy-Weisbach friction factor	dimensionless
G	Mass velocity (flow rate per unit flow area)	$lb_m/sec\text{-}ft^2$
h	Heat transfer coefficient	$Btu/ft^2\text{-}hr\ ^oF$
K	Slip ratio $\left(K = \frac{\text{vapor velocity}}{\text{liquid velocity}}\right)$	dimensionless
k	Thermal conductivity	$Btu\ ft/ft^2\ hr\ ^oF$
L	Length	ft
ℓ	Length	ft
M	Molecular weight	$lb_m/lb\text{-}mole$
P	Pressure	lb_f/ft^2
q	Rate of heat flow	Btu/sec
R	Universal gas constant	$\frac{1545\ ft\text{-}lb_f}{lb\ mole\ ^oR}$
r	Radius	ft
S	Entropy	$Btu/lb_m\ ^oR$
T	Temperature	^oF
t	Temperature	^oF
U	Overall heat transfer coefficient	$Btu/ft^2\ hr\ ^oF$
V	Velocity	ft/sec
w	Mass flow rate	lb_m/sec
x	Flowing quality $x = (w_g/w_{tot})$	dimensionless

Composite Latin Letter Symbols

Symbol	Quantity	Units
A_s	Shell flow area	ft^2

Composite Latin Letter Symbols (Cont'd)

Symbol	Quantity	Units
a_R	Radial acceleration	g's
C_p	Constant pressure specific heat	Btu/lb_m ^oF
$\bar{C}_p$	Average value of the specific heat in a region	Btu/lb_m ^oF
E_i	Individual error	dimensionless
G_s	Shell mass velocity	lb_m/ft^2-sec
G_c	Critical mass velocity	lb_m/ft^2-sec
g_c	Conversion factor	ft-lb_m/lb_f sec^2
h_c	Condensing heat transfer coefficient	Btu/ft^2 hr-^oF
h_f	Liquid film heat transfer coefficient	Btu/ft^2 hr-^oF
h_g	Enthalpy of the vapor	Btu/lb_m
h_L	Enthalpy of the liquid	Btu/lb_m
h_v	Vapor phase heat transfer coefficient	Btu/ft^2 hr-^oF
h_{fg}	Latent heat of vaporization	Btu/lb_m
k_f	Thermal conductivity of liquid film	Btu-ft/ft^2 hr ^oF
N_t	Number of tubes	dimensionless
N_{Nu}	Nusselt Number ($N_{Nu} = hD/k$)	dimensionless
N_{Nuc}	Nusselt condensing ratio ($N_{Nuc} = \frac{h}{k} (\frac{\nu^2}{g})^{1/3}$)	dimensionless
N_{Pe}	Peclet number ($N_{Pe} = 3600\ GD\ (C_p/k)$)	dimensionless
N_{Re}	Reynolds number ($N_{Re} = 3600\ DG/\mu$)	dimensionless
N_{ReL}	Liquid film Reynolds Number ($N_{ReL} = \frac{4\ w\ (1-x)}{\pi D \mu}$)	dimensionless
P/D	Pitch to diameter ratio	dimensionless
q"	Heat flux	Btu/ft^2 hr
q_c"	Critical heat flux	Btu/ft^2 hr
S_f	Liquid entropy	Btu/lb_m ^oR
S_g	Vapor entropy	Btu/lb_m ^oR

Composite Latin Letter Symbols (Cont'd)

Symbol	Quantity	Units
t	Variable time interval in Figure 26	seconds
Δt	Wall-to-fluid temperature difference	^oF
T_o	Initial plate temperature in Figure 26	^oF
T_{min}	Minimum plate temperature in Figure 26	^oF
V_f	Specific volume of liquid	ft^3/lb_m
V_g	Specific volume of vapor	ft^3/lb_m
V_m	Specific volume of two-phase mixture	ft^3/lb_m
WP	Wetted perimeter	ft
W_i	Weighting factor for integration error	dimensionless
y_i^P	Dummy variable-predicted value	dimensionless
y_i^C	Dummy variable-corrected value	dimensionless

Simple Greek Letter Symbols

Symbol	Quantity	Units
α	Void fraction	dimensionless
α'	Coefficient in equation 22 in Section VIII	dimensionless
β	Coefficient in equation 22 in Section VIII	dimensionless
γ	Coefficient in equation 22 in Section VIII	dimensionless
δ	Film thickness	ft
δ'	Variable exponent in equations (28) and (29) in Section VIII	dimensionless
ε_m	Eddy diffusivity	ft^2/sec
μ	Dynamic viscosity	$lb_m/ft\ sec$
ν	Kinematic viscosity	ft^2/sec
$\bar{\psi}$	Ratio of eddy diffusivity for heat transfer to eddy diffusivity for momentum	dimensionless
ϕ	Two-phase pressure drop multiplier	dimensionless
ρ	Mass density	lb_m/ft^3
$\bar{\rho}$	Average value of the mass density	lb_m/ft^3
τ	Time interval in Figure 26	seconds

Composite Greek Letter Symbols

Symbol	Quantity	Units
σ_c	Condensation coefficient	dimensionless
τ_v^*	Dimensionless shear stress	dimensionless
ϕ_{1-0}	Integrated two-phase multiplier (x = 1 to x = 0)	dimensionless
ϕ_{1-x}	Integrated two-phase multiplier (x = 1 to x = x)	dimensionless

Subscripts

B	Boiling section
c	Critical heat flux point
CB	Centerbody
D	Bare tube
eq	Equivalent
F	Friction
f	Saturated liquid
fr	friction
g	Saturated vapor
H	Helical
i	Inside diameter
I	Inlet
K	Potassium
M	Momentum
m	Momentum
max	Maximum
min	Minimum
O	Outlet
ot	Tube outside
P	Primary
S	Secondary
Sh	Shell
Sub	Subcooled section
Sup	Superheat section
tot	Total
z	Axial
θ	Tangential component

I SUMMARY

F.E. Tippets

This program is being conducted for the National Aeronautics and Space Administration under Contract NAS 3-2528 to obtain two-phase heat transfer and fluid flow data for potassium under conditions of boiling and condensing approximating those anticipated in large space turbo-electric power systems. Test equipment development, materials studies and theoretical analysis related to the experimental work are conducted as a support effort. The following items summarize the work performed during the quarter ending September 30, 1965.

300 KW Project

All boiling test data obtained with the 300 KW Facility have been reduced and reported in previous Quarterly Progress Reports. Analysis and treatment of these data, covering two-phase pressure drop, average boiling heat transfer coefficients, critical heat flux determinations, transition boiling heat transfer coefficients, and a few measurements of superheated vapor heat transfer coefficients, is nearly finished. The analytical work remaining under this project is to finish treatment of the superheated vapor heat transfer coefficients obtained and to finish an analysis of the significance of various heat transfer and pressure loss parameters to the thermal design of space power boilers. This remaining analytical effort should be completed early in the next quarter. A topical report covering the entire 300 KW Project is in preparation and should be completed during the next quarter.

Calculated critical heat flux values and transition boiling heat transfer coefficients, computed from the data obtained with the 1.0-inch nominal diameter boiler test section using helical inserts of pitch-to-diameter ratios of two and six, respectively, are presented in Section II. These results complement similar data presented previously in Reference 4 for the 3/4-inch nominal diameter test section. A correlation of the transition boiling data is presented in Section II.

All of the critical heat flux data obtained under this project, both with and without helical inserts, are presented in Section II together with critical heat flux data taken in the 100 KW Facility. An empirical equation correlating the critical heat flux as a function of local vapor quality and radial acceleration is also given.

100 KW Project

Tests with Test Section No. 5 were completed August 4. This test section is a 3/4-inch nominal diameter tube containing an instrumented wire-wrapped inlet plug insert in combination with a helical wire coil insert of pitch-to-diameter ratio equal to two. An artificial nucleator of the "hot-finger" type was placed upstream of the test section. Reduction and analysis of this data is in process. This concluded currently contracted testing under the heat transfer program and the 100 KW Facility has been shutdown in good working order.

The heat transfer data obtained with Test Section No. 4 are presented in Sections III and VII. This test section is a 3/4-inch nominal diameter tube containing an insert composed of a smooth plug at the inlet followed by a helix of pitch-to-diameter ratio equal to two (P/D = 2) with five internal thermocouples for fluid temperature distribution measurements. The data reported in Section III include critical heat flux determinations and measurements of nucleate, transition, film boiling and superheated vapor heat transfer coefficients at both $1800^{\circ}F$ and $2100^{\circ}F$ saturation temperature for the helical portion of the test section. The results of boiling inception tests and measurements of the nucleate boiling heat transfer coefficients in the vicinity of the boiling boundary located in the inlet-plug insert of Test Section No. 4 are discussed in Section VII. The two-phase pressure drop data obtained during Test Set No. 4 is being treated and will be reported on later.

The work under this project during the next quarter will be to complete the data reduction, evaluation and analysis, and the preparation of a topical report covering the 100 KW Project.

50 KW Project

All condensing test data obtained with the 50 KW Facility have been reduced and reported. Analysis and treatment of these data was completed during this quarter. The remaining effort under this project is the preparation of a topical report covering the entire 50 KW Project. This topical report should be completed during the next quarter.

An analysis is presented in Section IV which attempts to correct the indicated condensing heat transfer coefficients from Test Set No. 4 by taking into account the radial pressure gradient that is generated by the helical insert (5/8-inch ID tube with P/D = 6 instrumented helix insert). This correction brings the helical flow data of Test Set No. 4 into good agreement with the linear flow data of Test Set No. 5, for which a smooth tubular instrumented insert was used.

A comparison of data taken using a 5/8-inch diameter tube with no insert (Test Set No. 1) with the data taken in a 5/8-inch diameter test section using a smooth tubular instrumented insert (Test Set No. 5) is made in Section IV. For the comparison, different local fluid temperature distributions were used employing analytical models, which were tested against the measured fluid temperature distributions obtained during Test Set No. 5.

Also presented in Section IV are data on local and integrated overall two-phase friction pressure drop multipliers obtained during Test Set No. 4 and No. 5.

Facilities, Instrumentation and Materials Support

Facilities operation and equipment changes are described in Sections V and VI. This work is primarily concerned with completing the tests using the 100 KW Facility.

The 300 KW Facility primary loop was re-activated and operated briefly to obtain some flow-pressure head data for the sodium pump. These data were required in conjunction with the 300 KW Facility Modification Design effort (Section IX).

Accumulated operating times on the three heat transfer facilities to date are as follows:

300 KW Facility	-	4466 hours
100 KW Facility	-	6203 hours
50 KW Facility	-	1600 hours

All three facilities have been shutdown, in good working order.

Analysis

Analysis of data on boiling inception and associated stability behavior obtained in the 100 KW Facility is in progress. This work includes treatment of data taken during Test Set No. 3 and data taken at the inlet plug region of Test Sections No. 4 and No. 5 during special tests when the boiling inception boundary was held in that region. Some of these results, obtained during Test Sets No. 3 and No. 4, are given in Section VII.

An analysis of the critical mass velocity for two-phase flows is developed in Section VII for application to potassium. A comparison of analytical models is made, and working charts giving the critical mass velocity as a function of saturation temperature and vapor quality are presented.

The analytical effort over the next quarter will be primarily in association with the 100 KW Project, including preparation of the topical report for that project.

300 KW Facility and Test Condenser Design

This new work, which was initiated by Contract Modification No. 10, dated 6-18-65, is organized into the following groups of effort for execution and progress reporting:

1. Thermal Design Computer Code Development

2. 300 KW Facility Modification Design
   a) Loop Design
   b) Boiler Design

3. Multiple-Tube Test Condenser Design

Preparation of the boiler and condenser thermal design computer codes has been completed and they are now in use. Descriptions of these two codes, the analytical basis for them, and representative calculations to illustrate their use are presented in Section VIII.

Design of the modification of the 300 KW Facility to add a tertiary loop for testing multiple-tube condenser segments and to add a Haynes-25 alloy multiple-tube facility boiler for 300 KW thermal operation for the condenser tests is essentially finished, to the extent planned under the current contract. Descriptions of the loop and multiple-tube boiler designs and the analytical basis for thermal design of the boiler are given in Section IX.

Thermal analysis and mechanical design of the multiple-tube test condensers associated with this project were started at the end of the quarter. This portion of the work should be completed during the next quarter, to the extent planned under the current contract.

II 300 KW PROJECT

JR Peterson/DR Ferguson

The 300 KW Facility is used to obtain potassium boiling heat transfer data. The boiling test section is a controlled temperature type, i.e., it is a two-fluid heat exchanger with the temperatures of the heat transfer fluids rather than the surface heat flux being controlled. Reference 1 presents a detailed description of the facility.

Status of Loop and Test Section

Tests in the 300 KW Facility were completed on schedule in November, 1964. The facility is shutdown in good working order.

Status of Data Reduction

All data obtained with the 300 KW Facility have been initially reduced, corrected and reported in previous Quarterly Progress Reports. All of the data obtained since January, 1964, have been recalculated where necessary, with NRL thermodynamic properties (Reference 10) and improved calculational procedures.

Status of Data Evaluation

A. Average Results

The initial reporting of the boiling heat transfer coefficients and pressure drop multipliers averaged over the boiling length has been completed for the data obtained with the 300 KW Facility. All of the data obtained since January, 1964, including the data from the 1.0-inch and 3/4-inch nominal diameter L-605 boiler tubes, have been recomputed where necessary with the NRL thermodynamic properties (Reference 10) and improved calculational procedures and are now on a mutually consistent basis. The calculation of average parameters is now complete.

It is not planned to evaluate the data obtained in May and June of 1963 with the 1.0-inch nominal diameter molybdenum boiler tube containing no insert beyond the treatment reported in Reference 2. These early data are difficult to compare with the more recent results for the following reasons:

1. The early data were taken under transient conditions.

2. There were thermal shields over approximately 25% of the boiler tube length in the early tests, which were only partially effective. An approximate correction can be made for the effect of these shields but the correction is complex and subject to considerable error.

3. The test plan employed in the later tests was not followed in the experiments with the 1.0-inch molybdenum tube.

B. Local Results

1. Nucleate Boiling

Several nucleate boiling runs obtained with the 3/4-inch nominal diameter boiler tube containing an insert of pitch-to-diameter (P/D) ratio of six were analyzed on a local basis and the results for a typical case are presented in Reference 3. The results obtained showed the nucleate boiling thermal resistance to be negligibly small with respect to the tube wall and sodium resistance and of little significance in once-through boiler design. The analytical effort in this area was therefore terminated.

2. Transition Boiling

The major analysis effort during this reporting period was directed towards correlation of the transition boiling data obtained from the 300 KW Project. Transition boiling heat transfer coefficients calculated from the data obtained from a 0.67-inch ID boiler tube, with and without P/D = 6 helical insert, are reported in Table 1 of Reference 4. Additional values computed from the data obtained with a 0.92-inch boiler tube containing helical inserts of P/D = 2 and P/D = 6 are presented in Table 1 of this report. The calculational procedures utilized are presented and discussed in Reference 4.

The "critical heat flux point", at which it is thought the thin liquid film covering the boiler tube surface becomes unstable and disrupts, terminates the high-performance "nucleate" boiling region and marks the onset of the "transition" boiling region in a forced convection boiler. The liquid portion of the flow in the transition boiling region is thought to be arranged as drops or globules, some of which are in contact with the heat transfer surface and some of which are entrained in the vapor. The onset of "film" boiling, which demarks the end of the transition boiling region, is thought to occur when droplets in contact with the heat transfer surface become insulated from it by a film of vapor. The effective heat transfer coefficient in the transition region is lower than the nucleate boiling heat transfer coefficient, because only a fraction of the heat transfer surface is covered with liquid; but it is higher than would be obtained for complete film boiling, as the heat transfer surface is at least partially wetted in transition boiling, rather than insulated completely from the liquid by a vapor film as is thought to be the case in film boiling.

Investigators at Geoscience (Reference 5) have initiated studies regarding the vaporization lifetimes of single droplets of potassium on a heated surface, and have developed a theoretical prediction for the lifetimes when the droplets are in film boiling. The results obtained show a marked decrease in heat transfer rate (increase in droplet lifetime) with increasing surface-to-drop temperature difference before the onset of the film boiling, and indicate the onset of complete film boiling to occur at a surface-to-drop temperature difference of approximately 350°F for the conditions studied.

These results suggest that true film boiling, as defined previously, did not occur in the 300 KW Facility boiler testing, because no local temperature differences in excess of 350°F were obtained. In addition, the Geoscience results suggest that the surface-to-drop temperature difference is an important variable in transition boiling. The local quality must be a significant variable, as it is expected that the heat transfer coefficient will decrease with increasing quality in the transition region, since the amount of liquid which can be in contact with the heat transfer surface decreases with increasing quality. The transition boiling coefficient must eventually reduce to the vapor phase heat transfer coefficient as the vapor quality approaches 100%. Finally, the presence of an insert which generates a radial acceleration is expected to increase the transition boiling heat transfer coefficient, since the centrifugal force generated tends to increase the fraction of liquid in contact with the boiler tube wall.

Equation 1 following satisfies the qualitative observations regarding the transition region discussed above, and has been empirically fitted to the 300 KW transition boiling data.

$$\frac{\frac{h_{TB}}{h_V} - 1}{(1 + a_R)^a} = F \left(\frac{1 - x}{x}\right)^b \frac{1}{(\Delta t)^c} \qquad (1)$$

where

h_{TB} = transition boiling heat transfer coefficient

h_V = vapor phase heat transfer coefficient

x = vapor quality

Δt = heated surface to potassium temperature difference, ^oF

a_R = radial acceleration developed by insert, g's

F, a, b, c, = empirical constants determined by a fit to the data

The constant c was determined empirically by plotting the left side of Equation (1) versus $1/\Delta t$ for the no insert data (for which $a_R = 0$) for a narrow range of the parameter $(1 - x)/x$. The result is shown in Figure 1, from which it is seen that a value of c equal to 2.0 fits the data. The constants a, b and F were then determined empirically by plotting the left side of Equation (1) for all the data versus $\left(\frac{1 - x}{x}\right)^b \frac{1}{\Delta t^2}$, and adjusting a, b and F by trial until the best fit was obtained. Figure 2 shows the empirical correlation obtained, for which a = 1/5, b = 0.7 and $F = 2.55 \times 10^5\ ^oF^2$. The resulting empirical equation representing the 300 KW transition boiling data, which correlates 80% of the points within ± 30%, is as follows:

$$\frac{h_{TB}}{h_v} - 1 = 2.55 \times 10^5 \ \frac{(1+a_R)^{1/5} \left(\frac{1-x}{x}\right)^{0.7}}{(\Delta t)^2} \qquad (2)$$

The vapor phase heat transfer coefficients (h_v) employed in the correlation are calculated from the Colburn equation (Reference 6) for tubes without inserts and from the correlation presented in Reference 4 for tubes containing helical inserts.

Also shown in Figure 2 are three transition boiling heat transfer coefficients obtained from the 100 KW Facility, as discussed in Section III of this report. These three points were plotted after the empirical correlation, equation 2, had been established from the 300 KW Facility data; and thus the satisfactory agreement shown by these three data points constitutes an independent indication of the validity of the correlation. Including the three data points from the 100 KW Facility, the values plotted in Figure 2 encompass the following range of test variables.

Transition boiling h:	$174 \leq h_{TB} \leq 3966$ Btu/(hr-ft^2-^{o}F)
Vapor quality	$0.44 \leq x_{TB} \leq 0.93$
Potassium Temperature	$1512 \leq T_{KTB} \leq 2105^o$F
Mass Velocity	$16 \leq G_K \leq 101$ lb/(ft^2-sec)
Radial Acceleration	$0 \leq a_{RTB} \leq 140$ g's

3. Superheated Vapor

About five superheated vapor heat transfer coefficients were obtained from the 300 KW Project. They are not of high precision due to the difficulty involved in determining the relatively short superheated vapor length from the limited number of insert thermocouples. These data, will be presented in the topical report and compared to single phase predictions.

4. Critical Heat Flux

Critical heat flux values obtained with a 0.67-inch inside diameter boiler tube, with and without P/D = 6 insert, were presented in Reference 4. Additional values computed from the data obtained with a 0.92-inch ID boiler tube containing helical inserts of P/D = 2 and P/D = 6 are listed in Table 1 of this report. The calculational procedures utilized are presented and discussed in Reference 3.

All of the critical heat flux data obtained in the 300 KW Facility and some data obtained in the 100 KW Facility are plotted in Figure 3 as $q_c''/(1 + a_R)^{\frac{1}{4}}$ versus x_c, where q_c'' is the critical heat flux, x_c the quality at the critical heat flux point and a_R the radial acceleration developed by the insert in g's. Approximately two-thirds of the data are correlated within ± 30% by the following empirical equation.

$$\frac{q_c''}{10^6} = \frac{(1 + a_R)^{\frac{1}{4}}}{1 + 2\left(\frac{x_c}{1-x_c}\right)} \quad \text{Btu/(hr-ft}^2\text{)} \qquad (3)$$

The critical heat flux data plotted in Figure 3, obtained in the 100 KW and 300 KW Facilities, encompass the following range of test variables:

Critical Heat Flux:	$50,000 \leq q_c'' \leq 532,000$ Btu/(hr-ft^2)
Vapor Quality	$0.40 \leq x_c \leq 0.91$
Potassium Temperature	$1522 \leq T_{Kc} \leq 2106^oF$
Potassium Mass Velocity	$15 \leq G_K \leq 101$ lb/(ft^2-sec)
Radial Acceleration	$0 \leq a_{Rc} \leq 117$ g's

The critical heat flux data obtained in the 3/4-inch nominal diameter boiler tube of the 300 KW Facility were plotted in Reference 4 as $q_c''/(a_R)^{\frac{1}{4}}$ versus x_c rather than as $q_c''/(1 + a_R)^{\frac{1}{4}}$ versus x_c as recommended in this report. The use of $(1 + a_R)$ is a more logical technique, as a_R is mathematically equal to zero for tubes without inserts. It would be necessary to arbitrarily set the acceleration term equal to 1.0 for the no insert data if the former technique were employed. Changing the acceleration term does not affect the results significantly, as a_R is generally large in comparison to unity for the 300 KW data with inserts.

C. Additional Analysis

Analysis is proceeding to determine the effect of the various heat transfer and pressure loss parameters upon the thermal design of once-through potassium boilers for space power application. The reference design chosen for this study is an 8.3 MW-thermal boiler producing potassium vapor at an exit temperature of 2150^{o}F with 150^{o}F superheat from subcooled liquid at an inlet temperature of 1200^{o}F, employing lithium as the heating fluid. The boiler length required with and without helical inserts will be calculated, utilizing a design procedure based upon the data and correlations obtained under this contract. The effect upon the boiler length of errors in the various design parameters is being evaluated, and the significance of the critical heat flux, the various heat transfer coefficients and the potassium pressure loss is being determined. The results of these calculations will be reported in the topical report, covering results from the 300 KW Facility, which will be prepared during the next Quarter.

III 100 KW PROJECT

J.A. Bond

The 100 KW Facility is a single loop system used to study heat transfer to boiling alkali metals at temperatures up to 2100°F. The radiation heated boiling test sections consisted of various vertical pipes both with and without inserts. Thermocouples were attached on the outer wall of the test section and fluid temperatures were measured with insert thermocouples (in Test Sections 4 and 5). A preboiler, located upstream of and in series with the test section, controlled the enthalpy of the fluid entering the test section. The working fluid was potassium.

Status of Loop and Test Section

Boiling operation with Test Section No. 5 began on July 7, 1965. As described in Reference 4, Test Section No. 5 is a 3/4-inch nominal diameter pipe (0.74-inch ID, 30-inch heated length) containing an instrumented, combination wire coil and inlet plug insert. This test section also includes a radiant heated nucleator of the "hot-finger" type located between the preboiler outlet and the test section heated zone inlet, for use in boiling inception studies. A more detailed description, along with photographs, is presented in Reference 4. Testing was interrupted during July due to failure of the three insert thermocouples in the probe at the test section outlet. Replacement of these thermocouples resulted in about one week of "down-time". The planned tests with Test Section No. 5 were completed on August 4, 1965. This was the last of the currently-contracted experimental work in the 100 KW Facility. After removing Test Section No. 5 from the loop (for use in single-phase pressure drop tests), the facility was shutdown with all equipment in good working order.

During August, single-phase water pressure drop tests were conducted on Test Sections No. 4 and No. 5 and the results will be used in correlating two-phase potassium pressure drop data obtained with these test sections.

Status of Data Reduction

The nucleate boiling data obtained with Test Section No. 4 have been reduced and are tabulated in Appendix A , along with a test section instrumentation list. The critical heat flux, transition boiling, stable film boiling and superheated vapor data from Test Section No. 4 are presented in Table 2 . The data from Test Section No. 5 are being processed and will be presented in the next Monthly Progress Report.

Status of Data Evaluation

Nucleate Boiling Results Test Section No. 4 was a 3/4-inch (0.74-inch ID, 30-inch heated length) pipe containing an instrumented plug-helix insert. A detailed description of this test section, along with photographs, is given in Reference 4. Figure 4 is a plot of the 2100°F nucleate boiling data taken in Test Section No. 4. Over the heat flux range from 110,000 Btu/hr-ft^2 to 150,000 Btu/hr-ft^2, the data suggest the trend of increasing heat transfer coefficient with increasing heat flux. This trend is not apparent at the highest heat flux of 175,000 Btu/hr-ft^2. The data taken at T_{sat} = 1800°F are plotted in Figure 5. These heat transfer coefficients, like those taken at 2100°F, are somewhat lower than the corresponding data taken in a plain tube with no insert. In an attempt to explain why the nucleate boiling heat transfer coefficients obtained with helical inserts should be lower than corresponding data without inserts, some simple calculations were made to determine the radial pressure and corresponding saturation temperature rise associated with the tangential component of fluid velocity caused by the insert. The simplified equation of motion, in cylindrical coordinates, is:

$$\frac{dP}{dr} = \frac{\rho}{g_c} \frac{V_\theta^2}{r} \qquad (1)$$

Since the relationship between the tangential component of velocity, V_θ, and the radius, r, is unknown, an assumption must be made. For the initial calculation, it was assumed that the <u>axial</u> component of velocity, V_z, is independent of the radius r. In Reference 4, it was shown that

$$\frac{V_\theta}{V_z} = \frac{\pi(2r)}{P} \qquad (2)$$

Combining Equations (1) and (2) gives:

$$\frac{dP}{dr} = \frac{\rho}{g_c} \left(\frac{2\pi V_z}{P}\right)^2 r \qquad (3)$$

Assuming constant density, ρ, Equation (3) can be integrated to give:

$$P_i - P_{CB} = \frac{\rho}{2g_c} \left(\frac{\pi V_z}{P/D_i}\right)^2 \left[1 - \left(\frac{D_{CB}}{D_i}\right)^2\right] \qquad (4)$$

If the liquid fraction in the two-phase mixture is neglected, then

$$V_z = \frac{xG}{\rho} \qquad (5)$$

Combining Equations (4) and (5) gives:

$$P_i - P_{CB} = \frac{(xG)^2}{2g_c\,\rho}\left(\frac{\pi}{P/D_i}\right)^2\left[1 - \left(\frac{D_{CB}}{D_i}\right)^2\right] \qquad (6)$$

Equation (6) gives the pressure rise from the insert centerbody to the test section inside diameter, assuming that the axial component of velocity is independent of radial position. If the fluid is at saturation conditions, then this pressure rise results in a corresponding temperature rise. A "worst case" number was calculated for Test Section No. 4 by assuming $T_{sat} = 2100^{o}F$, x = 100% and G = 30 lb/sec-ft^2. The resulting pressure rise as evaluated from Equation (6), is approximately 0.6 psi. This corresponds to a temperature rise of about 1.3^{o}F, which is not enough to explain the relatively lower values of the heat transfer coefficient shown in Figure 4. This effect becomes more important for lower saturation temperatures.

Further analysis of the effect of the helical insert pitch-to-diameter ratio on the nucleate boiling heat transfer coefficient is in progress. This analysis will be presented in the topical report covering results from the 100 KW Facility.

Critical Heat Flux, Transition Boiling, Film Boiling and Superheated Vapor Results During the course of testing with Test Section No. 4, some data were obtained in transition boiling, stable film boiling and superheated vapor conditions, respectively. The data obtained during these runs is presented in Table 2A. Figures 6 through 15 are segments of recorder charts showing the behavior of pertinent system parameters during these runs. The general test procedure was to hold the saturation pressure, flow rate and test section heat flux constant while the quality was increased by increasing the preboiler power. After exceeding the critical quality corresponding to these conditions, further increase in quality resulted in the usual test section wall temperature oscillations (described in Reference 4) until at some point, stable film boiling was established. In some cases at the higher heat fluxes, the wall temperature during film boiling became too high, so that it was necessary to reduce the test section heat flux before proceeding into superheated vapor conditions. Conditions of exit vapor superheat up to 287°F were obtained in this manner.

The existence of superheat vapor was inferred when a power increase resulted in an increase in fluid temperature, as measured by the thermocouples contained within the centerbody of the insert. Examination of this superheated vapor data revealed a discrepancy between the measured enthalpy increase of the fluid and the calculated energy input based on the electrical power measurements (corrected for heat losses) together with the indicated flow rate. The discrepancy was that the calculated energy input was 8 to 17% greater than the measured enthalpy increase of the fluid. This energy balance discrepancy was assumed to be due to an error in flow rate measurement. With this assumption, the question was asked: For a given superheated vapor temperature rise, what flow rate would be required to be consistent with the measured superheat? The required flow rate was calculated from an energy balance between the preboiler inlet and the point in the test section where the superheat was measured. This flow rate is given by:

$$W = \frac{q}{h_{g2} - h_{\ell 1} + \bar{C}_p \, (\Delta T)_{SH}} \qquad (7)$$

where

q = Net power input up to the measuring station, Btu/sec

h_{g2} = Vapor enthalpy at the saturation temperature, Btu/sec

$h_{\ell 1}$ = Liquid enthalpy at the preboiler inlet, Btu/sec

$\bar{C}_p$ = Average superheated vapor specific heat, Btu/lb-$^{\circ}$F

$(\Delta T)_{SH}$ = Degrees of superheat, $^{\circ}$F

The flow rates calculated from Equation (7) were from 8% to 17% higher than the corresponding measured flow rates. The data presented in Table 2 have been corrected such that the flow rates are consistent with the measured superheat.

In order to investigate the validity of the assumption that the discrepancy in the energy balance was due to an error in flow rate, an independent check was made. This was done by selecting runs in which superheated vapor conditions existed at two axial measuring stations in the test section (thermocouple numbers 34 and 35 in Table A-1). The power input to the vapor between these stations was calculated from:

$$q_{34-35} = W \bar{C}_p (\Delta T)_{34-35} \quad (8)$$

The corresponding net electrical power input between stations was then calculated assuming uniform test section heat flux. It turned out that the ratio of the electrical power to the power given by Equation (8) was within about 1% of the calculated flow rate discrepancy. This means that if the flow rate used in Equation (8) were that calculated from Equation (7), then the energy balance between the two superheated vapor stations would check within about 1%. Although this agreement doesn't constitute absolute proof, it strongly suggests that the error in the energy balance is due primarily to the flow rate. This is so because the flow rate calculated from Equation (7) is a function of the preboiler power and the test section power, whereas the power in Equation (8) is a function of the test section power only. Since the preboiler power and the test section power are measured independently, it seems unlikely that errors in power would combine in such a way that the two energy balances described above would agree. The flowmeter in the 100 KW loop is calibrated from an energy balance during single-phase liquid runs. During these runs the temperature rise across the test section is on the order of 900°F. Any error in the values of the liquid enthalpy used in this energy balance would appear as an error in flow rate. The values of liquid enthalpy used in the 100 KW Facility flowmeter calibration were the preliminary NRL data from Reference 10. The final NRL data from Reference 21 shows some discrepancy with the earlier data. Specifically, on the basis of a liquid temperature rise from 1400°F to 2000°F, the liquid enthalpy change calculated from the earlier data (Reference 10) would be 8% higher than the corresponding change calculated from the final data (Reference 21). Assuming that the final data are correct, this means that the flow rates should be on the order of 8% low which is in agreement with the discrepancy observed during the superheated vapor runs.

In Reference 4, some film boiling and superheated vapor data taken with Test Section No. 3 were presented. Since then, three transition boiling heat transfer coefficients have been obtained from the data and are presented in this report as Table 2-B. For these runs, the wall temperature was oscillating. The procedure used to calculate the transition boiling heat transfer coefficient was to calculate the time-average wall temperature from digital recorder data taken at 3 printouts/second over an approximately 1-minute interval and to then use this time-average wall temperature in conjunction with the measured fluid temperature and test section heat flux. The same procedure was used to obtain the transition boiling heat transfer coefficients given in Table 2A for Test Set No. 4.

IV 50 KW PROJECT

S.G. Sawochka

Status of Loop and Test Section

Completion during March, 1965 of Test Set No. 5 (5/8-inch ID tube with 1/4-inch OD instrumented tubular insert) concluded the planned test program in the 50 KW Facility. The facility was then shutdown, in good working order.

Status of Data Reduction

All of the condensing heat transfer data have been reduced and reported. The helical insert data, Test Set No. 4, were recalculated to account for the effect of the radial pressure gradient caused by the tangential velocity component of the swirl flow. In addition, the treatment of the July, 1964, 5/8-inch ID tube data without insert, which is from Test Set No. 1, was extended. The additional treatment involved application of the measured axial temperature profiles obtained from the 5/8-inch ID tube with tubular insert to the estimation of the axial potassium temperature profiles, in the tube without insert instead of assuming a linear temperature profile as had been done previously (Reference 27).

A discussion of the integrated and local two-phase friction pressure drop multipliers for Test Sets No. 4 and No. 5 is also presented.

Status of Data Evaluation

Heat Transfer - All of the heat transfer data have been previously reported (References 3 and 4). A refinement in the calculational procedure used for Test Set No. 4 has been completed to account for the effect of the radial pressure difference from the helical insert centerbody to the condenser tube wall. This radial pressure difference is given approximately by:

$$P_D - P_{DCB} = \left(\frac{\pi D}{P}\right)^2 \left(\frac{G_g}{2\rho_g}\right) \frac{1}{g_c} \left[1 - \left(\frac{D_{CB}}{D}\right)^2\right] \qquad (1)$$

To correct for the effect of this pressure difference on the calculated condensing heat transfer coefficients, the potassium temperature measured by the insert was taken as representing the static pressure P_{DCB}. The incremental radial pressure caused by the swirling flow was then added to P_{DCB} to give P_D. A corrected value of T_K, the saturation temperature corresponding to P_D, was then used to calculate the corrected condensing heat transfer coefficient. The assumptions made were: (1) negligible film thickness compared to $(D - D_{CB})/2$, which was the case for the experimental range of variables; and (2) uniform axial velocity.

This correction decreased the experimental condensing heat transfer coefficient by increasing the vapor saturation temperature from the measured centerbody saturation temperature to that corresponding to the pressure at the liquid-vapor interface. Potassium saturation temperature corrections as high as 20°F were obtained.

The corrected results are presented in Figure 16 along with the tubular insert data. As can be seen, the correction procedure brings the last two sets of condensing test data (Test Sets No. 4 and No. 5, for which instrumented inserts were used) into agreement within the scatter of the data. Vapor phase heat transfer coefficients were separated from the condensing thermal resistance, in the manner described in Reference 4. These results are compared to the results obtained with the tubular insert in Figure 17. The corrected helical insert test results scatter on both sides of the correlating line for $\sigma = 0.19$ found to give the best correlation of the tubular insert data of Test Set No. 5. Before accounting for the radial pressure gradient, the helical insert test data gave consistently higher vapor phase heat transfer coefficients than those predicted for $\sigma = 0.19$. (Reference 4)

The possible error in the condensing heat transfer data obtained with the 5/8-inch ID tube without insert due to the use of a linear potassium axial temperature distribution during the data reduction procedure can be analyzed as follows.

In Reference 4, the pressure change between the test section inlet and an arbitrary quality x at length, ℓ , along the condenser tube is given by:

$$P_{\ell} - P_I = \frac{G^2}{\rho_f \, g_c} \left[\frac{\rho_f}{\rho_g} - \frac{\rho_f}{\hat{\rho}} - \phi_{1-x} \quad \frac{f\ell}{2D} \right] \qquad (2)$$

where

$$\frac{1}{\hat{\rho}} = \left[\frac{(1 - x)\ K}{\rho_f} + \frac{x}{\rho_g} \right] \left[\frac{1}{K} + x - \frac{x}{K} \right] \qquad (3)$$

For total condensation from x = 1 to x = 0, the pressure range is:

$$P_O - P_I = \frac{G^2}{\rho_f \, g_c} \left[\frac{\rho_f}{\rho_g} - 1 - \phi_{1-0} \quad \frac{fL}{2D} \right] \qquad (4)$$

for a linear axial quality variation.

Since comparison of the measured and predicted temperature distributions for the tubular insert tests was made to allow selection of a method of calculation of the axial temperature profile between measured inlet and outlet temperatures for the 5/8-inch ID tube without insert, only the ratio of the pressure change along the test section to the total condensing pressure change was considered. From Equations (2) and (4), assuming that the saturation temperature varies linearly with the pressure for small changes in pressure.

$$\frac{P_\ell - P_I}{P_0 - P_I} = \frac{T_K - T_{KI}}{T_{KO} - T_{KI}} = \frac{\rho_f/\rho_g - \rho_f/\hat{\rho} - \phi_{1-x} \frac{f\ell}{2D}}{\rho_f/\rho_g - 1 - \phi_{1-0} \frac{fL}{2D}} \qquad (5)$$

The following ranges of variables are pertinent for the 5/8-inch ID tube without insert, July, 1964, data.

Inlet Potassium Temperature, ^{o}F	1130 to 1312
Liquid Reynolds Number, Dimensionless	1600 - 3400
Net Power, KW	2.7 - 11.5

For the above range of variables the predicted dimensionless pressure distributions for the tubular insert test are presented in Figure 18 for homogeneous flow (a slip ratio K = 1) and for a slip ratio $K = \sqrt{\rho_f/\rho_g}$. As can be seen, the predicted dimensionless profiles are different for K = 1 and $K = \sqrt{\rho_f/\rho_g}$. Therefore, the slip is of importance in the prediction of the axial temperature profile. In Figure 19 data for several runs of Test Set No. 5 are presented and compared to the analytical prediction for a slip ratio K = 1, since it seems to give a better estimate of the measured profile than does the prediction with slip ratio $K = \sqrt{\rho_f/\rho_g}$. The predictions were made with the assumption of linear axial quality variation and constant potassium temperature; that is, the axial pressure change was assumed to have a negligible effect on the two-phase multiplier and saturation properties. For these reasons, only qualitative agreement between analysis and experiment was expected, particularly since the slip ratio is expected to vary as a function of quality and length thereby distorting the predicted momentum pressure gradient along the length of the test section.

Figure 19 indicates that at low quality near the test section outlet, the axial temperature profile approximates a linear function with length. However, near the test section inlet, which is the high quality region, the linear approximation is poor, and a better correlation can be obtained using the homogeneous flow model, particularly at 1200 and 1300^{o}F. A comparison of the calculated condensing heat transfer coefficients for the July 1964 data for 5/8-inch test section without insert is presented in Table 3 using a linear temperature profile, the analytical prediction for a slip ratio K = 1, and the analytical prediction for a slip ratio $K = \sqrt{\rho_f/\rho_g}$.

This tabulation shows that at temperatures greater than 1200^{o}F the calculated condensing heat transfer coefficients for the three assumed axial potassium temperature distributions agree within 48% of the arithmetic average of the values from the three methods. The results of this comparison can be summarized as follows:

1. At temperatures greater than 1200°F, the heat transfer coefficients calculated using linear axial temperature distributions and those using temperature distributions calculated from the homogeneous flow model, K = 1, agree with the arithmetic average value of the two methods within ± 35%. Thus, the assumption of a linear temperature distribution is apparently satisfactory for temperatures above 1200°F.

2. At temperatures less than 1200°F, considerable disagreement between the heat transfer coefficients calculated using the three procedures for estimating the local potassium temperatures is obtained. This might be explained by the large effect of small pressure change errors on the local saturation temperature (large dT/dP at low temperature), and also by the large value of the two-phase friction pressure drop multiplier.

3. For the data at temperatures greater than 1200°F, the three calculated values of the condensing heat transfer coefficient for each of the data runs are within the scatter of the instrumented insert test data, thereby indicating little or no effect of the smooth tubular insert on the condensing heat transfer process.

Pressure Change - The expression for the pressure change associated with the condensation of saturated vapor to 100% liquid was given in Equation 4.

where

$$\frac{G^2}{\rho_f\, g_c}\left(\frac{\rho_f}{\rho_g} - 1\right) = \text{Momentum pressure rise} \qquad (6)$$

$$\frac{G^2}{\rho_f\, g_c}\left(\phi_{1-0}\,\frac{fL}{2D}\right) = \text{Friction pressure drop} \qquad (7)$$

The momentum pressure rise can be evaluated for each data run from a knowledge of the mass velocity, and saturation conditions at the test section inlet and outlet, since it is independent of the heat flux distribution and axial temperature variation.

The friction pressure drop can be calculated by subtracting the calculated momentum pressure increase from the total pressure change, $P_O - P_I$. This friction pressure drop is then used to determine the two-phase integrated friction pressure drop multiplier ϕ_{1-0}.

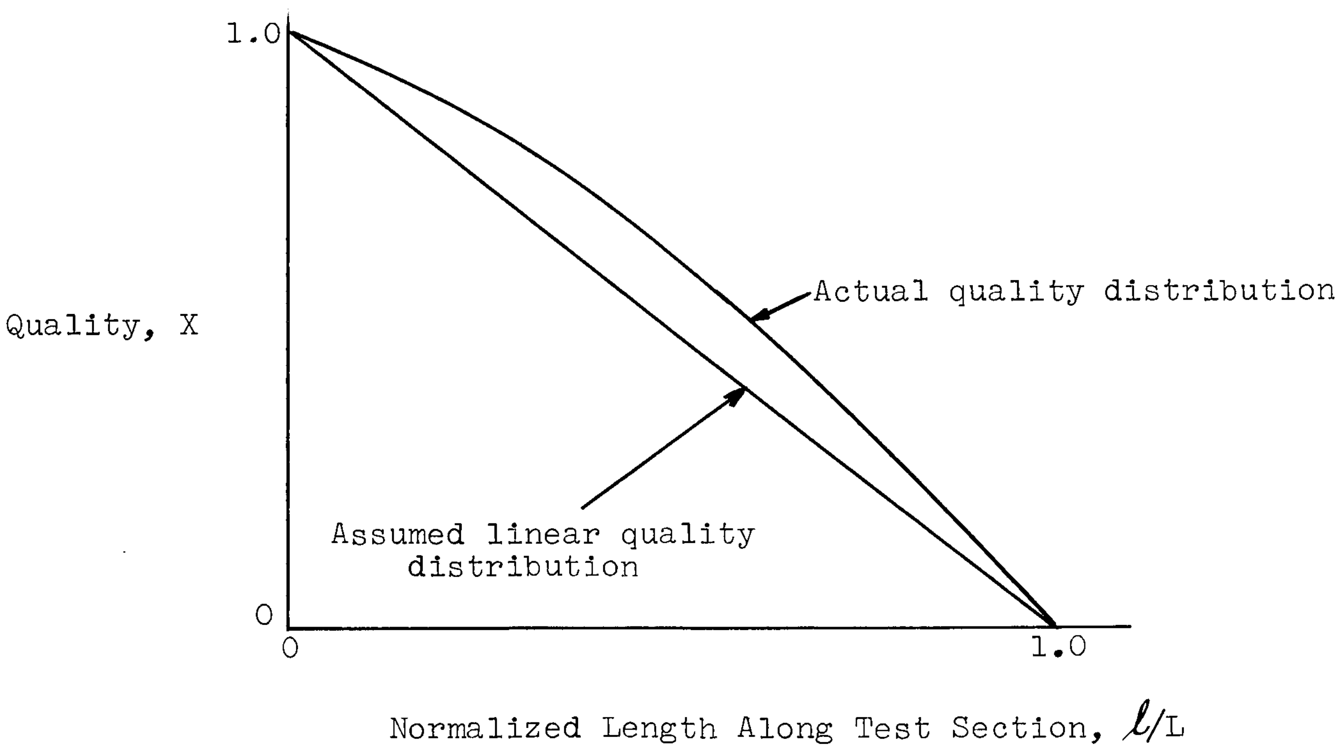
The results of this procedure for Test Sets No. 4 and No. 5, the helical and tubular insert tests, respectively, are presented in Figure 20. The predicted integrated pressure drop multipliers of the modified Martinelli model (Reference 2) and the homogeneous model are also presented for comparison to the experimental data. As suggested in Reference 4, the maximum helical velocity, and length were used to estimate the single-phase liquid pressure drop for the helical insert.

The potassium properties were evaluated at the average potassium temperature given by:

$$T_K = \frac{T_{KI} + T_{KO}}{2} \qquad (8)$$

In general it can be seen that the experimental two-phase multipliers are slightly greater than the homogeneous prediction with a slip ratio K = 1. This might be partially due to the method of calculation of the predicted ϕ, using an integration that assumes linear quality variation with test section length.

During the tests, the quality did not change linearly with test section length. In general, the heat flux peaked at the test section exit where the sodium temperature was at its minimum. Therefore the quality variation was actually as shown in the following sketch.



The actual quality variation indicates that a longer length of the test section is in the higher quality region than assumed. Since the local two-phase multiplier, ϕ, decreases with decreasing x and a longer section of the test section than assumed by a linear quality profile is taken in the higher quality region, the experimental two-phase multipliers should be higher than predicted, as is generally the case (see Figure 19).

Local Pressure Drop - To evaluate local friction pressure drop multipliers, the local condensing pressure gradient was estimated from the local temperature gradient by a linear approximation. The local momentum pressure gradient is given by:

$$\left(\frac{dP}{d\ell}\right)_M = \frac{G^2}{g_c}\left[\frac{1}{\rho_f}\ \frac{dx}{d\ell} + \frac{1}{\rho_g}\ \frac{dx}{d\ell}\right] \qquad (9)$$

for homogeneous flow, K = 1.

The local quality gradient was calculated from the local heat flux and weight flow rate. The momentum pressure gradient was calculated and subtracted from the condensing pressure gradient. Then, the friction pressure gradient is as follows:

$$\left(\frac{dP}{d\ell}\right)_f = \frac{dP}{d\ell} - \left(\frac{dP}{d\ell}\right)_M \qquad (10)$$

The two-phase multiplier based on the single-phase liquid pressure drop was calculated as follows:

$$\phi = \frac{2g_c\ D\ \rho_f}{fG^2}\ \left(\frac{dP}{d\ell}\right)_f \qquad (11)$$

The two-phase multiplier ϕ vs. temperature is given in Figure 21. The homogeneous model prediction and the modified Martinelli model (Reference 2) prediction for 20% and 80% quality are also presented for comparison. In general the local multipliers at the bottom axial station, x = 20%, are higher than predicted by either the homogeneous or modified Martinelli models. No significant trend of the experimental data at x = 80% with respect to the predictions is evident. Substantial scatter is evident in both sets of data, evidencing the inadequacy of both predictions.

V FACILITIES AND INSTRUMENTATION

J.C. Amos/W.H. Bennethum

300 KW Facility

Accurate knowledge of the 300 KW Loop sodium pump capability is required to refine the design of the shell-side geometry for the multiple-tube boiler associated with the facility conversion design (Section IX). An available stainless steel valve was therefore installed in the 300 KW sodium system and the loop was operated for a short period during August to obtain sodium pump performance data. Data were obtained in the $600^{\circ}F$ to $700^{\circ}F$ and $1300^{\circ}F$ to $1400^{\circ}F$ temperature ranges over flow ranges from 0 to 50 gpm. The loop operated very well with no indication of problems resulting from the long period of down time. The maximum flow rate was limited to 50 gpm by the small port size of the stainless steel valve used during the test. Since the sodium flows of interest for the multiple-tube boiler are up to 100 gpm at $1800^{\circ}F$, additional high-flow high-temperature runs are planned, to fully define the pump performance in the region of interest. The sodium throttle valve will be removed for this high-flow test.

The pump test required approximately 18 hours of loop operation bringing the total operating hours for this facility to 4466 hours.

100 KW Facility

Final instrumentation of Test Section No. 5 was completed July 2. Following thermocouple calibration, boiling tests were initiated July 7 and were completed August 5, 1965. During the boiling test operation, the three Pt10%Rh-Pt thermocouples located in the insert at the outlet of the test section became inoperative. Since the alumina insulators could not be removed from the insert tube, it was necessary to shutdown and cut the insert tube out of the test section and install a new tube. Five thermocouple pairs were installed in the new tube and satisfactory operation was obtained for the remainder of the tests. Following replacement of the thermocouple assembly the loop was flushed with potassium at a maximum temperature of 800°F for approximately 2 hours before boiling operation was resumed. Analysis of the oxygen concentration in the potassium after flushing operation indicated a level of 15 ppm O_2.

The facility operated a total of 306 hours, including 210 hours under boiling conditions, during the report quarter. On August 5, 1965 planned experimental work under the current program was completed and the facility was shutdown in good working order. Total facility operating hours above 800°F is 6203 hours.

The Test Section No. 5 was removed from the facility and water pressure drop tests were run on both Test Sections No. 4 and No. 5.

50 KW Facility

There was no activity on the 50 KW Facility during the report quarter. The facility has been shutdown, in good working order, since completion of experimental work planned under the current program on March 5, 1965.

VI MATERIALS SUPPORT

W.R. Young/W.H. Kearns

During the last series of tests in the 100 KW Facility with Test Section No. 5, the well thermocouples at the test section exit failed. Since attempts to remove the thermocouples from the well were unsuccessful, it was necessary to remove the thermocouple well from the facility to replace the failed thermocouples.

The 1-inch pipe shell, downstream of the boiler, was cut and the thermocouple well and support pipe were pulled from the test section. A new well of the same design was fabricated and joined to the test section piping.

The assembly was fabricated in the vacuum purge welding chamber. It was then reinstalled in the facility and the joint in the 1-inch, Schedule 80 pipe leg was welded using standard field welding procedures. The welded joints in the insert were heat treated at 2100°F during thermocouple calibration.

After completion of the boiling test series, the test section was removed from the facility. The piping was cut at the preboiler exit and condenser inlet coil. The facility piping was then capped at these two locations by field welding.

VII ANALYSIS

G.L. Converse

The analytical task during the current quarterly period has been directed largely toward the reduction and preliminary evaluation of the results of several stability tests conducted in the 100 KW loop. In addition, the prediction of the critical flow rate in a two-phase mixture utilizing several available analytical models was completed.

In the present section the results of the stability experiments conducted in the 100 KW loop during Test Sets No. 3 and No.4 will be reported and discussed. The results of the analytical prediction of the critical flow rate will then be presented both in graphical and tabular form.

Stability Investigations

1. Test Section No. 3, 100 KW Loop

On March 19, 1965, the 100 KW loop was operated for the specific purpose of obtaining additional data on the instability associated with boiling initiation. The test was conducted in the manner described in Reference 3. Operation was at a dump tank pressure of about 201 psia, corresponding to a saturation temperature of 2100°F. On April 2, 1965, two additional boiling initiation tests were conducted at dump tank pressures of about 80 psia and 27 psia, corresponding to saturation temperatures of about 1800°F and 1520°F, respectively. The tests were done with Test Section No. 3, which was a 0.423-inch inside diameter tube with no insert, at the various conditions summarized in the following table.

Range of Variables For Stability Tests In 100 KW Facility Using Test Section No. 3

Date	3/19/65	4/2/65	4/2/65
Flow Rate (lb_m/sec)	0.03	0.043	0.045
Test Section Mass Velocity ($lb_m/sec\text{-}ft^2$)	30.7	44.0	45.0
Initial Dump Tank Pressure (psia)	201	80	27
Test Section Exit Well Temperature (°F) (after boiling inception)	2145	1812(min)	1580(min)
Approximate Wall Superheat at Test Section Exit (°F)* (Just prior to boiling inception)	124	Unstable	Unstable
Test Section Inside Diameter (in.)	0.423	0.423	0.423
Single Phase Orifice Diameter (inches)(Located between the pump and the boiler inlet)	0.0625	0.0625	0.0625

*Calculated from the measured outside wall temperature approximately 1.6 inches from the end of the heated zone.

The Sanborn trace for the first test (P = 201 psia) is shown in Figure 22. As can be seen from this figure, oscillations in the wall temperature occur immediately after boiling inception and persist for about 3 minutes. The wall temperature then steadies out and the system proceeds into stable boiling.

The Sanborn trace for the second test done with Test Section No. 3 (P = 80 psia) is shown in Figures 23-a through 23-g. The Figures are reproductions of adjacent sequential sections of a continuous Sanborn oscillograph recorder trace made throughout the test. This trace covers the entire period of the test beginning with boiling initiation at the test section outlet after an increase of preboiler power (Figure 23a) followed by a period of oscillatory or unstable boiling operation (Figures 23b and 23c). A further increase in preboiler power resulted in an increase in the frequency of the oscillations (Figure 23d) and subsequent increases in preboiler power had a similar effect (Figure 23e). Following this, the test section power was then reduced in steps until the system was brought back into non-boiling liquid flow conditions (Figures 23f and 23g).

In order to have a somewhat more quantitative record of the fluid temperature oscillations than that provided by the Sanborn trace, a continuous digital printout of the test section exit well thermocouple was obtained for a portion of the time period covered by Figure 23c. The digital was allowed to run for about 6 minutes at a rate of 3 printouts per second. These data are contained in Table 4. The time co-ordinate should be read across and then down in this table. In Figures 24a and 24b the first 160 seconds of the continuous printout have been plotted on temperature vs. time co-ordinates. It is readily apparent from Figures 24a and 24b that the large oscillations in temperature are actually accompanied by a number of smaller oscillations.

The Sanborn trace for the third test done with Test Section No. 3 (P = 27 psia) is shown in Figure 25. There were significant oscillations of the dump tank level and small oscillations of the condenser inlet wall temperature at the beginning of the recorder chart segment reproduced in Figure 25. At the beginning of the chart the flow is steady and the well thermocouple and the wall thermocouple at the test section exit indicate by their steadiness and level above the saturation temperature corresponding to 27 psia

($1520^{o}F$) that the fluid is in a superheated liquid state at the test section exit. It is thought that these oscillations in the dump tank level and condenser inlet wall temperature are indicative that flashing of the superheated liquid into two-phase conditions was occurring in the cross-over pipe which connects the test section outlet with the condenser inlet. After boiling began at the test section exit, as indicated by an abrupt drop of the test section exit well and wall temperatures, the loop became highly unstable.

A quantitative analysis of the oscillation in test section well temperature after boiling inception, shown in Figures 24a and 24b, would require a careful analysis of the instrument responses in the 100 KW loop. However, some qualitative understanding of the gross temperature excursions (abrupt reductions in temperature followed by relatively slower temperature rise) can be obtained from the following simple analytical model.

Consider a semi-infinite plate. Assume that the plate is initially at a uniform temperature (T_o). Heat is then removed from the face of the plate (located at $\ell = 0$) at a uniform flux (q'') for a time interval τ. The face of the plate is then insulated and the heat removal stops. A solution for the temperature distribution in the plate as a function of position ℓ and time t after heat transfer starts is given in Reference 23. Using this model as a representation of the boiler tube wall of Test Section No. 3, $\ell = 0$ corresponds to the inner surface of the tube and $\ell = 0.124$-in corresponds to the outer surface of the tube. A calculation of the variation with time of the plate temperature at the positions $\ell = 0$ and $\ell = 0.124$-inch was made using the equations given in Reference 23. The results of this calculation are given in

Figure 26 showing the variation of the plate temperature at the positions $\ell = 0$ and $\ell = 0.124$-inch as a function of time after the beginning of heat removal. The similarity in the behavior of the plate temperature in Figure 26 to that shown in Figures 24a and 24b suggests that the sudden gross reductions in wall temperature are caused by a very high rate of heat removal (high heat flux) at the fluid surface of the boiler tube followed rapidly by a relatively low rate of heat removal. Such a behavior could be attributed to intermittent boiling, as discussed in Reference 4.

2. Test Section No. 4, 100 KW Loop

Three tests were conducted in the 100 KW Loop to obtain data on instability associated with boiling initiation and heat transfer in the vicinity of the boiling inception point with Test Section No. 4, shown in Figure 27. Two of the tests , done on June 2, 1965, were conducted at a flow rate of about 0.064 lb/sec, and the third test, done on June 3, 1965, was conducted at a flow rate of about 0.040 lb/sec. Since no effect of flow rate on stability was observed, only the results from the tests at 0.064 lb/sec flow rate will be discussed.

The tests were conducted in the following manner. The dump tank pressure was set at about 124 psia (1930°F saturation temperature), and the loop was operated in a single-phase (all liquid) condition. The preboiler power was then increased until boiling began at the test section exit. The resulting surges in flow, pressure and temperature were recorded on an 8-channel Sanborn recorder. The section of the recorder chart indicating boiling initiation is shown in Figure 28a. The preboiler power was then increased in order to move the point of boiling inception upstream in the test section. This procedure was continued until the boiling inception point moved upstream of the helical insert region and into the inlet plug region. Figures 28b and 28c show the boiling inception point passing insert thermocouple 32 (see Figure 27 for thermocouple locations). The boiling inception point was then maintained between insert thermocouples 31 and 32 and the test section power was increased in an effort to obtain the effect of heat flux on the heat transfer coefficient (Figures 28d and 28e). Little or no indication of instabilities in flow and pressure are evidenced by the recorder chart. There are, however, indications of temperature oscillations in the neighborhood of the boiling inception point (Figures 28b and 28c). Although the temperature of thermocouple 32 appears from the recorder chart to be steady once the boiling inception point has passed this point (Figures 28d and 28e) the digital printouts of the temperature of 32 evidence unexplained oscillations. The temperatures at thermocouples 31, 32 and 19, as determined from the digital printouts, are given in Table 5. Also shown in Table 5 are the test section heat flux and the quality and heat transfer coefficients calculated at the location of thermocouple 32.

The oscillations in the temperature at thermocouple 32 are evident from Table 5. These oscillations may be real or they may be due to noise. The latter explanation appears somewhat unlikely at the present time, since the maximum noise level on the 100 KW loop would not be expected to exceed $\pm$ 8°F while the oscillations are somewhat as much as 25°F. Additional analysis of this data is required.

Critical Flow

The critical flow of two-phase mixtures is a phenomenon which is often of interest in design applications. In some cases, the maximum heat load of a boiler or condenser may be limited by the critical flow condition. Analyses of off-design performance characteristics and of accident situations involving piping or containment ruptures in two-phase flow systems may also require consideration of critical flow conditions.

An analysis of the critical flow rate for saturated two-phase potassium was done. In particular, numerical calculations were carried out for the momentum exchange model of Levy (Reference 7) and a general model which assumes the slip ratio to be a function of the form:

$$K = \left(\frac{V_g}{V_f}\right)^n \qquad (1)$$

The case of $n = o$ corresponds to the homogeneous flow model. The cases with $n = \frac{1}{2}$ and $n = \frac{1}{3}$ have been treated in References 8 and 9 respectively, primarily for application to water.

The isentropic critical flow rate is given as:

$$G_c^2 = - g_c \Big/ \left(\frac{dV_m}{dP}\right)_s \qquad (2)$$

The specific volume of the saturated mixture (V_m) may be assumed to be a function of pressure and quality, such that

$$dV_m = \left(\frac{\partial V_m}{\partial P}\right)_x dP + \left(\frac{\partial V_m}{\partial x}\right)_P dx \qquad (3)$$

If both sides of Equation (3) are divided by dP, and a condition of constant entropy is imposed,

$$\left(\frac{dV_m}{dP}\right)_s = \left(\frac{\partial V_m}{\partial P}\right)_x + \left(\frac{\partial V_m}{\partial x}\right)_P \left(\frac{\partial x}{\partial P}\right)_s \qquad (4)$$

The entropy of the two-phase mixture may in turn be considered a function of pressure and quality. Thus,

$$ds = \left(\frac{\partial S}{\partial P}\right)_x dP + \left(\frac{\partial S}{\partial x}\right)_P dx \qquad (5)$$

If Equation 5 is divided by dP and subjected to the constraint of constant entropy,

$$\left(\frac{\partial x}{\partial P}\right)_s = -\frac{\left(\frac{\partial S}{\partial P}\right)_x}{\left(\frac{\partial S}{\partial x}\right)_P} \qquad (6)$$

Let the entropy of the two-phase mixture be given as:

$$S = S\,(1 - x) + S_g\,x \qquad (7)$$

where: $S_f = S_f\,(P)$
$S_g = S_g\,(P)$

Then

$$\left(\frac{\partial S}{\partial x}\right)_P = S_g - S_L \qquad (8)$$

and

$$\left(\frac{\partial S}{\partial P}\right)_x = (1 - x)\,\frac{dS_f}{dP} + \frac{dS_g}{dP} \qquad (9)$$

Substituting Equations (6), (8), and (9) into Equation (4) yields the final expression for the total derivative of mixture specific volume with respect to pressure at constant entropy.

$$\left(\frac{dV_m}{dP}\right)_s = \left(\frac{\partial V_m}{\partial P}\right)_x - \left(\frac{\partial V_m}{\partial x}\right)_P \left[\frac{(1-x)\frac{dS_f}{dP} + \frac{dS_g}{dP}}{S_g - S_f}\right] \quad (10)$$

The mixture specific volume may be formulated in terms of either void fraction or slip ratio. If the former is used:

$$V_m\,(x,\ P) = \frac{x^2\ V_g}{\alpha} + \frac{(1-x)^2\ V_f}{(1-\alpha)} \quad (11)$$

In the case of the latter:

$$V_m = V_g\left[(1-x)\frac{V_f}{V_g} + \frac{x}{K}\right]\left[1 + x\,(K-1)\right] \quad (12)$$

where in the most general case, the slip ratio is considered a function of both pressure and quality. Equations (10), (11), and (12), along with the equations for the state variables V_g, V_f, S_g, and S_f provide the basic relations necessary for the computation of the critical mass velocity as a function of pressure and quality. In the ensuing analysis, the derivatives of the state variables are obtained by differentiation of the equations in Reference 10.

1) Levy Momentum Exchange Model

For the Levy model (Reference 7), the quality-void fraction relationship is:

$$x = \frac{(1-2\alpha) + \alpha\sqrt{(1-2\alpha)^2 + \left[\frac{2V_g}{V_f}(1-\alpha)^2 + (1-2\alpha)\right]}}{\left(\frac{2V_g}{V_L}\right)(1-\alpha)^2 + \alpha\,(1-2\alpha)} \quad (13)$$

Utilizing Equations (11) and (13).

$$\left(\frac{\partial V_m}{\partial x}\right)_P = \frac{\left[V_L(1-x)^2\right]\left[2(1-x)V_f/(1-\alpha)-2xV_g/\alpha-(1-x)V_f/(1-\alpha)^2\right]}{(1-\alpha)^3\left[V_f(1-x)^2/(1-\alpha)^2-x^2V_g/\alpha^2-V_f(1-x)^2/(1-\alpha)^3\right]} - \frac{V_f(1-x)}{(1-\alpha)^2}($$

$$\left(\frac{\partial V_m}{\partial P}\right)_x = \frac{\left[V_f(1-x)^2\ x^2/\alpha\right]\left[\frac{V_g}{V_f}\frac{dV_f}{dP}-\frac{dV_g}{dP}\right]}{(1-\alpha)^3\left[V_f(1-x)^2/(1-\alpha)^2-x^2\ V_g/\alpha^2-V_f(1-x)^2/(1-\alpha)^3\right]} +$$

$$\frac{1}{2}\ \frac{dV_L}{dP}\left[\ 1+(1-x)^2/(1-\alpha)^2\right] \tag{15}$$

For the Levy model, the slip ratio is a function of both pressure and quality.

2) <u>Slip Ratio = $(V_g/V_f)^n$</u>

For this model, the derivatives of mixture specific volume are given as:

$$\left(\frac{\partial V_m}{\partial x}\right)_P = (1-2x)\ \frac{V_g}{K} + 2x\ V_g\quad\left[K-2\ xK-2+2x\right] \tag{16}$$

$$\left(\frac{\partial V_m}{\partial x}\right)_P = (x^2\quad x+1)\frac{dV_f}{dP} + (1-x)\left[\frac{Kx\frac{dV_g}{dP}-xV_g\ \frac{dK}{dP}}{K^2}\right] + (x-x^2)\left[K\ \frac{dV_f}{dP}+V_f\ \frac{dK}{dP}\right] + x^2\ \frac{dV_g}{dP} \tag{17}$$

Equation (12) has been utilized to obtain Equations (16) and (17). The derivative of slip ratio with respect to pressure is given as:

$$\frac{dK}{dP} = \frac{n\, V_f^{\,n}\, V_g^{\,n-1} - n\, V_g^{\,n}\, V_L^{\,n-1}}{V_L^2} \qquad (18)$$

3) Results

The results of the calculations are presented graphically in Figures 29 to 32, and tabulated in Appendix B. It should be noted that the critical mass velocity as calculated by Levy's model yields a maximum whereas those computed using $K = \left(\frac{V_g}{V_f}\right)^n$ do not. Figures 29 and 30 indicate that the critical flow values from the momentum exchange model are close to those using a slip ratio of

$$K = \left(\frac{V_g}{V_f}\right)^{\frac{1}{2}} .$$

Figures 29 to 32 can be employed as working charts for use in calculating critical flow rates for two-phase potassium. They should be used with caution, however, as experimental data for potassium to substantiate their accuracy and to provide a basis for choosing between the different models represented is lacking.

VIII COMPUTER CODE DEVELOPMENT

D.R. Ferguson

During the past quarter, boiler and condenser thermal design computer programs were developed for use in design application studies. This work is part of the analytical effort required under Tasks 11 and 12 of Contract Modification No. 10, dated 6-18-65. The programs are compiled in FORTRAN IV.

The basic design equations and the methods utilized to solve these equations are presented in the following section. In subsequent sections, the programs are described in detail. Representative test cases are given to illustrate the use of both codes.

BASIC DESIGN RELATIONS

A. Boiler Design Program

The boiler design code is applicable to once-through counterflow boilers with subcooled feed at the inlet and superheated vapor at the exit. The overall heat transfer and pressure drop data from the 300 KW Facility provide the thermal and fluid dynamic design bases for the program.

The determination of the required length of boiler tube for a fixed tube geometry, power level, and primary and secondary flow conditions involves a simultaneous solution of the applicable heat transfer and pressure drop relationships.

1. Basic Design Equations

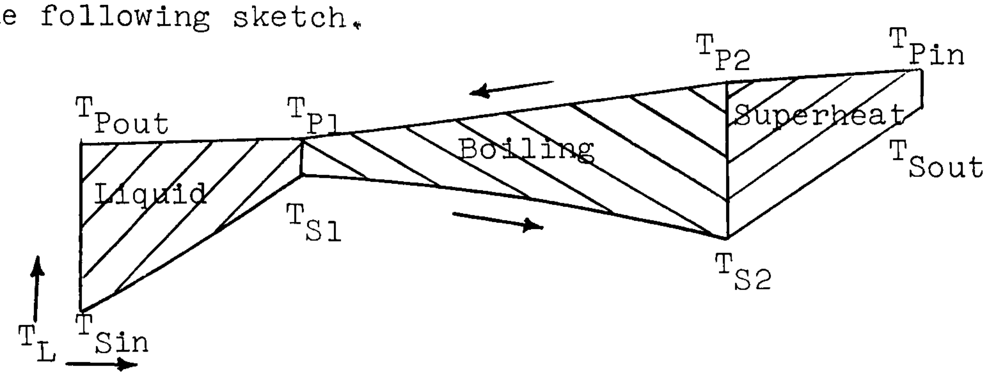
The total boiler length may be divided into a liquid region, a boiling region, and a superheat region. The respective channel lengths may be implicitly related to the total heat transfer rate, the regional overall heat transfer coefficients, and the logarithmic temperature difference in each region as follows:

$$L_{sub} = \frac{q_{sub}}{U_{sub} N_t \ \pi D_i \left[\dfrac{(T_{P1}-T_{S1}) - (T_{Pout}-T_{Sin})}{\ln \dfrac{T_{P1}-T_{S1}}{T_{Pout}-T_{Sin}}} \right]} \qquad (1)$$

$$L_B = \frac{q_B}{U_B \ N_t \ \pi D_i \left[\dfrac{(T_{P2}-T_{S2}) - (T_{P1}-T_{S1})}{\ln \dfrac{(T_{P2}-T_{S2})}{(T_{P1}-T_{S1})}} \right]} \qquad (2)$$

$$L_{sup} = \frac{q_{sup}}{U_{sup} N_t \ \pi D_i \left[\dfrac{(T_{Pin}-T_{Sout}) - (T_{P2}-T_{S2})}{\ln \dfrac{(T_{Pin}-T_{Sout})}{(T_{P2}-T_{S2})}} \right]} \qquad (3)$$

where the subscripts on the temperatures are keyed to the following sketch.



The remaining heat transfer relations are supplied by the heat balance relations:

$$q_{sub} = w_S \, C_{pS} \, (T_{S1} - T_{Sin}) = w_P \, \bar{C}_{pP} \, (T_{P1} - T_{Pout}) \qquad (4)$$

$$q_B = w_S \, h_{fg} = w_P \, \bar{C}_{pP} \, (T_{P2} - T_{P1}) \qquad (5)$$

$$q_{sup} = w_S \, \bar{C}_{pS} \, (T_{Sout} - T_{S2}) = w_P \, \bar{C}_{pP} \, (T_{Pin} - T_{P2}) \qquad (6)$$

$$q_{total} = q_{sub} + q_B + q_{sup} \qquad (7)$$

where it is assumed that the respective heat capacities are evaluated at the average temperature of the separate regions.

It should be noted that there are seven equations and nine unknowns; viz. L_{sub}, L_B, L_{sup}, q_B, q_{sup}, T_{P2}, T_{P1}, T_{S2}, and T_{S1}. The remaining two equations are the pressure drop relations for the boiling and the superheat regions.

The pressure drop in both the boiling and the superheat regions are composed of frictional and momentum contributions,

$$\Delta P_B = \Delta P_{frB} + \Delta P_{mB}$$

$$\Delta P_{sup} = \Delta P_{frsup} + \Delta P_{msup}$$

or

$$P_{S1} - P_{S2} = \frac{f_H\ L_B\ G_H^2}{2\bar{\rho}_f\ g_c\ D_H}\ \phi_{0-1} + \frac{G_H^2}{g_c}\ (\frac{1}{\rho_{g2}} - \frac{1}{\rho_{f1}}) \qquad (8)$$

$$P_{S2} - P_{Sout} = \frac{f_H\ L_{sup}\ G_H^2}{2\bar{\rho}_g\ g_c\ D_H} + \frac{G_H^2}{g_c}\ (\frac{1}{\rho_{gout}} - \frac{1}{\rho_{g2}}) \qquad (9)$$

The friction factor, mass velocity, and hydraulic diameter in Equations (8) and (9) are those pertinent to the helical flow pattern, as discussed in Reference 4. For tubes with no insert, these quantities reduce to the conventional smooth tube values.

2. Method of Solution

The unknown pressure P_{S1} and P_{S2} are related to the temperatures T_{S1} and T_{S2} by the vapor pressure, for which the data in Reference 10 is used. Equations (1) through (9) constitute a set of non-linear transcendental equations. For a given secondary exit pressure and degree of superheat, the boiling and superheat regions may be solved independently. In the boiler design program, the inlet temperatures to each region are determined by an iterative process known as dichotomization. Maximum and minimum temperatures are established to initially span the desired root. A separate subroutine then provides consecutive iterates of the true inlet temperature. This iteration is continued until the length computed by the pressure drop equation is within a certain tolerance of the length computed by the relevant heat transfer equations. Using this procedure, the inlet temperature to the superheat region is initially established. This temperature is then used as the exit temperature from the boiling region, and the inlet boiling temperature may be established in an analogous manner.

B. Condenser Design Program

The condenser design code is applicable to either counterflow or parallel flow condensers with saturated vapor at the inlet and subcooled liquid at the exit. In contrast to the boiler code, the condenser code utilizes local heat transfer data. The differential equations describing the thermal and fluid dynamic history of the secondary fluid are integrated with respect to quality to obtain the required length of a condenser for a specified power and inlet temperature level.

1. Basic Design Equations

The differential rate expression for the heat transferred from the secondary condensing fluid to the primary coolant is given as:

$$-dq = -U_i\ (\pi D_i\ N_t)(T_S - T_P)\ dL = w_S\ h_{fg}\ dx$$

then

$$\frac{dL}{dx} = -\frac{C_1}{(T_S - T_P)}$$

where

$$C_1 = \frac{w_S\ h_{fg}}{\pi D_i\ N_t\ U_i}$$

Differentiating,

$$\frac{d^2L}{dx^2} = \frac{C_1}{(T_S - T_P)^2}\left[\frac{dT_S}{dx} - \frac{dT_P}{dx}\right] \qquad (10)$$

It remains to determine expressions for the $\frac{dT}{dx}$ terms in Equation (10).

The coolant temperature gradient with respect to quality may be written as:

$$\frac{dT_P}{dx} = \pm \frac{w_S \; h_{fg}}{w_P \; C_{pP}} \qquad (11)$$

where the + sign pertains to counter-current flow, and the - sign indicates parallel flow.

The secondary temperature gradient may be written as:

$$\frac{dT_S}{dx} = \frac{dT_S}{dP_S} \frac{dP_S}{dL} \frac{dL}{dx} \qquad (12)$$

where

$\frac{dT_S}{dP_S}$ = Slope of vapor pressure curve

$\frac{dP_S}{dL}$ = Total 2-Ø pressure gradient

The total two-phase pressure gradient is composed of the frictional and momentum contributions, expressed as

$$\frac{dP_S}{dL} = \frac{dP_{fr}}{dL} + \frac{dP_m}{dL}$$

or

$$\frac{dP_S}{dL} = - \frac{fG^2 \, \emptyset}{2\rho_f \, g_c \, D_1} - \frac{G^2}{g_c} \frac{d}{dL} \left(\frac{1}{\hat{\rho}}\right)$$

or

$$\frac{dP_S}{dL} = - \frac{fG^2 \phi}{2\rho_f \, g_c \, D_i} - \frac{G^2}{g_c} \frac{d}{dx} \left(\frac{1}{\hat{\rho}}\right) \frac{dx}{dL} \qquad (13)$$

where

$$\frac{d}{dx} \left(\frac{1}{\hat{\rho}}\right) = \frac{1}{\rho_g} \left[\left[1 + x\,(K-1) \right] \left[\frac{1}{K} - \frac{\rho_g}{\rho_f} \right] + \left[(1-x) \frac{\rho_g}{\rho_f} + \frac{x}{K} \right] (K-1) \right]$$

and K = Slip ratio

Note that the friction pressure gradient term is negative whereas the momentum pressure gradient term is positive. The net effect is that the pressure gradient may be either favorable or adverse depending on the relative magnitude of these terms.

Substituting in Equation (12)

$$\frac{dT_S}{dx} = - \frac{fG^2 \phi}{2\rho_f \, g_c \, D_i} \; \frac{dT_S}{dP_S} \frac{dL}{dx} - \frac{G^2}{g_c} \frac{d}{dx} \left(\frac{1}{\hat{\rho}}\right) \frac{dT_S}{dP_S} \qquad (14)$$

Then, substituting Equations (11) and (14) into (10),

$$\frac{d^2L}{dx^2} = \left[\frac{C_1}{(T_S - T_P)^2} \right] \left[\frac{-fG^2 \phi}{2\rho_f \, g_c \, D_i} \; \frac{dT_S}{dP_S} \frac{dL}{dx} - \frac{G^2}{g_c} \frac{d}{dx} \left(\frac{1}{\hat{\rho}}\right) \frac{dT_S}{dP_S} \pm C_2 \right] \qquad (15)$$

where

$$C_2 = \frac{w_S \; h_{fg}}{w_P \; C_{pP}}$$

(+) = parallel flow

(-) = counterflow

Equation (15) is the final differential equation for the condensing length as a function of local quality. The additional equations to be solved along with Equation (15) are Equation (14) and the following differential equation:

$$\frac{dq}{dx} = - w_S h_{fg} \qquad (16)$$

These latter two equations yield the local secondary temperature and rate of heat transfer as functions of local quality.

2. Method of Solution

Equations (14) to (16) may be considered a set of linear differential equations with variable coefficients. Due to the complexity of the system, numerical methods are employed for the integrations. In order to reduce the system to a set of equations more amenable to computer solution, it is appropriate to make the variable transformation $J = \frac{dL}{dx}$. The system is then reduced to first order in the dependent variables L, J, T_S and q, and becomes:

$$\frac{dL}{dx} = J \qquad (17a)$$

$$\frac{dJ}{dx} = A(x)\, J + B\,(x) \qquad (17b)$$

$$\frac{dT_S}{dx} = - \frac{fG^2 \phi}{2\rho_f\, g_c\, D_i} \frac{dT_S}{dP_S} J - \frac{G^2}{g_c} \frac{d}{dx} \left(\frac{1}{\rho}\right) \frac{dT}{dP} \qquad (17c)$$

$$\frac{dq}{dx} = - w_S h_{fg} \qquad (17d)$$

The initial conditions at $x = x_{in}$ are:

$$x = x_{in}, \quad J = \frac{-C_1}{(T_{Sin} - T_P)}$$

$$L = 0$$

$$T_S = T_{Sin}$$

$$q = 0$$

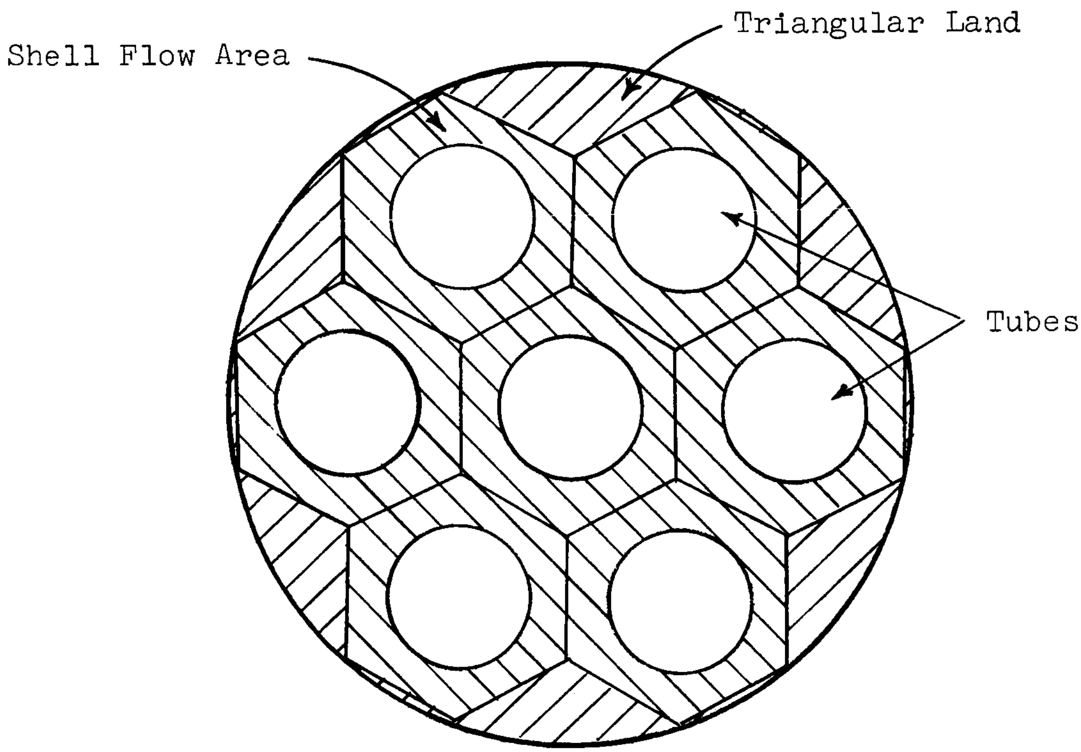
In the condenser design program, Equations (17) are integrated numerically using the 5 point Lanczos method (Reference 11). This technique was chosen for its inherent stability and capacity for yielding minimum round-off errors. The first four steps are taken using the Runge-Kutta-Gill method (Reference 22) to generate 5 points for the more accurate and faster Lanczos equations. Step size changes (halving and doubling) are made on the basis of pre-set error criteria.

C. Heat Transfer and Pressure Drop Relationships

1. Shell Side Equations

The shell side heat transfer and pressure drop relationships are common to both the boiler and condenser design programs. In the boiler code, the properties utilized in calculating the fluid Nusselt number are evaluated at the average of the inlet and exit bulk fluid temperatures. In the condenser program, the fluid properties are evaluated at the local bulk temperature of the primary fluid.

The basic shell geometry chosen is depicted schematically in the following sketch for 7-tubes.



As indicated by the sketch, the tubes are arranged in a triangular array. The inner periphery of the shell consists of a cylindrical geometry with triangular lands positioned in the spaces between the tubes in the outer row. The net flow area of the shell may be divided into hexagonal channels surrounding each tube in the array. For a geometry of this type, the following relationships hold:

$$D_{sh} = D_o \left(\frac{P}{D_o}\right) \left[\frac{2\sqrt{3}}{\pi} N_t \right]^{\frac{1}{2}} \qquad (18)$$

$$A_{sh} = \frac{\pi D_o^2}{4} N_t \left[\frac{2\sqrt{3}}{\pi} \left(\frac{P}{D_o}\right)^2 - 1 \right] \qquad (19)$$

The hydraulic diameter to be utilized in the shell Reynold's number may be evaluated as:

$$D_H = \frac{4A_{sh}}{\text{Wetted Perimeter}} = \frac{4A_{sh}}{WP} \qquad (20)$$

For the case at hand, the total wetted perimeter is given as:

$$WP = \pi (D_{sh} + N_t D_o) + N_o \left[\frac{2P}{\sqrt{3}} - D_{sh} \tan^{-1} \left(\frac{P}{\sqrt{D_{sh}^2 - P^2}} \right) \right] \qquad (21)$$

where N_o = Number of tubes in the outer row of the tube bundle

a. Heat Transfer Relationships

In the boiler design program, the shell side heat transfer coefficient is currently calculated by the method of Dwyer and Tu (Reference 12). The equation for parallel flow through rod bundles given in Reference 12 is:

$$N_{Nu} = \alpha' + \beta (\bar{\psi} N_{Pe})^{\gamma} \qquad (22)$$

where

$$\alpha' = .93 + 10.81 \left(\frac{P}{D_o}\right) - 2.01 \left(\frac{P}{D_o}\right)^2 \qquad (22a)$$

$$\beta = .0252 \left(\frac{P}{D_o}\right) \qquad (22b)$$

$$\gamma = 0.8 \qquad (22c)$$

The quantity $\bar{\Psi}$ represents the ratio of the eddy diffusivity for heat transfer to the eddy diffusivity for momentum transfer. From Reference 13,

$$\bar{\Psi} = 1 - \frac{1.82}{N_{Pr} \, (\epsilon_m/\nu)_{max}^{1.4}} \qquad (23)$$

$$\left(\frac{\epsilon_m}{\nu}\right)_{max} = \text{Function } (N_{Re}) \qquad (24)$$

At large Reynold's numbers, and correspondingly high turbulence levels $\bar{\Psi} \rightarrow 1$. At low Reynold's numbers and Peclet numbers, the predominant mode of heat transfer is molecular conduction, and $\bar{\Psi} \rightarrow 0$.

In a recent paper, Dwyer (Reference 13) has proposed a new prediction for parallel flow through rod bundles. Referring to Equation 22, the new coefficients based on the correlation in Reference 13 are:

$$\alpha' = 6.66 + 3.126 \left(\frac{P}{D_o}\right) + 1.184 \left(\frac{P}{D_o}\right)^2 \qquad (22d)$$

$$\beta = 0.0155 \qquad (22e)$$

$$\gamma = 0.86 \qquad (22f)$$

At higher Peclet Numbers, these coefficients yield Nusselt numbers that are almost identical with those obtained from equations 22a, b, c. For $P/D_o = 1.3$, $\gamma = 0.8$, $N_{Pe} = 600$, equations 22d, e,f yield a Nusselt number of 15.90, whereas equations 22a, b, c give a Nusselt number of 16.03. At lower Peclet Numbers, the

Dwyer-Tu coefficients (equations 22a, b, c) give Nusselt numbers which are up to 9 percent lower than those using the coefficients from equations 22d, e, f.

b. Pressure Drop Relationships

The shell pressure drop relations are identical in both the boiler and the condenser design code. The frictional pressure losses are given as:

$$\Delta P_{f\ sh} = \frac{f\ L_{tot}\ G_{sh}^{2}}{2\ \rho_f\, g_c\ D_{eq}} \qquad (25)$$

where

$$f = 0.316/\left(\frac{D_{eq}\ G_{sh}}{\mu}\right)^{0,25}$$

In addition, radial pressure losses occur in the cross-flow regions at the primary fluid inlet and exit. The analysis of Reference 14 is utilized to account for these losses. The final equation for the radial pressure loss is:

$$\Delta P_r = \frac{4}{2\rho_f\, g_c}\left[0{,}25 + \frac{0.118}{\left(\frac{P}{D_o} - 1\right)^{1.08}}\right]\left(\frac{D_o}{\mu}\right)^{-.16}\sum_{i=1}^{n} G_{max_i}^{1.84} \qquad (26)$$

The maximum mass velocity in any tube row is given as a function of the total flow rate and the shell geometry.

$$G_{max\ i} = \frac{w_i}{A_{min\ i}} = \frac{\left(\frac{3(i-1)^2}{3n^2 - 3n + 1}\right) w_P}{6(i-1)\ (P - D_o)} \qquad (27)$$

$$i = 1, n$$

where n = the total number of tube rows
i = the summation index on the tube rows

2. Two-Phase Pressure Drop Multipliers

The homogeneous model with a slip ratio K = 1 is currently being utilized in both programs. In the case of the local multipliers,

$$\phi_{loc} = \left\{ \frac{1}{1 + x\left[\left(\frac{\mu_f}{\mu_g}\right) - 1\right]} \right\}^{\delta'} \left\{ 1 + x\left(\frac{\rho_f}{\rho_g} - 1\right) \right\} \qquad (28)$$

where $\delta' = 0.25$

This relationship is applied on a point to point basis in the condenser program. The boiler design program utilizes an integrated average multiplier for the quality interval from $0 \rightarrow 1$. For a uniform heat flux in the boiler, quality is linear with tube length. Equation (28) may be integrated from 0 to 1 to yield:

$$\phi_{0 \rightarrow 1} = \frac{(1+b)^{1-\delta'}}{b(1-\delta')} - \frac{1}{b(1-\delta)} + \frac{a}{b^2} \left\{ \frac{1}{(\delta'-1)(1+b)^{\delta'-1}} - \frac{1}{(\delta'-2)(1-b)^{\delta'-2}} + \frac{1}{(\delta'-2)} - \frac{1}{(\delta'-1)} \right\} \qquad (29)$$

where: $a = \left(\frac{\rho_f}{\rho_g} - 1\right)$

$b = \left(\frac{\mu_f}{\mu_g} - 1\right)$

3. Condensing Heat Transfer Relations

The condensing heat transfer relations are taken from Reference 4, and are based on the condensing data from the 50 KW Facility.

The local condensing heat transfer resistance may be represented as the sum of a vapor phase and a liquid film resistance as follows:

$$\frac{1}{h_c} = \frac{1}{h_v} + \frac{1}{h_f} \qquad (30)$$

where $h_f = k_f/\delta$

The vapor phase heat transfer coefficient is given as:

$$h_v = \sigma_c \, h_{fg} \left(\frac{Mg_c}{2\pi RT}\right)^{\frac{1}{2}} \left\{ \frac{dP}{dT} - \frac{P}{2T} \right\} \qquad (31)$$

where T is in $^{\circ}R$

It is shown in Reference 4, that the condensation coefficient (σ_c) for potassium vapor is approximately 0.2 over the temperature range of 1100 to 1600°F.

The liquid film coefficient is calculated as the reciprocal of the conduction resistance of a film of thickness δ. The local film thickness is estimated using the velocity profile data of Dukler (Reference 16) for the cocurrent flow of a vapor and a liquid film. In the condenser program, the liquid film coefficient is implicitly represented in Nusselt's condensing ratio, which is a function of the local film Reynold's number and the local shear exerted by the vapor on the liquid film interface. The relevant defining equations are:

$$N_{NuC} = N_{NuC}\left(N_{ReL}, \tau_v^*\right) = \frac{h}{k_f}\left(\frac{\nu^2}{g}\right)^{1/3} \qquad (32)$$

$$\text{where } N_{ReL} = \frac{4(1-x)w}{\pi D \mu}$$

The dimensionless vapor shear, τ_v^* is estimated from the local two-phase frictional pressure gradient as:

$$\tau_v^* = \left\{ \frac{\rho_g \left(\frac{g}{g_c}\right) + \frac{\emptyset}{2} \frac{fG^2}{\rho_f g_c D_i}}{\rho_f \left(\frac{g}{g_c}\right)} \right\} \left(\frac{D_i}{4}\right)\left(\frac{g}{\nu^2}\right)^{1/3} \qquad (33)$$

II DESCRIPTION OF PROGRAMS

As indicated in the preceding sections, both the boiler and the condenser design codes are programmed in FORTRAN IV. Two data processing systems are currently in use at the G.E. Evendale computer installation. They are the IBM 7094 and the G.E. 625/635. The programs for both codes are compatible with either machine.

In both instances, the codes are broken down into a main program and a series of shorter subroutines. The majority of the numerical calculations are performed in the subroutines. The main programs are primarily utilized to call the calculation subroutines, read the input data, and transmit the output data to the peripheral I/O media.

The thermodynamic properties of saturated and superheated potassium are taken from Reference 10. The subprograms to compute these properties were developed by M.E. McCarthy and are identical to those being utilized in the Potassium Turbine Test data reduction program (Reference 17). The transport properties of potassium and the thermodynamic and transport properties of sodium, NaK, and lithium are those contained in Reference 18. In these cases, the properties are programmed directly into the subroutines as tubular functions of temperature. Required values of these properties are then determined by linear interpolation in the temperature-property tables.

A. Boiler Design Program

The boiler design program utilizes the basic boiler equations developed in the preceding part of this Section. The requisite input to the program consists of the shell and tube geometry, the total power level, the primary flow rate and inlet temperature, and the secondary inlet and exit temperatures. The secondary exit temperature is fixed by specifying the exit pressure and the degree of superheat above the saturation temperature corresponding to this pressure. The working fluid in the secondary is potassium. The primary fluid may be specified as either sodium or lithium.

The output produced by the program consists primarily of the required tube length to transfer the specified power at the given temperature levels of the primary and secondary streams. Additional output includes the design point performance as indicated by the tube and shell pressure drops, the inlet boiling initiation temperature, and the acceleration produced by the insert.

The boiler design code has been utilized in the parametric study of a 7-tube boiler for the 300 KW Facility. These results are presented and discussed in Section IX of this report. The utility of the program in obtaining design information is also discussed in this Section.

The following examples are utilized to illustrate the use of the program and the typical output produced by the program. The given design conditions are:

Tube material	L-605
Number of tubes	7
Tube O.D. inches	0.75
Tube wall thickness, inches	0.03
Tube P/D_o	1.3
Insert P/D	2.0 - 6.0
Power, KW	300
Potassium inlet temperature, ^oF	1200
Degree of superheat, ^oF	50
Potassium exit pressure, psia	56.7 (1700^oF sat.)
Sodium inlet temperature , ^oF	1850
Sodium flow rate, lbm/sec	9.08
Potassium boiling heat transfer coefficient, Btu/ft^2-hr-^oF	4000
Radial pressure drop in shell	0

The average potassium heat transfer coefficient of 4000 Btu/ft^2-hr-^oF is typical of the data obtained in the 300 KW single tube boiling tests.

The printed output for these cases are given in Figure 33a to 33c. The nomenclature of the output is keyed to Table 6. The results are given graphically in Figure 34 as a plot of total tube length versus insert P/D at constant average potassium heat transfer coefficient.

The approximate machine time per case is 3 seconds on the IBM 7094. In general, it has been found that 20 to 30 iterations are adequate to obtain convergence of the superheat and boiling lengths to within 0.5 percent.

B. Condenser Design Program

The condenser design program utilizes the basic condenser equations given in the preceding part of this Section. The input to the program consists primarily of the shell and tube geometry, the total power, the primary flow rate and inlet temperature, the secondary inlet temperature and quality, and the level of subcooling at the condenser exit. Additional input information includes the starting increment in quality, the flow direction of the primary and secondary fluids, and the parameters pertinent to the step error of the integration routine. It is well to discuss at this time the method of handling the numerical errors in the condenser design program.

In the numerical integration of a system of ordinary differential equations, the truncation error in the i-th dependent variable refers to the step difference between the predicted and corrected values of the particular variable being integrated. Using the Lanczos method (Reference 11) this error is given as:

$$E_i = 0.11 \left| y_i^c - y_i^p \right| \qquad (34)$$

These errors may be treated independently by requiring that individual variable errors be less than a set of corresponding maximum tolerable errors. However, in the condenser design program, it has been found to be more convenient to use a weighted error for all the differential equations, as follows:

$$E_{tot} = 0.11 \sum_i W_i \left| \frac{y_i^c - y_i^p}{y_i^c} \right| \qquad (35)$$

$$i = 1, 4$$

The weighting factor (W_i) and an allowable maximum error limit (E_{max}) are read into the program. Within the program, an additional minimum error is established as:

$$E_{min} = E_{max}/40 \qquad (36)$$

For a given incremental step in quality, E_{tot} is compared to E_{max}. If $E_{tot} > E_{max}$, the step size is halved and the step is repeated. If E_{tot} is still greater than E_{max}, the step size is again halved, and the integration is restarted at this increment. Five such restarts are allowed for each case being calculated. If $E_{tot} < E_{max}$ it is then compared to E_{min}. If $E_{tot} > E_{min}$, the integration is continued with the current step size. If, on the other hand, $E_{tot} < E_{min}$, the current step size is doubled, and the next step is taken with

$\Delta x_{new} = 2\ \Delta x_{old}$. Doubling is restricted to every fourth step to prevent too rapid a growth of the step size in regions of small truncation error.

As in the case of the boiler design program, the output produced by the program consists of the total tube length and the shell and tube side parameters which provide a measure of the design point performance. The printout of local conditions along the condenser is optional. If desired, the local values of quality, length, static pressure, primary and secondary temperatures, heat transfer coefficients, secondary film Reynold's numbers, heat flux, and cumulative heat transferred are printed. In this case, the interval between local print points may be specified as 1, 2, 4, or 5. The first page of output contains the tube length and the relevant design point performance parameters. The local conditions are printed consecutively on the following pages.

The following example is utilized to illustrate the use of the program and the typical output produced by the program. The specified design conditions are:

Tube material	316 ss
Number of tubes	7
Tube O.D. inches	0.645
Wall thickness, inches	0.020
Tube, P/D_o	1.3
Power, KW	150
Potassium inlet temperature, ^oF	1300
Potassium inlet quality	1.0
Potassium exit temperature, ^oF	1260

Primary coolant	NaK (counterflow)
NaK Inlet temperature, ^{o}F	1190
NaK flow rate, lb_m/sec	7.5
Initial quality increment Δx	0.001
Maximum allowable error	0.05%
Shell radial pressure drop	0

The printed output for this case is shown in Figure 35. The nomenclature of the output is given in Table 6. The local temperature and pressure profiles as a function of axial tube length are depicted in Figure 36.

The approximate machine time per case is 7 seconds on the IBM 7094, using a starting step size in quality of - 0.001.

IX 300 KW FACILITY MODIFICATION DESIGN

JC Amos/RA Fuller/RR Oliver/JR Peterson

Work is in progress, in accordance with Task 11 of Contract Modification No. 10, dated 6-18-65, on design of a modification of the 300 KW Heat Transfer Facility to test multiple-tube, NaK-cooled, potassium condensers over the following ranges of conditions:

Power levels, to 300 KW
Potassium inlet temperatures, 1200°F to 1600°F
Inlet vapor quality, to 100%
Outlet vapor quality, 0% (liquid)

This design work on the modification of the 300 KW Facility includes design of a new facility boiler, since the single-tube boiler used for the boiling tests done in the 300 KW Facility (Section II) is limited to about 100 KW. Progress on the work and descriptions of the suggested modifications are summarized in the following items.

Figure 37 shows a schematic flow diagram of the modified 300 KW Facility and Figure 38 shows the arrangement of the NaK tertiary loop and interconnections to the existing potassium secondary system.

Suggested modifications to the existing primary (sodium) and secondary (potassium) systems include the following:

1. Installation of an L-605 multiple-tube boiler to provide thermal power capability to 300 KW, in place of the existing single-tube boiler, which is limited to about 100 KW.

2. Modification of the existing potassium vapor throttle valve located in the vapor discharge line from the boiler, to improve the bellows design suitable for operation to 1700°F. This valve experienced several bellows failures during early test operation with the Facility and subsequently was eliminated from service by removal of the plug, stem and bellows assembly and capping of the remaining valve body. The life of this valve can be extended by using care in operation; and damage to other system components in the event of failure of the valve can be eliminated by providing an inert gas back-up for the bellows as part of the modification.

3. Replacement of the existing vertical condenser in the potassium system with a shorter condenser of similar design to be used together with the existing air-cooled horizontal condenser. The combined capacity of this vertical condenser and the existing horizontal condenser would be suitable for boiler shakedown tests up to 300 KW. The vertical condenser would also serve as a desuperheater during condenser test operation. Shortening of this condenser would provide complete drainability of the modified potassium system.

4. Replacement of the existing L-605 potassium dump tank, because it has a temporary patch. The new dump tank would

be made of stainless steel and would contain getter material to provide capability for hot trapping of the potassium inventory to 1400°F.

5. Placement of pressure transducers at the discharge of the sodium and potassium pumps as an aid to establishing proper operating conditions and to provide a direct indication of maximum loop operating pressure.

In the proposed design the NaK tertiary loop and test condensers are enclosed in a new test cell addition to the SPPS Liquid Metal Heat Transfer Laboratory adjacent to the existing 300 KW Facility enclosure, The steel wall between the two cells will be retained to provide personnel safety when it is necessary to work on the tertiary loop while the primary and secondary loops are operating.

The tertiary loop will be constructed entirely of stainless steel, with dissimilar metal welds between stainless steel and L-605 in the vapor line near the outlet of the vertical condenser and in the liquid potassium return line near the potassium pump suction. The tertiary loop will accommodate one or two test condensers installed horizontally in a location easily accessible for instrumentation,installation, maintenance and changes. Space is provided in the design to accommodate test condensers of different geometries.

Other major components included in the NaK tertiary loop are listed below:

1. A helical induction pump 100 gpm 50 psi 1400°F

2. An electromagnetic flow meter

3. One diffusion type cold trap for oxide control

4. One 300 KW NaK-to-air cooler

5. One NaK surge tank. The NaK dump tank will be equipped with zirconium gettering material for NaK purification

6. One NaK throttle valve and a NaK dump valve

7. A potassium head tank to be used for condenser start-up and shakedown and to provide for non-condensable gas collection and removal.

The tertiary loop will be supported by rod hangers to accommodate thermal expansion.

Specifications were prepared for the NaK Tertiary Loop Pump and the liquid metal valves. Preliminary material lists were prepared for other major components and loop piping and hardware. These specifications and material lists, as well as raw material specifications and welding and quality control specifications, will be included in the topical report covering this design work.

As discussed in Section VIII of this report, the thermal and hydraulic boiler design computer code using heat transfer and pressure drop parameters averaged over the boiling length has been completed. This code has been employed to determine the tube length and insert twist ratio P/D for a seven-tube facility boiler that satisfies the following specified conditions.

Specified Design Conditions
300 KW Facility Boiler

Total Heat Transferred	=	300 KW
Number of Tubes	=	7
Tube O.D. and Wall Thickness	=	0.75" and 0.030"
Tube Spacing Between Centers	=	0.975"
Sodium Inlet Temperature	=	1850°F
Sodium Exit Temperature	=	1750°F
Potassium Inlet Temperature	=	1200°F
Potassium Exit Temperature	=	1700°F
Potassium Exit Quality	=	100%

Using the quantities listed above as inputs, the code computes the required boiler tube length as a function of the insert P/D and the average potassium heat transfer coefficient. The code also computes the radial acceleration developed by the insert as a function of P/D at the specified conditions. The computed results obtained for the conditions listed in the above Table are shown in Figure 39. This Figure indicates that the required boiler tube length is larger for lower values of the average heat transfer coefficient ($\bar{h}_B$), and becomes very large at small values of P/D. This latter result is due to the increase in potassium pressure drop at tight twist ratios, which, for a fixed potassium outlet pressure, decreases the sodium-to-potassium temperature difference and requires increased boiler length for the specified power. Counteracting this pressure drop effect is an increase in the average boiling heat transfer coefficient with decreasing insert P/D. Thus, an optimum twist ratio P/D exists and can be computed for any given boiler.

To determine this optimum insert twist ratio, the experimental results from the 300 KW Facility single tube tests are employed. Figure 40 shows the boiling heat transfer coefficients averaged over the boiling length from 0 to 100% quality for two tube diameters and three inserts, as a function of the radial acceleration developed by the insert, the latter calculated according to the methods presented in Reference 4 at 100% quality. The use of the radial acceleration as a correlating parameter is suggested by the results of the analysis of local critical heat flux and transition boiling data given in Section II, which shows the acceleration to be an important variable for both the critical heat flux and transition boiling results. Below approximately 80 g's, the experimental values of the average heat transfer coefficient decrease with decreasing acceleration, whereas for accelerations greater than 80 g's, the experimental values of the average boiling heat transfer coefficient fall between the approximate limits of 3000-6000 Btu/(hr-ft^2-^{o}F). The box drawn on Figure 40 shows these limits. Also shown is a line judged to be the most probable relation between $\bar{h}_B$ and acceleration for the design conditions.

The line relating h_B to acceleration can be transferred to the design curves by use of the second plot of Figure 39, which relates acceleration to P/D at the design conditions. This is accomplished as follows For h_B = 3000 Btu/hr-ft^2-^{o}F, for example, the acceleration required by the most probable line of Figure 40 is approximately 50 g's. From the second plot of Figure 39, 50 g's corresponds to a P/D of 4.5 at the design conditions. The point P/D = 4.5 and $\bar{h}_B$ = 3000 is now located on the design curves, as shown on Figure 41. In a similar manner, the entire design line shown on Figure 41 is obtained.

The total range of data encompassed by the box on Figure 40 may be similarly transferred to Figure 41. The 80 g lower limit of acceleration corresponds to a P/D of 3.6 from the second plot of Figure 39. Thus the range of experimental data, shown on Figure 41 by the cross-hatched area, lies between the $\bar{h}_B = 3000$ and $\bar{h}_B = 6000$ Btu/(hr-ft^2-^{o}F) design curves for P/D less than 3.6.

The design curve of Figure 41 shows a P/D of approximately 2.5 to give the minimum required boiler tube length of about 53-inches. Due to the rapid increase in required tube length for twist ratios less than the optimum, a twist ratio (P/D) of 3.0 has been selected. A boiler tube length of 60-inches will be specified to provide some conservatism in the thermal design. At the P/D selected, for example, a boiler length of only 62-inches is predicted for the lower bound of the average coefficient data ($\bar{h}_B = 3000$ Btu/(hr-ft^2-^{o}F), indicating the design to be reasonably conservative.

The seven tube boiler design falls within the range of the test conditions encompassed by the single tube tests of the 300 KW Project. Had this not been the case, a more complicated design procedure employing the local heat transfer parameters derived from the test data would be required, as the average heat transfer coefficients cannot be employed outside the range of test conditions with confidence. A local design procedure would also eliminate judgment involved in the selection of the most probable line on Figure 41 for the design.

Some design uncertainty exists regarding the compatibility of the sodium-side pressure drop in the seven tube boiler with the head available from the facility primary pump at the design flow rate, since complete head flow data are not available for the pump and since there is considerable uncertainty in the pressure drop calculations due to the complex shell-side geometry. A conservative approach with respect to meeting the condenser test conditions has been employed, however, in that the design point of the boiler calls for a potassium exit temperature of 1700°F whereas a maximum of 1600°F is required for the condenser tests. Thus, even if the sodium flow rate specified for the boiler design cannot quite be obtained, the requirement of 1600°F and 100% vapor quality at the test condenser inlet can still be met.

A suggested mechanical design concept for the 300 KW Facility boiler is shown in Figure No. 42. This boiler is a multiple tube (7-tube), floating header, counterflow, shell and tube type heat exchanger. The sodium or primary fluid in the boiler flows in the main shell surrounding the tubes and the secondary fluid or the potassium passes through the boiler inside the seven tubes. The floating header is positioned at the potassium inlet end of the boiler. Relative expansion between the shell and tubes due to temperature differences is accommodated by a single bent tube which forms an expansion leg connecting the floating header to the shell at the potassium inlet.

The floating header arrangement shown in Figure 42 provides for differential thermal expansion and also makes it possible for the seven tubes to be installed between the fixed header and the floating header prior to attachment of the boiler shell. This is a desirable feature because it permits complete inspection and leak test of the critical tube-to-header welds prior to assembling the tube bundle in the shell. The whole assembly will be sized to allow the shell to slide over the tube bundle from the floating header end, prior to attachment of the bent tube expansion leg.

Since this boiler is part of a facility intended to test condensers up to 1600°F it is necessary for the boiler to deliver a higher potassium vapor temperature than 1600°F. The primary side of the boiler is expected to employ temperatures as high as 1850°F. This temperature requirement dictates that L-605 be used for the boiler material. In order to assure adequate life of the boiler as part of the facility, the design stresses will be kept under 1000 psi.

To control the initial and operating tube spacing to the limits considered desirable it is necessary to restrain the tubes in relation to each other and to the shell. The restraining devices should cause a minimum of flow disturbance and a minimum pressure loss of the primary side flow. In addition to control of the spacing, the primary side flow area available to each tube must be designed to produce nearly uniform flow around the tube circumference. It is believed that uniform flow can be achieved by providing flow equalization inserts in the larger spaces between the six outside tubes and the inner circumference of the boiler shell. Figure 43 is an exploded view of the tube bundle section of the boiler. With the arrangement illustrated in Figure 43 each tube is given support at three points 120° apart at four locations along the length.

In spite of the internal tube supports, distortions of the main boiler shell, which could be caused by external forces from the facility piping, might have a detrimental effect on the tube to tube performance of the boiler by decreasing the uniformity of the spacings between the tubes or by causing distortion of the tubes. In order to minimize shell deformation, it is proposed to stiffen the shell by externally attached longitudinal ribs, such as are shown in Figure 42 (Section B-B).

The sodium inlet and exit connections are made through large distribution manifolds which provide a low pressure drop and therefore uniform distribution of the flow from the inlet pipe all around the tube bundle. The uniformity of circumferential flow is further assured by a perforated liner in the manifold section.

Each of the seven tubes in the boiler contains a helical insert which surrounds a tubular centerbody. Each centerbody will contain seven thermocouples for fluid temperature distribution measurement. The drawing shows a typical helical insert, having a pitch to diameter ratio (P/D) of three, as determined from the performance calculations.

To assure uniform flow from tube to tube the inlet of each of the seven tubes will be equipped with an orifice. The orifices will be of a standard ASME sharp edge type located in the tube inlets as shown in View C Figure 42. The orifices can be removed for changing by making three cuts. Two of the cuts would be made on the shell to release the reducer and elbow portion of the outer shell and thus allow it to be moved axially to expose the large end of the floating header. The third cut would be on the floating header to expose the orifices for removal.

For best reliability, tube-to-header joints in multiple-tube heat exchangers should be crevice free. From this standpoint, the best design of the tube-to-header joint is to use a butt weld between the tube and an appropriately sized tube boss on the header side. Tube-to-header joints of this type are indicated in Figure 42.

One difficulty of the butt-welded tube-to-header joint in compact multiple-tube boilers and condensers is that close spacing of the tubes makes the joints not readily accessible for external welding. A method that has been developed for fabricating this type of joint with closely spaced tube bundles is internal welding using the tungsten-inert gas process with automatic equipment (References 19 and 20). The weld is accomplished by rotating a tungsten electrode along the joint inside the tube. An insulated shaft and electrode holder, inserted thru the header, is rotated by a motor drive. Welding current is provided by a programmed arc welding machine, coordinated with the electrode rotation. The outside diameter of the header boss is about 0.04-inch larger than the tube diameter. The header boss is counterbored about 0.02-inch to align the inside diameters of the tube and boss. The external shoulder on the boss is consumed during welding producing a taper on the exterior weld surface.

Since no previous experience had been reported on welding L-605 tube joints by this process, arrangements were made with the Baldwin-Lima-Hamilton Corporation to make several sample tube-to-header weld joints with L-605. One sample weld joint made between a 0.75-inch OD, 0.02-inch wall L-605 tube and an L-605 model header boss is shown in Figure 44. Radiographic examination of seven other identical sample welds showed no porosity in the weld metal.

Welding of the samples demonstrated the feasibility of joining L-605 tubes to header bosses by this process. Weld joints of this type do not contain a crevice at the weld root that exists in conventional designs where the tube extends thru the header. The welds can be radiographically inspected for soundness and are easily repairable during initial manufacturing.

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Table 1

Critical Heat Flux and Transition Boiling Data

300 KW Facility

0.92-inch I.D. Boiler Tube Containing P/D = 6 Helical Insert

Date 1964	Time	G_K	T_{KC}	T_{KTB}	X_C	X_{TB}	q''_c	q''_{TB}	Δt_{TB}	h_{TB}	a_{Rc}	a_{RTB}
7/25	0100	19.1	1674.5	1680.0	.864	.932	386,150	28,400	161	177	15.81	18.36
	0120	19.1	1675.0	1682.8	.727	.864	401,500	51,400	154	334	11.17	15.68
	0145	18.1	1637.7	1649.9	.667	.833	457,900	53,800	201	267	9.58	15.06
7/28	0017	37.1	1563.2	1541.0	.793	.897	341,700	304,700	77	3966	74.21	94.76
	0100	33.5	1563.5	1551.5	.739	.869	437,400	143,450	205	699	52.47	72.70
	1740	19.8	1543.5	1527.4	.722	.861	269,100	81,700	137	596	18.87	27.02
	1845	18.4	1521.9	1512.2	.788	.894	438,300	40,000	230	174	21.02	27.02

0.92-inch I.D. Boiler Tube Containing P/D = 2 Helical Insert

Date 1964	Time	G_K	T_{KC}	T_{KTB}	X_C	X_{TB}	q''_c	q''_{TB}	Δt_{TB}	h_{TB}	a_{Rc}	a_{RTB}
5/27	0005	18.8	1655.0	1677.5	.839	.920	412,500	48,500	174	279	116.65	140.03
	0020	16.4	1624.0	1654.3	.827	.914	532,300	37,800	215	175	96.21	117.16
7/1	2120	16.1	1541.3	1523.4	.664	.832	285,600	78,750	121	650	80.28	125.94
	2130	16.0	1550.5	1525.8	.680	.840	340,100	54,700	153	359	81.62	124.45

T

CRITICAL HEAT FLUX, TRANSITION BOIL

100 KW LOOP (

Date	Time	T_{sat} °F	G lb/sec-ft^2	q" Btu/hr-ft^2	X_c %	X_{TB} %	h_{TB} Btu/hr-ft^2-°F	X_{FBE} %	X_{FB} %
5/23/65	1353	2100	32.0	148,000	79				
5/23/65	1414	2100	32.0	148,000	-	-	-	87	-
5/27/65	1610	2100	28.6	159,000	-	-	-	-	-
5/28/65	1400	2100	20.4	153,000	87	-	-	-	-
	1418	2100	19.8	155,240	-	95	1106	-	-
	1430	2106	19.8	155,800	-	-	-	98	98
	1450	2100	19.9	122,720	-	94	2360	-	-
	1527	2100	19.9	121,950	-	-	-	95	95
	1529	2100	19.9	121,950	-	-	-	-	96
	1608	2105	19.9	76,830	-	-	-	96	96
	1618	2104	19.9	78,140	-	-	-	-	99
	1624	2104	19.6	77,270	90	-	-	-	-
	1624	2104	19.6	77,270	-	-	-	-	-
	1634	2103	19.5	55,200	-	-	-	99	99
	1645	2103	19.6	56,750	-	-	-	-	-
	1651	2100	19.2	56,300	95	-	-	-	-
	1651	2100	19.2	56,300	-	-	-	-	-
	1659	2100	19.5	55,700	-	-	--	-	-
	1707	2100	19.6	56,030	-	-	-	-	-
	1714	2100	19.6	56,500	-	-	-	99	99
6/8/65	1723	1823	21.7	149,620	83	-	-	-	-
	1729	1827	20.4	150,905	-	91	1796	-	-
	1733	1824	20.4	150,340	-	-	-	93	93
	1804	1813	21.9	106,380	89	-	-	-	-
	1809	1819	21.9	105,900	-	-	-	90	90
	1816	1824	21.3	105,520	-	-	-	-	97
	1824	1825	20.4	104,470	87	-	-	-	-
	1824	1825	20.4	104,470	-	-	-	-	-
	1832	1825	21.0	104,140	-	-	-	-	-
	1843	1825	21.3	103,630	-	-	-	91	-
6/10/65	1602	1804	25.3	148,400	88	-	-	-	-
	1620	1802	24.0	147,840	-	96	410	-	-
	1613	1809	24.6	148,260	89	-	-	-	-
	1625	1813	24.0	146,520	-	91	1368	-	-
	1625	1813	24.0	146,520	-	-	-	98	98
	1652	1807	24.1	100,800	91	-	-	-	-
	1652	1807	24.1	100,800	-	-	-	96	96
	1705	1807	23.4	105,000	-	-	-	-	-

:ABLE 2A

ING, FILM BOILING AND SUPERHEATED VAPOR DATA
TEST SECTION NO. 4)

h_{FB} Btu/hr-ft^2-^oF	$(\Delta T)_{SH}$ ^oF	h_{SH} Btu/hr-ft^2-^oF	Insert Geometry At measuring Station
			Helix
-	-	-	Helix
260	-	-	Helix
-	-	-	Helix
-	-	-	Helix
335	-	-	Helix
-	-	-	Helix
214	-	-	Helix
196	-	-	Helix
249	-	-	Helix
172	-	-	Helix
-	-	-	Plug Annulus
-	15	162	Helix
188	-	-	Helix
-	5	152	Helix
-	-	-	Plug Annulus
-	144	183	Helix
-	40	172	Helix
-	5	152	Helix
176	-	-	Helix
-	-	-	Helix
-	-	-	Helix
222	-	-	Helix
-	-	-	Helix
217	-	-	Helix
148	-	-	Helix
-	-	-	Plug Annulus
-	85	145	Helix
-	15	143	Helix
-	-	-	Helix
-	-	-	Helix
-	-	-	Helix
-	-	-	Helix
-	-	-	Helix
196	-	-	Helix
-	-	-	Helix
185	-	-	Helix
-	287	187	Helix

Radial Acceleration, a_R g's
131.1
159.0
—
64.6
72.6
76.2
71.8
73.3
74.9
74.1
78.9
-
-
75.9
-
-
-
-
-
77.2
132.8
139.4
146.8
160.0
160.7
174.1
-
-
-
152.9
214.2
230.9
204.1
200.9
233.0
206.0
199.9
-

X_c = Critical Quality

h_{TB} = Transition Boiling Heat Transfer Coefficient

X_{TB} = Quality corresponding to h_{TB}

X_{FBE} = Quality at which stable film boiling was established

h_{FB} = Film boiling heat transfer coefficient

X_{FB} = Quality corresponding to h_{FB}

h_{SH} = Superheated vapor heat transfer coefficient

$(\Delta T)_{SH}$ = Degrees of superheat

Tube diameter = 0.742-in. ID

Helix P/D = 2

Table 2-B

Transition Boiling Data - 100 KW Loop (Test Section No. 3)

Date	Time	T_{sat} ^oF	G $lb/sec\text{-}ft^2$	q" $Btu/hr\text{-}ft^2$	X_{TB} o	h_{TB} $Btu/hr\text{-}ft^2\text{-}^oF$
3/31/65	1208	2105	47.6	94,000	92	3481
3/31/65	1212	2105	47.6	94,000	93	2848
3/31/65	1336	2105	47.6	49,900	91	1663

h_{TB} = Transition Boiling Heat Transfer Coefficient

X_{TB} = Quality corresponding to h_{TB}

TABLE 3

Calculated Condensing Heat Transfer Coefficients,* July, 1964
5/8-inch I.D. Plain Tube Test Section

		Top Station L/D = 13			Bottom Station L/D = 46			
		Method of temperature Calculation			Method of temperature Calculation			
Date	Time	Linear Interpolation	K=1	$K=\sqrt{\rho_L/\rho_g}$	Linear Interpolation	K=1	$K=\sqrt{\rho_L/\rho_g}$	Inlet T_K
7/21/64	1945	21000	-71,600	30500	18200	-197,500	15800	1138°F
7/21/64	2000	16800	-177,400	23300	17600	-191,300	15500	1133°F
7/22/64	0234	12300	25,000	12400	13800	31,600	12100	1160°F
7/22/64	0845	13200	15,000	12700	12500	14,200	11800	1249°F
7/22/64	0945	14200	17,500	13500	11400	13,400	10600	1271°F
7/22/64	1100	11900	14,800	11400	11800	14,600	10800	1240°F
7/22/64	1235	18500	35,300	17800	15300	24,800	13400	1216°F
7/22/64	1630	20700	25,500	19500	12500	14,200	11700	1312°F

* $Btu/Hr\text{-}ft^2\text{-}^\circ F$

TABLE 4

TEMP-TIME VARIATION OF THERMOCOUPLE NO.34 (3TEMP.READINGS/SE

100 KW FACILITY, TEST SECTION NO. 3

	119	120	121	122	123	124
	TEMPB4	TEMPB4	TEMPB4	TEMPB4	TEMPB4	TEMPB4
1	1.9020+03	1.9060+03	1.9099+03	1.9160+03	1.9189+03	1.9217+03
2	1.8998+03	1.8995+03	1.8997+03	1.8988+03	1.8978+03	1.8988+03
3	1.9076+03	1.9048+03	1.9021+03	1.8997+03	1.8969+03	1.8974+03
4	1.9207+03	1.9161+03	1.9134+03	1.9099+03	1.9086+03	1.9088+03
5	1.9313+03	1.9294+03	1.9282+03	1.9270+03	1.9268+03	1.9251+03
6	1.9410+03	1.9409+03	1.9410+03	1.9398+03	1.9395+03	1.9360+03
7	1.9515+03	1.9526+03	1.9512+03	1.9503+03	1.9476+03	1.9438+03
8	1.9610+03	1.9606+03	1.9586+03	1.9562+03	1.9540+03	1.9513+03
9	1.9672+03	1.9645+03	1.9614+03	1.9608+03	1.9591+03	1.9594+03
10	1.9695+03	1.9663+03	1.9658+03	1.9649+03	1.9653+03	1.9668+03
11	1.9701+03	1.9688+03	1.9697+03	1.9703+03	1.9709+03	1.9718+03
12	1.9724+03	1.9734+03	1.9750+03	1.9746+03	1.9749+03	1.9731+03
13	1.9756+03	1.9774+03	1.9772+03	1.9776+03	1.9760+03	1.9734+03
14	1.9797+03	1.9795+03	1.9793+03	1.9776+03	1.9755+03	1.9741+03
15	1.9807+03	1.9807+03	1.9793+03	1.9773+03	1.9757+03	1.9772+03
16	1.9821+03	1.9823+03	1.9812+03	1.9786+03	1.9808+03	1.9797+03
17	1.9841+03	1.9824+03	1.9806+03	1.9800+03	1.9787+03	1.9799+03
18	1.9836+03	1.9812+03	1.9811+03	1.9800+03	1.9810+03	1.9834+03
19	1.9820+03	1.9820+03	1.9813+03	1.9823+03	1.9843+03	1.9852+03
20	1.9827+03	1.9818+03	1.9830+03	1.9849+03	1.9857+03	1.9841+03
21	1.9826+03	1.9838+03	1.9858+03	1.9869+03	1.9850+03	1.9827+03
22	1.9839+03	1.9861+03	1.9871+03	1.9854+03	1.9831+03	1.9831+03
23	1.9867+03	1.9879+03	1.9860+03	1.9832+03	1.9833+03	1.9829+03
24	1.9886+03	1.9870+03	1.9842+03	1.9840+03	1.9837+03	1.9850+03
25	1.9877+03	1.9851+03	1.9842+03	1.9855+03	1.9865+03	1.9873+03
26	1.9853+03	1.9844+03	1.9860+03	1.9878+03	1.9881+03	1.9892+03
27	1.9847+03	1.9862+03	1.9885+03	1.9882+03	1.9869+03	1.9876+03
28	1.9864+03	1.9890+03	1.9889+03	1.9893+03	1.9881+03	1.9859+03
29	1.9897+03	1.9898+03	1.9894+03	1.9878+03	1.9864+03	1.9850+03
30	1.9909+03	1.9899+03	1.9885+03	1.9872+03	1.9858+03	1.9874+03
31	1.9902+03	1.9881+03	1.9881+03	1.9871+03	1.9882+03	1.9906+03
32	1.9557+03	1.9669+03	1.9777+03	1.9882+03	1.9906+03	1.9919+03
33	1.9043+03	1.9102+03	1.9106+03	1.9484+03	1.9395+03	1.9471+03
34	1.8890+03	1.8887+03	1.8919+03	1.8965+03	1.8987+03	1.9019+03
35	1.8875+03	1.8884+03	1.8907+03	1.8917+03	1.8901+03	1.8892+03
36	1.8991+03	1.8983+03	1.8976+03	1.8946+03	1.8907+03	1.8895+03
37	1.9117+03	1.9099+03	1.9067+03	1.9025+03	1.8999+03	1.8997+03
38	1.9234+03	1.9207+03	1.9173+03	1.9138+03	1.9134+03	1.9138+03
39	1.9330+03	1.9298+03	1.9264+03	1.9259+03	1.9270+03	1.9256+03
40	1.9417+03	1.9394+03	1.9387+03	1.9393+03	1.9387+03	1.9353+03

TEMP-TIME VARIATION OF THERMOCOUPLE NO.34(3TEMP.READINGS/SE

	119	120	121	122	123	124
	TEMPB4	TEMPB4	TEMPB4	TEMPB4	TEMPB4	TEMPB4
41	1.9505+03	1.9504+03	1.9511+03	1.9512+03	1.9480+03	1.9438+03
42	1.9587+03	1.9592+03	1.9595+03	1.9570+03	1.9529+03	1.9515+03
43	1.9656+03	1.9660+03	1.9636+03	1.9598+03	1.9585+03	1.9585+03
44	1.9716+03	1.9694+03	1.9659+03	1.9647+03	1.9646+03	1.9652+03
45	1.9741+03	1.9710+03	1.9696+03	1.9703+03	1.9708+03	1.9711+03
46	1.9746+03	1.9729+03	1.9743+03	1.9763+03	1.9757+03	1.9760+03
47	1.9751+03	1.9766+03	1.9787+03	1.9783+03	1.9788+03	1.9771+03
48	1.9796+03	1.9815+03	1.9810+03	1.9808+03	1.9790+03	1.9767+03
49	1.9836+03	1.9832+03	1.9835+03	1.9820+03	1.9797+03	1.9782+03
50	1.9849+03	1.9850+03	1.9850+03	1.9819+03	1.9797+03	1.9812+03
51	1.9864+03	1.9866+03	1.9850+03	1.9827+03	1.9813+03	1.9828+03
52	1.9881+03	1.9868+03	1.9846+03	1.9832+03	1.9846+03	1.9867+03
53	1.9866+03	1.9854+03	1.9839+03	1.9855+03	1.9882+03	1.9882+03
54	1.9859+03	1.9849+03	1.9860+03	1.9885+03	1.9891+03	1.9881+03
55	1.9865+03	1.9878+03	1.9893+03	1.9904+03	1.9888+03	1.9861+03
56	1.9903+03	1.9900+03	1.9908+03	1.9894+03	1.9867+03	1.9862+03
57	1.9913+03	1.9903+03	1.9892+03	1.9877+03	1.9862+03	1.9880+03
58	1.9904+03	1.9886+03	1.9882+03	1.9870+03	1.9882+03	1.9909+03
59	1.9886+03	1.9886+03	1.9883+03	1.9892+03	1.9913+03	1.9923+03
60	1.9881+03	1.9887+03	1.9896+03	1.9913+03	1.9926+03	1.9909+03
61	1.9495+03	1.9627+03	1.9750+03	1.9868+03	1.9910+03	1.9884+03
62	1.9100+03	1.9153+03	1.9218+03	1.9265+03	1.9307+03	1.9380+03
63	1.8947+03	1.8972+03	1.8977+03	1.8976+03	1.8996+03	1.9047+03
64	1.8943+03	1.8928+03	1.8907+03	1.8892+03	1.8911+03	1.8939+03
65	1.8988+03	1.8965+03	1.8933+03	1.8935+03	1.8951+03	1.8946+03
66	1.9094+03	1.9073+03	1.9065+03	1.9067+03	1.9056+03	1.9019+03
67	1.9256+03	1.9247+03	1.9239+03	1.9209+03	1.9223+03	1.9113+03
68	1.9393+03	1.9397+03	1.9381+03	1.9374+03	1.9340+03	1.9291+03
69	1.9527+03	1.9515+03	1.9492+03	1.9463+03	1.9427+03	1.9395+03
70	1.9608+03	1.9597+03	1.9571+03	1.9541+03	1.9514+03	1.9516+03
71	1.9672+03	1.9649+03	1.9623+03	1.9597+03	1.9599+03	1.9618+03
72	1.9702+03	1.9683+03	1.9670+03	1.9675+03	1.9696+03	1.9692+03
73	1.9734+03	1.9719+03	1.9725+03	1.9745+03	1.9750+03	1.9724+03
74	1.9748+03	1.9757+03	1.9780+03	1.9783+03	1.9769+03	1.9747+03
75	1.9790+03	1.9808+03	1.9816+03	1.9794+03	1.9770+03	1.9764+03
76	1.9829+03	1.9837+03	1.9818+03	1.9794+03	1.9791+03	1.9781+03
77	1.9852+03	1.9832+03	1.9806+03	1.9806+03	1.9797+03	1.9807+03
78	1.9849+03	1.9824+03	1.9824+03	1.9818+03	1.9828+03	1.9843+03
79	1.9837+03	1.9833+03	1.9826+03	1.9836+03	1.9857+03	1.9865+03
80	1.9844+03	1.9836+03	1.9849+03	1.9870+03	1.9878+03	1.9859+03

TEMP-TIME VARIATION OF THERMOCOUPLE NO. 34 (3TEMP.READINGS/SE

	119	120	121	122	123	124
	TEMPB4	TEMPB4	TEMPB4	TEMPB4	TEMPB4	TEMPB4
81	1.9839+03	1.9850+03	1.9874+03	1.9881+03	1.9864+03	1.9844+03
82	1.9861+03	1.9887+03	1.9894+03	1.9879+03	1.9866+03	1.9854+03
83	1.9893+03	1.9898+03	1.9888+03	1.9871+03	1.9862+03	1.9848+03
84	1.9819+03	1.9895+03	1.9877+03	1.9865+03	1.9852+03	1.9866+03
85	1.9236+03	1.9291+03	1.9355+03	1.9440+03	1.9570+03	1.9713+03
86	1.8961+03	1.8976+03	1.8995+03	1.9050+03	1.9125+03	1.9178+03
87	1.8867+03	1.8861+03	1.8886+03	1.8923+03	1.8938+03	1.8952+03
88	1.8880+03	1.8888+03	1.8911+03	1.8906+03	1.8901+03	1.8884+03
89	1.8993+03	1.8998+03	1.8982+03	1.8954+03	1.8927+03	1.8904+03
90	1.9154+03	1.9130+03	1.9101+03	1.9066+03	1.9031+03	1.8998+03
91	1.9275+03	1.9250+03	1.9214+03	1.9184+03	1.9153+03	1.9148+03
92	1.9397+03	1.9362+03	1.9331+03	1.9297+03	1.9292+03	1.9295+03
93	1.9487+03	1.9456+03	1.9427+03	1.9430+03	1.9441+03	1.9423+03
94	1.9566+03	1.9543+03	1.9545+03	1.9559+03	1.9549+03	1.9521+03
95	1.9620+03	1.9625+03	1.9643+03	1.9639+03	1.9614+03	1.9586+03
96	1.9682+03	1.9700+03	1.9703+03	1.9680+03	1.9656+03	1.9641+03
97	1.9745+03	1.9750+03	1.9727+03	1.9703+03	1.9694+03	1.9677+03
98	1.9790+03	1.9769+03	1.9743+03	1.9735+03	1.9724+03	1.9727+03
99	1.9795+03	1.9764+03	1.9760+03	1.9762+03	1.9769+03	1.9784+03
100	1.9784+03	1.9775+03	1.9786+03	1.9801+03	1.9803+03	1.9812+03
101	1.9790+03	1.9800+03	1.9823+03	1.9819+03	1.9822+03	1.9808+03
102	1.9825+03	1.9839+03	1.9850+03	1.9829+03	1.9802+03	1.9805+03
103	1.9855+03	1.9861+03	1.9847+03	1.9818+03	1.9812+03	1.9818+03
104	1.9864+03	1.9851+03	1.9838+03	1.9822+03	1.9837+03	1.9859+03
105	1.9851+03	1.9850+03	1.9841+03	1.9852+03	1.9873+03	1.9880+03
106	1.9850+03	1.9857+03	1.9865+03	1.9881+03	1.9893+03	1.9875+03
107	1.9871+03	1.9890+03	1.9890+03	1.9899+03	1.9883+03	1.9855+03
108	1.9902+03	1.9900+03	1.9898+03	1.9891+03	1.9869+03	1.9857+03
109	1.9916+03	1.9899+03	1.9881+03	1.9876+03	1.9864+03	1.9875+03
110	1.9905+03	1.9873+03	1.9878+03	1.9876+03	1.9885+03	1.9906+03
111	1.9888+03	1.9877+03	1.9891+03	1.9904+03	1.9910+03	1.9921+03
112	1.9885+03	1.9896+03	1.9922+03	1.9924+03	1.9921+03	1.9910+03
113	1.9905+03	1.9921+03	1.9933+03	1.9916+03	1.9893+03	1.9893+03
114	1.9313+03	1.9382+03	1.9458+03	1.9551+03	1.9657+03	1.9788+03
115	1.9055+03	1.9049+03	1.9076+03	1.9107+03	1.9170+03	1.9249+03
116	1.9008+03	1.8991+03	1.9002+03	1.9015+03	1.9027+03	1.9054+03
117	1.9088+03	1.9085+03	1.9094+03	1.9078+03	1.9070+03	1.9045+03
118	1.9234+03	1.9236+03	1.9229+03	1.9189+03	1.9147+03	1.9122+03
119	1.9376+03	1.9367+03	1.9334+03	1.9284+03	1.9259+03	1.9241+03
120	1.9497+03	1.9467+03	1.9433+03	1.9397+03	1.9393+03	1.9397+03

TEMP-TIME VARIATION OF THERMOCOUPLE NO. 34(3TEMP.READINGS/SE

	119 TEMPB4	120 TEMPB4	121 TEMPB4	122 TEMPB4	123 TEMPB4	124 TEMPB4
121	1.9555+03	1.9544+03	1.9526+03	1.9526+03	1.9533+03	1.9526+03
122	1.9630+03	1.9630+03	1.9630+03	1.9628+03	1.9626+03	1.9596+03
123	1.9698+03	1.9713+03	1.9703+03	1.9703+03	1.9680+03	1.9648+03
124	1.9766+03	1.9764+03	1.9755+03	1.9735+03	1.9711+03	1.9690+03
125	1.9804+03	1.9784+03	1.9764+03	1.9753+03	1.9735+03	1.9744+03
126	1.9574+03	1.9661+03	1.9764+03	1.9770+03	1.9777+03	1.9799+03
127	1.9062+03	1.9112+03	1.9180+03	1.9262+03	1.9362+03	1.9477+03
128	1.8854+03	1.8890+03	1.8932+03	1.8968+03	1.9016+03	1.9042+03
129	1.8827+03	1.8853+03	1.8852+03	1.8865+03	1.8861+03	1.8847+03
130	1.8896+03	1.8891+03	1.8875+03	1.8856+03	1.8836+03	1.8816+03
131	1.9039+03	1.8993+03	1.8946+03	1.8923+03	1.8897+03	1.8887+03
132	1.9188+03	1.9141+03	1.9108+03	1.9090+03	1.9075+03	1.9054+03
133	1.9288+03	1.9254+03	1.9255+03	1.9258+03	1.9239+03	1.9225+03
134	1.9400+03	1.9392+03	1.9399+03	1.9383+03	1.9357+03	1.9325+03
135	1.9536+03	1.9547+03	1.9553+03	1.9499+03	1.9454+03	1.9435+03
136	1.9648+03	1.9658+03	1.9618+03	1.9553+03	1.9533+03	1.9530+03
137	1.9729+03	1.9693+03	1.9642+03	1.9614+03	1.9629+03	1.9646+03
138	1.9725+03	1.9703+03	1.9671+03	1.9692+03	1.9740+03	1.9726+03
139	1.9105+03	1.9166+03	1.9285+03	1.9448+03	1.9576+03	1.9666+03
140	1.8873+03	1.8909+03	1.8963+03	1.9023+03	1.9037+03	1.9043+03
141	1.8927+03	1.8920+03	1.8930+03	1.8899+03	1.8851+03	1.8852+03
142	1.9042+03	1.9007+03	1.8970+03	1.8926+03	1.8886+03	1.8905+03
143	1.9177+03	1.9103+03	1.9079+03	1.9037+03	1.9033+03	1.9061+03
144	1.9290+03	1.9250+03	1.9249+03	1.9250+03	1.9247+03	1.9247+03
145	1.9416+03	1.9418+03	1.9448+03	1.9431+03	1.9400+03	1.9356+03
146	1.9573+03	1.9572+03	1.9582+03	1.9531+03	1.9467+03	1.9450+03
147	1.9682+03	1.9665+03	1.9629+03	1.9580+03	1.9548+03	1.9562+03
148	1.9730+03	1.9669+03	1.9662+03	1.9640+03	1.9650+03	1.9686+03
149	1.9734+03	1.9699+03	1.9729+03	1.9765+03	1.9755+03	1.9771+03
150	1.9754+03	1.9770+03	1.9808+03	1.9816+03	1.9784+03	1.9758+03
151	1.9841+03	1.9844+03	1.9862+03	1.9829+03	1.9769+03	1.9766+03
152	1.9883+03	1.9875+03	1.9850+03	1.9812+03	1.9789+03	1.9814+03
153	1.9890+03	1.9844+03	1.9843+03	1.9818+03	1.9839+03	1.9888+03
154	1.9862+03	1.9859+03	1.9860+03	1.9878+03	1.9904+03	1.9926+03
155	1.9866+03	1.9890+03	1.9911+03	1.9925+03	1.9945+03	1.9913+03
156	1.9896+03	1.9947+03	1.9947+03	1.9952+03	1.9928+03	1.9882+03
157	1.9952+03	1.9962+03	1.9939+03	1.9915+03	1.9894+03	1.9869+03
158	1.9985+03	1.9949+03	1.9904+03	1.9903+03	1.9887+03	1.9907+03
159	1.9961+03	1.9910+03	1.9903+03	1.9914+03	1.9936+03	1.9961+03
160	1.9853+03	1.9894+03	1.9928+03	1.9967+03	1.9966+03	1.9988+03

TEMP-TIME VARIATION OF THERMOCOUPLE NO.34 (3TEMP.READINGS/SE

	119	120	121	122	123	124
	TEMPB4	TEMPB4	TEMPB4	TEMPB4	TEMPB4	TEMPB4
161	1.9224+03	1.9322+03	1.9458+03	1.9567+03	1.9671+03	1.9769+03
162	1.9002+03	1.9053+03	1.9116+03	1.9124+03	1.9128+03	1.9185+03
163	1.8951+03	1.8961+03	1.8943+03	1.8907+03	1.8904+03	1.8951+03
164	1.8961+03	1.8921+03	1.8907+03	1.8875+03	1.8900+03	1.8952+03
165	1.9014+03	1.8988+03	1.8969+03	1.8976+03	1.9000+03	1.9002+03
166	1.9135+03	1.9145+03	1.9158+03	1.9137+03	1.9141+03	1.9089+03
167	1.9305+03	1.9337+03	1.9315+03	1.9294+03	1.9247+03	1.9186+03
168	1.9461+03	1.9478+03	1.9483+03	1.9429+03	1.9349+03	1.9376+03
169	1.9599+03	1.9598+03	1.9555+03	1.9487+03	1.9467+03	1.9459+03
170	1.9678+03	1.9633+03	1.9598+03	1.9560+03	1.9585+03	1.9615+03
171	1.9698+03	1.9690+03	1.9668+03	1.9679+03	1.9713+03	1.9708+03
172	1.9738+03	1.9755+03	1.9768+03	1.9781+03	1.9797+03	1.9755+03
173	1.9802+03	1.9838+03	1.9830+03	1.9842+03	1.9811+03	1.9759+03
174	1.9877+03	1.9883+03	1.9859+03	1.9835+03	1.9803+03	1.9772+03
175	1.9922+03	1.9882+03	1.9835+03	1.9832+03	1.9810+03	1.9830+03
176	1.9912+03	1.9858+03	1.9851+03	1.9860+03	1.9874+03	1.9903+03
177	1.9886+03	1.9859+03	1.9889+03	1.9918+03	1.9923+03	1.9941+03
178	1.9878+03	1.9903+03	1.9952+03	1.9953+03	1.9945+03	1.9921+03
179	1.9933+03	1.9960+03	1.9985+03	1.9949+03	1.9899+03	1.9903+03
180	1.9969+03	1.9987+03	1.9961+03	1.9912+03	1.9903+03	1.9913+03
181	1.9972+03	1.9952+03	1.9927+03	1.9901+03	1.9932+03	1.9973+03
182	1.9925+03	1.9924+03	1.9920+03	1.9942+03	1.9983+03	1.9993+03
183	1.9913+03	1.9946+03	1.9982+03	1.9982+03	2.0005+03	1.9974+03
184	1.9952+03	2.0001+03	2.0006+03	1.9994+03	1.9976+03	1.9945+03
185	1.9994+03	2.0021+03	1.9987+03	1.9943+03	1.9945+03	1.9931+03
186	2.0005+03	1.9981+03	1.9945+03	1.9927+03	1.9951+03	1.9975+03
187	1.9957+03	1.9955+03	1.9933+03	1.9957+03	2.0008+03	2.0006+03
188	1.9935+03	1.9956+03	1.9980+03	2.0005+03	2.0030+03	1.9993+03
189	1.9967+03	2.0016+03	2.0011+03	2.0019+03	1.9996+03	1.9952+03
190	1.9389+03	1.9491+03	1.9574+03	1.9669+03	1.9776+03	1.9865+03
191	1.9083+03	1.9086+03	1.9081+03	1.9134+03	1.9177+03	1.9267+03
192	1.8930+03	1.8895+03	1.8888+03	1.8931+03	1.8973+03	1.9025+03
193	1.8902+03	1.8866+03	1.8894+03	1.8940+03	1.8938+03	1.8952+03
194	1.8967+03	1.8974+03	1.9007+03	1.9009+03	1.8963+03	1.8925+03
195	1.9147+03	1.9134+03	1.9128+03	1.9072+03	1.9003+03	1.8988+03
196	1.9323+03	1.9298+03	1.9252+03	1.9186+03	1.9141+03	1.9147+03
197	1.9443+03	1.9386+03	1.9366+03	1.9321+03	1.9322+03	1.9350+03
198	1.9517+03	1.9494+03	1.9477+03	1.9480+03	1.9492+03	1.9497+03
199	1.9586+03	1.9607+03	1.9628+03	1.9621+03	1.9629+03	1.9587+03
200	1.9698+03	1.9735+03	1.9723+03	1.9707+03	1.9672+03	1.9620+03

TEMP-TIME VARIATION OF THERMOCOUPLE NO.34 (3TEMP.READINGS/SE

	119	120	121	122	123	124
	TEMPB4	TEMPB4	TEMPB4	TEMPB4	TEMPB4	TEMPB4
201	1.9804+03	1.9814+03	1.9775+03	1.9733+03	1.971[illegible]+03	1.9682+03
202	1.9147+03	1.9148+03	1.917[illegible]+03	1.9158+03	1.9408+03	1.9774+03
203	1.9343+03	1.9345+03	1.9346+03	1.9285+03	1.9225+03	1.9190+03
204	1.9498+03	1.9502+03	1.9449+03	1.9374+03	1.9349+03	1.9339+03
205	1.9621+03	1.9580+03	1.9521+03	1.9485+03	1.9501+03	1.9512+03
206	1.9671+03	1.9639+03	1.9600+03	1.9615+03	1.9644+03	1.9628+03
207	1.9703+03	1.9682+03	1.9696+03	1.9734+03	1.9740+03	1.9703+03
208	1.9758+03	1.9774+03	1.9787+03	1.9806+03	1.9766+03	1.9712+03
209	1.9853+03	1.9847+03	1.9850+03	1.9818+03	1.9765+03	1.9742+03

TABLE 5

BOILING HEAT TRANSFER DATA NEAR BOILING INCEPTION POINT

100 KW LOOP, TEST SECTION NO. 4

Date 6/2/65

Time	TC-19 (°F) Outside Wall Temp.	TC-32 (°F)	TC-31 (°F)	q" Heat Flux Btu/hr-ft^2	h Btu/hr-ft^2-°F at TC-32	Quality at TC-32
1150	1984.9	1918.9	1789.5	100,690	2910	.0906
	1985.2	1918.9	1799.9	100,710	2886	.0913
	1983.6	1923.8	1787.8	100,750	3548	.0910
1220	2001.2	1925.5	1802.6	115,600	2919	.0959
	2000.1	1925.8	1802.9	115,600	3026	.0955
	1995.9	1929.9	1802.5	115,600	3866	.0955
1246	2009.4	1922.5	1813.4	126,750	2680	.107
	1999.3	1944.8	1839.0	126,610	8441	.107
	2000.5	1930.1	1820.4	126,770	4116	.107
1327	2017.5	1939.7	1858.0	148,390	4711	.136
	2018.5	1932.6	1856.8	148,430	3748	.137
	2026.7	1941.4	1870.3	148,290	3802	.137
1505	2032.4	1925.4	1614.7	173,220	3274	.105
	2024.3	1934.6	1639.0	173,120	4849	.104
	2025.0	1925.2	1622.1	173,250	3791	.105
1423	2045.6	1928.0	1877.7	171,990	2692	.153
	2036.8	1944.4	1905.2	171,860	4429	.152
	2034.5	1937.3	1886.6	172,020	3954	.153

Date 6/3/65

Time	TC-19 (°F) Outside Wall Temp.	TC-32 (°F)	TC-31 (°F)	q" Heat Flux Btu/hr-ft^2	h Btu/hr-ft^2-°F at TC-32	Quality at TC-32
1855	1986.0	1927.5	1775.1	103,200	3894	.149
	1986.4	1942.7	1789.0	103,140	8815	.149
	1985.5	1926.7	1765.4	103,230	3852	.152
1953	2017.6	1918.2	1777.7	152,540	2968	.223
	2018.2	1920.3	1780.9	152,550	3057	.223
	2017.9	1935.5	1802.1	152,490	4433	.219
2030	2035.9	1922.3	1724.3	180,780	3139	.247
	2037.8	1926.4	1729.0	180,800	3264	.245
	2038.0	1927.3	1730.7	180,910	3307	.244
2110	2028.5	1914.2	1531.7	182,280	3181	.198
	2029.9	1926.7	1543.0	182,290	3946	.197
	2029.4	1939.7	1568.6	182,140	5570	.195

TABLE 6

NOMENCLATURE FOR BOILER DESIGN CODE PRINTOUT

Symbol	Quantity	Units
ACCL	Radial acceleration	ft/sec^2
ACCL/G	Ratio of radial acceleration to the local gravitational acceleration	g's
DELTAP	Primary friction pressure drop or Secondary total pressure drop in boiling region	psia
DPFRIC	Secondary friction pressure drop in boiling region	psia
DPMOM	Secondary momentum pressure drop in boiling region	psia
DPRIN	Primary radial pressure drop at inlet	psia
DPROUT	Primary radial pressure drop at exit	psia
DPSUP	Secondary total pressure drop in superheat region	psia
DPSFRIC	Secondary friction pressure drop in superheat region	psia
DPSMOM	Secondary momentum pressure drop in superheat region	psia
GMAX	Secondary maximum helical mass velocity	lbm/ft^2 sec
GP	Primary mass velocity	lbm/ft^2 sec
HB	Boiling heat transfer coefficient	Btu/ft^2-hr-^{o}F
HP	Primary heat transfer coefficient	Btu/ft^2-hr-^{o}F
HSL	Secondary heat transfer coefficient in liquid region	Btu/ft^2-hr-^{o}F
HSUPS	Secondary heat transfer coefficient in superheat region	Btu/ft^2-hr-^{o}F
HWALL	Effective wall heat transfer coefficient	Btu/ft^2-hr-^{o}F

Symbol	Quantity	Units
LTOT	Total tube length	ft.
LB	Tube length in boiling region	ft.
LSC	Tube length in subcooled region	ft.
LSUP	Tube length in superheat region	ft.
NT	Number of tubes	dimensionless
PEL	Secondary fluid Peclet number	dimensionless
PEP	Primary fluid Peclet number	dimensionless
POWER	Total power	KW
P/D	Pitch to diameter ratio	dimensionless
QB	Heat transfer rate in boiling region	Btu/sec
QSC	Heat transfer rate in subcooled region	Btu/sec
QSUP	Heat transfer rate in superheat region	Btu/sec
QTOT	Total heat transfer rate	Btu/sec
Q/A BOILING	Heat flux in boiling region	Btu/ft^2-sec
REP	Primary fluid Reynold's number	dimensionless
REL	Secondary fluid Reynold's number	dimensionless
TPIN	Primary inlet temperature	^oF
TPOUT	Primary exit temperature	^oF
TSIN	Secondary inlet temperature	^oF
TSAT	Secondary temperature at inlet to boiling region	^oF
TSOUT	Secondary exit superheated vapor temperature	^oF
UIB	Overall heat transfer coefficient in boiling region	Btu/ft^2-hr-^oF
UIL	Overall heat transfer coefficient liquid region	Btu/ft^2-hr-^oF
VMAX	Maximum secondary helical velocity	fps
VP	Primary fluid axial velocity	fps
WP	Primary fluid flow rate	lb_m/sec
WS	Secondary fluid flow rate	lb_m/sec
XW	Wall thickness	inches

TABLE 7

NOMENCLATURE FOR CONDENSER DESIGN CODE PRINTOUT

Symbol	Quantity	Units
DELTAP	Net condensing pressure drop	psia
DPFRIC	Primary frictional pressure drop or condensing friction pressure drop	psia
DPMOM	Condensing momentum pressure drop	psia
GP	Primary mass velocity	lb_m/ft^2-sec
GS	Secondary mass velocity	lb_m/ft^2-sec
HP	Local primary heat transfer coefficient	Btu/ft^2-hr-^oF
HSC	Local condensing heat transfer co-efficient	Btu/ft^2-hr-^oF
HSL	Secondary heat transfer coefficient in liquid region	Btu/ft^2-hr-^oF
NT	Number of tubes	
PEL	Secondary Peclet number in liquid region	dimensionless
POWER	Total power	KW
PLOCAL	Local secondary static pressure	psia
Q	Cumulative heat transfer rate	Btu/sec
QCOND	Heat transfer rate in condensing region	Btu/sec
QSUB	Heat transfer rate in subcooled region	Btu/sec
QTOT	Total heat transfer rate	Btu/sec
QOA	Local heat flux	Btu/ft^2-hr
REL	Secondary Reynold's number in liquid region	dimensionless
REP	Primary Reynold's number	dimensionless
REZ	Local secondary film Reynold's number	dimensionless
TPC	Local primary fluid temperature	^oF
TPIN	Primary fluid inlet temperature	^oF
TPOUT	Primary fluid exit temperature	^oF
TSC	Local secondary fluid saturation temperature	^oF

Symbol	Quantity	Units
TSIN	Secondary fluid inlet temperature	^oF
TSOUT	Secondary fluid subcooled exit temperature	^oF
UI	Local overall heat transfer coefficient	Btu/ft^2-hr-^oF
UIL	Overall heat transfer coefficient in liquid region	Btu/ft^2-hr-^oF
VMAX	Inlet secondary vapor velocity	fps
VP	Primary fluid velocity	fps
WP	Primary flowrate	lb_m/sec
WS	Secondary flow rate	lb_m/sec
X	Local secondary quality	dimensionless
XW	Wall thickness	in
Z	Length	ft

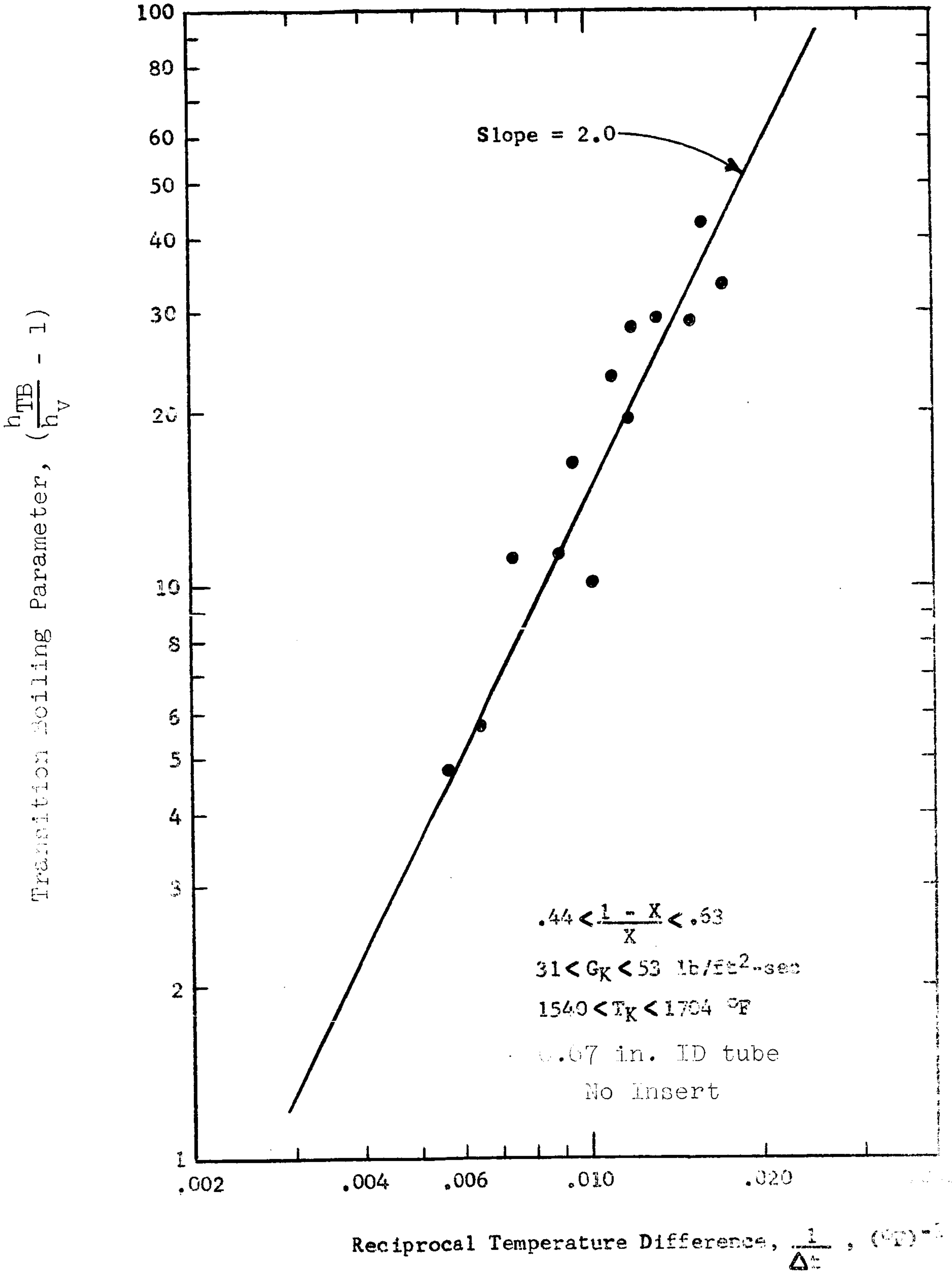


Figure 1. Effect of Wall-To-Fluid Temperature Difference On Transition Boiling Parameter (300 KW Facility)

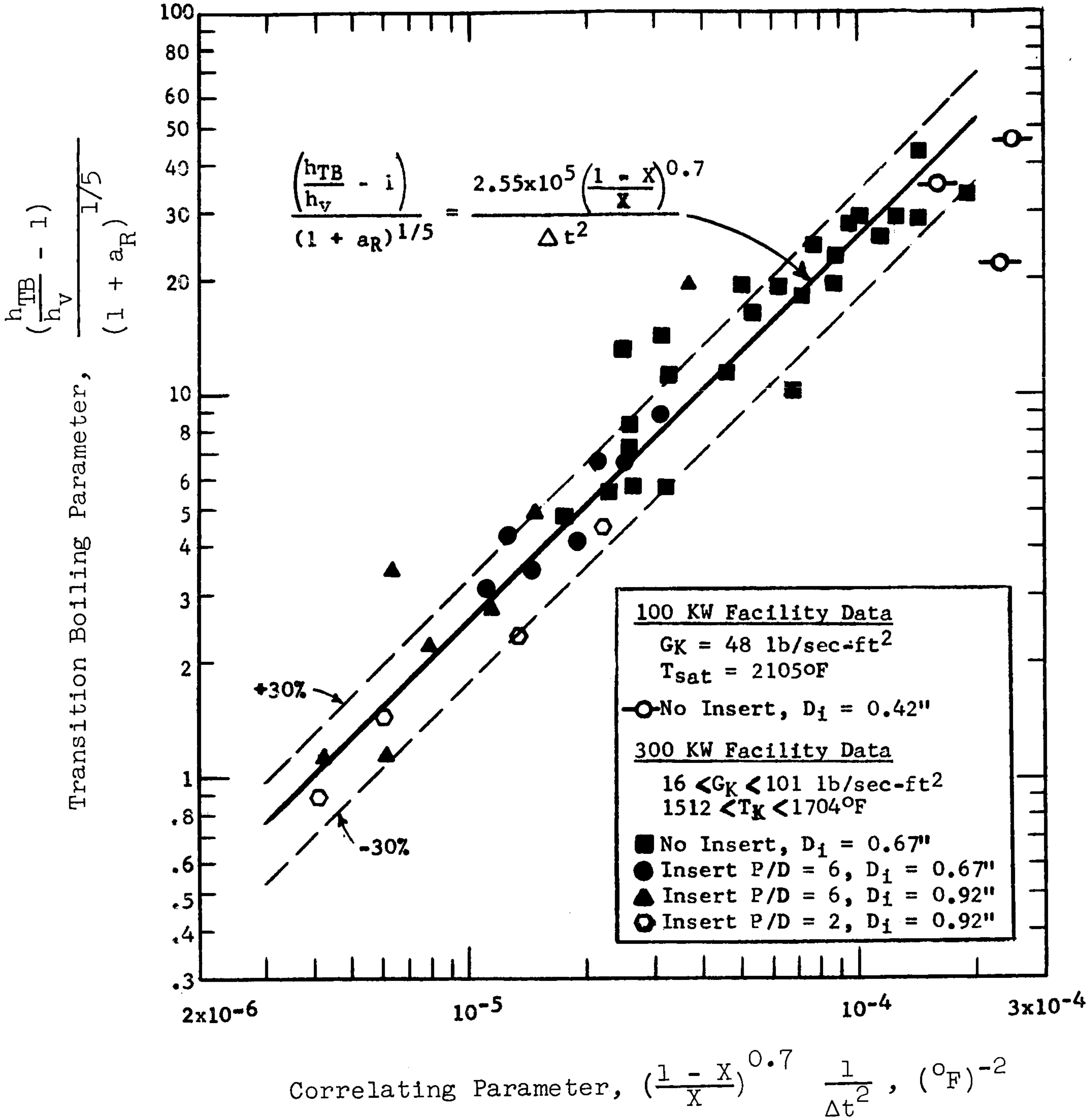


Figure 2. Comparison of Potassium Transition Boiling Data With Proposed Empirical Correlation (Equation 2, Sec.III, Text)

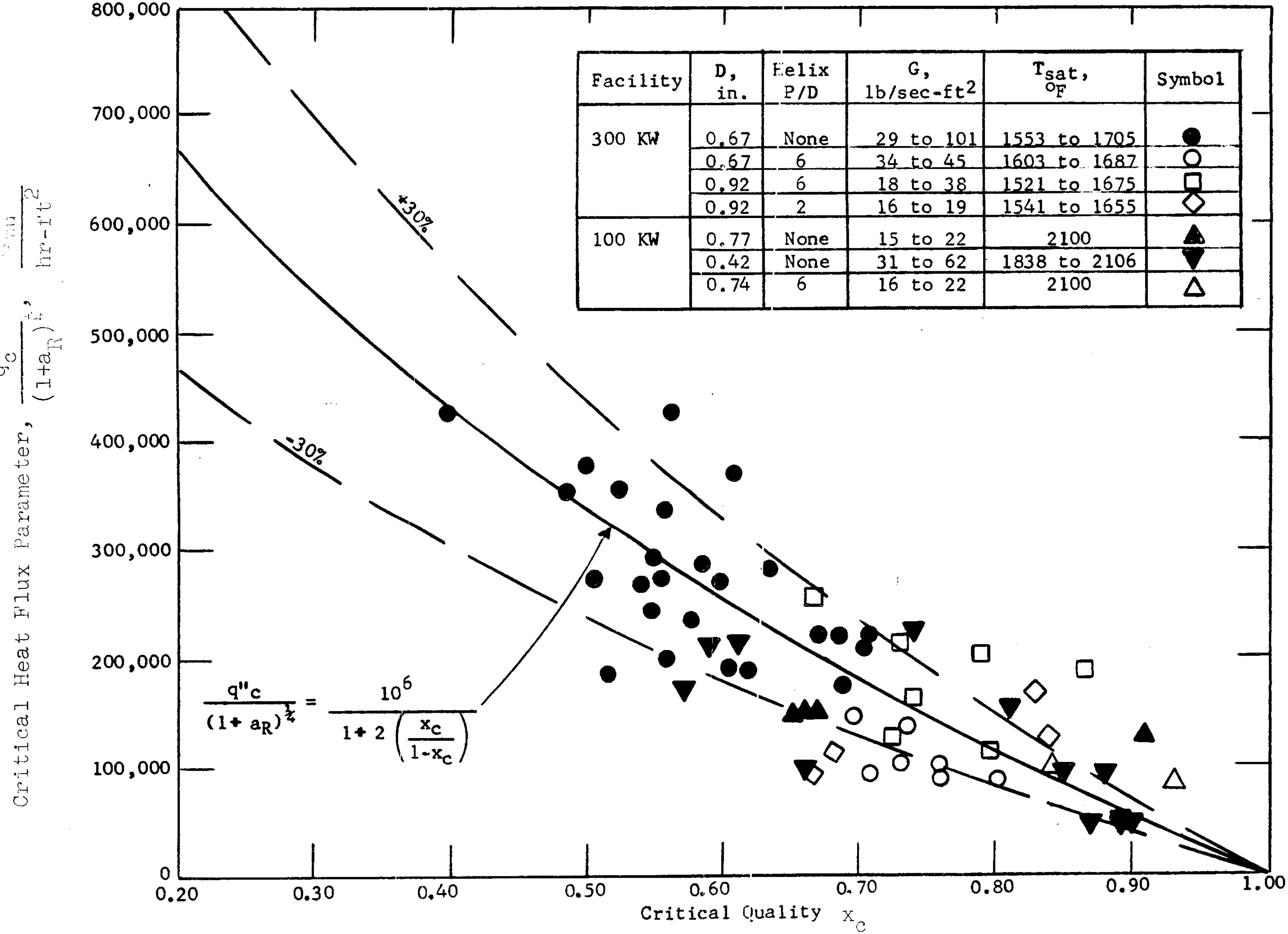


Figure 3. Critical Heat Flux Data and Proposed Empirical Correlation

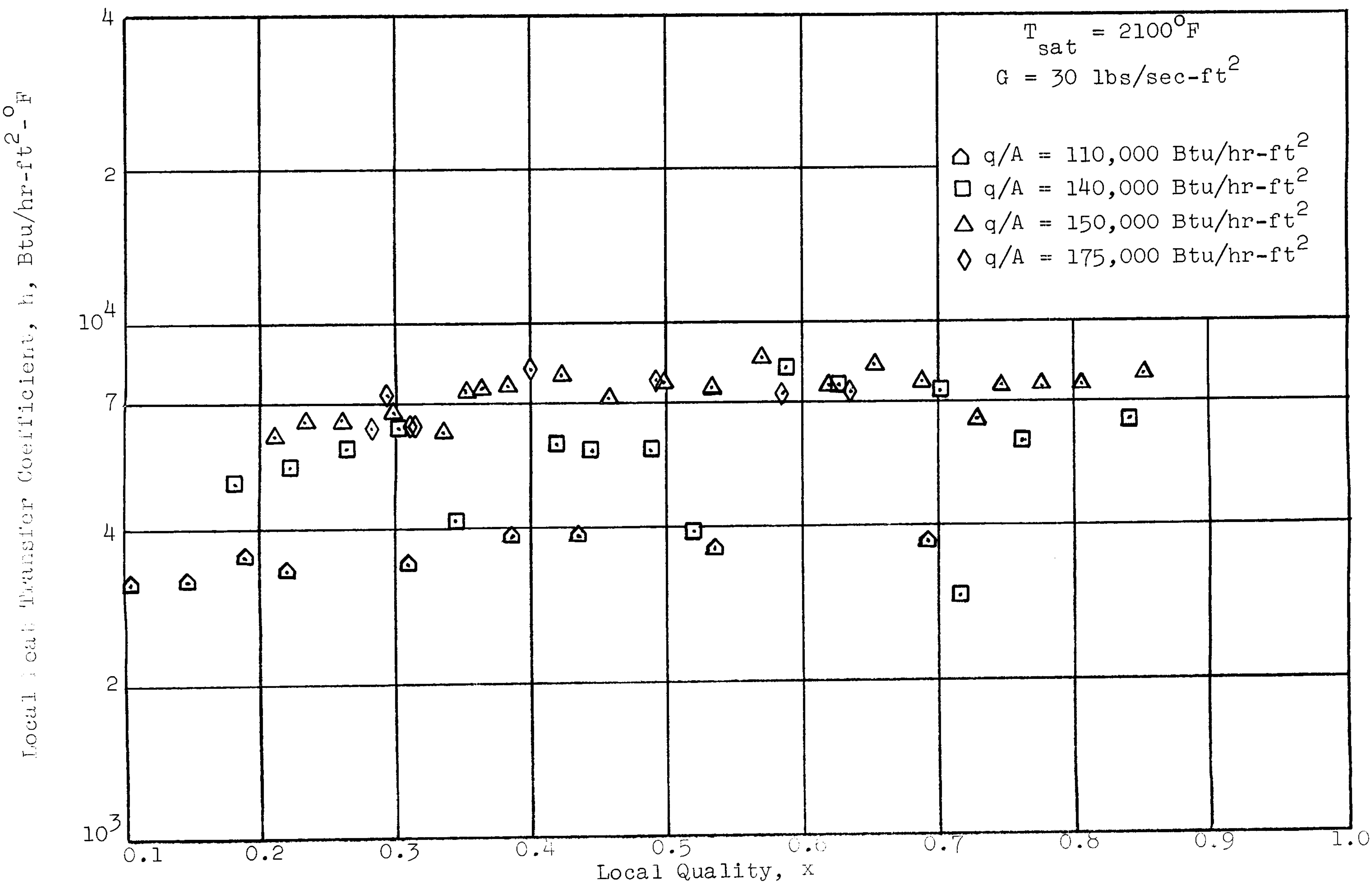


Figure 4 . Local Nucleate Boiling Heat Transfer Coefficient As A Function of Quality (100 KW Facility). 0.738-inch ID Tube With Helical Insert, P/D = 2 (Test Section No. 4) T_{sat} = 2100^{o}F

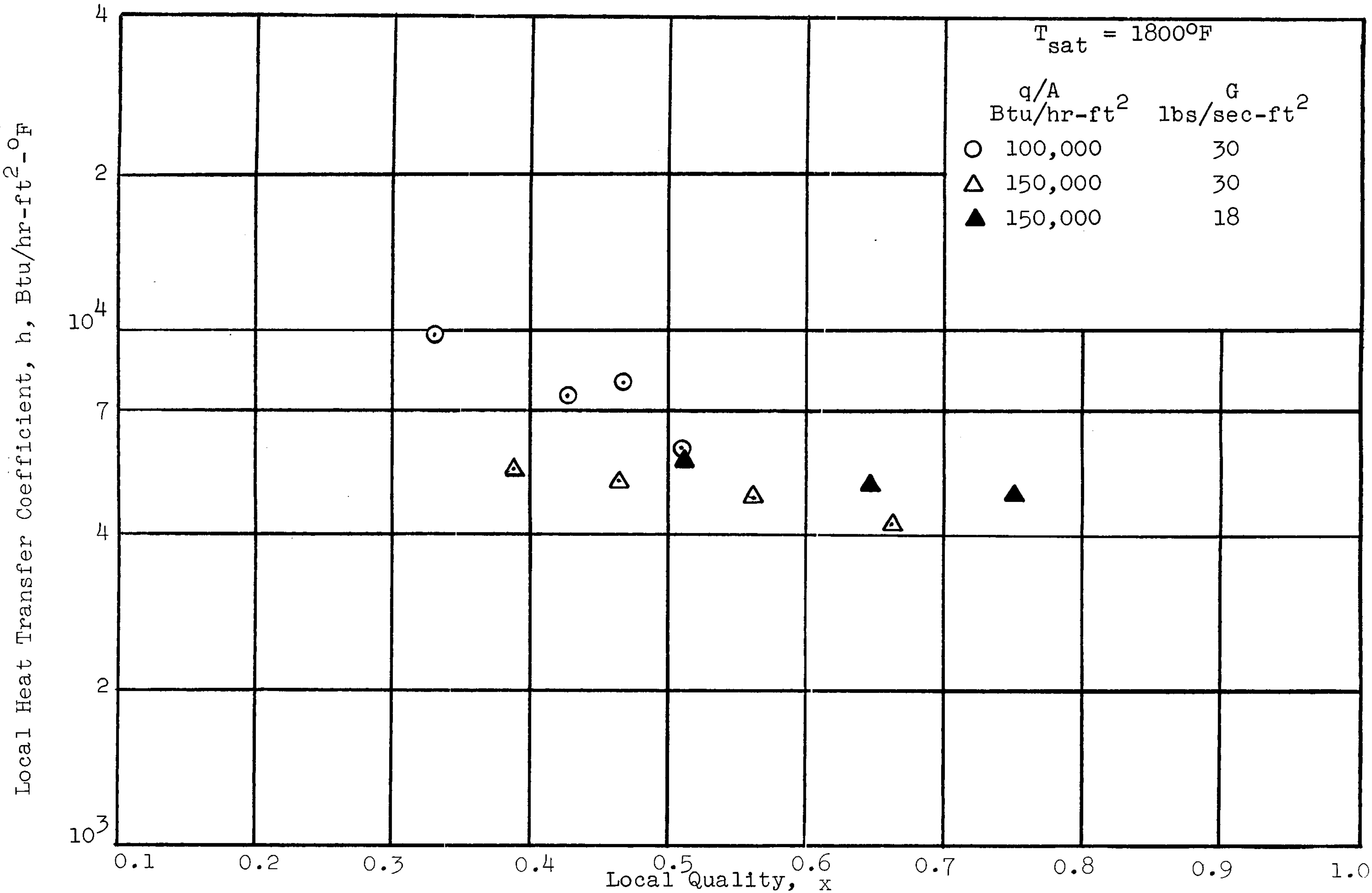
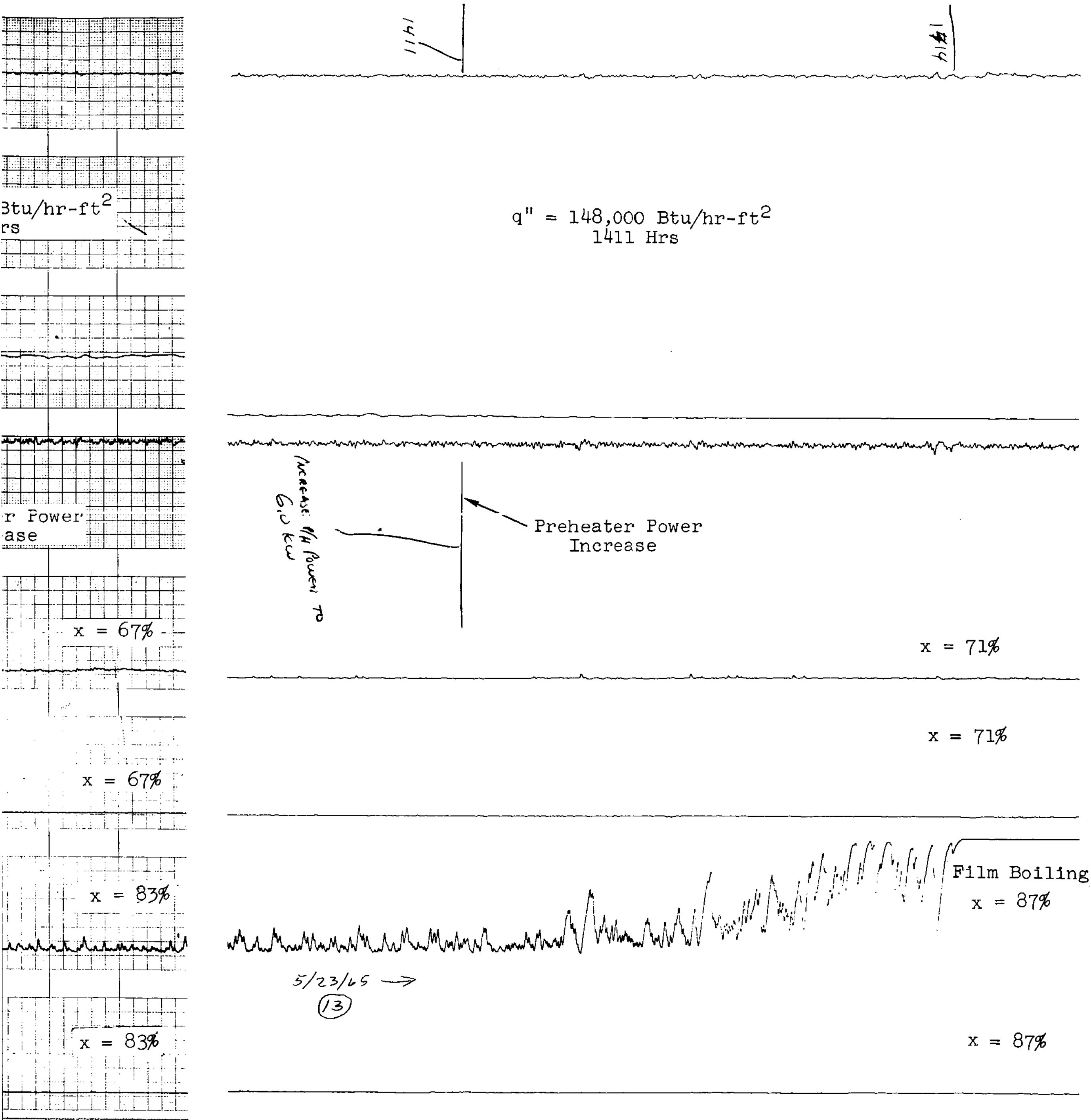


Figure 5 . Local Nucleate Boiling Heat Transfer Coefficient As A Function Of Quality (100 KW Facility). 0.738-inch ID Tube With Helical Insert, P/D = 2 (Test Section No. 4) T_{sat} = 1800°F



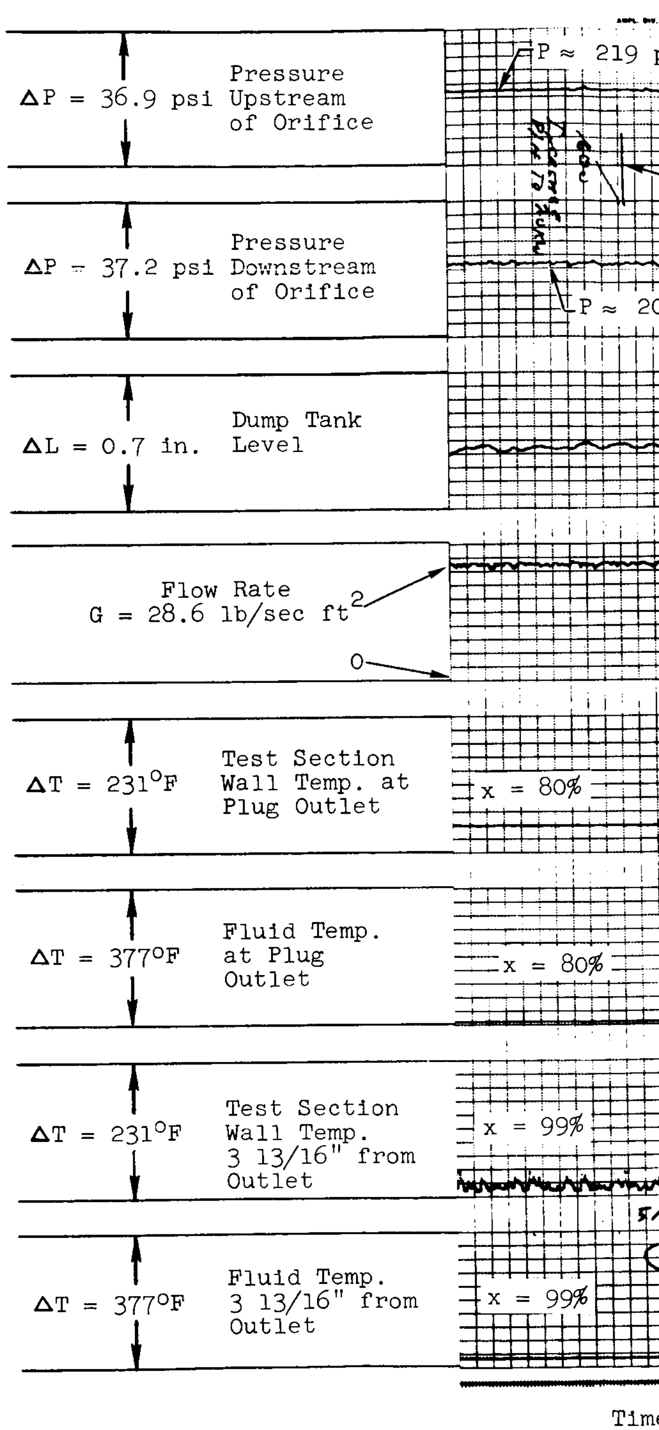
, 1 Mark/Sec

T_{sat} = 2100°F

Test Section #4

r Chart Showing The Onset Of Film Boiling -
Loop (5/23/65)

(2)



ΔP = 36.9 psi
Pressure Upstream of Orifice
P ≈ 219
ΔP = 37.2 psi
Pressure Downstream of Orifice
P ≈ 20
ΔL = 0.7 in.
Dump Tank Level
Flow Rate
G = 28.6 lb/sec ft2
0
ΔT = 231°F
Test Section Wall Temp. at Plug Outlet
x = 80%
ΔT = 377°F
Fluid Temp. at Plug Outlet
x = 80%
ΔT = 231°F
Test Section Wall Temp. 3 13/16" from Outlet
x = 99%
ΔT = 377°F
Fluid Temp. 3 13/16" from Outlet
x = 99%
Tim

Figure 7.

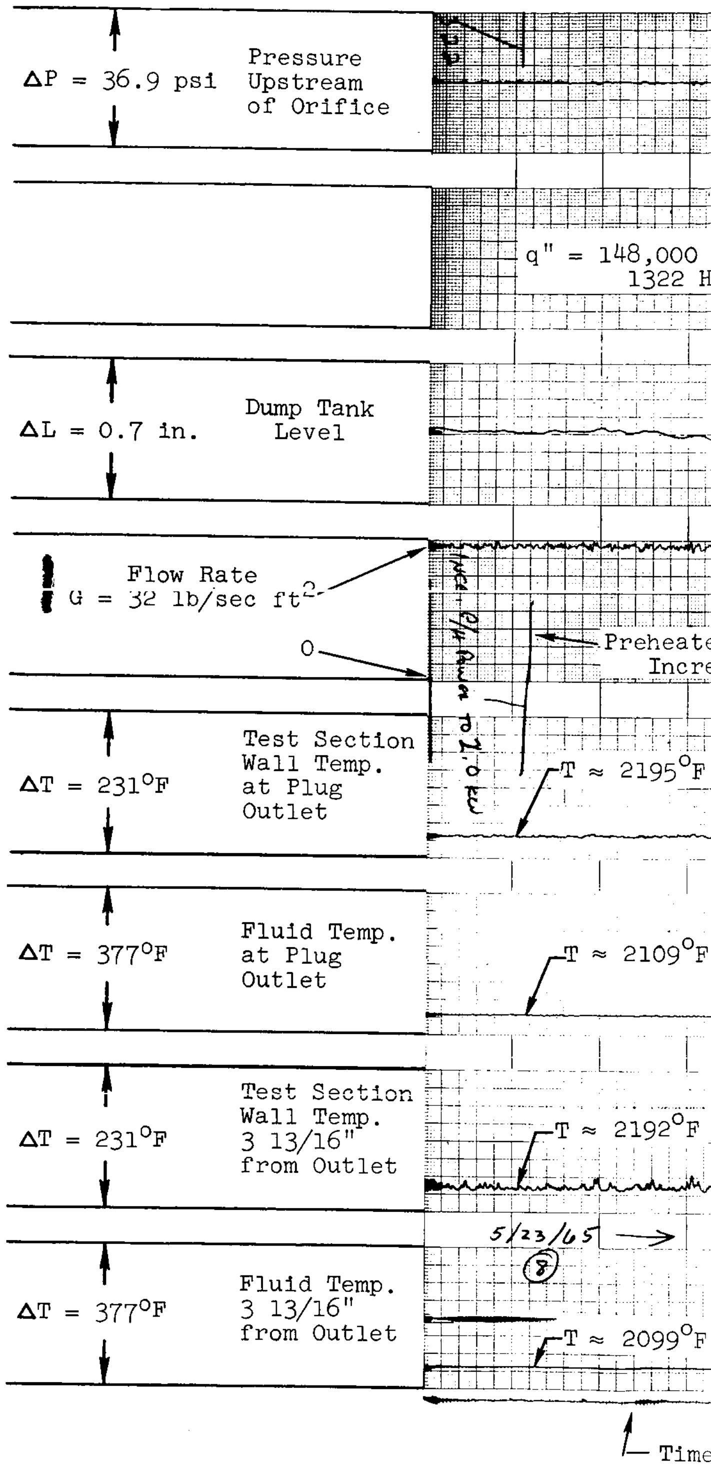
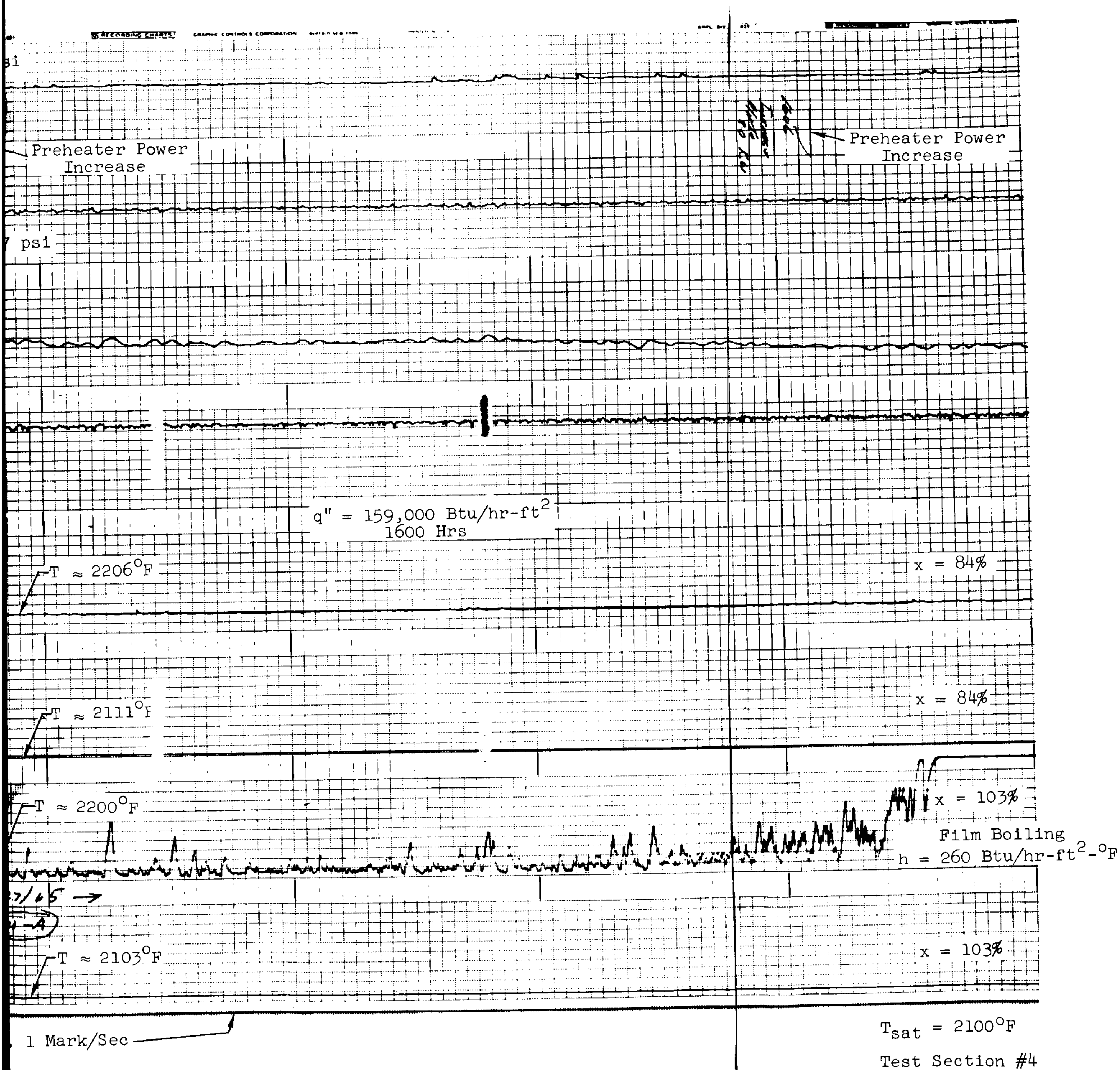
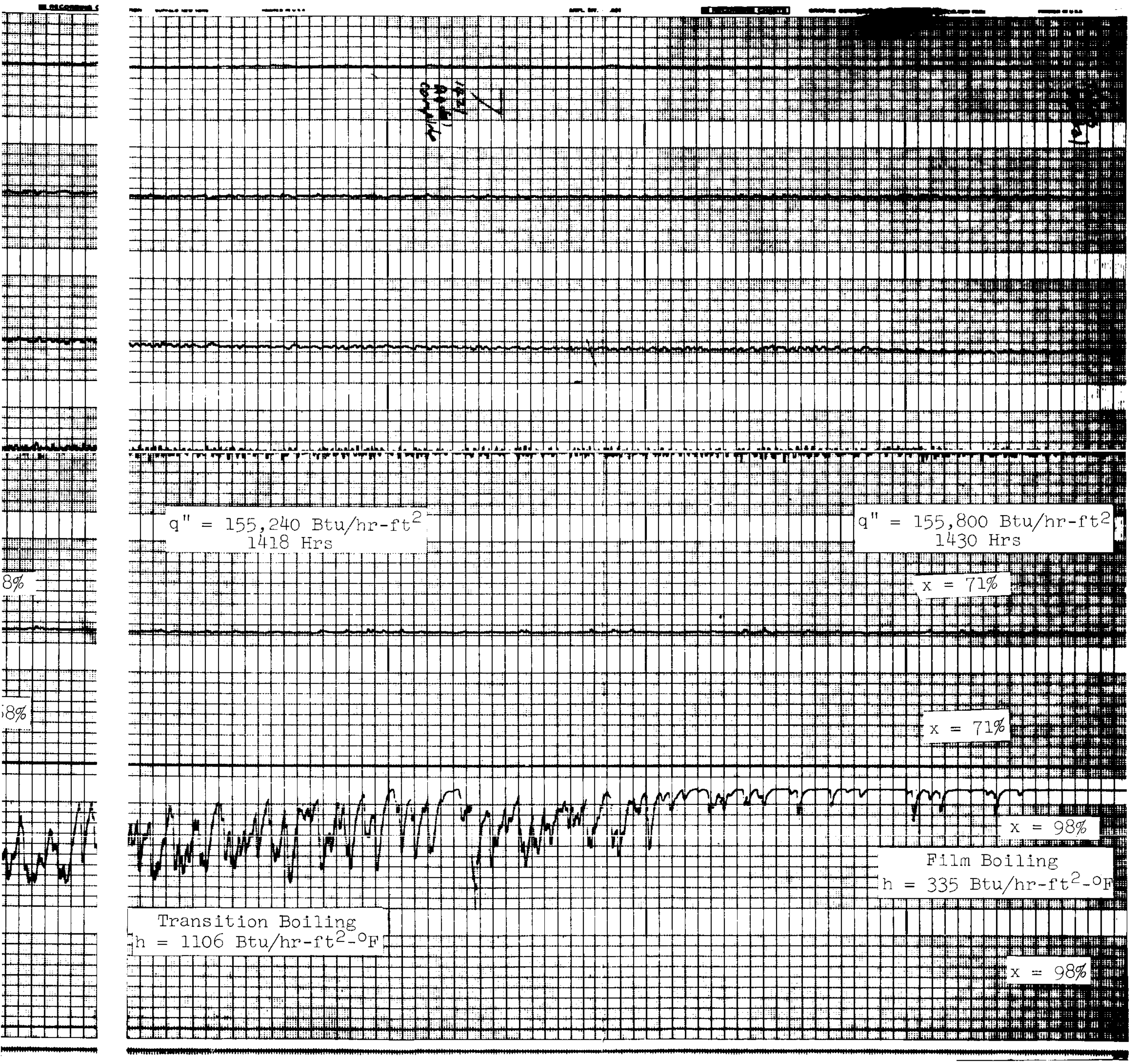


Figure 6. Recorde
100 KW

113



Recorder Chart Showing The Onset Of Film Boiling - 100 KW Loop (5/27/65)



T_{sat} = 2100°F

Test Section #4

howing Onset Of The Film Boiling
Btu/hr-ft^2 - 100 KW Loop (5/28/65)

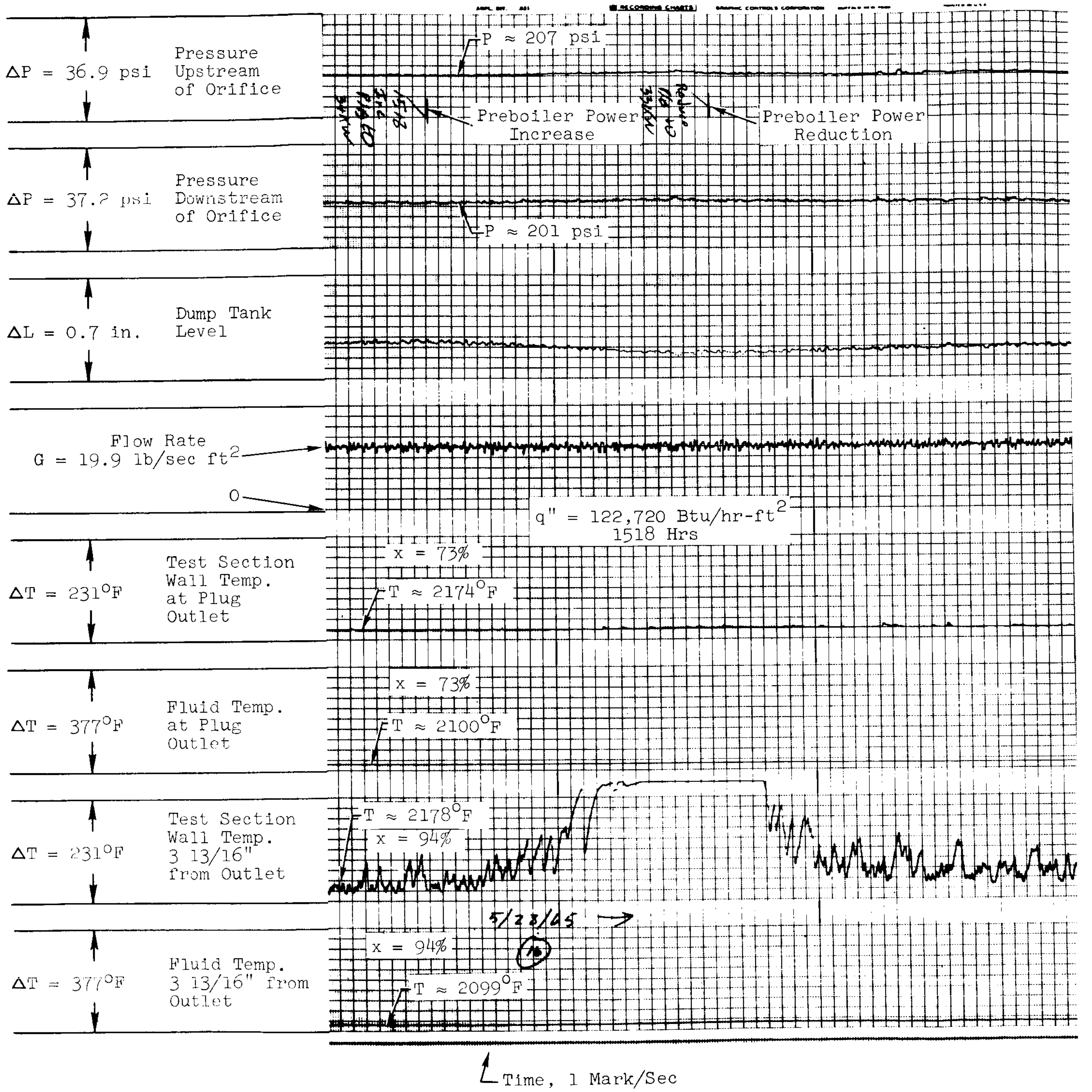


Figure 9. Recorde
q" = 12

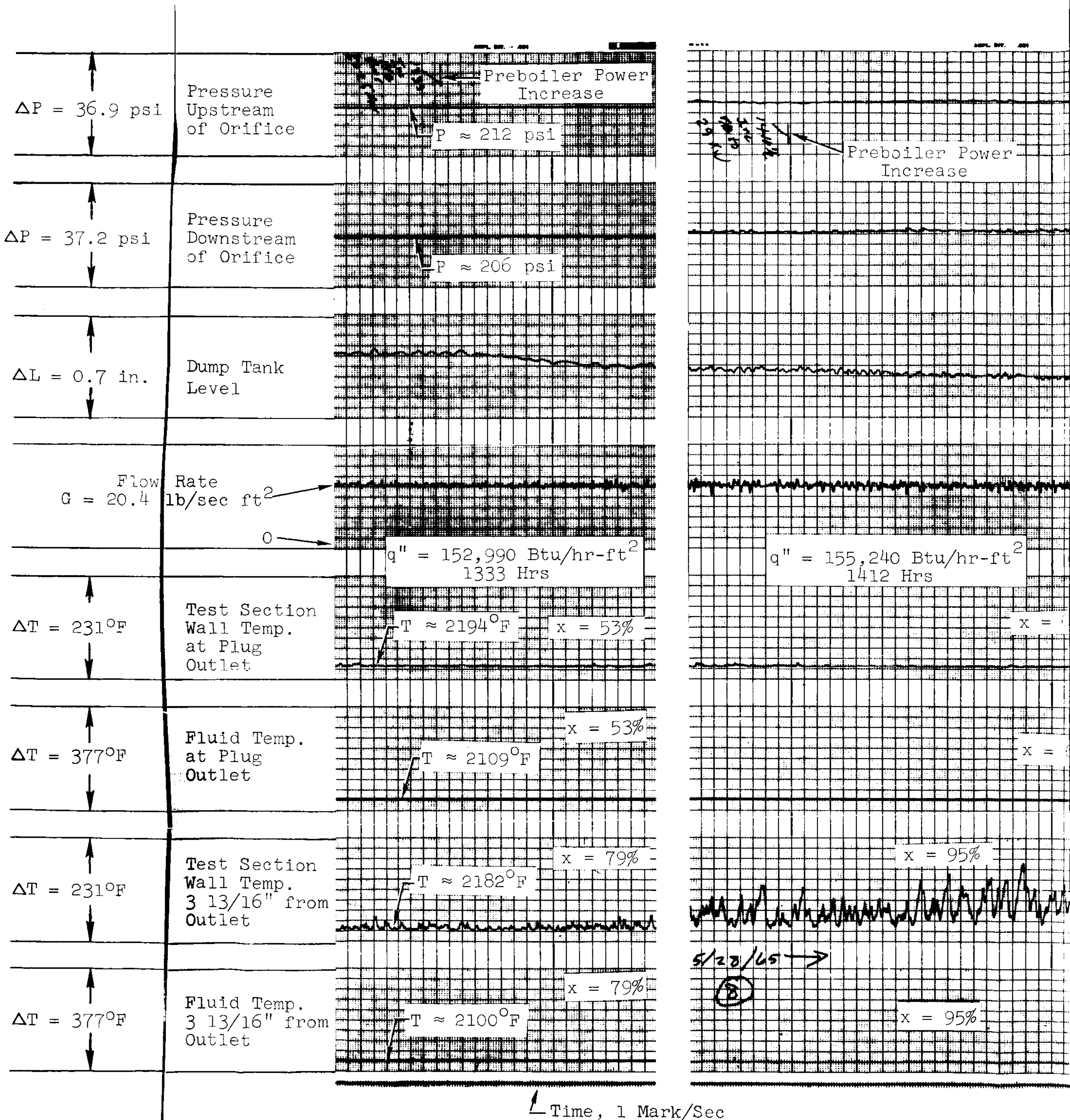
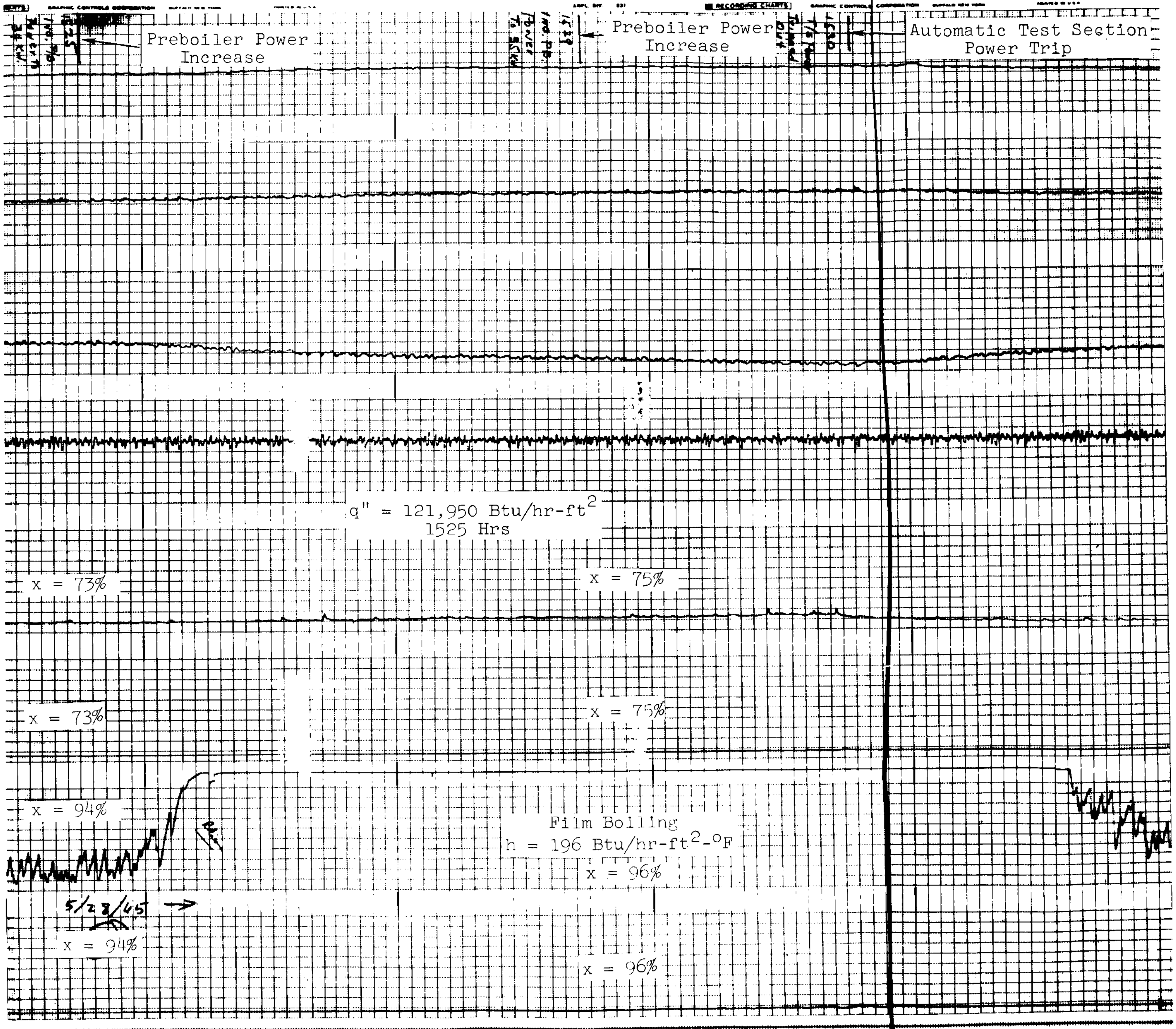


Figure 8. Recorder Chart S
At q" = 155,800

115 ①



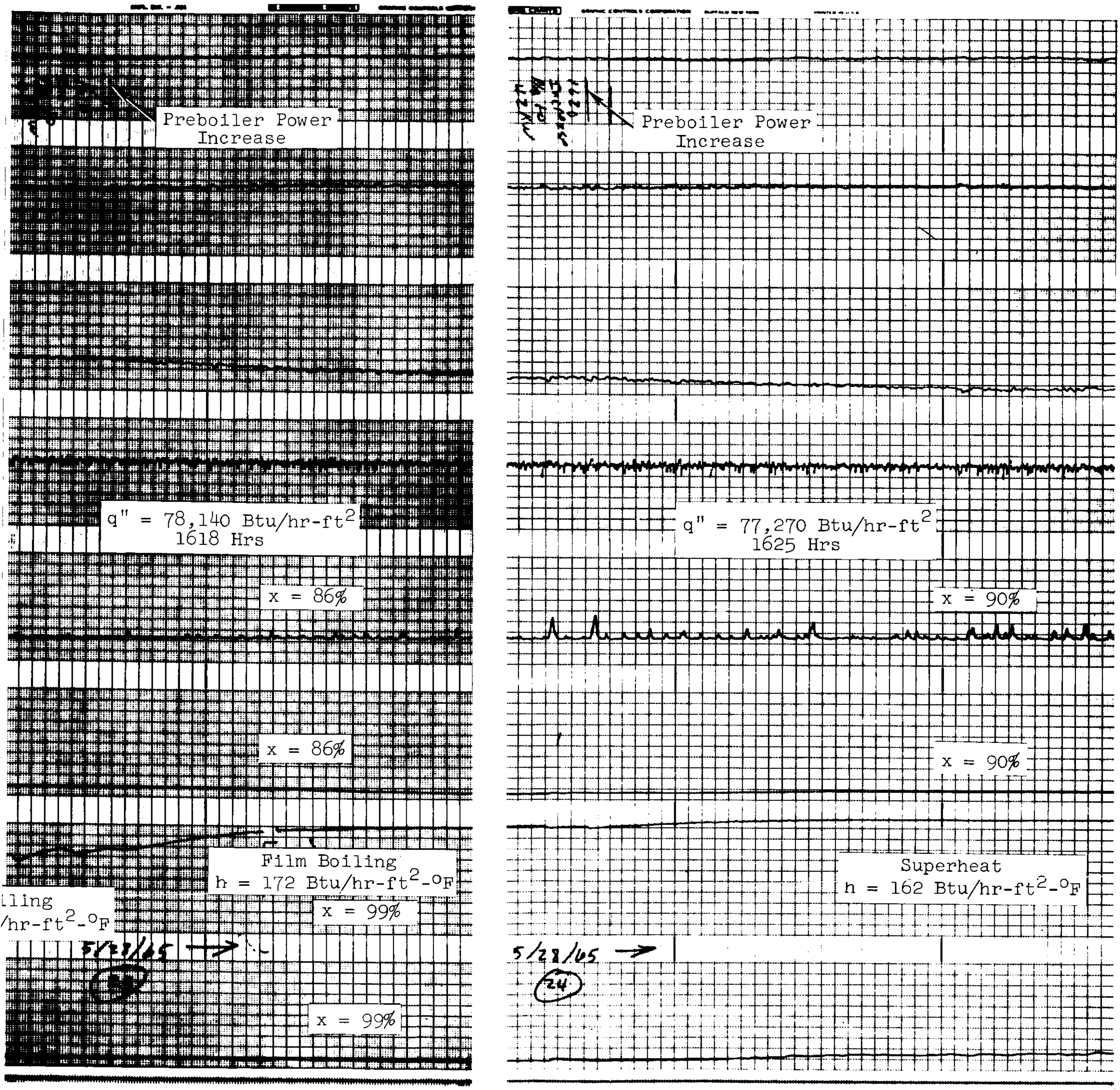
T_{sat} = 2100°F

Test Section #4

Chart Showing Onset Of Film Boiling At ,950 Btu/hr-ft^2 - 100 KW Loop (5/28/65)

116 (2)

116 (3)



T_{sat} = 2100°F

Test Section #4

t Showing Onset Of Film Boiling And
apor Conditions - 100 KW Loop

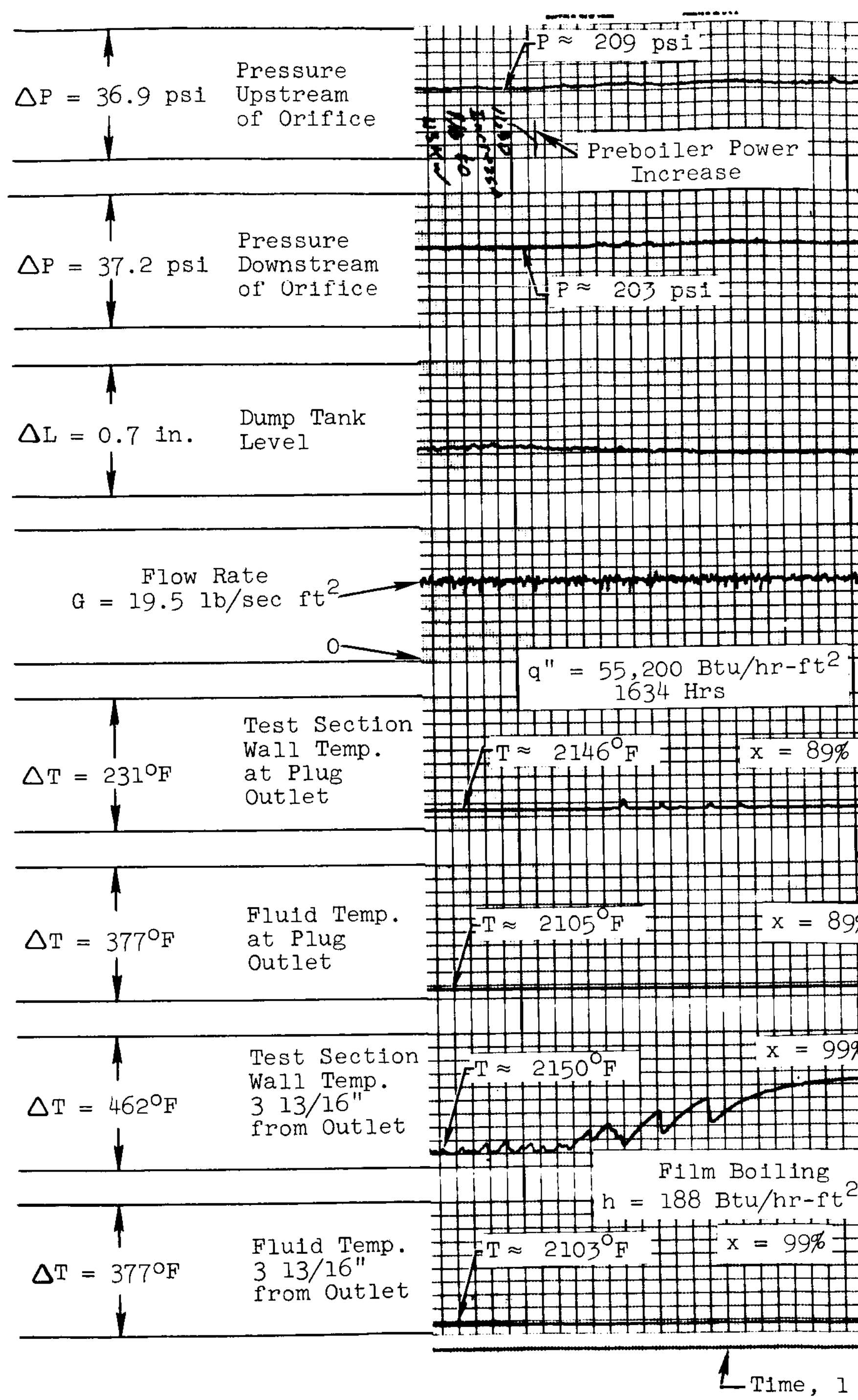


Figure 11a. R
S
B

(1)

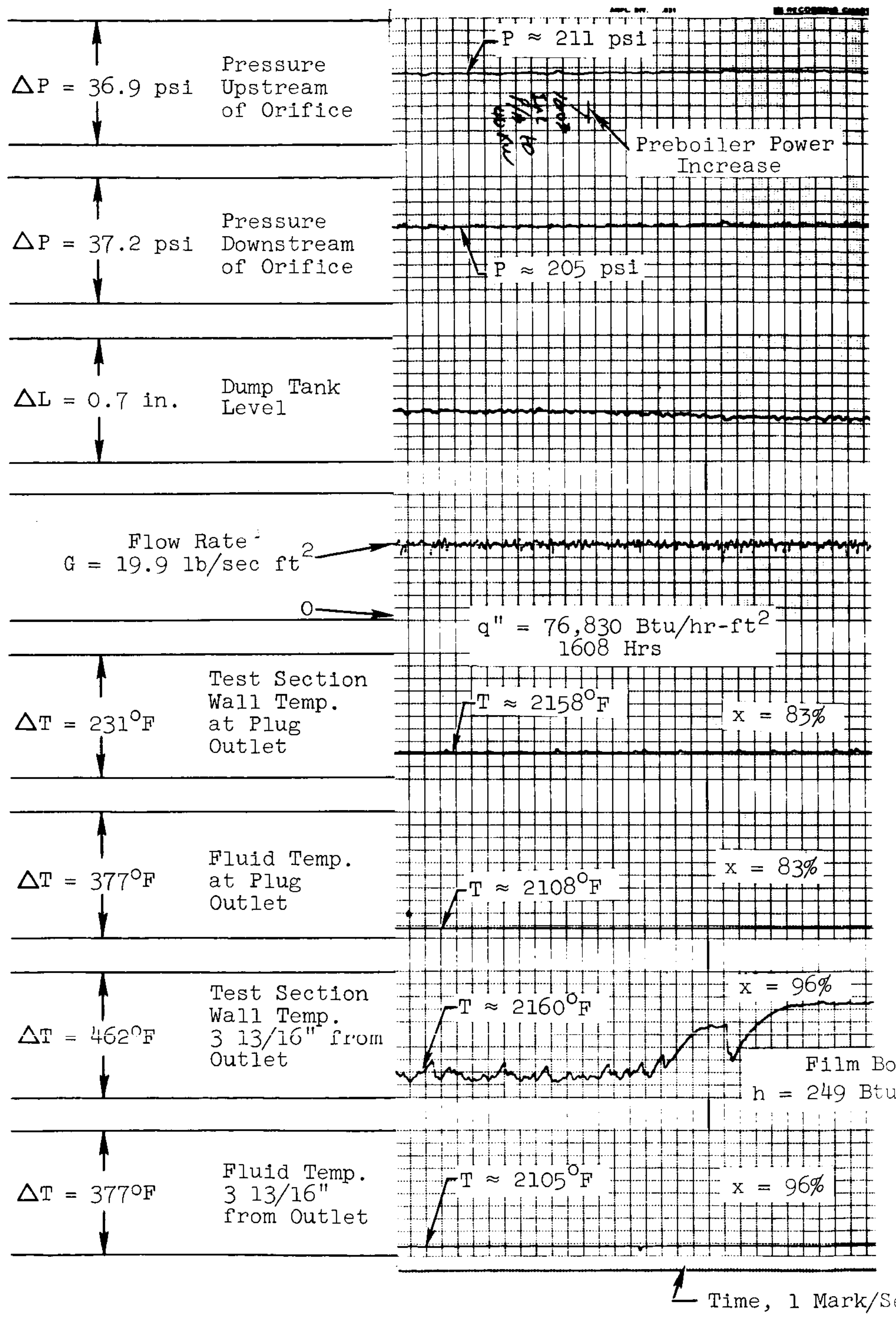
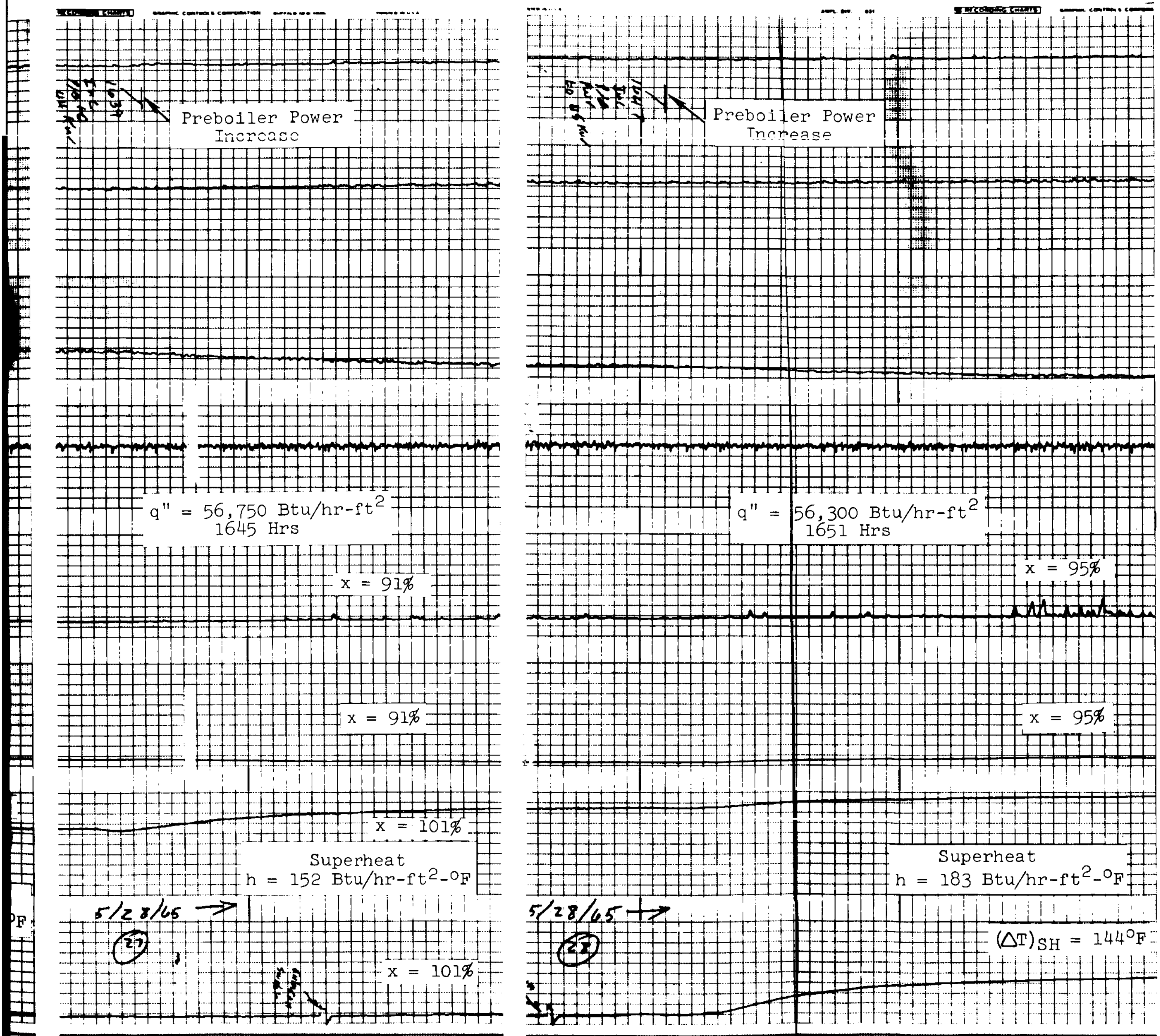


Figure 10. Recorder Cha
Superheated
(5/28/65)



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T_{sat} = 2100°F

Test Section #4

corder Chart Showing Onset of Film Boiling And perheated Vapor Conditions at q" = 56,000 u/hr-ft^2 - 100 KW Loop (5/28/65)

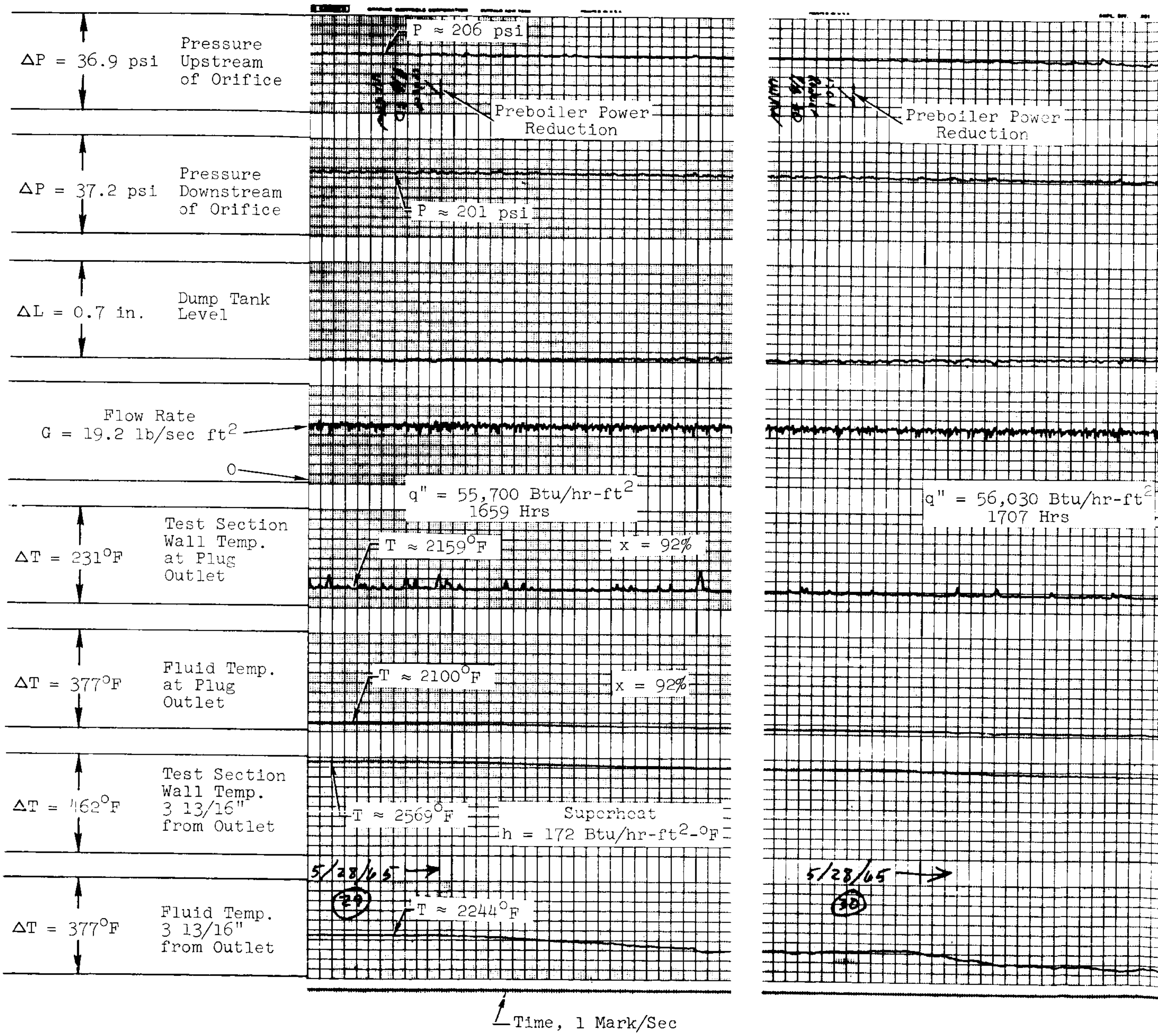
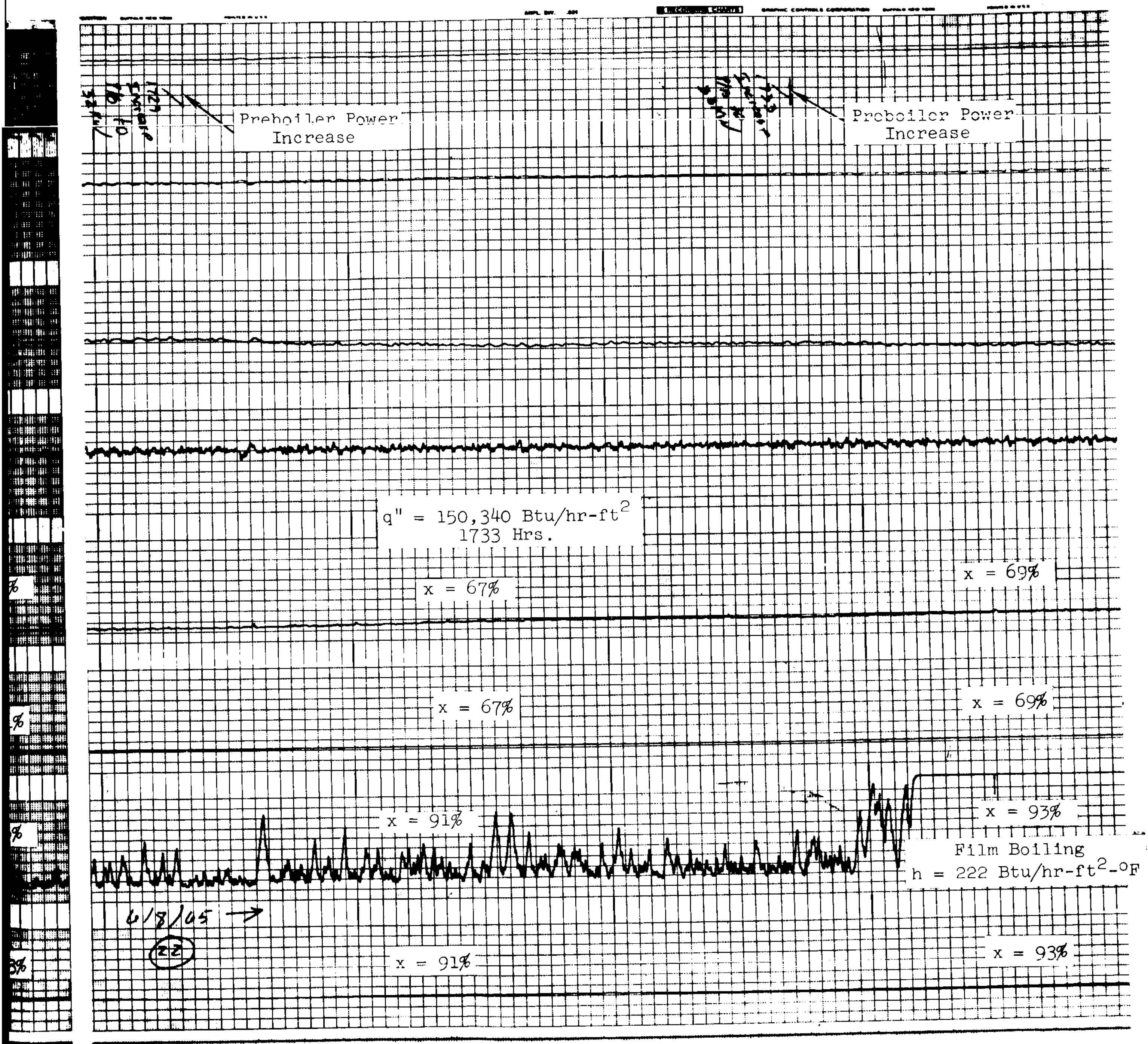


Figure 11b. Recorder Cha
heated Vapor
Btu/hr-ft2 -



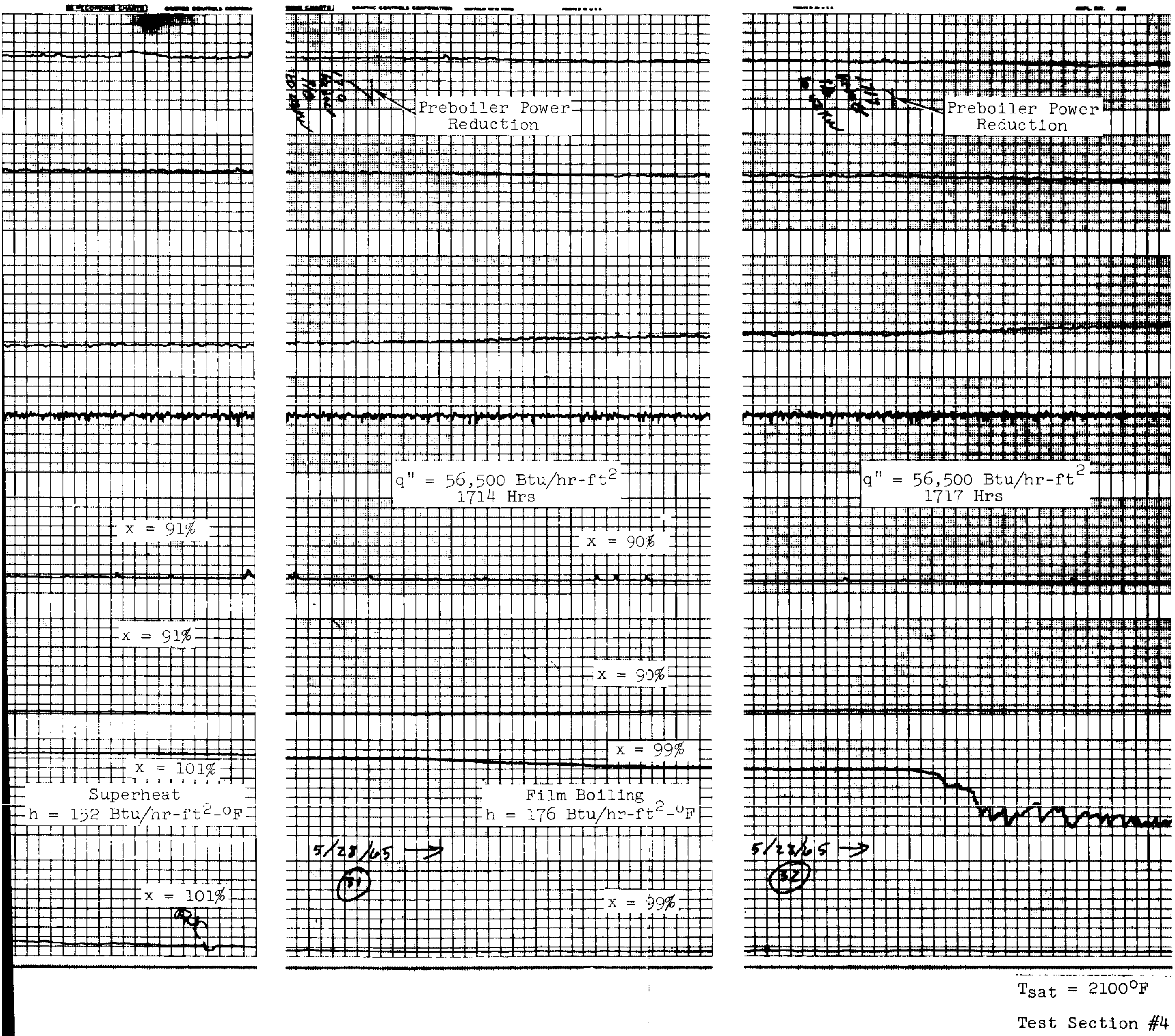
/Sec

T_{sat} = 1825°F

Test Section #4

Chart Showing The Onset Of Film Boiling -
op (6/8/65)

120 (1)



rt Showing Film Boiling And Super-
Conditions at $q'' = 56,000$.
100 KW Loop (5/28/65)

2

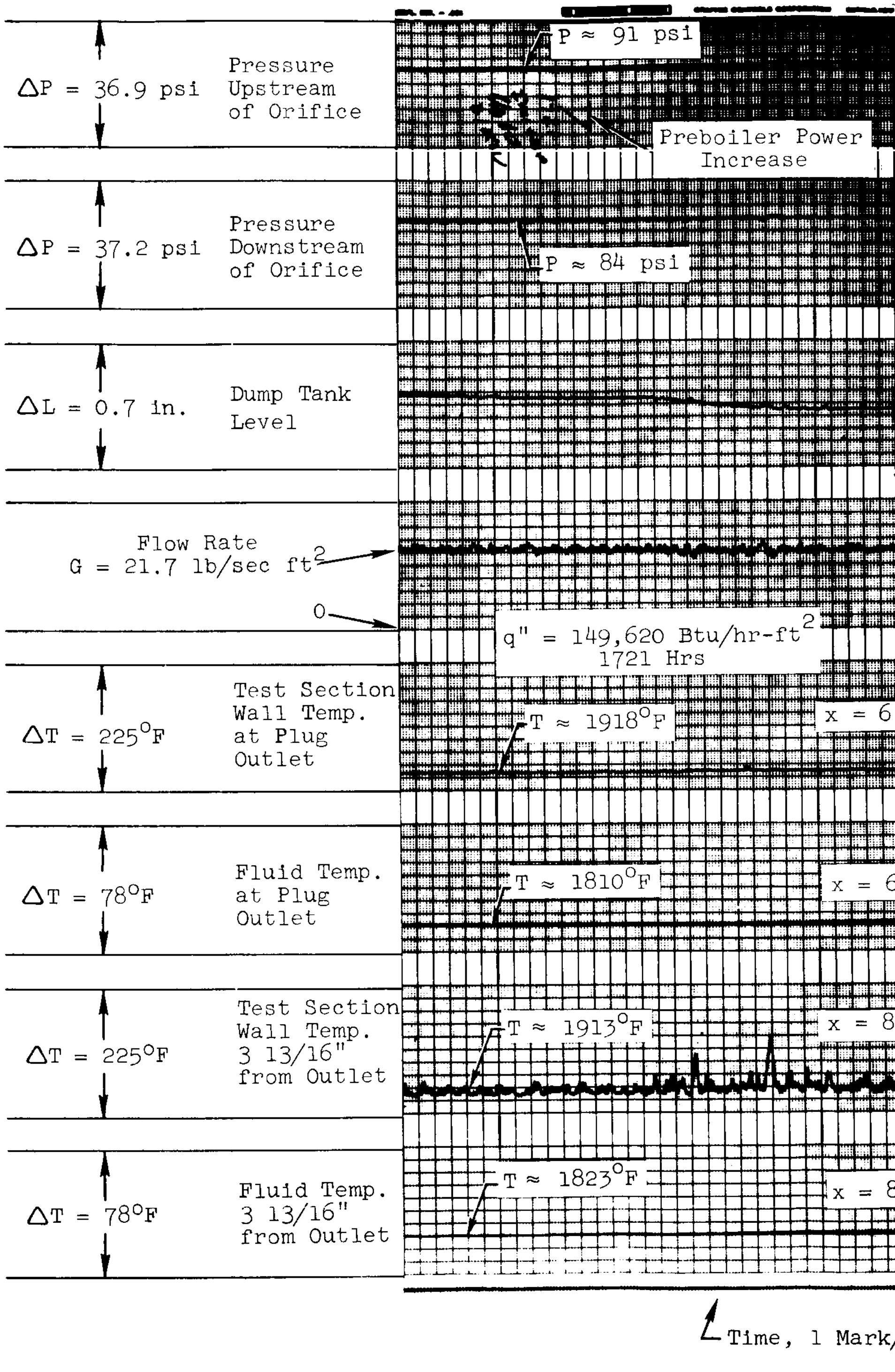
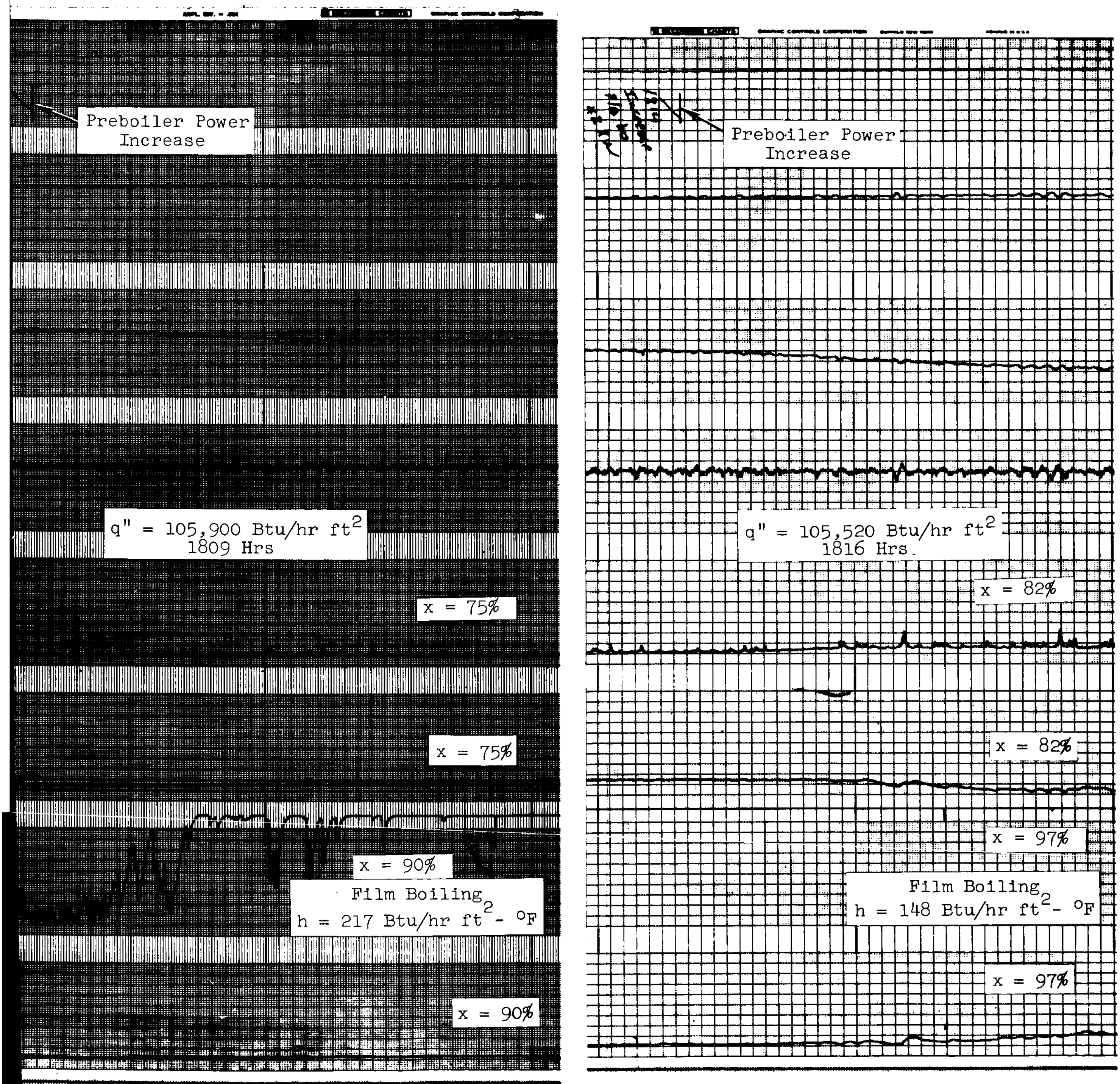


Figure 12. Recorder
100 KW Lo



art Showing The Onset Of Film Boiling -
ated Vapor Conditions - 100 KW Loop

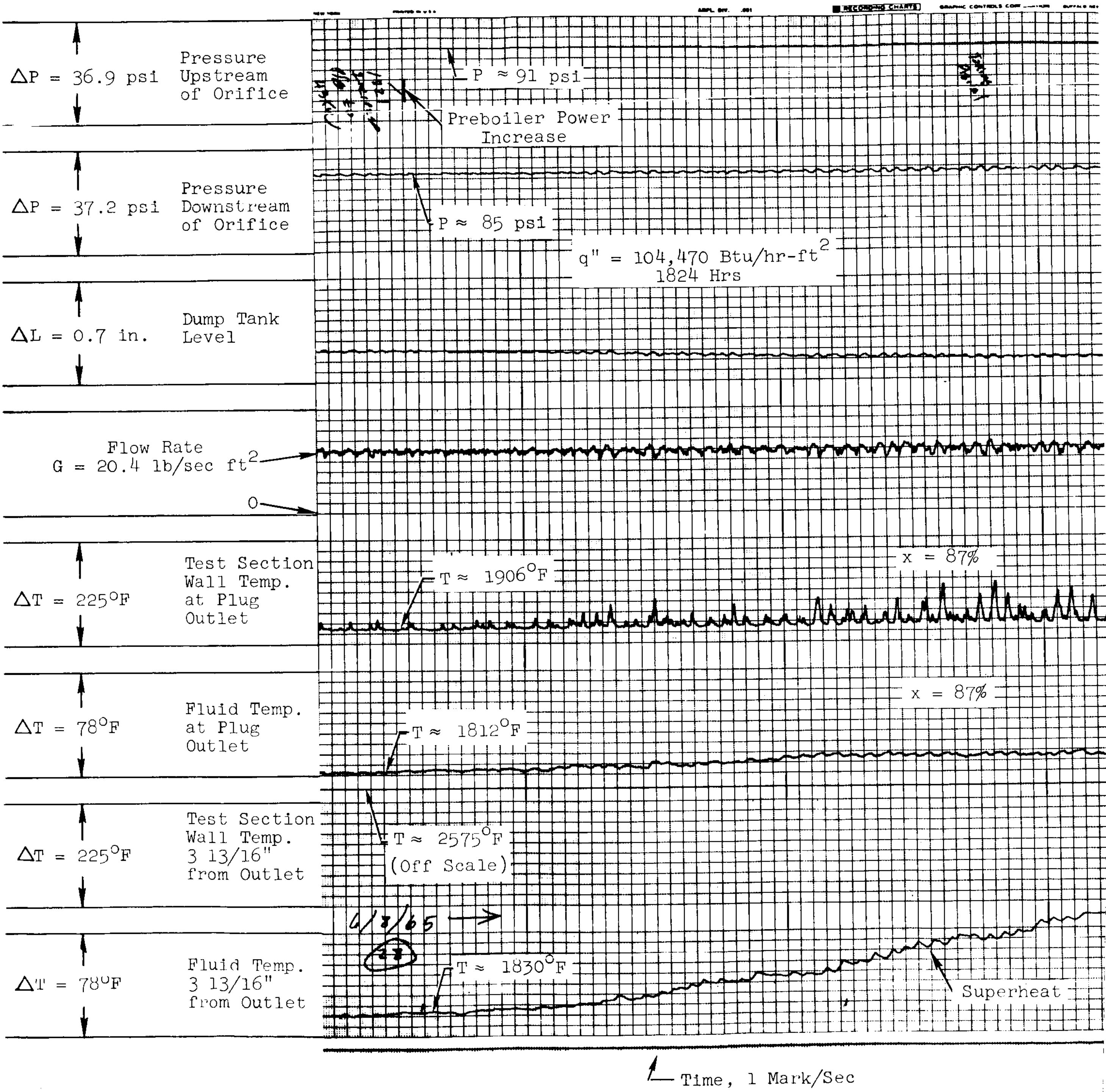


Figure 13b. Recorder Chart S
Boiling Conditio

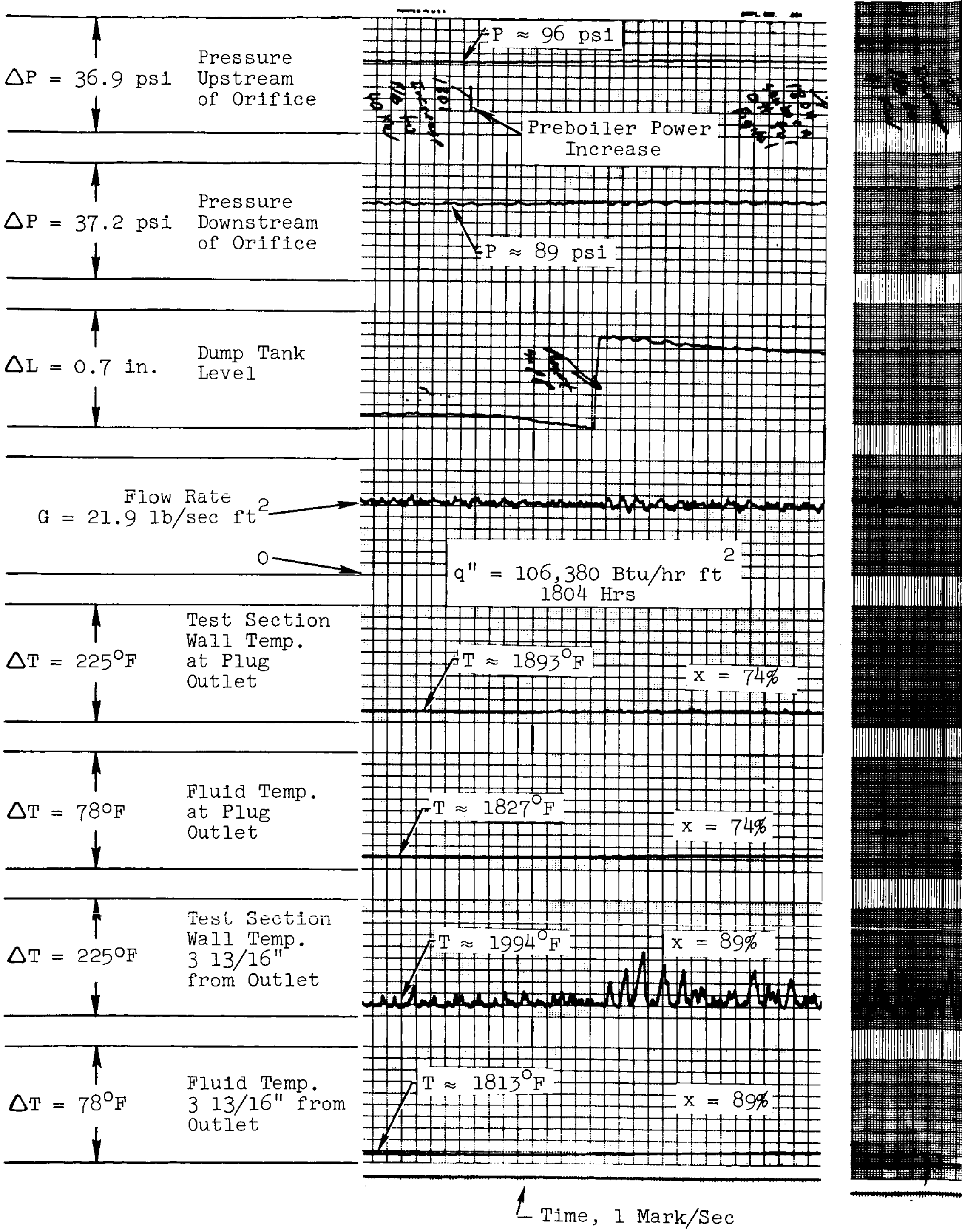
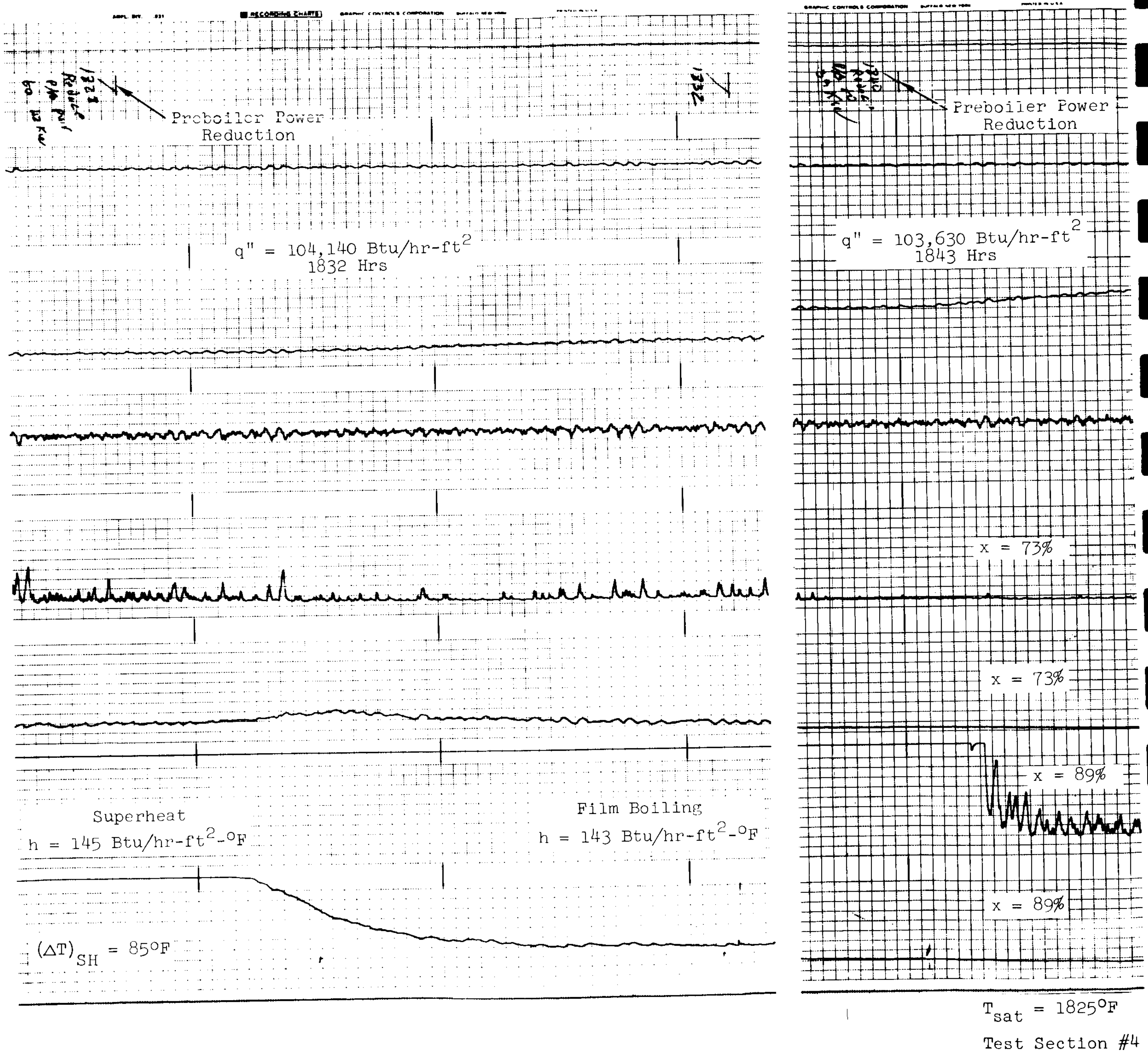
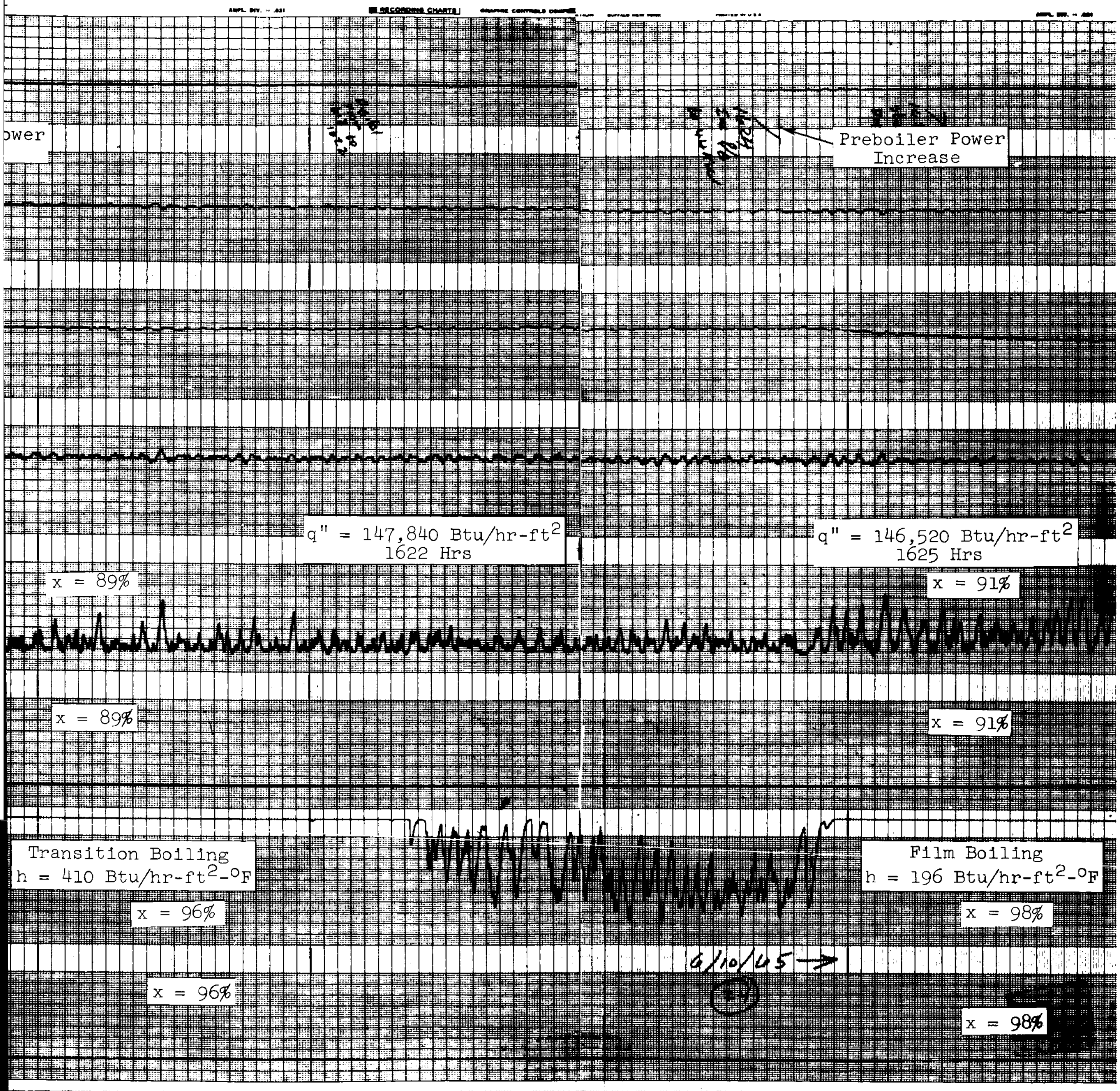


Figure 13a. Recorder Ch
And Superhe
(6/8/65)



howing Superheated Vapor And Film
ns - 100 KW Loop (6/8/65)

122 (2)   122 (3)



$T_{sat} = 1800^{\circ}F$

Test Section #4

owing The Onset Of Film Boiling -
/65)

(2)

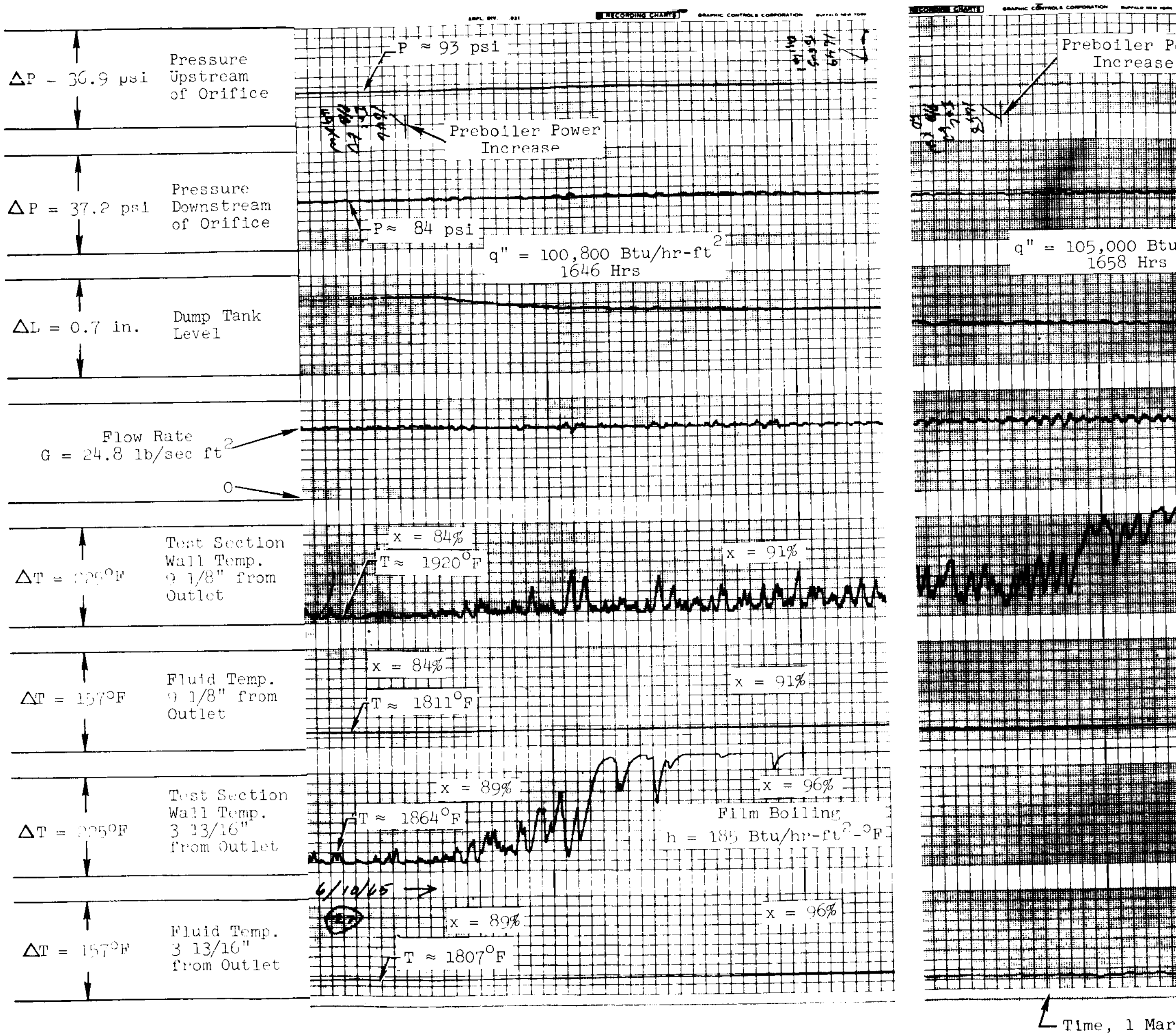


Figure 15. Recorder Chart
Superheated Vap
(6/10/65)

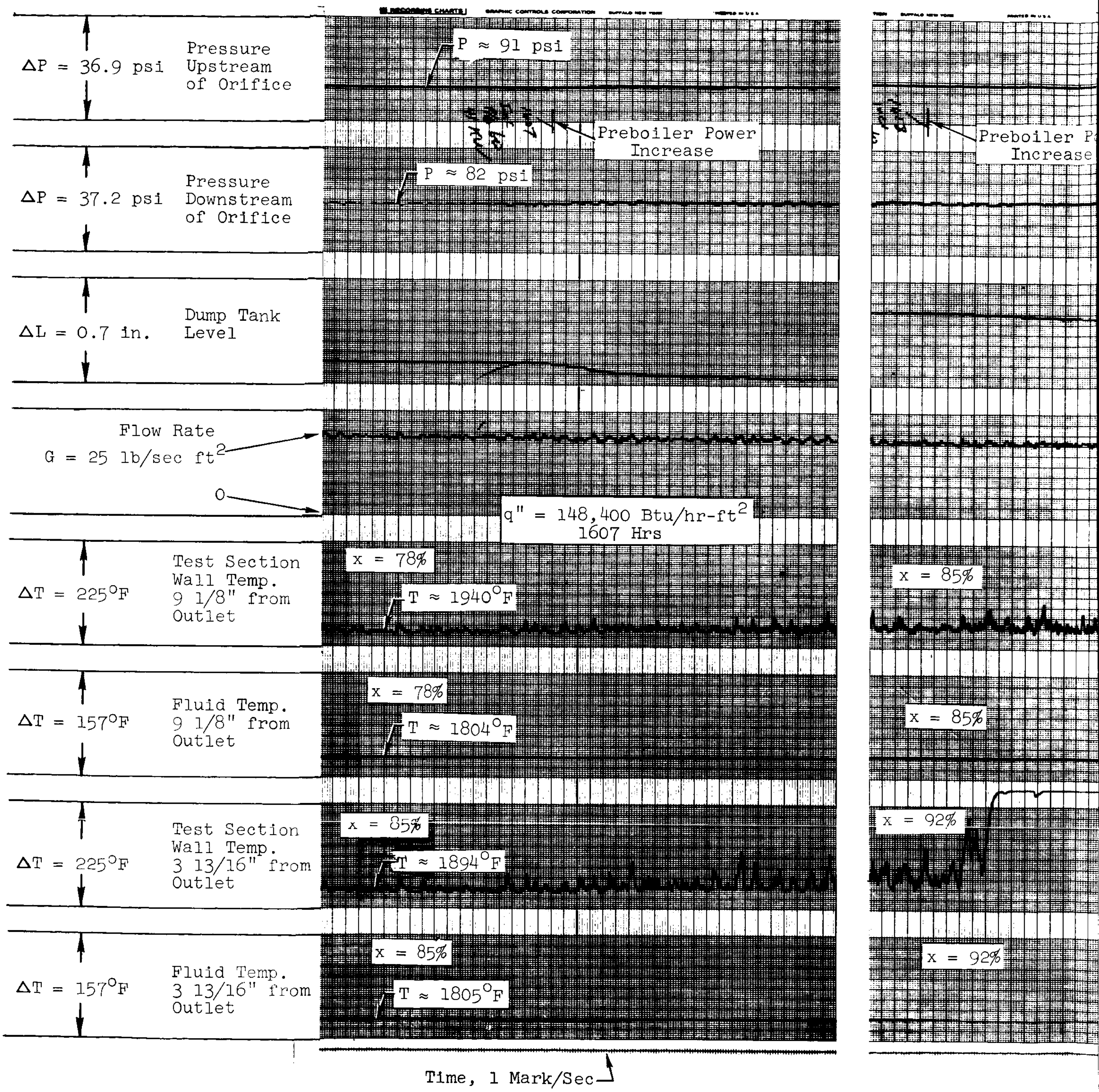
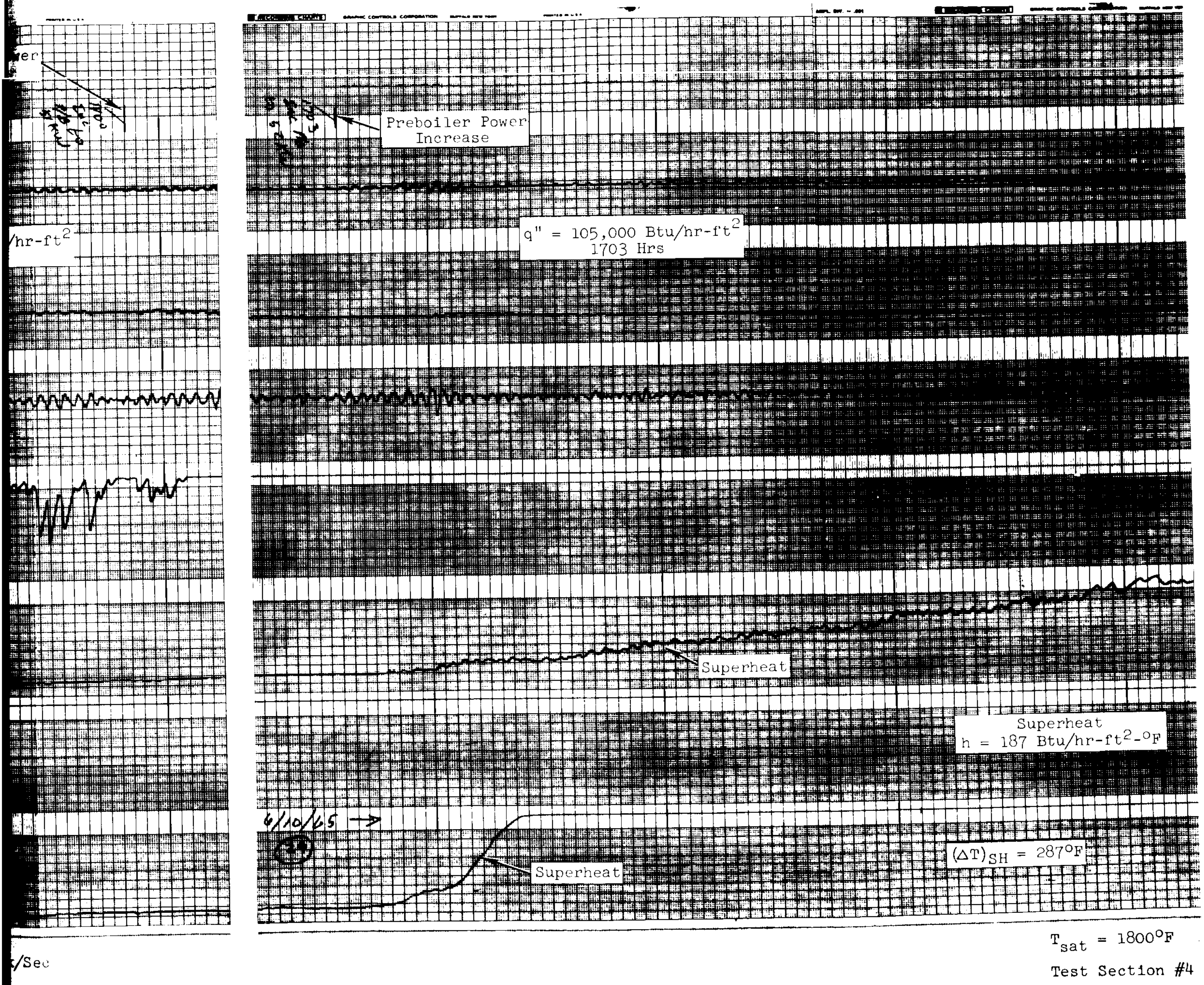


Figure 14. Recorder Chart Sho
100 KW Loop (6/10/

123



Showing Onset Of Film Boiling And
or Conditions - 100 KW Loop

124 ②

124 ③

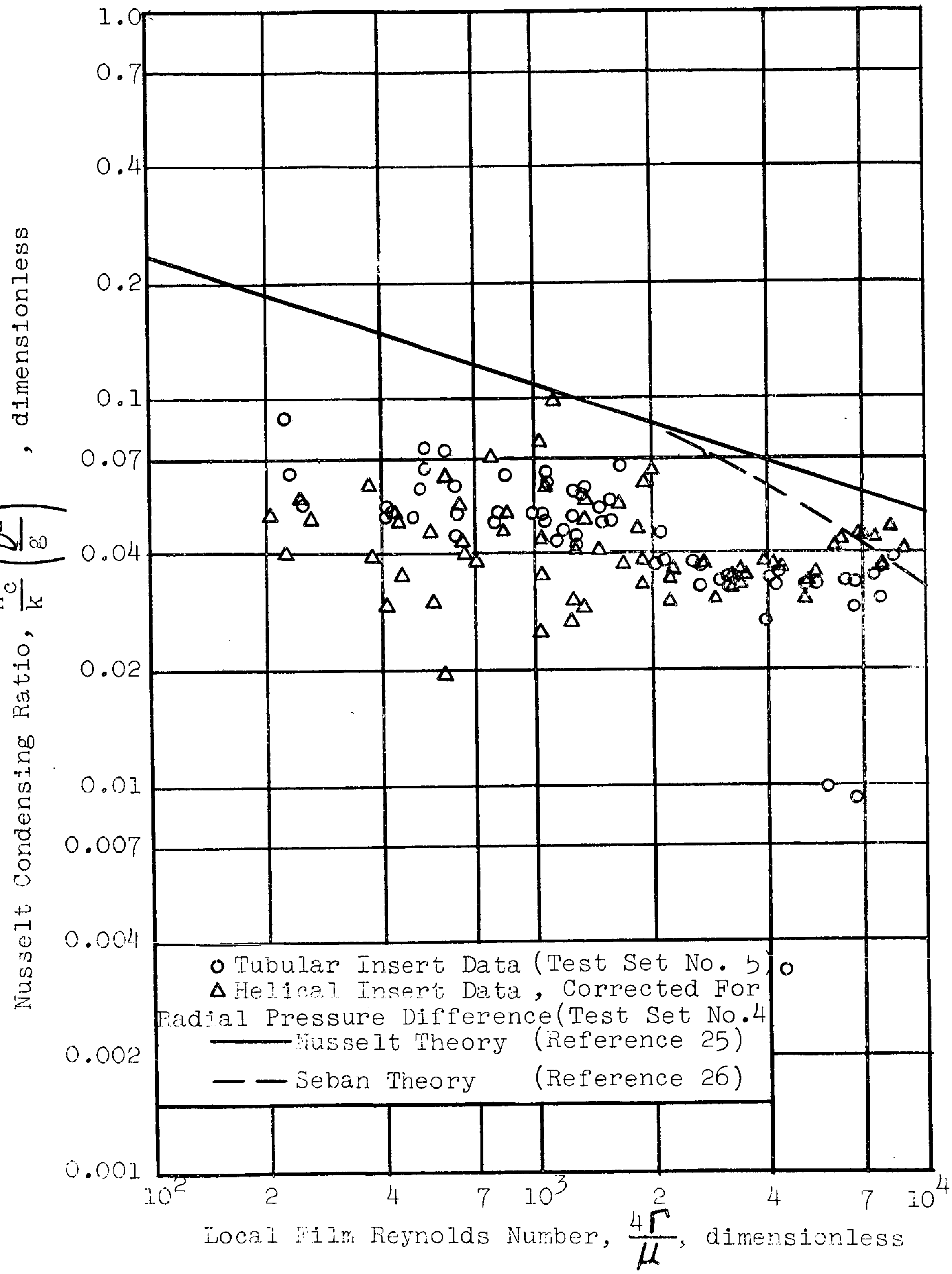


Figure 16. Comparison of Condensing Heat Transfer Coefficient Data From 50 KW Facility With Theory

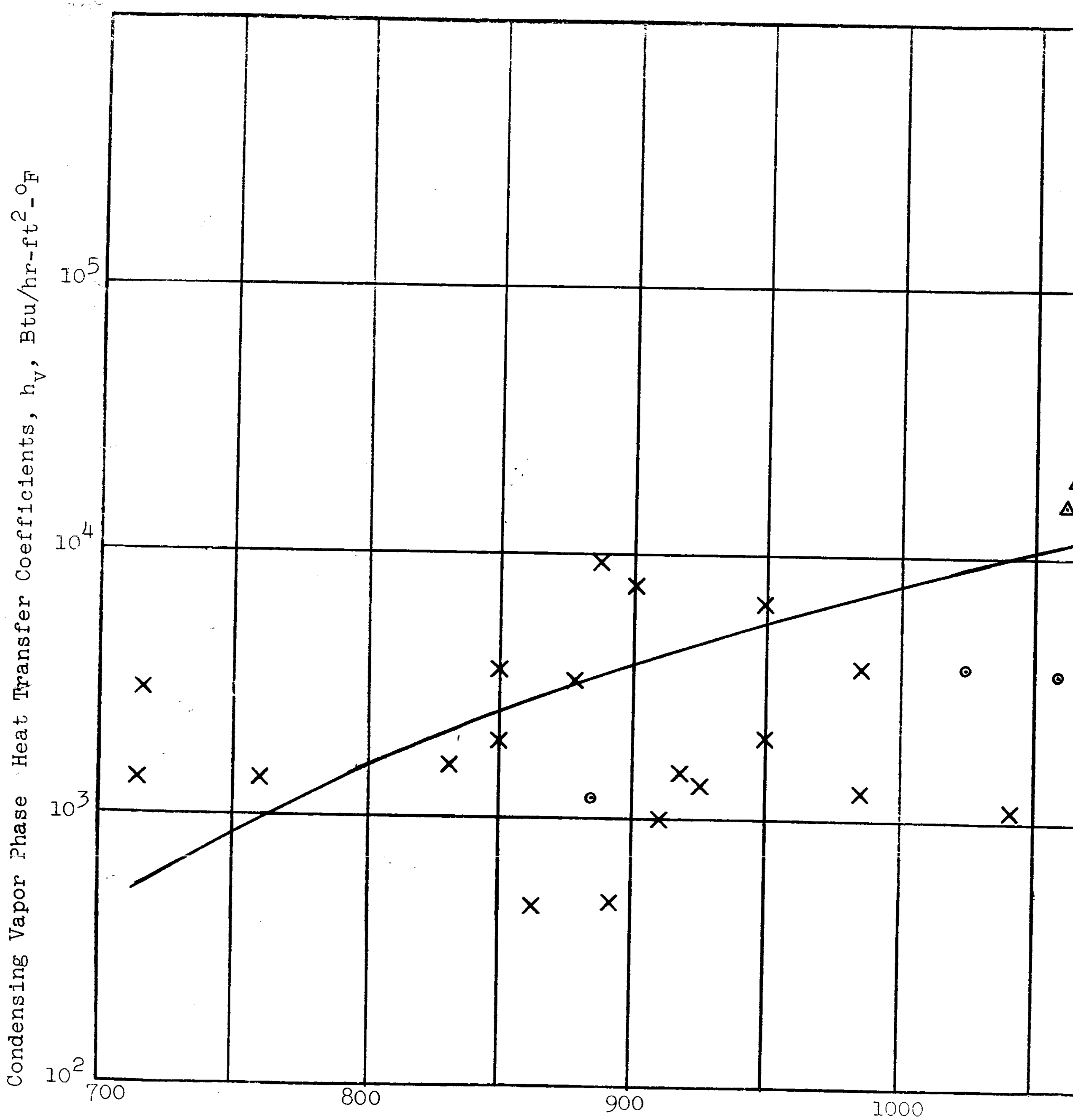
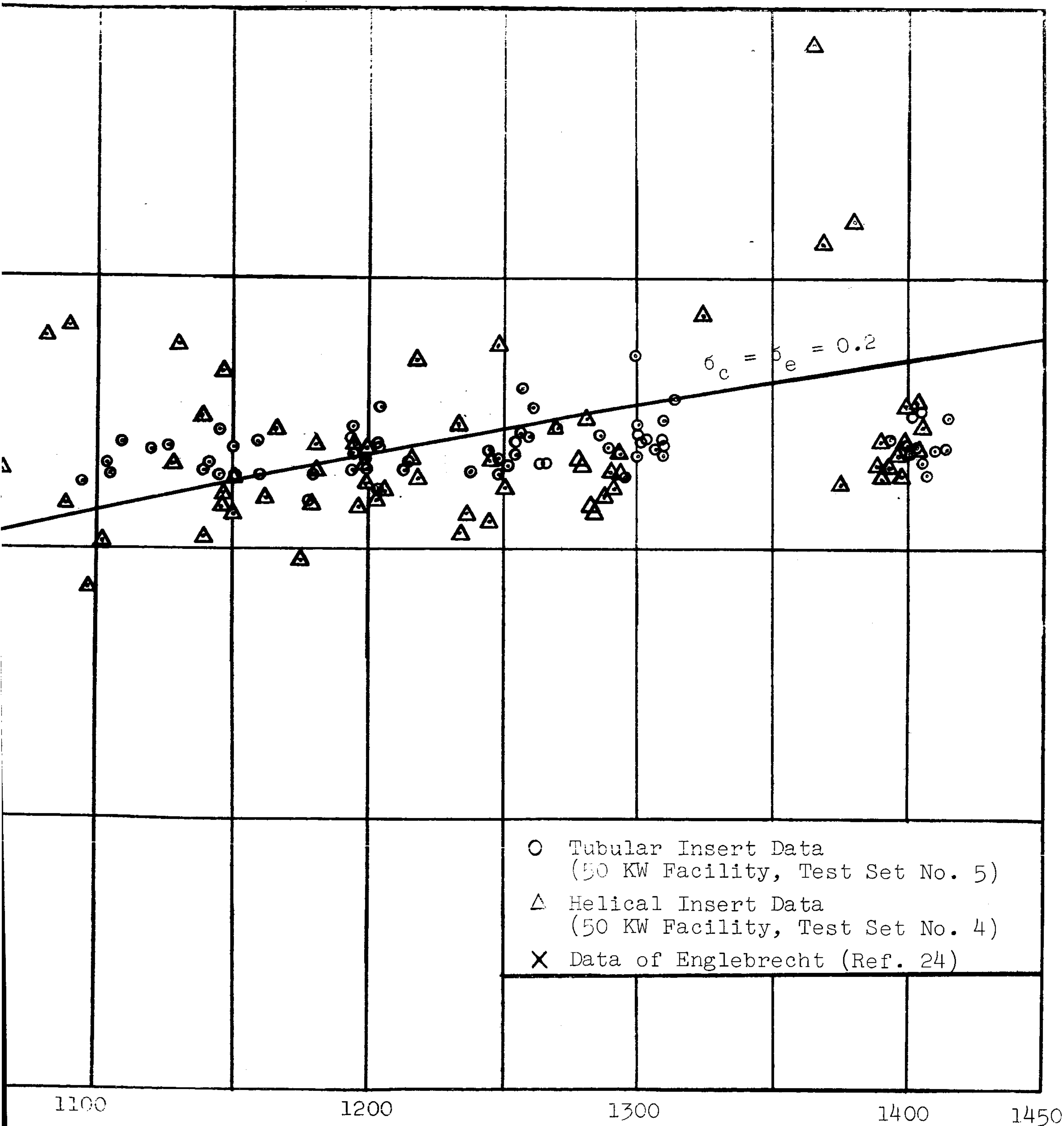


Figure 17 . Comparison of Potassi
Based On Kinetic Theo

127



um Condensing Heat Transfer Coefficient Data With Correlation
ry and An Assumed Condensation Coefficient $\sigma_c = 0.2$.

96

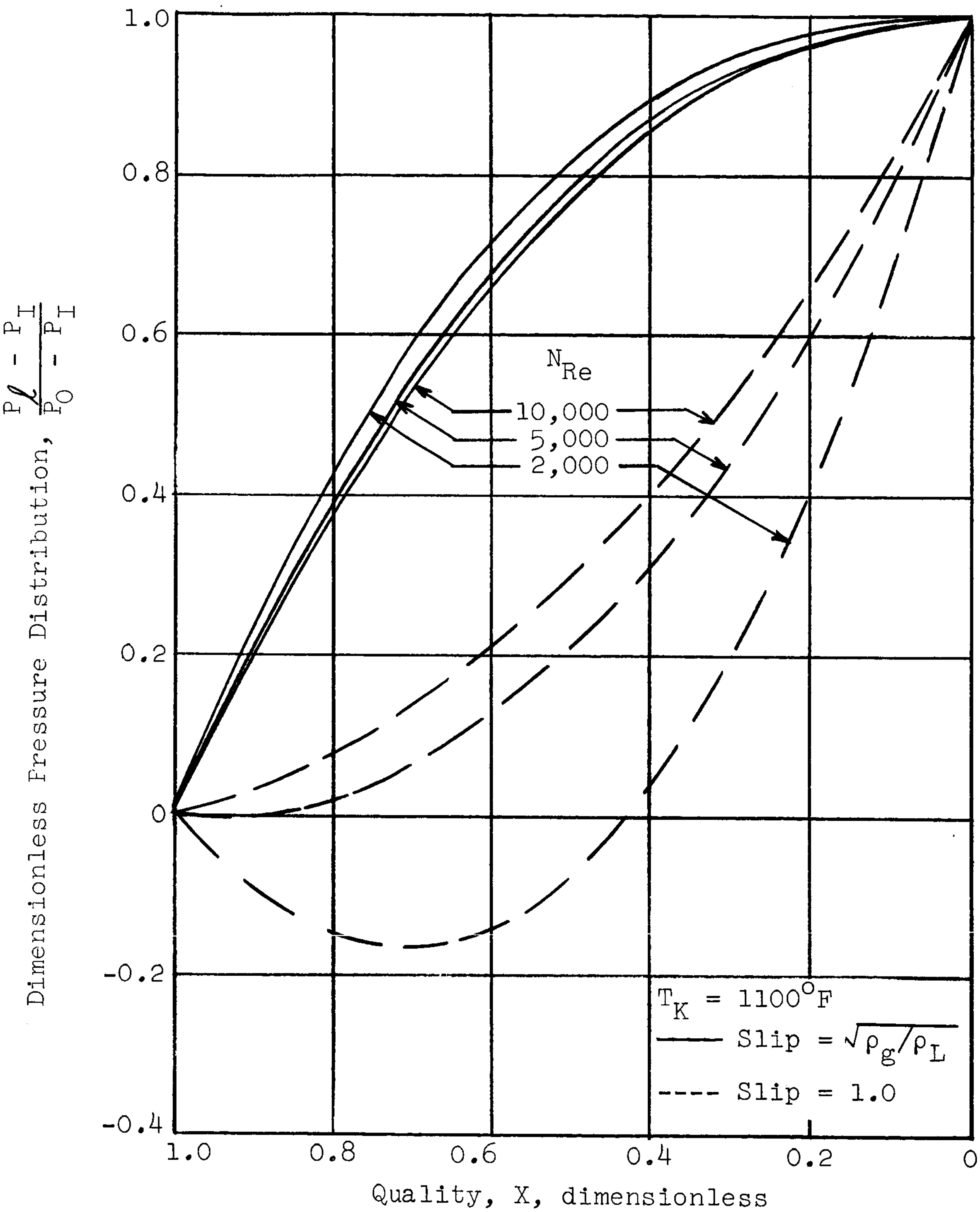


Figure 18a. Calculated Dimensionless Pressure Distribution Vs. Local Vapor Quality At 1100°F For Test Section No. 5, 50 KW Facility

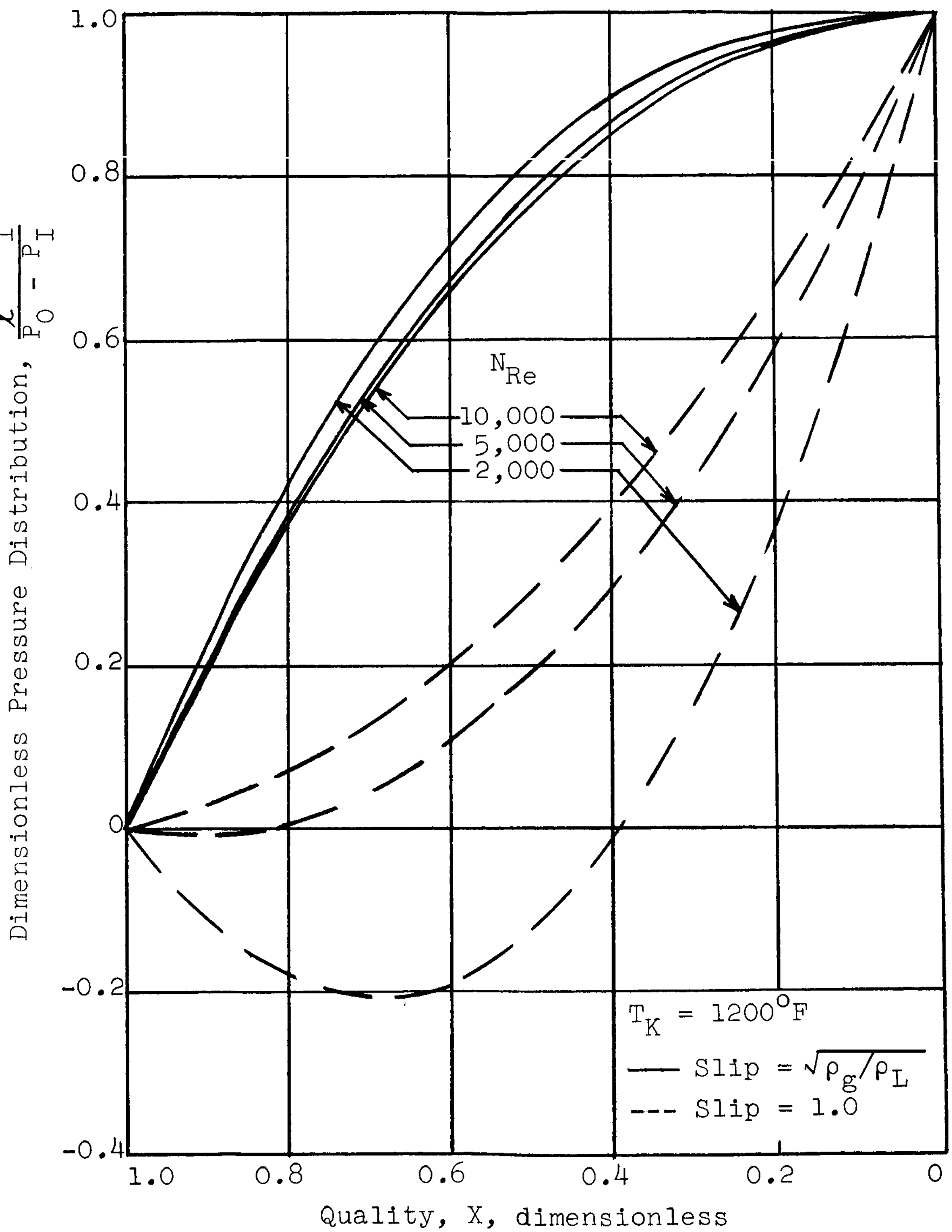


Figure 18b. Calculated Dimensionless Pressure Distribution vs. Local Vapor Quality at 1200°F For Test Section No. 5, 50 KW Facility

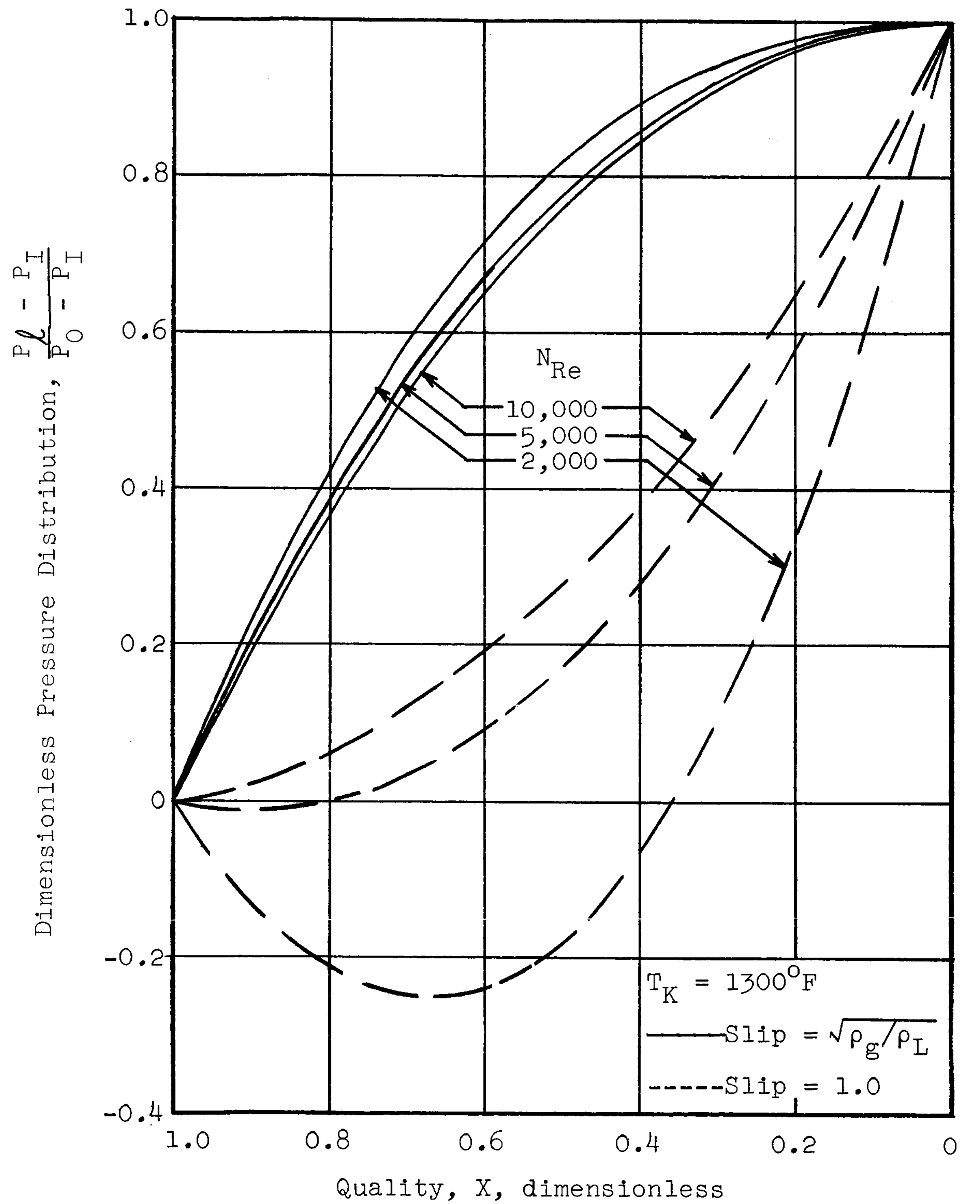


Figure 18c. Calculated Dimensionless Pressure Distribution vs. Local Vapor Quality at 1300°F For Test Section No. 5, 50 KW Facility

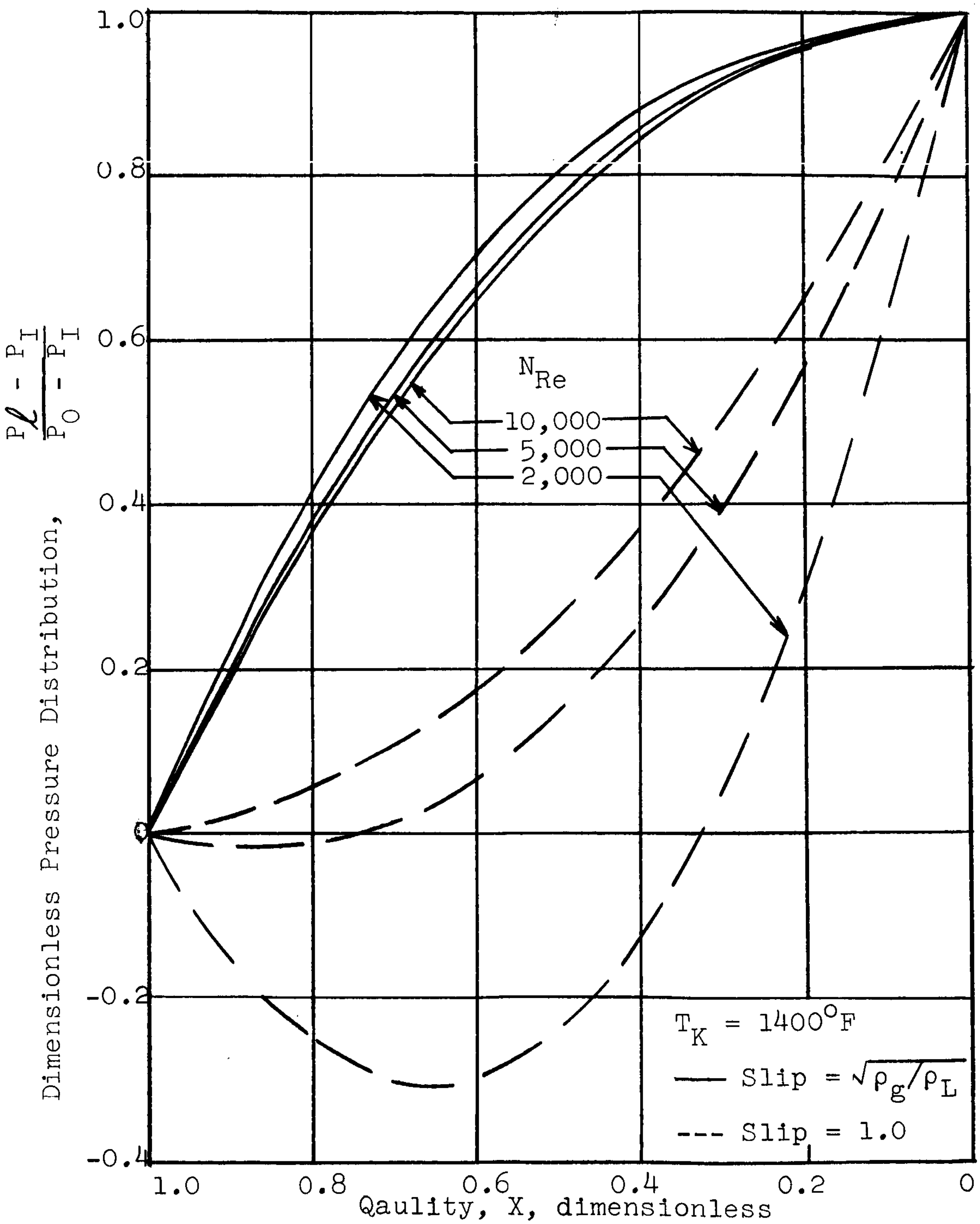


Figure 18d. Calculated Dimensionless Pressure Distribution vs. Local Vapor Quality at 1400°F For Test Section No. 5, 50 KW Facility

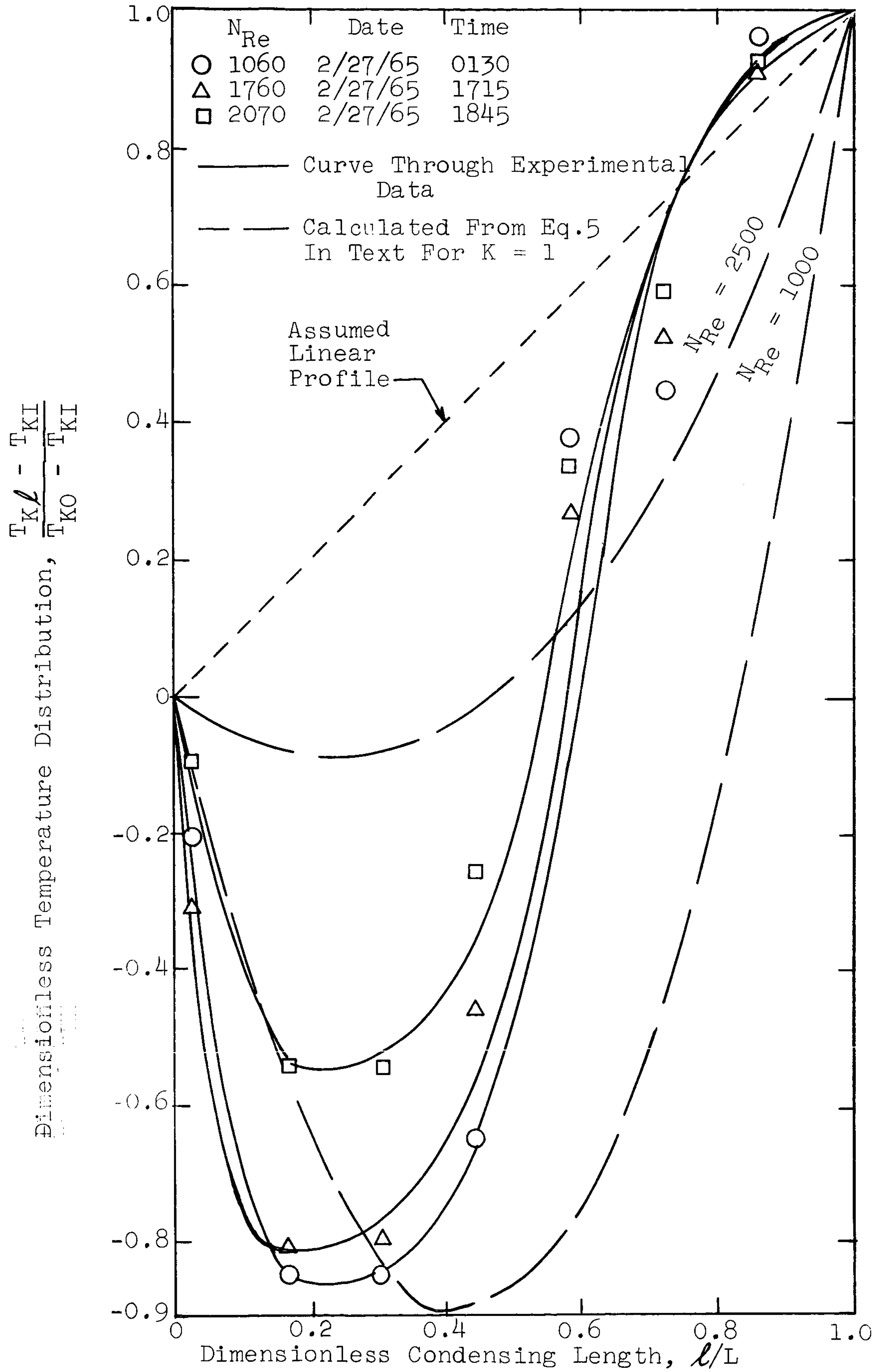


Figure 19a. Comparison of Calculated and Experimental Dimensionless Temperature Distributions At 1100°F Inlet Temperature For Test Section No. 5, 50 KW Facility

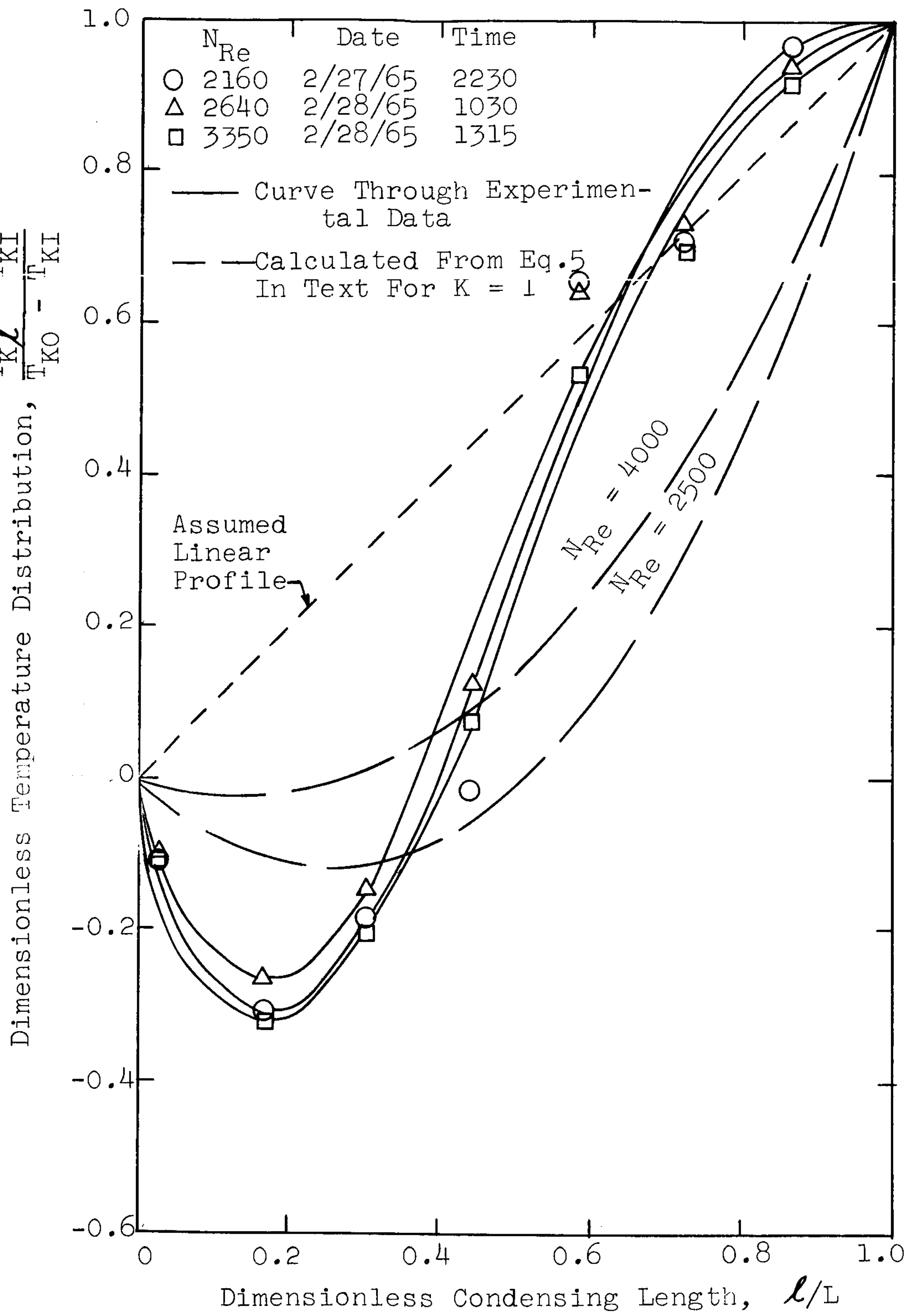


Figure 19b. Comparison of Calculated and Experimental Dimensionless Temperature Distributions At 1200°F Inlet Temperature For Test Section No. 5, 50 KW Facility

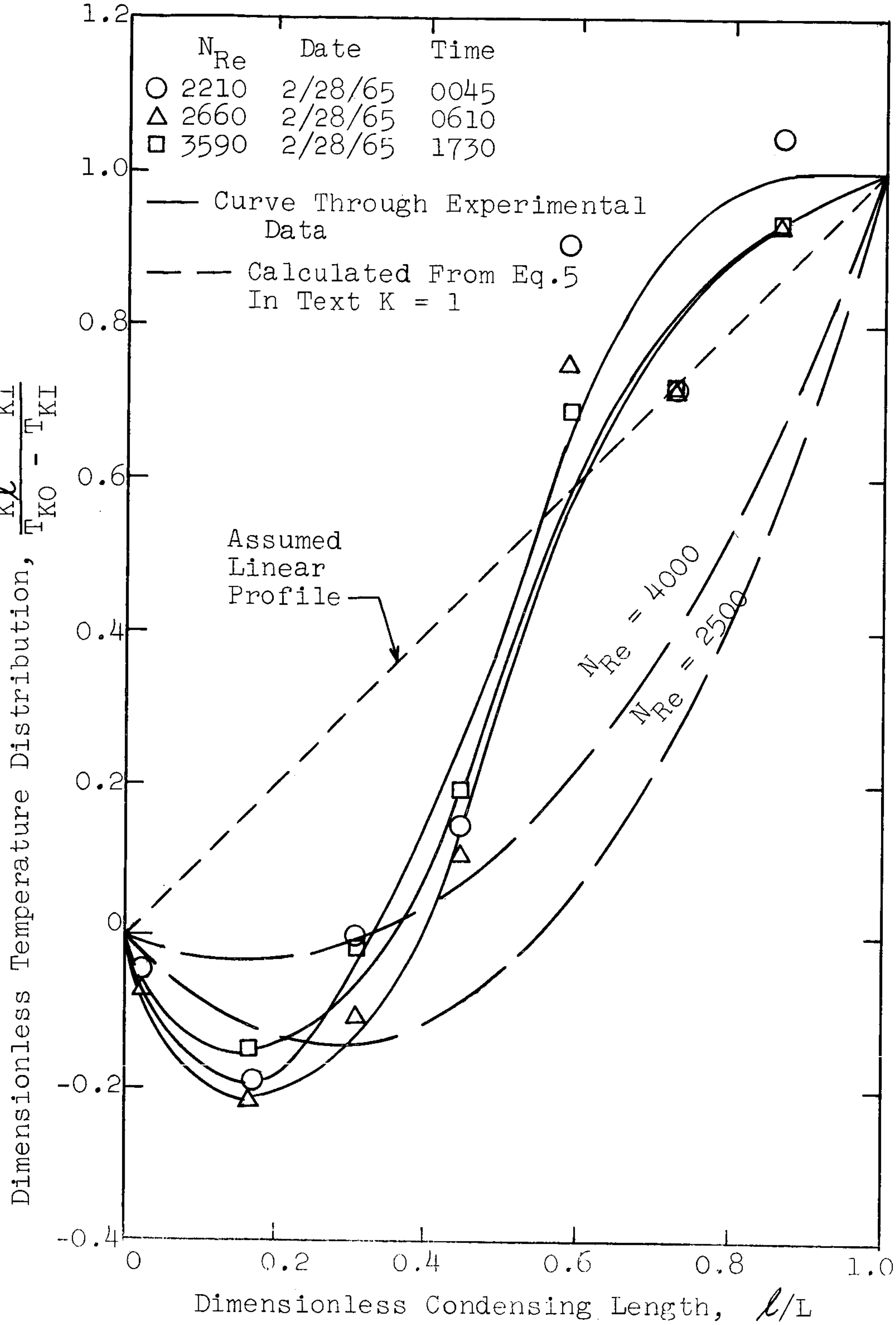


Figure 19c. Comparison of Calculated and Experimental Dimensionless Temperature Distributions At 1300°F Inlet Temperature For Test Section No. 5, 50 KW Facility

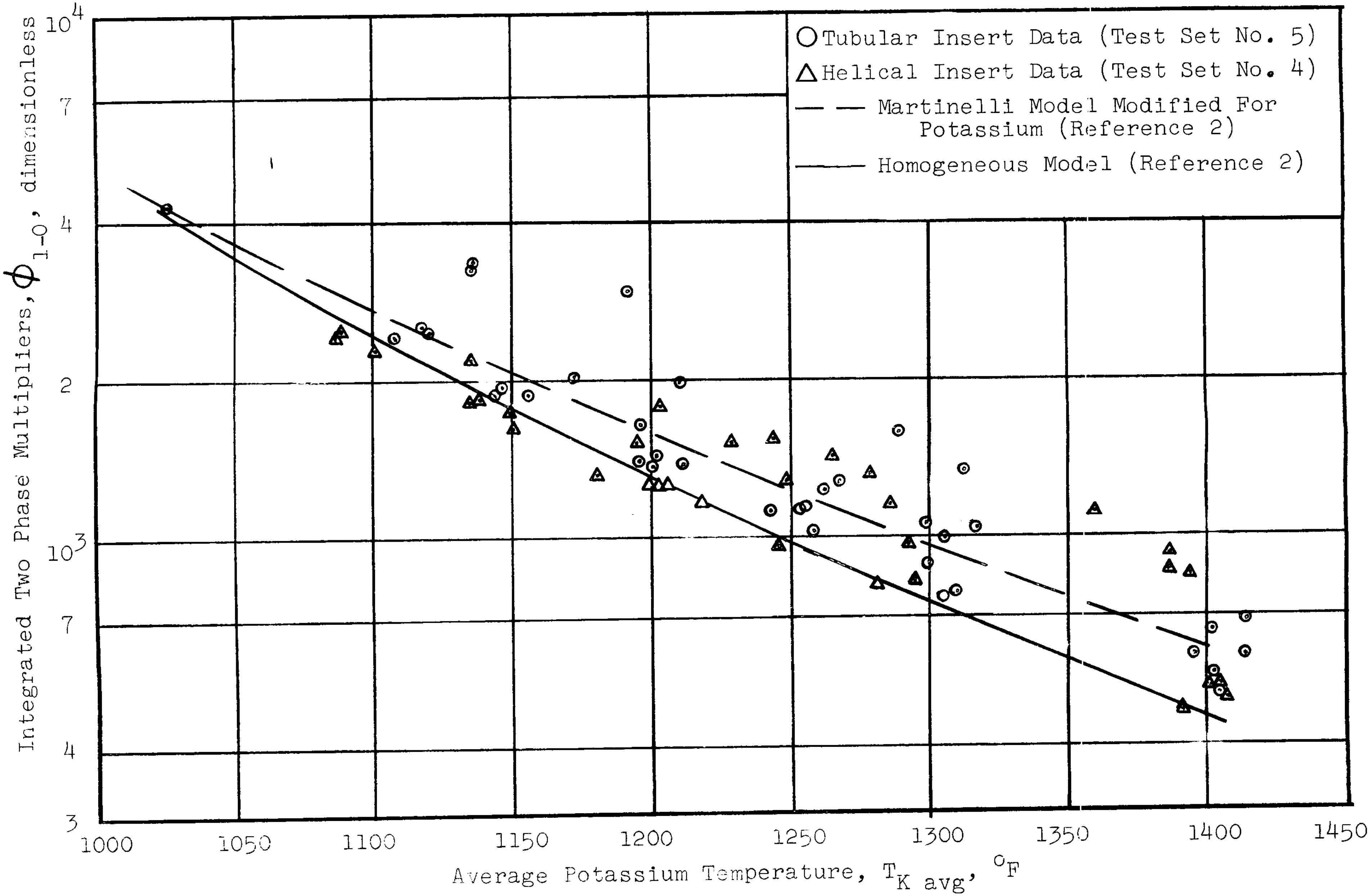


Figure 20. Integrated Two-Phase Friction Multipliers, 100% to 0% Quality, As Function of Temperature (Data From 50 KW Facility)

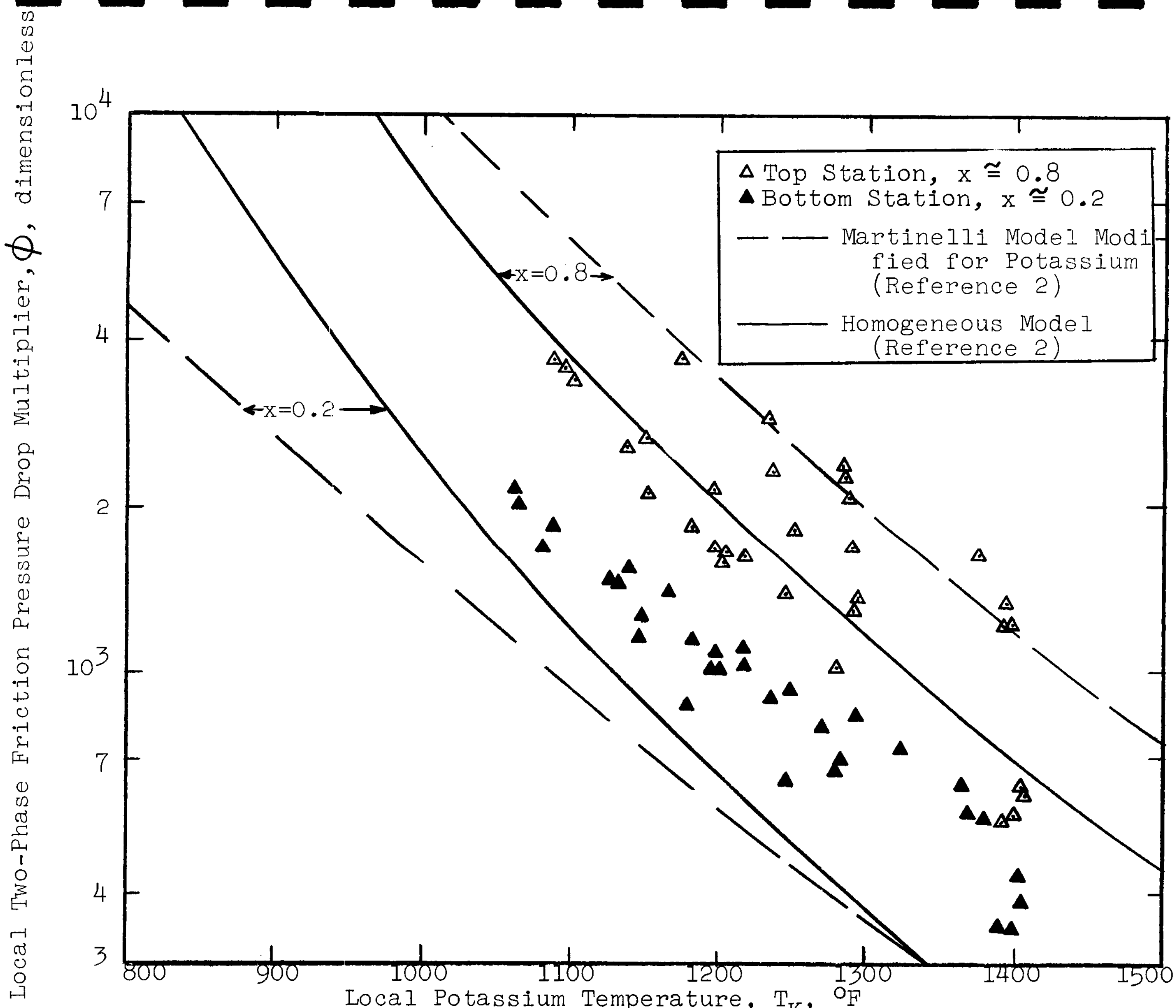


Figure 21a. Local Two-Phase Friction Multipliers As Function of Temperature, Helical Insert Data From Test Set No. 4, 50 KW Facility

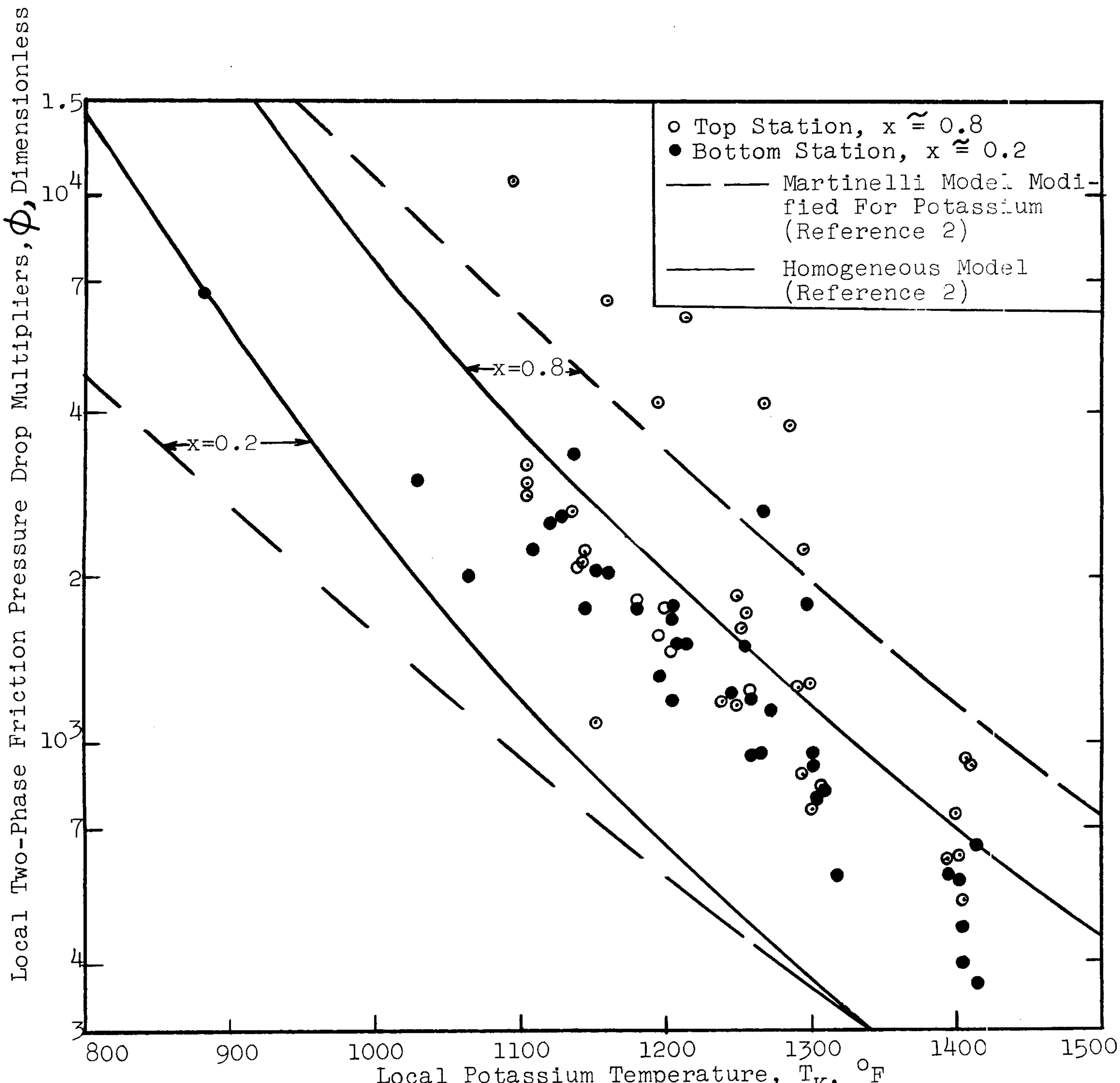


Figure 21b. Local Two-Phase Friction Multipliers As Function Of Temperature. Tubular Insert Data From Test Set No. 5, 50 KW Facility

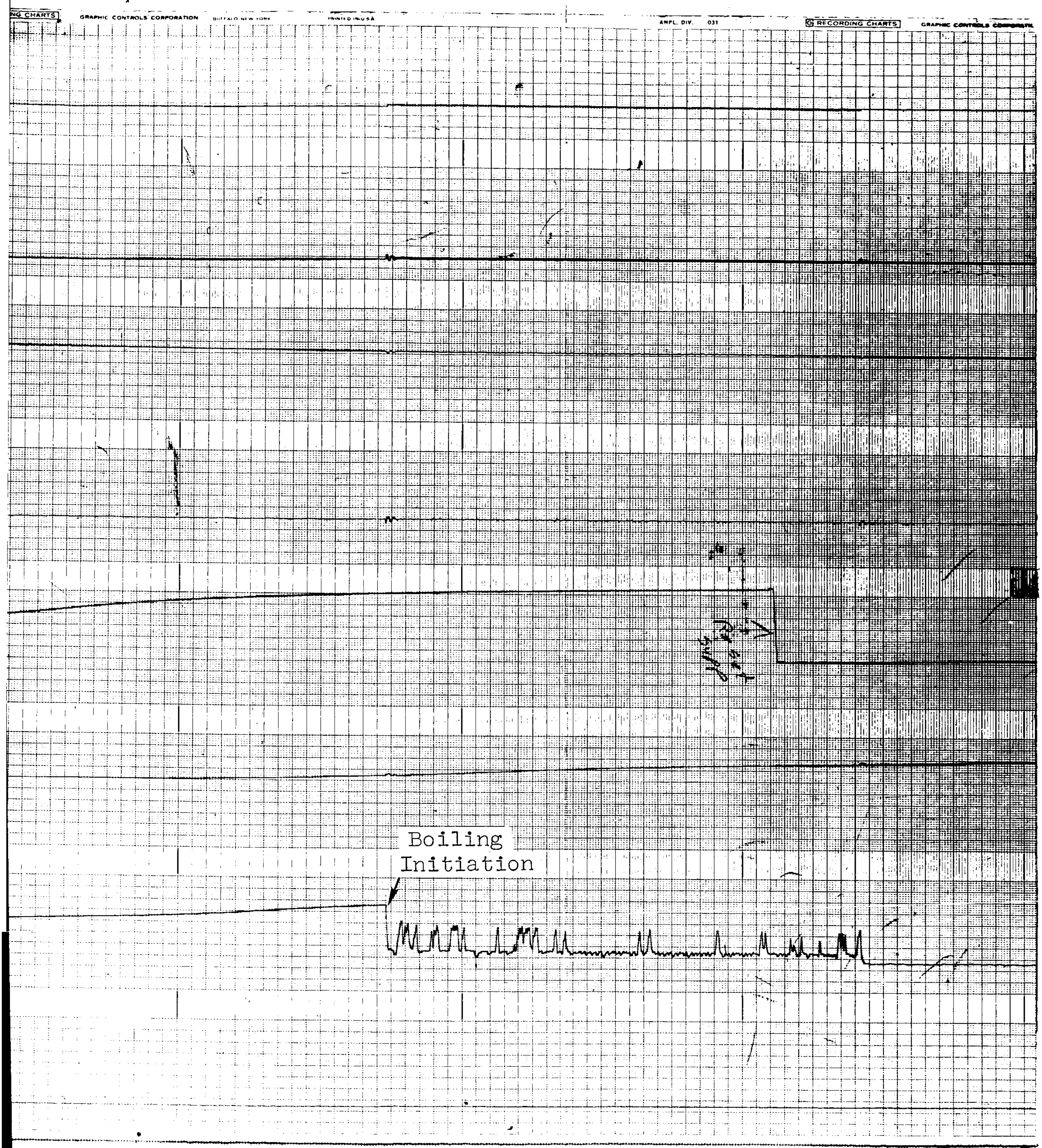


Chart Showing Boiling Inception at P = 201 psia.
acility, Test Section No. 3).

$G = 31\ \mathrm{lb/sec\text{-}ft^2}$

$q'' = 55{,}000\ \mathrm{Btu/hr\text{-}ft^2}$

$W = 0.03\ \mathrm{lb/sec}$

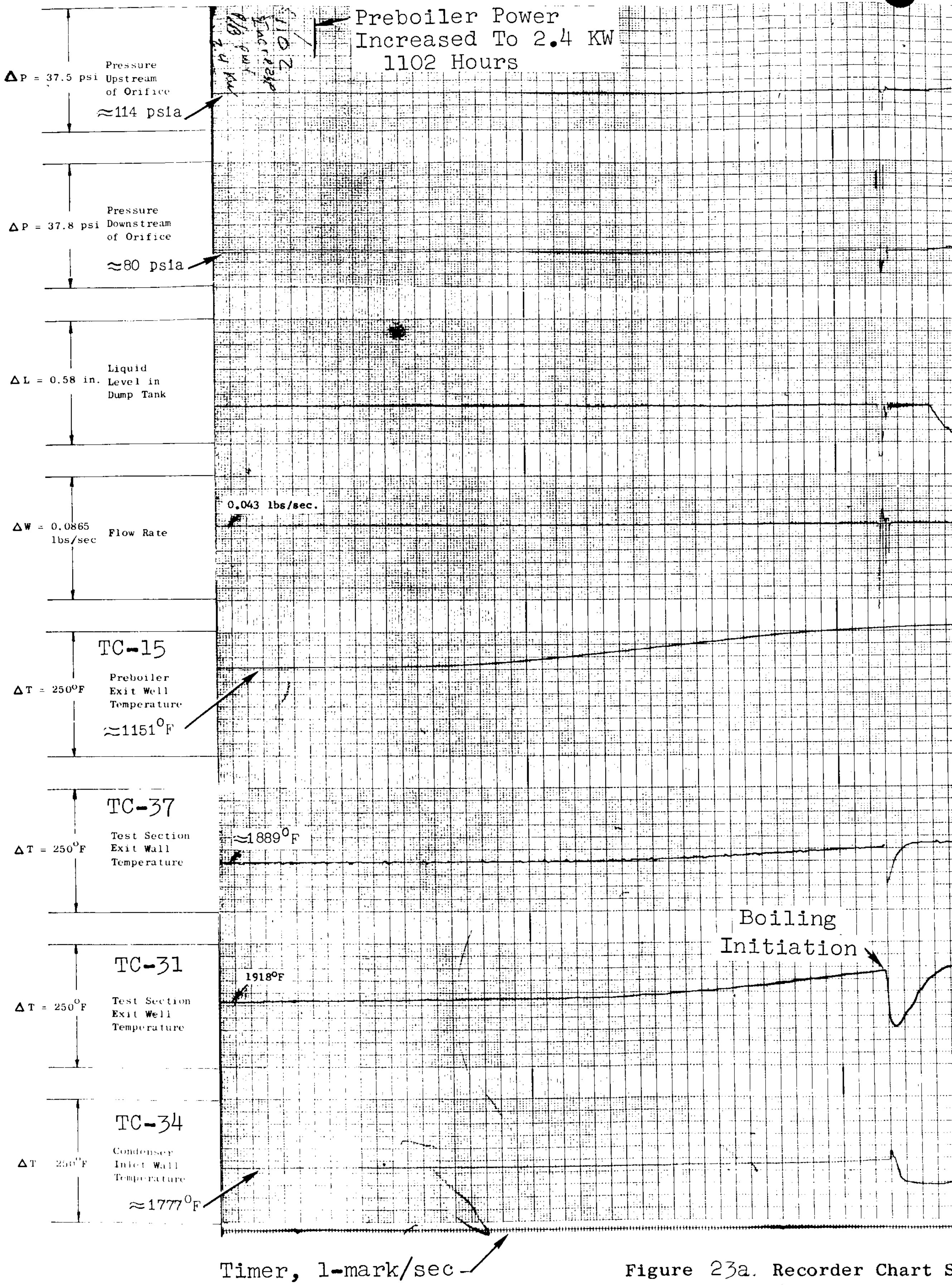


Figure 23a. Recorder Chart S
(100 KW Facility

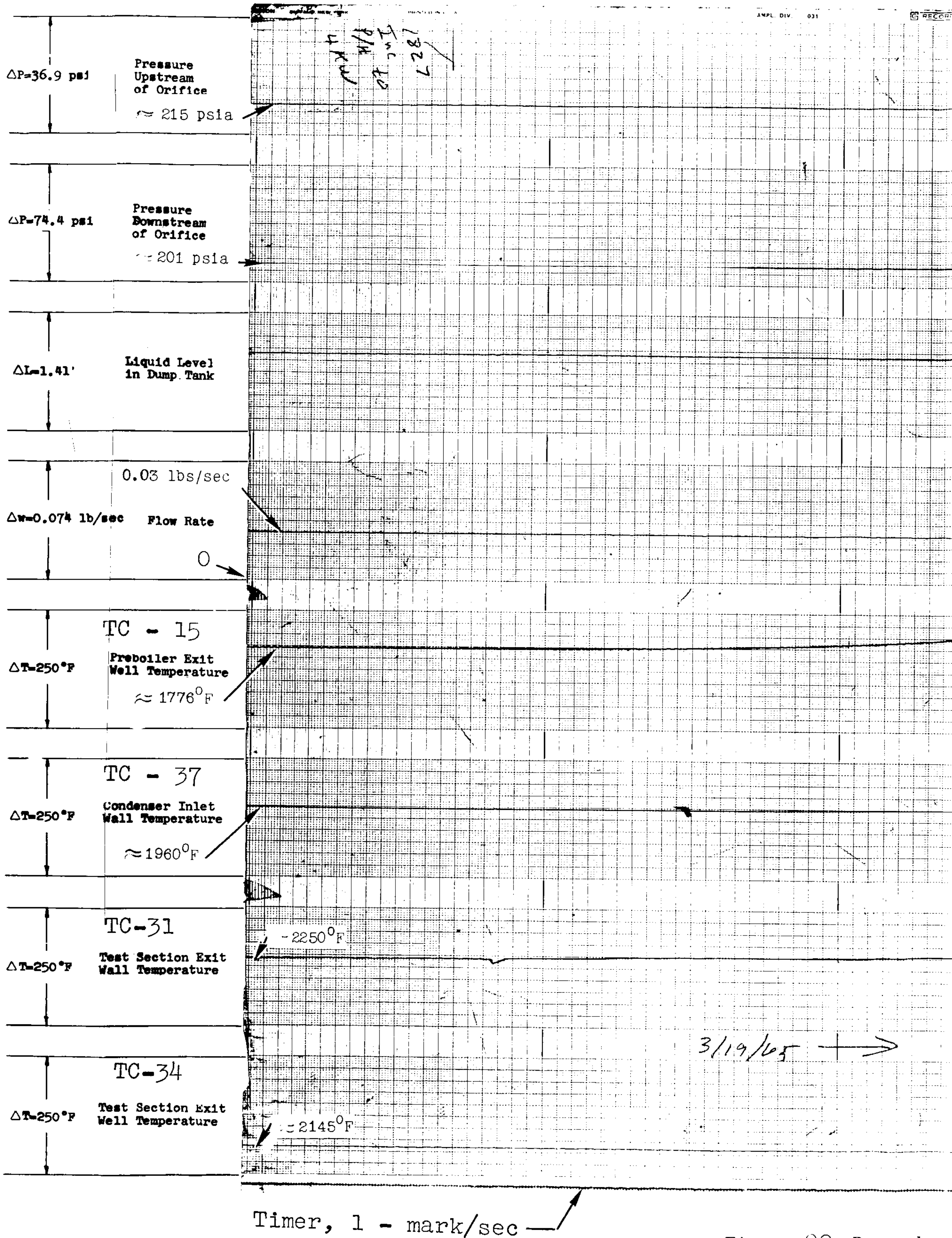
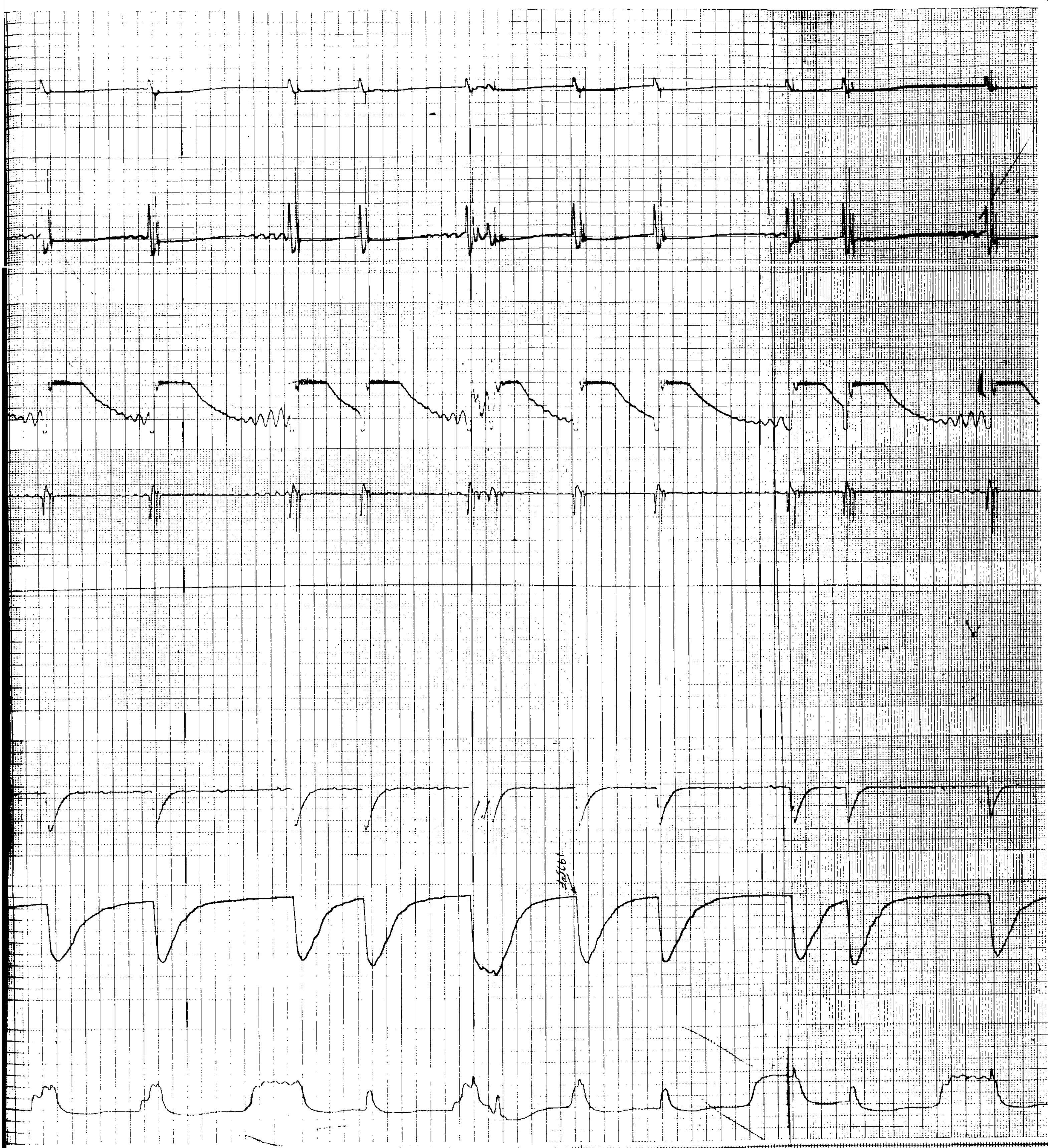
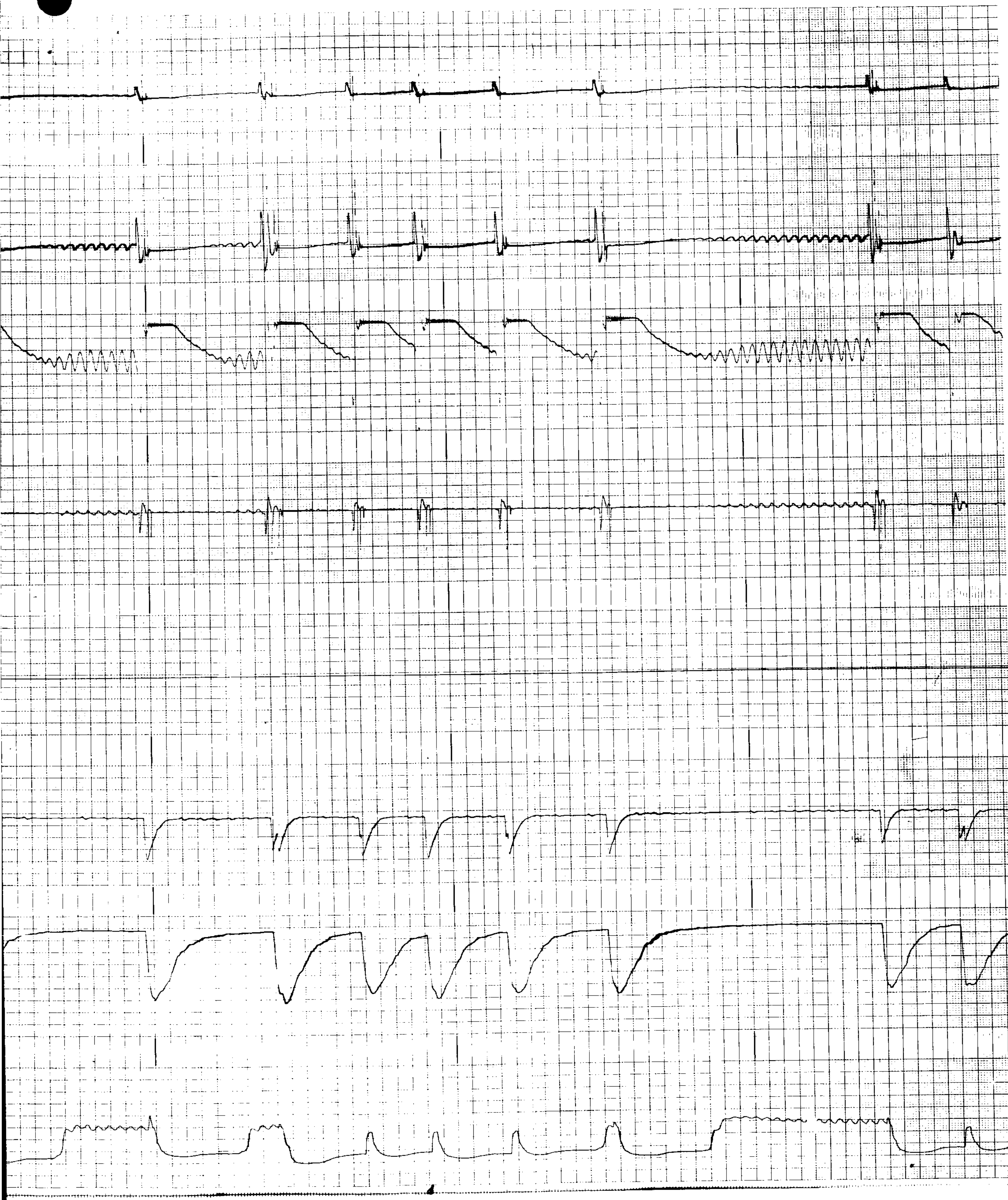


Figure 22. Recorder
(100 KW



owing Boiling Inception at P = 80 psia.
Test Section No. 3).

$G = 44$ lbs/sec-ft^2
$q'' = 105{,}000$ BTU/hr-ft^2



Boiling Inception at P = 80 psia. (Continued from Figure 23a) Section No. 3).

G = 44 lbs/sec-ft^2
q"= 105,000 BTU/hr-ft^2

(2)

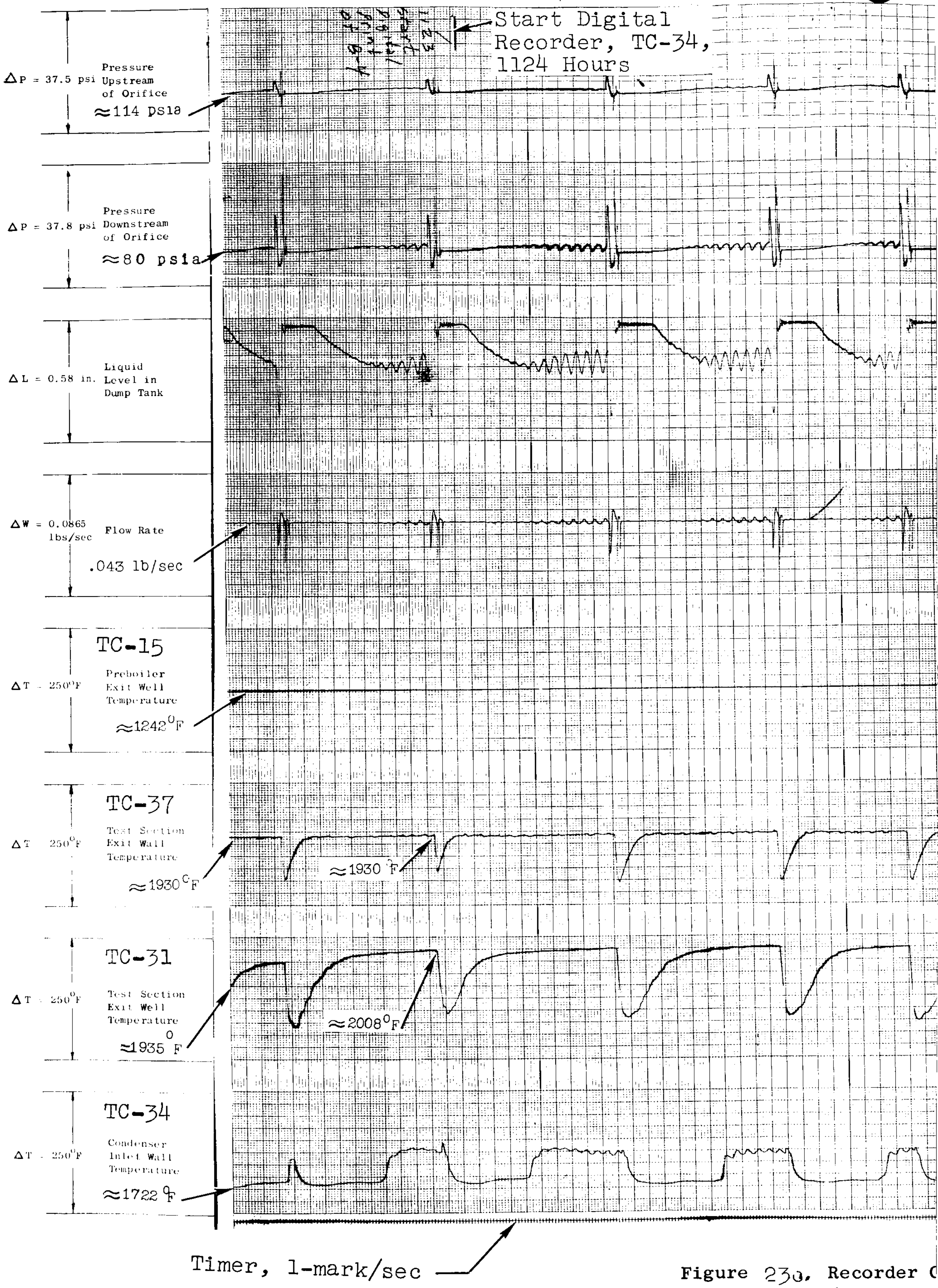


Figure 23a, Recorder C
(100 KW Fa

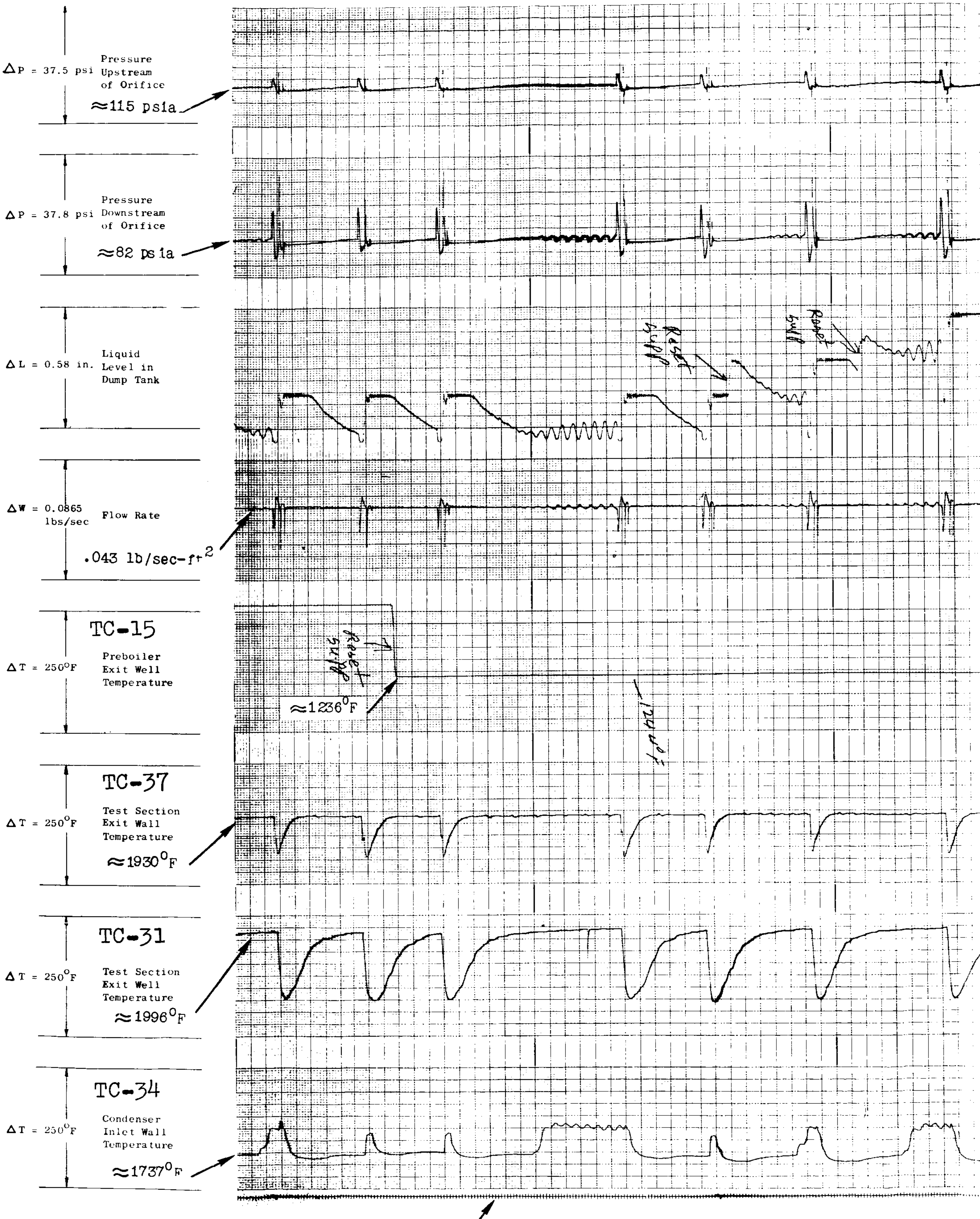


Figure 23b. Recorder Chart Showin
(100 KW Facility, Tes

1414

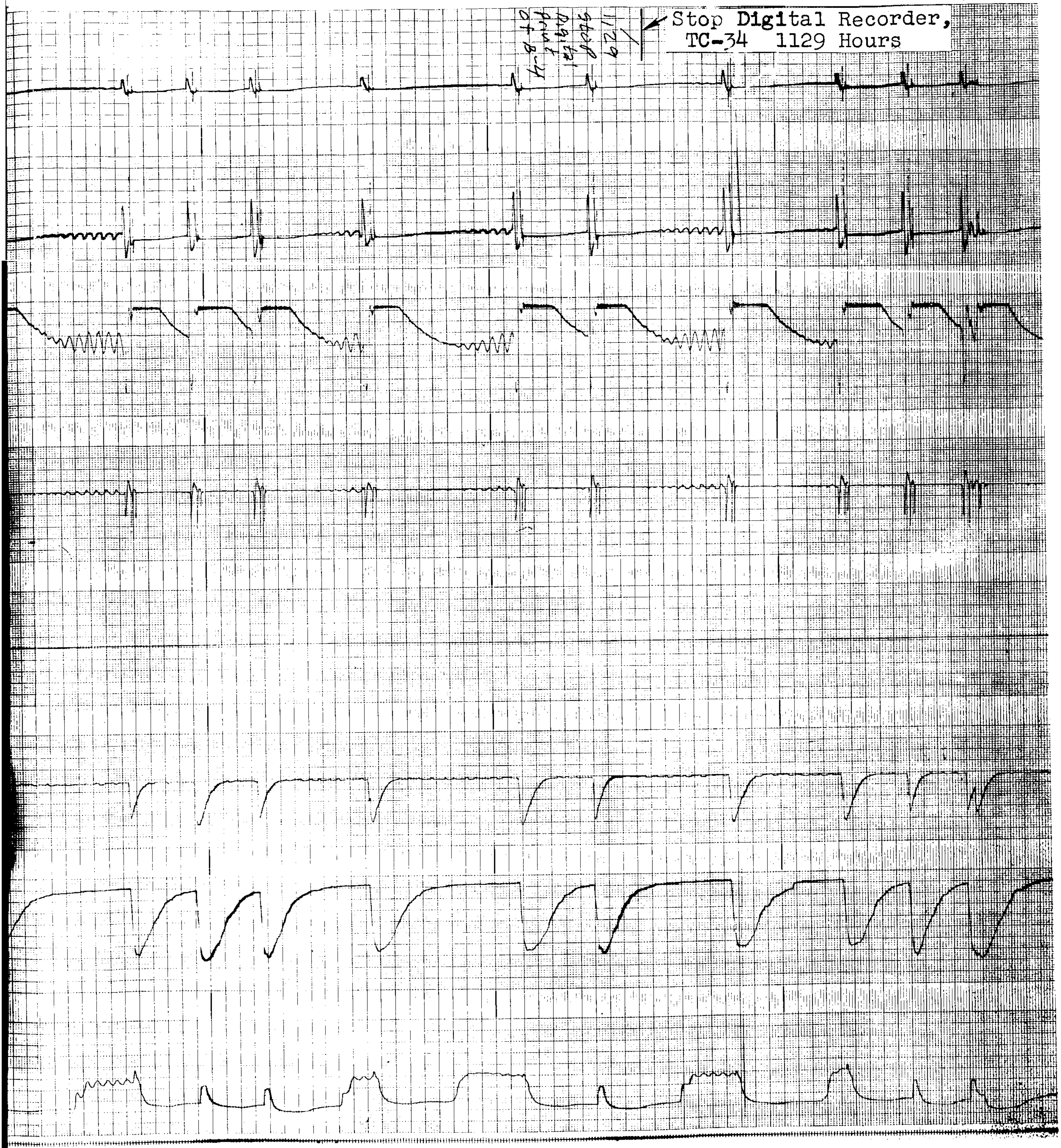


Chart Showing Boiling Inception at P = 80 psia. (Continued From **Figure** 23b)
acility, Test Section No. 3).

$G = 44$ lbs/sec-ft^2
$q'' = 105{,}000$ BTU/hr-ft^2

wing Boiling Inception at P = 80 psia. (Continued From Figure 23c)
Test Section No. 3).

G = 44 lbs/sec-ft^2
q" = 105,000 BTU/hr-ft^2

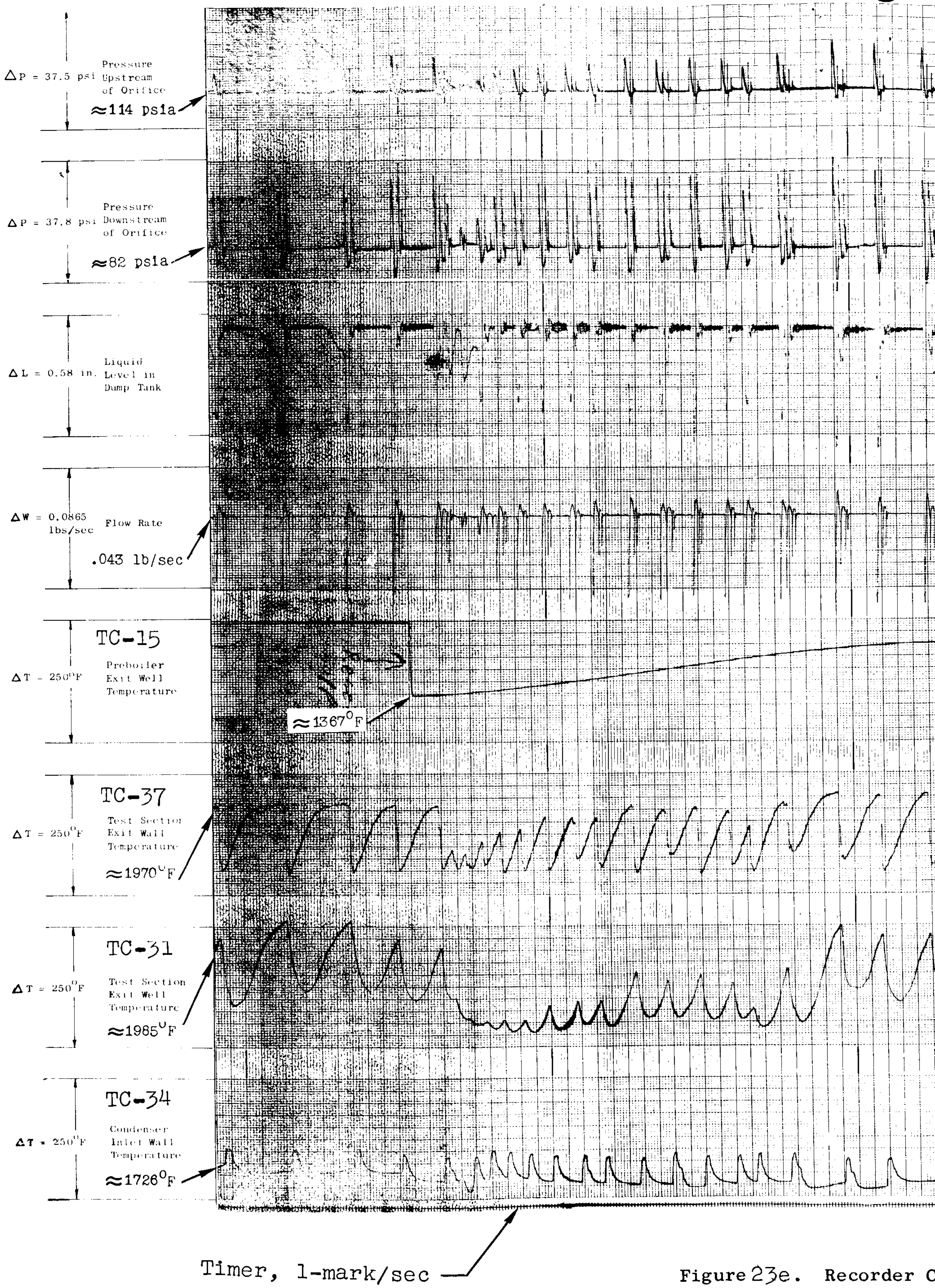


Figure 23e. Recorder C
(100 KW Fa

#1

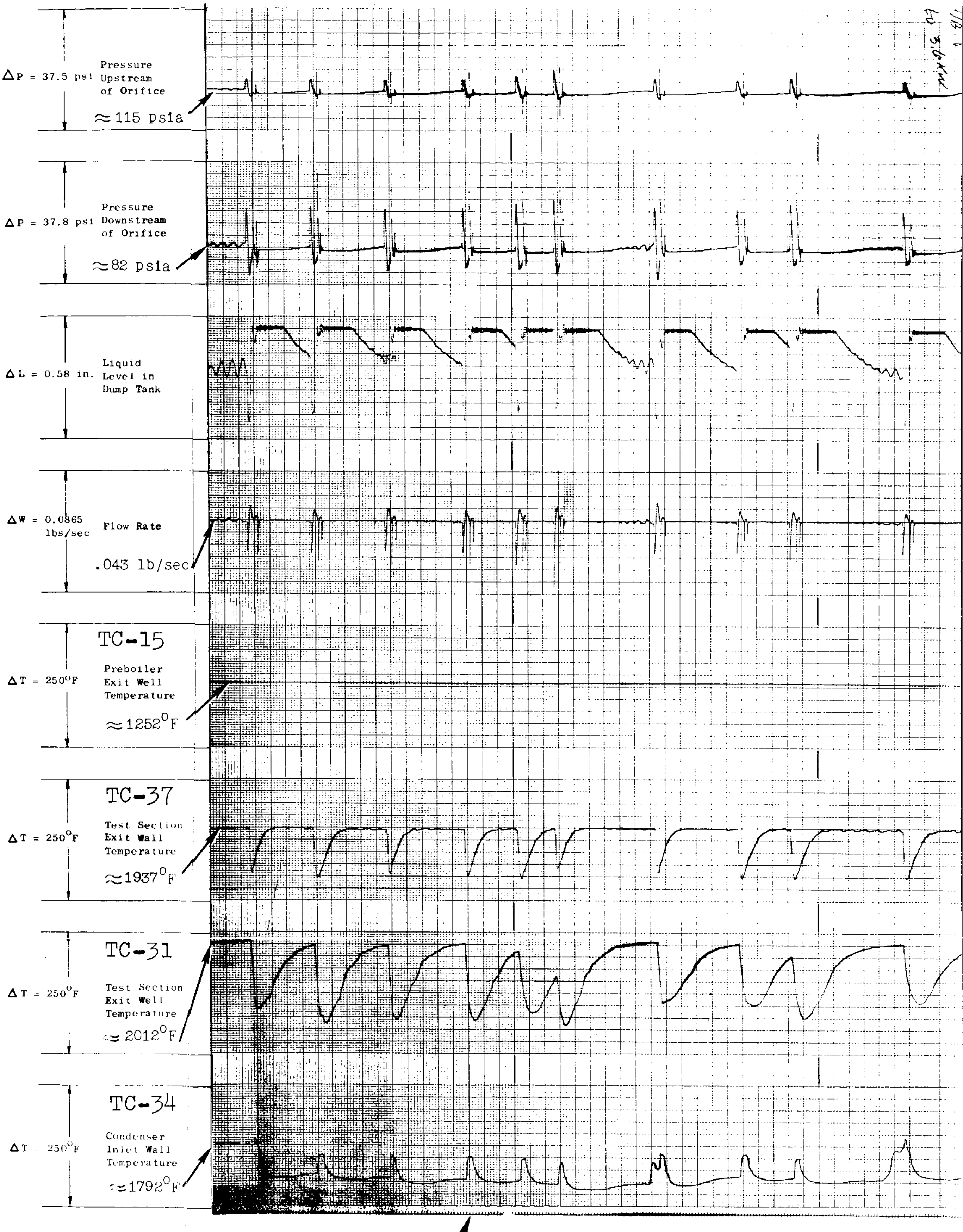
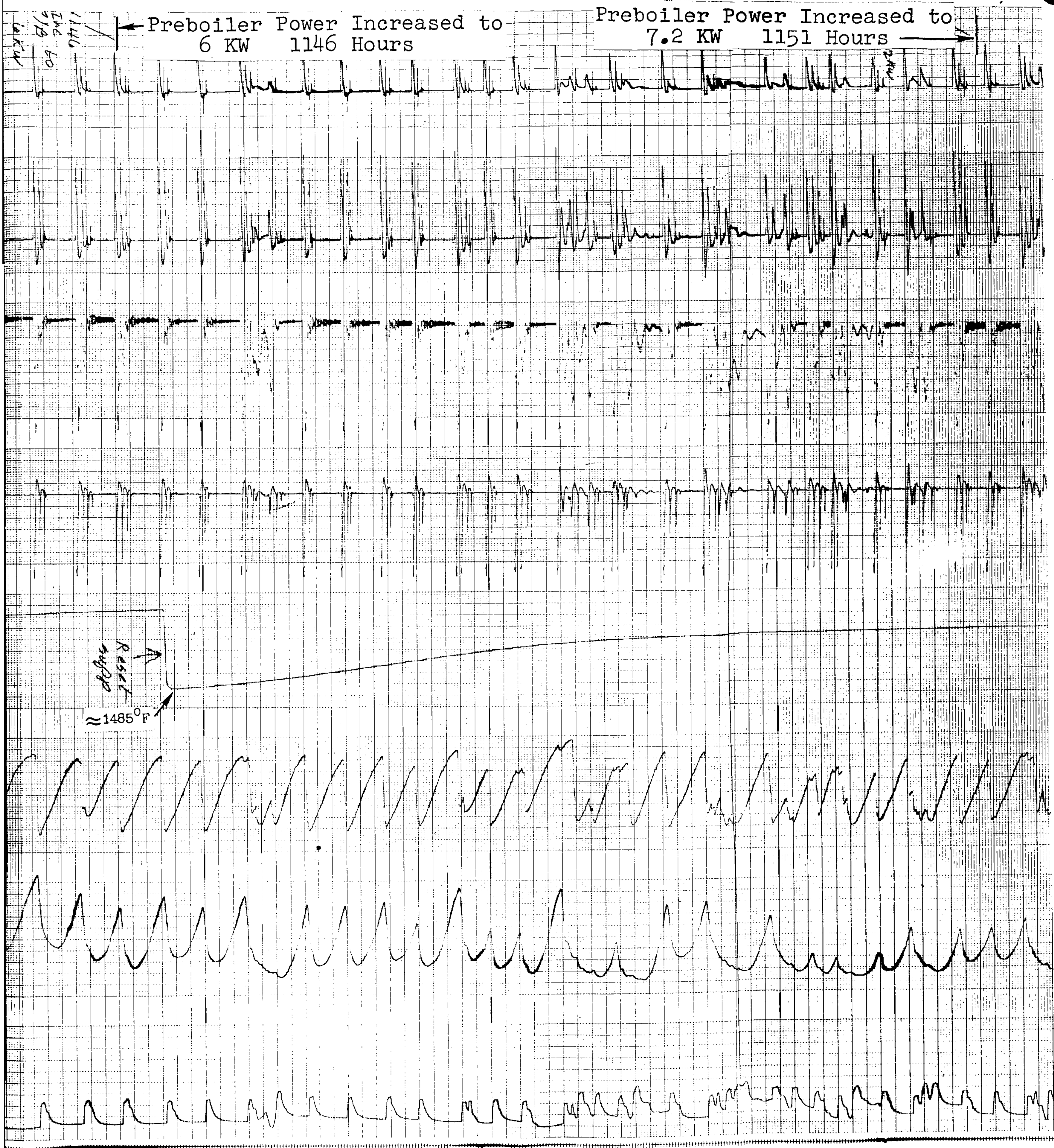


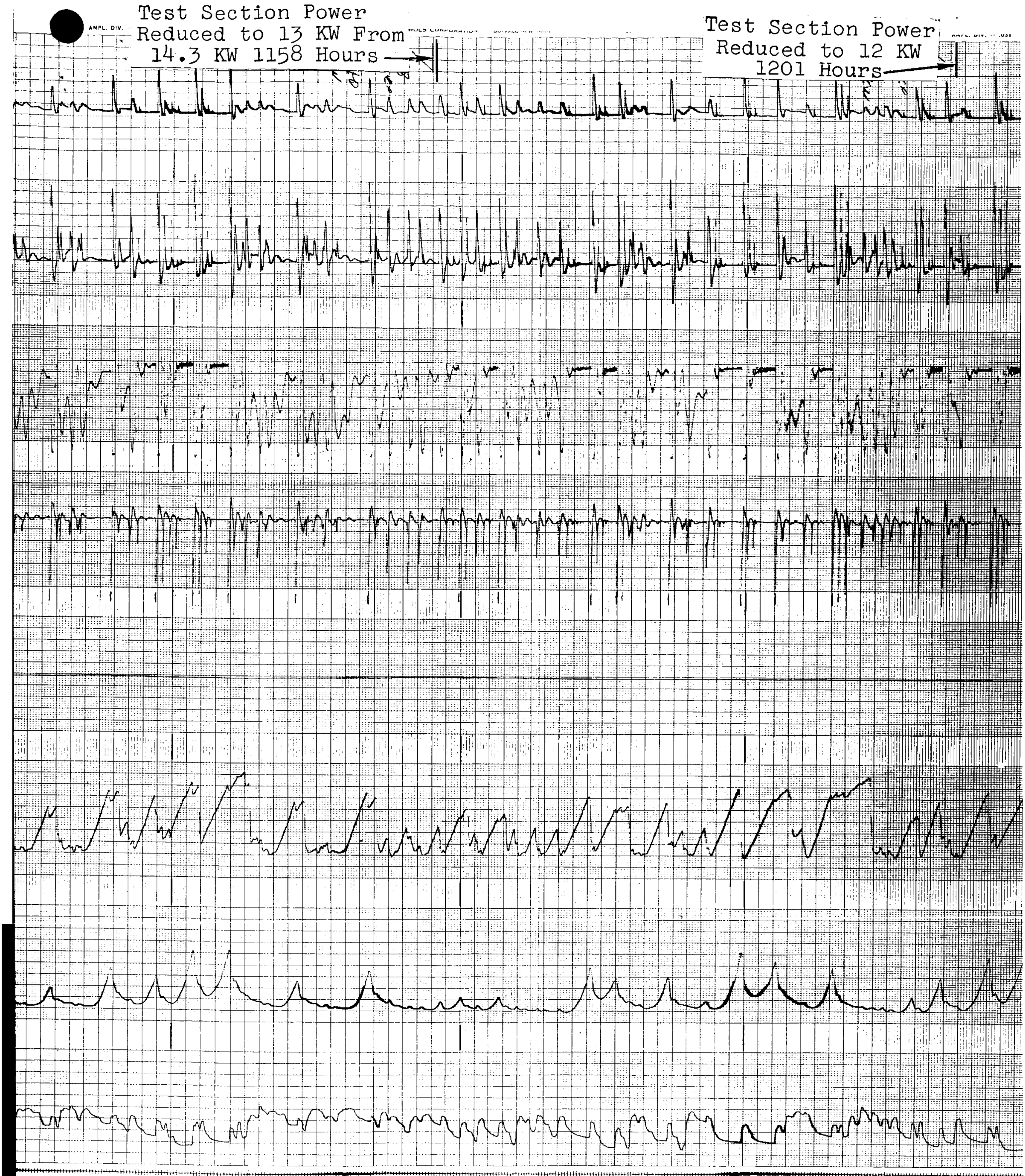
Figure 23d. Recorder Chart Sho
(100 KW Facility,

1430



art Showing Boiling Inception at P = 80 psia. (Continued From Figure 23d)
ility, Test Section No. 3).

G = 44 lbs/sec-ft^2
q" = 105,000 BTU/hr-ft^2



Showing Boiling Inception at P = 80 psia. (Continued From Figure 23e)
ty, Test Section No. 3).

$G = 44$ lbs/sec-ft^2
$q'' = 105,000$ BTU/hr-ft^2

145 ②

3

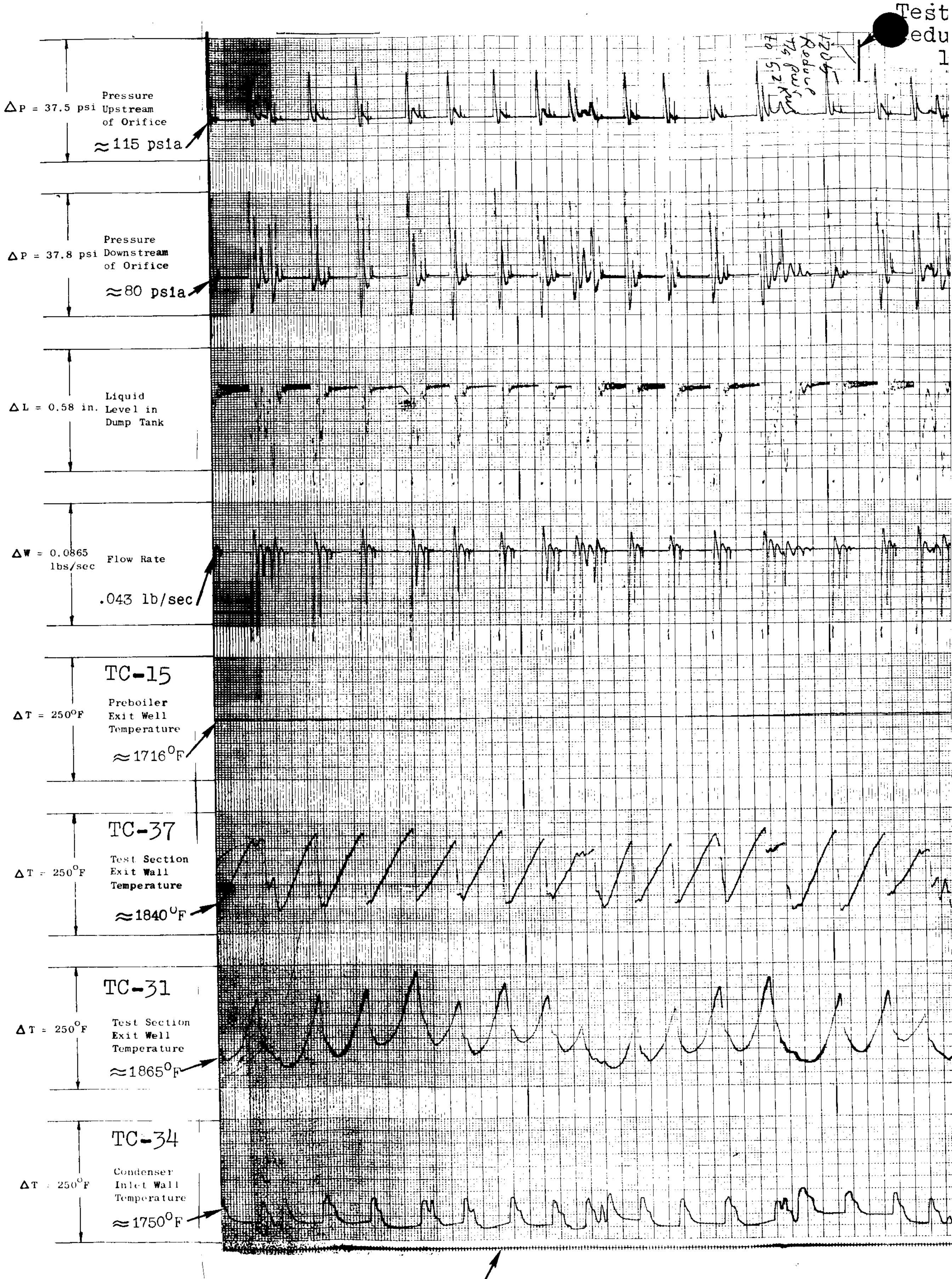


Figure 23g. Recorder Cha
(100 KW Faci

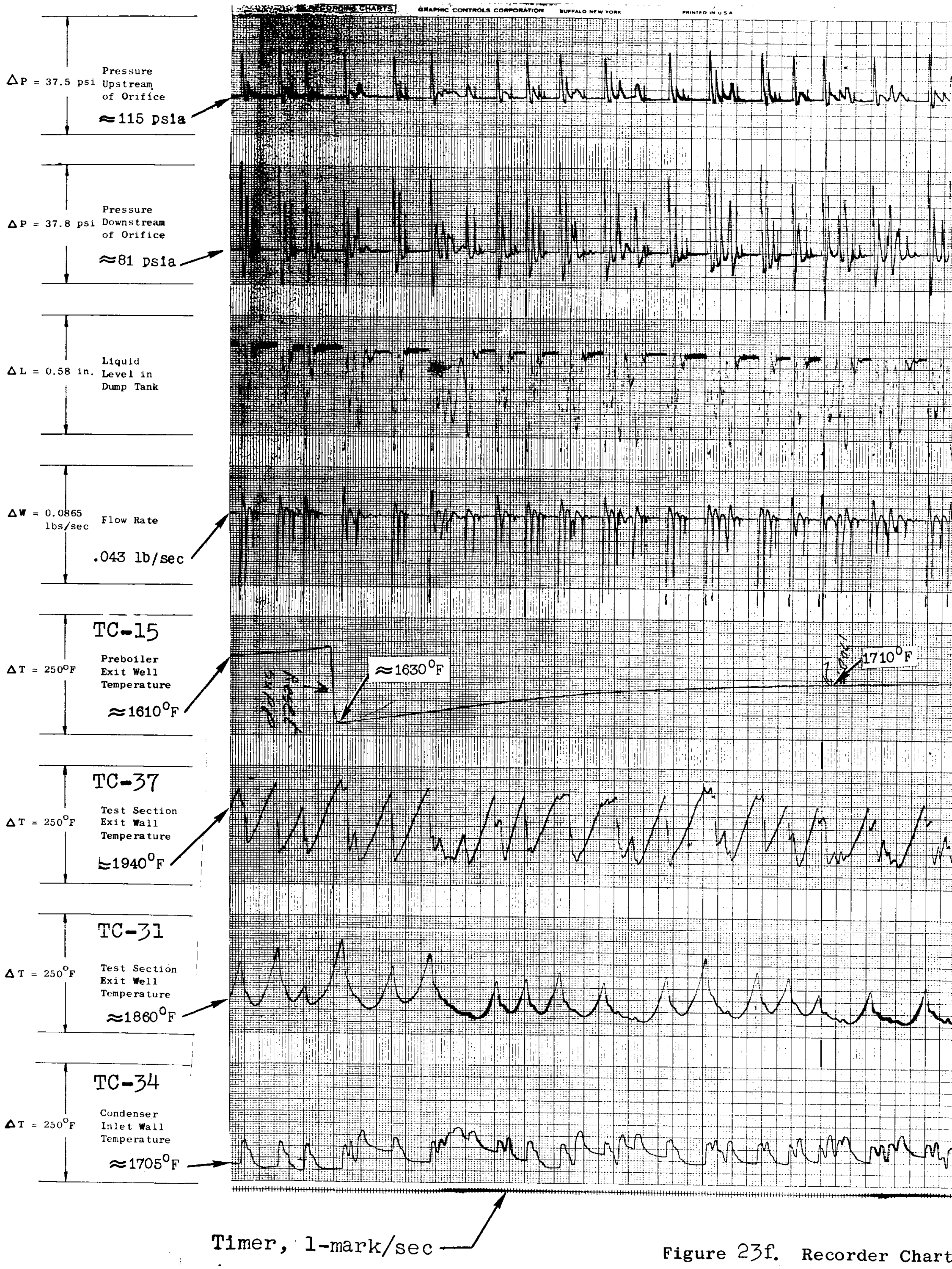
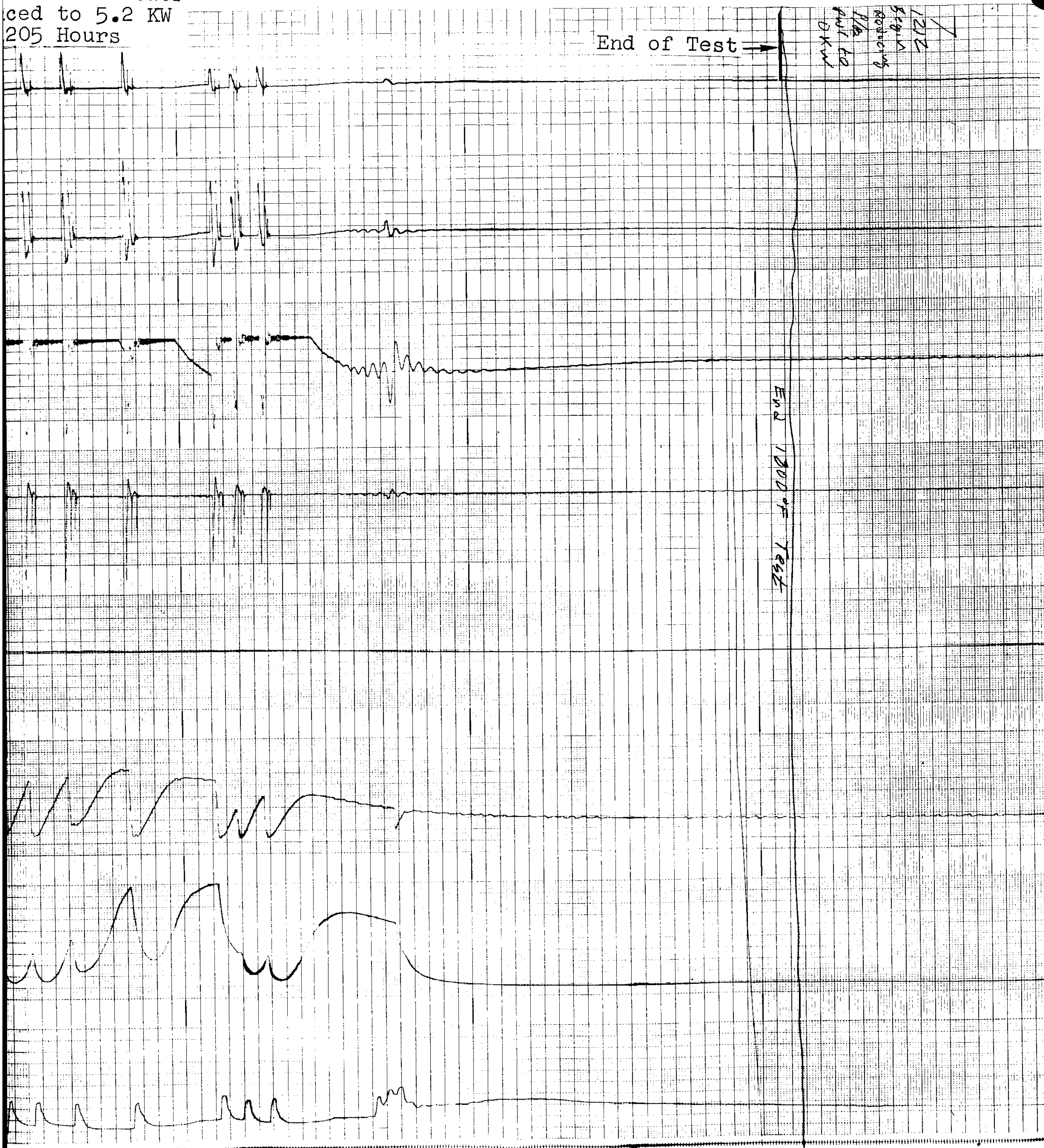


Figure 23f. Recorder Chart
(100 KW Facili

Section Power
ced to 5.2 KW
205 Hours



rt Showing Boiling Inception at P = 80 psia. (Continued From Figure 23f)
lity, Test Section No. 3).

$G = 44$ lbs/sec-ft^2
$q'' = 105{,}000$ BTU/hr-ft^2

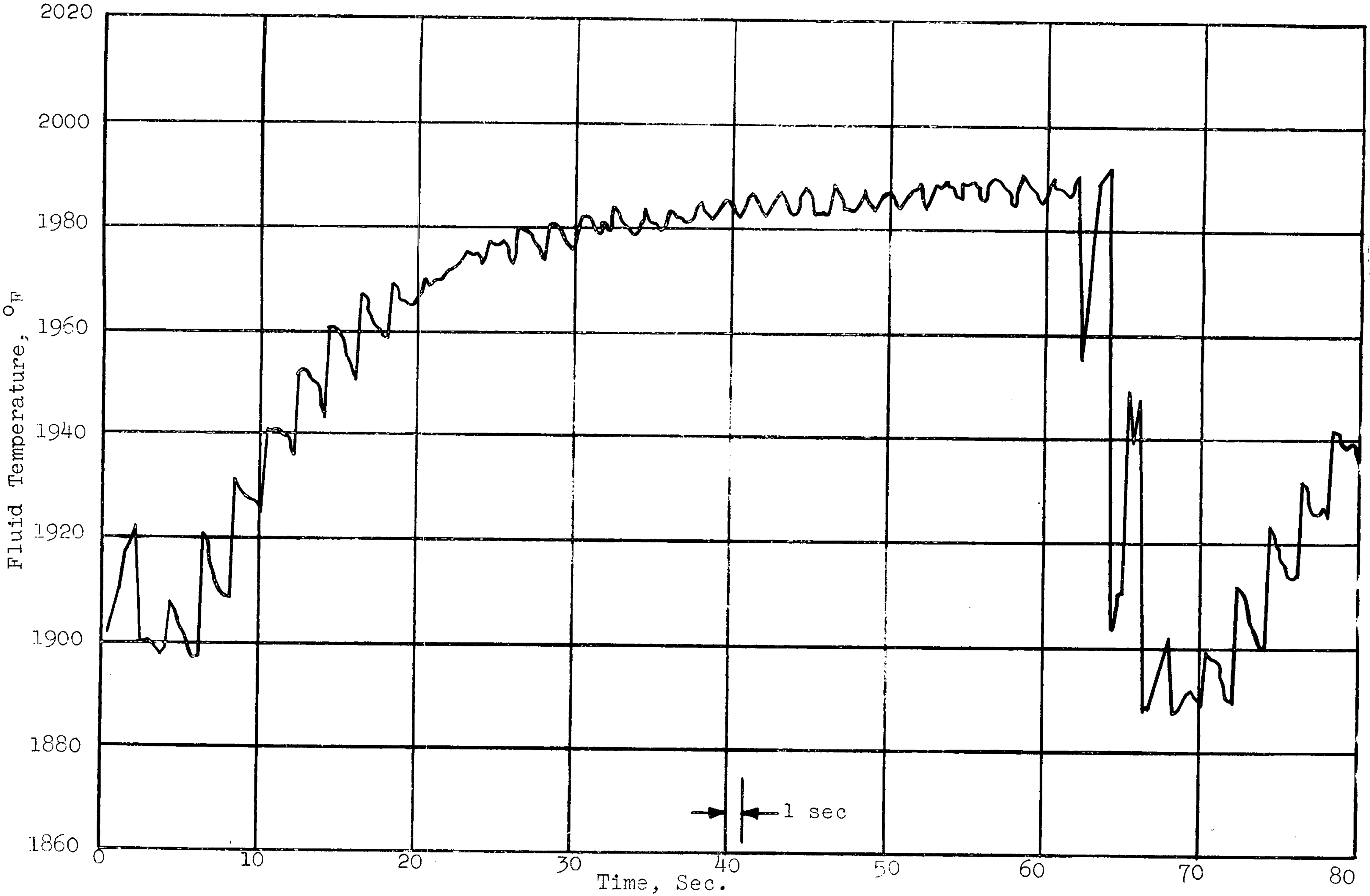


Figure 24a Temperature Trace of A Test Secton Well Thermocouple (100 KW Facility, Test Section No. 3)

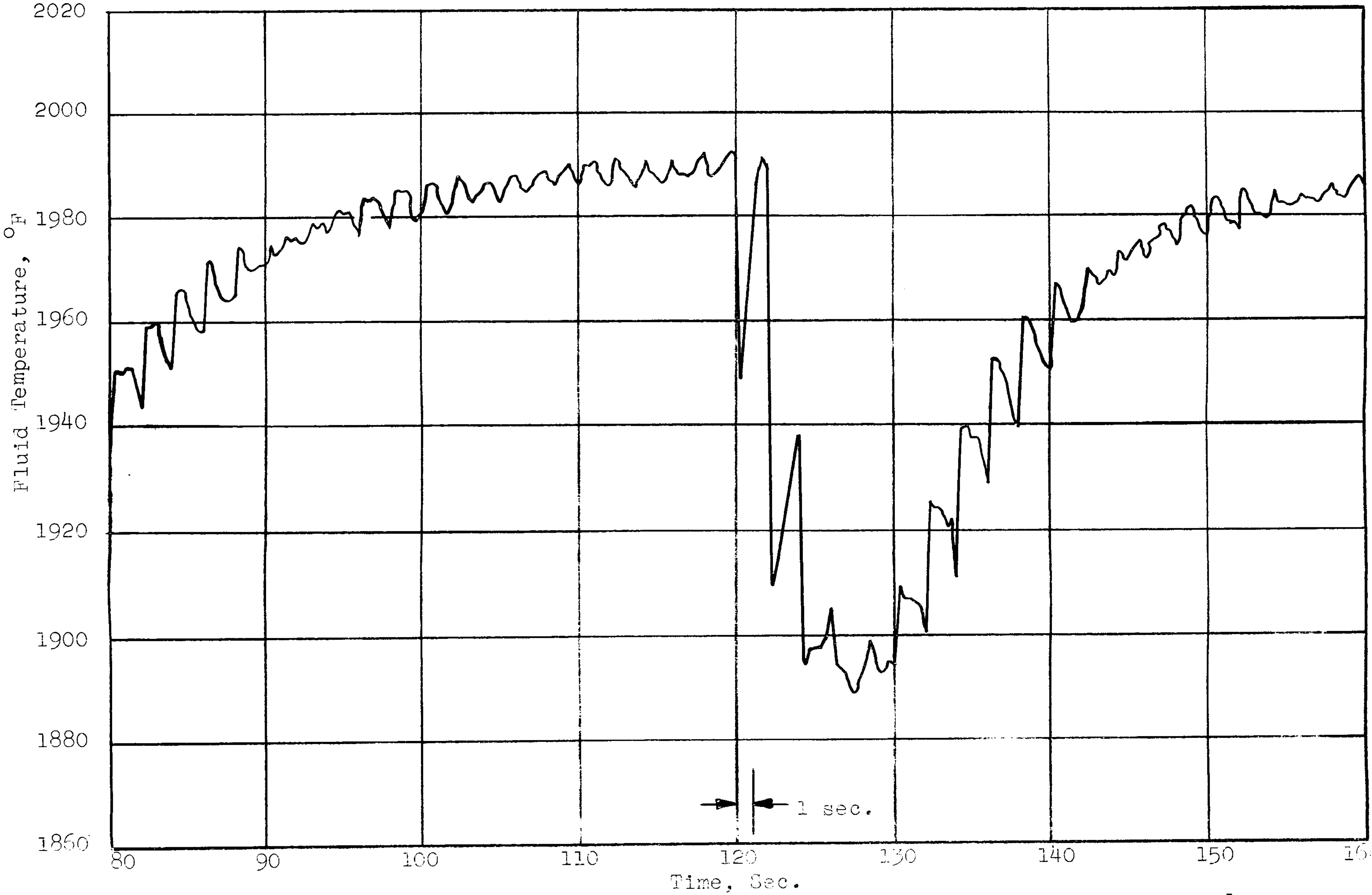


Figure 24b. Temperature Trace of A Test Section Exit Well Thermocouple (Continued From Figure 24a) (100 KW Facility)

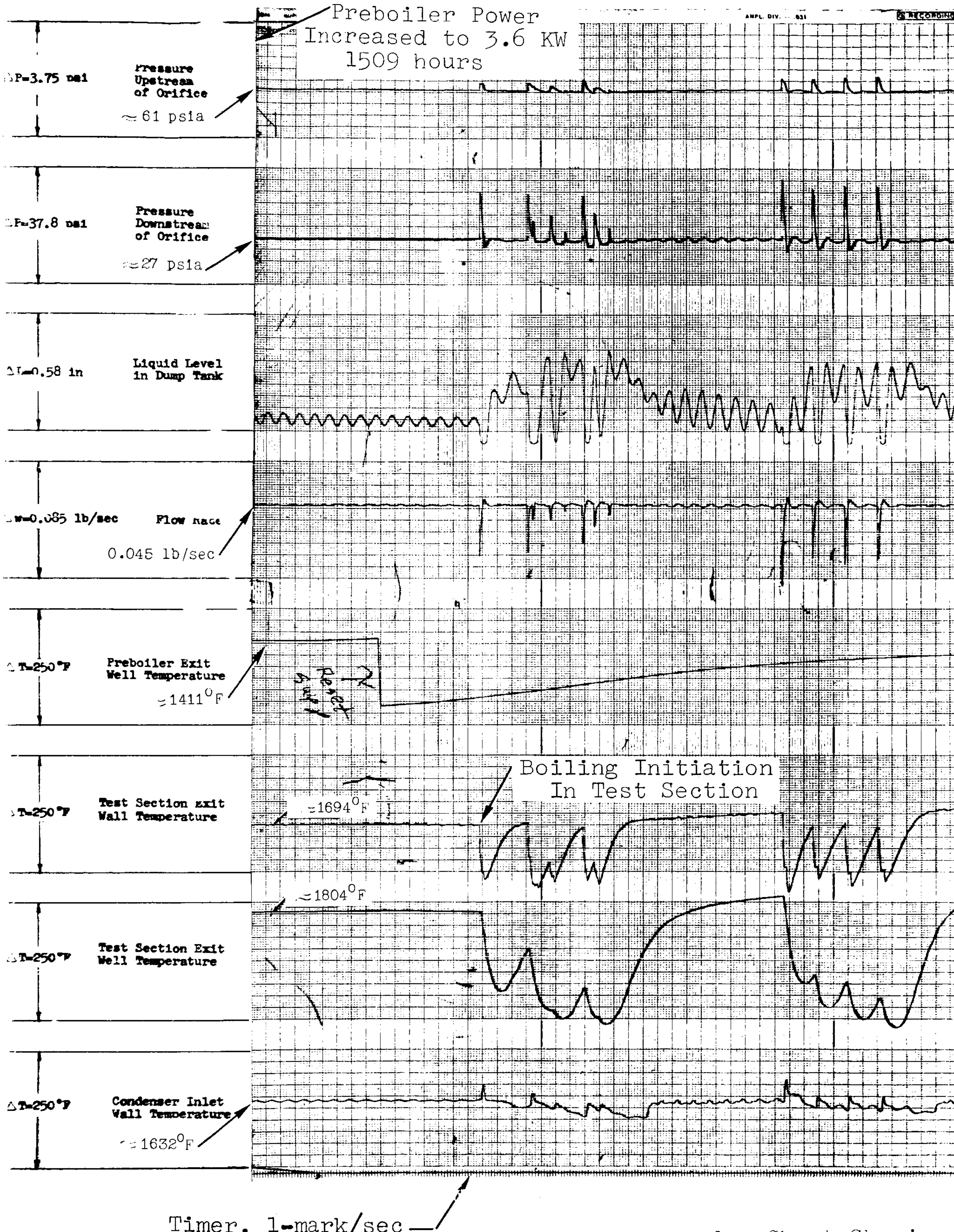
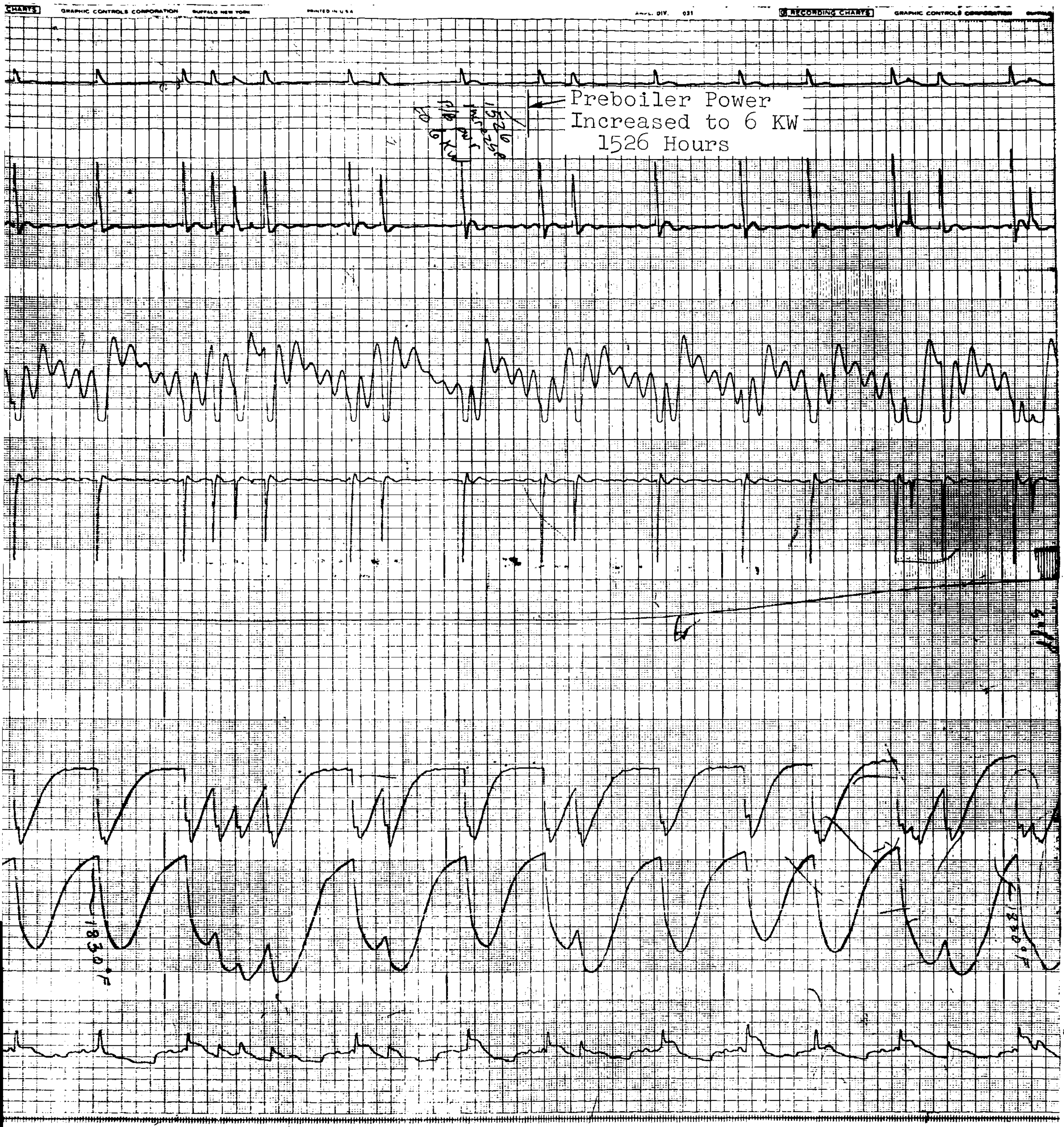


Figure 25 Recorder Chart Showing
Following A Preboiler
Test Sectio



$G = 45$ lb/sec-ft^2

$q'' = 65{,}000$ Btu/hr-ft^2

$w = 0.045$ lb/sec

Boiling Inception at P = 27 psia,
ower Increase (100 KW Facility,
n No. 3).

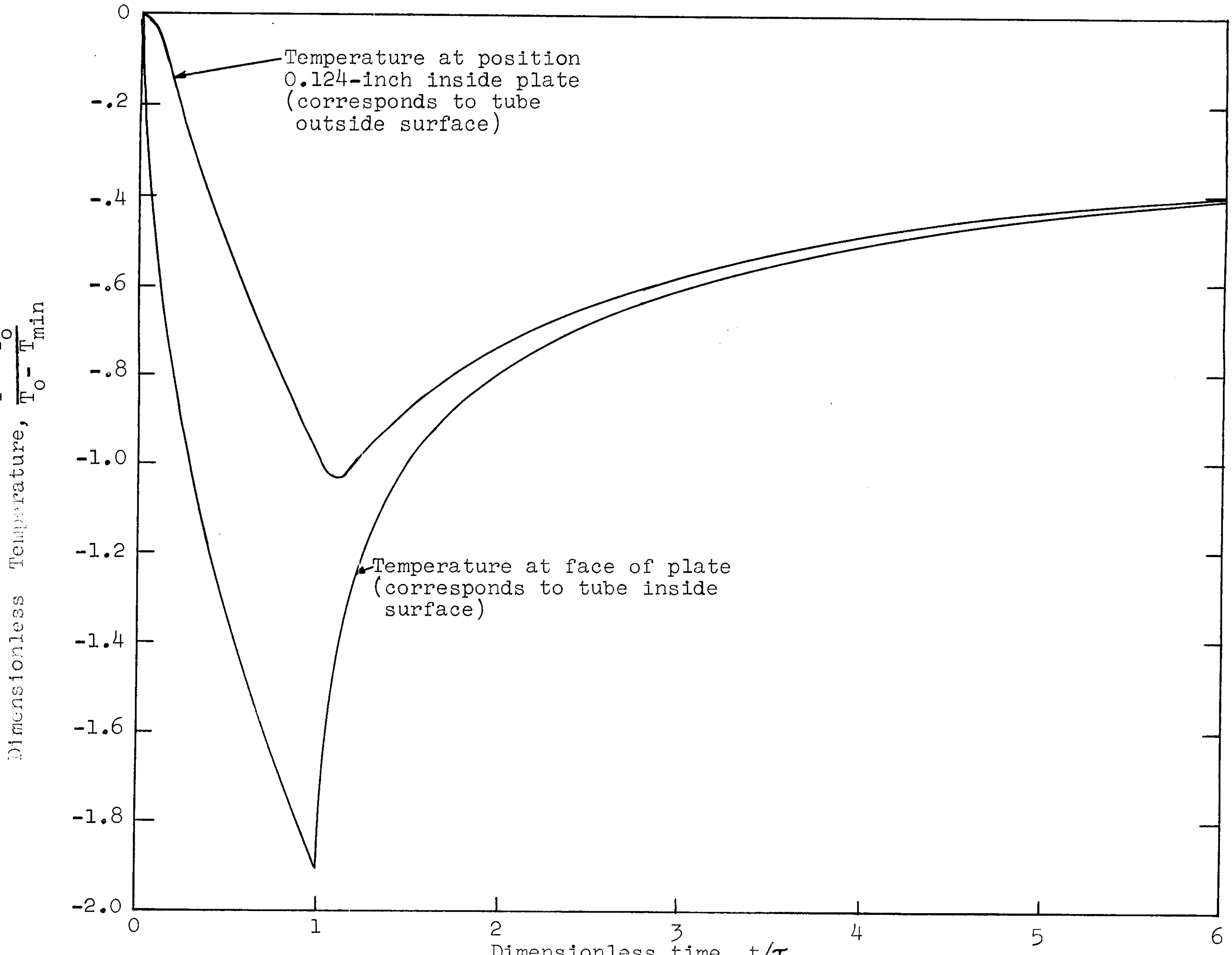


Figure 26. Temperature Response of a Semi-infinite Flat Plate After A Step Change In Surface Heat Flux

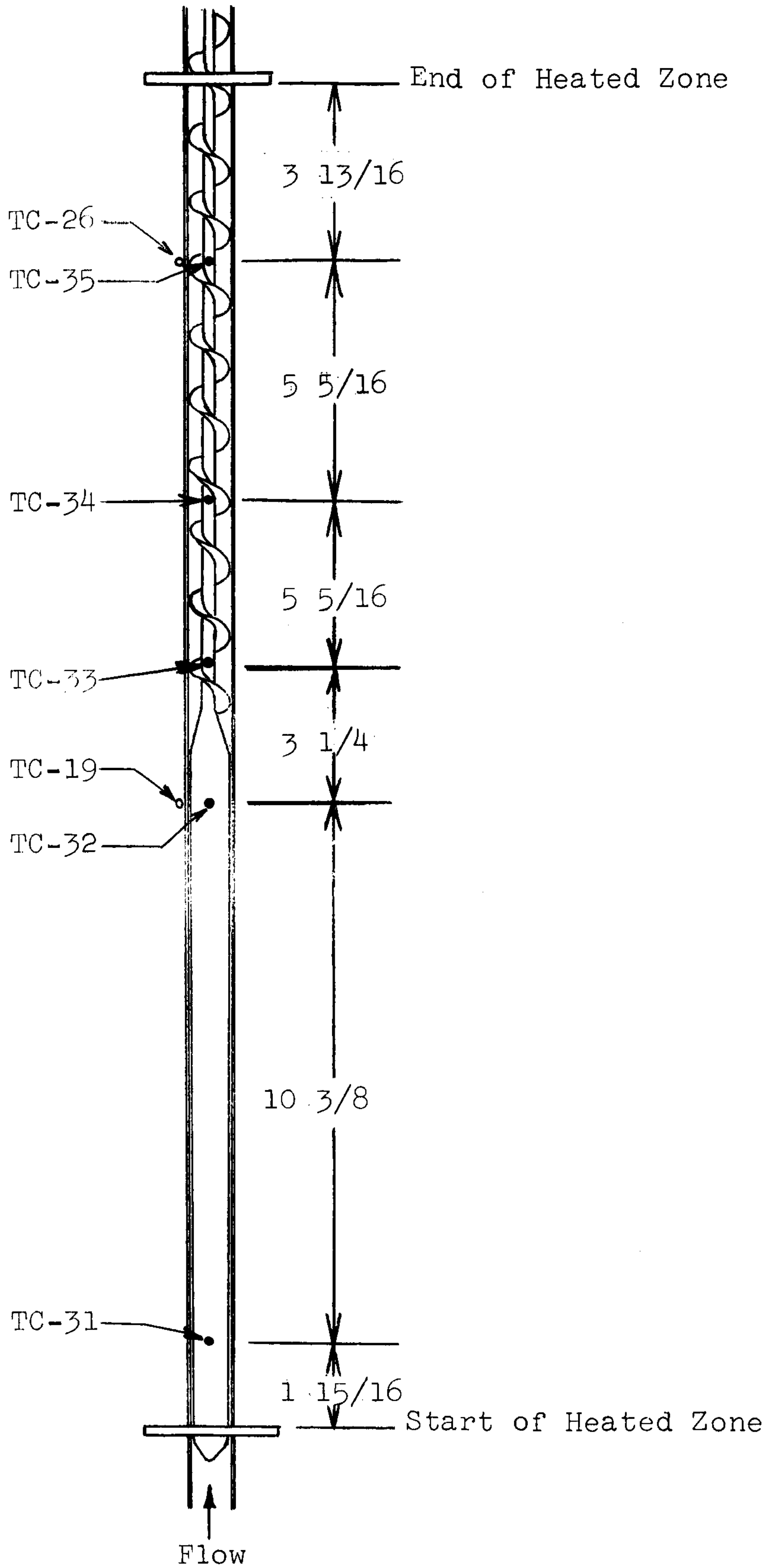
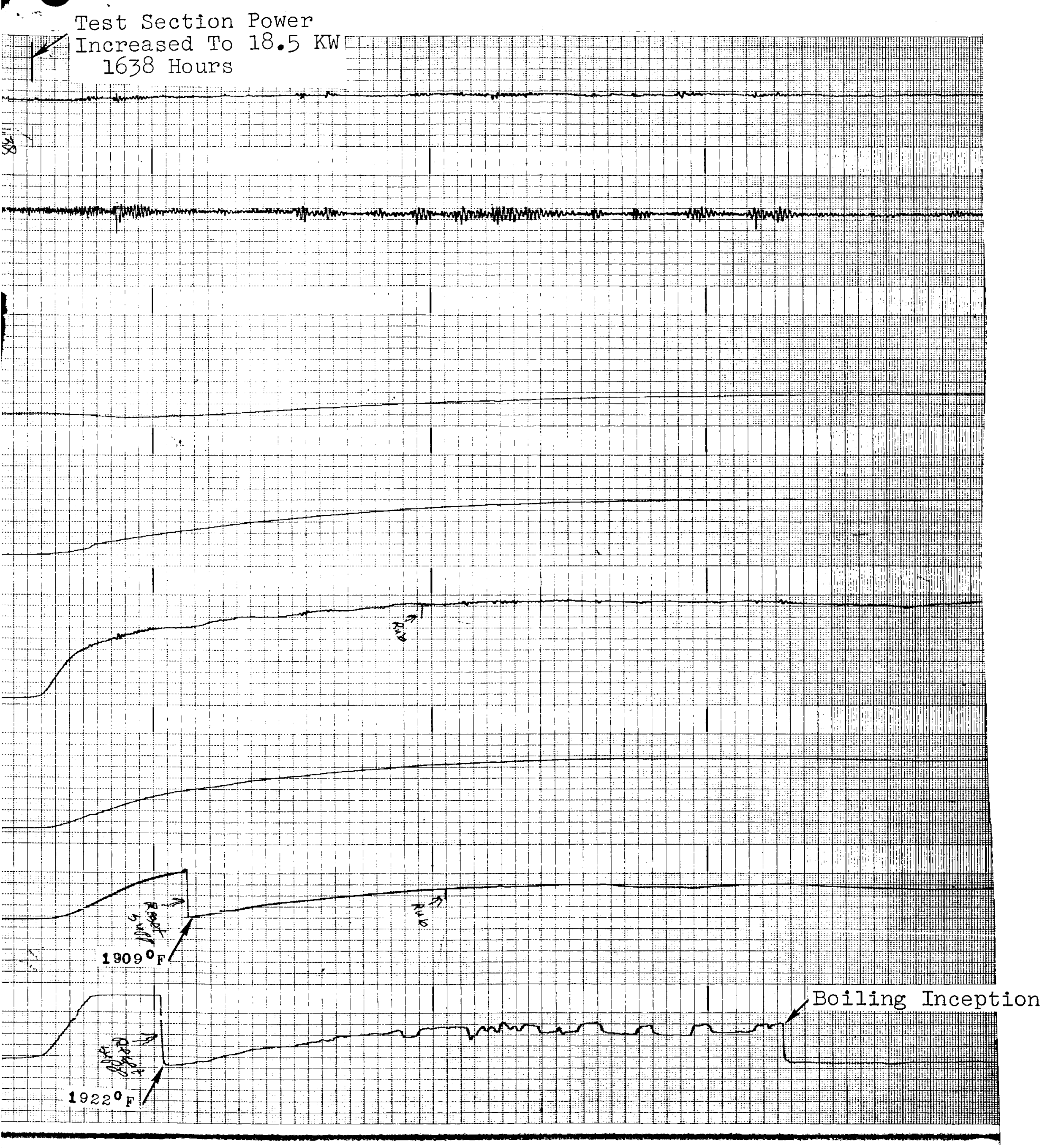


Figure 27. 100 KW Insert Thermocouple Locations for Test Section No. 4 with Instrumented Plug Helical Insert (I.D. = 0.738 in., P/D = 2.0)



q" = 83,000 - 108,000 Btu/hr-ft^2

ing Test (Test Section #4, 100 KW Facility).

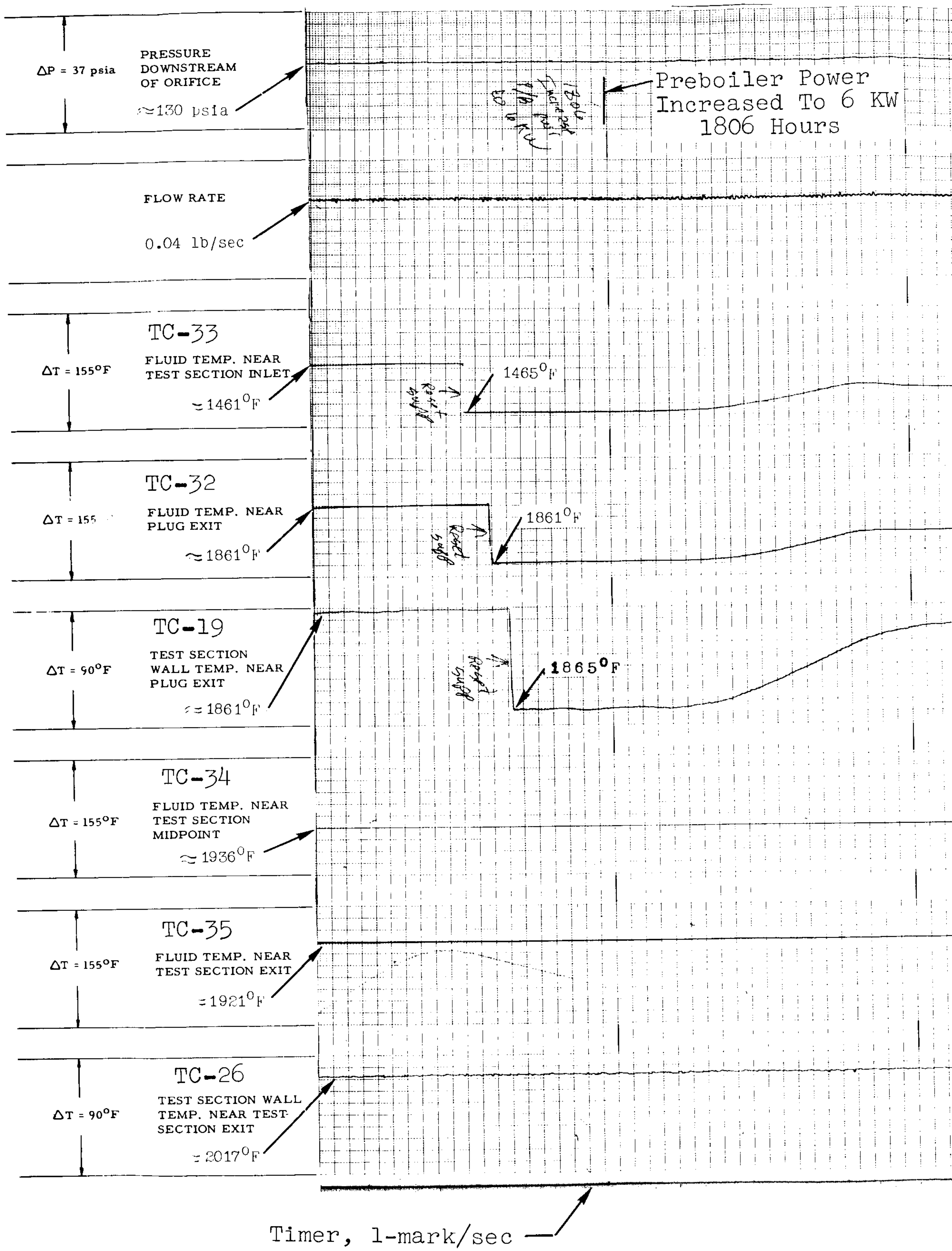


Figure 28b. Boili
1

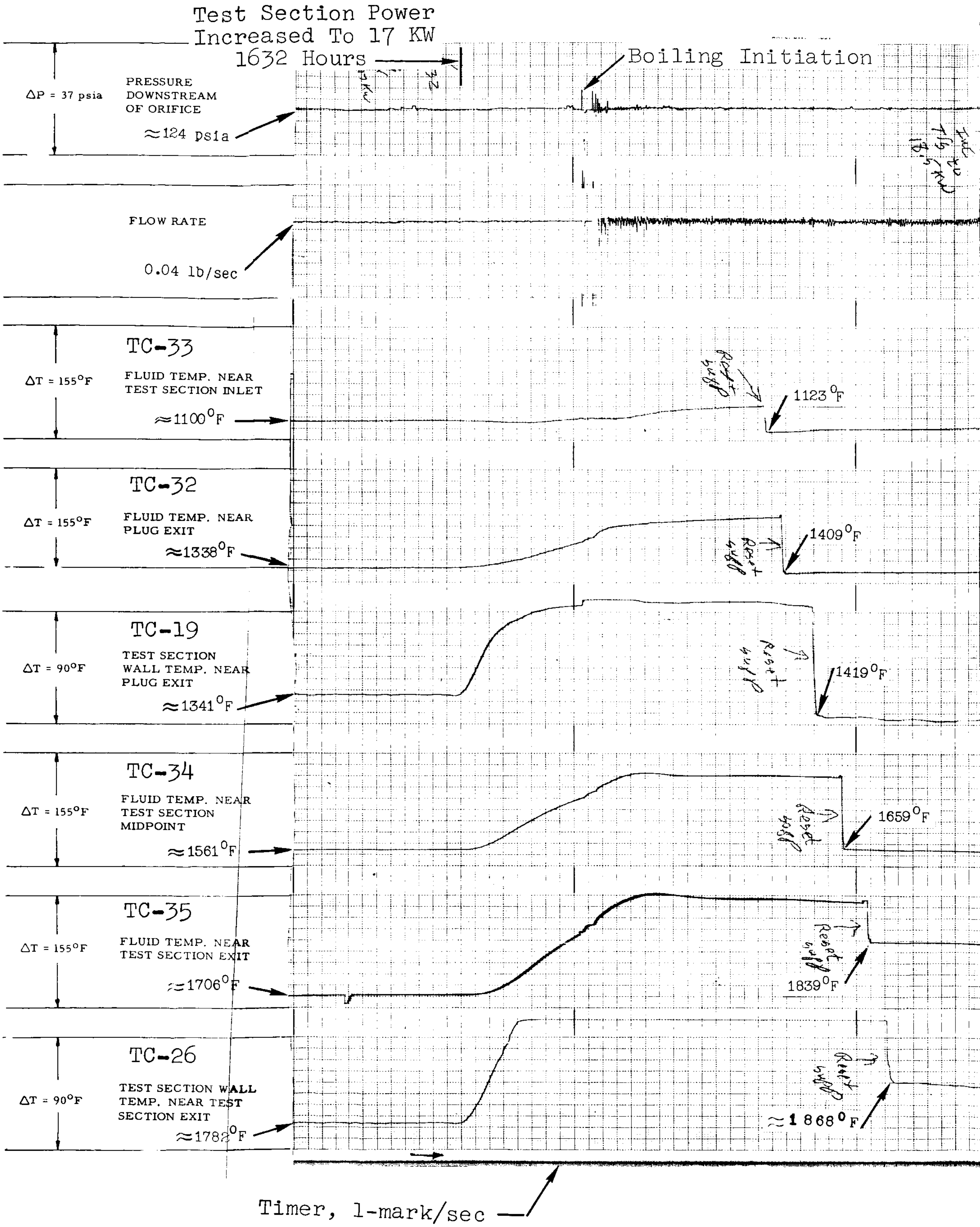
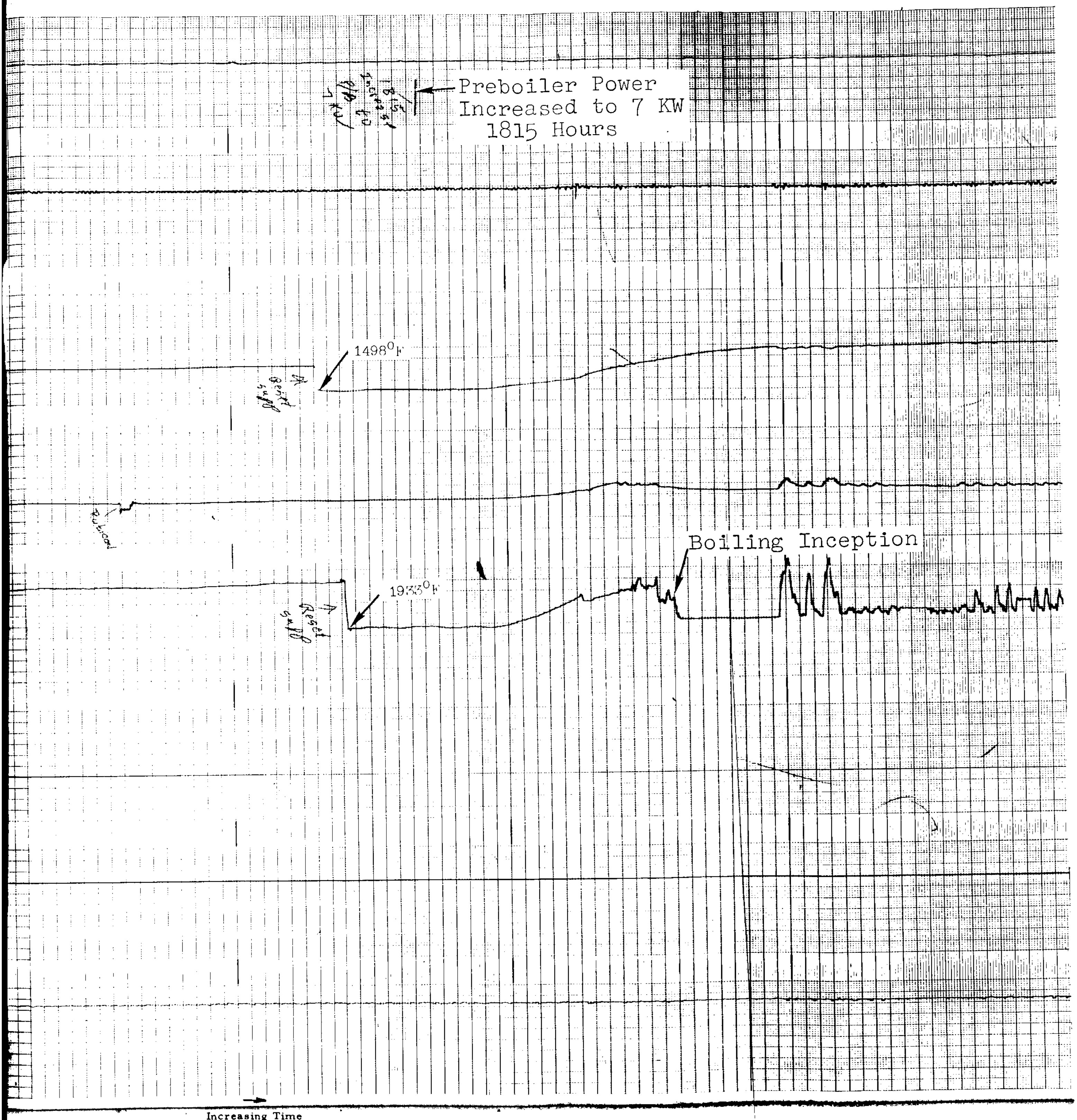


Figure 28a. Boiling Boundary Travers



q" - 108,000 Btu/hr-ft^2

Boundary Traversing Test (Test Section No. 4, KW Facility), Continued From Figure 28a.

154 (2)

154 (3)

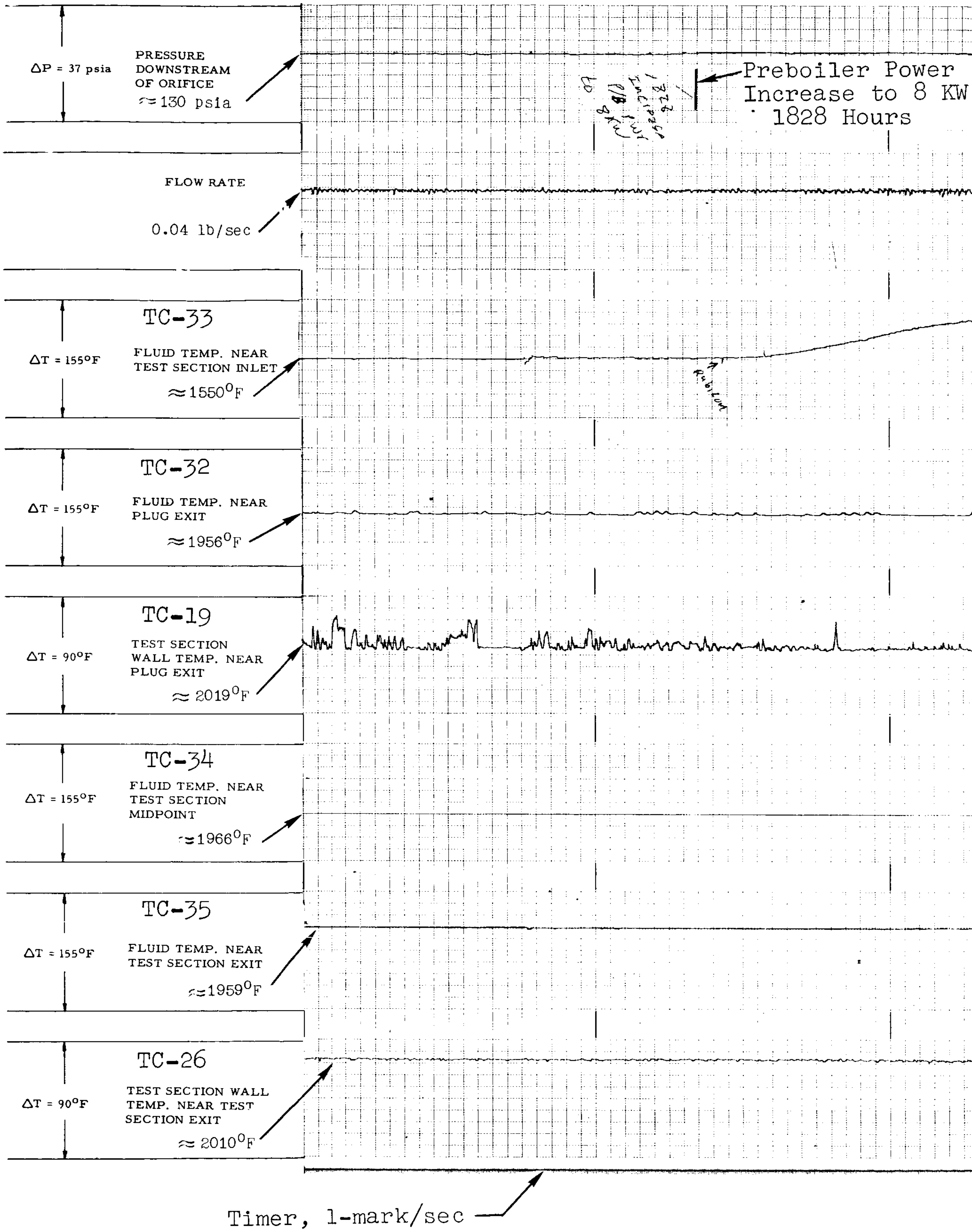
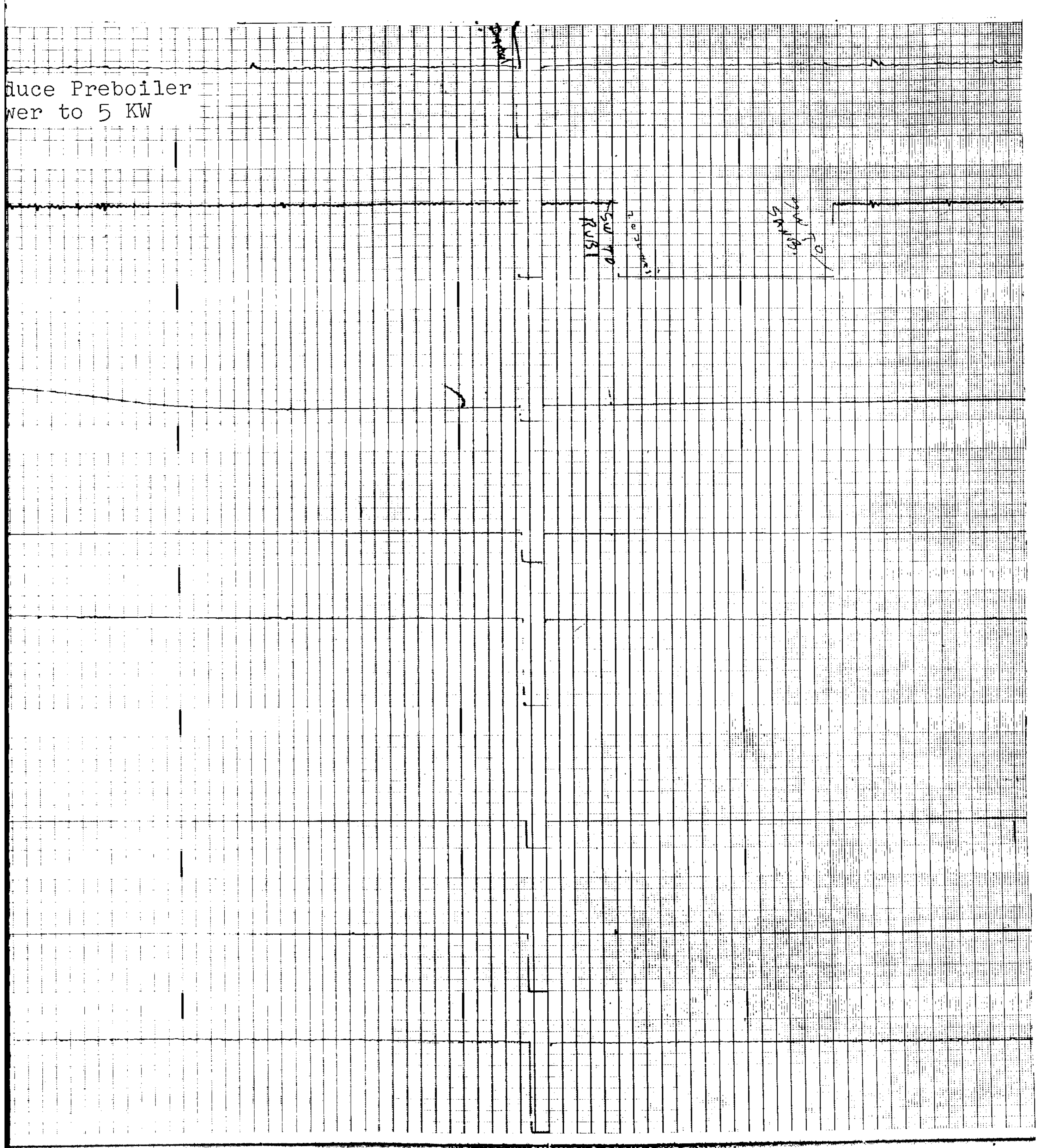


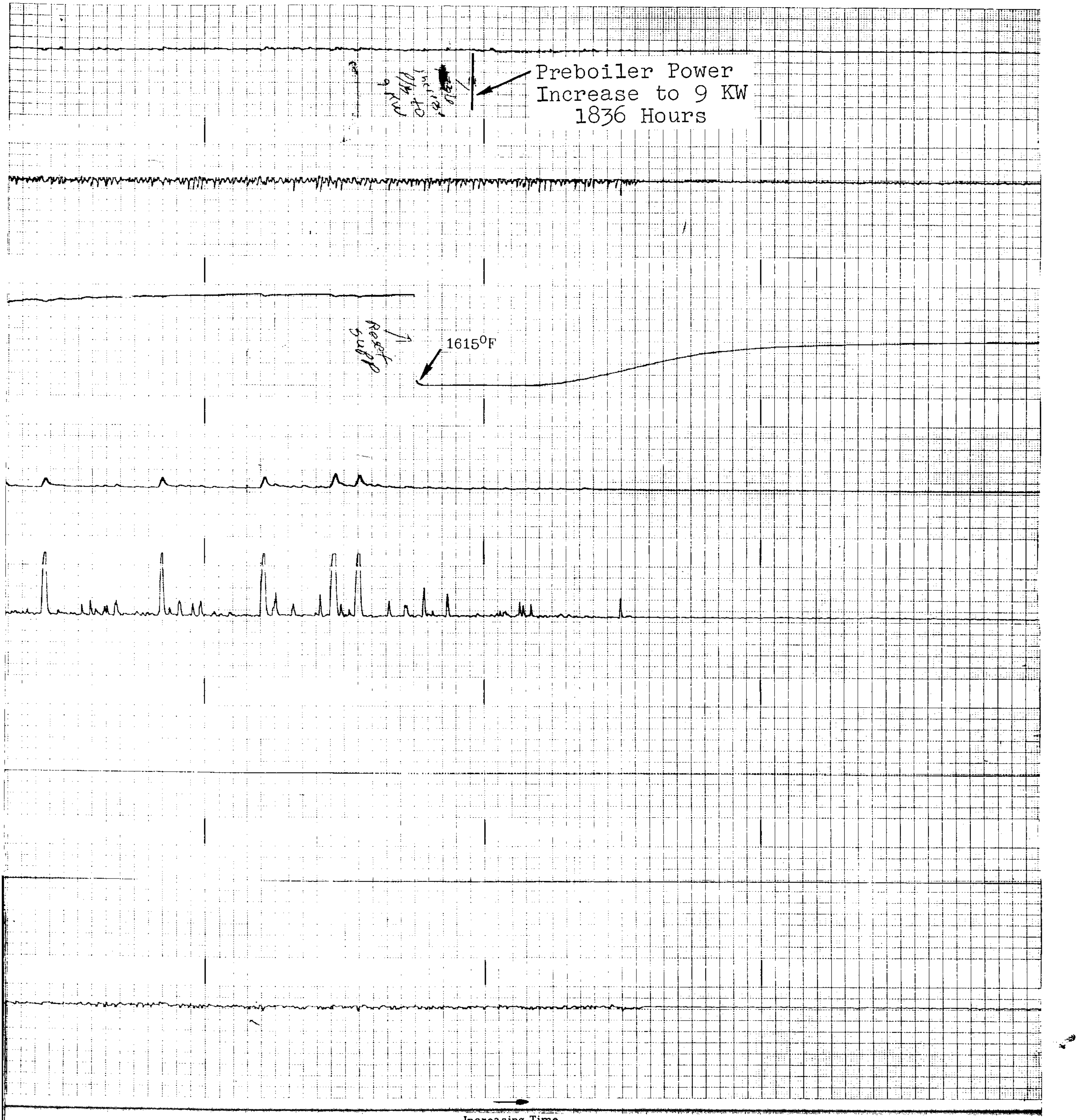
Figure 28c. Boiling Bo
100 KW Fac

155 (1)



$q'' = 181{,}000$ Btu/hr-ft^2

ary Traversing Test (Test Section No. 4,
cility), Continued From Figure 28c.



$q'' = 108{,}000$ Btu/hr-ft^2

undary Traversing Test (Test Section No. 4,
ility), Continued From Figure 28b.

(2)

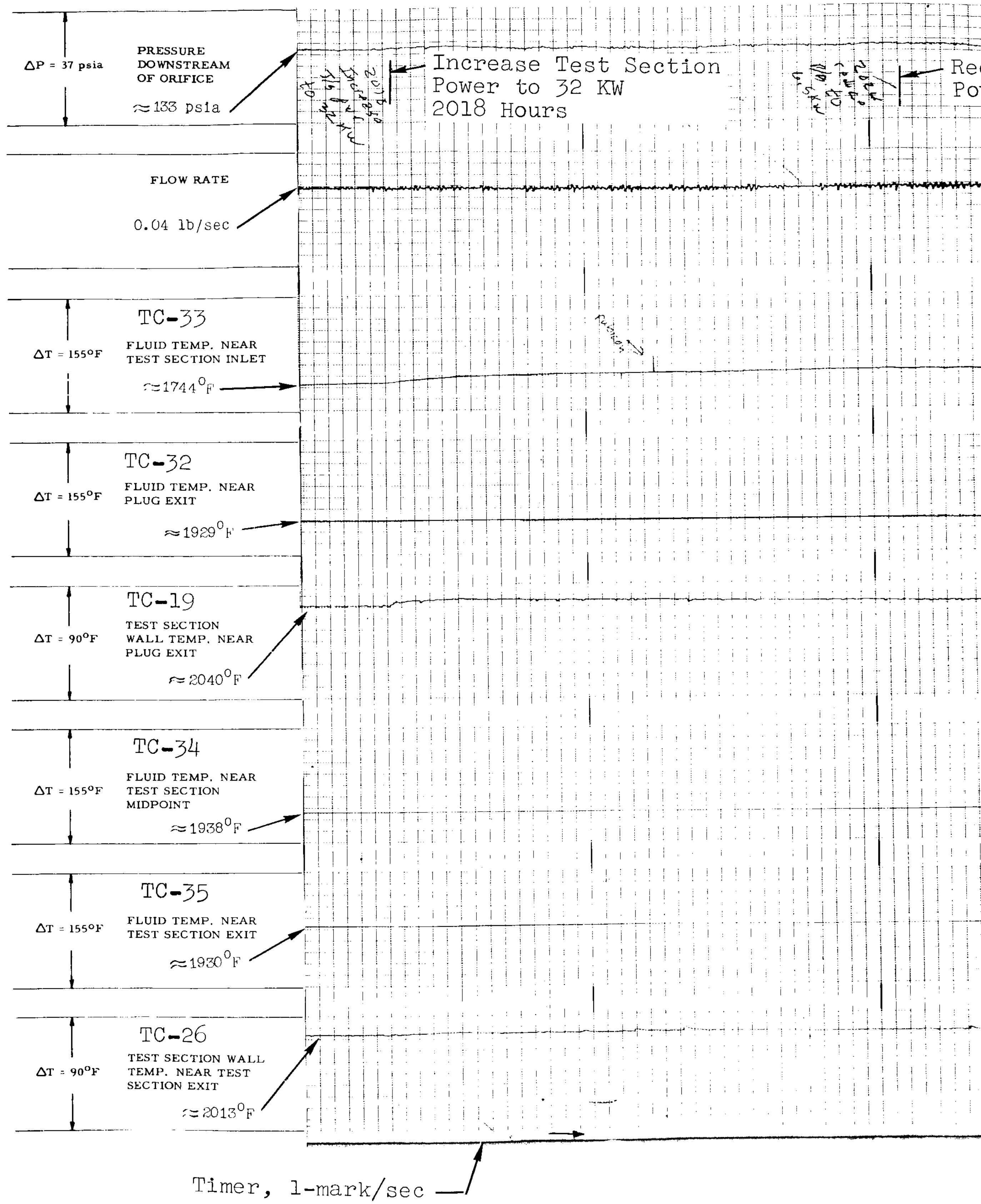


Figure 28d. Boiling Boun
100 KW F

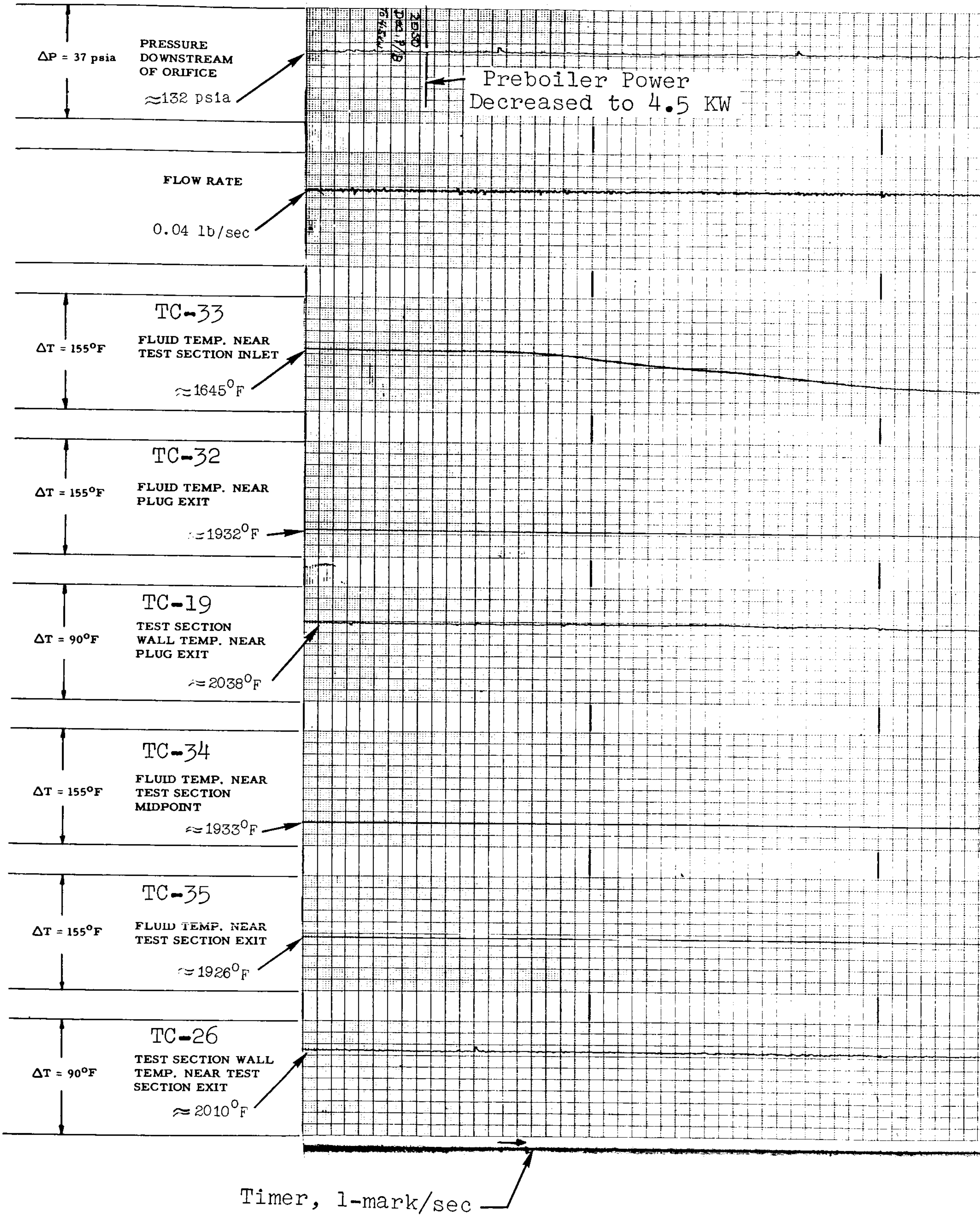
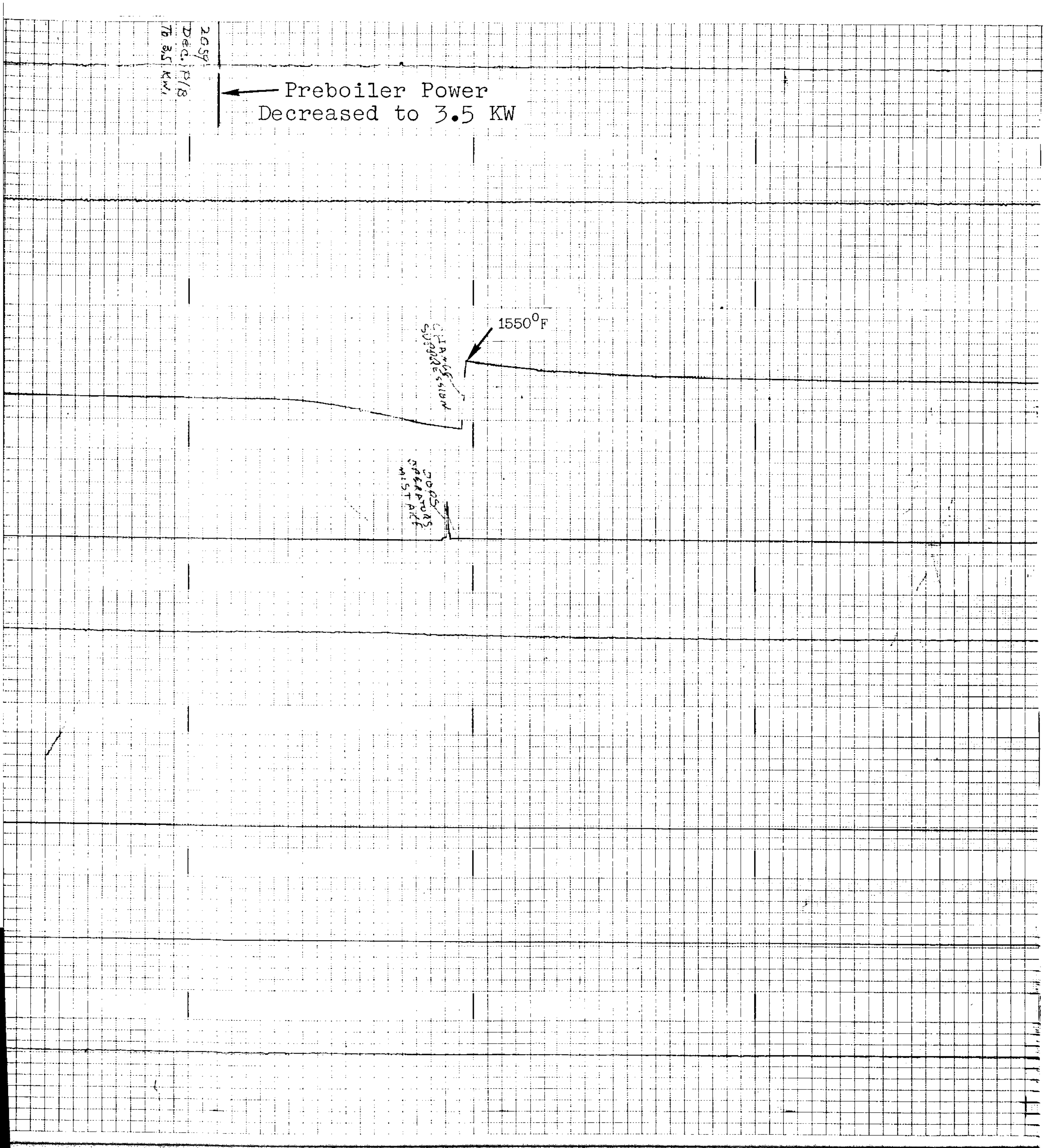


Figure 28e. Boiling Boun
100 KW Facil



q" = 182,000 Btu/hr-ft^2

dary Traversing Test (Test Section No. 4,
ty), Continued From Figure 28d.

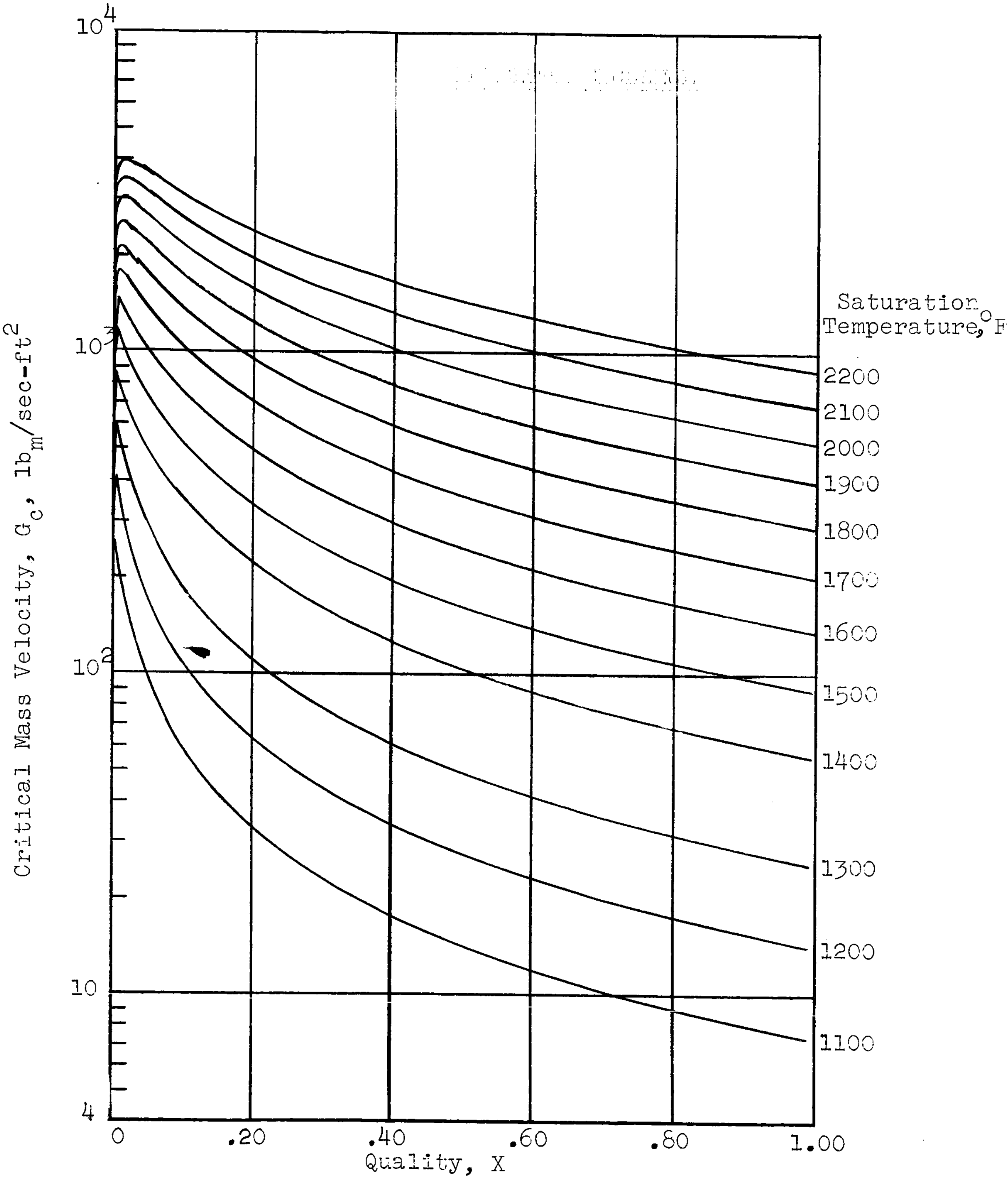


Figure 29. Critical Mass Velocity as a Function of Temperature and Quality(Levy Momentum Exchange Model, (Reference 7)

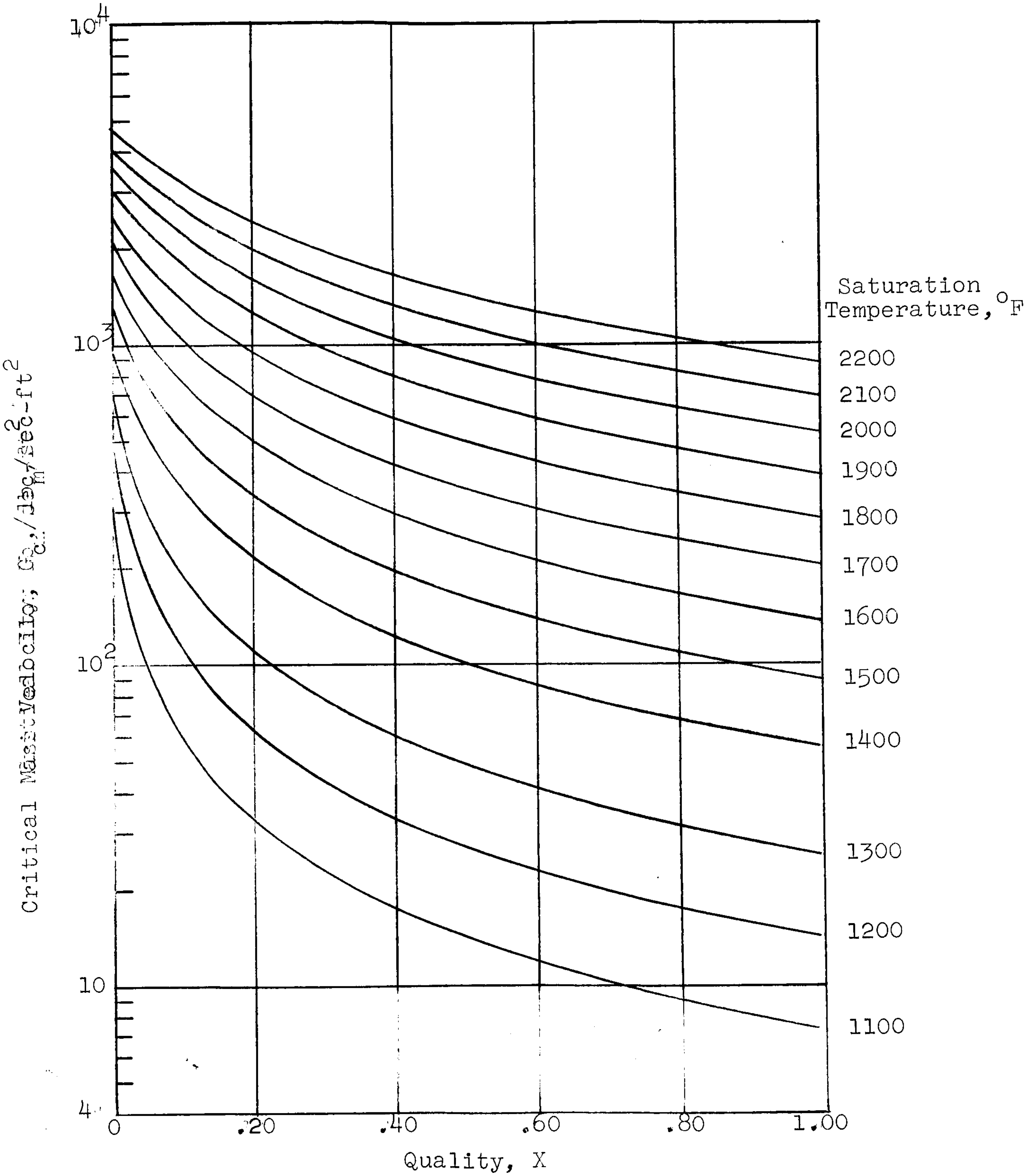


Figure 30 - Critical Mass Velocity as a Function of Temperature and Quality (Fauske Model for Slip Ratio = $\sqrt{\rho_f/\rho_g}$, Reference 8)

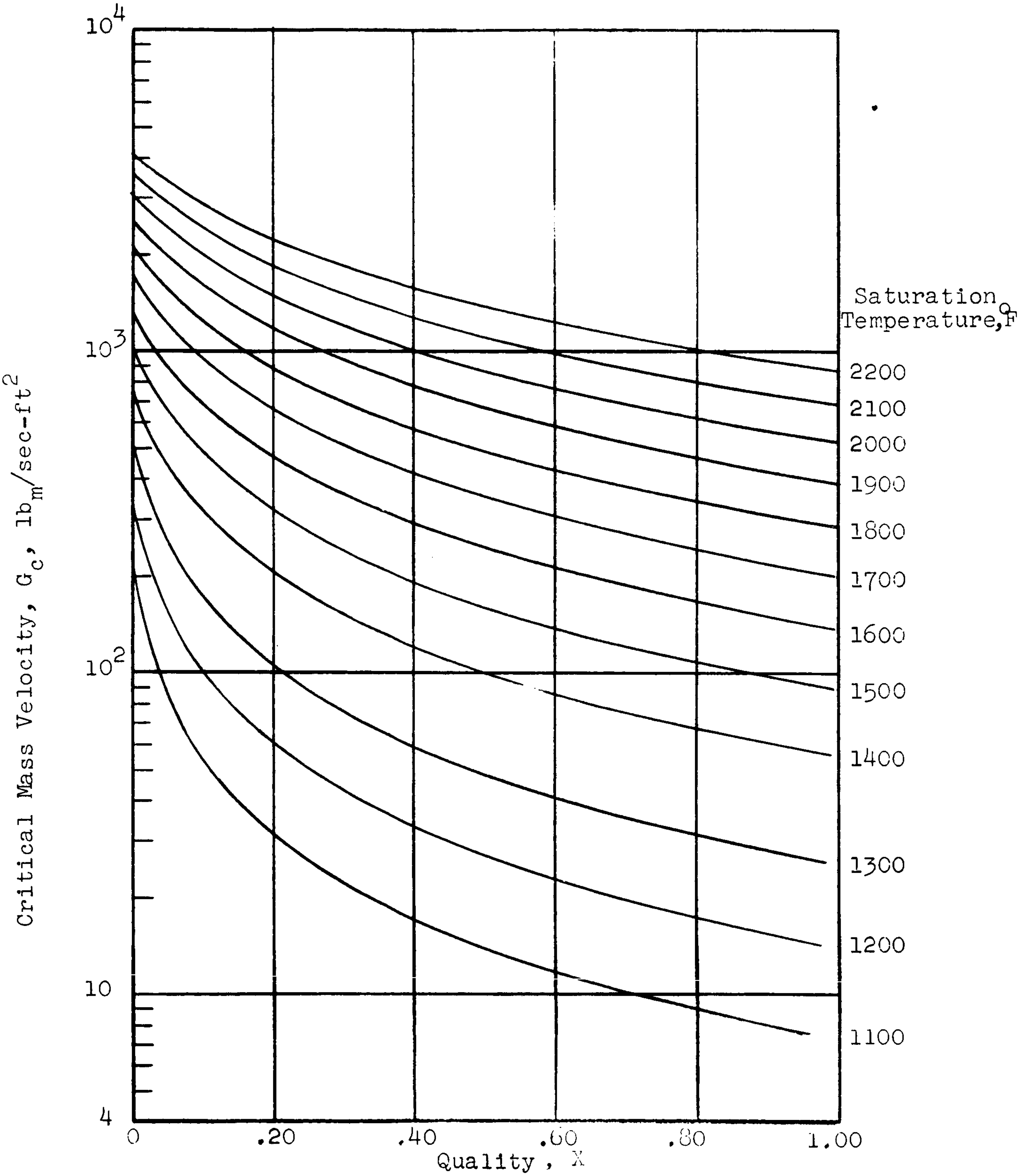


Figure 31 - Critical Mass Velocity as a Function of Temperature and Quality (Moody Model for Slip Ratio $=\sqrt[3]{\rho_f/\rho_g}$, Reference 9)

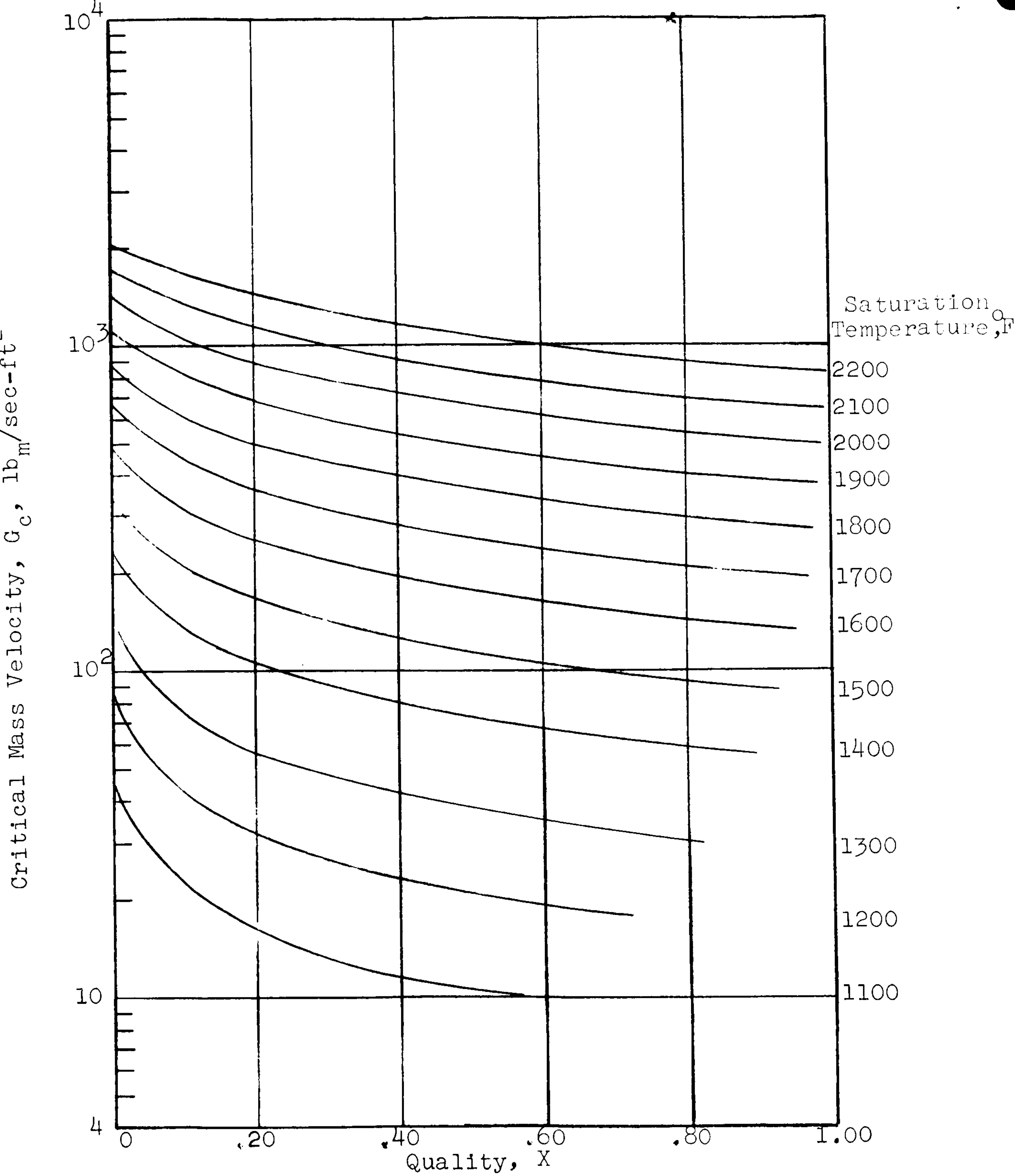


Figure 32 - Critical Mass Velocity as a Function of Temperature and Quality (Homogeneous Model, Slip Ratio = 1, Equation (2), Te...)

POWER BOILER THERMAL/HYDRAULIC DESIGN

TITLE= 7-TUBE BOILER. CASE 1-F

GEOMETRY

NT =	7	TUBE P/D =	1.30000
TUBE ID =	0.6900 INCHES	TUBE FLOW AREA =	0.018177 FT 2
TUBE OD =	0.7500 INCHES	INSERT P/D =	2.00
WALL XW =	0.0300 INCHES	SHELL ID =	2.709 INCHES
TUBE LTOT=	9.6543 FEET	SHELL FLOW AREA=	0.0185 FT 2
TUBE LB =	7.4808 FEET		
TUBE LSC =	0.9115 FEET		

THERMAL PARAMETERS

POWER KW	QTOT BTU/SEC	QB BTU/SEC	QSC BTU/SEC	Q/A BOILING BTU/FT2 HR
300.	284.34	248.67	32.46	94638.28

PRIMARY			SECONDARY		
TPIN =	1850.00	DEG F	TSIN =	1200.00	DEG F
TPOUT =	1750.18	DEG F	TSAT =	1749.08	DEG F
WP =	9.080	LBM/SEC	TSOUT =	1710.89	DEG F
GP =	489.645	LBM/FT2SEC	WS =	0.315	LBM/SEC
VP =	10.845	FT/SEC	GMAX =	37.343	LBM/FT2 SEC
REP =	180115.0		VMAX =	280.84	FT/SEC
PEP =	614.10		ACCL =	743367.47	FT/SEC2
HP =	13483.46	B/FT2HRDEG	ACCL/G =	85197.75	GEES
HWALL =	6837.90	B/FT2HRDEG	HSL =	847.59	B/FT2HR DEG
DELTAP =	2.455	PSIA	HB =	4000.00	B/FT2HR DEG
DPRIN =	0.	PSIA	REL =	12884.2	
DPROUT =	0.	PSIA	PEL =	52.85	
			UIL =	713.64	B/FT2HR DEG
			UIB =	2152.97	B/FT2HR DEG
			DELTAP =	8.866	PSIA
			DPFRIC =	6.192	PSIA
			DPMOM =	2.673	PSIA

SUPERHEAT REGION

QSUP BTU/SEC	HSUPS HR UNITS	TSUPS DEG F	TUBE LSUP FT	DPSUP PSI	DPSFRIC PSI	DPSMOM PSI
3.21	71.08	1750.00	1.2619	2.362	2.155	0.2062

Figure 33a - Typical Computer Printout from the Boiler Design Program

POWER BOILER THERMAL/HYDRAULIC DESIGN

TITLE= 7-TUBE BOILER. CASE 1-B

GEOMETRY

NT = 7		TUBE P/D = 1.30000
TUBE ID = 0.6900 INCHES		TUBE FLOW AREA = 0.018177 FT 2
TUBE OD = 0.7500 INCHES		INSERT P/D = 4.00
WALL XW = 0.0300 INCHES		SHELL ID = 2.709 INCHES
TUBE LTOT= 7.0434 FEET		SHELL FLOW AREA= 0.0185 FT 2
TUBE LB = 4.6559 FEET		
TUBE LSC = 0.6078 FEET		

THERMAL PARAMETERS

POWER KW	QTOT BTU/SEC	QB BTU/SEC	QSC BTU/SEC	Q/A BOILING BTU/FT2 HR
300.	284.34	250.10	30.56	152933.29

PRIMARY			SECONDARY		
TPIN =	1850.00	DEG F	TSIN =	1200.00	DEG F
TPOUT =	1750.18	DEG F	TSAT =	1717.10	DEG F
WP =	9.080	LBM/SEC	TSOUT =	1705.10	DEG F
GP =	489.645	LBM/FT2SEC	WS =	0.315	LBM/SEC
VP =	10.845	FT/SEC	GMAX =	25.500	LBM/FT2 SEC
REP =	180115.0		VMAX =	143.26	FT/SEC
PEP =	614.10		ACCL =	713808.62	FT/SEC2
HP =	13483.46	B/FT2HRDEG	ACCL/G =	22167.97	GEES
HWALL =	6819.52	B/FT2HRDEG	HSL =	849.10	B/FT2HR DEG
DELTAP =	1.791	PSIA	HB =	4000.00	B/FT2HR DEG
DPRIN =	0.	PSIA	REL =	12797.3	
DPROUT =	0.	PSIA	PEL =	51.93	
			UIL =	715.25	B/FT2HR DEG
			UIB =	2151.14	B/FT2HR DEG
			DELTAP =	2.643	PSIA
			DPFRIC =	1.371	PSIA
			DPMOM =	1.272	PSIA

SUPERHEAT REGION

QSUP BTU/SEC	HSUPS HR UNITS	TSUPS DEG F	TUBE LSUP FT	DPSUP PSI	DPSFRIC PSI	DPSMOM PSI
3.68	57.37	1750.00	1.7798	1.098	1.027	0.0709

Figure 33b - Typical Computer Printout from the Boiler Design Program

POWER BOILER THERMAL/HYDRAULIC DESIGN

TITLE= 7-TUBE BOILER. CASE 1-C

GEOMETRY

NT	=	7	TUBE P/D	=	1.30000
TUBE ID	=	0.6900 INCHES	TUBE FLOW AREA	=	0.018177 FT 2
TUBE OD	=	0.7500 INCHES	INSERT P/D	=	6.00
WALL XW	=	0.0300 INCHES	SHELL ID	=	2.709 INCHES
TUBE LTOT	=	7.0105 FEET	SHELL FLOW AREA	=	0.0185 FT 2
TUBE LB	=	4.4770 FEET			
TUBE LSC	=	0.5858 FEET			

THERMAL PARAMETERS

POWER KW	QTOT BTU/SEC	QB BTU/SEC	QSC BTU/SEC	Q/A BOILING BTU/FT2 HR
300.	284.34	250.26	30.30	159146.26

PRIMARY				SECONDARY			
TPIN	=	1850.00	DEG F	TSIN	=	1200.00	DEG F
TPOUT	=	1750.18	DEG F	TSAT	=	1712.86	DEG F
WP	=	9.030	LBM/SEC	TSOUT	=	1703.95	DEG F
GP	=	489.645	LBM/FT2SEC	WS	=	0.315	LBM/SEC
VP	=	10.845	FT/SEC	GMAX	=	22.637	LBM/FT2 SEC
REP	=	180115.0		VMAX	=	95.88	FT/SEC
PEP	=	614.10		ACCL	=	319781.24	FT/SEC2
HP	=	13483.46	B/FT2HRDEG	ACCL/G	=	9931.09	GEES
HWALL	=	6816.14	B/FT2HRDEG	HSL	=	849.40	B/FT2HR DEG
DELTAP	=	1.783	PSIA	HB	=	4000.00	B/FT2HR DEG
DPRIN	=	0.	PSIA	REL	=	12785.0	
DPROUT	=	0.	PSIA	PEL	=	51.80	
				UIL	=	715.50	B/FT2HR DEG
				UIB	=	2150.80	B/FT2HR DEG
				DELTAP	=	1.947	PSIA
				DPFRIC	=	0.940	PSIA
				DPMOM	=	1.006	PSIA

SUPERHEAT REGION

QSUP BTU/SEC	HSUPS HR UNITS	TSUPS DEG F	TUBE LSUP FT	DPSUP PSI	DPSFRIC PSI	DPSMOM PSI
3.77	53.66	175C.00	1.9478	0.850	0.798	0.0519

Figure 33c - Typical Computer Printout from the Boiler Design Program

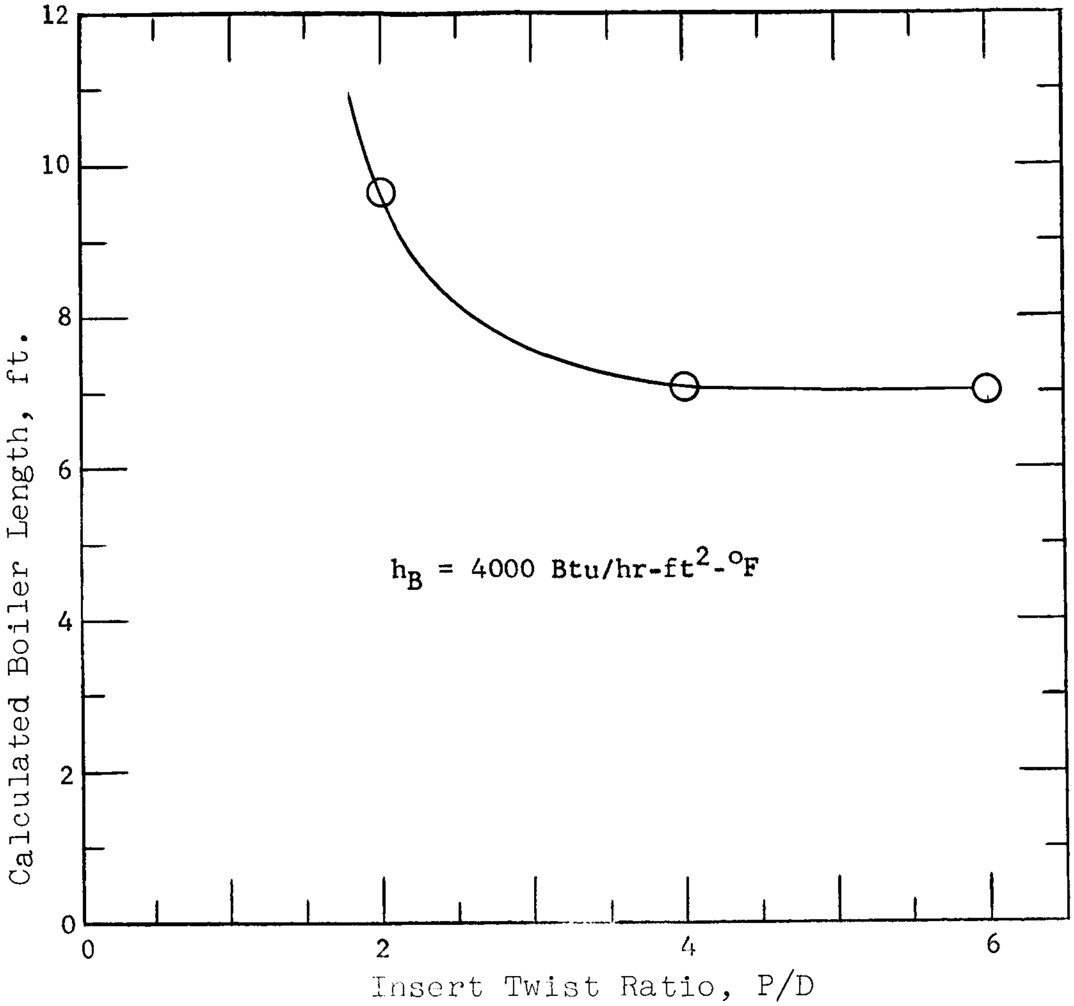


Figure 34. Boiler Length Vs. Helical Insert Twist Ratio As Calculated By Boiler Computer Program

CONDENSER DESIGN (GENERAL PARAMETERS)

TITLE= TEST CASE. POWER-150KW,HSHELL-CALC., TSAT-1300

GEOMETRY

NT	= 7	COND LENGTH	= 3.2188 FEET
TUBE ID	= 0.6250 INCHES	SUBC LENGTH	= 0.0492 FEET
TUBE OD	= 0.6650 INCHES	TOTL LENGTH	= 3.2680 FEET
WALL XW	= 0.0200 INCHES	TUBE P/D	= 1.30
TUBE FLOW AREA	= 0.01491 SQ FT	SHELL ID	= 2.402 INCHES
CENTER BODY OD	= 0. INCHES	SHELL FLOW AREA	= 0.0146 SQ FT

THERMAL PARAMETERS

POWER KW	QTOT,BTU/SEC	QCOND,BTU/SEC	QSUB,BTU/SEC
150.00	142.17	140.73	1.44

PRIMARY		SECONDARY	
TPIN	= 1190.00 DEG F	TSIN	= 1300.00 DEG F
TPOUT	= 1280.12 DEG F	TSATCE	= 1314.41 DEG F
WP	= 7.5000 LBM/SEC	TSOUT	= 1260.00 DEG F
GP	= 514.441 LBM/FT2SEC	WS	= 0.16515 LBM/SEC
VP	= -0.000 FT/SEC	GS	= 11.074 LBM/FT2SEC
REP	=149677.2	VMAX	= 572.906 FT/SEC
		HSL	= 1307.33 B/FT2HRDEG
		REL	= 6132.9
DPFRIC	= 1.102 PSIA	PEL	= 21.26
DPRAD	= 0. PSIA	UIL	= 980.41 B/FT2HRDEG
		DELTAP	= -0.754 PSIA
DPTOT	= 1.102 PSIA	DPFRIC	= 0.613 PSIA
		DPMOM	= -1.368 PSIA

Figure 35a - Typical Computer Printout from the Condenser Design Program.

CONDENSER DESIGN (LOCAL CONDITIONS) 1

TITLE= TEST CASE. POWER-150Kw,HSHELL-CALC., TSAT-1300

X	Z FT.	TSC DEG F	PLOCAL PSIA	TPC DEG F	HSC HR UNITS	HP HR UNITS	UI HR UNITS	Q B/SEC	QOA B/FT2 HR	REZ
1.00000	0.	1300.00	8.822	1280.12	30541.7	7780.2	3470.2	0.	69003.0	0.
0.99900	0.0064	1299.99	8.821	1280.03	34672.5	7780.2	3517.8	0.14	70231.8	6.2
0.99800	0.0128	1299.98	8.821	1279.94	34670.4	7780.3	3517.8	0.28	70513.8	12.4
0.99700	0.0192	1299.97	8.821	1279.85	34668.3	7780.3	3517.8	0.42	70796.3	18.5
0.99600	0.0255	1299.96	8.820	1279.76	34666.2	7780.3	3517.8	0.56	71079.3	24.7
0.99500	0.0318	1299.96	8.820	1279.67	34664.2	7780.3	3517.8	0.70	71362.7	30.9
0.99400	0.0382	1299.95	8.819	1279.58	34662.1	7780.4	3517.7	0.85	71646.7	37.1
0.99300	0.0444	1299.94	8.819	1279.49	34660.1	7780.4	3517.7	0.99	71931.0	43.3
0.99200	0.0507	1299.93	8.818	1279.40	34658.1	7780.4	3517.7	1.13	72215.8	49.4
0.99100	0.0570	1299.92	8.818	1279.31	34656.1	7780.4	3517.7	1.27	72501.2	55.6
0.99000	0.0632	1299.92	8.818	1279.22	34654.1	7780.5	3517.7	1.41	72786.9	61.8
0.98800	0.0756	1299.90	8.817	1279.05	34650.2	7780.5	3517.6	1.69	73359.8	74.2
0.98600	0.0980	1299.89	8.816	1278.87	34646.3	7780.5	3517.6	1.97	73934.4	86.5
0.98400	0.1003	1299.87	8.815	1278.69	34642.5	7780.6	3517.6	2.25	74510.9	98.9
0.98200	0.1125	1299.86	8.815	1278.51	34556.7	7780.6	3516.7	2.54	75070.9	111.2
0.98000	0.1246	1299.85	8.814	1278.33	34468.4	7780.7	3515.8	2.82	75631.7	123.6
0.97600	0.1487	1299.82	8.813	1277.98	34306.4	7780.8	3514.1	3.38	76760.9	148.3
0.97200	0.1725	1299.80	8.812	1277.62	34159.9	7780.9	3512.6	3.94	77898.6	173.0
0.96800	0.1961	1299.78	8.811	1277.26	34025.4	7781.0	3511.2	4.51	79044.5	197.7
0.96400	0.2194	1299.76	8.810	1276.91	33881.5	7781.1	3509.7	5.07	80193.4	222.4
0.96000	0.2424	1299.74	8.809	1276.55	33744.2	7781.1	3508.2	5.63	81348.7	247.1
0.95200	0.2878	1299.71	8.807	1275.84	33490.5	7781.3	3505.5	6.76	83679.6	296.6
0.94400	0.3322	1299.69	8.806	1275.13	33218.3	7781.5	3502.5	7.89	86024.2	346.0
0.93600	0.3758	1299.67	8.805	1274.41	32961.0	7781.7	3499.7	9.01	88390.3	395.4
0.92800	0.4184	1299.66	8.805	1273.70	32718.4	7781.9	3497.0	10.14	90777.3	444.8
0.92000	0.4603	1299.65	8.804	1272.99	32488.4	7782.1	3494.3	11.27	93183.8	494.3
0.90400	0.5417	1299.66	8.805	1271.56	32059.0	7782.4	3489.4	13.52	98051.7	593.1
0.88800	0.6202	1299.69	8.806	1270.14	31643.3	7782.8	3484.5	15.78	102979.7	692.0
0.87200	0.6961	1299.74	8.808	1268.71	31252.8	7783.2	3479.8	18.03	107966.9	790.9
0.85600	0.7695	1299.80	8.812	1267.28	30861.3	7783.6	3474.9	20.28	112998.2	889.8
0.84000	0.8406	1299.88	8.816	1265.86	30485.6	7783.9	3470.2	22.54	118076.3	988.7
0.80800	0.9766	1300.09	8.826	1263.00	29723.2	7784.7	3460.2	27.04	128329.3	1186.5
0.77600	1.1053	1300.35	8.840	1260.15	29003.2	7785.4	3450.4	31.55	138713.2	1384.5
0.74400	1.2277	1300.66	8.855	1257.30	28316.7	7786.1	3440.6	36.06	149200.7	1582.5
0.71200	1.3444	1301.01	8.873	1254.44	27655.5	7786.9	3430.8	40.56	159768.1	1780.7
0.68000	1.4562	1301.40	8.893	1251.59	27013.6	7787.6	3420.8	45.07	170394.1	1979.0
0.61600	1.6673	1302.27	8.937	1245.88	26093.5	7789.1	3405.9	54.08	192055.7	2375.9
0.55200	1.8636	1303.25	8.988	1240.17	25086.9	7790.6	3388.4	63.09	213737.5	2773.3
0.48800	2.0491	1304.32	9.043	1234.46	23790.1	7792.1	3363.9	72.10	234789.4	3171.3
0.42400	2.2239	1305.47	9.102	1228.75	22264.1	7793.6	3331.8	81.11	255598.2	3569.9
0.36000	2.3914	1306.67	9.165	1223.04	20728.1	7795.1	3295.6	90.11	275614.1	3969.1
0.29600	2.5512	1307.94	9.232	1217.33	19484.0	7796.5	3262.7	99.11	295632.7	4369.0
0.23200	2.7050	1309.26	9.301	1211.62	18171.9	7798.0	3223.9	108.11	314781.1	4769.6
0.16800	2.8536	1310.62	9.373	1205.91	16675.4	7799.5	3173.6	117.11	332324.8	5170.9
0.10400	2.9969	1312.03	9.448	1200.20	14818.7	7801.0	3100.0	126.11	346677.7	5572.9
0.04000	3.1363	1313.48	9.526	1194.49	12771.7	7802.5	2999.6	135.10	356934.3	5975.6
0.	3.2188	1314.41	9.576	1190.92	12230.8	7803.5	2968.9	140.73	36[illegible]56.5	6227.7

Figure 35b - Typical Computer Printout from the Condenser Design Program

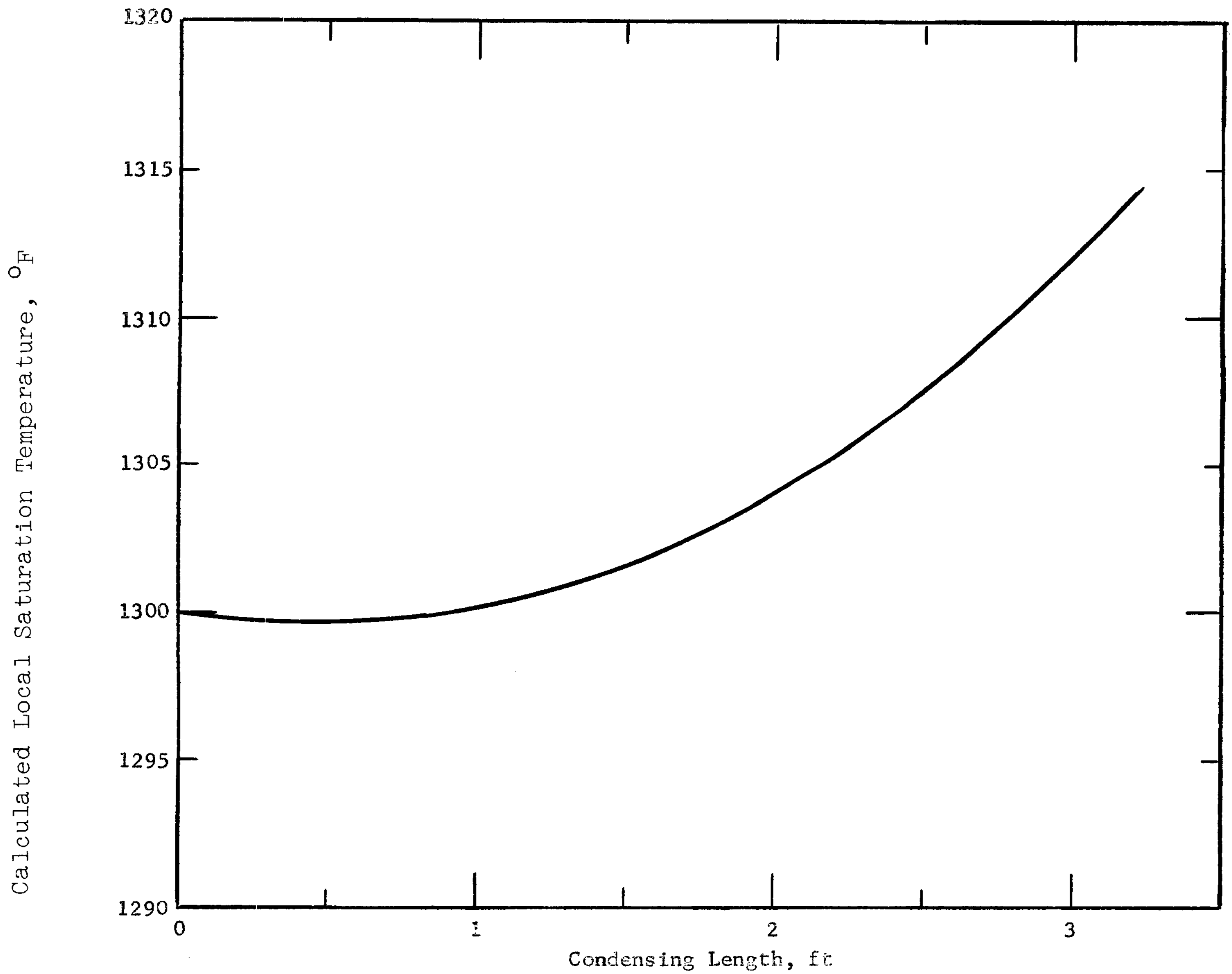


Figure 36. Typical Saturation Temperature Distribution With Length In Condenser A_S Calculated By Condenser Computer Program

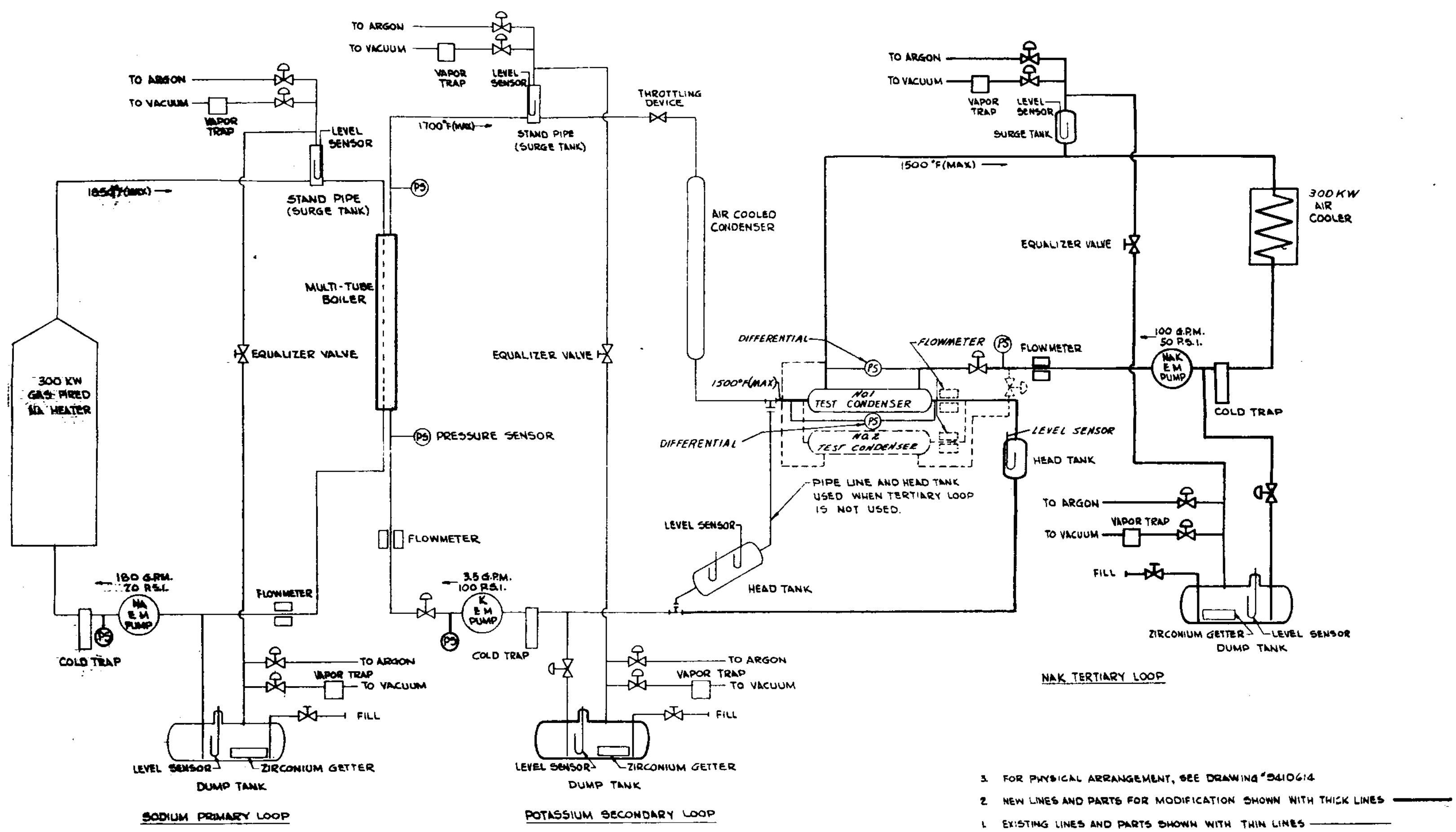
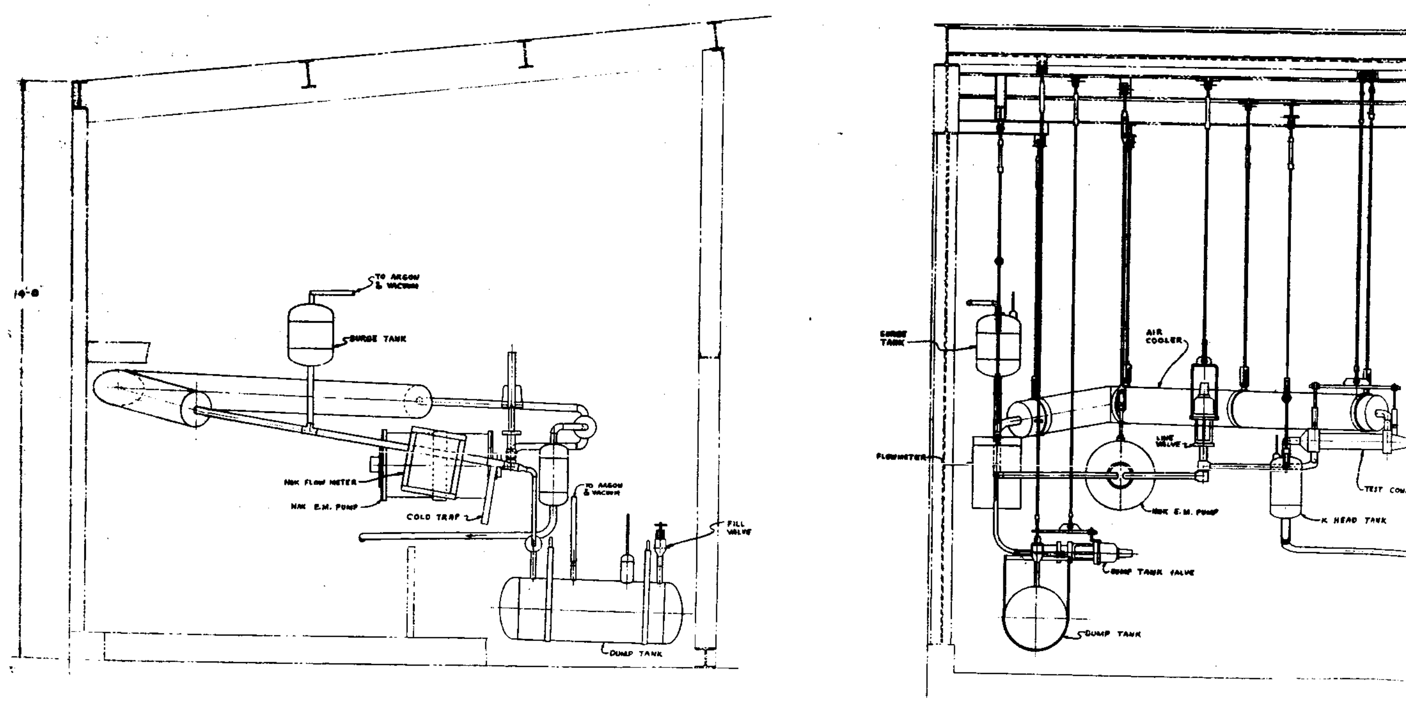


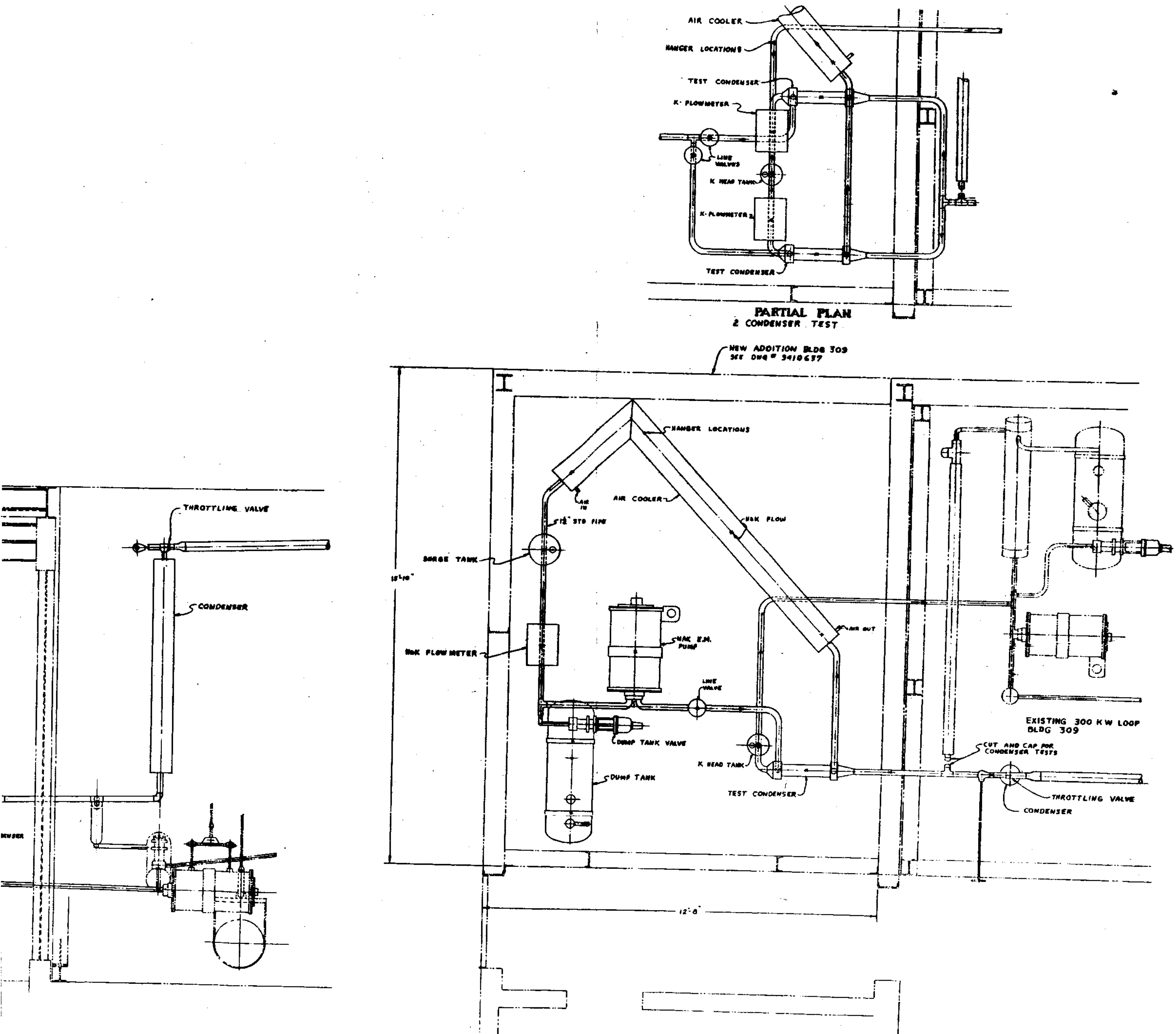
Figure 37. Flow Diagram For Proposed 300 KW Facility Modification For Testing Multiple Tube Condensers



SIDE ELEVATION
LOOKING NORTH

ELEVATION
LOOKING WEST

Figure 38. Tertiary Loop Arrangeme



PLAN
NGLE CONDENSER TEST

nt For Proposed 300 KW Facility Modification.

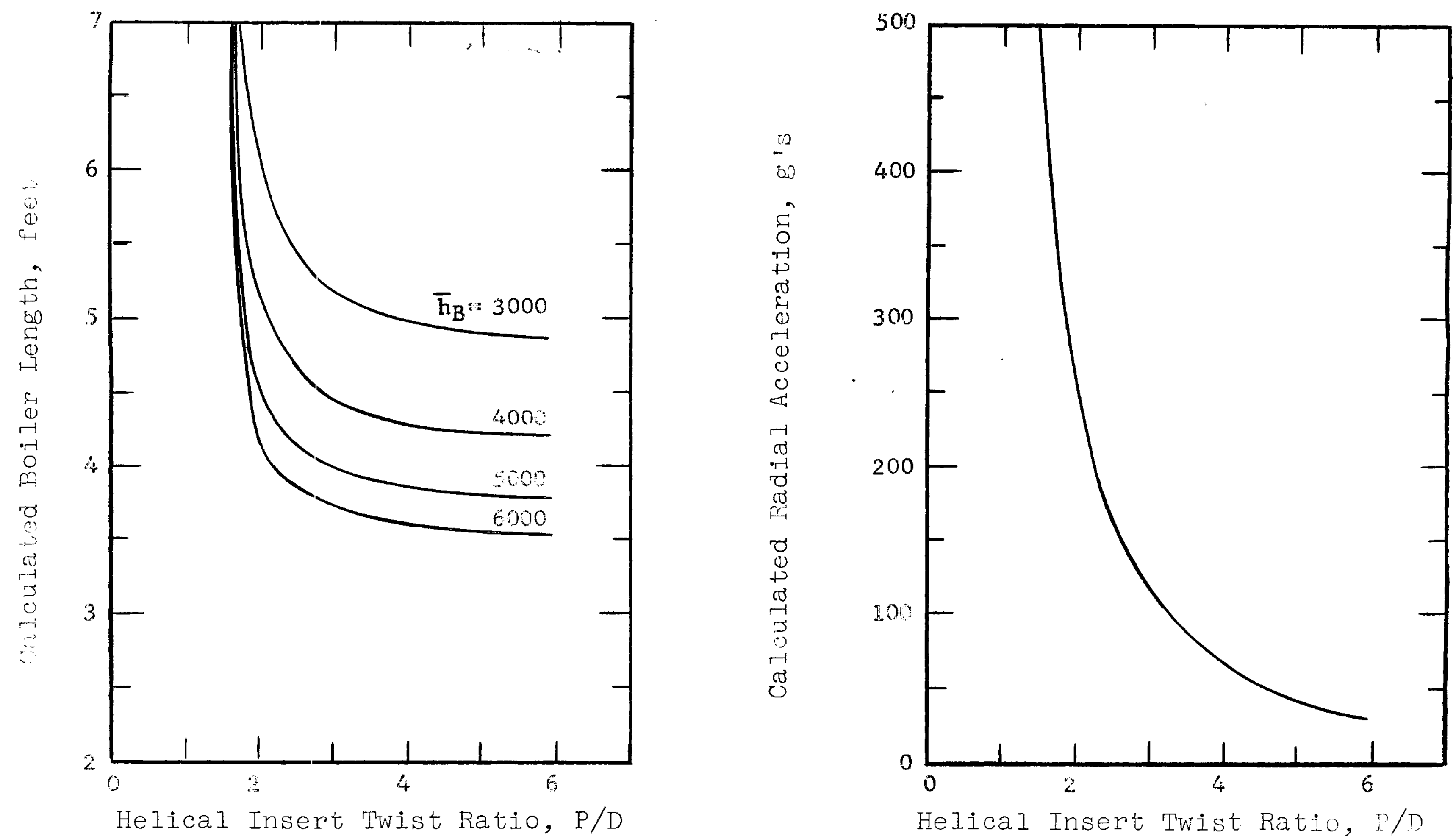


Figure 39. Boiler Length and Fluid Radial Acceleration For Proposed 300 KW Facility Boiler As Calculated By Boiler Computer Program

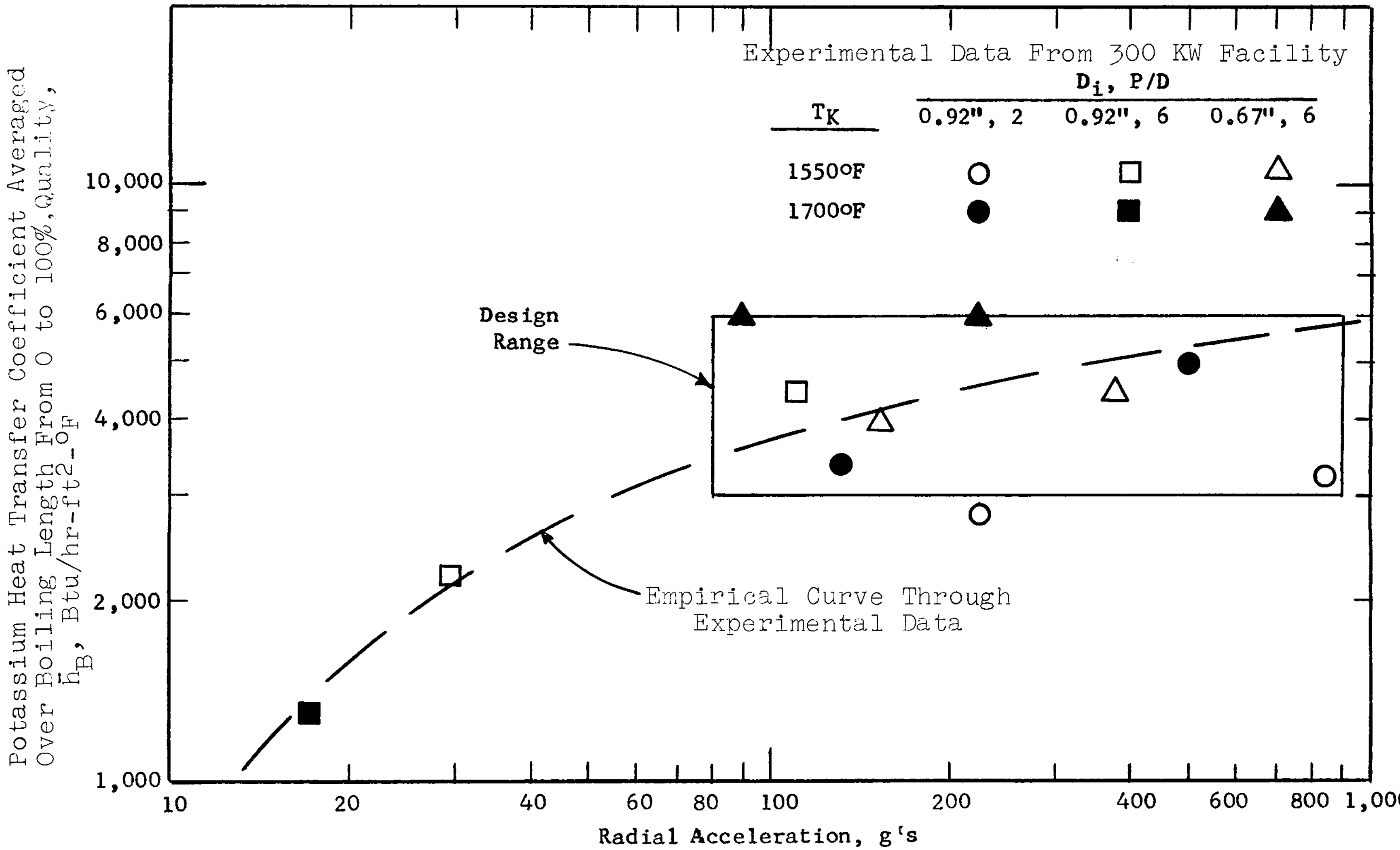


Figure 40. Potassium Heat Transfer Coefficients Averaged Over Boiling Length From 0 to 100% Quality As Function of Radial Acceleration Developed By Helical Insert (Data From 300 KW Facility)

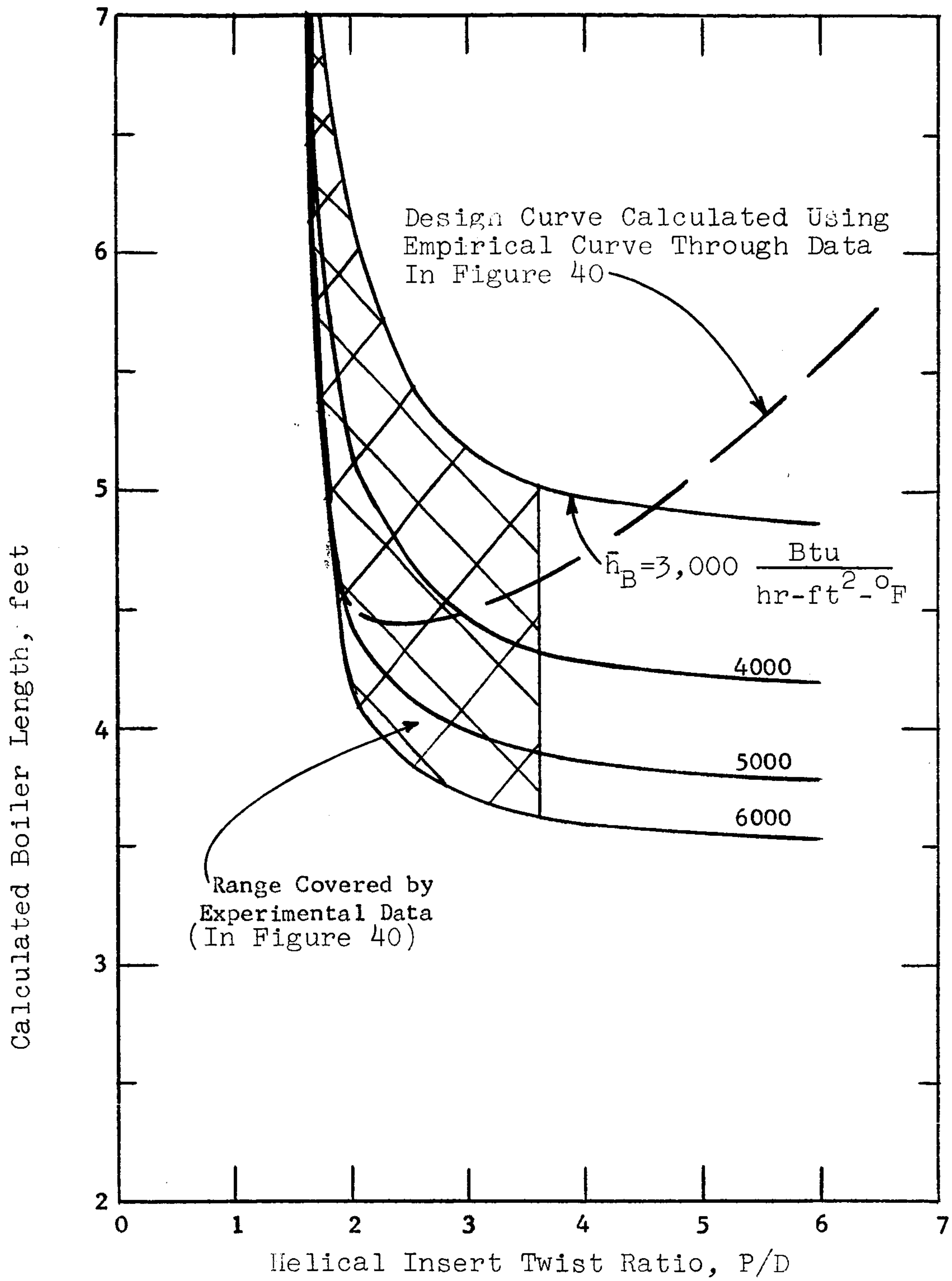


Figure 41. Thermal Design Curves For Proposed 300 KW Facility Boiler Showing Boiler Length As Function of Helical Insert Twist Ratio And Average Potassium Boiling Heat Transfer Coefficient Showing Optimization of Insert Twist Ratio.

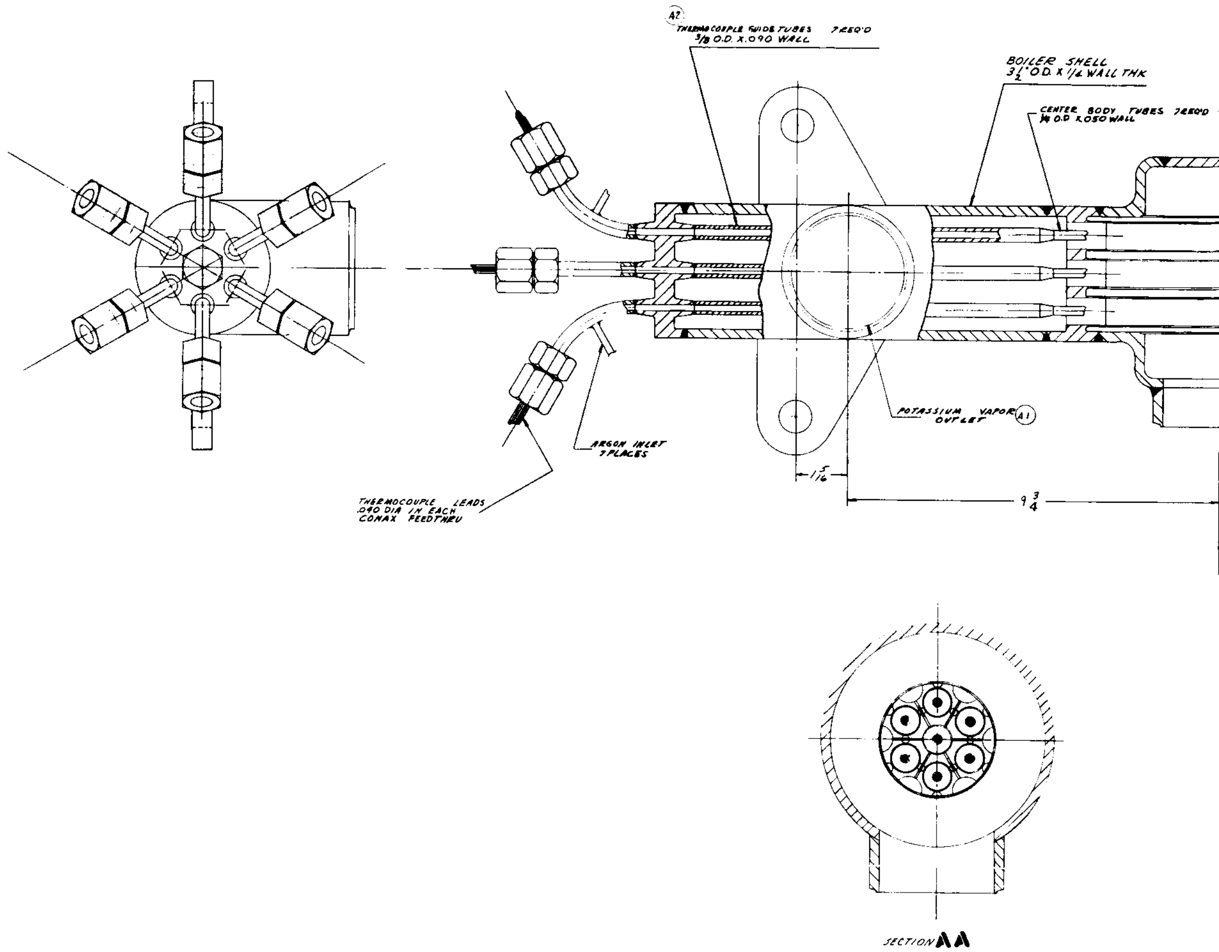
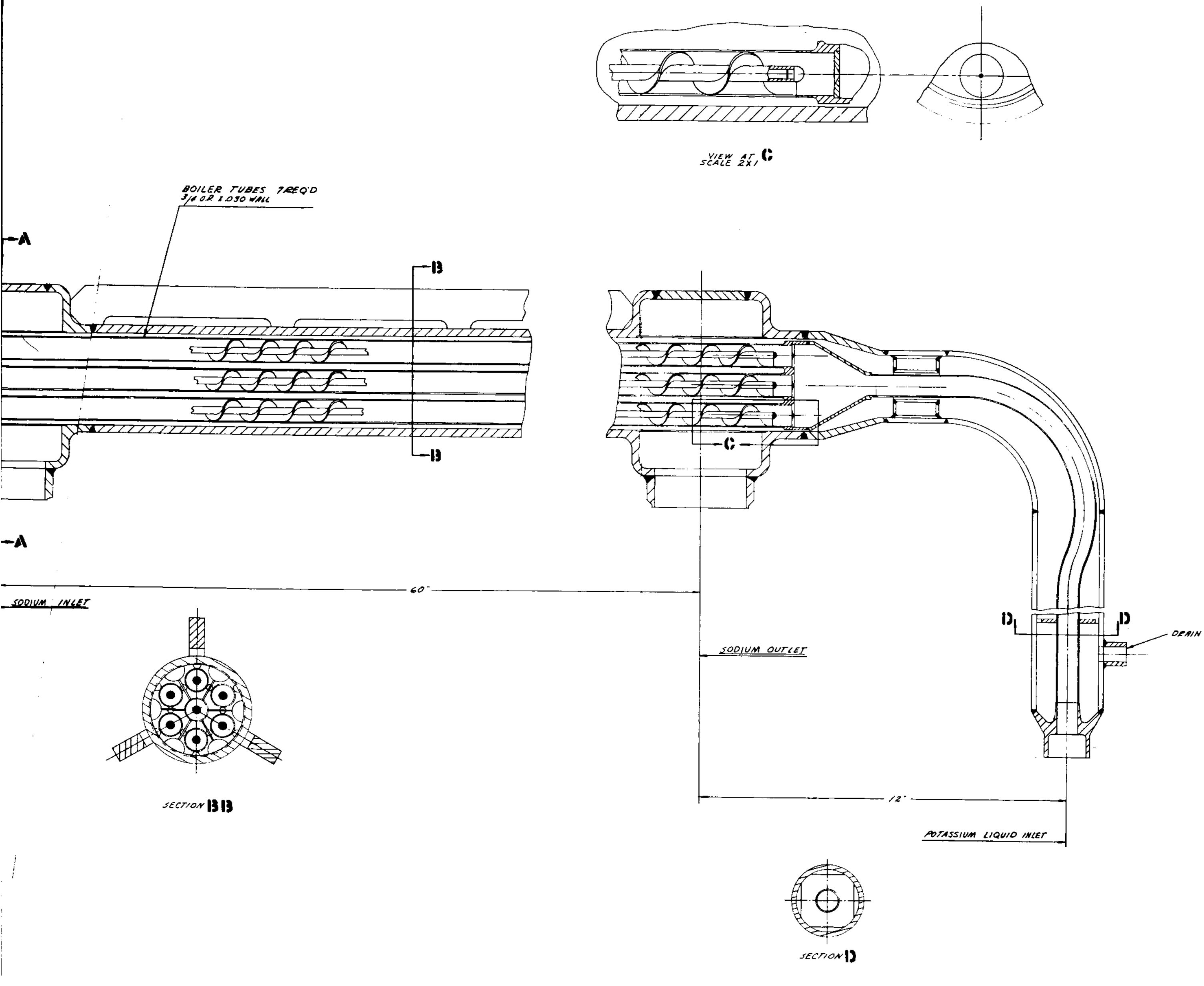


Figure 42. Assembly Drawi
300 KW Facilit
Tube Condenser

177D



ng Of Facility Boiler For Proposed
y Modification For Testing Multiple
s

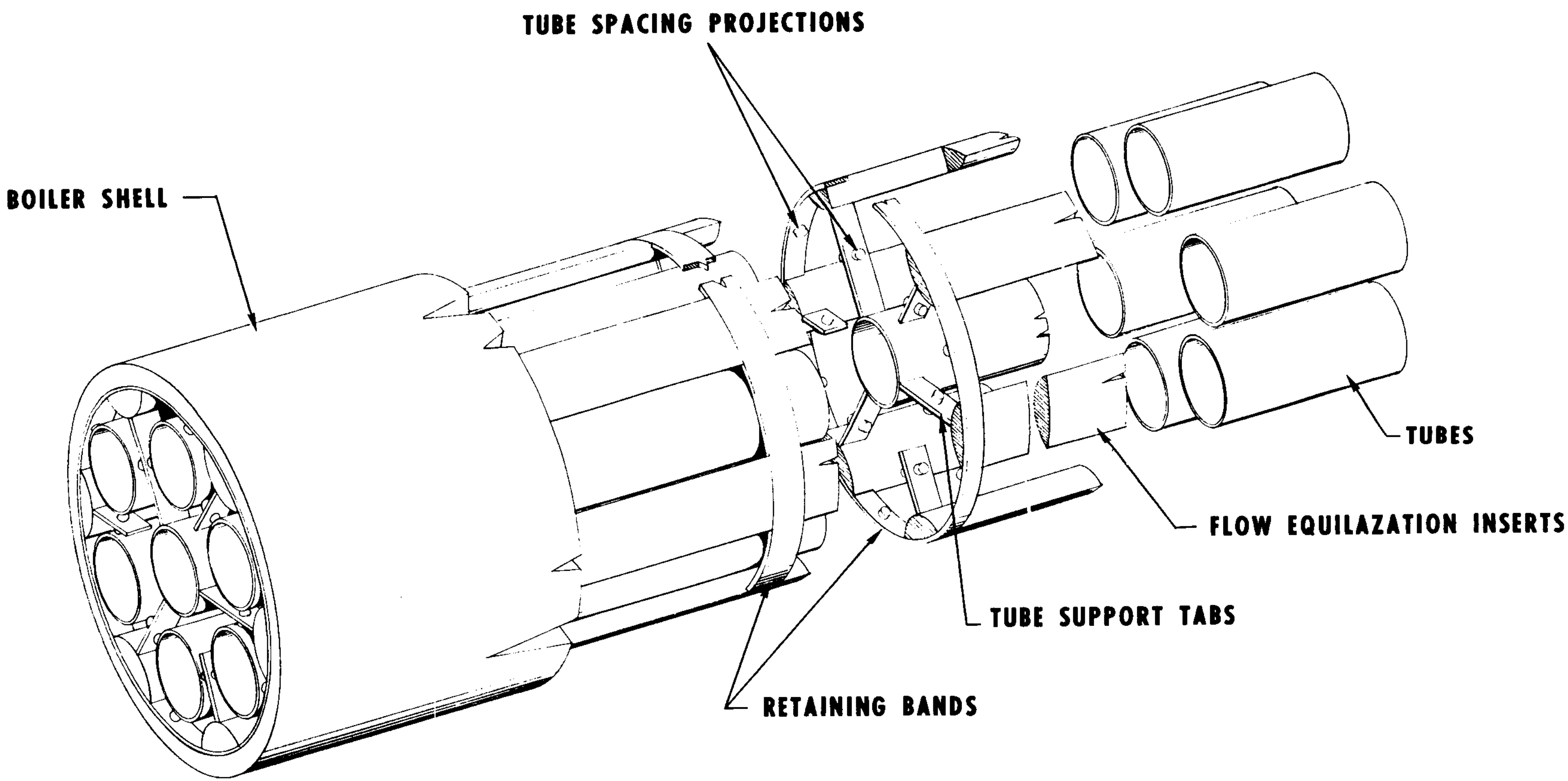


Figure 43. Exploded View Of Tube Bundle - 300 KW Facility Boiler

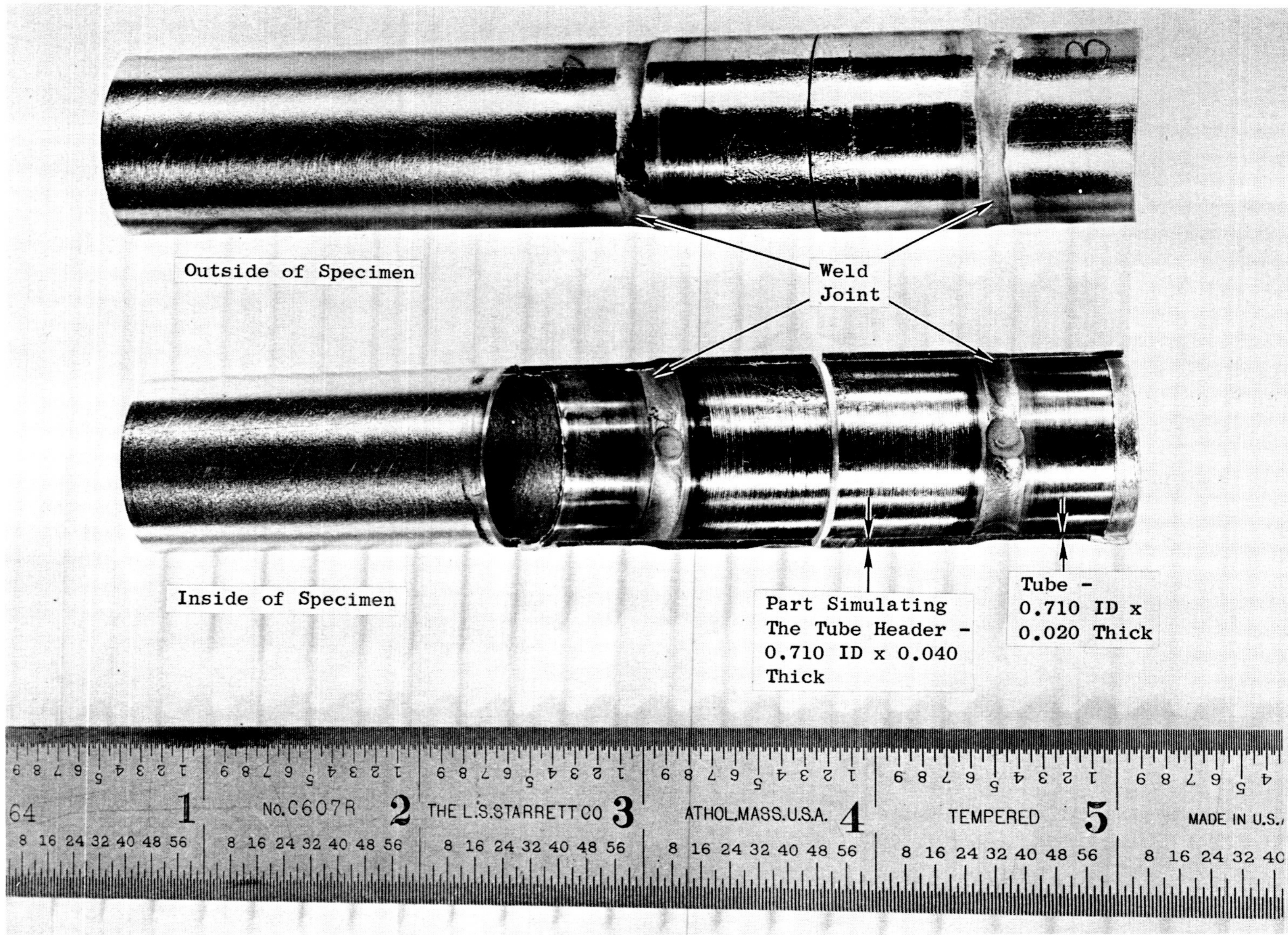


Figure 44 - Specimen of Internal Tube to Header Weld with L-605 Material

APPENDIX A

100 KW BOILING DATA

TABLE A-1

100 KW LOOP TEST SECTION INSTRUMENTATION FOR DATA TAKEN BETWEEN 5-10-65 AND 5-14-65
(Data Tabulated In Table A-3)

T/C No.	Location	Distance Inches
	Start of Heated Zone	14 1/2
31	Insert Thermocouple	16 7/16
17	Test Section Wall	16 7/16
18	Test Section Wall	16 7/16
32	Insert Thermocouple	26 13/16
19	Test Section Wall	26 13/16
20	Test Section Wall	26 13/16
21	Test Section Wall	26 13/16
33	Insert Thermocouple	30 1/16
22	Test Section Wall	30 1/16
15	Test Section Wall	30 1/16
34	Insert Thermocouple	35 3/8
23	Test Section Wall	35 3/8
24	Test Section Wall	35 3/8
35	Insert Thermocouple	40 11/16
25	Test Section Wall	40 11/16
26	Test Section Wall	40 11/16
27	Test Section Wall	40 11/16
16	Test Section Wall	40 11/16
	End of Heated Zone	44 1/2

Test Section I.D. = 0.738 inches, with Instrumented Plug-Helical Insert

Test Section Arrangement

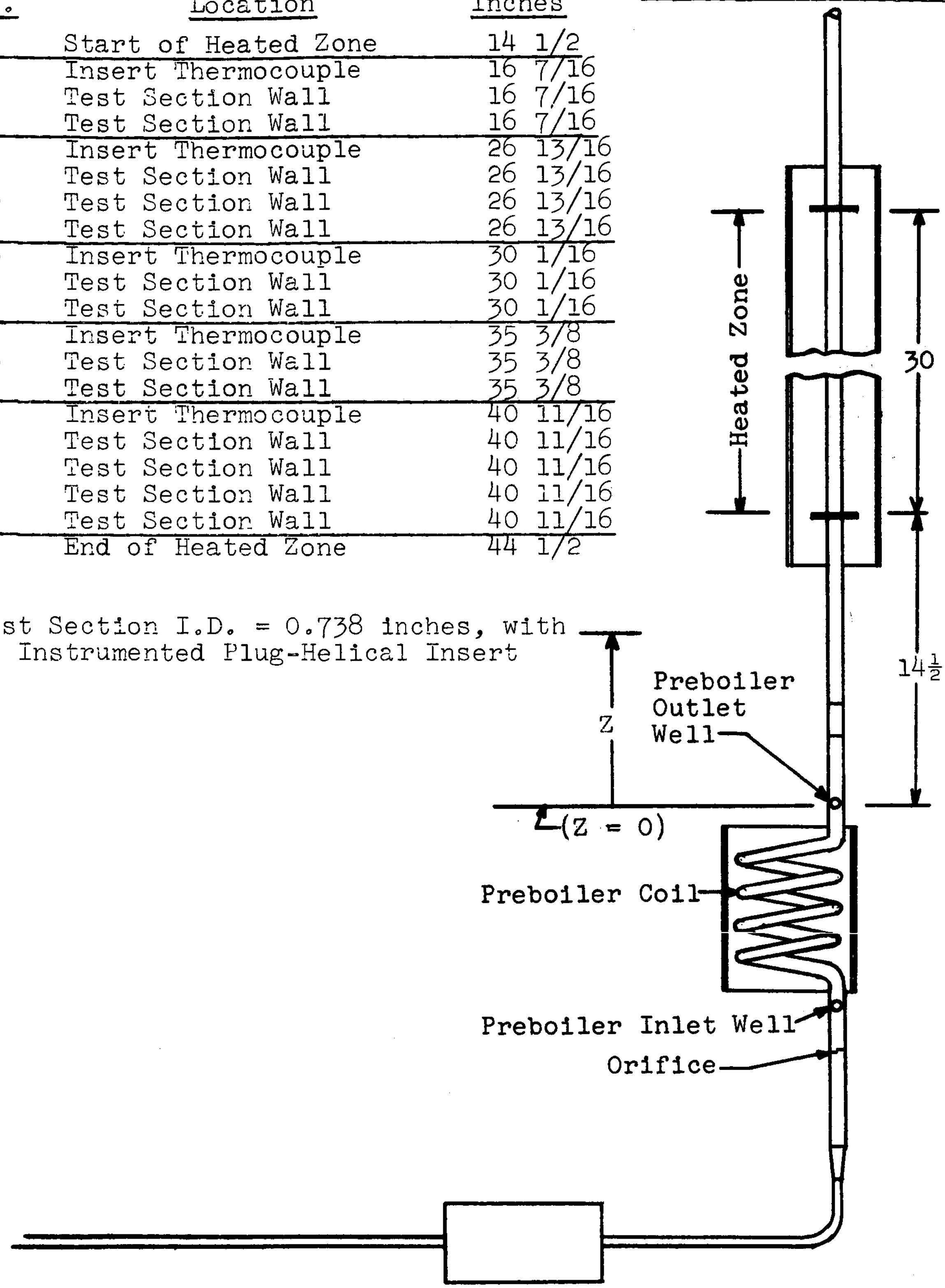


TABLE A-2

100 KW BOILING DATA .738-INCH TUBE, WITH INSTRUMENTED PLUG-HELICAL INSERT

(Key to Table A-3)

Col No.	Heading	Description
244	DATE	(e.g., 5.1050 + 03 = 5-10-65)
245	TIME	(e.g., 5.4200 + 02 = 0542)
271	TK FM	Fluid temperature at flowmeter, ^{o}F
278,285	TPB IN	Fluid temperature at preboiler inlet, ^{o}F
292-341	PBC N	Preboiler coil temperature, ^{o}F
350,359	TPBOUT	Fluid temperature at preboiler outlet, ^{o}F
368-476	TWO N	Test section outside pipe wall temperature, ^{o}F
485-521	INS N	Fluid temperature at insert thermocouple N, ^{o}F
554-584	CND N	Condenser temperature at N, ^{o}F
686	MAGNET	Flowmeter magnet temperature, ^{o}F
707-712	PBRADS	Preboiler radiation shield temperature, ^{o}F
713-720	TSRADS	Test section radiation shield temperature, ^{o}F
769	QN PB	Net preboiler power, KW
775	QN TS	Net test section power, KW
779	Q/A TS	T/S heat flux, $Btu/hr\text{-}ft^2$
801	FLOW	Flow rate, lb/sec
803	G	Mass velocity, $lb/sec\text{-}ft^2$
813	X PB	Preboiler exit quality
820	X TS	Test section exit quality
839-851	X N	Quality at insert thermocouple N
1054,1075, 1089	TWI N	Inside wall temperature at N, ^{o}F
1055,1076 1090	DT N	(TWI N) - (INS N), ^{o}F
1056,1077, 1091	H N	$\frac{Q/A}{DT\ N}$, $Btu/hr\text{-}ft^2\text{-}^{o}F$

Table A-3

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	244	245	271	278	285	292
	DATE	TIME	TK FM	TPB IN	TPB IN	PBC 5
1	5.1050+03	5.4200+02	1.0979+03	1.1104+03	1.1063+03	1.2290+03
2	5.1050+03	8.4500+02	1.1156+03	1.1286+03	1.1244+03	1.2902+03
3	5.1050+03	1.2100+03	1.1395+03	1.1536+03	1.1492+03	1.3477+03
4	5.1050+03	1.8130+03	1.1656+03	1.1815+03	1.1765+03	1.4119+03
5	5.1050+03	2.2200+03	1.1904+03	1.2088+03	1.2022+03	1.5126+03
6	5.1150+03	4.3000+01	1.2304+03	1.2498+03	1.2424+03	1.6061+03
7	5.1150+03	2.1500+02	1.1056+03	1.1181+03	1.1081+03	1.2305+03
8	5.1150+03	3.2000+02	1.2597+03	1.2783+03	1.2723+03	1.6589+03
9	5.1150+03	6.2400+02	1.3188+03	1.3388+03	1.3314+03	1.7687+03
10	5.1150+03	9.2000+02	1.3783+03	1.3977+03	1.3913+03	1.8730+03
11	5.1150+03	1.4300+03	1.4311+03	1.4331+03	1.4437+03	1.9378+03
12	5.1250+03	5.1200+02	1.1237+03	1.1373+03	1.1274+03	1.2836+03
13	5.1250+03	8.0000+02	1.1507+03	1.1653+03	1.1556+03	1.3429+03
14	5.1250+03	1.0450+03	1.1705+03	1.1865+03	1.1768+03	1.3985+03
15	5.1250+03	1.4000+03	1.1931+03	1.2107+03	1.2004+03	1.4571+03
16	5.1350+03	1.2000+02	1.2314+03	1.2493+03	1.2391+03	1.5350+03
17	5.1350+03	4.2000+02	1.2447+03	1.2628+03	1.2524+03	1.5669+03
18	5.1350+03	6.4000+02	1.2698+03	1.2886+03	1.2778+03	1.6187+03
19	5.1350+03	1.8100+03	1.2913+03	1.3108+03	1.2992+03	1.6529+03
20	5.1350+03	2.0250+03	1.3488+03	1.3683+03	1.3560+03	1.7437+03
21	5.1350+03	2.2150+03	1.4077+03	1.4264+03	1.4144+03	1.8242+03
22	5.1450+03	1.5000+02	1.4636+03	1.4818+03	1.4701+03	1.8993+03
23	5.1450+03	4.4500+02	1.5203+03	1.5364+03	1.5254+03	1.9802+03
24	5.1450+03	9.1500+02	1.6191+03	1.8268+03	1.7880+03	2.1700+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	299	306	313	320	341	350
	PBC 6	PBC 7	PBC 8	PBC 9	PBC 12	TPBOUT
1	1.3154+03	1.3830+03	1.4766+03	1.5088+03	1.6121+03	1.6261+03
2	1.4068+03	1.4986+03	1.6256+03	1.6696+03	1.8013+03	1.8184+03
3	1.4952+03	1.6085+03	1.7621+03	1.8154+03	1.9626+03	1.9818+03
4	1.5881+03	1.7217+03	1.8980+03	1.9583+03	2.1140+03	2.0981+03
5	1.7152+03	1.8862+03	2.0896+03	2.1577+03	2.0893+03	2.1073+03
6	1.8208+03	2.0142+03	2.1458+03	2.1457+03	2.0892+03	2.1047+03
7	1.3062+03	1.3803+03	1.4803+03	1.5206+03	1.6331+03	1.6468+03
8	1.8956+03	2.0939+03	2.1489+03	2.1515+03	2.0931+03	2.1069+03
9	2.0241+03	2.2157+03	2.1597+03	2.1626+03	2.0961+03	2.1079+03
10	2.1208+03	2.1740+03	2.1666+03	2.1615+03	2.1079+03	2.1139+03
11	2.2039+03	2.1767+03	2.1655+03	2.1671+03	2.1102+03	2.1102+03
12	1.3836+03	1.4807+03	1.6128+03	1.6640+03	1.8047+03	1.8219+03
13	1.4700+03	1.5927+03	1.7538+03	1.8142+03	1.9716+03	1.9910+03
14	1.5559+03	1.7040+03	1.8945+03	1.9640+03	2.1267+03	2.1022+03
15	1.6368+03	1.8043+03	2.0110+03	2.0819+03	2.0774+03	2.0958+03
16	1.7374+03	1.9166+03	2.1265+03	2.1511+03	2.0842+03	2.1003+03
17	1.7839+03	1.9731+03	2.1524+03	2.1466+03	2.0927+03	2.1087+03
18	1.8489+03	2.0467+03	2.1416+03	2.1455+03	2.0913+03	2.1055+03
19	1.8953+03	2.0960+03	2.1533+03	2.1620+03	2.1023+03	2.1145+03
20	1.9933+03	2.1953+03	2.1586+03	2.1665+03	2.1654+03	2.1112+03
21	2.0801+03	2.1835+03	2.1647+03	2.1698+03	2.1087+03	2.1150+03
22	2.1725+03	2.1814+03	2.1723+03	2.1703+03	2.1111+03	2.1137+03
23	2.2428+03	2.1864+03	2.1641+03	2.1671+03	2.1090+03	2.1096+03
24	2.1832+03	2.1856+03	2.1895+03	2.1770+03		2.1167+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	359	368	377	386	422	431
	TPBOUT	TWO 17	TWO 18	TWO 19	TWO 15	TWO 23
1	1.6134+03	1.8303+03	1.8345+03	2.1106+03	2.1721+03	2.1590+03
2	1.8110+03	1.9951+03	2.0047+03	2.1476+03	2.1652+03	2.1714+03
3	1.9798+03	2.1281+03	2.1355+03	2.1479+03	2.1623+03	2.1641+03
4	2.0966+03	2.1487+03	2.1501+03	2.1467+03	2.1593+03	2.1652+03
5	2.1069+03	2.1560+03	2.1567+03	2.1541+03	2.1650+03	2.1725+03
6	2.1044+03	2.1536+03	2.1540+03	2.1505+03	2.1603+03	2.1720+03
7	1.6426+03	1.8643+03	1.8735+03	2.1606+03	2.1787+03	2.1898+03
8	2.1071+03	2.1565+03	2.1566+03	2.1529+03	2.1634+03	2.1720+03
9	2.1077+03	2.1557+03	2.1562+03	2.1526+03	2.1637+03	2.1690+03
10	2.1138+03	2.1607+03	2.1604+03	2.1558+03	2.1669+03	2.1701+03
11	2.1107+03	2.1561+03	2.1564+03	2.1501+03	2.1577+03	2.1704+03
12	1.8196+03	2.0201+03	2.0395+03	2.1581+03	2.1775+03	2.1837+03
13	1.9915+03	2.1635+03	2.1822+03	2.1560+03	2.1849+03	2.1783+03
14	2.1018+03	2.1586+03	2.1610+03	2.1589+03	2.1768+03	2.1740+03
15	2.0955+03	2.1527+03	2.1553+03	2.1524+03	2.1744+03	2.1655+03
16	2.1004+03	2.1578+03	2.1600+03	2.1577+03	2.1842+03	2.1677+03
17	2.1086+03	2.1649+03	2.1671+03	2.1628+03	2.1909+03	2.1744+03
18	2.1050+03	2.1612+03	2.1640+03	2.1580+03	2.1883+03	2.1712+03
19	2.1158+03	2.1726+03	2.1739+03	2.1659+03	2.2008+03	2.1814+03
20	2.1118+03	2.1691+03	2.1707+03	2.1616+03	2.1985+03	2.1778+03
21	2.1165+03	2.1727+03	2.1752+03	2.1651+03	2.2040+03	2.1817+03
22	2.1154+03	2.1711+03	2.1725+03	2.1614+03	2.1991+03	2.1783+03
23	2.1112+03	2.1659+03	2.1670+03	2.1621+03	2.1903+03	2.1715+03
24	2.1188+03	2.1720+03	2.1725+03	2.1676+03	2.1927+03	2.1763+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	458	476	485	494	503	512
	TWO 26	TWO 16	INS 31	INS 32	INS 33	INS 34
1	2.1665+03	2.1699+03	1.7628+03	2.0837+03	2.0982+03	2.0986+03
2	2.1685+03	2.1723+03	1.9258+03	2.1014+03	2.1009+03	2.1018+03
3	2.1680+03	2.1657+03	2.0545+03	2.0986+03	2.0988+03	2.0991+03
4	2.1594+03	2.1637+03	2.0942+03	2.0951+03	2.0952+03	2.0958+03
5	2.1627+03	2.1698+03	2.1014+03	2.1034+03	2.1030+03	2.1027+03
6	2.1570+03	2.1624+03	2.0969+03	2.0982+03	2.0980+03	2.0981+03
7	2.1702+03	2.1713+03	1.8044+03	2.0964+03	2.0970+03	2.0974+03
8	2.1584+03	2.1628+03	2.0986+03	2.0994+03	2.0991+03	2.0991+03
9	2.1560+03	2.1628+03	2.0976+03	2.0978+03	2.0975+03	2.0972+03
10	2.1599+03	2.1674+03	2.1029+03	2.1029+03	2.1021+03	2.1018+03
11	2.1550+03	2.1618+03	2.0976+03	2.0975+03	2.0970+03	2.0970+03
12	2.1651+03	2.1674+03	1.9525+03	2.0962+03	2.0953+03	2.0954+03
13	2.1613+03	2.1648+03	2.0824+03	2.0949+03	2.0946+03	2.0952+03
14	2.1606+03	2.1660+03	2.0817+03	2.0992+03	2.0991+03	2.0990+03
15	2.1534+03	2.1693+03	2.0887+03	2.0912+03	2.0908+03	2.0908+03
16	2.1587+03	2.1634+03	2.0923+03	2.0940+03	2.0938+03	2.0940+03
17	2.1591+03	2.1711+03	2.1004+03	2.1023+03	2.1016+03	2.1027+03
18	2.1533+03	2.1670+03	2.0966+03	2.0980+03	2.0977+03	2.0986+03
19	2.1759+03	2.1877+03	2.1058+03	2.1071+03	2.1067+03	2.1080+03
20	2.1733+03	2.1644+03	2.1023+03	2.1026+03	2.1018+03	2.1029+03
21	2.1745+03	2.1686+03	2.1045+03	2.1051+03	2.1039+03	2.1047+03
22	2.1740+03	2.1940+03	2.1031+03	2.1028+03	2.1015+03	2.1019+03
23	2.1539+03	2.1638+03	2.0978+03	2.0976+03	2.0959+03	2.0967+03
24	2.1607+03	2.1682+03	2.1056+03	2.1038+03	2.1023+03	2.1027+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	521	554	558	562	566	570
	INS 35	CND 41	CND 42	CND 43	CND 44	CND 45
1	2.0986+03	1.3021+03	1.2833+03	1.2580+03	1.2363+03	1.2171+03
2	2.1021+03	1.3314+03	1.3126+03	1.2862+03	1.2638+03	1.2439+03
3	2.0993+03	1.3611+03	1.3422+03	1.3147+03	1.2910+03	1.2703+03
4	2.0955+03	1.4035+03	1.3842+03	1.3548+03	1.3287+03	1.3063+03
5	2.1027+03	1.4575+03	1.4350+03	1.4031+03	1.3743+03	1.3487+03
6	2.0981+03	1.5305+03	1.5041+03	1.4658+03	1.4331+03	1.4040+03
7	2.0972+03	1.3522+03	1.3266+03	1.2962+03		1.2405+03
8	2.0991+03	1.5969+03	1.5654+03	1.5202+03	1.4828+03	1.4487+03
9	2.0971+03	1.7573+03	1.7034+03	1.6394+03	1.5893+03	1.5438+03
10	2.1014+03	2.0043+03	1.9008+03	1.8002+03	1.7243+03	1.6596+03
11	2.0968+03	2.0228+03	2.0356+03	2.0049+03	1.8861+03	1.7901+03
12	2.0956+03	1.3879+03	1.3604+03	1.3283+03		1.2691+03
13	2.0948+03	1.4282+03	1.3993+03	1.3656+03	1.2109+03	1.3025+03
14	2.0988+03	1.4659+03	1.4348+03	1.3989+03	1.2413+03	1.3322+03
15	2.0907+03	1.5176+03	1.4816+03	1.4424+03	1.2797+03	1.3699+03
16	2.0937+03	1.6089+03	1.5627+03	1.5160+03	1.3430+03	1.4313+03
17	2.1018+03	1.6404+03	1.5908+03	1.5405+03	1.3627+03	1.4508+03
18	2.0978+03	1.7138+03	1.6542+03	1.5947+03	1.4042+03	1.4939+03
19	2.1066+03	1.7829+03	1.7126+03	1.6458+03	1.4404+03	1.5323+03
20	2.1017+03	1.9713+03	1.8649+03	1.7752+03	1.5306+03	1.6318+03
21	2.1033+03	2.0410+03	2.0512+03	1.9459+03	1.6484+03	1.7491+03
22	2.1014+03	2.0374+03	2.0467+03	2.0520+03	1.8268+03	1.9117+03
23	2.0958+03	2.0317+03	2.0402+03	2.0485+03		2.0377+03
24	2.1022+03	2.0362+03	2.0451+03	2.0537+03	1.8524+03	2.0451+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	577	584	686	707	708	709
	CND 46	CND 47	MAGNET	PBRADS	PBRADS	PBRADS
1	1.1944+03	1.1759+03	5.5656+02	7.3538+02	8.1214+02	7.4723+02
2	1.2203+03	1.2009+03	5.7703+02	7.9964+02	8.6808+02	7.9745+02
3	1.2459+03	1.2253+03	5.9795+02	8.5685+02	9.1719+02	8.4224+02
4	1.2810+03	1.2592+03	6.1456+02	9.1319+02	9.6774+02	8.8905+02
5	1.3212+03	1.2977+03	6.3883+02	9.7781+02	1.0222+03	9.6277+02
6	1.3730+03	1.3463+03	6.6260+02	1.0236+03	1.0629+03	1.0097+03
7	1.2151+03	1.1897+03	5.3532+02	7.2138+02	7.9435+02	7.3141+02
8	1.4146+03	1.3848+03	6.8012+02	1.0539+03	1.0905+03	1.0600+03
9	1.5011+03	1.4642+03	7.0969+02	1.0988+03	1.1336+03	1.1078+03
10	1.6022+03	1.5533+03	7.3493+02	1.1341+03	1.1693+03	1.1571+03
11	1.7124+03	1.6466+03	7.4964+02	1.1462+03	1.1843+03	1.1858+03
12	1.2428+03	1.2163+03	5.5312+02	7.8095+02	8.4466+02	7.7873+02
13	1.2751+03	1.2477+03	5.7430+02	8.4016+02	8.9520+02	8.2725+02
14	1.3031+03	1.2751+03	5.9165+02	8.9418+02	9.4196+02	8.7127+02
15	1.3385+03	1.3075+03	6.1024+02	9.3509+02	9.7683+02	9.0886+02
16	1.3956+03	1.3602+03	6.3305+02	9.7983+02	1.0163+03	9.5149+02
17	1.4132+03	1.3766+03	6.4124+02	9.9810+02	1.0324+03	9.6889+02
18	1.4527+03	1.4122+03	6.5523+02	1.0210+03	1.0543+03	9.9304+02
19	1.4861+03	1.4436+03	6.6469+02	1.0374+03	1.0684+03	1.0089+03
20	1.5736+03	1.5217+03	6.9144+02	1.0698+03	1.1039+03	1.0463+03
21	1.6757+03	1.6116+03	7.1436+02	1.0985+03	1.1357+03	1.0793+03
22	1.8076+03	1.7220+03	7.3680+02	1.1239+03	1.1648+03	1.1093+03
23	1.9558+03	1.8395+03	7.5409+02	1.1382+03	1.1826+03	1.1283+03
24	2.0533+03	1.9611+03	7.8307+02	1.1319+03	1.1936+03	1.1524+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	710 PBRADS	711 PBRADS	712 PBRADS	713 TSRADS	714 TSRADS	715 TSRADS
1	7.0604+02	7.0684+02	7.5054+02	1.1418+03	1.1419+03	1.1424+03
2	7.7056+02	7.6735+02	8.1452+02	1.1423+03	1.1424+03	1.1450+03
3	8.2727+02	8.1949+02	8.7214+02	1.1394+03	1.1396+03	1.1413+03
4	8.8441+02	8.7141+02	9.2776+02	1.1356+03	1.1358+03	1.1407+03
5	9.5012+02	9.3416+02	9.8732+02	1.1360+03	1.1362+03	1.1409+03
6	9.9622+02	9.8000+02	1.0290+03	1.1408+03	1.1409+03	1.1463+03
7	6.9218+02	6.9564+02	7.3167+02	1.1128+03	1.1078+03	1.1146+03
8	1.0268+03	1.0088+03	1.0567+03	1.1427+03	1.1429+03	1.1498+03
9	1.0728+03	1.0555+03	1.0991+03	1.1449+03	1.1451+03	1.1519+03
10	1.1085+03	1.0969+03	1.1328+03	1.1420+03	1.1422+03	1.1497+03
11	1.1213+03	1.1124+03	1.1455+03	1.1358+03	1.1359+03	1.1436+03
12	7.5233+02	7.5204+02	7.9195+02	1.1110+03	1.1112+03	1.1190+03
13	8.1247+02	8.0767+02	8.5338+02	1.1167+03	1.1168+03	1.1235+03
14	8.6706+02	8.5772+02	9.0866+02	1.1207+03	1.1208+03	1.1274+03
15	9.0900+02	8.9826+02	9.4697+02	1.1218+03	1.1220+03	1.1278+03
16	9.5381+02	9.4379+02	9.8735+02	1.1267+03	1.1268+03	1.1324+03
17	9.7259+02	9.6257+02	1.0050+03	1.1258+03	1.1259+03	1.1317+03
18	9.9585+02	9.8702+02	1.0267+03	1.1280+03	1.1282+03	1.1331+03
19	1.0113+03	1.0028+03	1.0416+03	1.1319+03	1.1321+03	1.1362+03
20	1.0443+03	1.0384+03	1.0720+03	1.1358+03	1.1360+03	1.1407+03
21	1.0726+03	1.0684+03	1.0988+03	1.1428+03	1.1430+03	1.1480+03
22	1.0974+03	1.0943+03	1.1223+03	1.1402+03	1.1404+03	1.1439+03
23	1.1096+03	1.1081+03	1.1341+03	1.1373+03	1.1375+03	1.1426+03
24	1.1223+03	1.1324+03	1.1432+03	1.1368+03	1.1369+03	1.1428+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	716	717	718	719	720	769
	TSRADS	TSRADS	TSRADS	TSRADS	TSRADS	QN PB
1	1.1260+03	1.1469+03	1.1336+03	1.1141+03	1.1203+03	7.2694+00
2	1.1298+03	1.1506+03	1.1388+03	1.1240+03	1.1309+03	9.8586+00
3	1.1262+03	1.1483+03	1.1367+03	1.1249+03	1.1327+03	1.2331+01
4	1.1276+03	1.1459+03	1.1362+03	1.1246+03	1.1339+03	1.4699+01
5	1.1271+03	1.1451+03	1.1355+03	1.1326+03	1.1328+03	1.8519+01
6	1.1314+03	1.1497+03	1.1394+03	1.1365+03	1.1367+03	2.2269+01
7	1.1099+03	1.1064+03	1.1062+03	1.0966+03	1.0968+03	7.7231+00
8	1.1343+03	1.1524+03	1.1421+03	1.1389+03	1.1391+03	2.4882+01
9	1.1367+03	1.1546+03	1.1450+03	1.1412+03	1.1414+03	2.9589+01
10	1.1331+03	1.1526+03	1.1423+03	1.1381+03	1.1383+03	3.3890+01
11	1.1264+03	1.1444+03	1.1326+03	1.1290+03	1.1292+03	3.6810+01
12	1.1140+03	1.1115+03	1.1106+03	1.1043+03	1.1045+03	1.0151+01
13	1.1182+03	1.1169+03	1.1148+03	1.0889+03	1.1109+03	1.2426+01
14	1.1216+03	1.1212+03	1.1183+03	1.0948+03	1.1154+03	1.4735+01
15	1.1213+03	1.1216+03	1.1173+03	1.0955+03	1.1146+03	1.7041+01
16	1.1248+03	1.1261+03	1.1191+03	1.1008+03	1.1185+03	1.9871+01
17	1.1238+03	1.1251+03	1.1178+03	1.1170+03	1.1172+03	2.1595+01
18	1.1249+03	1.1279+03	1.1193+03	1.1189+03	1.1190+03	2.3389+01
19	1.1262+03	1.1320+03	1.1194+03	1.1214+03	1.1216+03	2.4988+01
20	1.1291+03	1.1372+03	1.1236+03	1.1253+03	1.1255+03	2.8125+01
21	1.1351+03	1.1451+03	1.1298+03	1.1321+03	1.1323+03	2.9551+01
22	1.1303+03	1.1427+03	1.1257+03	1.1285+03	1.1287+03	3.4140+01
23	1.1287+03	1.1418+03	1.1238+03	1.1207+03	1.1281+03	3.5885+01
24	1.1271+03	1.1409+03	1.1224+03	1.1214+03	1.1256+03	3.6870+01

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	775	779	801	803	813	820
	QN TS	Q/A TS	FLOW	G	X PB	X TS
1	1.5834+01	1.1181+05	7.4766-02	2.9541+01	-1.4524-02	1.2133-01
2	1.5664+01	1.1061+05	7.4267-02	2.9344+01	-2.0340-02	1.7090-01
3	1.5643+01	1.1046+05	7.4694-02	2.9512+01	-2.0796-02	2.1892-01
4	1.5560+01	1.0987+05	7.6638-02	3.0280+01	-1.3522-02	2.5397-01
5	1.5549+01	1.0979+05	7.4246-02	2.9335+01	6.6639-02	3.4369-01
6	1.5730+01	1.1107+05	7.4687-02	2.9509+01	1.4282-01	4.2164-01
7	2.0101+01	1.4194+05	7.4338-02	2.9372+01	-1.2117-02	2.0884-01
8	1.5691+01	1.1080+05	7.5471-02	2.9819+01	1.9180-01	4.6741-01
9	1.5655+01	1.1054+05	7.5043-02	2.9650+01	2.9355-01	5.7043-01
10	2.0548+01	1.4509+05	7.5107-02	2.9676+01	3.8410-01	7.4697-01
11	1.5667+01	1.1063+05	7.5102-02	2.9674+01	4.4879-01	7.2585-01
12	2.0034+01	1.4146+05	7.4293-02	2.9354+01	-1.5755-02	2.5650-01
13	2.0093+01	1.4188+05	7.4576-02	2.9466+01	-1.9530-02	3.0336-01
14	1.9929+01	1.4072+05	7.4613-02	2.9480+01	-6.7410-03	3.4566-01
15	1.9926+01	1.4070+05	7.5233-02	2.9725+01	3.9791-02	3.8905-01
16	2.0111+01	1.4201+05	7.3850-02	2.9179+01	1.0514-01	4.6484-01
17	1.9845+01	1.4013+05	7.4323-02	2.9366+01	1.3486-01	4.8828-01
18	1.9816+01	1.3992+05	7.3675-02	2.9110+01	1.7831-01	5.3407-01
19	2.0024+01	1.4140+05	7.4173-02	2.9307+01	2.0745-01	5.6548-01
20	2.0112+01	1.4201+05	7.4703-02	2.9516+01	2.7683-01	6.3366-01
21	2.0506+01	1.4480+05	7.5592-02	2.9867+01	3.1149-01	6.7167-01
22	1.9810+01	1.3988+05	7.5243-02	2.9729+01	4.1073-01	7.6008-01
23	1.9697+01	1.3909+05	7.5318-02	2.9759+01	4.5750-01	8.0422-01
24	1.9710+01	1.3918+05	7.6701-02	3.0305+01	5.4288-01	8.8401-01

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	839	842	845	848	851	1054
	X 31	X 32	X 33	X 34	X 35	TWI 23
1	-5.7497-03	4.1234-02	5.5951-02	8.0009-02	1.0407-01	2.1233+03
2	-7.9891-03	5.8147-02	7.8865-02	1.1273-01	1.4659-01	2.1361+03
3	-5.3140-03	7.7589-02	1.0356-01	1.4601-01	1.8846-01	2.1289+03
4	3.7536-03	9.6263-02	1.2524-01	1.7261-01	2.1998-01	2.1302+03
5	8.4532-02	1.6035-01	2.1036-01	2.5942-01	3.0648-01	2.1376+03
6	1.6082-01	2.5725-01	2.8746-01	3.3683-01	3.8621-01	2.1366+03
7	2.1529-03	7.8559-02	1.0251-01	1.4160-01	1.8076-01	2.1446+03
8	2.0960-01	3.0491-01	3.3477-01	3.3358-01	4.3236-01	2.1367+03
9	3.1143-01	4.0718-01	4.3718-01	4.8671-01	5.3524-01	2.1337+03
10	4.0754-01	5.3301-01	5.7234-01	6.3660-01	7.0086-01	2.1239+03
11	4.6668-01	5.6250-01	5.9251-01	6.4157-01	6.9064-01	2.1352+03
12	1.8278-03	9.5983-02	1.2548-01	1.7369-01	2.2190-01	2.1387+03
13	1.3240-03	1.1299-01	1.4797-01	2.0515-01	2.6233-01	2.1331+03
14	1.6018-02	1.3789-01	1.7607-01	2.3847-01	3.0086-01	2.1291+03
15	6.2347-02	1.8313-01	2.2097-01	2.8282-01	3.4467-01	2.1206+03
16	1.2837-01	2.5276-01	2.9173-01	3.5543-01	4.1913-01	2.1224+03
17	1.5769-01	2.7991-01	3.1820-01	3.8078-01	4.4337-01	2.1297+03
18	2.0129-01	3.2432-01	3.6286-01	4.2596-01	4.8986-01	2.1266+03
19	2.3057-01	3.5439-01	3.9318-01	4.5658-01	5.1998-01	2.1364+03
20	2.9987-01	4.2328-01	4.6193-01	5.2512-01	5.8831-01	2.1325+03
21	3.3475-01	4.5932-01	4.9834-01	5.6212-01	6.2590-01	2.1355+03
22	4.3329-01	5.5411-01	5.9195-01	6.5382-01	7.1568-01	2.1327+03
23	4.7989-01	5.9980-01	6.3736-01	6.9876-01	7.6015-01	2.1272+03
24	5.6491-01	6.8288-01	7.1984-01	7.8025-01	8.4066-01	2.1319+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	1055	1056	1075	1076	1077	1089
	DT 23	H 23	TWI 26	DT 26	H 26	TWI 16
1	2.4688+01	4.5289+03	2.1309+03	3.2260+01	3.4659+03	2.1342+03
2	3.4370+01	3.2181+03	2.1333+03	3.1216+01	3.5433+03	2.1371+03
3	2.9727+01	3.7157+03	2.1327+03	3.3491+01	3.2981+03	2.1305+03
4	3.4376+01	3.1962+03	2.1244+03	2.8869+01	3.8058+03	2.1287+03
5	3.4806+01	3.1544+03	2.1277+03	2.4975+01	4.3961+03	2.1348+03
6	3.8567+01	2.8801+03	2.1216+03	2.3522+01	4.7221+03	2.1270+03
7	4.7208+01	3.0066+03	2.1250+03	2.7747+01	5.1153+03	2.1261+03
8	3.7615+01	2.9455+03	2.1231+03	2.3986+01	4.6191+03	2.1275+03
9	3.6512+01	3.0276+03	2.1207+03	2.3574+01	4.6893+03	2.1276+03
10	2.2069+01	6.5746+03	2.1137+03	1.2302+01	1.1794+04	2.1212+03
11	3.8221+01	2.8943+03	2.1197+03	2.2901+01	4.8305+03	2.1265+03
12	4.3226+01	3.2726+03	2.1200+03	2.4411+01	5.7951+03	2.1223+03
13	3.7962+01	3.7375+03	2.1160+03	2.1258+01	6.6743+03	2.1195+03
14	3.0089+01	4.6769+03	2.1157+03	1.6884+01	8.3346+03	2.1211+03
15	2.9802+01	4.7212+03	2.1085+03	1.7879+01	7.8694+03	2.1245+03
16	2.8431+01	4.9950+03	2.1134+03	1.9711+01	7.2045+03	2.1181+03
17	2.7034+01	5.1834+03	2.1144+03	1.2556+01	1.1160+04	2.1264+03
18	2.8017+01	4.9944+03	2.1086+03	1.0870+01	1.2872+04	2.1224+03
19	2.8361+01	4.9855+03	2.1308+03	2.4202+01	5.8424+03	2.1427+03
20	2.9570+01	4.8027+03	2.1280+03	2.6328+01	5.3940+03	2.1191+03
21	3.0814+01	4.6990+03	2.1284+03	2.5051+01	5.7802+03	2.1224+03
22	3.1824+01	4.3955+03	2.1294+03	2.7999+01	4.9958+03	2.1495+03
23	3.0483+01	4.5628+03	2.1095+03	1.3737+01	1.0125+04	2.1194+03
24	2.9237+01	4.7602+03	2.1164+03	1.4106+01	9.8667+03	2.1238+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

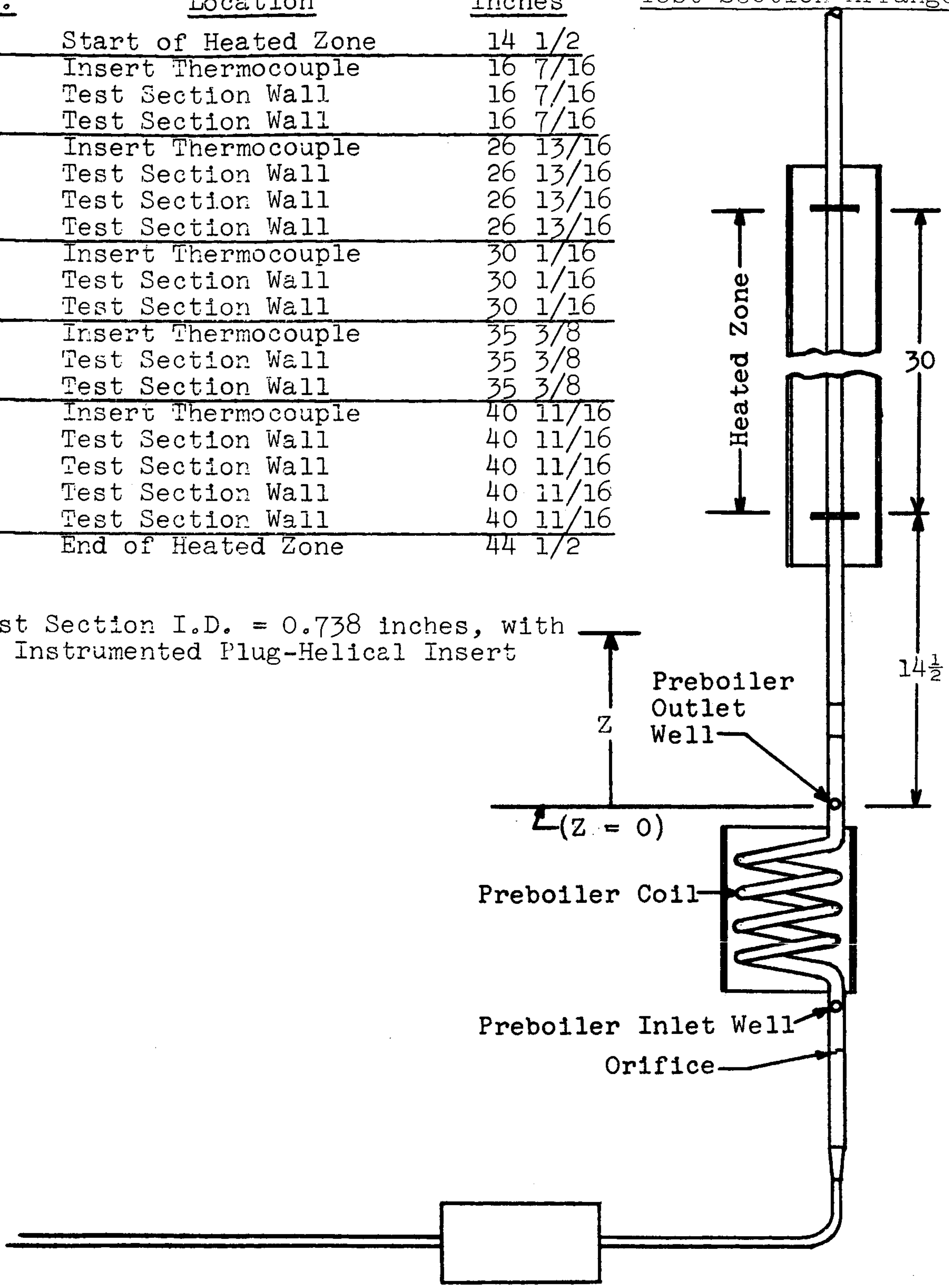
	1090	1091
	DT 16	H 16
1	3.5640+01	3.1372+03
2	3.4997+01	3.1605+03
3	3.1231+01	3.5368+03
4	3.3187+01	3.3106+03
5	3.2093+01	3.4210+03
6	2.8944+01	3.8376+03
7	2.8882+01	4.9144+03
8	2.8421+01	3.8984+03
9	3.0434+01	3.6323+03
10	1.9815+01	7.3225+03
11	2.9714+01	3.7229+03
12	2.6751+01	5.2880+03
13	2.4783+01	5.7249+03
14	2.2323+01	6.3038+03
15	3.3786+01	4.1644+03
16	2.4352+01	5.8316+03
17	2.4615+01	5.6927+03
18	2.4595+01	5.6891+03
19	3.6085+01	3.9184+03
20	1.7441+01	8.1426+03
21	1.9113+01	7.5758+03
22	4.8055+01	2.9108+03
23	2.3659+01	5.8789+03
24	2.1552+01	6.4576+03

TABLE A-4

100 KW LOOP TEST SECTION INSTRUMENTATION FOR DATA TAKEN BETWEEN 5-21-65 AND 6-10-65
(Data Tabulated In Tables A-6a and A-6b)

T/C No.	Location	Distance Inches
	Start of Heated Zone	14 1/2
31	Insert Thermocouple	16 7/16
17	Test Section Wall	16 7/16
18	Test Section Wall	16 7/16
32	Insert Thermocouple	26 13/16
19	Test Section Wall	26 13/16
20	Test Section Wall	26 13/16
21	Test Section Wall	26 13/16
33	Insert Thermocouple	30 1/16
22	Test Section Wall	30 1/16
15	Test Section Wall	30 1/16
34	Insert Thermocouple	35 3/8
23	Test Section Wall	35 3/8
24	Test Section Wall	35 3/8
35	Insert Thermocouple	40 11/16
25	Test Section Wall	40 11/16
26	Test Section Wall	40 11/16
27	Test Section Wall	40 11/16
16	Test Section Wall	40 11/16
	End of Heated Zone	44 1/2

Test Section Arrangement



Test Section I.D. = 0.738 inches, with Instrumented Plug-Helical Insert

TABLE A-5

100 KW BOILING DATA .738-INCH TUBE, WITH INSTRUMENTED PLUG-HELICAL INSERT

(Key to Table A-6)

Col No.	Heading	Description
244	DATE	(e.g., 5.2150 + 03 = 5-21-65)
245	TIME	(e.g., 5.4700 + 02 = 0547)
271	TK FM	Fluid temperature at flowmeter, °F
278,285	TPB IN	Fluid temperature at preboiler inlet, °F
292,341	PBC N	Preboiler coil temperature, °F
350,359	TPBOUT	Fluid temperature at preboiler outlet, °F
368-476	TWO N	Test section outside pipe wall temperature, °F
485-521	INS N	Fluid temperature at insert thermocouple N, °F
554-584	CND N	Condenser temperature at N, °F
686	MAGNET	Flowmeter magnet temperature, °F
707-712	PBRADS	Preboiler radiation shield temperature, °F
713-720	TSRADS	Test section radiation shield temperature, °F
769	QN PB	Net preboiler power, KW
775	QN TS	Net test section power, KW
779	Q/A TS	T/S heat flux, Btu/hr-ft^2
801	FLOW	Flow rate, lb/sec
803	G	Mass velocity, lb/sec-ft^2
813	X PB	Preboiler exit quality
820	X TS	Test section exit quality
822	ENTOUT	Mixture entralpy at T/S Outlet
839-851	X N	Quality at insert thermocouple N
1005-1061	TWI N	Inside wall temperature at N, °F
1068,1075 1089	TWI N	Inside wall temperature at N, °F
1069,1076 1090	DT N	(TWI N) + (INS N), °F
1070,1077 1091	H N	$\frac{Q/A}{DT\ N}$, Btu/hr-ft^2-°F

TABLE A-63

100 KW BOILING DATA TAKEN BETWEEN 5-21-65 AND 5-23-65

.738-inch Tube with Instrumented Plug Helical Insert

RESULTS BASED ON NRL FLUID PROPERTIES

TABLE A-6 a

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	244	245	271	278	285	292
	DATE	TIME	TK FM	TPB IN	TPB IN	PBC 5
1	5.2150+03	5.4700+02	9.6143+02	1.1565+03	1.1564+03	1.3299+03
2	5.2150+03	8.3000+02	9.6327+02	1.1755+03	1.1753+03	1.3782+03
3	5.2150+03	1.3000+03	9.5682+02	1.1953+03	1.1969+03	1.4275+03
4	5.2150+03	1.8300+03	1.0058+03	1.2140+03	1.2139+03	1.4764+03
5	5.2150+03	2.0380+03	9.9484+02	1.2266+03	1.2265+03	1.5300+03
6	5.2150+03	2.1330+03	1.0365+03	1.2457+03	1.2456+03	1.5724+03
7	5.2250+03	1.3000+02	1.0418+03	1.2559+03	1.2557+03	1.6225+03
8	5.2250+03	4.0000+02	1.0500+03	1.2724+03	1.2722+03	1.6682+03
9	5.2250+03	6.3000+02	1.0759+03	1.2870+03	1.2868+03	1.7235+03
10	5.2250+03	9.0000+02	1.0885+03	1.3048+03	1.3047+03	1.7625+03
11	5.2250+03	1.2150+03	1.1041+03	1.3302+03	1.3300+03	1.6794+03
12	5.2250+03	1.6300+03	1.1178+03	1.3466+03	1.3465+03	1.8267+03
13	5.2250+03	1.8300+03	1.1303+03	1.3864+03	1.3862+03	1.7755+03
14	5.2250+03	2.0300+03	1.1114+03	1.3910+03	1.3909+03	1.8147+03
15	5.2250+03	2.2300+03	1.1634+03	1.4359+03	1.4358+03	1.8627+03
16	5.2350+03	1.2000+02	1.1172+03	1.4759+03	1.4758+03	1.9153+03
17	5.2350+03	4.0500+02	1.1147+03	1.4938+03	1.4937+03	1.9295+03
18	5.2350+03	6.2000+02	1.1759+03	1.5351+03	1.5351+03	1.9799+03
19	5.2350+03	9.1500+02	1.2790+03	1.5751+03	1.5751+03	2.0330+03
20	5.2350+03	2.3150+03	1.0124+03	1.2082+03	1.2082+03	1.3068+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	299	306	313	320	327	334
	PBC 6	PBC 7	PBC 8	PBC 9	PBC 10	PBC 11
1	1.3570+03	1.4302+03	1.5312+03	1.5674+03	1.6000+03	1.6590+03
2	1.4093+03	1.4952+03	1.6124+03	1.6538+03	1.6918+03	1.7586+03
3	1.4637+03	1.5615+03	1.6940+03	1.7404+03	1.7836+03	1.8578+03
4	1.5248+03	1.6388+03	1.7893+03	1.8411+03	1.8890+03	1.9709+03
5	1.5857+03	1.7203+03	1.8907+03	1.9481+03	2.0014+03	2.0874+03
6	1.6381+03	1.7817+03	1.9622+03	2.0232+03	2.0781+03	2.1070+03
7	1.6940+03	1.8514+03	2.0396+03	2.1046+03	2.1228+03	2.1049+03
8	1.7467+03	1.9122+03	2.1054+03	2.1724+03	2.1140+03	2.1074+03
9	1.7137+03	1.9807+03	2.1608+03	2.1428+03	2.1177+03	2.1105+03
10	1.8556+03	2.0449+03	2.1435+03	2.1451+03	2.1236+03	2.1150+03
11	1.9042+03	2.0985+03	2.1442+03	2.1465+03	2.1248+03	2.1146+03
12	1.9489+03	2.1469+03	2.1470+03	2.1485+03	2.1261+03	2.1167+03
13	2.0184+03	2.2239+03	2.1553+03	2.1575+03	2.1332+03	2.1213+03
14	2.0512+03	2.1888+03	2.1617+03	2.1567+03	2.1371+03	2.1249+03
15	2.1047+03	2.1759+03	2.1610+03	2.1616+03	2.1374+03	2.1280+03
16	2.1669+03	2.1820+03	2.1630+03	2.1663+03	2.1434+03	2.1339+03
17	2.1978+03	2.1836+03	2.1630+03	2.1646+03	2.1424+03	2.1322+03
18	2.2046+03	2.1863+03	2.1658+03	2.1675+03	2.1461+03	2.1347+03
19	2.2051+03	2.1919+03	2.1670+03	2.1693+03	2.1497+03	2.1382+03
20	1.3718+03	1.4292+03	1.5121+03	1.6330+03	1.5687+03	1.6238+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	341	350	359	368	377	386
	PBC 12	TPBOUT	TPBOUT	TWO 17	TWO 18	TWO 19
1	1.6696+03	1.6749+03	1.6702+03	1.9142+03	1.9286+03	2.1860+03
2	1.7690+03	1.7766+03	1.7721+03	1.9968+03	2.0141+03	2.1846+03
3	1.8679+03	1.8769+03	1.8745+03	2.0786+03	2.1014+03	2.1901+03
4	1.9798+03	1.9901+03	1.9917+03	2.1714+03	2.1912+03	2.1862+03
5	1.2003+03	1.2123+03	1.2155+03	2.1657+03	2.1661+03	2.1922+03
6	2.0873+03	2.0982+03	2.1001+03	2.1673+03	2.1672+03	2.1970+03
7	2.0866+03	2.0988+03	2.1001+03	2.1635+03	2.1656+03	2.1890+03
8	2.0881+03	2.0988+03	2.0998+03	2.1641+03	2.1660+03	2.1880+03
9	2.0896+03	2.0998+03	2.1011+03	2.1648+03	2.1665+03	2.1883+03
10	2.0929+03	2.1026+03	2.1045+03	2.1659+03	2.1676+03	2.1889+03
11	2.0924+03	2.1015+03	2.1037+03	2.1651+03	2.1669+03	2.1888+03
12	2.0938+03	2.1014+03	2.1036+03	2.1640+03	2.1653+03	2.1853+03
13	2.1002+03	2.1058+03	2.1080+03	2.1691+03	2.1713+03	2.1925+03
14	2.1012+03	2.1051+03	2.1080+03	2.1673+03	2.1693+03	2.1878+03
15	2.1039+03	2.1066+03	2.1092+03	2.1682+03	2.1701+03	2.1879+03
16	2.1084+03	2.1091+03	2.1116+03	2.1715+03	2.1728+03	2.1920+03
17	2.1061+03	2.1063+03	2.1084+03	2.1676+03	2.1692+03	2.1889+03
18	2.1078+03	2.1070+03	2.1093+03	2.1667+03	2.1685+03	2.1864+03
19	2.1107+03	2.1089+03	2.1109+03	2.1697+03	2.1708+03	2.1888+03
20	1.6313+03	1.6366+03	1.6288+03	1.8805+03	1.8962+03	2.0983+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	413	431	440	458	476	485
	TWO 22	TWO 23	TWO 24	TWO 26	TWO 16	INS 31
1	2.1724+03	2.1670+03	2.1954+03	2.1721+03	2.1660+03	1.8454+03
2	2.1650+03	2.1642+03	2.1862+03	2.1733+03	2.1663+03	1.9224+03
3	2.1752+03	2.1631+03	2.1827+03	2.1749+03	2.1687+03	1.9990+03
4	2.1779+03	2.1544+03	2.1706+03	2.1707+03	2.1652+03	2.0820+03
5	2.1852+03	2.1578+03	2.1718+03	2.1732+03	2.1698+03	2.1015+03
6	2.1867+03	2.1614+03	2.1687+03	2.1701+03	2.1724+03	2.0996+03
7	2.1810+03	2.1576+03	2.1671+03	2.1696+03	2.1698+03	2.0993+03
8	2.1850+03	2.1546+03	2.1660+03	2.1660+03	2.1691+03	2.0984+03
9	2.1794+03	2.1556+03	2.1652+03	2.1673+03	2.1697+03	2.0992+03
10	2.1803+03	2.1606+03	2.1685+03	2.1688+03	2.1700+03	2.1013+03
11	2.1860+03	2.1574+03	2.1662+03	2.1660+03	2.1688+03	2.0991+03
12	2.1740+03	2.1574+03	2.1664+03	2.1649+03		2.0993+03
13	2.1816+03	2.1605+03	2.1695+03	2.1718+03		2.1018+03
14	2.1770+03	2.1602+03	2.1693+03	2.1688+03		2.1030+03
15	2.1769+03	2.1611+03	2.1697+03	2.1697+03		2.1033+03
16	2.1819+03	2.1619+03	2.1735+03	2.1726+03		2.1050+03
17	2.1736+03	2.1573+03	2.1703+03	2.1690+03		2.1021+03
18	2.1750+03	2.1595+03	2.1691+03	2.1674+03		2.1017+03
19	2.1778+03	2.1575+03	2.1688+03	2.1689+03		2.1035+03
20	2.1888+03	2.1674+03	2.1857+03	2.1819+03		1.8069+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	494	503	512	521	554	558
	INS 32	INS 33	INS 34	INS 35	CND 41	CND 42
1	2.1004+03	2.0987+03	2.0987+03	2.0956+03	1.3885+03	1.3683+03
2	2.1006+03	2.0983+03	2.0988+03	2.0987+03	1.4203+03	1.3910+03
3	2.1008+03	2.0987+03	2.0994+03	2.1001+03	1.4475+03	1.4171+03
4	2.0970+03	2.0951+03	2.0961+03	2.0970+03	1.4773+03	1.4450+03
5	2.1019+03	2.0992+03	2.1004+03	2.1016+03	1.5084+03	1.4741+03
6	2.1024+03	2.1004+03	2.1010+03	2.1021+03	1.5381+03	1.5018+03
7	2.1023+03	2.1008+03	2.1013+03	2.1019+03	1.5763+03	1.5346+03
8	2.1010+03	2.0996+03	2.0995+03	2.1004+03	1.6170+03	1.5695+03
9	2.1016+03	2.0998+03	2.0997+03	2.0991+03	1.6836+03	1.6270+03
10	2.1035+03	2.1018+03	2.1019+03	2.1014+03	1.7484+03	1.6799+03
11	2.1012+03	2.0993+03	2.0998+03	2.0987+03	1.8395+03	1.7566+03
12	2.1011+03	2.0990+03	2.0992+03	2.0986+03	1.9268+03	1.8233+03
13	2.1041+03	2.1019+03	2.1027+03	2.1015+03	2.0381+03	1.9944+03
14	2.1043+03	2.1023+03	2.1026+03	2.1016+03	2.0389+03	2.0424+03
15	2.1049+03	2.1023+03	2.1023+03	2.1012+03	2.0377+03	2.0452+03
16	2.1065+03	2.1039+03	2.1041+03	2.1033+03	2.0364+03	2.0443+03
17	2.1032+03	2.1009+03	2.1011+03	2.1003+03	2.0343+03	2.0410+03
18	2.1026+03	2.1003+03	2.1007+03	2.0995+03	2.0322+03	2.0415+03
19	2.1043+03	2.1015+03	2.1023+03	2.1011+03	2.0323+03	2.0430+03
20	2.0988+03	2.1004+03	2.1001+03	2.1003+03	1.4724+03	1.4367+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	562	566	570	577	584	686
	CND 43	CND 44	CND 45	CND 46	CND 47	MAGNET
1	1.3380+03	1.1894+03	1.2810+03	1.2549+03	1.2289+03	6.1051+02
2	1.3596+03	1.2088+03	1.3011+03	1.2749+03	1.2484+03	6.2363+02
3	1.3851+03	1.2314+03	1.3243+03	1.2971+03	1.2696+03	6.3379+02
4	1.4109+03	1.2538+03	1.3458+03	1.3183+03	1.2901+03	6.4525+02
5	1.4368+03	1.2768+03	1.3676+03	1.3383+03	1.3082+03	6.5689+02
6	1.4637+03	1.2993+03	1.3917+03	1.3609+03	1.3303+03	6.6710+02
7	1.4922+03	1.3216+03	1.4135+03	1.3805+03	1.3475+03	6.7592+02
8	1.5239+03	1.3463+03	1.4389+03	1.4037+03	1.3689+03	6.8471+02
9	1.5741+03	1.3840+03	1.4770+03	1.4381+03	1.3994+03	6.9442+02
10	1.6175+03	1.4156+03	1.5078+03	1.4654+03	1.4247+03	7.0120+02
11	1.6842+03	1.4638+03	1.5607+03	1.5115+03	1.4646+03	7.1064+02
12	1.7363+03	1.4981+03	1.5945+03	1.5402+03	1.4891+03	7.1482+02
13	1.8728+03	1.5889+03	1.6839+03	1.6176+03	1.5581+03	7.2851+02
14	1.9070+03	1.6124+03	1.7054+03	1.6360+03	1.5714+03	7.3267+02
15	2.0294+03	1.6952+03	1.7840+03	1.7025+03	1.6290+03	7.4568+02
16	2.0535+03	1.8311+03	1.9101+03	1.8056+03	1.7153+03	7.5852+02
17	2.0518+03	1.8350+03	1.9965+03	1.8699+03	1.7643+03	7.6156+02
18	2.0516+03	1.8388+03	2.0375+03	1.9673+03	1.8421+03	7.7016+02
19	2.0533+03	1.8429+03	2.0394+03	2.0547+03	1.9375+03	7.7590+02
20	1.4001+03	1.2178+03	1.3291+03	1.3000+03	1.2698+03	5.4580+02

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	707 PBRADS	708 PBRADS	709 PBRADS	710 PBRADS	711 PBRADS	712 PBRADS
1	7.8366+02	8.2690+02	7.7967+02	7.4770+02	7.4263+02	7.9315+02
2	8.1802+02	8.0386+02	7.8753+02	7.8257+02	7.7589+02	8.2796+02
3	8.5020+02	8.2495+02	8.3348+02	8.1538+02	8.0726+02	8.6093+02
4	8.8585+02	8.4304+02	8.6148+02	8.5210+02	8.4129+02	8.9798+02
5	9.2160+02	8.5940+02	8.8982+02	8.8843+02	8.7512+02	9.3437+02
6	9.4790+02	8.7305+02	9.1199+02	9.1507+02	9.0095+02	9.5944+02
7	9.7135+02	8.9108+02	9.3251+02	9.3946+02	9.2438+02	9.8126+02
8	9.8961+02	8.9911+02	9.5011+02	9.5835+02	9.4242+02	9.9792+02
9	1.0116+03	9.1427+02	9.7173+02	9.8088+02	9.6478+02	1.0179+03
10	1.0295+03	9.2674+02	9.9040+02	1.0000+03	9.8466+02	1.0353+03
11	1.0443+03	9.4003+02	1.0086+03	1.0161+03	1.0024+03	1.0494+03
12	1.0558+03	9.4611+02	1.0200+03	1.0294+03	1.0166+03	1.0612+03
13	1.0767+03	9.6634+02	1.0459+03	1.0510+03	1.0399+03	1.0812+03
14	1.0862+03	9.7111+02	1.0553+03	1.0613+03	1.0504+03	1.0906+03
15	1.1007+03	9.8365+02	1.0727+03	1.0756+03	1.0663+03	1.1040+03
16	1.1178+03	1.0001+03	1.0940+03	1.0923+03	1.0846+03	1.1199+03
17	1.1241+03	1.0048+03	1.1012+03	1.0982+03	1.0919+03	1.1259+03
18	1.1344+03	1.0156+03	1.1138+03	1.1075+03	1.1022+03	1.1348+03
19	1.1445+03	1.0234+03	1.1280+03	1.1160+03	1.1121+03	1.1433+03
20	7.2587+02	7.6507+02	7.2422+02	6.9406+02	6.9698+02	7.3487+02

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	713 TSRADS	714 TSRADS	715 TSRADS	716 TSRADS	717 TSRADS	718 TSRADS
1	1.1153+03	1.1156+03	1.1173+03	1.1177+03	1.1274+03	1.1040+03
2	1.1174+03	1.1176+03	1.1178+03	1.1181+03	1.1295+03	1.1053+03
3	1.1211+03	1.1213+03	1.1222+03	1.1226+03	1.1361+03	1.1116+03
4	1.1188+03	1.1190+03	1.1215+03	1.1219+03	1.1371+03	1.1130+03
5	1.1226+03	1.1229+03	1.1272+03	1.1276+03	1.1422+03	1.1184+03
6	1.1204+03	1.1206+03	1.1253+03	1.1257+03	1.1411+03	1.1170+03
7	1.1159+03	1.1162+03	1.1225+03	1.1229+03	1.1387+03	1.1153+03
8	1.1182+03	1.1185+03	1.1218+03	1.1222+03	1.1386+03	1.1146+03
9	1.1174+03	1.1176+03	1.1224+03	1.1228+03	1.1398+03	1.1152+03
10	1.1145+03	1.1147+03	1.1188+03	1.1193+03	1.1382+03	1.1117+03
11	1.1144+03	1.1146+03	1.1152+03	1.1157+03	1.1347+03	1.1079+03
12	1.1095+03	1.1097+03	1.1088+03	1.1092+03	1.1291+03	1.1005+03
13	1.1198+03	1.1200+03	1.1186+03	1.1191+03	1.1404+03	1.1099+03
14	1.1101+03	1.1102+03	1.1066+03	1.1071+03	1.1303+03	1.0979+03
15	1.1114+03	1.1116+03	1.1071+03	1.1076+03	1.1313+03	1.0969+03
16	1.1161+03	1.1163+03	1.1074+03	1.1078+03	1.1335+03	1.0969+03
17	1.1102+03	1.1103+03	1.1029+03	1.1034+03	1.1305+03	1.0928+03
18	1.1111+03	1.1113+03	1.1029+03	1.1034+03	1.1310+03	1.0929+03
19	1.1120+03	1.1121+03	1.1033+03	1.1038+03	1.1321+03	1.0936+03
20	1.0919+03	1.0921+03	1.0872+03	1.0874+03	1.0914+03	1.0721+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	719	720	769	775	779	801
	TSRADS	TSRADS	QN PB	QN TS	Q/A TS	FLOW
1	1.0894+03	1.1004+03	7.2508+00	2.1431+01	1.5133+05	7.3739-02
2	1.0949+03	1.1052+03	8.9529+00	2.1245+01	1.5001+05	7.4217-02
3	1.1042+03	1.1137+03	1.0481+01	2.1405+01	1.5114+05	7.4826-02
4	1.1085+03	1.1176+03	1.2184+01	2.1546+01	1.5214+05	7.4289-02
5	1.1156+03	1.1239+03	1.3713+01	2.1814+01	1.5403+05	7.3215-02
6	1.1152+03	1.1227+03	1.5381+01	2.1587+01	1.5243+05	7.5207-02
7	1.1132+03	1.1200+03	1.6876+01	2.1282+01	1.5028+05	7.4395-02
8	1.1156+03	1.1213+03	1.8539+01	2.1371+01	1.5090+05	7.3879-02
9	1.1158+03	1.1204+03	2.0360+01	2.1369+01	1.5089+05	7.3994-02
10	1.1136+03	1.1168+03	2.2086+01	2.1415+01	1.5122+05	7.3758-02
11	1.1107+03	1.1118+03	2.3902+01	2.1459+01	1.5152+05	7.4144-02
12	1.1049+03	1.1033+03	2.5642+01	2.1555+01	1.5220+05	7.4195-02
13	1.1165+03	1.1130+03	2.7540+01	2.1996+01	1.5532+05	7.4298-02
14	1.1064+03	1.1008+03	2.9234+01	2.1565+01	1.5228+05	7.3507-02
15	1.1075+03	1.1000+03	3.0990+01	2.1557+01	1.5222+05	7.4401-02
16	1.1131+03	1.1034+03	3.3497+01	2.1766+01	1.5370+05	7.4354-02
17	1.1068+03	1.0959+03	3.4593+01	2.1497+01	1.5179+05	7.3731-02
18	1.1077+03	1.0957+03	3.6020+01	2.1340+01	1.5069+05	7.4126-02
19	1.1098+03	1.0972+03	3.8250+01	2.1575+01	1.5234+05	7.4779-02
20	1.0534+03	1.0668+03	7.5770+00	2.5272+01	1.7845+05	7.3288-02

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	803	813	820	822	839	842
	G	X PB	X TS	ENTOUT	X 31	X 32
1	2.9135+01	-1.5645-02	2.4017-01	6.8047+02	8.7699-04	8.9347-02
2	2.9324+01	-1.1746-02	2.6811-01	7.0112+02	6.3278-03	1.0311-01
3	2.9564+01	-1.0731-02	2.9867-01	7.2338+02	9.2518-03	1.1625-01
4	2.9352+01	-8.6266-03	3.4099-01	7.5336+02	1.3952-02	1.3486-01
5	2.8928+01	2.0823-01	3.8451-01	7.8543+02	2.1961-01	2.8058-01
6	2.9715+01	2.0947-02	3.9802-01	7.9523+02	4.5300-02	1.7571-01
7	2.9394+01	5.3032-02	4.2896-01	8.1748+02	7.7311-02	2.0732-01
8	2.9190+01	8.9342-02	4.6977-01	8.4664+02	1.1391-01	2.4548-01
9	2.9235+01	1.2492-01	5.0530-01	8.7206+02	1.4949-01	2.8103-01
10	2.9142+01	1.6102-01	5.4385-01	9.0012+02	1.8575-01	3.1814-01
11	2.9295+01	1.9864-01	5.8041-01	9.2612+02	2.2329-01	3.5533-01
12	2.9315+01	2.3392-01	6.1710-01	9.5254+02	2.5867-01	3.9119-01
13	2.9356+01	2.7709-01	6.6815-01	9.8963+02	3.0235-01	4.3759-01
14	2.9043+01	3.1412-01	7.0151-01	1.0137+03	3.3914-01	4.7311-01
15	2.9396+01	3.5152-01	7.3445-01	1.0373+03	3.7625-01	5.0868-01
16	2.9378+01	4.0731-01	7.9436-01	1.0807+03	4.3231-01	5.6616-01
17	2.9132+01	4.3772-01	8.2290-01	1.1009+03	4.6260-01	5.9581-01
18	2.9288+01	4.7168-01	8.5221-01	1.1220+03	4.9626-01	6.2786-01
19	2.9546+01	5.1674-01	8.9817-01	1.1552+03	5.4137-01	6.7328-01
20	2.8957+01	1.3562-02	3.3101-01	7.4669+02	3.4064-02	1.4385-01

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	845	848	851	1005	1012	1019
	X 33	X 34	X 35	TWI 17	TWI 18	TWI 19
1	1.1706-01	1.6236-01	2.0766-01	1.8652+03	1.8796+03	2.1378+03
2	1.3343-01	1.8299-01	2.3255-01	1.9485+03	1.9658+03	2.1369+03
3	1.4977-01	2.0456-01	2.5935-01	2.0301+03	2.0530+03	2.1420+03
4	1.7273-01	2.3464-01	2.9656-01	2.1229+03	2.1428+03	2.1377+03
5	2.9967-01	3.3089-01	3.6211-01	2.1166+03	2.1170+03	2.1432+03
6	2.1656-01	2.8333-01	3.5010-01	2.1187+03	2.1186+03	2.1485+03
7	2.4804-01	3.1461-01	3.8118-01	2.1156+03	2.1177+03	2.1411+03
8	2.8669-01	3.5406-01	4.2142-01	2.1160+03	2.1179+03	2.1400+03
9	3.2224-01	3.8960-01	4.5696-01	2.1167+03	2.1184+03	2.1403+03
10	3.5961-01	4.2741-01	4.9520-01	2.1177+03	2.1194+03	2.1408+03
11	3.9668-01	4.6429-01	5.3190-01	2.1168+03	2.1186+03	2.1406+03
12	4.3270-01	5.0055-01	5.6841-01	2.1155+03	2.1168+03	2.1368+03
13	4.7995-01	5.4920-01	6.1845-01	2.1196+03	2.1218+03	2.1431+03
14	5.1508-01	5.8368-01	6.5228-01	2.1187+03	2.1208+03	2.1394+03
15	5.5016-01	6.1797-01	6.8578-01	2.1197+03	2.1216+03	2.1395+03
16	6.0809-01	6.7663-01	7.4517-01	2.1225+03	2.1238+03	2.1431+03
17	6.3754-01	7.0575-01	7.7395-01	2.1192+03	2.1208+03	2.1406+03
18	6.6908-01	7.3647-01	8.0385-01	2.1187+03	2.1204+03	2.1385+03
19	7.1460-01	7.8215-01	8.4969-01	2.1212+03	2.1222+03	2.1403+03
20	1.7824-01	2.3445-01	2.9067-01	1.8226+03	1.8383+03	2.0412+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	1040	1054	1061	1075	1076	1077
	TWI 22	TWI 23	TWI 24	TWI 26	DT 26	H 26
1	2.1242+03	2.1188+03	2.1473+03	2.1239+03	2.8281+01	5.3508+03
2	2.1172+03	2.1164+03	2.1384+03	2.1255+03	2.6790+01	5.5996+03
3	2.1270+03	2.1149+03	2.1345+03	2.1267+03	2.6626+01	5.6765+03
4	2.1295+03	2.1059+03	2.1221+03	2.1222+03	2.5247+01	6.0261+03
5	2.1361+03	2.1087+03	2.1227+03	2.1241+03	2.2476+01	6.8529+03
6	2.1381+03	2.1128+03	2.1201+03	2.1215+03	1.9460+01	7.8330+03
7	2.1331+03	2.1097+03	2.1192+03	2.1217+03	1.9736+01	7.6142+03
8	2.1369+03	2.1065+03	2.1179+03	2.1179+03	1.7539+01	8.6039+03
9	2.1313+03	2.1074+03	2.1171+03	2.1192+03	2.0081+01	7.5143+03
10	2.1322+03	2.1123+03	2.1203+03	2.1206+03	1.9197+01	7.8772+03
11	2.1377+03	2.1091+03	2.1179+03	2.1177+03	1.9037+01	7.9595+03
12	2.1255+03	2.1088+03	2.1179+03	2.1164+03	1.7842+01	8.5307+03
13	2.1321+03	2.1109+03	2.1200+03	2.1223+03	2.0782+01	7.4737+03
14	2.1285+03	2.1116+03	2.1208+03	2.1202+03	1.8583+01	8.1943+03
15	2.1284+03	2.1125+03	2.1212+03	2.1212+03	2.0021+01	7.6032+03
16	2.1329+03	2.1129+03	2.1245+03	2.1237+03	2.0335+01	7.5583+03
17	2.1252+03	2.1089+03	2.1219+03	2.1206+03	2.0380+01	7.4481+03
18	2.1270+03	2.1114+03	2.1211+03	2.1194+03	1.9871+01	7.5835+03
19	2.1292+03	2.1089+03	2.1203+03	2.1204+03	1.9245+01	7.9161+03
20	2.1320+03	2.1105+03	2.1288+03	2.1250+03	2.4757+01	7.2081+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	1089	1090	1091
	TWI 16	DT 16	H 16
1	2.1178+03	2.2146+01	6.8332+03
2	2.1185+03	1.9858+01	7.5543+03
3	2.1205+03	2.0407+01	7.4063+03
4	2.1167+03	1.9742+01	7.7063+03
5	2.1207+03	1.9090+01	8.0685+03
6	2.1239+03	2.1798+01	6.9928+03
7	2.1219+03	1.9983+01	7.5203+03
8	2.1211+03	2.0658+01	7.3049+03
9	2.1216+03	2.2450+01	6.7212+03
10	2.1218+03	2.0473+01	7.3862+03
11	2.1205+03	2.1763+01	6.9625+03
12			
13			
14			
15			
16			
17			
18			
19			
20			

TABLE A-6b

100 KW BOILING DATA TAKEN BETWEEN 5-26-65 AND 5-27-65

.738-inch Tube with Instrumented Plug-Helical Insert

RESULTS BASED ON NRL FLUID PROPERTIES

TABLE A-6b

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	244	245	271	278	285	292
	DATE	TIME	TK FM	TPB IN	TPB IN	PBC 5
1	5.2650+03	4.5500+02	1.0157+03	1.1809+03	1.1739+03	1.3009+03
2	5.2650+03	6.3000+02	1.0091+03	1.1940+03	1.1867+03	1.3320+03
3	5.2650+03	9.1500+02	9.9679+02	1.2074+03	1.1991+03	1.3605+03
4	5.2650+03	1.2350+03	1.0079+03	1.2242+03	1.2152+03	1.4157+03
5	5.2650+03	1.6250+03	1.0335+03	1.2553+03	1.2454+03	1.4820+03
6	5.2750+03	1.4000+02	1.0238+03	1.2946+03	1.2828+03	1.5611+03
7	5.2750+03	5.1000+02	1.0951+03	1.3566+03	1.3450+03	1.6712+03
8	5.2750+03	1.0300+03	1.0923+03	1.3797+03	1.3672+03	1.7316+03
9	5.2750+03	1.3300+03	1.1509+03	1.4456+03	1.4336+03	1.8483+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	299	306	313	327	334	341
	PBC 6	PBC 7	PBC 8	PBC 10	PBC 11	PBC 12
1	1.3762+03	1.4433+03	1.4501+03	1.6010+03	1.6592+03	1.6670+03
2	1.4231+03	1.5051+03	1.6176+03	1.6920+03	1.7597+03	1.7680+03
3	1.4684+03	1.5630+03	1.6912+03	1.7770+03	1.8521+03	1.8606+03
4	1.5499+03	1.6695+03	1.8260+03	1.9291+03	2.0152+03	2.0229+03
5	1.6364+03	1.7747+03	1.9497+03	2.0630+03	2.1107+03	2.0830+03
6	1.7532+03	1.9236+03	2.1269+03	2.1112+03	2.1073+03	2.0870+03
7	1.8873+03	2.0695+03	2.1469+03	2.1234+03	2.1163+03	2.0946+03
8	1.9682+03	2.1575+03	2.1497+03	2.1267+03	2.1190+03	2.0969+03
9	2.1000+03	2.1796+03	2.1598+03	2.1379+03	2.1281+03	2.1052+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	350	359	368	377	386	431
	TPBOUT	TPBOUT	TWO 17	TWO 18	TWO 19	TWO 23
1	1.6700+03	1.6570+03	1.9384+03	1.9613+03	2.1874+03	2.1643+03
2	1.7730+03	1.7669+03	2.0342+03	2.0523+03	2.1895+03	2.1616+03
3	1.8679+03	1.8645+03	2.0995+03	2.1139+03	2.1865+03	2.1591+03
4	2.0327+03	2.0349+03	2.2212+03	2.2095+03	2.1855+03	2.1542+03
5	2.0902+03	2.0929+03	2.1677+03	2.1667+03	2.1881+03	2.1528+03
6	2.0919+03	2.0954+03	2.1716+03	2.1687+03	2.1900+03	2.1615+03
7	2.0982+03	2.0999+03	2.1765+03	2.1742+03	2.1960+03	2.1671+03
8	2.0972+03	2.0995+03	2.1728+03	2.1694+03	2.1934+03	2.1602+03
9	2.1018+03	2.1036+03	2.1738+03	2.1708+03	2.1948+03	2.1614+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	440	458	476	485	494	503
	TWO 24	TWO 26	TWO 16	INS 31	INS 32	INS 33
1	2.2012+03	2.1799+03	2.1817+03	1.8506+03	2.0942+03	2.1038+03
2	2.2012+03	2.1788+03	2.1815+03	1.9311+03	2.0947+03	2.1043+03
3	2.1966+03	2.1750+03	2.1740+03	1.9938+03	2.0932+03	2.0938+03
4	2.1896+03	2.1688+03	2.1728+03	2.1058+03	2.0928+03	2.0939+03
5	2.1847+03	2.1646+03	2.1725+03	2.0937+03	2.0950+03	2.0954+03
6	2.1850+03	2.1653+03	2.1786+03	2.0958+03	2.0972+03	2.0978+03
7	2.1903+03	2.1698+03	2.1840+03	2.0999+03	2.1004+03	2.1008+03
8	2.1795+03	2.1636+03	2.1786+03	2.0997+03	2.0985+03	2.0991+03
9	2.1810+03	2.1657+03	2.1806+03	2.1005+03	2.0994+03	2.0995+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	512	521	554	558	562	566
	INS 34	INS 35	CND 41	CND 42	CND 43	CND 44
1	2.0953+03	2.0947+03	1.4629+03	1.4292+03	1.3943+03	1.2207+03
2	2.0961+03	2.0954+03	1.4867+03	1.4493+03	1.4139+03	1.2383+03
3	2.0953+03	2.0945+03	1.4966+03	1.4596+03	1.4229+03	1.2463+03
4	2.0950+03	2.0943+03	1.5273+03	1.4879+03	1.4496+03	1.2715+03
5	2.0955+03	2.0949+03	1.6018+03	1.5527+03	1.5090+03	1.3209+03
6	2.0971+03	2.0965+03	1.7324+03	1.6641+03	1.6027+03	1.3781+03
7	2.0996+03	2.0989+03	1.9228+03	1.8231+03	1.7369+03	1.4770+03
8	2.0980+03	2.0973+03	2.0132+03	1.8871+03	1.7838+03	1.4944+03
9	2.0989+03	2.0981+03	2.0459+03	2.0520+03	2.0116+03	1.6525+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	570	577	584	686	707	708
	CND 45	CND 46	CND 47	MAGNET	PBRADS	PBRADS
1	1.3264+03	1.2984+03	1.2683+03	5.7591+02	7.4146+02	8.0752+02
2	1.3431+03	1.3136+03	1.2828+03	5.8602+02	7.7484+02	8.3493+02
3	1.3523+03	1.3218+03	1.2909+03	5.9621+02	8.0733+02	8.5829+02
4	1.3753+03	1.3439+03	1.3112+03	6.0915+02	8.6218+02	9.0340+02
5	1.4257+03	1.3905+03	1.3548+03	6.2855+02	9.1093+02	9.4753+02
6	1.4918+03	1.4483+03	1.4054+03	6.4927+02	9.7239+02	9.9262+02
7	1.5931+03	1.5390+03	1.4863+03	6.7934+02	1.0177+03	1.0370+03
8	1.6196+03	1.5593+03	1.5032+03	6.8440+02	1.0498+03	1.0548+03
9	1.7735+03	1.6892+03	1.6132+03	7.0748+02	1.0882+03	1.0957+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	709	710	711	712	713	714
	PBRADS	PBRADS	PBRADS	PBRADS	TSRADS	TSRADS
1	7.4666+02	7.1022+02	7.1421+02	7.5424+02	1.1109+03	1.1111+03
2	7.7223+02	7.4426+02	7.4650+02	7.8832+02	1.1135+03	1.1137+03
3	7.9460+02	7.7650+02	7.7622+02	8.2046+02	1.1026+03	1.1028+03
4	8.3577+02	8.3192+02	8.2727+02	8.7608+02	1.0965+03	1.0967+03
5	8.7789+02	8.8173+02	8.7384+02	9.2454+02	1.1079+03	1.1081+03
6	9.3285+02	9.4661+02	9.4011+02	9.8274+02	1.1220+03	1.1221+03
7	9.7959+02	9.9178+02	9.8634+02	1.0254+03	1.1310+03	1.1311+03
8	1.0035+03	1.0249+03	1.0177+03	1.0563+03	1.1216+03	1.1217+03
9	1.0464+03	1.0639+03	1.0582+03	1.0928+03	1.1247+03	1.1248+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	715	716	717	718	719	720
	TSRADS	TSRADS	TSRADS	TSRADS	TSRADS	TSRADS
1	1.1060+03	1.1063+03	1.1181+03	1.0883+03	1.0747+03	1.0790+03
2	1.1059+03	1.1062+03	1.1208+03	1.0910+03	1.0797+03	1.0822+03
3	1.0933+03	1.0936+03	1.1088+03	1.0791+03	1.0731+03	1.0737+03
4	1.0867+03	1.0870+03	1.1050+03	1.0734+03	1.0712+03	1.0698+03
5	1.0990+03	1.0993+03	1.1186+03	1.0855+03	1.0862+03	1.0823+03
6	1.1048+03	1.1052+03	1.1336+03	1.0918+03	1.0999+03	1.0865+03
7	1.1125+03	1.1128+03	1.1452+03	1.0992+03	1.1124+03	1.0932+03
8	1.0984+03	1.0988+03	1.1387+03	1.0884+03	1.1057+03	1.0828+03
9	1.0987+03	1.0991+03	1.1434+03	1.0893+03	1.1127+03	1.0833+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	769	775	779	801	803	813
	QN PB	QN TS	Q/A TS	FLOW	G	X PB
1	7.6795+00	2.5458+01	1.7976+05	7.4154-02	2.9299+01	-1.8726-03
2	9.1443+00	2.5172+01	1.7774+05	7.3276-02	2.8952+01	-1.7279-03
3	1.0792+01	2.3748+01	1.6769+05	7.3913-02	2.9204+01	1.1954-03
4	1.3293+01	2.2532+01	1.5910+05	7.4108-C2	2.9281+01	1.6738-04
5	1.5757+01	2.3625+01	1.6682+05	7.4246-02	2.9335+01	3.4567-02
6	2.0147+01	2.3820+01	1.6820+05	7.4058-02	2.9261+01	1.2315-01
7	2.3974+01	2.4182+01	1.7075+05	7.3851-02	2.9179+01	2.0837-01
8	2.8432+01	2.2937+01	1.6197+05	7.5440-02	2.9807+01	2.8368-01
9	3.2893+01	2.2398+01	1.5816+05	7.4971-02	2.9622+01	3.8301-01

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	820	822	839	842	845	848
	X TS	ENTOUT	X 31	X 32	X 33	X 34
1	3.2214-01	7.3940+02	1.9053-02	1.3111-01	1.6621-01	2.2359-01
2	3.5366-01	7.6224+02	2.1224-02	1.4413-01	1.8263-01	2.4556-01
3	3.5600-01	7.6379+02	2.4110-02	1.4681-01	1.8525-01	2.4808-01
4	3.8176-01	7.8234+02	2.4812-02	1.5678-01	1.9812-01	2.6569-01
5	4.5187-01	8.3298+02	6.1517-02	2.0583-01	2.5104-01	3.2494-01
6	5.4534-01	9.0058+02	1.5041-01	2.9642-01	3.4216-01	4.1692-01
7	6.3924-01	9.6852+02	2.3620-01	3.8521-01	4.3189-01	5.0819-01
8	6.8382-01	1.0005+03	3.0952-01	4.4791-01	4.9125-01	5.6211-01
9	7.7700-01	1.0677+03	4.0845-01	5.4471-01	5.8739-01	6.5716-01

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	851	1005	1012	1019	1054	1061
	X 35	TWI 17	TWI 18	TWI 19	TWI 23	TWI 24
1	2.8097-01	1.8802+03	1.9032+03	2.1302+03	2.1069+03	2.1440+03
2	3.0849-01	1.9771+03	1.9952+03	2.1329+03	2.1049+03	2.1446+03
3	3.1091-01	2.0458+03	2.0603+03	2.1331+03	2.1056+03	2.1432+03
4	3.3326-01	2.1707+03	2.1590+03	2.1348+03	2.1034+03	2.1389+03
5	3.9884-01	2.1145+03	2.1135+03	2.1350+03	2.0996+03	2.1315+03
6	4.9169-01	2.1180+03	2.1151+03	2.1365+03	2.1078+03	2.1314+03
7	5.8449-01	2.1221+03	2.1198+03	2.1417+03	2.1127+03	2.1359+03
8	6.3297-01	2.1212+03	2.1178+03	2.1418+03	2.1085+03	2.1280+03
9	7.2693-01	2.1234+03	2.1204+03	2.1444+03	2.1109+03	2.1306+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	1075	1076	1077	1089	1090	1091
	TWI 26	DT 26	H 26	TWI 16	DT 16	H 16
1	2.1227+03	2.8005+01	6.4190+03	2.1244+03	2.9764+01	6.0396+03
2	2.1222+03	2.6768+01	6.6403+03	2.1248+03	2.9462+01	6.0331+03
3	2.1216+03	2.7084+01	6.1915+03	2.1206+03	2.6147+01	6.4133+03
4	2.1181+03	2.3835+01	6.6751+03	2.1221+03	2.7779+01	5.7275+03
5	2.1114+03	1.6477+01	1.0124+04	2.1193+03	2.4425+01	6.8299+03
6	2.1117+03	1.5195+01	1.1069+04	2.1251+03	2.8526+01	5.8962+03
7	2.1154+03	1.6503+01	1.0347+04	2.1296+03	3.0763+01	5.5506+03
8	2.1119+03	1.4642+01	1.1062+04	2.1270+03	2.9739+01	5.4463+03
9	2.1153+03	1.7181+01	9.2051+03	2.1303+03	3.2187+01	4.9136+03

TABLE A-6c

100 KW BOILING DATA TAKEN ON 6-3-65

.738-inch Tube with Instrumented Plug-Helical Insert

RESULTS BASED ON NRL FLUID PROPERTIES

TABLE A-6c

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	244	245	271	278	285	292
	DATE	TIME	TK FM	TPB IN	TPB IN	PBC 5
1	6.0350+03	4.5000+02	1.0133+03	1.2622+03	1.2494+03	1.4710+03
2	6.0350+03	9.1500+02		1.3924+03	1.3798+03	1.6314+03
3	6.0350+03	1.2400+03		1.5541+03	1.5433+03	1.8042+03
4	6.0350+03	1.3450+03	1.2936+03	1.5178+03	1.5071+03	1.7654+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	299	306	313	327	334	341
	PBC 6	PBC 7	PBC 8	PBC 10	PBC 11	PBC 12
1	1.6241+03	1.7518+03	1.9110+03	1.8221+03	1.8152+03	1.8020+03
2	1.8041+03	1.9352+03	1.8570+03	1.8373+03	1.8291+03	1.8150+03
3	1.9064+03	1.8864+03	1.8720+03	1.8562+03	1.8435+03	1.8299+03
4	1.9356+03	1.8855+03	1.8721+03	1.8556+03	1.8452+03	1.8295+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	350	359	368	377	386	431
	TPBOUT	TPBOUT	TWO 17	TWO 18	TWO 19	TWO 23
1	1.8126+03	1.8134+03	1.8663+03	1.8630+03	1.8694+03	1.8525+03
2	1.8214+03	1.8221+03	1.8726+03	1.8693+03	1.8732+03	1.8580+03
3	1.8324+03	1.8335+03	1.8813+03	1.8768+03	1.8799+03	1.8638+03
4	1.8334+03	1.8329+03	1.8808+03	1.8761+03	1.8804+03	1.8523+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	458	476	485	494	503	512
	TWO 26	TWO 16	INS 31	INS 32	INS 33	INS 34
1	1.8487+03	1.8503+03	1.8115+03	1.8107+03	1.8094+03	1.8071+03
2	1.8515+03	1.8535+03	1.8171+03	1.8121+03	1.8110+03	1.8077+03
3	1.8568+03	1.8595+03	1.8211+03	1.8159+03	1.8144+03	1.8110+03
4	1.8568+03	1.8590+03	1.8304+03	1.8203+03	1.8217+03	1.8049+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	521	554	558	562	566	570
	INS 35	CND 41	CND 42	CND 43	CND 44	CND 45
1	1.8067+03	1.6746+03	1.6068+03	1.5438+03	1.3027+03	1.4388+03
2	1.8067+03	1.7636+03	1.7676+03	1.7701+03		1.6576+03
3	1.8093+03	1.7637+03	1.7686+03	1.7709+03		1.7673+03
4	1.8139+03	1.7679+03	1.7717+03	1.7751+03	1.5357+03	1.7681+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	577	584	686	707	708	709
	CND 46	CND 47	MAGNET	PBRADS	PBRADS	PBRADS
1	1.3917+03	1.3540+03	5.7509+02	8.6677+02	8.9087+02	8.3633+02
2	1.5845+03	1.5276+03	6.2366+02	9.2812+02	9.5429+02	9.0500+02
3	1.7642+03	1.7456+03	6.6792+02	9.6885+02	1.0006+03	9.5487+02
4	1.7470+03	1.6591+03	6.5718+02	9.6650+02	9.8766+02	9.4367+02

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	710	711	712	713	714	715
	PBRADS	PBRADS	PBRADS	TSRADS	TSRADS	TSRADS
1	8.4035+02	8.4414+02	8.6910+02	9.5301+02	9.5315+02	9.2751+02
2	9.0082+02	9.0776+02	9.2555+02	9.5889+02	9.5903+02	9.3296+02
3	9.3869+02	9.5107+02	9.6119+02	9.6345+02	9.6363+02	9.3529+02
4	9.3715+02	9.4878+02	9.5972+02	9.7096+02	9.7114+02	9.3818+02

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	716	717	718	719	720	769
	TSRADS	TSRADS	TSRADS	TSRADS	TSRADS	QN PB
1	9.2778+02	9.5089+02	9.2395+02	9.2972+02	9.2205+02	1.6297+01
2	9.3328+02	9.6016+02	9.3045+02	9.4263+02	9.2852+02	2.0301+01
3	9.3568+02	9.6637+02	9.3275+02	9.5106+02	9.3288+02	2.2912+01
4	9.3856+02	9.7891+02	9.7929+02	9.6040+02	9.3561+02	2.3000+01

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	775	779	801	803	813	820
	QN TS	Q/A TS	FLOW	G	X PB	X TS
1	1.4155+01	9.9949+04	7.3835-02	2.9173+01	1.2158-01	3.5923-01
2	1.4114+01	9.9659+04	7.4310-02	2.9361+01	2.1854-01	4.5585-01
3	1.3974+01	9.8673+04	7.4423-02	2.9405+01	3.0301-01	5.3929-01
4	1.3818+01	9.7569+04	7.8723-02	3.1104+01	2.7362-01	4.9426-01

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	822	839	842	845	848	851
	ENT OUT	X 31	X 32	X 33	X 34	X 35
1	7.2224+02	1.3693-01	2.1912-01	2.4486-01	2.8695-01	3.2903-01
2	7.9660+02	2.3387-01	3.1594-01	3.4164-01	3.8367-01	4.2569-01
3	8.6113+02	3.1827-01	3.9998-01	4.2558-01	4.6742-01	5.0926-01
4	8.2708+02	2.8787-01	3.6417-01	3.8807-01	4.2714-01	4.6622-01

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	1005	1012	1019	1054	1075	1076
	TWI 17	TWI 18	TWI 19	TWI 23	TWI 26	DT 26
1	1.8339+03	1.8305+03	1.8370+03	1.8200+03	1.8162+03	9.4468+00
2	1.8402+03	1.8369+03	1.8408+03	1.8256+03	1.8191+03	1.2315+01
3	1.8492+03	1.8447+03	1.8479+03	1.8317+03	1.8247+03	1.5347+01
4	1.8491+03	1.8445+03	1.8487+03	1.8206+03	1.8251+03	1.1128+01

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	1077	1089	1090	1091
	H 26	TWI 16	DT 16	H 16
1	1.0580+04	1.8178+03	1.1039+01	9.0546+03
2	8.0926+03	1.8211+03	1.4342+01	6.9486+03
3	6.4293+03	1.8274+03	1.8052+01	5.4662+03
4	8.7675+03	1.8273+03	1.3336+01	7.3160+03

TABLE A-6d

100 KW BOILING DATA TAKEN BETWEEN 6-8-65 AND 6-10-65

.738-inch Tube with Instrumented Plug-Helical Insert

RESULTS BASED ON NRL FLUID PROPERTIES

TABLE A-6d

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	244	245	271	278	285	292
	DATE	TIME	TK FM	TPB IN	TPB IN	PBC 5
1	6.0850+03	9.1900+02	9.0425+02	9.1421+02	9.0707+02	1.1281+03
2	6.0850+03	1.3020+03	9.4572+02	9.6316+02	9.5077+02	1.2576+03
3	6.0850+03	1.5450+03	1.0292+03	1.0477+03	1.0337+03	1.4018+03
4	6.1050+03	3.3000+02	1.0470+03	1.0625+03	1.0495+03	1.2843+03
5	6.1050+03	6.2500+02	1.1046+03	1.1234+03	1.1087+03	1.3963+03
6	6.1050+03	1.0150+03	1.1727+03	1.1912+03	1.1772+03	1.5055+03
7	6.1050+03	1.3000+03	1.2810+03	1.2968+03	1.2848+03	1.6513+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	299	306	313	327	334	341
	PBC 6	PBC 7	PBC 8	PBC 10	PBC 11	PBC 12
1	1.2690+03	1.4033+03	1.5898+03	1.7851+03	1.8171+03	1.8320+03
2	1.4646+03	1.6464+03	1.8720+03	1.9123+03	1.8143+03	1.7994+03
3	1.6472+03	1.8462+03	1.8510+03	1.9619+03	1.8239+03	1.8105+03
4	1.4295+03	1.5569+03	1.7394+03		1.8186+03	1.8073+03
5	1.5793+03	1.7327+03	1.9364+03		1.8274+03	1.8147+03
6	1.7213+03	1.8894+03	1.8616+03	2.0837+03	1.8339+03	1.8203+03
7	1.8864+03	1.8964+03	1.8799+03		1.8504+03	1.8350+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	350	359	377	395	413	431
	TPBOUT	TPBOUT	TWO 18	TWO 20	TWO 22	TWO 23
1	1.8568+03	1.8574+03	1.8801+03	1.8696+03	1.8814+03	1.8777+03
2	1.8106+03	1.8121+03	1.8830+03	1.8731+03	1.8807+03	1.8866+03
3	1.8189+03	1.8195+03	1.8880+03	1.8755+03	1.8845+03	1.8865+03
4	1.8175+03	1.8150+03	1.8883+03	1.8784+03	1.8903+03	1.8853+03
5	1.8209+03	1.8194+03	1.8902+03	1.8773+03	1.8882+03	1.8822+03
6	1.8227+03	1.8211+03	1.8898+03	1.8743+03	1.8854+03	1.8898+03
7	1.8330+03	1.8322+03	1.8982+03	1.8809+03	1.8909+03	1.8971+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	449	476	485	494	503	512
	TWO 25	TWO 16	INS 31	INS 32	INS 33	INS 34
1	1.8882+03	1.8808+03	1.8117+03	1.8101+03	1.8119+03	1.8098+03
2	1.8879+03	1.8863+03	1.8120+03	1.8108+03	1.8108+03	1.8097+03
3	1.8894+03	1.8881+03	1.8144+03	1.8124+03	1.8128+03	1.8107+03
4	1.8877+03	1.8829+03	1.8157+03	1.8134+03	1.8135+03	1.8114+03
5	1.8880+03	1.8800+03	1.8177+03	1.8138+03	1.8126+03	1.8099+03
6	1.8829+03	1.8788+03	1.8143+03	1.8084+03	1.8071+03	1.8036+03
7	1.8903+03	1.8846+03	1.8204+03	1.8125+03	1.8097+03	1.8057+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	521	554	558	562	566	570
	INS 35	CND 41	CND 42	CND 43	CND 44	CND 45
1	1.8087+03	1.2640+03	1.1613+03	1.0845+03		1.0332+03
2	1.8086+03	1.5127+03	1.2701+03	1.1653+03		1.1001+03
3	1.8095+03	1.7364+03	1.4522+03	1.2947+03		1.2085+03
4	1.8106+03	1.4579+03	1.3472+03	1.2647+03	1.0750+03	1.1539+03
5	1.8085+03	1.6847+03	1.5015+03	1.3780+03	1.1536+03	1.2282+03
6	1.8016+03	1.7594+03	1.7346+03	1.5318+03	1.2452+03	1.3158+03
7	1.8036+03	1.7542+03	1.7569+03	1.7623+03		1.4893+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	577	584	686	707	708	709
	CND 46	CND 47	MAGNET	PBRADS	PBRADS	PBRADS
1	1.0080+03	9.8346+02	4.8555+02	7.3070+02	7.4137+02	6.8349+02
2	1.0697+03	1.0417+03	5.1745+02	8.1240+C2	8.1106+02	7.5957+02
3	1.1695+03	1.1330+03	5.5070+02	8.7831+02	8.7109+02	8.2612+02
4	1.1106+03	1.0733+03	5.4961+02	8.4256+02	8.5117+02	7.9777+02
5	1.1736+03	1.1277+03	5.8127+02	9.0558+02	9.0676+02	8.5892+02
6	1.2467+03	1.1901+03	6.1284+02	9.4923+02	9.4937+02	9.0536+02
7	1.3796+03	1.2963+03	6.4760+02	1.0028+03	1.0026+03	9.6169+02

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	710	711	712	713	714	715
	PBRADS	PBRADS	PBRADS	TSRADS	TSRADS	TSRADS
1	6.9792+02	6.9648+02	7.3994+02	1.0078+03	1.0051+03	1.0104+03
2	7.7988+02	7.7812+02	8.1487+02	1.0167+03	1.0138+03	1.0191+03
3	8.4580+02	8.4714+02	8.7573+02	1.0236+03	1.0208+03	1.0278+03
4	8.1148+02	8.1017+02	8.4850+02	1.0327+03	1.0328+03	1.0320+03
5	8.7498+02	8.7606+02	9.0600+02	1.0388+03	1.0389+03	1.0397+03
6	9.1862+02	9.2134+02	9.4672+02	1.0443+03	1.0460+03	1.0471+03
7	9.7145+02	9.7537+02	9.9604+02	1.0512+03	1.0519+03	1.0553+03

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	716	717	718	719	720	769
	TSRADS	TSRADS	TSRADS	TSRADS	TSRADS	QN PB
1	1.0220+03	1.0177+03	1.0168+03	9.7773+02	1.0039+03	9.6359+00
2	1.0324+03	1.0293+03	1.0295+03	9.8827+02	1.0146+03	1.3945+01
3	1.0404+03	1.0400+03	1.0402+03	9.9754+02	1.0250+03	1.8441+01
4	1.0465+03	1.0359+03	1.0419+03	9.9655+02	1.0267+03	1.7260+01
5	1.0548+03	1.0458+03	1.0531+03	1.0078+03	1.0375+03	2.0916+01
6	1.0635+03	1.0556+03	1.0634+03	1.0179+03	1.0489+03	2.4833+01
7	1.0709+03	1.0670+03	1.0742+03	1.0315+03	1.0632+03	2.9681+01

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	775	779	801	803	813	820
	QN TS	Q/A TS	FLOW	G	X PB	X TS
1	2.1328+01	1.5060+05	4.6541-02	1.8389+01	7.4555-03	5.8532-01
2	2.1269+01	1.5019+05	4.6045-02	1.8193+01	1.4905-01	7.1881-01
3	2.1130+01	1.4920+05	4.7641-02	1.8823+01	2.7130-01	8.1995-01
4	2.0822+01	1.4703+05	7.4156-02	2.9300+01	8.5213-02	4.3276-01
5	2.0684+01	1.4606+05	7.4026-02	2.9248+01	1.6052-01	5.0757-01
6	2.1048+01	1.4862+05	7.3117-02	2.8889+01	2.4784-01	6.0642-01
7	2.1138+01	1.4926+05	7.3929-02	2.9210+01	3.4971-01	7.0731-01

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	822	839	842	845	848	851
	ENT OUT	X 31	X 32	X 33	X 34	X 35
1	8.9647+02	4.4776-02	2.4462-01	3.0722-01	4.0955-01	5.1188-01
2	9.9916+02	1.8585-01	3.8289-01	4.4461-01	5.4551-01	6.4640-01
3	1.0770+03	3.0673-01	4.9648-01	5.5591-01	6.5307-01	7.5023-01
4	7.7936+02	1.0766-01	2.2785-01	2.6550-01	3.2705-01	3.8859-01
5	8.3662+02	1.8294-01	3.0296-01	3.4055-01	4.0201-01	4.6346-01
6	9.1193+02	2.7099-01	3.9501-01	4.3385-01	4.9735-01	5.6085-01
7	9.8986+02	3.7280-01	4.9647-01	5.3521-01	5.9854-01	6.6186-01

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	1012 TWI 18	1026 TWI 20	1040 TWI 22	1054 TWI 23	1068 TWI 25	1069 DT 25
1	1.8312+03	1.8206+03	1.8325+03	1.8287+03	1.8393+03	3.0627+01
2	1.8342+03	1.8243+03	1.8320+03	1.8378+03	1.8392+03	3.0543+01
3	1.8396+03	1.8270+03	1.8361+03	1.8381+03	1.8410+03	3.1513+01
4	1.8406+03	1.8306+03	1.8425+03	1.8376+03	1.8400+03	2.9384+01
5	1.8428+03	1.8299+03	1.8408+03	1.8347+03	1.8406+03	3.2111+01
6	1.8416+03	1.8260+03	1.8372+03	1.8415+03	1.8347+03	3.3101+01
7	1.8498+03	1.8324+03	1.8425+03	1.8487+03	1.8418+03	3.8203+01

100 KW BOIL. DATA .738-IN. TUBE W/INST. PLUG-HELICAL INSERT

	1070	1089	1090	1091
	H 25	TWI 16	DT 16	H 16
1	4.9174+03	1.8319+03	2.3225+01	6.4847+03
2	4.9172+03	1.8376+03	2.8922+01	5.1927+03
3	4.7346+03	1.8396+03	3.0182+01	4.9435+03
4	5.0037+03	1.8352+03	2.4536+01	5.9924+03
5	4.5484+03	1.8325+03	2.4068+01	6.0685+03
6	4.4900+03	1.8306+03	2.9010+01	5.1233+03
7	3.9070+03	1.8362+03	3.2582+01	4.5809+03

APPENDIX B
CRITICAL FLOW TABLES

Table B-1

NOMENCLATURE FOR TABLE B-2

Symbol	Quantity	Units
ALP	Void Fraction	dimensionless
G	Critical Mass Velocity	lb_m/ft^2-sec.
PS	Saturation Pressure	psia
RHOMIX	Mixture Density	lb_m/ft^3
SLIP	Slip Ratio	dimensionless
SLIPL	Slip Ratio for Levy Momentum Exchange Model	dimensionless
TS	Saturation Temperature	^oF
X	Quality	dimensionless

Table B-2

CRITICAL FLOW TABLES

CHOKED FLOW PROGRAM

IDENT= LEVY MODEL

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1100.00	2.276	

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0000992	208.172	41.802557	14.216
0.1000000	0.0002927	237.761	39.602729	19.876
0.1500000	0.0005662	252.548	37.402902	24.214
0.2000000	0.0009228	259.921	35.203075	27.868
0.2500000	0.0013717	262.514	33.003247	31.084
0.3000000	0.0019274	261.599	30.803420	33.990
0.3500000	0.0026101	257.886	28.603592	36.659
0.4000000	0.0034475	251.809	26.403764	39.143
0.4500000	0.0044784	243.634	24.203937	41.474
0.5000000	0.0057570	233.526	22.004109	43.677
0.5200000	0.0063542	228.963	21.124178	44.527
0.5400000	0.0070098	224.108	20.244247	45.361
0.5600000	0.0077313	218.962	19.364316	46.179
0.5800000	0.0085278	213.525	18.484385	46.982
0.6000000	0.0094103	207.795	17.604454	47.772
0.6200000	0.0103918	201.767	16.724523	48.548
0.6400000	0.0114883	195.439	15.844592	49.312
0.6600000	0.0127196	188.802	14.964661	50.064
0.6800000	0.0141101	181.848	14.084730	50.804
0.7000000	0.0156907	174.567	13.204799	51.533
0.7200000	0.0175008	166.946	12.324868	52.252
0.7400000	0.0195915	158.970	11.444937	52.961
0.7600000	0.0220306	150.620	10.565006	53.660
0.7800000	0.0249094	141.876	9.685075	54.350
0.8000000	0.0283545	132.712	8.805144	55.031
0.8200000	0.0325462	123.098	7.925213	55.704
0.8400000	0.0377506	112.998	7.045282	56.368
0.8600000	0.0443772	102.371	6.165350	57.024
0.8800000	0.0530913	91.166	5.285420	57.672
0.9000000	0.0650498	79.322	4.405489	58.314
0.9100000	0.0728647	73.138	3.965523	58.631
0.9200000	0.0824581	66.765	3.525558	58.947
0.9300000	0.0945120	60.192	3.085592	59.262
0.9400000	0.1101078	53.405	2.645627	59.574
0.9500000	0.1310699	46.391	2.205661	59.885
0.9600000	0.1607354	39.131	1.765696	60.194
0.9700000	0.2059319	31.608	1.325730	60.502
0.9800000	0.2831566	23.802	0.885765	60.808
0.9900000	0.4450814	15.687	0.445799	61.112
0.9910000	0.4716062	14.858	0.401802	61.143
0.9920000	0.5013972	14.025	0.357806	61.173
0.9930000	0.5350983	13.189	0.313810	61.203
0.9940000	0.5735321	12.349	0.269813	61.234
0.9950000	0.6177712	11.506	0.225816	61.264
0.9960000	0.6692381	10.659	0.181820	61.294
0.9970000	0.7298612	9.809	0.137823	61.325
0.9980000	0.8023234	8.956	0.093827	61.355
0.9990000	0.8904670	8.098	0.049830	61.385
0.9995000	0.9421010	7.669	0.027832	61.400
0.9999000	0.9878644	7.324	0.010233	61.411

CHOKED FLOW PROGRAM

IDENT= LEVY MODEL

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1200.00	4.573	

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0001397	321.772	40.993721	10.364
0.1000000	0.0004105	366.955	38.836739	14.427
0.1500000	0.0007924	389.409	36.679756	17.540
0.2000000	0.0012897	400.428	34.522774	20.160
0.2500000	0.0019151	404.048	32.365791	22.466
0.3000000	0.0026884	402.221	30.208809	24.549
0.3500000	0.0036375	396.043	28.051826	26.462
0.4000000	0.0048008	386.181	25.894845	28.241
0.4500000	0.0062312	373.054	23.737862	29.911
0.5000000	0.0080034	356.923	21.580879	31.489
0.5200000	0.0088305	349.666	20.718086	32.097
0.5400000	0.0097378	341.957	19.855293	32.694
0.5600000	0.0107358	333.801	18.992501	33.280
0.5800000	0.0118368	325.197	18.129707	33.855
0.6000000	0.0130558	316.144	17.266915	34.420
0.6200000	0.0144104	306.640	16.404121	34.976
0.6400000	0.0159226	296.679	15.541329	35.522
0.6600000	0.0176190	286.254	14.678536	36.060
0.6800000	0.0195326	275.354	13.815742	36.590
0.7000000	0.0217053	263.968	12.952950	37.112
0.7200000	0.0241900	252.080	12.090157	37.626
0.7400000	0.0270555	239.674	11.227364	38.133
0.7600000	0.0303925	226.727	10.364571	38.633
0.7800000	0.0343230	213.215	9.501778	39.127
0.8000000	0.0390149	199.109	8.638985	39.614
0.8200000	0.0447067	184.375	7.776192	40.095
0.8400000	0.0517478	168.974	6.913400	40.570
0.8600000	0.0606723	152.861	6.050606	41.039
0.8800000	0.0723391	135.980	5.187814	41.503
0.9000000	0.0882233	118.270	4.325021	41.961
0.9100000	0.0985257	109.001	3.893624	42.188
0.9200000	0.1110895	99.655	3.462228	42.414
0.9300000	0.1267468	89.982	3.030831	42.639
0.9400000	0.1467952	80.049	2.599435	42.862
0.9500000	0.1733762	69.841	2.168038	43.085
0.9600000	0.2102941	59.345	1.736642	43.306
0.9700000	0.2650189	48.543	1.305245	43.526
0.9800000	0.3545017	37.417	0.873849	43.744
0.9900000	0.5272110	25.948	0.442453	43.962
0.9910000	0.5537454	24.781	0.399313	43.984
0.9920000	0.5829998	23.611	0.356173	44.005
0.9930000	0.6154147	22.437	0.313034	44.027
0.9940000	0.6515320	21.259	0.269894	44.049
0.9950000	0.6920240	20.077	0.226754	44.070
0.9960000	0.7377367	18.892	0.183614	44.092
0.9970000	0.7897489	17.703	0.140475	44.114
0.9980000	0.8494597	16.510	0.097335	44.135
0.9990000	0.9187145	15.313	0.054196	44.157
0.9995000	0.9576656	14.713	0.032626	44.168
0.9999000	0.9912409	14.233	0.015370	44.174

CHOKED FLOW PROGRAM

IDENT= LEVY MODEL

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1300.00	8.473	

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0001902	469.957	40.176559	7.866
0.1000000	0.0005558	535.028	38.063026	10.890
0.1500000	0.0010700	567.191	35.949493	13.207
0.2000000	0.0017384	582.723	33.835960	15.157
0.2500000	0.0025780	587.456	31.722427	16.872
0.3000000	0.0036150	584.219	29.608895	18.420
0.3500000	0.0048863	574.606	27.495362	19.842
0.4000000	0.0064427	559.592	25.381829	21.164
0.4500000	0.0083542	539.797	23.268296	22.404
0.5000000	0.0107190	515.617	21.154764	23.576
0.5200000	0.0118216	504.773	20.309351	24.028
0.5400000	0.0130303	493.277	19.463938	24.471
0.5600000	0.0143588	481.133	18.618525	24.905
0.5800000	0.0158233	468.346	17.773111	25.332
0.6000000	0.0174432	454.916	16.927698	25.752
0.6200000	0.0192418	440.842	16.082285	26.164
0.6400000	0.0212474	426.120	15.236872	26.570
0.6600000	0.0234947	410.743	14.391459	26.969
0.6800000	0.0260267	394.701	13.546046	27.362
0.7000000	0.0288973	377.983	12.700633	27.749
0.7200000	0.0321749	360.573	11.855220	28.130
0.7400000	0.0359478	342.453	11.009806	28.506
0.7600000	0.0403321	323.601	10.164393	28.877
0.7800000	0.0454833	303.991	9.318980	29.243
0.8000000	0.0516146	283.594	8.473567	29.604
0.8200000	0.0590264	262.376	7.628154	29.961
0.8400000	0.0681560	240.297	6.782741	30.313
0.8600000	0.0796659	217.311	5.937328	30.661
0.8800000	0.0946096	193.366	5.091915	31.005
0.9000000	0.1147703	168.402	4.246502	31.344
0.9100000	0.1277338	155.516	3.823795	31.513
0.9200000	0.1434244	142.349	3.401089	31.680
0.9300000	0.1627988	128.890	2.978382	31.847
0.9400000	0.1873203	115.128	2.555676	32.012
0.9500000	0.2193460	101.050	2.132969	32.177
0.9600000	0.2629312	86.645	1.710263	32.341
0.9700000	0.3256956	71.896	1.287556	32.504
0.9800000	0.4238416	56.791	0.864849	32.666
0.9900000	0.5989759	41.311	0.442143	32.827
0.9910000	0.6243515	39.742	0.399872	32.843
0.9920000	0.6518862	38.169	0.357601	32.859
0.9930000	0.6818675	36.592	0.315331	32.875
0.9940000	0.7146370	35.011	0.273060	32.891
0.9950000	0.7506024	33.426	0.230790	32.907
0.9960000	0.7902550	31.837	0.188519	32.923
0.9970000	0.8341921	30.243	0.146248	32.939
0.9980000	0.8831483	28.646	0.103978	32.955
0.9990000	0.9380352	27.045	0.061707	32.971
0.9995000	0.9680499	26.243	0.040572	32.979
0.9999000	0.9934456	25.601	0.023663	32.983

CHOKED FLOW PROGRAM

IDENT= LEVY MODEL

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1400.00	15.177	

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0002517	662.523	39.351307	6.175
0.1000000	0.0007308	753.800	37.281875	8.496
0.1500000	0.0014026	799.714	35.212443	10.273
0.2000000	0.0022743	822.793	33.143010	11.769
0.2500000	0.0033674	831.117	31.073578	13.083
0.3000000	0.0047157	828.609	29.004146	14.270
0.3500000	0.0063665	817.470	26.934713	15.359
0.4000000	0.0083848	799.041	24.865281	16.371
0.4500000	0.0108600	774.162	22.795848	17.320
0.5000000	0.0139172	743.351	20.726416	18.217
0.5200000	0.0153409	729.435	19.898642	18.563
0.5400000	0.0169003	714.625	19.070870	18.901
0.5600000	0.0186128	698.927	18.243097	19.234
0.5800000	0.0204988	682.340	17.415324	19.560
0.6000000	0.0225829	664.859	16.587551	19.881
0.6200000	0.0248944	646.475	15.759778	20.196
0.6400000	0.0274688	627.173	14.932005	20.507
0.6600000	0.0303496	606.935	14.104232	20.812
0.6800000	0.0335906	585.736	13.276459	21.112
0.7000000	0.0372587	563.544	12.448686	21.408
0.7200000	0.0414391	540.323	11.620913	21.699
0.7400000	0.0462410	516.026	10.793140	21.987
0.7600000	0.0518074	490.601	9.965367	22.270
0.7800000	0.0583287	463.983	9.137594	22.550
0.8000000	0.0660646	436.097	8.309821	22.826
0.8200000	0.0753787	406.854	7.482048	23.098
0.8400000	0.0867957	376.148	6.654275	23.367
0.8600000	0.1011023	343.851	5.826502	23.633
0.8800000	0.1195339	309.814	4.998729	23.895
0.9000000	0.1441477	273.854	4.170956	24.155
0.9100000	0.1598236	255.086	3.757070	24.283
0.9200000	0.1786418	235.750	3.343183	24.411
0.9300000	0.2016457	215.812	2.929297	24.538
0.9400000	0.2303998	195.232	2.515410	24.665
0.9500000	0.2673583	173.966	2.101524	24.790
0.9600000	0.3166044	151.963	1.687637	24.915
0.9700000	0.3854695	129.169	1.273751	25.040
0.9800000	0.4885652	105.521	0.859864	25.163
0.9900000	0.6598062	80.948	0.445978	25.286
0.9910000	0.6833664	78.436	0.404589	25.299
0.9920000	0.7085934	75.915	0.363200	25.311
0.9930000	0.7356703	73.383	0.321812	25.323
0.9940000	0.7648086	70.841	0.280423	25.336
0.9950000	0.7962527	68.289	0.239034	25.348
0.9960000	0.8302877	65.726	0.197646	25.360
0.9970000	0.8672470	63.152	0.156257	25.372
0.9980000	0.9075250	60.568	0.114869	25.384
0.9990000	0.9515892	57.973	0.073480	25.397
0.9995000	0.9752119	56.672	0.052785	25.403
0.9999000	0.9949444	55.629	0.036230	25.405

CHOKED FLOW PROGRAM

IDENT= LEVY MODEL

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1500.00	24.666	

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0003255	884.425	38.518211	4.991
0.1000000	0.0009381	1004.338	36.493582	6.817
0.1500000	0.0017939	1064.626	34.468952	8.215
0.2000000	0.0029019	1094.783	32.444323	9.391
0.2500000	0.0042890	1105.425	30.419694	10.425
0.3000000	0.0059972	1101.715	28.395065	11.357
0.3500000	0.0080856	1086.562	26.370435	12.213
0.4000000	0.0106348	1061.738	24.345806	13.007
0.4500000	0.0137559	1028.364	22.321177	13.752
0.5000000	0.0176038	987.133	20.296548	14.456
0.5200000	0.0193932	968.537	19.486696	14.727
0.5400000	0.0213513	948.762	18.676844	14.993
0.5600000	0.0234994	927.816	17.866993	15.254
0.5800000	0.0258629	905.701	17.057141	15.510
0.6000000	0.0284715	882.412	16.247289	15.761
0.6200000	0.0313610	857.940	15.437438	16.008
0.6400000	0.0345749	832.270	14.627586	16.251
0.6600000	0.0381658	805.378	13.817734	16.491
0.6800000	0.0421987	777.237	13.007883	16.726
0.7000000	0.0467546	747.812	12.198031	16.958
0.7200000	0.0519357	717.058	11.388179	17.186
0.7400000	0.0578728	684.923	10.578328	17.411
0.7600000	0.0647359	651.345	9.768476	17.633
0.7800000	0.0727507	616.250	8.958625	17.852
0.8000000	0.0822225	579.552	8.148773	18.068
0.8200000	0.0935755	541.149	7.338921	18.282
0.8400000	0.1074166	500.920	6.529070	18.492
0.8600000	0.1246450	458.724	5.719218	18.700
0.8800000	0.1466535	414.393	4.909366	18.906
0.9000000	0.1757203	367.728	4.099514	19.109
0.9100000	0.1940425	343.447	3.694589	19.209
0.9200000	0.2158450	318.489	3.289663	19.309
0.9300000	0.2422167	292.816	2.884737	19.409
0.9400000	0.2747540	266.388	2.479811	19.508
0.9500000	0.3158952	239.157	2.074885	19.606
0.9600000	0.3695593	211.074	1.669960	19.704
0.9700000	0.4424718	182.080	1.265034	19.801
0.9800000	0.5472241	152.114	0.860108	19.898
0.9900000	0.7104533	121.105	0.455182	19.994
0.9910000	0.7319300	117.943	0.414690	20.004
0.9920000	0.7546759	114.771	0.374197	20.014
0.9930000	0.7788066	111.587	0.333704	20.023
0.9940000	0.8044529	108.391	0.293212	20.033
0.9950000	0.8317620	105.184	0.252719	20.042
0.9960000	0.8609009	101.965	0.212226	20.052
0.9970000	0.8920595	98.735	0.171734	20.061
0.9980000	0.9254560	95.492	0.131241	20.071
0.9990000	0.9613399	92.238	0.090749	20.080
0.9995000	0.9803030	90.606	0.070502	20.085
0.9999000	0.9959990	89.300	0.054305	20.085

CHOKED FLOW PROGRAM

IDENT= LEVY MODEL

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1600.00	38.191	

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0004128	1141.741	37.677512	4.136
0.1000000	0.0011799	1293.794	35.698445	5.604
0.1500000	0.0022473	1370.261	33.719378	6.727
0.2000000	0.0036256	1408.372	31.740311	7.672
0.2500000	0.0053478	1421.585	29.761244	8.502
0.3000000	0.0074650	1416.460	27.782177	9.250
0.3500000	0.0100489	1396.701	25.803110	9.936
0.4000000	0.0131974	1364.576	23.824043	10.574
0.4500000	0.0170450	1321.524	21.844976	11.171
0.5000000	0.0217787	1268.448	19.865909	11.735
0.5200000	0.0239764	1244.539	19.074282	11.952
0.5400000	0.0263789	1219.130	18.282655	12.165
0.5600000	0.0290116	1192.235	17.491028	12.374
0.5800000	0.0319048	1163.858	16.699401	12.579
0.6000000	0.0350939	1133.996	15.907775	12.780
0.6200000	0.0386216	1102.640	15.116148	12.978
0.6400000	0.0425391	1069.774	14.324521	13.172
0.6600000	0.0469088	1035.375	13.532894	13.364
0.6800000	0.0518071	999.410	12.741267	13.552
0.7000000	0.0573291	961.841	11.949641	13.738
0.7200000	0.0635939	922.618	11.158014	13.920
0.7400000	0.0707536	881.683	10.366387	14.101
0.7600000	0.0790049	838.967	9.574760	14.278
0.7800000	0.0886066	794.386	8.783134	14.453
0.8000000	0.0999071	747.845	7.991507	14.626
0.8200000	0.1133858	699.229	7.199880	14.796
0.8400000	0.1297219	648.408	6.408253	14.965
0.8600000	0.1499095	595.225	5.616626	15.131
0.8800000	0.1754655	539.498	4.825000	15.295
0.9000000	0.2088238	481.014	4.033372	15.458
0.9100000	0.2296249	450.659	3.637559	15.538
0.9200000	0.2541526	419.516	3.241746	15.618
0.9300000	0.2834998	387.545	2.845932	15.697
0.9400000	0.3192331	354.702	2.450119	15.776
0.9500000	0.3636805	320.941	2.054306	15.855
0.9600000	0.4204582	286.210	1.658492	15.933
0.9700000	0.4955049	250.449	1.262679	16.011
0.9800000	0.5993019	213.597	0.866865	16.088
0.9900000	0.7522455	175.583	0.471052	16.165
0.9910000	0.7716178	171.714	0.431471	16.173
0.9920000	0.7919524	167.833	0.391889	16.180
0.9930000	0.8133226	163.940	0.352308	16.188
0.9940000	0.8358098	160.034	0.312727	16.196
0.9950000	0.8595039	156.115	0.273145	16.203
0.9960000	0.8845045	152.184	0.233564	16.211
0.9970000	0.9109224	148.239	0.193983	16.219
0.9980000	0.9388823	144.282	0.154401	16.226
0.9990000	0.9685227	140.311	0.114820	16.234
0.9995000	0.9840212	138.321	0.095029	16.238
0.9999000	0.9967641	136.728	0.079197	16.238

CHOKED FLOW PROGRAM

IDENT= LEVY MODEL

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1700.00	56.719	

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0005152	1432.279	36.829458	3.503
0.1000000	0.0014589	1619.278	34.896769	4.703
0.1500000	0.0027662	1713.416	32.964079	5.623
0.2000000	0.0044498	1760.227	31.031391	6.395
0.2500000	0.0065486	1776.243	29.098702	7.073
0.3000000	0.0091237	1769.548	27.166013	7.685
0.3500000	0.0122604	1744.719	25.233324	8.246
0.4000000	0.0160752	1704.569	23.300635	8.766
0.4500000	0.0207272	1650.893	21.367945	9.253
0.5000000	0.0264371	1584.827	19.435256	9.713
0.5200000	0.0290833	1555.095	18.662181	9.890
0.5400000	0.0319728	1523.518	17.889106	10.064
0.5600000	0.0351354	1490.113	17.116030	10.234
0.5800000	0.0386062	1454.888	16.342954	10.401
0.6000000	0.0424266	1417.843	15.569879	10.565
0.6200000	0.0466460	1378.971	14.796803	10.727
0.6400000	0.0513238	1338.256	14.023728	10.885
0.6600000	0.0565317	1295.673	13.250652	11.041
0.6800000	0.0623577	1251.188	12.477576	11.195
0.7000000	0.0689103	1204.760	11.704501	11.346
0.7200000	0.0763253	1156.335	10.931425	11.494
0.7400000	0.0847747	1105.850	10.158350	11.641
0.7600000	0.0944800	1053.228	9.385274	11.786
0.7800000	0.1057306	998.380	8.612199	11.928
0.8000000	0.1189129	941.200	7.839123	12.069
0.8200000	0.1345538	881.567	7.066047	12.207
0.8400000	0.1533918	819.336	6.292972	12.344
0.8600000	0.1764939	754.341	5.519896	12.480
0.8800000	0.2054623	686.387	4.746821	12.613
0.9000000	0.2428173	615.247	3.973745	12.745
0.9100000	0.2658528	578.400	3.587207	12.811
0.9200000	0.2927651	540.653	3.200669	12.876
0.9300000	0.3246152	501.965	2.814131	12.940
0.9400000	0.3628901	462.290	2.427594	13.005
0.9500000	0.4097410	421.581	2.041056	13.068
0.9600000	0.4683995	379.784	1.654518	13.132
0.9700000	0.5439550	336.840	1.267980	13.195
0.9800000	0.6449119	292.686	0.881443	13.258
0.9900000	0.7866334	247.252	0.494905	13.321
0.9910000	0.8040163	242.635	0.456251	13.327
0.9920000	0.8221303	238.005	0.417597	13.333
0.9930000	0.8410221	233.361	0.378944	13.339
0.9940000	0.8607431	228.703	0.340290	13.345
0.9950000	0.8813492	224.031	0.301636	13.352
0.9960000	0.9029011	219.345	0.262982	13.358
0.9970000	0.9254653	214.645	0.224328	13.364
0.9980000	0.9491150	209.931	0.185675	13.370
0.9990000	0.9739304	205.202	0.147021	13.376
0.9995000	0.9868024	202.833	0.127694	13.379
0.9999000	0.9973322	200.946	0.112232	13.374

CHOKED FLOW PROGRAM

IDENT= LEVY MODEL

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1800.00	81.249	

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0006341	1752.951	35.974293	3.024
0.1000000	0.0017778	1976.877	34.088854	4.020
0.1500000	0.0033545	2089.814	32.203414	4.784
0.2000000	0.0053785	2145.916	30.317976	5.425
0.2500000	0.0078957	2164.948	28.432536	5.988
0.3000000	0.0109774	2156.607	26.547096	6.496
0.3500000	0.0147233	2126.400	24.661657	6.961
0.4000000	0.0192692	2077.726	22.776217	7.392
0.4500000	0.0247999	2012.761	20.890778	7.796
0.5000000	0.0315710	1932.902	19.005338	8.177
0.5200000	0.0347029	1896.992	18.251162	8.323
0.5400000	0.0381184	1858.872	17.496987	8.467
0.5600000	0.0418518	1818.564	16.742811	8.608
0.5800000	0.0459431	1776.082	15.988635	8.746
0.6000000	0.0504396	1731.430	15.234460	8.882
0.6200000	0.0553972	1684.603	14.480284	9.016
0.6400000	0.0608833	1635.586	13.726108	9.147
0.6600000	0.0669789	1584.355	12.971932	9.276
0.6800000	0.0737826	1530.874	12.217756	9.403
0.7000000	0.0814158	1475.100	11.463580	9.527
0.7200000	0.0900298	1416.976	10.709405	9.650
0.7400000	0.0998148	1356.435	9.955229	9.772
0.7600000	0.1110143	1293.396	9.201053	9.891
0.7800000	0.1239442	1227.762	8.446877	10.009
0.8000000	0.1390228	1159.421	7.692702	10.125
0.8200000	0.1568150	1088.243	6.938526	10.240
0.8400000	0.1781032	1014.075	6.184350	10.353
0.8600000	0.2040032	936.740	5.430174	10.464
0.8800000	0.2361626	856.035	4.675999	10.575
0.9000000	0.2771206	771.719	3.921823	10.684
0.9100000	0.3020956	728.122	3.544735	10.738
0.9200000	0.3310055	683.514	3.167647	10.791
0.9300000	0.3648520	637.854	2.790559	10.845
0.9400000	0.4050080	591.095	2.413471	10.898
0.9500000	0.4534082	543.188	2.036383	10.951
0.9600000	0.5128679	494.078	1.659295	11.003
0.9700000	0.5876493	443.707	1.282207	11.055
0.9800000	0.6845275	392.010	0.905120	11.107
0.9900000	0.8149633	338.916	0.528032	11.159
0.9910000	0.8305345	333.527	0.490323	11.164
0.9920000	0.8466639	328.123	0.452614	11.169
0.9930000	0.8633821	322.705	0.414905	11.174
0.9940000	0.8807221	317.271	0.377197	11.179
0.9950000	0.8987190	311.822	0.339488	11.184
0.9960000	0.9174110	306.358	0.301779	11.189
0.9970000	0.9368387	300.879	0.264070	11.194
0.9980000	0.9570469	295.385	0.226361	11.200
0.9990000	0.9780833	289.875	0.188652	11.205
0.9995000	0.9889281	287.115	0.169798	11.207
0.9999000	0.9977653	284.925	0.154715	11.200

CHOKED FLOW PROGRAM

IDENT= LEVY MODEL

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1900.00	112.783	

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0007715	2100.035	35.112261	2.655
0.1000000	0.0021396	2361.973	33.274994	3.492
0.1500000	0.0040158	2494.436	31.437729	4.134
0.2000000	0.0064162	2560.253	29.600462	4.674
0.2500000	0.0093935	2582.494	27.763196	5.148
0.3000000	0.0130299	2572.518	25.925929	5.574
0.3500000	0.0174400	2536.801	24.088663	5.965
0.4000000	0.0227793	2479.349	22.251396	6.327
0.4500000	0.0292590	2402.746	20.414130	6.666
0.5000000	0.0371700	2308.663	18.576863	6.986
0.5200000	0.0408213	2266.383	17.841957	7.109
0.5400000	0.0447980	2221.519	17.107050	7.229
0.5600000	0.0491384	2174.099	16.372144	7.347
0.5800000	0.0538877	2124.144	15.637237	7.463
0.6000000	0.0590984	2071.662	14.902331	7.577
0.6200000	0.0648333	2016.651	14.167424	7.689
0.6400000	0.0711669	1959.098	13.432518	7.799
0.6600000	0.0781888	1898.980	12.697611	7.907
0.6800000	0.0860079	1836.262	11.962704	8.013
0.7000000	0.0947571	1770.899	11.227798	8.118
0.7200000	0.1046013	1702.834	10.492891	8.221
0.7400000	0.1157469	1631.994	9.757984	8.322
0.7600000	0.1284558	1558.295	9.023078	8.422
0.7800000	0.1430656	1481.637	8.288171	8.521
0.8000000	0.1600193	1401.901	7.553265	8.618
0.8200000	0.1799091	1318.950	6.818358	8.714
0.8400000	0.2035456	1232.625	6.083452	8.808
0.8600000	0.2320686	1142.740	5.348545	8.902
0.8800000	0.2671331	1049.082	4.613639	8.994
0.9000000	0.3112369	951.403	3.878732	9.085
0.9100000	0.3378307	900.968	3.511279	9.130
0.9200000	0.3683361	849.416	3.143825	9.175
0.9300000	0.4036765	796.705	2.776372	9.220
0.9400000	0.4450910	742.786	2.408919	9.264
0.9500000	0.4942819	687.611	2.041466	9.308
0.9600000	0.5536525	631.123	1.674012	9.352
0.9700000	0.6267113	573.264	1.306559	9.396
0.9800000	0.7187880	513.968	0.939106	9.439
0.9900000	0.8383920	453.165	0.571652	9.482
0.9910000	0.8523479	446.999	0.534907	9.486
0.9920000	0.8667334	440.817	0.498162	9.491
0.9930000	0.8815687	434.619	0.461416	9.495
0.9940000	0.8968754	428.405	0.424671	9.499
0.9950000	0.9126761	422.174	0.387926	9.504
0.9960000	0.9289952	415.928	0.351180	9.508
0.9970000	0.9458584	409.665	0.314435	9.512
0.9980000	0.9632936	403.386	0.277690	9.516
0.9990000	0.9813300	397.091	0.240944	9.521
0.9995000	0.9905834	393.939	0.222572	9.522
0.9999000	0.9981023	391.439	0.207874	9.518

CHOKED FLOW PROGRAM

IDENT= LEVY MODEL

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
2000.00	152.296	

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0009293	2469.421	34.243596	2.365
0.1000000	0.0025477	2769.537	32.455472	3.076
0.1500000	0.0047544	2921.840	30.667350	3.623
0.2000000	0.0075675	2997.623	28.879227	4.082
0.2500000	0.0110467	3023.244	27.091102	4.484
0.3000000	0.0152852	3011.735	25.302979	4.847
0.3500000	0.0204128	2970.549	23.514856	5.179
0.4000000	0.0266050	2904.319	21.726733	5.486
0.4500000	0.0340997	2816.045	19.938609	5.774
0.5000000	0.0432222	2707.687	18.150486	6.045
0.5200000	0.0474232	2659.014	17.435236	6.150
0.5400000	0.0519919	2607.381	16.719987	6.252
0.5600000	0.0569709	2552.827	16.004738	6.352
0.5800000	0.0624097	2495.376	15.289488	6.450
0.6000000	0.0683664	2435.044	14.574239	6.547
0.6200000	0.0749097	2371.831	13.858990	6.642
0.6400000	0.0821208	2305.728	13.143741	6.735
0.6600000	0.0900974	2236.714	12.428491	6.826
0.6800000	0.0989571	2164.756	11.713242	6.916
0.7000000	0.1088431	2089.808	10.997992	7.005
0.7200000	0.1199319	2011.811	10.282743	7.092
0.7400000	0.1324431	1930.693	9.567494	7.178
0.7600000	0.1466534	1846.366	8.852244	7.263
0.7800000	0.1629167	1758.726	8.136995	7.346
0.8000000	0.1816929	1667.651	7.421745	7.428
0.8200000	0.2035905	1572.998	6.706496	7.509
0.8400000	0.2294328	1474.603	5.991247	7.589
0.8600000	0.2603602	1372.273	5.275997	7.668
0.8800000	0.2980010	1265.790	4.560748	7.747
0.9000000	0.3447618	1154.898	3.845499	7.824
0.9100000	0.3726492	1097.708	3.487874	7.862
0.9200000	0.4043572	1039.302	3.130249	7.900
0.9300000	0.4407205	979.637	2.772625	7.937
0.9400000	0.4828364	918.663	2.415000	7.975
0.9500000	0.5321765	856.331	2.057375	8.012
0.9600000	0.5907609	792.584	1.699751	8.049
0.9700000	0.6614410	727.362	1.342126	8.086
0.9800000	0.7483747	660.602	0.984501	8.123
0.9900000	0.8578730	592.232	0.626877	8.159
0.9910000	0.8704056	585.304	0.591114	8.163
0.9920000	0.8832719	578.358	0.555352	8.166
0.9930000	0.8964853	571.396	0.519589	8.170
0.9940000	0.9100601	564.417	0.483827	8.174
0.9950000	0.9240113	557.420	0.448064	8.177
0.9960000	0.9383546	550.406	0.412302	8.181
0.9970000	0.9531068	543.375	0.376539	8.184
0.9980000	0.9682857	536.327	0.340777	8.188
0.9990000	0.9839102	529.260	0.305014	8.192
0.9995000	0.9918955	525.722	0.287133	8.193
0.9999000	0.9983669	522.987	0.272828	8.182

CHOKED FLOW PROGRAM

IDENT= LEVY MODEL

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
2100.00	200.712	

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0011097	2856.830	33.368528	2.135
0.1000000	0.0030055	3194.386	31.630557	2.744
0.1500000	0.0055748	3366.437	29.892587	3.213
0.2000000	0.0088374	3452.265	28.154615	3.607
0.2500000	0.0128601	3481.413	26.416644	3.953
0.3000000	0.0177474	3468.554	24.678673	4.264
0.3500000	0.0236440	3422.113	22.940702	4.549
0.4000000	0.0307458	3347.344	21.202731	4.813
0.4500000	0.0393164	3247.672	19.464760	5.059
0.5000000	0.0497153	3125.349	17.726789	5.292
0.5200000	0.0544924	3070.421	17.031600	5.381
0.5400000	0.0596798	3012.165	16.336412	5.469
0.5600000	0.0653237	2950.630	15.641224	5.554
0.5800000	0.0714780	2885.847	14.946035	5.638
0.6000000	0.0782057	2817.837	14.250847	5.721
0.6200000	0.0855808	2746.607	13.555658	5.802
0.6400000	0.0936908	2672.151	12.860470	5.882
0.6600000	0.1026399	2594.451	12.165282	5.960
0.6800000	0.1125536	2513.475	11.470093	6.037
0.7000000	0.1235835	2429.180	10.774905	6.113
0.7200000	0.1359155	2341.507	10.079716	6.187
0.7400000	0.1497793	2250.382	9.384528	6.261
0.7600000	0.1654622	2155.717	8.689339	6.333
0.7800000	0.1833288	2057.406	7.994151	6.404
0.8000000	0.2038483	1955.324	7.298963	6.475
0.8200000	0.2276352	1849.326	6.603774	6.544
0.8400000	0.2555099	1739.242	5.908586	6.612
0.8600000	0.2885937	1624.878	5.213397	6.680
0.8800000	0.3284591	1506.008	4.518209	6.746
0.9000000	0.3773837	1382.374	3.823020	6.812
0.9100000	0.4062506	1318.679	3.475426	6.845
0.9200000	0.4387943	1253.677	3.127832	6.877
0.9300000	0.4757575	1187.325	2.780238	6.909
0.9400000	0.5180967	1119.573	2.432644	6.941
0.9500000	0.5670663	1050.370	2.085049	6.973
0.9600000	0.6243443	979.662	1.737455	7.005
0.9700000	0.6922266	907.387	1.389861	7.036
0.9800000	0.7739413	833.482	1.042267	7.067
0.9900000	0.8741747	757.875	0.694673	7.098
0.9910000	0.8854609	750.218	0.659913	7.101
0.9920000	0.8970086	742.544	0.625154	7.105
0.9930000	0.9088268	734.851	0.590394	7.108
0.9940000	0.9209252	727.140	0.555635	7.111
0.9950000	0.9333140	719.411	0.520875	7.114
0.9960000	0.9460036	711.664	0.486116	7.117
0.9970000	0.9590049	703.899	0.451357	7.120
0.9980000	0.9723299	696.116	0.416597	7.123
0.9990000	0.9859907	688.313	0.381838	7.126
0.9995000	0.9929510	684.405	0.364458	7.128
0.9999000	0.9985808	681.422	0.350554	7.118

CHOKED FLOW PROGRAM

IDENT= LEVY MODEL

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
2200.00	258.882	

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0013150	3258.000	32.487276	1.950
0.1000000	0.0035170	3631.402	30.800497	2.476
0.1500000	0.0064820	3822.723	29.113719	2.881
0.2000000	0.0102314	3918.509	27.426941	3.223
0.2500000	0.0148393	3951.302	25.740162	3.522
0.3000000	0.0204210	3937.350	24.053384	3.791
0.3500000	0.0271366	3886.017	22.366605	4.037
0.4000000	0.0352013	3803.170	20.679827	4.265
0.4500000	0.0449041	3692.651	18.993048	4.478
0.5000000	0.0566369	3557.005	17.306270	4.679
0.5200000	0.0620130	3496.103	16.631559	4.756
0.5400000	0.0678413	3431.524	15.956847	4.832
0.5600000	0.0741717	3363.323	15.282136	4.906
0.5800000	0.0810618	3291.541	14.607425	4.978
0.6000000	0.0885789	3216.204	13.932713	5.050
0.6200000	0.0968018	3137.325	13.258002	5.120
0.6400000	0.1058232	3054.904	12.583291	5.188
0.6600000	0.1157531	2968.926	11.908579	5.256
0.6800000	0.1267230	2879.362	11.233867	5.322
0.7000000	0.1388913	2786.172	10.559156	5.387
0.7200000	0.1524507	2689.296	9.884445	5.452
0.7400000	0.1676378	2588.665	9.209733	5.515
0.7600000	0.1847466	2484.189	8.535022	5.577
0.7800000	0.2041467	2375.761	7.860311	5.639
0.8000000	0.2263091	2263.257	7.185600	5.699
0.8200000	0.2518445	2146.529	6.510888	5.759
0.8400000	0.2815577	2025.407	5.836177	5.818
0.8600000	0.3165329	1899.694	5.161465	5.876
0.8800000	0.3582651	1769.164	4.486754	5.933
0.9000000	0.4088759	1633.556	3.812043	5.990
0.9100000	0.4384303	1563.755	3.474687	6.018
0.9200000	0.4714798	1492.569	3.137331	6.046
0.9300000	0.5086758	1419.953	2.799975	6.073
0.9400000	0.5508418	1345.859	2.462620	6.101
0.9500000	0.5990358	1270.236	2.125264	6.128
0.9600000	0.6546383	1193.028	1.787909	6.155
0.9700000	0.7194866	1114.175	1.450553	6.182
0.9800000	0.7960804	1033.615	1.113197	6.209
0.9900000	0.8879098	951.277	0.775841	6.236
0.9910000	0.8981068	942.942	0.742106	6.239
0.9920000	0.9085104	934.590	0.708370	6.241
0.9930000	0.9191271	926.218	0.674635	6.244
0.9940000	0.9299635	917.828	0.640899	6.247
0.9950000	0.9410263	909.418	0.607164	6.249
0.9960000	0.9523229	900.990	0.573428	6.252
0.9970000	0.9638605	892.544	0.539693	6.255
0.9980000	0.9756469	884.079	0.505957	6.257
0.9990000	0.9876906	875.594	0.472221	6.260
0.9995000	0.9938112	871.353	0.455353	6.261
0.9999000	0.9987534	868.306	0.441859	6.245

CHOKED FLOW PROGRAM

IDENT= SLIP=SQUARE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1100.00	2.276	86.85

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0006056	301.727	39.760299	
0.1000000	0.0012777	291.817	35.733186	
0.1500000	0.0020277	281.618	31.921048	
0.2000000	0.0028702	271.106	28.323885	
0.2500000	0.0038233	260.253	24.941697	
0.3000000	0.0049103	249.027	21.774483	
0.3500000	0.0061616	237.392	18.822244	
0.4000000	0.0076175	225.304	16.084980	
0.4500000	0.0093326	212.714	13.562690	
0.5000000	0.0113828	199.562	11.255375	
0.5200000	0.0123197	194.128	10.392642	
0.5400000	0.0133361	188.588	9.564305	
0.5600000	0.0144424	182.935	8.770364	
0.5800000	0.0156513	177.165	8.010818	
0.6000000	0.0169776	171.270	7.285669	
0.6200000	0.0184394	165.244	6.594916	
0.6400000	0.0200586	159.077	5.938559	
0.6600000	0.0218619	152.763	5.316597	
0.6800000	0.0238827	146.290	4.729032	
0.7000000	0.0261629	139.649	4.175862	
0.7200000	0.0287558	132.829	3.657088	
0.7400000	0.0317305	125.817	3.172711	
0.7600000	0.0351781	118.598	2.722729	
0.7800000	0.0392210	111.156	2.307143	
0.8000000	0.0440279	103.475	1.925954	
0.8200000	0.0498381	95.534	1.579160	
0.8400000	0.0570023	87.310	1.266762	
0.8600000	0.0660562	78.777	0.988760	
0.8800000	0.0778611	69.907	0.745154	
0.9000000	0.0938953	60.665	0.535944	
0.9100000	0.1042785	55.892	0.444238	
0.9200000	0.1169276	51.012	0.361130	
0.9300000	0.1326751	46.017	0.286621	
0.9400000	0.1528185	40.902	0.220712	
0.9500000	0.1794968	35.659	0.163401	
0.9600000	0.2165059	30.281	0.114690	
0.9700000	0.2712873	24.759	0.074577	
0.9800000	0.3606880	19.085	0.043064	
0.9900000	0.5326833	13.248	0.020149	
0.9910000	0.5590457	12.655	0.018330	
0.9920000	0.5880916	12.060	0.016598	
0.9930000	0.6202525	11.463	0.014951	
0.9940000	0.6560583	10.865	0.013391	
0.9950000	0.6961656	10.265	0.011916	
0.9960000	0.7413991	9.663	0.010528	
0.9970000	0.7928083	9.059	0.009225	
0.9980000	0.8517514	8.454	0.008009	
0.9990000	0.9200152	7.846	0.006878	
0.9995000	0.9583615	7.542	0.006345	
0.9999000	0.9913886	7.298	0.005934	

CHOKED FLOW PROGRAM

IDENT= SLIP=SQUARE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1200.00	4.573	62.47

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0008417	465.023	39.009154	
0.1000000	0.0017754	449.219	35.076507	
0.1500000	0.0028168	432.970	31.352762	
0.2000000	0.0039857	416.239	27.837918	
0.2500000	0.0053073	398.987	24.531976	
0.3000000	0.0068133	381.169	21.434935	
0.3500000	0.0085454	362.732	18.546797	
0.4000000	0.0105585	343.617	15.867560	
0.4500000	0.0129271	323.753	13.397225	
0.5000000	0.0157545	303.061	11.135791	
0.5200000	0.0170451	294.530	10.289711	
0.5400000	0.0184439	285.846	9.477054	
0.5600000	0.0199655	276.999	8.697822	
0.5800000	0.0216265	267.983	7.952014	
0.6000000	0.0234471	258.788	7.239630	
0.6200000	0.0254515	249.405	6.560671	
0.6400000	0.0276690	239.825	5.915136	
0.6600000	0.0301355	230.036	5.303025	
0.6800000	0.0328954	220.028	4.724338	
0.7000000	0.0360043	209.786	4.179076	
0.7200000	0.0395330	199.298	3.667238	
0.7400000	0.0435726	188.547	3.188824	
0.7600000	0.0482427	177.518	2.743835	
0.7800000	0.0537034	166.192	2.332270	
0.8000000	0.0601741	154.549	1.954129	
0.8200000	0.0679637	142.565	1.609412	
0.8400000	0.0775208	130.217	1.298120	
0.8600000	0.0895244	117.477	1.020252	
0.8800000	0.1050515	104.313	0.775808	
0.9000000	0.1259204	90.691	0.564789	
0.9100000	0.1393006	83.695	0.471813	
0.9200000	0.1554606	76.570	0.387194	
0.9300000	0.1753671	69.309	0.310930	
0.9400000	0.2004938	61.907	0.243023	
0.9500000	0.2332040	54.356	0.183471	
0.9600000	0.2775409	46.650	0.132276	
0.9700000	0.3410435	38.781	0.089437	
0.9800000	0.4395654	30.740	0.054954	
0.9900000	0.6131027	22.520	0.028827	
0.9910000	0.6380114	21.688	0.026674	
0.9920000	0.6649730	20.854	0.024604	
0.9930000	0.6942519	20.018	0.022618	
0.9940000	0.7261609	19.180	0.020716	
0.9950000	0.7610706	18.340	0.018897	
0.9960000	0.7994254	17.498	0.017162	
0.9970000	0.8417611	16.654	0.015510	
0.9980000	0.8887324	15.808	0.013942	
0.9990000	0.9411443	14.961	0.012457	
0.9995000	0.9696946	14.536	0.011746	
0.9999000	0.9937907	14.196	0.011192	

CHOKED FLOW PROGRAM

IDENT= SLIP=SQUARE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1300.00	8.473	46.65

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0011270	676.981	38.252985	
0.1000000	0.0023763	653.252	34.418360	
0.1500000	0.0037689	628.882	30.786217	
0.2000000	0.0053309	603.824	27.356555	
0.2500000	0.0070953	578.025	24.129373	
0.3000000	0.0091041	551.425	21.104674	
0.3500000	0.0114118	523.956	18.282456	
0.4000000	0.0140907	495.540	15.662720	
0.4500000	0.0172379	466.089	13.245465	
0.5000000	0.0209881	435.501	11.030692	
0.5200000	0.0226974	422.921	10.201477	
0.5400000	0.0245486	410.133	9.404659	
0.5600000	0.0265601	397.126	8.640239	
0.5800000	0.0287537	383.892	7.908215	
0.6000000	0.0311552	370.421	7.208589	
0.6200000	0.0337958	356.700	6.541359	
0.6400000	0.0367129	342.719	5.906527	
0.6600000	0.0399524	328.466	5.304091	
0.6800000	0.0435710	313.926	4.734053	
0.7000000	0.0476391	299.084	4.196412	
0.7200000	0.0522463	283.927	3.691167	
0.7400000	0.0575072	268.435	3.218320	
0.7600000	0.0635715	252.592	2.777870	
0.7800000	0.0706386	236.376	2.369817	
0.8000000	0.0789796	219.767	1.994161	
0.8200000	0.0889730	202.740	1.650902	
0.8400000	0.1011639	185.270	1.340039	
0.8600000	0.1163666	167.329	1.061574	
0.8800000	0.1358545	148.884	0.815506	
0.9000000	0.1617367	129.902	0.601835	
0.9100000	0.1781471	120.197	0.507149	
0.9200000	0.1977780	110.344	0.420562	
0.9300000	0.2216809	100.336	0.342073	
0.9400000	0.2514203	90.169	0.271685	
0.9500000	0.2894312	79.835	0.209395	
0.9600000	0.3397220	69.328	0.155205	
0.9700000	0.4093898	58.642	0.109114	
0.9800000	0.5123058	47.770	0.071122	
0.9900000	0.6797302	36.704	0.041229	
0.9910000	0.7024313	35.586	0.038686	
0.9920000	0.7266505	34.467	0.036223	
0.9930000	0.7525451	33.345	0.033841	
0.9940000	0.7802956	32.221	0.031540	
0.9950000	0.8101088	31.096	0.029320	
0.9960000	0.8422235	29.968	0.027182	
0.9970000	0.8769166	28.838	0.025124	
0.9980000	0.9145122	27.706	0.023147	
0.9990000	0.9553902	26.572	0.021251	
0.9995000	0.9771974	26.004	0.020333	
0.9999000	0.9953565	25.549	0.019614	

CHOKED FLOW PROGRAM

IDENT= SLIP=SQUARE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1400.00	15.177	35.93

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0014628	954.198	37.491827	
0.1000000	0.0030832	923.760	33.758648	
0.1500000	0.0048880	892.446	30.221204	
0.2000000	0.0069105	860.182	26.879494	
0.2500000	0.0091929	826.884	23.733520	
0.3000000	0.0117884	792.458	20.783280	
0.3500000	0.0147665	756.792	18.028775	
0.4000000	0.0182183	719.758	15.470006	
0.4500000	0.0222666	681.204	13.106971	
0.5000000	0.0270807	640.952	10.939671	
0.5200000	0.0292714	624.329	10.127557	
0.5400000	0.0316414	607.386	9.346760	
0.5600000	0.0342137	590.104	8.597281	
0.5800000	0.0370153	572.466	7.879120	
0.6000000	0.0400784	554.452	7.192276	
0.6200000	0.0434413	536.040	6.536750	
0.6400000	0.0471504	517.208	5.912541	
0.6600000	0.0512619	497.928	5.319650	
0.6800000	0.0558451	478.174	4.758076	
0.7000000	0.0609863	457.913	4.227820	
0.7200000	0.0667937	437.111	3.728882	
0.7400000	0.0734059	415.730	3.261261	
0.7600000	0.0810027	393.728	2.824958	
0.7800000	0.0898218	371.057	2.419972	
0.8000000	0.1001837	347.664	2.046304	
0.8200000	0.1125323	323.489	1.703954	
0.8400000	0.1274994	298.464	1.392921	
0.8600000	0.1460168	272.513	1.113206	
0.8800000	0.1695177	245.547	0.864808	
0.9000000	0.2003265	217.464	0.647728	
0.9100000	0.2196264	202.968	0.550932	
0.9200000	0.2424797	188.147	0.461965	
0.9300000	0.2699670	172.983	0.380828	
0.9400000	0.3036569	157.458	0.307520	
0.9500000	0.3459158	141.549	0.242042	
0.9600000	0.4004895	125.235	0.184393	
0.9700000	0.4736791	108.489	0.134573	
0.9800000	0.5769684	91.286	0.092583	
0.9900000	0.7337319	73.593	0.058422	
0.9910000	0.7539906	71.796	0.055437	
0.9920000	0.7753554	69.993	0.052530	
0.9930000	0.7979193	68.186	0.049701	
0.9940000	0.8217864	66.372	0.046950	
0.9950000	0.8470728	64.554	0.044278	
0.9960000	0.8739091	62.730	0.041684	
0.9970000	0.9024420	60.900	0.039168	
0.9980000	0.9328380	59.066	0.036731	
0.9990000	0.9652857	57.225	0.034372	
0.9995000	0.9823449	56.303	0.033222	
0.9999000	0.9964198	55.564	0.032316	

CHOKED FLOW PROGRAM

IDENT= SLIP=SQUARE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1500.00	24.666	28.40

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0018496	1269.517	36.725644	
0.1000000	0.0038967	1228.729	33.097139	
0.1500000	0.0061748	1186.787	29.657326	
0.2000000	0.0087251	1143.597	26.406203	
0.2500000	0.0115998	1099.050	23.343772	
0.3000000	0.0148647	1053.027	20.470031	
0.3500000	0.0186053	1005.386	17.784983	
0.4000000	0.0229335	955.965	15.288625	
0.4500000	0.0279997	904.575	12.980959	
0.5000000	0.0340103	850.994	10.861984	
0.5200000	0.0367403	828.891	10.067228	
0.5400000	0.0396903	806.376	9.302662	
0.5600000	0.0428880	783.429	8.568287	
0.5800000	0.0463658	760.027	7.864102	
0.6000000	0.0501624	736.148	7.190108	
0.6200000	0.0543235	711.764	6.546305	
0.6400000	0.0589045	686.847	5.932692	
0.6600000	0.0639722	661.367	5.349270	
0.6800000	0.0696085	635.289	4.796039	
0.7000000	0.0759148	608.577	4.272998	
0.7200000	0.0830181	581.191	3.780147	
0.7400000	0.0910797	553.085	3.317488	
0.7600000	0.1003076	524.210	2.885018	
0.7800000	0.1109746	494.512	2.482740	
0.8000000	0.1234458	463.930	2.110652	
0.8200000	0.1382212	432.396	1.768755	
0.8400000	0.1560044	399.834	1.457048	
0.8600000	0.1778180	366.157	1.175532	
0.8800000	0.2052073	331.269	0.924206	
0.9000000	0.2406231	295.060	0.703071	
0.9100000	0.2625308	276.421	0.603825	
0.9200000	0.2881996	257.403	0.512127	
0.9300000	0.3186893	237.986	0.427976	
0.9400000	0.3554986	218.151	0.351373	
0.9500000	0.4008194	197.876	0.282318	
0.9600000	0.4579899	177.137	0.220810	
0.9700000	0.5323566	155.909	0.166850	
0.9800000	0.6330512	134.164	0.120438	
0.9900000	0.7770623	111.871	0.081573	
0.9910000	0.7949456	109.610	0.078102	
0.9920000	0.8136328	107.344	0.074706	
0.9930000	0.8331792	105.072	0.071386	
0.9940000	0.8536457	102.794	0.068141	
0.9950000	0.8750987	100.509	0.064971	
0.9960000	0.8976114	98.219	0.061877	
0.9970000	0.9212640	95.923	0.058859	
0.9980000	0.9461456	93.621	0.055916	
0.9990000	0.9723546	91.313	0.053048	
0.9995000	0.9859905	90.156	0.051643	
0.9999000	0.9971674	89.230	0.050532	

CHOKED FLOW PROGRAM

IDENT= SLIP=SQUARE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1600.00	38.191	22.96

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0022872	1632.899	35.954349	
0.1000000	0.0048164	1580.272	32.433503	
0.1500000	0.0076280	1526.183	29.094043	
0.2000000	0.0107720	1470.513	25.935969	
0.2500000	0.0143113	1413.133	22.959280	
0.3000000	0.0183254	1353.891	20.163978	
0.3500000	0.0229165	1292.618	17.550061	
0.4000000	0.0282188	1229.117	15.117530	
0.4500000	0.0344115	1163.157	12.866384	
0.5000000	0.0417394	1094.473	10.796624	
0.5200000	0.0450609	1066.168	10.019508	
0.5400000	0.0486453	1037.354	9.271414	
0.5600000	0.0525249	1008.008	8.552341	
0.5800000	0.0567379	978.102	7.862290	
0.6000000	0.0613291	947.609	7.201261	
0.6200000	0.0663519	916.498	6.569254	
0.6400000	0.0718701	884.736	5.966268	
0.6600000	0.0779608	852.288	5.392304	
0.6800000	0.0847180	819.113	4.847362	
0.7000000	0.0922575	785.171	4.331441	
0.7200000	0.1007233	750.413	3.844542	
0.7400000	0.1102974	714.790	3.386665	
0.7600000	0.1212127	678.246	2.957810	
0.7800000	0.1337723	640.719	2.557976	
0.8000000	0.1483778	602.141	2.187164	
0.8200000	0.1655737	562.437	1.845374	
0.8400000	0.1861160	521.522	1.532605	
0.8600000	0.2110870	479.304	1.248858	
0.8800000	0.2420918	435.675	0.994133	
0.9000000	0.2816178	390.519	0.768430	
0.9100000	0.3057551	367.327	0.666461	
0.9200000	0.3337376	343.701	0.571748	
0.9300000	0.3665639	319.621	0.484290	
0.9400000	0.4056108	295.067	0.404088	
0.9500000	0.4528315	270.015	0.331141	
0.9600000	0.5110927	244.442	0.265450	
0.9700000	0.5847790	218.321	0.207014	
0.9800000	0.6809508	191.625	0.155833	
0.9900000	0.8117534	164.323	0.111908	
0.9910000	0.8274718	161.558	0.107915	
0.9920000	0.8437773	158.787	0.103994	
0.9930000	0.8607034	156.009	0.100145	
0.9940000	0.8782864	153.225	0.096370	
0.9950000	0.8965651	150.434	0.092666	
0.9960000	0.9155819	147.637	0.089036	
0.9970000	0.9353819	144.833	0.085477	
0.9980000	0.9560152	142.022	0.081992	
0.9990000	0.9775350	139.205	0.078579	
0.9995000	0.9886455	137.794	0.076900	
0.9999000	0.9977092	136.664	0.075569	

CHOKED FLOW PROGRAM

IDENT= SLIP=SQUARE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1700.00	56.719	18.91

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0027751	2040.378	35.177814	
0.1000000	0.0058406	1974.671	31.767337	
0.1500000	0.0092445	1907.168	28.530718	
0.2000000	0.0130461	1837.733	25.467956	
0.2500000	0.0173195	1766.206	22.579051	
0.3000000	0.0221583	1692.411	19.864004	
0.3500000	0.0276826	1616.146	17.322814	
0.4000000	0.0340493	1537.176	14.955482	
0.4500000	0.0414669	1455.235	12.762006	
0.5000000	0.0502190	1370.010	10.742389	
0.5200000	0.0541772	1334.921	9.983222	
0.5400000	0.0584423	1299.222	9.251872	
0.5600000	0.0630515	1262.886	8.548339	
0.5800000	0.0680482	1225.882	7.872624	
0.6000000	0.0734833	1188.177	7.224726	
0.6200000	0.0794173	1149.738	6.604644	
0.6400000	0.0859221	1110.526	6.012381	
0.6600000	0.0930843	1070.501	5.447934	
0.6800000	0.1010087	1029.618	4.911304	
0.7000000	0.1098239	987.830	4.402492	
0.7200000	0.1196892	945.085	3.921496	
0.7400000	0.1308038	901.326	3.468318	
0.7600000	0.1434214	856.491	3.042957	
0.7800000	0.1578687	810.512	2.645414	
0.8000000	0.1745749	763.314	2.275687	
0.8200000	0.1941149	714.815	1.933778	
0.8400000	0.2172762	664.925	1.619686	
0.8600000	0.2451685	613.540	1.333411	
0.8800000	0.2794063	560.550	1.074953	
0.9000000	0.3224328	505.827	0.844312	
0.9100000	0.3483718	477.772	0.739423	
0.9200000	0.3781303	449.230	0.641489	
0.9300000	0.4126189	420.180	0.550509	
0.9400000	0.4530628	390.599	0.466483	
0.9500000	0.5011501	360.466	0.389411	
0.9600000	0.5592737	329.754	0.319294	
0.9700000	0.6309420	298.437	0.256130	
0.9800000	0.7215135	266.487	0.199922	
0.9900000	0.8396035	233.873	0.150667	
0.9910000	0.8534163	230.574	0.146124	
0.9920000	0.8676620	227.267	0.141651	
0.9930000	0.8823610	223.954	0.137247	
0.9940000	0.8975357	220.634	0.132912	
0.9950000	0.9132093	217.307	0.128648	
0.9960000	0.9294069	213.972	0.124452	
0.9970000	0.9461550	210.630	0.120327	
0.9980000	0.9634826	207.281	0.116271	
0.9990000	0.9814200	203.925	0.112284	
0.9995000	0.9906275	202.244	0.110317	
0.9999000	0.9981121	200.898	0.108755	

CHOKED FLOW PROGRAM

IDENT= SLIP=SQUARE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1800.00	81.249	15.84

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0033123	2486.705	34.395888	
0.1000000	0.0069669	2406.980	31.098191	
0.1500000	0.0110199	2325.117	27.966642	
0.2000000	0.0155402	2240.953	25.001241	
0.2500000	0.0206135	2154.305	22.201987	
0.3000000	0.0263479	2064.968	19.568882	
0.3500000	0.0328816	1972.708	17.101924	
0.4000000	0.0403943	1877.258	14.801115	
0.4500000	0.0491238	1778.309	12.666453	
0.5000000	0.0593919	1675.507	10.697940	
0.5200000	0.0640244	1633.216	9.957056	
0.5400000	0.0690081	1590.214	9.242756	
0.5600000	0.0743848	1546.468	8.555039	
0.5800000	0.0802028	1501.944	7.893906	
0.6000000	0.0865186	1456.607	7.259357	
0.6200000	0.0933991	1410.416	6.651391	
0.6400000	0.1009236	1363.331	6.070010	
0.6600000	0.1091868	1315.306	5.515211	
0.6800000	0.1183033	1266.292	4.986997	
0.7000000	0.1284123	1216.237	4.485366	
0.7200000	0.1396852	1165.082	4.010318	
0.7400000	0.1523355	1112.766	3.561855	
0.7600000	0.1666318	1059.221	3.139975	
0.7800000	0.1829179	1004.374	2.744679	
0.8000000	0.2016402	948.142	2.375966	
0.8200000	0.2233897	890.438	2.033838	
0.8400000	0.2489649	831.163	1.718292	
0.8600000	0.2794727	770.210	1.429331	
0.8800000	0.3164924	707.460	1.166953	
0.9000000	0.3623581	642.778	0.931159	
0.9100000	0.3896619	609.668	0.823231	
0.9200000	0.4206705	576.018	0.721949	
0.9300000	0.4561928	541.807	0.627312	
0.9400000	0.4972917	507.012	0.539322	
0.9500000	0.5453923	471.610	0.457977	
0.9600000	0.6024503	435.575	0.383279	
0.9700000	0.6712249	398.879	0.315226	
0.9800000	0.7557377	361.494	0.253819	
0.9900000	0.8620891	323.389	0.199059	
0.9910000	0.8742556	319.537	0.193948	
0.9920000	0.8867447	315.678	0.188904	
0.9930000	0.8995696	311.812	0.183926	
0.9940000	0.9127439	307.938	0.179015	
0.9950000	0.9262823	304.056	0.174170	
0.9960000	0.9401999	300.166	0.169392	
0.9970000	0.9545127	296.269	0.164680	
0.9980000	0.9692382	292.364	0.160035	
0.9990000	0.9843942	288.451	0.155456	
0.9995000	0.9921397	286.492	0.153192	
0.9999000	0.9984186	284.923	0.151392	

CHOKED FLOW PROGRAM

IDENT= SLIP=SQUARE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1900.00	112.783	13.45

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0038974	2965.748	33.608409	
0.1000000	0.0081923	2871.412	30.425589	
0.1500000	0.0129489	2774.588	27.401070	
0.2000000	0.0182459	2675.093	24.534851	
0.2500000	0.0241808	2572.720	21.826932	
0.3000000	0.0308763	2467.234	19.277314	
0.3500000	0.0384885	2358.372	16.885996	
0.4000000	0.0472198	2245.834	14.652979	
0.4500000	0.0573362	2129.273	12.578261	
0.5000000	0.0691959	2008.294	10.661845	
0.5200000	0.0745325	1958.564	9.939603	
0.5400000	0.0802641	1908.020	9.242688	
0.5600000	0.0864363	1856.629	8.571102	
0.5800000	0.0931021	1804.353	7.924843	
0.6000000	0.1003229	1751.151	7.303913	
0.6200000	0.1081712	1696.980	6.708310	
0.6400000	0.1167325	1641.795	6.138036	
0.6600000	0.1261086	1585.547	5.593090	
0.6800000	0.1364216	1528.181	5.073472	
0.7000000	0.1478192	1469.641	4.579182	
0.7200000	0.1604821	1409.864	4.110220	
0.7400000	0.1746335	1348.783	3.666586	
0.7600000	0.1905520	1286.326	3.248280	
0.7800000	0.2085908	1222.412	2.855303	
0.8000000	0.2292038	1156.956	2.487653	
0.8200000	0.2529842	1089.863	2.145331	
0.8400000	0.2807229	1021.029	1.828338	
0.8600000	0.3134979	950.339	1.536672	
0.8800000	0.3528177	877.670	1.270335	
0.9000000	0.4008602	802.881	1.029325	
0.9100000	0.4291128	764.645	0.918318	
0.9200000	0.4608901	725.819	0.813644	
0.9300000	0.4968957	686.382	0.715301	
0.9400000	0.5380335	646.312	0.623290	
0.9500000	0.5854852	605.582	0.537612	
0.9600000	0.6408250	564.168	0.458265	
0.9700000	0.7061985	522.041	0.385251	
0.9800000	0.7846061	479.171	0.318568	
0.9900000	0.8803778	435.529	0.258217	
0.9910000	0.8911346	431.121	0.252531	
0.9920000	0.9021350	426.705	0.246907	
0.9930000	0.9133872	422.281	0.241347	
0.9940000	0.9249004	417.848	0.235850	
0.9950000	0.9366834	413.408	0.230417	
0.9960000	0.9487459	408.959	0.225047	
0.9970000	0.9610980	404.502	0.219740	
0.9980000	0.9737502	400.036	0.214496	
0.9990000	0.9867137	395.562	0.209316	
0.9995000	0.9933157	393.322	0.206749	
0.9999000	0.9986565	391.529	0.204708	

CHOKED FLOW PROGRAM

IDENT= SLIP=SQUARE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
2000.00	152.296	11.57

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0045291	3470.880	32.815201	
0.1000000	0.0095135	3361.685	29.749039	
0.1500000	0.0150257	3249.661	26.833235	
0.2000000	0.0211539	3134.601	24.067788	
0.2500000	0.0280078	3016.275	21.452699	
0.3000000	0.0357241	2894.424	18.987967	
0.3500000	0.0444767	2768.755	16.673592	
0.4000000	0.0544894	2638.936	14.509575	
0.4500000	0.0660553	2504.588	12.495916	
0.5000000	0.0795663	2365.274	10.632613	
0.5200000	0.0856291	2308.047	9.929393	
0.5400000	0.0921291	2249.911	9.250229	
0.5600000	0.0991154	2190.826	8.595123	
0.5800000	0.1066448	2130.752	7.964073	
0.6000000	0.1147831	2069.646	7.357082	
0.6200000	0.1236072	2007.462	6.774147	
0.6400000	0.1332077	1944.149	6.215269	
0.6600000	0.1436918	1879.654	5.680449	
0.6800000	0.1551873	1813.921	5.169685	
0.7000000	0.1678480	1746.887	4.682979	
0.7200000	0.1818606	1678.487	4.220330	
0.7400000	0.1974537	1608.649	3.781739	
0.7600000	0.2149108	1537.294	3.367204	
0.7800000	0.2345873	1464.340	2.976727	
0.8000000	0.2569352	1389.695	2.610307	
0.8200000	0.2825381	1313.258	2.267944	
0.8400000	0.3121631	1234.922	1.949639	
0.8600000	0.3468388	1154.567	1.655390	
0.8800000	0.3879770	1072.063	1.385199	
0.9000000	0.4375702	987.265	1.139065	
0.9100000	0.4663960	943.958	1.025019	
0.9200000	0.4985233	900.016	0.916988	
0.9300000	0.5345537	855.417	0.814971	
0.9400000	0.5752445	810.137	0.718968	
0.9500000	0.6215624	764.152	0.628980	
0.9600000	0.6747613	717.435	0.545005	
0.9700000	0.7364978	669.957	0.467046	
0.9800000	0.8090063	621.689	0.395100	
0.9900000	0.8953755	572.599	0.329169	
0.9910000	0.9049293	567.644	0.322906	
0.9920000	0.9146692	562.680	0.316704	
0.9930000	0.9246008	557.707	0.310562	
0.9940000	0.9347299	552.726	0.304480	
0.9950000	0.9450623	547.736	0.298459	
0.9960000	0.9556042	542.737	0.292497	
0.9970000	0.9663620	537.730	0.286595	
0.9980000	0.9773426	532.714	0.280754	
0.9990000	0.9885528	527.689	0.274973	
0.9995000	0.9942463	525.173	0.272105	
0.9999000	0.9988444	523.159	0.269821	

CHOKED FLOW PROGRAM

IDENT= SLIP=SQUARE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
2100.00	200.712	10.06

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0052059	3995.309	32.016097	
0.1000000	0.0109271	3871.347	29.068055	
0.1500000	0.0172440	3744.227	26.262374	
0.2000000	0.0242547	3613.723	23.599054	
0.2500000	0.0320803	3479.584	21.078096	
0.3000000	0.0408714	3341.525	18.699499	
0.3500000	0.0508187	3199.230	16.463264	
0.4000000	0.0621662	3052.337	14.369389	
0.4500000	0.0752320	2900.436	12.417876	
0.5000000	0.0904382	2743.056	10.608724	
0.5200000	0.0972419	2678.451	9.924925	
0.5400000	0.1045227	2612.845	9.263903	
0.5600000	0.1123325	2546.198	8.625659	
0.5800000	0.1207314	2478.465	8.010193	
0.6000000	0.1297884	2409.600	7.417505	
0.6200000	0.1395842	2339.555	6.847594	
0.6400000	0.1502130	2268.276	6.300462	
0.6600000	0.1617857	2195.707	5.776107	
0.6800000	0.1744338	2121.787	5.274530	
0.7000000	0.1883148	2046.451	4.795731	
0.7200000	0.2036179	1969.630	4.339709	
0.7400000	0.2205736	1891.247	3.906465	
0.7600000	0.2394648	1811.221	3.495999	
0.7800000	0.2606430	1729.465	3.108312	
0.8000000	0.2845503	1645.883	2.743401	
0.8200000	0.3117505	1560.371	2.401269	
0.8400000	0.3429743	1472.817	2.081914	
0.8600000	0.3791858	1383.097	1.785337	
0.8800000	0.4216837	1291.077	1.511538	
0.9000000	0.4722608	1196.609	1.260517	
0.9100000	0.5013348	1148.407	1.143548	
0.9200000	0.5334627	1099.531	1.032274	
0.9300000	0.5691524	1049.957	0.926694	
0.9400000	0.6090307	999.662	0.826808	
0.9500000	0.6538811	948.620	0.732617	
0.9600000	0.7046954	896.804	0.644120	
0.9700000	0.7627477	844.186	0.561318	
0.9800000	0.8297031	790.737	0.484210	
0.9900000	0.9077799	736.424	0.412797	
0.9910000	0.9163068	730.944	0.405969	
0.9920000	0.9249778	725.455	0.399198	
0.9930000	0.9337964	719.956	0.392484	
0.9940000	0.9427666	714.449	0.385826	
0.9950000	0.9518923	708.933	0.379226	
0.9960000	0.9611774	703.408	0.372682	
0.9970000	0.9706263	697.873	0.366196	
0.9980000	0.9802433	692.329	0.359767	
0.9990000	0.9900330	686.776	0.353394	
0.9995000	0.9949940	683.996	0.350229	
0.9999000	0.9989952	681.770	0.347707	

CHOKED FLOW PROGRAM

IDENT= SLIP=SQUARE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
2200.00	258.882	8.83

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0059264	4532.360	31.210929	
0.1000000	0.0124295	4394.030	28.382154	
0.1500000	0.0195977	4252.236	25.687732	
0.2000000	0.0275386	4106.734	23.127663	
0.2500000	0.0363841	3957.253	20.701946	
0.3000000	0.0462983	3803.489	18.410581	
0.3500000	0.0574872	3645.103	16.253569	
0.4000000	0.0702136	3481.708	14.230909	
0.4500000	0.0848178	3312.866	12.342602	
0.5000000	0.1017484	3138.078	10.588648	
0.5200000	0.1093006	3066.372	9.924685	
0.5400000	0.1173669	2993.583	9.282218	
0.5600000	0.1260014	2919.668	8.661247	
0.5800000	0.1352665	2844.580	8.061773	
0.6000000	0.1452339	2768.273	7.483796	
0.6200000	0.1559865	2690.692	6.927314	
0.6400000	0.1676209	2611.784	6.392330	
0.6600000	0.1802502	2531.489	5.878841	
0.6800000	0.1940078	2449.743	5.386849	
0.7000000	0.2090519	2366.479	4.916353	
0.7200000	0.2255719	2281.625	4.467354	
0.7400000	0.2437961	2195.100	4.039851	
0.7600000	0.2640025	2106.823	3.633845	
0.7800000	0.2865333	2016.700	3.249335	
0.8000000	0.3118138	1924.635	2.886321	
0.8200000	0.3403803	1830.520	2.544804	
0.8400000	0.3729178	1734.240	2.224783	
0.8600000	0.4103164	1635.668	1.926258	
0.8800000	0.4537532	1534.668	1.649230	
0.9000000	0.5048191	1431.089	1.393698	
0.9100000	0.5338699	1378.282	1.273994	
0.9200000	0.5657175	1324.767	1.159663	
0.9300000	0.6007862	1270.521	1.050707	
0.9400000	0.6395906	1215.520	0.947124	
0.9500000	0.6827614	1159.738	0.848916	
0.9600000	0.7310795	1103.149	0.756082	
0.9700000	0.7855237	1045.723	0.668621	
0.9800000	0.8473379	987.432	0.586535	
0.9900000	0.9181274	928.243	0.509823	
0.9910000	0.9257758	922.274	0.502448	
0.9920000	0.9335369	916.295	0.495126	
0.9930000	0.9414132	910.307	0.487858	
0.9940000	0.9494072	904.309	0.480643	
0.9950000	0.9575218	898.302	0.473483	
0.9960000	0.9657595	892.286	0.466376	
0.9970000	0.9741232	886.260	0.459323	
0.9980000	0.9826158	880.224	0.452323	
0.9990000	0.9912404	874.179	0.445378	
0.9995000	0.9956031	871.153	0.441925	
0.9999000	0.9991179	868.730	0.439172	

CHOKED FLOW PROGRAM

IDENT= SLIP=CUBE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1100.00	2.276	19.61

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0001368	202.301	41.701793	
0.1000000	0.0002888	201.385	39.401800	
0.1500000	0.0004586	200.373	37.102502	
0.2000000	0.0006496	199.247	34.804024	
0.2500000	0.0008659	197.989	32.506517	
0.3000000	0.0011130	196.573	30.210177	
0.3500000	0.0013980	194.967	27.915249	
0.4000000	0.0017303	193.130	25.622061	
0.4500000	0.0021227	191.010	23.331042	
0.5000000	0.0025932	188.533	21.042782	
0.5200000	0.0028087	187.421	20.128423	
0.5400000	0.0030428	186.230	19.214700	
0.5600000	0.0032981	184.950	18.301689	
0.5800000	0.0035775	183.570	17.389481	
0.6000000	0.0038848	182.079	16.478182	
0.6200000	0.0042241	180.461	15.567917	
0.6400000	0.0046009	178.702	14.658837	
0.6600000	0.0050216	176.780	13.751121	
0.6800000	0.0054945	174.673	12.844990	
0.7000000	0.0060299	172.352	11.940711	
0.7200000	0.0066412	169.781	11.038618	
0.7400000	0.0073455	166.920	10.139130	
0.7600000	0.0081659	163.714	9.242777	
0.7800000	0.0091338	160.097	8.350248	
0.8000000	0.0102927	155.984	7.462446	
0.8200000	0.0117055	151.264	6.580585	
0.8400000	0.0134659	145.790	5.706332	
0.8600000	0.0157200	139.362	4.842045	
0.8800000	0.0187095	131.701	3.991165	
0.9000000	0.0228645	122.407	3.158924	
0.9100000	0.0256149	116.970	2.752225	
0.9200000	0.0290313	110.876	2.353685	
0.9300000	0.0333888	103.994	1.965284	
0.9400000	0.0391382	96.153	1.589695	
0.9500000	0.0470735	87.128	1.230624	
0.9600000	0.0587337	76.614	0.893357	
0.9700000	0.0775459	64.183	0.585708	
0.9800000	0.1130011	49.211	0.319727	
0.9900000	0.2047044	30.750	0.115030	
0.9910000	0.2225657	28.660	0.099059	
0.9920000	0.2437950	26.519	0.084065	
0.9930000	0.2694438	24.323	0.070097	
0.9940000	0.3010529	22.072	0.057205	
0.9950000	0.3409729	19.763	0.045445	
0.9960000	0.3929775	17.394	0.034875	
0.9970000	0.4635325	14.960	0.025560	
0.9980000	0.5647194	12.461	0.017565	
0.9990000	0.7220166	9.892	0.010964	
0.9995000	0.8386387	8.581	0.008209	
0.9999000	0.9629580	7.519	0.006278	

CHOKED FLOW PROGRAM

IDENT= SLIP=CUBE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1200.00	4.573	15.74

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0002123	326.983	40.873943	
0.1000000	0.0004480	325.118	38.598065	
0.1500000	0.0007114	323.061	36.323215	
0.2000000	0.0010075	320.782	34.049572	
0.2500000	0.0013429	318.243	31.777354	
0.3000000	0.0017259	315.395	29.506842	
0.3500000	0.0021674	312.181	27.238392	
0.4000000	0.0026821	308.522	24.972467	
0.4500000	0.0032897	304.321	22.709680	
0.5000000	0.0040178	299.446	20.450861	
0.5200000	0.0043512	297.270	19.548687	
0.5400000	0.0047133	294.945	18.647418	
0.5600000	0.0051080	292.454	17.747163	
0.5800000	0.0055399	289.780	16.848044	
0.6000000	0.0060146	286.901	15.950209	
0.6200000	0.0065388	283.792	15.053829	
0.6400000	0.0071205	280.425	14.159108	
0.6600000	0.0077699	276.766	13.266290	
0.6800000	0.0084994	272.776	12.375670	
0.7000000	0.0093249	268.406	11.487606	
0.7200000	0.0102667	263.598	10.602538	
0.7400000	0.0113511	258.285	9.721016	
0.7600000	0.0126132	252.379	8.843731	
0.7800000	0.0141007	245.775	7.971566	
0.8000000	0.0158798	238.340	7.105667	
0.8200000	0.0180455	229.903	6.247553	
0.8400000	0.0207393	220.244	5.399273	
0.8600000	0.0241811	209.069	4.563666	
0.8800000	0.0287327	195.982	3.744780	
0.9000000	0.0350341	180.431	2.948595	
0.9100000	0.0391898	171.495	2.561712	
0.9200000	0.0443344	161.618	2.184325	
0.9300000	0.0508684	150.635	1.818499	
0.9400000	0.0594427	138.342	1.466948	
0.9500000	0.0711897	124.475	1.133309	
0.9600000	0.0882702	108.692	0.822563	
0.9700000	0.1153832	90.538	0.541732	
0.9800000	0.1650429	69.388	0.301036	
0.9900000	0.2853910	44.358	0.115945	
0.9910000	0.3075699	41.596	0.101330	
0.9920000	0.3334298	38.782	0.087535	
0.9930000	0.3639698	35.913	0.074594	
0.9940000	0.4005875	32.987	0.062540	
0.9950000	0.4452972	30.004	0.051410	
0.9960000	0.5011145	26.960	0.041243	
0.9970000	0.5727651	23.854	0.032080	
0.9980000	0.6681012	20.684	0.023963	
0.9990000	0.8011915	17.448	0.016939	
0.9995000	0.8896730	15.804	0.013852	
0.9999000	0.9758076	14.476	0.011591	

CHOKED FLOW PROGRAM

IDENT= SLIP=CUBE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1300.00	8.473	12.96

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0003133	495.784	40.038156	
0.1000000	0.0006613	492.336	37.787458	
0.1500000	0.0010499	488.546	35.538197	
0.2000000	0.0014866	484.361	33.290619	
0.2500000	0.0019812	479.714	31.045025	
0.3000000	0.0025458	474.526	28.801795	
0.3500000	0.0031965	468.695	26.561412	
0.4000000	0.0039546	462.093	24.324501	
0.4500000	0.0048490	454.556	22.091884	
0.5000000	0.0059202	445.869	19.864666	
0.5200000	0.0064104	442.011	18.975611	
0.5400000	0.0069426	437.902	18.087778	
0.5600000	0.0075226	433.517	17.201306	
0.5800000	0.0081571	428.825	16.316356	
0.6000000	0.0088541	423.795	15.433119	
0.6200000	0.0096233	418.387	14.551814	
0.6400000	0.0104765	412.557	13.672705	
0.6600000	0.0114284	406.253	12.796102	
0.6800000	0.0124972	399.414	11.922377	
0.7000000	0.0137056	391.969	11.051980	
0.7200000	0.0150830	383.832	10.185462	
0.7400000	0.0166676	374.900	9.323498	
0.7600000	0.0185098	365.051	8.466934	
0.7800000	0.0206781	354.130	7.616836	
0.8000000	0.0232675	341.952	6.774572	
0.8200000	0.0264137	328.281	5.941926	
0.8400000	0.0303181	312.817	5.121265	
0.8600000	0.0352923	295.174	4.315806	
0.8800000	0.0418457	274.839	3.530028	
0.9000000	0.0508723	251.122	2.770362	
0.9100000	0.0567961	237.710	2.403141	
0.9200000	0.0640977	223.064	2.046383	
0.9300000	0.0733210	206.997	1.702132	
0.9400000	0.0853396	189.282	1.373000	
0.9500000	0.1016513	169.634	1.062380	
0.9600000	0.1250563	147.699	0.774767	
0.9700000	0.1614673	123.020	0.516234	
0.9800000	0.2258964	95.006	0.295199	
0.9900000	0.3709065	62.862	0.123679	
0.9910000	0.3960479	59.382	0.109868	
0.9920000	0.4247832	55.849	0.096743	
0.9930000	0.4579422	52.261	0.084329	
0.9940000	0.4966320	48.618	0.072647	
0.9950000	0.5423619	44.917	0.061724	
0.9960000	0.5972461	41.158	0.051586	
0.9970000	0.6643382	37.338	0.042259	
0.9980000	0.7482225	33.456	0.033771	
0.9990000	0.8561043	29.511	0.026153	
0.9995000	0.9225101	27.514	0.022680	
0.9999000	0.9834840	25.905	0.020066	

CHOKED FLOW PROGRAM

IDENT= SLIP=CUBE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1400.00	15.177	10.89

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0004438	721.577	39.195184	
0.1000000	0.0009364	716.570	36.971289	
0.1500000	0.0014864	711.074	34.749315	
0.2000000	0.0021044	705.011	32.529582	
0.2500000	0.0028039	698.291	30.312487	
0.3000000	0.0036022	690.798	28.098523	
0.3500000	0.0045217	682.391	25.888314	
0.4000000	0.0055922	672.891	23.682665	
0.4500000	0.0068545	662.067	21.482626	
0.5000000	0.0083649	649.620	19.289596	
0.5200000	0.0090557	644.102	18.414752	
0.5400000	0.0098054	638.231	17.541478	
0.5600000	0.0106221	631.972	16.669950	
0.5800000	0.0115149	625.284	15.800365	
0.6000000	0.0124951	618.121	14.932959	
0.6200000	0.0135763	610.431	14.068002	
0.6400000	0.0147749	602.151	13.205814	
0.6600000	0.0161110	593.210	12.346770	
0.6800000	0.0176098	583.526	11.491319	
0.7000000	0.0193029	572.997	10.639999	
0.7200000	0.0212308	561.509	9.793458	
0.7400000	0.0234458	548.918	8.952493	
0.7600000	0.0260174	535.056	8.118083	
0.7800000	0.0290392	519.714	7.291453	
0.8000000	0.0326406	502.632	6.474154	
0.8200000	0.0370063	483.488	5.668175	
0.8400000	0.0424083	461.867	4.876119	
0.8600000	0.0492653	437.231	4.101451	
0.8800000	0.0582566	408.867	3.348887	
0.9000000	0.0705625	375.801	2.625021	
0.9100000	0.0785892	357.097	2.276666	
0.9200000	0.0884298	336.660	1.939361	
0.9300000	0.1007774	314.217	1.615044	
0.9400000	0.1167296	289.430	1.306132	
0.9500000	0.1381350	261.870	1.015684	
0.9600000	0.1683660	230.989	0.747624	
0.9700000	0.2142984	196.067	0.507074	
0.9800000	0.2924559	156.134	0.300848	
0.9900000	0.4550748	109.838	0.138210	
0.9910000	0.4815543	104.790	0.124801	
0.9920000	0.5112420	99.657	0.111967	
0.9930000	0.5447583	94.437	0.099726	
0.9940000	0.5828955	89.127	0.088094	
0.9950000	0.6266796	83.724	0.077087	
0.9960000	0.6774651	78.226	0.066724	
0.9970000	0.7370769	72.630	0.057023	
0.9980000	0.8080359	66.932	0.048004	
0.9990000	0.8939223	61.129	0.039686	
0.9995000	0.9440169	58.187	0.035797	
0.9999000	0.9882829	55.814	0.032818	

CHOKED FLOW PROGRAM

IDENT= SLIP=CUBE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1500.00	24.666	9.31

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0006070	989.060	38.345699	
0.1000000	0.0012805	981.235	36.150699	
0.1500000	0.0020322	972.667	33.958172	
0.2000000	0.0028765	963.245	31.768522	
0.2500000	0.0038317	952.833	29.582243	
0.3000000	0.0049211	941.266	27.399952	
0.3500000	0.0061752	928.339	25.222426	
0.4000000	0.0076342	913.794	23.050657	
0.4500000	0.0093530	897.304	20.885933	
0.5000000	0.0114078	878.449	18.729958	
0.5200000	0.0123467	870.125	17.870507	
0.5400000	0.0133652	861.293	17.012996	
0.5600000	0.0144739	851.903	16.157633	
0.5800000	0.0156854	841.900	15.304656	
0.6000000	0.0170146	831.223	14.454341	
0.6200000	0.0184795	819.797	13.607006	
0.6400000	0.0201021	807.542	12.763024	
0.6600000	0.0219092	794.360	11.922832	
0.6800000	0.0239343	780.142	11.086945	
0.7000000	0.0262193	764.755	10.255980	
0.7200000	0.0288176	748.047	9.430674	
0.7400000	0.0317985	729.835	8.611918	
0.7600000	0.0352532	709.900	7.800804	
0.7800000	0.0393044	687.977	6.998680	
0.8000000	0.0441211	663.739	6.207227	
0.8200000	0.0499429	636.786	5.428579	
0.8400000	0.0571213	606.610	4.665476	
0.8600000	0.0661928	572.562	3.921501	
0.8800000	0.0780200	533.797	3.201427	
0.9000000	0.0940836	489.186	2.511765	
0.9100000	0.1044852	464.225	2.181048	
0.9200000	0.1171561	437.177	1.861621	
0.9300000	0.1329298	407.743	1.555260	
0.9400000	0.1531050	375.560	1.264141	
0.9500000	0.1798227	340.179	0.990948	
0.9600000	0.2168812	301.041	0.739034	
0.9700000	0.2717248	257.428	0.512645	
0.9800000	0.3611981	208.408	0.317237	
0.9900000	0.5332337	152.736	0.159941	
0.9910000	0.5595908	146.742	0.146648	
0.9920000	0.5886272	140.663	0.133839	
0.9930000	0.6207732	134.497	0.121526	
0.9940000	0.6565571	128.241	0.109720	
0.9950000	0.6966332	121.893	0.098435	
0.9960000	0.7418229	115.452	0.087681	
0.9970000	0.7931713	108.914	0.077473	
0.9980000	0.8520305	102.276	0.067824	
0.9990000	0.9201778	95.538	0.058747	
0.9995000	0.9584497	92.129	0.054427	
0.9999000	0.9914075	89.384	0.051078	

CHOKED FLOW PROGRAM

IDENT= SLIP=CUBE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1600.00	38.191	8.08

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0008060	1305.380	37.490279	
0.1000000	0.0016999	1293.841	35.326653	
0.1500000	0.0026972	1281.239	33.166106	
0.2000000	0.0038168	1267.421	31.009129	
0.2500000	0.0050825	1252.199	28.856321	
0.3000000	0.0065252	1235.346	26.708427	
0.3500000	0.0081847	1216.584	24.566379	
0.4000000	0.0101137	1195.564	22.431358	
0.4500000	0.0123838	1171.849	20.304890	
0.5000000	0.0150942	1144.875	18.188976	
0.5200000	0.0163315	1133.016	17.346136	
0.5400000	0.0176729	1120.465	16.505613	
0.5600000	0.0191321	1107.159	15.667644	
0.5800000	0.0207252	1093.025	14.832505	
0.6000000	0.0224717	1077.983	14.000507	
0.6200000	0.0243949	1061.939	13.172013	
0.6400000	0.0265228	1044.790	12.347442	
0.6600000	0.0288901	1026.413	11.527283	
0.6800000	0.0315396	1006.668	10.712110	
0.7000000	0.0345250	985.392	9.902601	
0.7200000	0.0379144	962.394	9.099563	
0.7400000	0.0417958	937.449	8.303963	
0.7600000	0.0462847	910.291	7.516971	
0.7800000	0.0515358	880.598	6.740018	
0.8000000	0.0577613	847.981	5.974867	
0.8200000	0.0652602	811.964	5.223724	
0.8400000	0.0744675	771.955	4.489378	
0.8600000	0.0860424	727.209	3.775410	
0.8800000	0.1010326	676.768	3.086502	
0.9000000	0.1212113	619.378	2.428885	
0.9100000	0.1341679	587.573	2.114347	
0.9200000	0.1498361	553.354	1.811042	
0.9300000	0.1691667	516.407	1.520566	
0.9400000	0.1936136	476.358	1.244830	
0.9500000	0.2255179	432.752	0.986147	
0.9600000	0.2689060	385.029	0.747337	
0.9700000	0.3313390	332.496	0.531883	
0.9800000	0.4288821	274.273	0.344127	
0.9900000	0.6027377	209.225	0.189563	
0.9910000	0.6279087	202.291	0.176187	
0.9920000	0.6552162	195.272	0.163220	
0.9930000	0.6849438	188.167	0.150670	
0.9940000	0.7174288	180.974	0.138545	
0.9950000	0.7530732	173.690	0.126855	
0.9960000	0.7923615	166.315	0.115608	
0.9970000	0.8358821	158.845	0.104813	
0.9980000	0.8843588	151.279	0.094480	
0.9990000	0.9386887	143.614	0.084618	
0.9995000	0.9683902	139.744	0.079867	
0.9999000	0.9935165	136.630	0.076154	

CHOKED FLOW PROGRAM

IDENT= SLIP=CUBE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1700.00	56.719	7.10

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0010434	1668.061	36.629419	
0.1000000	0.0022002	1651.867	34.499938	
0.1500000	0.0034899	1634.229	32.374180	
0.2000000	0.0049368	1614.941	30.252728	
0.2500000	0.0065716	1593.760	28.136287	
0.3000000	0.0084334	1570.389	26.025728	
0.3500000	0.0105730	1544.466	23.922133	
0.4000000	0.0130575	1515.542	21.826872	
0.4500000	0.0159777	1483.058	19.741694	
0.5000000	0.0194592	1446.301	17.668878	
0.5200000	0.0210467	1430.205	16.843857	
0.5400000	0.0227663	1413.210	16.021522	
0.5600000	0.0246355	1395.238	15.202138	
0.5800000	0.0266745	1376.200	14.386008	
0.6000000	0.0289075	1355.997	13.573480	
0.6200000	0.0313637	1334.516	12.764951	
0.6400000	0.0340783	1311.627	11.960877	
0.6600000	0.0370943	1287.184	11.161789	
0.6800000	0.0404649	1261.017	10.368307	
0.7000000	0.0442565	1232.933	9.581154	
0.7200000	0.0485532	1202.704	8.801186	
0.7400000	0.0534632	1170.065	8.029421	
0.7600000	0.0591278	1134.702	7.267075	
0.7800000	0.0657356	1096.245	6.515621	
0.8000000	0.0735435	1054.247	5.776855	
0.8200000	0.0829109	1008.167	5.052989	
0.8400000	0.0943572	957.339	4.346784	
0.8600000	0.1086607	900.938	3.661724	
0.8800000	0.1270437	837.918	3.002280	
0.9000000	0.1515417	766.932	2.374270	
0.9100000	0.1671238	727.920	2.074375	
0.9200000	0.1858147	686.209	1.785429	
0.9300000	0.2086478	641.479	1.508834	
0.9400000	0.2371715	593.351	1.246246	
0.9500000	0.2738162	541.374	0.999629	
0.9600000	0.3226257	485.005	0.771331	
0.9700000	0.3908630	423.583	0.564186	
0.9800000	0.4930093	356.289	0.381642	
0.9900000	0.6626966	282.095	0.227944	
0.9910000	0.6860474	274.249	0.214353	
0.9920000	0.7110515	266.319	0.201108	
0.9930000	0.7378908	258.304	0.188216	
0.9940000	0.7667754	250.203	0.175681	
0.9950000	0.7979482	242.014	0.163511	
0.9960000	0.8316922	233.735	0.151713	
0.9970000	0.8683390	225.365	0.140292	
0.9980000	0.9082806	216.902	0.129256	
0.9990000	0.9519819	208.343	0.118612	
0.9995000	0.9754123	204.027	0.113439	
0.9999000	0.9949857	200.557	0.109373	

CHOKED FLOW PROGRAM

IDENT= SLIP=CUBE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1800.00	81.249	6.31

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0013216	2073.033	35.763534	
0.1000000	0.0027859	2051.257	33.671174	
0.1500000	0.0044175	2027.597	31.583211	
0.2000000	0.0062466	2001.795	29.500311	
0.2500000	0.0083115	1973.545	27.423283	
0.3000000	0.0106609	1942.474	25.353118	
0.3500000	0.0133579	1908.133	23.291045	
0.4000000	0.0164860	1869.968	21.238603	
0.4500000	0.0201572	1827.292	19.197748	
0.5000000	0.0245268	1779.236	17.171006	
0.5200000	0.0265165	1758.269	16.364970	
0.5400000	0.0286700	1736.182	15.561966	
0.5600000	0.0310085	1712.883	14.762285	
0.5800000	0.0335567	1688.264	13.966254	
0.6000000	0.0363444	1662.209	13.174246	
0.6200000	0.0394069	1634.583	12.386684	
0.6400000	0.0427869	1605.235	11.604056	
0.6600000	0.0465365	1573.995	10.826920	
0.6800000	0.0507199	1540.667	10.055927	
0.7000000	0.0554168	1505.024	9.291830	
0.7200000	0.0607282	1466.809	8.535512	
0.7400000	0.0667830	1425.718	7.788014	
0.7600000	0.0737490	1381.399	7.050572	
0.7800000	0.0818486	1333.436	6.324662	
0.8000000	0.0913830	1281.331	5.612066	
0.8200000	0.1027708	1224.491	4.914952	
0.8400000	0.1166102	1162.193	4.235986	
0.8600000	0.1337886	1093.547	3.578482	
0.8800000	0.1556801	1017.447	2.946617	
0.9000000	0.1845329	932.486	2.345723	
0.9100000	0.2026969	886.136	2.058975	
0.9200000	0.2242948	836.848	1.782722	
0.9300000	0.2504022	784.304	1.518180	
0.9400000	0.2825956	728.129	1.266765	
0.9500000	0.3232843	667.886	1.030127	
0.9600000	0.3763419	603.054	0.810208	
0.9700000	0.4484193	533.012	0.609303	
0.9800000	0.5519771	457.006	0.430149	
0.9900000	0.7134013	374.111	0.276034	
0.9910000	0.7346475	365.401	0.262146	
0.9920000	0.7571511	356.609	0.248552	
0.9930000	0.7810270	347.734	0.235256	
0.9940000	0.8064052	338.775	0.222264	
0.9950000	0.8334317	329.731	0.209579	
0.9960000	0.8622726	320.600	0.197207	
0.9970000	0.8931166	311.380	0.185152	
0.9980000	0.9261805	302.071	0.173420	
0.9990000	0.9617126	292.670	0.162016	
0.9995000	0.9804922	287.934	0.156438	
0.9999000	0.9960381	284.129	0.152036	

CHOKED FLOW PROGRAM

IDENT= SLIP=CUBE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1900.00	112.783	5.66

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0016425	2515.032	34.892956	
0.1000000	0.0034611	2486.806	32.840832	
0.1500000	0.0054859	2456.214	30.793783	
0.2000000	0.0077539	2422.940	28.752557	
0.2500000	0.0103119	2386.612	26.718060	
0.3000000	0.0132193	2346.781	24.691396	
0.3500000	0.0165527	2302.908	22.673925	
0.4000000	0.0204134	2254.331	20.667337	
0.4500000	0.0249371	2200.236	18.673768	
0.5000000	0.0303107	2139.603	16.695950	
0.5200000	0.0327538	2113.240	15.909995	
0.5400000	0.0353955	2085.530	15.127389	
0.5600000	0.0382609	2056.363	14.348439	
0.5800000	0.0413798	2025.619	13.573492	
0.6000000	0.0447872	1993.162	12.802938	
0.6200000	0.0485253	1958.840	12.037220	
0.6400000	0.0526446	1922.481	11.276842	
0.6600000	0.0572064	1883.891	10.522382	
0.6800000	0.0622863	1842.852	9.774505	
0.7000000	0.0679776	1799.110	9.033978	
0.7200000	0.0743981	1752.377	8.301691	
0.7400000	0.0816972	1702.321	7.578687	
0.7600000	0.0900687	1648.554	6.866189	
0.7800000	0.0997676	1590.622	6.165648	
0.8000000	0.1111368	1527.991	5.478794	
0.8200000	0.1246484	1460.023	4.807707	
0.8400000	0.1409711	1385.955	4.154910	
0.8600000	0.1610838	1304.854	3.523498	
0.8800000	0.1864801	1215.575	2.917303	
0.9000000	0.2195568	1116.685	2.341131	
0.9100000	0.2401530	1063.085	2.066152	
0.9200000	0.2644184	1006.360	1.801095	
0.9300000	0.2934293	946.198	1.547007	
0.9400000	0.3287287	882.236	1.305085	
0.9500000	0.3726098	814.054	1.076706	
0.9600000	0.4286351	741.163	0.863468	
0.9700000	0.5026557	662.983	0.667224	
0.9800000	0.6050004	578.827	0.490146	
0.9900000	0.7557731	487.865	0.334793	
0.9910000	0.7748694	478.357	0.320565	
0.9920000	0.7949142	468.771	0.306587	
0.9930000	0.8159798	459.104	0.292863	
0.9940000	0.8381465	449.356	0.279396	
0.9950000	0.8615028	439.525	0.266190	
0.9960000	0.8861472	429.610	0.253248	
0.9970000	0.9121890	419.611	0.240575	
0.9980000	0.9397510	409.525	0.228173	
0.9990000	0.9689699	399.351	0.216046	
0.9995000	0.9842482	394.231	0.210087	
0.9999000	0.9968107	390.119	0.205371	

CHOKED FLOW PROGRAM

IDENT= SLIP=CUBE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
2000.00	152.296	5.11

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0020077	2987.996	34.017958	
0.1000000	0.0042289	2952.561	32.009246	
0.1500000	0.0066999	2914.245	30.006276	
0.2000000	0.0094651	2872.675	28.009875	
0.2500000	0.0125804	2827.414	26.021035	
0.3000000	0.0161169	2777.936	24.040959	
0.3500000	0.0201661	2723.613	22.071118	
0.4000000	0.0248483	2663.681	20.113334	
0.4500000	0.0303244	2597.203	18.169887	
0.5000000	0.0368151	2523.012	16.243673	
0.5200000	0.0397610	2490.861	15.478813	
0.5400000	0.0429427	2457.134	14.717579	
0.5600000	0.0463898	2421.711	13.960290	
0.5800000	0.0501367	2384.455	13.207302	
0.6000000	0.0542244	2345.215	12.459018	
0.6200000	0.0587018	2303.822	11.715890	
0.6400000	0.0636271	2260.087	10.978431	
0.6600000	0.0690712	2213.798	10.247225	
0.6800000	0.0751207	2164.712	9.522937	
0.7000000	0.0818825	2112.556	8.806333	
0.7200000	0.0894901	2057.019	8.098294	
0.7400000	0.0981129	1997.741	7.399841	
0.7600000	0.1079688	1934.308	6.712166	
0.7800000	0.1193424	1866.239	6.036664	
0.8000000	0.1326137	1792.970	5.374985	
0.8200000	0.1483008	1713.836	4.729090	
0.8400000	0.1671293	1628.046	4.101327	
0.8600000	0.1901480	1534.644	3.494538	
0.8800000	0.2189307	1432.470	2.912189	
0.9000000	0.2559523	1320.091	2.358555	
0.9100000	0.2787433	1259.530	2.094123	
0.9200000	0.3053411	1195.710	1.838970	
0.9300000	0.3367862	1128.328	1.593985	
0.9400000	0.3745366	1057.038	1.360176	
0.9500000	0.4207002	981.444	1.138686	
0.9600000	0.4784422	901.088	0.930821	
0.9700000	0.5527431	815.437	0.738078	
0.9800000	0.6519182	723.866	0.562182	
0.9900000	0.7909698	625.638	0.405132	
0.9910000	0.8080131	615.416	0.390549	
0.9920000	0.8257704	605.118	0.376181	
0.9930000	0.8442874	594.743	0.362029	
0.9940000	0.8636142	584.290	0.348096	
0.9950000	0.8838049	573.757	0.334385	
0.9960000	0.9049188	563.144	0.320899	
0.9970000	0.9270206	552.450	0.307639	
0.9980000	0.9501815	541.673	0.294610	
0.9990000	0.9744793	530.813	0.281813	
0.9995000	0.9870811	525.351	0.275503	
0.9999000	0.9973902	520.966	0.270497	

CHOKED FLOW PROGRAM

IDENT= SLIP=CUBE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
2100.00	200.712	4.66

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0024185	3485.438	33.138748	
0.1000000	0.0050921	3442.172	31.176630	
0.1500000	0.0080634	3395.493	29.220899	
0.2000000	0.0113848	3344.975	27.272445	
0.2500000	0.0151224	3290.114	25.332336	
0.3000000	0.0193594	3230.315	23.401860	
0.3500000	0.0242033	3164.863	21.482579	
0.4000000	0.0297943	3092.897	19.576419	
0.4500000	0.0363197	3013.367	17.685768	
0.5000000	0.0440354	2924.977	15.813636	
0.5200000	0.0475306	2886.790	15.070795	
0.5400000	0.0513008	2846.809	14.331810	
0.5600000	0.0553799	2804.900	13.597006	
0.5800000	0.0598075	2760.915	12.866745	
0.6000000	0.0646301	2714.690	12.141431	
0.6200000	0.0699031	2666.042	11.421520	
0.6400000	0.0756927	2614.766	10.707523	
0.6600000	0.0820787	2560.634	10.000017	
0.6800000	0.0891583	2503.388	9.299661	
0.7000000	0.0970510	2442.737	8.607203	
0.7200000	0.1059053	2378.350	7.923498	
0.7400000	0.1159085	2309.851	7.249532	
0.7600000	0.1272997	2236.805	6.586443	
0.7800000	0.1403892	2158.713	5.935555	
0.8000000	0.1555875	2074.994	5.298413	
0.8200000	0.1734487	1984.966	4.676838	
0.8400000	0.1947401	1887.825	4.072984	
0.8600000	0.2205546	1782.612	3.489426	
0.8800000	0.2525048	1668.171	2.929259	
0.9000000	0.2930736	1543.095	2.396243	
0.9100000	0.3177584	1476.040	2.141319	
0.9200000	0.3462915	1405.641	1.894990	
0.9300000	0.3796490	1331.611	1.658010	
0.9400000	0.4191674	1253.623	1.431218	
0.9500000	0.4667271	1171.307	1.215561	
0.9600000	0.5250605	1084.241	1.012105	
0.9700000	0.5982962	991.938	0.822057	
0.9800000	0.6929809	893.835	0.646788	
0.9900000	0.8201541	789.276	0.487864	
0.9910000	0.8353133	778.436	0.472937	
0.9920000	0.8510112	767.523	0.458194	
0.9930000	0.8672768	756.537	0.443635	
0.9940000	0.8841417	745.476	0.429264	
0.9950000	0.9016396	734.339	0.415082	
0.9960000	0.9198068	723.125	0.401090	
0.9970000	0.9386823	711.835	0.387292	
0.9980000	0.9583087	700.465	0.373689	
0.9990000	0.9787314	689.017	0.360284	
0.9995000	0.9892567	683.263	0.353656	
0.9999000	0.9978336	678.645	0.348390	

CHOKED FLOW PROGRAM

IDENT= SLIP=CUBE ROOT

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
2200.00	258.882	4.27

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0028763	4000.764	32.255483	
0.1000000	0.0060528	3949.206	30.343098	
0.1500000	0.0095792	3893.703	28.437701	
0.2000000	0.0135166	3833.775	26.540241	
0.2500000	0.0179414	3768.861	24.651845	
0.3000000	0.0229498	3698.296	22.773866	
0.3500000	0.0286657	3621.291	20.907939	
0.4000000	0.0352503	3536.896	19.056060	
0.4500000	0.0429179	3443.962	17.220691	
0.5000000	0.0519596	3341.078	15.404906	
0.5200000	0.0560469	3296.759	14.684913	
0.5400000	0.0604498	3250.443	13.968957	
0.5600000	0.0652064	3201.984	13.257363	
0.5800000	0.0703610	3151.226	12.550490	
0.6000000	0.0759659	3097.993	11.848741	
0.6200000	0.0820826	3042.091	11.152563	
0.6400000	0.0887846	2983.304	10.462460	
0.6600000	0.0961603	2921.392	9.778996	
0.6800000	0.1043164	2856.085	9.102806	
0.7000000	0.1133839	2787.079	8.434613	
0.7200000	0.1235246	2714.032	7.775234	
0.7400000	0.1349408	2636.553	7.125606	
0.7600000	0.1478895	2554.200	6.486799	
0.7800000	0.1627015	2466.461	5.860051	
0.8000000	0.1798099	2372.749	5.246790	
0.8200000	0.1997940	2272.378	4.648683	
0.8400000	0.2234450	2164.546	4.067683	
0.8600000	0.2518745	2048.305	3.506094	
0.8800000	0.2866930	1922.525	2.966650	
0.9000000	0.3303272	1785.841	2.452628	
0.9100000	0.3565671	1712.904	2.206354	
0.9200000	0.3866103	1636.588	1.967982	
0.9300000	0.4213484	1556.623	1.738141	
0.9400000	0.4619749	1472.705	1.517532	
0.9500000	0.5101258	1384.492	1.306934	
0.9600000	0.5681050	1291.597	1.107215	
0.9700000	0.6392634	1193.580	0.919347	
0.9800000	0.7286710	1089.936	0.744423	
0.9900000	0.8443805	980.087	0.583672	
0.9910000	0.8578516	968.735	0.568428	
0.9920000	0.8717310	957.314	0.553342	
0.9930000	0.8860375	945.824	0.538414	
0.9940000	0.9007912	934.262	0.523646	
0.9950000	0.9160134	922.628	0.509039	
0.9960000	0.9317268	910.922	0.494596	
0.9970000	0.9479554	899.143	0.480317	
0.9980000	0.9647252	887.289	0.466205	
0.9990000	0.9820636	875.361	0.452260	
0.9995000	0.9909551	869.369	0.445352	
0.9999000	0.9981785	864.561	0.439855	

CHOKED FLOW PROGRAM

IDENT=   SLIP=1

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1100.00	2.276	1.00

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0000070	46.856	41.802557	
0.1000000	0.0000147	46.850	39.602730	
0.1500000	0.0000234	46.842	37.402902	
0.2000000	0.0000331	46.834	35.203074	
0.2500000	0.0000442	46.825	33.003247	
0.3000000	0.0000568	46.815	30.803419	
0.3500000	0.0000714	46.802	28.603592	
0.4000000	0.0000884	46.788	26.403764	
0.4500000	0.0001085	46.772	24.203937	
0.5000000	0.0001325	46.751	22.004109	
0.5200000	0.0001436	46.742	21.124178	
0.5400000	0.0001556	46.732	20.244247	
0.5600000	0.0001687	46.722	19.364316	
0.5800000	0.0001830	46.710	18.484385	
0.6000000	0.0001988	46.697	17.604454	
0.6200000	0.0002162	46.682	16.724523	
0.6400000	0.0002356	46.666	15.844592	
0.6600000	0.0002573	46.648	14.964661	
0.6800000	0.0002816	46.628	14.084730	
0.7000000	0.0003092	46.605	13.204799	
0.7200000	0.0003408	46.580	12.324868	
0.7400000	0.0003772	46.550	11.444937	
0.7600000	0.0004196	46.515	10.565006	
0.7800000	0.0004698	46.474	9.685075	
0.8000000	0.0005300	46.425	8.805144	
0.8200000	0.0006036	46.365	7.925213	
0.8400000	0.0006955	46.291	7.045282	
0.8600000	0.0008137	46.196	6.165351	
0.8800000	0.0009712	46.070	5.285420	
0.9000000	0.0011917	45.896	4.405489	
0.9100000	0.0013386	45.781	3.965523	
0.9200000	0.0015222	45.639	3.525558	
0.9300000	0.0017582	45.457	3.085592	
0.9400000	0.0020726	45.219	2.645627	
0.9500000	0.0025125	44.892	2.205661	
0.9600000	0.0031716	44.416	1.765696	
0.9700000	0.0042681	43.655	1.325730	
0.9800000	0.0064540	42.248	0.885765	
0.9900000	0.0129544	38.752	0.445799	
0.9910000	0.0143874	38.092	0.401803	
0.9920000	0.0161728	37.315	0.357806	
0.9930000	0.0184589	36.385	0.313810	
0.9940000	0.0214904	35.254	0.269813	
0.9950000	0.0257033	33.843	0.225816	
0.9960000	0.0319551	32.031	0.181820	
0.9970000	0.0421982	29.603	0.137823	
0.9980000	0.0620477	26.138	0.093827	
0.9990000	0.1169489	20.602	0.049830	
0.9995000	0.2094906	16.096	0.027832	
0.9999000	0.5699934	10.144	0.010233	

CHOKED FLOW PROGRAM

IDENT=   SLIP=1

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1200.00	4.573	1.00

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0000135	84.957	40.993721	
0.1000000	0.0000285	84.937	38.836739	
0.1500000	0.0000452	84.915	36.679756	
0.2000000	0.0000640	84.890	34.522774	
0.2500000	0.0000854	84.863	32.365791	
0.3000000	0.0001098	84.831	30.208809	
0.3500000	0.0001379	84.794	28.051827	
0.4000000	0.0001708	84.752	25.894844	
0.4500000	0.0002096	84.701	23.737862	
0.5000000	0.0002561	84.641	21.580879	
0.5200000	0.0002775	84.613	20.718087	
0.5400000	0.0003007	84.583	19.855294	
0.5600000	0.0003260	84.551	18.992501	
0.5800000	0.0003537	84.515	18.129708	
0.6000000	0.0003842	84.476	17.266915	
0.6200000	0.0004179	84.432	16.404122	
0.6400000	0.0004553	84.384	15.541329	
0.6600000	0.0004971	84.331	14.678536	
0.6800000	0.0005442	84.271	13.815743	
0.7000000	0.0005975	84.203	12.952950	
0.7200000	0.0006584	84.125	12.090157	
0.7400000	0.0007287	84.036	11.227364	
0.7600000	0.0008107	83.932	10.364571	
0.7800000	0.0009076	83.810	9.501778	
0.8000000	0.0010238	83.665	8.638985	
0.8200000	0.0011658	83.488	7.776193	
0.8400000	0.0013433	83.268	6.913400	
0.8600000	0.0015714	82.989	6.050606	
0.8800000	0.0018754	82.621	5.187814	
0.9000000	0.0023006	82.114	4.325021	
0.9100000	0.0025839	81.781	3.893624	
0.9200000	0.0029378	81.371	3.462228	
0.9300000	0.0033925	80.854	3.030831	
0.9400000	0.0039980	80.179	2.599435	
0.9500000	0.0048445	79.264	2.168038	
0.9600000	0.0061116	77.951	1.736642	
0.9700000	0.0082162	75.908	1.305245	
0.9800000	0.0123989	72.282	0.873849	
0.9900000	0.0247378	64.012	0.442453	
0.9910000	0.0274381	62.552	0.399313	
0.9920000	0.0307924	60.871	0.356173	
0.9930000	0.0350713	58.911	0.313034	
0.9940000	0.0407180	56.592	0.269894	
0.9950000	0.0485133	53.799	0.226754	
0.9960000	0.0599716	50.354	0.183614	
0.9970000	0.0784674	45.964	0.140475	
0.9980000	0.1133582	40.090	0.097335	
0.9990000	0.2037955	31.495	0.054196	
0.9995000	0.3387003	25.128	0.032626	
0.9999000	0.7192474	17.657	0.015370	

CHOKED FLOW PROGRAM

IDENT= SLIP=1

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1300.00	8.473	1.00

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0000242	142.705	40.176558	
0.1000000	0.0000511	142.654	38.063026	
0.1500000	0.0000811	142.597	35.949493	
0.2000000	0.0001149	142.533	33.835960	
0.2500000	0.0001532	142.460	31.722428	
0.3000000	0.0001969	142.377	29.608895	
0.3500000	0.0002474	142.282	27.495362	
0.4000000	0.0003063	142.171	25.381829	
0.4500000	0.0003759	142.040	23.268296	
0.5000000	0.0004594	141.884	21.154764	
0.5200000	0.0004976	141.812	20.309351	
0.5400000	0.0005392	141.735	19.463937	
0.5600000	0.0005846	141.650	18.618525	
0.5800000	0.0006343	141.558	17.773111	
0.6000000	0.0006889	141.457	16.927698	
0.6200000	0.0007493	141.345	16.082285	
0.6400000	0.0008164	141.221	15.236872	
0.6600000	0.0008914	141.083	14.391459	
0.6800000	0.0009757	140.928	13.546046	
0.7000000	0.0010712	140.753	12.700633	
0.7200000	0.0011804	140.554	11.855220	
0.7400000	0.0013064	140.326	11.009807	
0.7600000	0.0014533	140.061	10.164393	
0.7800000	0.0016268	139.749	9.318980	
0.8000000	0.0018350	139.379	8.473567	
0.8200000	0.0020893	138.930	7.628154	
0.8400000	0.0024070	138.375	6.782741	
0.8600000	0.0028152	137.673	5.937328	
0.8800000	0.0033590	136.753	5.091915	
0.9000000	0.0041193	135.497	4.246502	
0.9100000	0.0046255	134.680	3.823795	
0.9200000	0.0052575	133.680	3.401089	
0.9300000	0.0060689	132.428	2.978382	
0.9400000	0.0071488	130.816	2.555676	
0.9500000	0.0086566	128.660	2.132969	
0.9600000	0.0109098	125.628	1.710263	
0.9700000	0.0146425	121.045	1.287556	
0.9800000	0.0220240	113.287	0.864849	
0.9900000	0.0435194	97.096	0.442143	
0.9910000	0.0481684	94.423	0.399872	
0.9920000	0.0539166	91.405	0.357601	
0.9930000	0.0612058	87.965	0.315331	
0.9940000	0.0707519	83.995	0.273060	
0.9950000	0.0837948	79.350	0.230790	
0.9960000	0.1026868	73.808	0.188519	
0.9970000	0.1324995	67.023	0.146248	
0.9980000	0.1865523	58.380	0.103978	
0.9990000	0.3146603	46.565	0.061707	
0.9995000	0.4788193	38.456	0.040572	
0.9999000	0.8212808	29.818	0.023663	

CHOKED FLOW PROGRAM

IDENT=   SLIP=1

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1400.00	15.177	1.00

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0000408	227.412	39.351308	
0.1000000	0.0000861	227.320	37.281876	
0.1500000	0.0001367	227.216	35.212443	
0.2000000	0.0001936	227.100	33.143011	
0.2500000	0.0002582	226.969	31.073579	
0.3000000	0.0003319	226.820	29.004146	
0.3500000	0.0004170	226.648	26.934713	
0.4000000	0.0005162	226.447	24.865281	
0.4500000	0.0006335	226.211	22.795848	
0.5000000	0.0007742	225.929	20.726416	
0.5200000	0.0008386	225.800	19.898643	
0.5400000	0.0009087	225.660	19.070870	
0.5600000	0.0009851	225.508	18.243097	
0.5800000	0.0010688	225.342	17.415324	
0.6000000	0.0011608	225.159	16.587551	
0.6200000	0.0012625	224.958	15.759778	
0.6400000	0.0013755	224.735	14.932005	
0.6600000	0.0015017	224.487	14.104232	
0.6800000	0.0016437	224.208	13.276459	
0.7000000	0.0018045	223.894	12.448686	
0.7200000	0.0019883	223.537	11.620913	
0.7400000	0.0022002	223.127	10.793140	
0.7600000	0.0024474	222.652	9.965367	
0.7800000	0.0027393	222.094	9.137594	
0.8000000	0.0030895	221.432	8.309821	
0.8200000	0.0035170	220.630	7.482048	
0.8400000	0.0040510	219.641	6.654275	
0.8600000	0.0047367	218.390	5.826502	
0.8800000	0.0056495	216.758	4.998729	
0.9000000	0.0069245	214.538	4.170956	
0.9100000	0.0077728	213.099	3.757070	
0.9200000	0.0088310	211.343	3.343183	
0.9300000	0.0101883	209.153	2.929297	
0.9400000	0.0119923	206.345	2.515410	
0.9500000	0.0145069	202.613	2.101524	
0.9600000	0.0182548	197.409	1.687637	
0.9700000	0.0244383	189.635	1.273751	
0.9800000	0.0365747	176.717	0.859864	
0.9900000	0.0712371	150.658	0.445978	
0.9910000	0.0786038	146.466	0.404589	
0.9920000	0.0876496	141.768	0.363200	
0.9930000	0.0990219	136.456	0.321812	
0.9940000	0.1137514	130.389	0.280423	
0.9950000	0.1335817	123.368	0.239034	
0.9960000	0.1617172	115.107	0.197646	
0.9970000	0.2047572	105.165	0.156257	
0.9980000	0.2788135	92.795	0.114869	
0.9990000	0.4362965	76.514	0.073480	
0.9995000	0.6076492	65.893	0.052785	
0.9999000	0.8856709	55.313	0.036230	

CHOKED FLOW PROGRAM

IDENT= SLIP=1

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1500.00	24.666	1.00

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0000652	338.539	38.518211	
0.1000000	0.0001377	338.350	36.493581	
0.1500000	0.0002187	338.140	34.468952	
0.2000000	0.0003098	337.904	32.444323	
0.2500000	0.0004130	337.637	30.419694	
0.3000000	0.0005310	337.333	28.395065	
0.3500000	0.0006670	336.983	26.370435	
0.4000000	0.0008257	336.577	24.345806	
0.4500000	0.0010132	336.098	22.321177	
0.5000000	0.0012380	335.527	20.296548	
0.5200000	0.0013411	335.266	19.486696	
0.5400000	0.0014530	334.984	18.676845	
0.5600000	0.0015752	334.676	17.866993	
0.5800000	0.0017089	334.340	17.057141	
0.6000000	0.0018559	333.972	16.247290	
0.6200000	0.0020184	333.567	15.437438	
0.6400000	0.0021989	333.119	14.627587	
0.6600000	0.0024005	332.620	13.817735	
0.6800000	0.0026272	332.062	13.007883	
0.7000000	0.0028840	331.433	12.198031	
0.7200000	0.0031774	330.719	11.388180	
0.7400000	0.0035156	329.901	10.578328	
0.7600000	0.0039100	328.955	9.768476	
0.7800000	0.0043756	327.849	8.958625	
0.8000000	0.0049339	326.537	8.148773	
0.8200000	0.0056153	324.957	7.338921	
0.8400000	0.0064657	323.017	6.529070	
0.8600000	0.0075570	320.578	5.719218	
0.8800000	0.0090084	317.418	4.909366	
0.9000000	0.0110331	313.161	4.099515	
0.9100000	0.0123784	310.426	3.694589	
0.9200000	0.0140548	307.116	3.289663	
0.9300000	0.0162019	303.027	2.884737	
0.9400000	0.0190501	297.847	2.479811	
0.9500000	0.0230101	291.067	2.074885	
0.9600000	0.0288904	281.802	1.669960	
0.9700000	0.0385353	268.351	1.265034	
0.9800000	0.0572614	246.942	0.860108	
0.9900000	0.1093047	206.809	0.455182	
0.9910000	0.1200991	200.687	0.414690	
0.9920000	0.1332295	193.926	0.374197	
0.9930000	0.1495465	186.405	0.333704	
0.9940000	0.1703703	177.967	0.293212	
0.9950000	0.1978673	168.401	0.252719	
0.9960000	0.2358570	157.409	0.212226	
0.9970000	0.2917612	144.550	0.171734	
0.9980000	0.3821629	129.113	0.131241	
0.9990000	0.5532401	109.805	0.090749	
0.9995000	0.7124716	97.916	0.070502	
0.9999000	0.9253417	86.757	0.054305	

CHOKED FLOW PROGRAM

IDENT= SLIP=1

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1600.00	38.191	1.00

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0000998	481.484	37.677512	
0.1000000	0.0002108	481.132	35.698445	
0.1500000	0.0003347	480.740	33.719378	
0.2000000	0.0004741	480.300	31.740311	
0.2500000	0.0006320	479.803	29.761244	
0.3000000	0.0008124	479.237	27.782177	
0.3500000	0.0010206	478.587	25.803110	
0.4000000	0.0012632	477.832	23.824043	
0.4500000	0.0015499	476.945	21.844976	
0.5000000	0.0018937	475.888	19.865909	
0.5200000	0.0020511	475.406	19.074282	
0.5400000	0.0022223	474.884	18.282655	
0.5600000	0.0024089	474.317	17.491029	
0.5800000	0.0026132	473.698	16.699401	
0.6000000	0.0028378	473.020	15.907775	
0.6200000	0.0030860	472.275	15.116148	
0.6400000	0.0033615	471.451	14.324521	
0.6600000	0.0036694	470.537	13.532894	
0.6800000	0.0040155	469.515	12.741267	
0.7000000	0.0044074	468.365	11.949641	
0.7200000	0.0048549	467.063	11.158014	
0.7400000	0.0053709	465.575	10.366387	
0.7600000	0.0059721	463.859	9.574760	
0.7800000	0.0066817	461.857	8.783134	
0.8000000	0.0075318	459.493	7.991507	
0.8200000	0.0085689	456.658	7.199880	
0.8400000	0.0098623	453.195	6.408253	
0.8600000	0.0115203	448.869	5.616626	
0.8800000	0.0137222	443.310	4.824999	
0.9000000	0.0167886	435.902	4.033373	
0.9100000	0.0188222	431.189	3.637559	
0.9200000	0.0213525	425.533	3.241746	
0.9300000	0.0245866	418.617	2.845932	
0.9400000	0.0288656	409.965	2.450119	
0.9500000	0.0347935	398.820	2.054306	
0.9600000	0.0435509	383.901	1.658492	
0.9700000	0.0577987	362.842	1.262679	
0.9800000	0.0850577	330.658	0.866865	
0.9900000	0.1581269	274.178	0.471052	
0.9910000	0.1728072	265.957	0.431471	
0.9920000	0.1904530	256.991	0.391889	
0.9930000	0.2120636	247.154	0.352308	
0.9940000	0.2391448	236.286	0.312727	
0.9950000	0.2740747	224.179	0.273145	
0.9960000	0.3208435	210.546	0.233564	
0.9970000	0.3866978	194.978	0.193983	
0.9980000	0.4863167	176.857	0.154401	
0.9990000	0.6546183	155.147	0.114820	
0.9995000	0.7913446	142.390	0.095029	
0.9999000	0.9499255	130.921	0.079197	

CHOKED FLOW PROGRAM

IDENT= SLIP=1

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1700.00	56.719	1.00

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0001471	658.498	36.829458	
0.1000000	0.0003105	657.890	34.896769	
0.1500000	0.0004931	657.212	32.964079	
0.2000000	0.0006984	656.452	31.031391	
0.2500000	0.0009310	655.595	29.098702	
0.3000000	0.0011967	654.619	27.166013	
0.3500000	0.0015031	653.500	25.233324	
0.4000000	0.0018603	652.202	23.300635	
0.4500000	0.0022822	650.679	21.367946	
0.5000000	0.0027879	648.867	19.435257	
0.5200000	0.0030195	648.042	18.662181	
0.5400000	0.0032712	647.150	17.889106	
0.5600000	0.0035455	646.181	17.116030	
0.5800000	0.0038459	645.125	16.342954	
0.6000000	0.0041760	643.971	15.569879	
0.6200000	0.0045407	642.703	14.796803	
0.6400000	0.0049455	641.304	14.023728	
0.6600000	0.0053976	639.752	13.250652	
0.6800000	0.0059057	638.022	12.477576	
0.7000000	0.0064810	636.080	11.704501	
0.7200000	0.0071376	633.884	10.931425	
0.7400000	0.0078941	631.383	10.158350	
0.7600000	0.0087753	628.506	9.385274	
0.7800000	0.0098147	625.163	8.612199	
0.8000000	0.0110591	621.230	7.839123	
0.8200000	0.0125757	616.535	7.066047	
0.8400000	0.0144650	610.833	6.292972	
0.8600000	0.0168836	603.760	5.519896	
0.8800000	0.0200898	594.751	4.746821	
0.9000000	0.0245436	582.879	3.973745	
0.9100000	0.0274904	575.405	3.587207	
0.9200000	0.0311489	566.513	3.200669	
0.9300000	0.0358125	555.755	2.814131	
0.9400000	0.0419612	542.464	2.427594	
0.9500000	0.0504388	525.611	2.041056	
0.9600000	0.0628776	503.501	1.654518	
0.9700000	0.0829002	473.115	1.267980	
0.9800000	0.1204838	428.388	0.881443	
0.9900000	0.2167754	354.350	0.494905	
0.9910000	0.2353782	344.012	0.456251	
0.9920000	0.2574249	332.858	0.417597	
0.9930000	0.2839691	320.766	0.378944	
0.9940000	0.3165440	307.586	0.340290	
0.9950000	0.3574675	293.122	0.301636	
0.9960000	0.4104212	277.119	0.262982	
0.9970000	0.4816231	259.226	0.224328	
0.9980000	0.5824714	238.941	0.185675	
0.9990000	0.7363485	215.494	0.147021	
0.9995000	0.8482220	202.211	0.127694	
0.9999000	0.9654620	190.629	0.112232	

CHOKED FLOW PROGRAM

IDENT= SLIP=1

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1800.00	81.249	1.00

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0002098	870.664	35.974294	
0.1000000	0.0004428	869.678	34.088854	
0.1500000	0.0007031	868.580	32.203415	
0.2000000	0.0009957	867.351	30.317976	
0.2500000	0.0013272	865.965	28.432536	
0.3000000	0.0017058	864.390	26.547096	
0.3500000	0.0021422	862.585	24.661657	
0.4000000	0.0026509	860.496	22.776217	
0.4500000	0.0032514	858.049	20.890778	
0.5000000	0.0039711	855.143	19.005338	
0.5200000	0.0043006	853.823	18.251163	
0.5400000	0.0046585	852.395	17.496987	
0.5600000	0.0050486	850.847	16.742811	
0.5800000	0.0054756	849.163	15.988635	
0.6000000	0.0059448	847.324	15.234460	
0.6200000	0.0064629	845.306	14.480284	
0.6400000	0.0070380	843.084	13.726108	
0.6600000	0.0076799	840.624	12.971932	
0.6800000	0.0084010	837.886	12.217756	
0.7000000	0.0092171	834.819	11.463581	
0.7200000	0.0101480	831.362	10.709405	
0.7400000	0.0112201	827.433	9.955229	
0.7600000	0.0124678	822.930	9.201053	
0.7800000	0.0139384	817.716	8.446877	
0.8000000	0.0156973	811.607	7.692702	
0.8200000	0.0178386	804.353	6.938526	
0.8400000	0.0205022	795.594	6.184350	
0.8600000	0.0239056	784.809	5.430174	
0.8800000	0.0284069	771.195	4.675999	
0.9000000	0.0346393	753.464	3.921823	
0.9100000	0.0387501	742.418	3.544735	
0.9200000	0.0438395	729.391	3.167647	
0.9300000	0.0503045	713.792	2.790559	
0.9400000	0.0587896	694.760	2.413471	
0.9500000	0.0704172	670.991	2.036383	
0.9600000	0.0873298	640.400	1.659295	
0.9700000	0.1141900	599.391	1.282207	
0.9800000	0.1634312	541.054	0.905120	
0.9900000	0.2830023	449.372	0.528032	
0.9910000	0.3050748	437.034	0.490323	
0.9920000	0.3308251	423.849	0.452614	
0.9930000	0.3612559	409.706	0.414905	
0.9940000	0.3977713	394.469	0.377197	
0.9950000	0.4423987	377.970	0.339488	
0.9960000	0.4981790	359.992	0.301779	
0.9970000	0.5698893	340.254	0.264070	
0.9980000	0.6654923	318.371	0.226361	
0.9990000	0.7993146	293.801	0.188652	
0.9995000	0.8885152	280.266	0.169798	
0.9999000	0.9755289	268.717	0.154715	

CHOKED FLOW PROGRAM

IDENT= SLIP=1

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
1900.00	112.783	1.00

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0002908	1117.887	35.112262	
0.1000000	0.0006137	1116.377	33.274995	
0.1500000	0.0009743	1114.698	31.437729	
0.2000000	0.0013797	1112.820	29.600462	
0.2500000	0.0018388	1110.704	27.763196	
0.3000000	0.0023629	1108.303	25.925929	
0.3500000	0.0029669	1105.555	24.088663	
0.4000000	0.0036708	1102.378	22.251396	
0.4500000	0.0045013	1098.665	20.414130	
0.5000000	0.0054961	1094.267	18.576863	
0.5200000	0.0059513	1092.271	17.841957	
0.5400000	0.0064457	1090.117	17.107050	
0.5600000	0.0069845	1087.783	16.372144	
0.5800000	0.0075739	1085.247	15.637237	
0.6000000	0.0082215	1082.482	14.902331	
0.6200000	0.0089362	1079.454	14.167424	
0.6400000	0.0097292	1076.124	13.432518	
0.6600000	0.0106139	1072.444	12.697611	
0.6800000	0.0116073	1068.358	11.962704	
0.7000000	0.0127308	1063.792	11.227798	
0.7200000	0.0140117	1058.657	10.492891	
0.7400000	0.0154855	1052.840	9.757985	
0.7600000	0.0171994	1046.195	9.023078	
0.7800000	0.0192172	1038.530	8.288172	
0.8000000	0.0216276	1029.590	7.553265	
0.8200000	0.0245577	1019.029	6.818358	
0.8400000	0.0281957	1006.356	6.083452	
0.8600000	0.0328334	990.867	5.348545	
0.8800000	0.0389487	971.495	4.613639	
0.9000000	0.0473812	946.556	3.878732	
0.9100000	0.0529212	931.179	3.511279	
0.9200000	0.0597562	913.203	3.143825	
0.9300000	0.0684004	891.892	2.776372	
0.9400000	0.0796818	866.199	2.408919	
0.9500000	0.0950244	834.574	2.041466	
0.9600000	0.1171025	794.595	1.674012	
0.9700000	0.1515990	742.219	1.306559	
0.9800000	0.2130910	669.986	0.939106	
0.9900000	0.3536361	561.603	0.571652	
0.9910000	0.3783109	547.493	0.534907	
0.9920000	0.4066257	532.543	0.498162	
0.9930000	0.4394501	516.655	0.461416	
0.9940000	0.4779552	499.714	0.424671	
0.9950000	0.5237548	481.581	0.387926	
0.9960000	0.5791388	462.084	0.351180	
0.9970000	0.6474669	441.007	0.314435	
0.9980000	0.7338785	418.069	0.277690	
0.9990000	0.8466467	392.900	0.240944	
0.9995000	0.9169939	379.326	0.222572	
0.9999000	0.9822247	367.920	0.207874	

CHOKED FLOW PROGRAM

IDENT=   SLIP=1

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
2000.00	152.296	1.00

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0003931	1398.989	34.243597	
0.1000000	0.0008296	1396.789	32.455473	
0.1500000	0.0013170	1394.344	30.667350	
0.2000000	0.0018647	1391.612	28.879226	
0.2500000	0.0024847	1388.538	27.091103	
0.3000000	0.0031923	1385.055	25.302979	
0.3500000	0.0040076	1381.074	23.514856	
0.4000000	0.0049571	1376.481	21.726733	
0.4500000	0.0060768	1371.123	19.938609	
0.5000000	0.0074172	1364.790	18.150486	
0.5200000	0.0080303	1361.923	17.435236	
0.5400000	0.0086959	1358.830	16.719987	
0.5600000	0.0094210	1355.485	16.004738	
0.5800000	0.0102139	1351.855	15.289488	
0.6000000	0.0110847	1347.902	14.574239	
0.6200000	0.0120453	1343.581	13.858990	
0.6400000	0.0131105	1338.838	13.143741	
0.6600000	0.0142983	1333.608	12.428491	
0.6800000	0.0156311	1327.812	11.713241	
0.7000000	0.0171373	1321.351	10.997992	
0.7200000	0.0188531	1314.106	10.282743	
0.7400000	0.0208253	1305.923	9.567493	
0.7600000	0.0231163	1296.606	8.852244	
0.7800000	0.0258101	1285.903	8.136995	
0.8000000	0.0290230	1273.477	7.421746	
0.8200000	0.0329213	1258.873	6.706496	
0.8400000	0.0377503	1241.461	5.991247	
0.8600000	0.0438887	1220.336	5.275997	
0.8800000	0.0519524	1194.157	4.560748	
0.9000000	0.0630157	1160.835	3.845499	
0.9100000	0.0702489	1140.500	3.487874	
0.9200000	0.0791348	1116.923	3.130249	
0.9300000	0.0903131	1089.241	2.772625	
0.9400000	0.1048020	1056.245	2.415000	
0.9500000	0.1243280	1016.180	2.057375	
0.9600000	0.1520704	966.370	1.699751	
0.9700000	0.1945975	902.482	1.342126	
0.9800000	0.2680208	816.821	0.984501	
0.9900000	0.4252181	693.533	0.626877	
0.9910000	0.4513994	677.955	0.591114	
0.9920000	0.4809527	661.573	0.555352	
0.9930000	0.5145738	644.306	0.519589	
0.9940000	0.5531656	626.061	0.483827	
0.9950000	0.5979178	606.727	0.448064	
0.9960000	0.6504335	586.173	0.412302	
0.9970000	0.7129242	564.240	0.376539	
0.9980000	0.7885315	540.729	0.340777	
0.9990000	0.8818686	515.393	0.305014	
0.9995000	0.9372560	501.944	0.287133	
0.9999000	0.9867930	490.766	0.272828	

CHOKED FLOW PROGRAM

IDENT= SLIP=1

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
2100.00	200.712	1.00

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0005201	1711.847	33.368529	
0.1000000	0.0010973	1708.777	31.630558	
0.1500000	0.0017416	1705.369	29.892587	
0.2000000	0.0024655	1701.564	28.154615	
0.2500000	0.0032846	1697.289	26.416644	
0.3000000	0.0042192	1692.452	24.678673	
0.3500000	0.0052953	1686.932	22.940702	
0.4000000	0.0065478	1680.575	21.202731	
0.4500000	0.0080240	1673.174	19.464760	
0.5000000	0.0097897	1664.449	17.726789	
0.5200000	0.0105968	1660.505	17.031600	
0.5400000	0.0114727	1656.258	16.336412	
0.5600000	0.0124264	1651.670	15.641224	
0.5800000	0.0134688	1646.698	14.946035	
0.6000000	0.0146130	1641.293	14.250847	
0.6200000	0.0158744	1635.394	13.555658	
0.6400000	0.0172723	1628.932	12.860470	
0.6600000	0.0188299	1621.820	12.165282	
0.6800000	0.0205764	1613.956	11.470093	
0.7000000	0.0225482	1605.213	10.774905	
0.7200000	0.0247920	1595.436	10.079716	
0.7400000	0.0273682	1584.426	9.384528	
0.7600000	0.0303567	1571.937	8.689339	
0.7800000	0.0338649	1557.645	7.994151	
0.8000000	0.0380414	1541.129	7.298963	
0.8200000	0.0430972	1521.821	6.603774	
0.8400000	0.0493427	1498.943	5.908586	
0.8600000	0.0572539	1471.392	5.213397	
0.8800000	0.0675995	1437.554	4.518209	
0.9000000	0.0817078	1394.960	3.823020	
0.9100000	0.0908784	1369.222	3.475426	
0.9200000	0.1020873	1339.617	3.127832	
0.9300000	0.1160990	1305.176	2.780238	
0.9400000	0.1341148	1264.563	2.432644	
0.9500000	0.1581374	1215.875	2.085049	
0.9600000	0.1917719	1156.279	1.737455	
0.9700000	0.2422299	1081.315	1.389861	
0.9800000	0.3263432	983.361	1.042267	
0.9900000	0.4946322	847.579	0.694673	
0.9910000	0.5212119	830.878	0.659913	
0.9920000	0.5507472	813.430	0.625154	
0.9930000	0.5837601	795.171	0.590394	
0.9940000	0.6209037	776.028	0.555635	
0.9950000	0.6630047	755.917	0.520875	
0.9960000	0.7111265	734.741	0.486116	
0.9970000	0.7666597	712.384	0.451357	
0.9980000	0.8314604	688.709	0.416597	
0.9990000	0.9080589	663.552	0.381838	
0.9995000	0.9518373	650.356	0.364458	
0.9999000	0.9899853	639.478	0.350554	

CHOKED FLOW PROGRAM

IDENT= SLIP=1

TS(DEG F)	PS(PSI)	SLIP(DIMENSIONLESS)
2200.00	258.882	1.00

ALP	X	G LBM/FT2 SEC	RHOMIX LBM/FT3	SLIPL
0.0500000	0.0006749	2053.582	32.487276	
0.1000000	0.0014236	2049.458	30.800498	
0.1500000	0.0022592	2044.885	29.113719	
0.2000000	0.0031975	2039.786	27.426941	
0.2500000	0.0042588	2034.064	25.740163	
0.3000000	0.0054689	2027.598	24.053384	
0.3500000	0.0068616	2020.233	22.366605	
0.4000000	0.0084814	2011.766	20.679827	
0.4500000	0.0103890	2001.931	18.993048	
0.5000000	0.0126684	1990.365	17.306270	
0.5200000	0.0137096	1985.148	16.631559	
0.5400000	0.0148389	1979.536	15.956847	
0.5600000	0.0160679	1973.482	15.282136	
0.5800000	0.0174104	1966.933	14.607424	
0.6000000	0.0188830	1959.823	13.932713	
0.6200000	0.0205054	1952.078	13.258002	
0.6400000	0.0223019	1943.609	12.583291	
0.6600000	0.0243018	1934.308	11.908579	
0.6800000	0.0265421	1924.048	11.233868	
0.7000000	0.0290686	1912.669	10.559156	
0.7200000	0.0319400	1899.980	9.884445	
0.7400000	0.0352322	1885.737	9.209734	
0.7600000	0.0390449	1869.636	8.535022	
0.7800000	0.0435121	1851.285	7.860311	
0.8000000	0.0488183	1830.175	7.185600	
0.8200000	0.0552241	1805.626	6.510888	
0.8400000	0.0631112	1776.717	5.836177	
0.8600000	0.0730602	1742.155	5.161465	
0.8800000	0.0860014	1700.078	4.486754	
0.9000000	0.1035238	1647.679	3.812043	
0.9100000	0.1148368	1616.315	3.474687	
0.9200000	0.1285828	1580.513	3.137331	
0.9300000	0.1456411	1539.225	2.799975	
0.9400000	0.1673732	1491.030	2.462620	
0.9500000	0.1960045	1433.940	2.125264	
0.9600000	0.2354406	1365.065	1.787909	
0.9700000	0.2932200	1279.979	1.450553	
0.9800000	0.3860196	1171.398	1.113197	
0.9900000	0.5595225	1025.905	0.775841	
0.9910000	0.5855489	1008.434	0.742106	
0.9920000	0.6140542	990.288	0.708370	
0.9930000	0.6454102	971.415	0.674635	
0.9940000	0.6800675	951.762	0.640899	
0.9950000	0.7185761	931.264	0.607164	
0.9960000	0.7616156	909.851	0.573428	
0.9970000	0.8100356	887.441	0.539693	
0.9980000	0.8649129	863.942	0.505957	
0.9990000	0.9276311	839.243	0.472221	
0.9995000	0.9624752	826.404	0.455353	
0.9999000	0.9922657	815.883	0.441859	