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HEAT TRANSFER IN PULSED SUPERCONDUCTING MAGNETS

V. Arp, P. J. Giarratano, R. C. Hess, and M. C. Jones

Cryogenics Division
Institute for Basic Standards
National Bureau of Standards
Boulder, Colorado 80302

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Interim Report

Prepared for:
Air Force Aero Propulsion Laboratory
Wright Patterson Air Force Base, Ohio 45433

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U.S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

FOREWORD

This program was completed under the sponsorship of the Department of the Air Force, Wright Patterson Air Force Base, Ohio, and was funded with FY 1973 AF Aero Propulsion Director's Funds. It is divided into three parts. A fourth part, presenting advanced information on liquid helium pumps, will be reported separately; it is being delayed so that further information being developed under another program can be used to assist in providing a more comprehensive data analysis.

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FOR THE COMMANDER

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* This paper was presented at the 1973 Cryogenic Engineering Conference in Atlanta, Georgia.

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HEAT TRANSFER IN PULSED SUPERCONDUCTING MAGNETS

ABSTRACT

The first section of this report summarizes design problems for the development of advanced superconducting pulse magnets, leading to recommendations for future work, primarily in (1) evaluation of eddy-current, hysteresis, and frictional losses, and (2) transient heat transfer between the superconductor and the helium. Two subsequent sections report measurements of forced convection heat transfer respectively to subcooled liquid helium and to supercritical helium just above the critical pressure.

Key words: Forced convection heat transfer; pulsed power systems; pulsed superconducting magnets; superconductor losses; supercritical helium; transient heat transfer.

1. RESEARCH NEEDED FOR PULSED SUPERCONDUCTIVE ENERGY STORAGE SYSTEMS

V. Arp

1.1 Introduction

Pulsed power systems under study use superconducting coils for accumulating the energy which is delivered at each pulse. Such systems are lighter in weight than equivalent capacitive systems when the stored energy exceeds about 10 kilojoules [1], and so are important for possible airborne applications. Experience to date shows that the superconducting coils dissipate less than 1% of the stored energy at each pulse, so that high efficiencies are possible.

We have reviewed the current problems in developing useful pulsed power systems for the sponsor's needs. In doing so, we have held discussions with responsible technical people in three companies under contract to the sponsor - Avco, Magnetic Corporation of America (MCA), and Westinghouse - as well as with other researchers who are recognized for contributions to superconducting technology. Included among these are specialists in properties of materials, electrical machinery, helium flow and heat transfer, and refrigeration. This report is our perspective on the problems which must be considered as development proceeds.

1.2 The Present Art

Superconducting magnets of reliable steady-state performance have proven their value in many applications, in sizes ranging up to 10^8 joules of stored energy. Development of superconducting devices is proceeding in several directions to include superconducting motors, generators, power lines, pulsed synchrotrons, and high-power pulsed energy sources. The total of these development efforts, not including materials electronics, instrumentation or auxiliary systems development or basic studies, utilizes annual funding within the U. S. of about $26 M.

Many of these applications utilize superconductors in a. c. circuits, where heat generation from residual eddy-currents (proportional to frequency) and hysteresis (independent of frequency) are important factors in the system design. At the lowest frequencies are found synchrotron magnets, which are run from zero to full field in a few seconds, corresponding to frequencies in the neighborhood of 0. 3 Hz. Even at this low frequency, some designs have exhibited a deterioration in critical current below steady state values due to the a. c. heating [2]. The design and eventual practicality of superconducting power lines at 50 or 60 Hz is strongly dependent on minimizing the a. c. heating in superconducting materials, and a major effort is being expended to develop conductors having lower losses. The pulsed energy coils under consideration in this report exhibit relatively high losses typical of high frequencies, corresponding to pulse discharge times in the neighborhood of 0. 05 milliseconds and pulse repetition rates of from 5 per second (at this date) to 200 per second (desired in the future). At these highest frequencies, the losses are so large as to possibly quench the superconductor during the discharge period, at least for magnets operating close to their critical current.

1. 2. 1 Operational Time Constants

Figure 1 and tables 1 and 2 list the relevant time constants which must be considered in developing a pulsed energy system for the sponsor's needs. The ranges listed include, approximately, the existing values on model coils and the desired values on the next generation of systems. Table 2 summarizes the cryogenic design features which can be associated with the listed time constants.

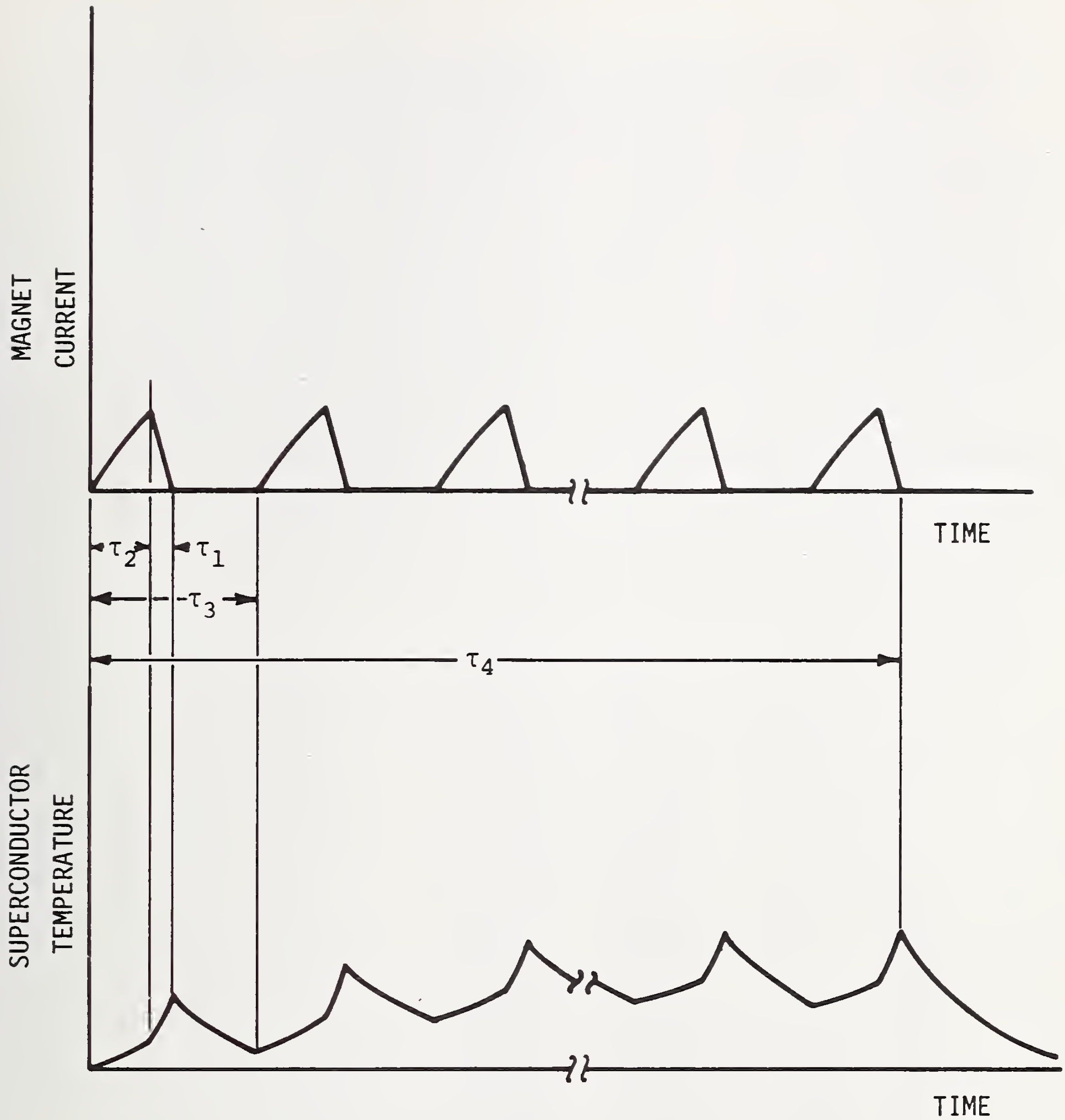

Figure 1. Approximate representation of magnet current and magnet winding temperature as a function of time, showing the times τ_1, τ_2, τ_3, and τ_4 as defined in the text.

Table 1. Operational Time Constants for Pulsed Magnetic Energy Storage

Discharge time	$\tau_1 \approx 0.05$ to 0.3 ms
Charge time	$\tau_2 \approx 1$ to 100 ms
Pulse repetition time	$\tau_3 \approx 5$ to 100 ms
Duration of pulse train	$\tau_4 \approx 20$ to 200 s
Standby between pulse trains	$\tau_5 > 500$ s
Mission duration	$\tau_6 \approx 10^4$ s

Table 2. Cryogenic design as related to operational time constants.

Operational Time Scale	Related Cryogenic Design Concepts	Present Status
τ_1	Heat transfer is negligible in this short interval; temperature rise depends on wire properties and possible wire motions.	Losses and temperature rise cannot be calculated reliably within a factor of 2 or 3.
τ_2	Thermal diffusivity through bonding solids (if any) into helium must restrict superconductor temperature rise to $< T_c$.	Pulsed helium heat transfer data virtually unknown; non-linear interaction with solid thermal diffusion has never been studied.
τ_3	All heat generated during pulse must be transmitted to the helium with minimal temperature difference between helium and superconductor remaining at beginning of charge period.	Pulsed helium heat transfer data virtually unknown; has never been studied in combination with time-dependent solid thermal diffusion.
τ_4	The system must maintain nominally steady helium temperature and flow during this time, e. g., avoid excessive vapor formation.	Basic pumping and flow information available; application to special geometries may need experimental test.
τ_5	Stratification of helium must be avoided to maintain readiness.	Design information available.
τ_6	Determines overall dewar capacity and refrigeration requirement.	Design information available.

Successful system operation requires that the conductor temperature during (i. e., at the end of) the charge period, τ_2, be less than the superconducting critical temperature for the given field and current. It is preferable that the conductor temperature also remain below T_c during the discharge period, τ_1, but this is not necessary provided that all the heat generated during τ_2 and τ_1 can be removed prior to the next charging period, beginning after time, τ_3. More delicate is the requirement of equality between the heat generated per pulse and the heat transferred to the helium per pulse, so that there occurs no slow rise in average temperature which would finally drive the system normal before the desired completion of pulsed operation at τ_4 [4]. To accomplish this requires (1) adequate pulsed heat transfer during the interval, τ_3, so that any deficit in pulsed heat transfer rate can be made up by a very small average temperature rise in the superconductor, and (2) maintenance of the helium temperature and density, averaged over time, τ_3, at or below a safe design value for the duration of the pulsed operation, τ_4. This latter requires that hot spots in the coil and excessive vapor formation in the coolant passages not occur and was the motivation for our studies of helium pumping and heat transfer problems for the sponsor last year [5]. Finally, the very long time constants, τ_5 and τ_6, have little effect on the design problems considered here, and we do not discuss them further in this report.

1.2.2 Choice of Conductor

The dominant design consideration of pulsed magnets, then, involves the transfer of heat generated in the superconductor at each pulse to the helium bath, and thus, the selection of a superconductor of minimal losses is of great importance [6, 7]. Existing designs all use some sort of braided cable superconducting winding to meet external requirements of low inductance and high current along with minimum induced currents in conductors in parallel. Beyond this point, however, there are two noticeable differences in the coils used respectively by Avco and MCA. Avco chooses a braid at which there is a solder (electrical) connection at each point where one strand within the braid touches the next. MCA chooses to insulate each strand within the braid. Avco chooses a multifilament superconducting strand, whereas MCA claims that a copper-clad single large filament will have lower losses than the multifilament conductor of the same outside diameter and current capacity. Both select conductors of about 0.12 mm diameter. In all cases the intent is the same, to minimize the total losses.

Whichever of these configurations is used it appears that the integrated loss per pulse can be calculated from the conductor specifications to within a factor of about two of the value obtained from helium boiloff measurements. It would be desirable to increase the accuracy of the loss predictions to something like the 20% which might be expected of most other design parameters.

The significant amount of ongoing work on losses in superconducting power lines is certain to generate information on losses which will be useful in subsequent pulsed magnet designs. In the further discussions in this report we assume implicitly that the eddy current and hysteresis losses can be calculated or measured to an accuracy consistent with the other design parameters.

1.2.3 Forces

Substantial mechanical stresses can build up within a coil due to localized pressure of the magnetic field on the conductor windings. Suppliers have not indicated any severe problems with the overall containment of these forces on the pulsed energy coils to date. However, as coil sizes increase, so will at least some of the stress levels in the windings, assuming that the peak magnetic field is essentially constant (being determined by superconducting properties). This is best understood by considering the hydraulic analog, in which container wall tensile stresses increase as container diameter increases, for constant internal fluid pressure. Though the added stresses are not expected to present severe problems in preventing gross coil rupture, they could present problems in two areas (1) frictional heating from release of mechanically stored energy in a slightly inelastic coil structure as the forces are removed (during discharge), and (2) frictional heating from relative motions of individual cable strands by just a few micrometers [4]. In short, the relatively loose or porous structures which provide excellent heat transfer to helium may at the same time be subject to higher losses from frictional movements. These movements can be reduced greatly by impregnating the coil with epoxy or other filler chosen on the basis of various thermal or mechanical properties. This is commonly done, in fact, on small coils and/or coils wound with relatively stable superconductors. However, heat transfer from the conductor to the helium is much impeded at the same time, and this could be decisively detrimental to pulsed coil operation. What is needed is to obtain definitive information on frictional losses in coil structures during pulsed discharge, as distinct from hysteresis and eddy-current losses in the superconductors themselves. The mechanical losses might in fact turn out to be negligible, but there is insufficient information upon which to make reliable advanced design decisions at the present time.

The cumulative effect of high repetitive mechanical stresses may also lead to fatigue failure in the coil, though little data exists on this topic. Copper (which is commonly used in stabilizing superconductors) is well-known for its work-hardening. Necessary measurements on epoxies or epoxy-copper laminates have never been made, so that estimations of this mode of possible coil failure cannot be made at this time. Fatigue failure has not been reported on the test coils, but it probably will become important for continued field service.

1.2.4 Heat Transfer

The people who have designed the existing pulsed coils tell us that if an effective heat transfer coefficient could be assured, they could design the coil fairly accurately on that basis, obtaining a more compact coil system if the design value were higher than (conservative) values previously accepted. Magnet design for quasi-steady state performance is commonly based upon heat transfer rates of 0.2 to 0.4 W/cm^2 which can be achieved in pool boiling. There is some evidence that higher heat transfer rates in pool boiling can be achieved for short times [8, 9], but the subject has not been investigated thoroughly in a way which is useful for general analysis. The Avco design assumed higher values, based on Jackson's paper.

We have reviewed the various thermal and kinetic factors which may be important in determining heat transfer rates on the time scale of the pulse repetition time in table 1. They are given in concise form in table 3 and deserve elaboration here.

First, we consider nucleate boiling heat transfer. This involves generation of low density vapor which must be allowed to escape from the heated surface. In non-horizontal cooling passages of small L/D, vapor removal may be accomplished by natural convection, driven by the liquid-to-vapor density difference. This method was used on the MCA model coil, though the Avco coil used forced circulation. It is questionable that natural convection vapor removal would be successful on larger coils, since L/D ratios will probably scale non-linearly with overall size (see discussion on section 8); likewise, it is questionable on faster-pulsing

Table 3. Time constants of helium heat transfer and flow systems

Time Scale	Conceptual Mechanism	Approximate Magnitude
τ_n	Duration of high nucleate-boiling heat transfer to saturated liquid, prior to film boiling	Depends on Thermal flux; 0.5 to 10 ms at q 1 - 3 W/cm^2
$\tau_f = \frac{D}{4fU}$	Time to reach local kinetic equilibrium due to change in pressure gradient	6 to 60 ms*
$\tau_d \approx \frac{100}{FRe} \frac{D}{U}$	Time of thermal diffusion into laminar boundry layer, for pressurized fluid.	0.01 to 0.1 ms* assuming constant fluid properties; perhaps 10 to 100 times larger near transposed critical line †
$\tau_e \approx 10 \frac{D}{U}$	time to reach steady-state heat transfer, for pressurized fluid.	2 to 20 ms*; changes near transposed critical† have not been investigated.

* Assuming $D/U = 10^{-3}$ cm^2/s, which is representative of helium cooling system designs for superconducting coils.

† The transposed critical line is an extension of the liquid-vapor equilibrium line in the P-T plane to pressures greater than the critical pressure. Near this line some fluid properties exhibit anomalous behavior.

coils, since the onset of film boiling would be determined largely by the time-average rate of vapor formation, so that the total allowed heat transferred per pulse would be reduced as the pulse rate increased. Hence, some form of forced flow superimposed on the natural convection associated with nucleate heat transfer will probably be necessary to avoid failure through vapor-lock in the channels, thus achieving the high heat transfer rates which may be available on a short time scale. As indicated in table 3, enhanced nucleate-boiling heat transfer rates would be associated with times, τ_n, of roughly 0.5 to 10 milliseconds, depending strongly on the integrated heat transfer, surface conditions, and perhaps other parameters. Our recent work [10] has shown that superimposed flow does not measurably change the nucleate-boiling heat transfer rates under steady state conditions, but its effect during pulsed heat transfer has never been investigated. Surface roughness may be especially important on this time scale.

In time-dependent forced-convection heat transfer, we are able to identify more parameters. In the shortest interval, τ_d, following the heat pulse, the dominant mechanism is thermal diffusion into the non-turbulent part of the boundary layer. Assuming constant fluid properties at a temperature about 4 K in the liquid region (for this discussion, the results are not very sensitive to fluid conditions provided immediate vicinity of the critical point is excluded), Baylis [11] has shown that

$$\tau_d \approx \frac{100}{F} \frac{D}{\Pr \operatorname{Re} U},$$

where f is the fluid friction factor, U is the fluid velocity, Re is the pipe Reynolds number, D is the pipe diameter, and Pr is the fluid Prandtl number, generally about 0.7. If we normalize all of the calculations to helium flowing at 3 meters per second in a 1 mm diameter channel, corresponding to a Reynolds number of about 10^5, $\tau_d \approx 0.05$ milliseconds, about the same as the coil discharge time, τ_1. However, preliminary calculations [12] suggest that, at supercritical pressures, as the wall temperature rises to not far above the critical temperature, an expanding region of lower density fluid will be formed adjacent to the wall, such that the effective boundary layer thickness increases with heat input. The net effect is to increase τ_d markedly, perhaps by as much as one or two orders of magnitude and to decrease the heat transfer rate during this interval, since heat transfer is by thermal conduction over relatively large distance without aid of turbulent convection.

The next forced convection time constant to consider is the equilibration time between thermal and velocity profiles, as controlled by turbulent effects. In essence, this is the time required to establish steady state heat transfer. By analogy with the position-dependent development of the thermal profile within the steady-state flow of fluid entering a heated conduit, we estimate that this time $\tau_e \approx 10\ D/U$, ≈ 3 milliseconds using our previous normalization and assuming constant fluid properties. The accuracy of this analogy is probably within a factor of two for constant fluid properties, but the effect of variable fluid properties is unknown.

Another time constant of importance is the time to reach local flow equilibrium due to a flow perturbation (change in pressure gradient). From a systems standpoint, this must be considered where the density decreases and frictional pressure drop increases in a heated channel. It can be shown that this time constant is $\tau_f = D/4fU$. Using our previous normalization, this time is then $\tau_f \approx 30$ milliseconds.

Other thermal time constants for helium heat transfer in superconducting systems have been described. In a report on the Brookhaven Superconducting Power Line Project [13], a time constant of 8.6 seconds is calculated for achievement of steady state after a perturbing thermal overload. We tend to believe that this calculation is incorrect. Baylis [11] has estimated the time for a heat pulse to travel in helium from the laminar boundary layer through a layer of developing turbulence to a fully turbulent core. This is a most difficult calculation to perform convincingly, and the result must certainly be less than τ_e.

As we look further into these time-dependent heat transfer problems, various features are found which further complicate the analysis. For example, the standard velocity and temperature profiles for turbulent flow in a heated pipe have been derived for steady state flow of a fluid having constant properties. In unsteady flow of a fluid with variable properties, the local relationships between mean turbulent velocities, viscous dissipation, eddy diffusivity, etc., which are implicit in the standard profiles, may no longer be good approximations, and considerable care must be used in sorting out the appropriate relationships.

1.2.5 Composite Structures

The time constant for diffusion of thermal energy a distance x through a solid having a thermal diffusivity α is

$$\tau_s \approx (1/\alpha)\, x^2 ,$$

where we neglect geometrical factors like π, 1/2, etc. The diffusivity of a typical composite superconducting wire will be somewhere between that of reasonably pure copper at 4K, $\alpha \approx 5000\ \mathrm{cm}^2/\mathrm{s}$ and stainless steel at 4K, $\alpha \approx 3\ \mathrm{cm}^2/\mathrm{s}$, probably closer to that of copper. For typical wire radii of about 0.006 cm, the time constant will be in the range of a few microseconds. Because this is much less than any other time constant considered in this study, it is reasonable to assume for these heat transfer calculations that the temperature of the wire surface is equal to that of the active superconducting filament.

Since it may be necessary for structural reasons to impregnate the windings, or portions of the windings, with non-conducting filler (such as epoxy), we must consider the effect this has on the transient heat transfer. For a typical polymer in the helium range, the diffusivity is probably within a factor of 3 of the value

$$\alpha\ (cm^2/s) \approx 1./T^2 .$$

From this we estimate that for the typical insulation thickness on a wire (about 0.03 mm) at 4K, the thermal time constant is

$$\tau_s \approx 0.1 \text{ millisecond.}$$

For a potted, braided cable where the smallest relevant value of x may be ten times larger, and the time constant would rise to about 10 milliseconds or more; however, the effective diffusivity may also change in this last case depending on the relative volumes of conductor and epoxy along the heat transfer path, so that the time constant is strongly dependent on the winding configuration.

The effect of this τ_s is to decrease the amplitude of the alternating temperature variations at the insulator to helium surface for those frequencies much greater than $1/\tau_s$. Thus, in order to transfer heat at a given average rate (equal to the integrated heat generated in the superconductor per pulse rate divided by the pulse repetition rate), this attenuation of the a.c. component is accompanied by an increase in the d.c. component, i.e., the average difference between the surface temperature and the bath temperature.

If the helium could be regarded as a temperature-invariant heat sink, the relative magnitudes of these steady and alternating heat transfer rates would be determined by comparison of τ_s with the generating times τ_1, τ_2, and τ_3. However, these are of the same order of magnitude as τ_d, τ_e, and τ_f, which characterize various fluid heat transfer regimes related to the alternating component of thermal flux. Further, the transient heat transfer rate would probably be modified by the steady component of thermal flux. One can see that the total problem becomes highly nonlinear, involving all of the named constants. For analysis purposes, one could bracket real system performance by assuming various approximations on the relative magnitudes of the operational, solid diffusion, and heat transfer time constants, but this may not be very helpful for detailed system design. We do not believe that the problem of calculating the overall, time-dependent heat transfer rate is impossible, but neither is it going to be done on the back of an envelope.

1.3 Extrapolation to Larger Systems

A major question to be considered is the extent to which the superconducting coil performance can be analyzed in terms of separable concepts: heat generation in superconductors, heat diffusion through solids and potted windings, heat transfer at helium-cooled surfaces, heat generation from mechanical motions and flexing of windings, fluid flow through coolant channels, etc. The question is particularly relevant to the complex relationships among all the short time constants ($\leqslant$ 100 milliseconds) discussed above. There is no easy answer to it, and it is appropriate to dwell briefly on it here. We discuss several subsidiary questions.

Will unusual or irregular (e. g. , braided cable) windings make it impossible to evaluate local heat transfer coefficients or flow fields to the usual accuracy? The answer depends partly on the heat transfer mode. Nucleate boiling heat transfer coefficients are relatively independent of any superimposed forced flow, whereas forced-convection heat transfer analysis will probably have to rely on additional empirical correlations between flow and heat transfer as are commonly used in heat exchanger analysis and design. We feel that experimental work on typical braids (or other representative geometries) will be required, and that appropriate analysis can be made in parallel with that for other fluid heat transfer systems.

Will a realistic analysis require so many additional parameters, such as the correlation above, or measures of surface conditions, as to be not very dependable or useful for advanced design? There is no reason to believe that this would be the case, in that the logical procedure would be to determine such parameters in separate experiments, just as we now determine, separately, the specific heat of superconductor, the thermal conductivity of helium, etc.

Because of the strong interaction between the various heat transfer mechanisms on the millisecond time scale, will the subsequent nonlinear dependence of system performance on the various parameters, and the uncertainty in individual estimates of those parameters, combine to reduce the accuracy of correlations between theory and experiment to such low values as to be useless for subsequent design? This question is most difficult to answer at this stage, primarily because of insufficient knowledge of transient helium heat transfer. It should be reviewed when and if work in this field progresses.

If the above complex interactions are not understood, can scaling from a successful test coil allow reliable design of large-scale system performance? We think that the answer is no, because the correct scaling laws would not be known. For example, if the design limitation was primarily that of obtaining adequate helium flow, the scaling would be dominated by considerations of length to diameter ratios in the cooling channels. If the primary design limitation was that of thermal diffusion through a composite solid, then scaling could involve increased numbers of flow channels, keeping diffusion distances about constant. If, as is more likely, the design limitation involves some sort of delicate balance between solid diffusion times and time-dependent heat transfer to the helium, it would be difficult to deduce the scaling laws without understanding that balance.

1.4 Summary and Conclusions

The sponsor's goals for pulsed power systems are one to two orders of magnitude beyond the existing coils in terms of both stored energy and repetition rate, and we do not think that this gap can be bridged efficiently without systematic evaluation of some of the more important design elements. Further, we conclude that it is possible to identify design elements which can be studied separately and then integrated into advanced design. These elements are summarized in Table 4.

Item 1 relates to calculation of the total energy dissipation in the superconductor at each pulse, and how this is influenced by the choice of conductor, the winding tension, coil impregnation, etc. The total losses will probably decrease as the structural regidity increases, but by how much? An increase in rigidity will generally decrease the heat transfer surface to the helium, and thus tend to raise the average temperature of the coil. At the present time, the basic loss mechanisms are understood, but evaluation as a function of specific design features can be and needs to be done to better accuracy than at present. Appropriate laboratory measurements can be made on coils or samples which need not be capable of operating at the high repetition rate required for a working system. Also, there is considerable input to this problem from ongoing studies of superconducting power lines and of large pulsed magnets for high energy physics, though this will not answer all the questions for these rapid pulse applications. We give this high priority just under item 3 below.

Item 2 relates to possible degradation in the performance of an initially successful design, due to mechanical fatigue failures from repetitive pulsed forces on the windings. Fatigue stress limits are largely unknown at low temperature, and are a source of concern to

Table 4. Summary of program areas

Program	Status	Priority for Further Research
1. Evaluation of total heat generation in various braided conductor geometries during pulsed operation.	Accuracy now $\approx$ factor of 2. More information needed on frictional heating, and possible reduction from coil impregnation.	#2 Data from sychrotron and power line research will contribute here.
2. Evaluation of mechanical properties and fatigue mechanisms in composite windings.	Very little information available. May be important for extended-life operation.	#4 Data from motor and generator research will contribute.
3. Evaluation of time-dependent helium heat transfer coefficients, time scales typified by τ_d, τ_e, and τ_f.	Very little is known, and almost no work is ongoing at present.	#1 Difficulty of the study precludes quick answers.
4. Evaluation of thermal diffusivity in composite superconducting windings.	Some information is known, and more is being obtained.	#5 Probably can obtain most needed data from other programs.
5. Evaluation of steady state heat transfer and flow friction through braided cables.	Empirical estimates can be made, but have not been tested.	#3 Importance rises in proportion to the need for forced flow to prevent vapor lock.

superconductor motor and generator design. For pulsed energy storage applications, this will probably be an important long-range consideration, but we give it lower priority at this date. Fatigue studies on superconducting materials are being initiated now in support of Naval ship propulsion studies.

Items 3, 4, and 5 relate to the general problem of providing adequate cooling to the coil during pulsed operation. This general category can be divided into two parts (a) time dependent heat transfer, where variations in relevant parameters during the time τ_3 must be considered, and (b) maintenance of the helium temperature and density in the flow passages, averaged over the time, τ_3, at or below design values during the duration of the pulsed operation, τ_4. Part (a) contains many mutually interacting subfactors, some of which are very poorly understood at this time, including items 3 and 4. Part (b) has motivated the helium pumping studies recently supported by the sponsor, and further contains item 5.

The evaluation of time-dependent heat transfer coefficients to helium, item 3, deserves highest priority because least is known about it, analysis is difficult and not to be obtained in brief programs, very little active work is ongoing at the present time, and design data is presently uncertain by factors of roughly half an order of magnitude or more. We recommend a comprehensive program of analytical and experimental work on a practical geometry, e.g., a single conducting strand or surface cooled by helium under variable conditions, to obtain time dependent heat transfer coefficients on time scales typified by τ , τ_e, and τ_f. Because of the close proximity of the critical point, at 2.2 atmospheres and 5.2K, to helium conditions which may exist within the coil structure, it may be necessary to take explicit account of the non-ideal properties of helium in many of these studies. Evidence is clear that they will be much different than steady state heat transfer coefficients, and it is necessary to pin this down in order to make use of (possible) enhanced values in advanced designs.

Item 4 relates to calculation of time-dependent thermal gradients in composite structures, i.e., insulating layers, possible impregnated coil structures. Relevant information is being developed in this area through other programs, and consequently we give this low priority as a need of the pulsed energy program. Also the data can probably be obtained with shorter lead time than that of item 3 above. Further, results from item 1 may influence the type and detail of information which is needed.

Item 5 relates to evaluation of time-independent flow friction factors and effective heat transfer coefficients at braids or other practical superconductor configuration. This is important in determining the required flow conditions, channel sizes, etc., to maintain adequate cooling during all of the pulse repetition time, τ_4. The study would be analogous to those which are performed on heat exchangers of special geometry, and is the logical evolution of the helium pumping work previously supported by the sponsor. However, we give this lower priority than items 1 and 3, since studies made there may influence the configurations of most interest, and the lead time required to develop the information is less than that for item 3.

1.5 Acknowledgment

Dr. M. C. Jones has participated in valuable discussions of many of these problems, particularly as a result of our joint trip to Westinghouse, MIT, Magnetic Corporation of America, and Avco. Our principle contacts at these locations were, respectively, Dr. Michael Walker, Prof. Joseph Smith, Dr. Richard Thome, and Dr. Tim Hatch, all of whom contributed valuable information.

HELIUM AT 2.5 ATMOSPHERES

Patricia J. Giarratano and M. C. Jones

2.1 Introduction

In a previous study of forced convection heat transfer to supercritical helium in a vertical tube [14] a correlation was developed from the experimental data to predict the heat transfer in this region. The correlation is:

$$\frac{hD^{0.2}}{G^{0.8}}\left(\frac{T_W}{T_B}\right)^{0.716} = 0.0259\, k^{0.6}\, C_p^{0.4}/\mu^{0.4} \qquad (1)$$

in which fluid properties μ, C_p and k have been collected together on the right hand side. Equation (1) predicts a maximum in the heat transfer coefficient when the bulk fluid temperature is equal to the transposed critical temperature. For a given pressure, the transposed critical temperature is defined as the temperature at which C_p is a maximum. The prediction of equation (1) is consistent with the experimental observations of Johannes [15] and Ogata and Sato [16] in their investigations of supercritical helium heat transfer under low to moderate heat flux conditions. Similar enhancement in heat transfer to carbon dioxide as the bulk fluid approaches the transposed critical temperature has been observed by Tanaka et al. [17].

In reference [14] we noted that the peak in the properties parameter, $k^{0.6}\, C_p^{0.4}/\mu^{0.4}$, at the transposed critical temperature accounts for the enhanced heat transfer observed under the operating conditions of that study.

However, at high heat fluxes, a degradation, rather than enhancement, in heat transfer in the transposed critical region has been observed by many investigators, e.g. Ogata and Sato [16] for helium, Shiralkar and Griffith [18] for carbon dioxide, Shitsman [19] for water, and Powell [20] for oxygen.

As summarized by Shiralkar and Griffith, the conditions under which degradation occurred are:

1. The wall temperature must be above, and the bulk temperature below the transposed critical temperature.

2. The heat flux must be above a certain value, dependent on the flow rate and pressure.

Heat transfer degradation seems therefore to be a function of the inhomogeneity of the fluid resulting from the temperature dependence of fluid properties. Equation (1) when $T_W \approx T_B$, is essentially a homogeneous heat transfer model.

With the experimental apparatus described in reference [14] for supercritical helium it was not possible to attain both criteria noted above. Because of the inefficiency of the heat exchanger, as the heat flux to the test section was increased there was a corresponding increase in the inlet bulk fluid temperature. Therefore high heat flux measurements were obtained only for high bulk temperatures (greater than T_{TC}).

Subsequent revision of the experimental apparatus, including the heat exchanger, for subcritical helium heat transfer studies[21] has enabled us to obtain supercritical helium heat transfer data under conditions described in the above two criteria. We chose, therefore, in the present study to attempt to verify the above criteria for the degradation of heat transfer to supercritical helium and to quantify them as far as possible. An operating pressure of 2.5 atm was selected as being one which could be comfortably controlled and which would at the same time be close enough to the critical pressure of 2.245 atm to give good definition to specifically supercritical effects.

In this paper we present the experimental data and discuss the conditions under which departures of supercritical helium heat transfer from equation (1) were observed. The probable limitations to the previously developed correlation, equation (1), are also discussed.

The ranges of experimental variables are as follows:

Pressure - 2.5 atm (T_{TC} = 5.4 K)

Mass velocity - 7, 12, 22 g/s-cm^2

Test section inlet temperature - 4.05, 5.04 K

Heat flux - 0.008 to 0.713 W/cm^2

Flow direction - vertically downward

Reference[21] contains a complete description of the experimental apparatus.

2.2 Experimental Results and Discussion

2.2.1 Heat Transfer Coefficients Profiles

The experimental results are shown first in the form of heat transfer coefficient profiles, Figure 2, for the uniformly heated 0.213 cm i.d. x 10 cm long stainless steel test section. The estimated systematic error in the measured heat transfer coefficients varies from 55 percent for the worst condition (high flowrate and low heat flux) to 8 percent for the most favorable condition (low flowrate and high heat flux). However, the plot of Figure 4 which compares the experimental heat transfer coefficient with that predicted by equation (1) suggests the systematic error is much lower than the estimated upper bound of 55 percent. The major source of error arises from the uncertainty in the outside wall temperature and thickness of the stainless steel test section.

For a constant property fluid having a fully developed turbulent velocity profile along the entire length of a uniformly heated tube, the typical variation of the heat transfer coefficient h with position in the tube is one of rapid reduction from a high value at the entrance of the tube (the thermal entrance region) to a lower and essentially constant value at positions in the tube more than approximately 20 diameters from the beginning of the heated section. As can be seen in Figure 2 for helium at 2.5 atm and conditions noted, the variation of h with position in the tube is generally in contrast with that expected for a fluid having negligible property variation. Although the usual entrance effects are exhibited in the profiles, the subsequent peaks (or in some instances further deterioration in heat transfer coefficient) can be related to the rapidly changing properties in the tube (in the vicinity of the transposed critical temperature.)

General trends can be noted by reference to Figures 2 (a) through 2 (d). At low heat flux, e.g.: 0.028 W/cm^2, Figure 2 (b), and bulk fluid temperature less than 4.264 K a heat transfer coefficient profile typical of that expected

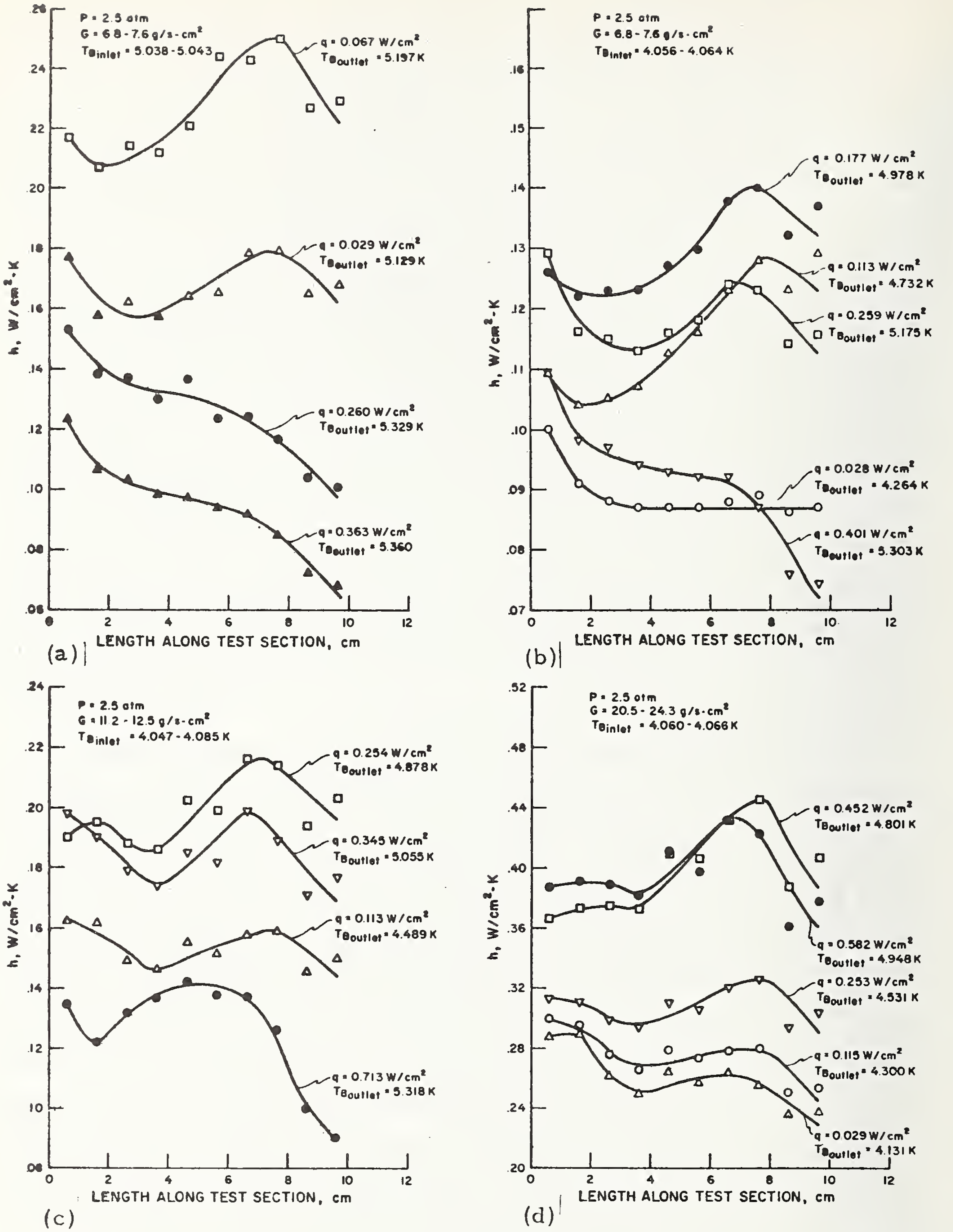

Figure 2. Heat transfer coefficient profiles at 2.5 atm.

for turbulent heat transfer to a constant property fluid is observed. An increase in the heat flux to 0.113 W/cm^2, and as a consequence, increase in the temperature rise of the bulk fluid, produces a substantial change in the shape of the h vs length curve. In addition to the overall increase in h, after the initial reduction of heat transfer coefficient in the thermal entrance region it rises to a maximum value at 37 diameters from inlet, deteriorating again beyond. Further increase in heat flux produces a similar result until, eventually, a heat flux somewhere above 0.177 W/cm^2 is reached where the overall magnitude of the heat transfer coefficient decreases. However, the characteristic shape remains the same (e.g.: 0.259 W/cm^2 curve). Finally, at 0.401 W/cm^2 the overall heat transfer coefficient is seen to be further reduced and the peak exhibited at the lower heat fluxes has disappeared, the profile generally exhibiting deterioration along the entire length of the test section.

2.2.2 Comparison of Supercritical and Subcritical Helium Heat Transfer Coefficient Profiles

It has been suggested by Goldmann[22]that supercritical fluids exhibit "pseudo boiling" like characteristics under high heat fluxes and low bulk temperatures. Figures 3(a) and 3(b) show heat transfer coefficient profiles for subcritical helium at 1.05 and 1.97 atm (taken from data of reference [21]); the transition from nucleate to film boiling at a critical heat flux is evidenced by the sharp reduction in the heat transfer coefficient.

The critical heat flux phenomenon observed in the supercritical case bears some analogy, but we note two striking differences. In the first place the supercritical heat transfer coefficients are almost two orders of magnitude lower than the subcritical coefficients before degradation or transition. Only at high mass velocities (e.g. $\sim$ 75 g/s-cm^2) are comparable supercritical heat transfer coefficients obtained[14]. Secondly, the transition in the subcritical case is much sharper, i.e. a small change in heat flux gives rise to a more dramatic decline in the heat transfer coefficient than is observed for supercritical helium. This evidence does not therefore specifically substantiate the pseudo boiling hypothesis, although qualitative simularities are undeniable.

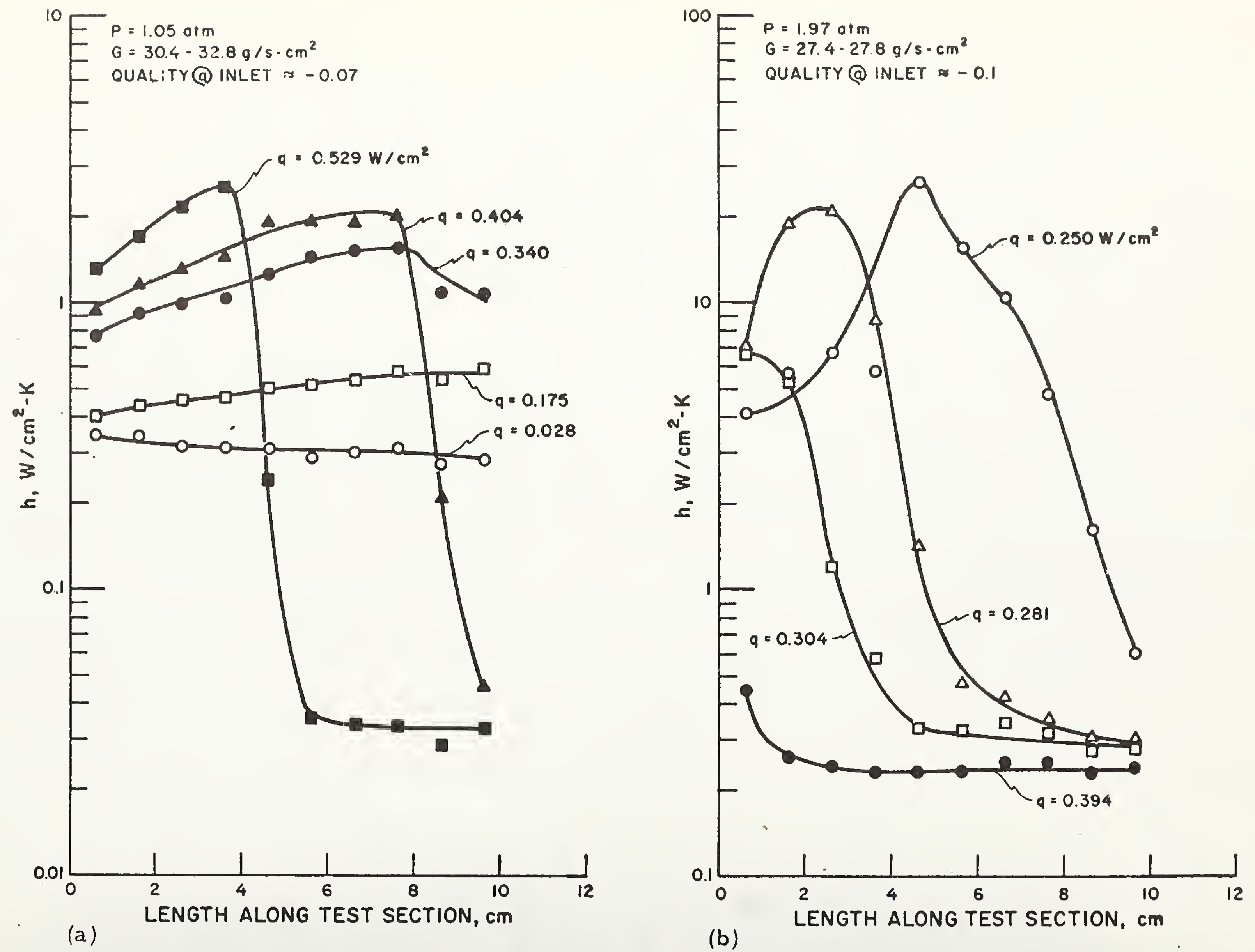

Figure 3. Heat transfer coefficient profiles at subcritical pressures (1.05 and 1.97 atm).

2.2.3 Correlation of Experimental Results

We have examined the data for some indicator of heat transfer coefficient degradation in order to provide a quantitative criterion for this phenomenon. While the criteria of Shiralkar and Griffith were generally found to be true when degradation took place, it was not possible for the present experimental conditions to relate the maximum in the heat transfer coefficient with the bulk fluid temperature being at the transposed critical, as was found in reference [14]. Neither was this true for a film temperature (defined as the mean of wall and bulk fluid temperature) or wall temperature being at the transposed critical. Although there are many possibilities which we have not tried, we present in Figure 4 a plot of the ratio of the observed heat transfer coefficient to that calculated from equation (1) versus a dimensionless parameter Φ. Φ is defined as

$$\Phi = \frac{\text{heat per unit mass added to fluid up to a given point along the tube}}{\text{enthalpy at transposed critical - enthalpy at inlet}}$$

$$= \frac{Q(z)/\dot{m}}{i_{TC} - i_{IN}} = \frac{4zq}{(i_{TC} - i_{IN})GD}$$

Φ is thus the fraction of the heat required to bring the fluid to T_{TC} which has been added up to point z. The data plotted are for two different inlet temperatures, 4 K and 5 K, and for three different thermometer stations clear of the entrance region where $z/D = 22$, 31 and 45 respectively. This plot appears to bring the data together fairly well and adds confirmation to our interpretation of equation (1), developed in our earlier work. The data exhibit a clear deviation from the predicted heat transfer for $\Phi > 0.3$ (relatively high heat flux conditions) and show somewhat of a crisis as Φ approaches 1.0. However, equation (1) is apparently a good representation of low heat flux data and according to Figure 4 at least, should be valid for $\Phi \leq 0.3$.

While it correlates the present data, the plot of Figure 4 may not be universally applicable for all inlet conditions. For example, when inlet temperatures are very near the transposed critical, substantial values of Φ could

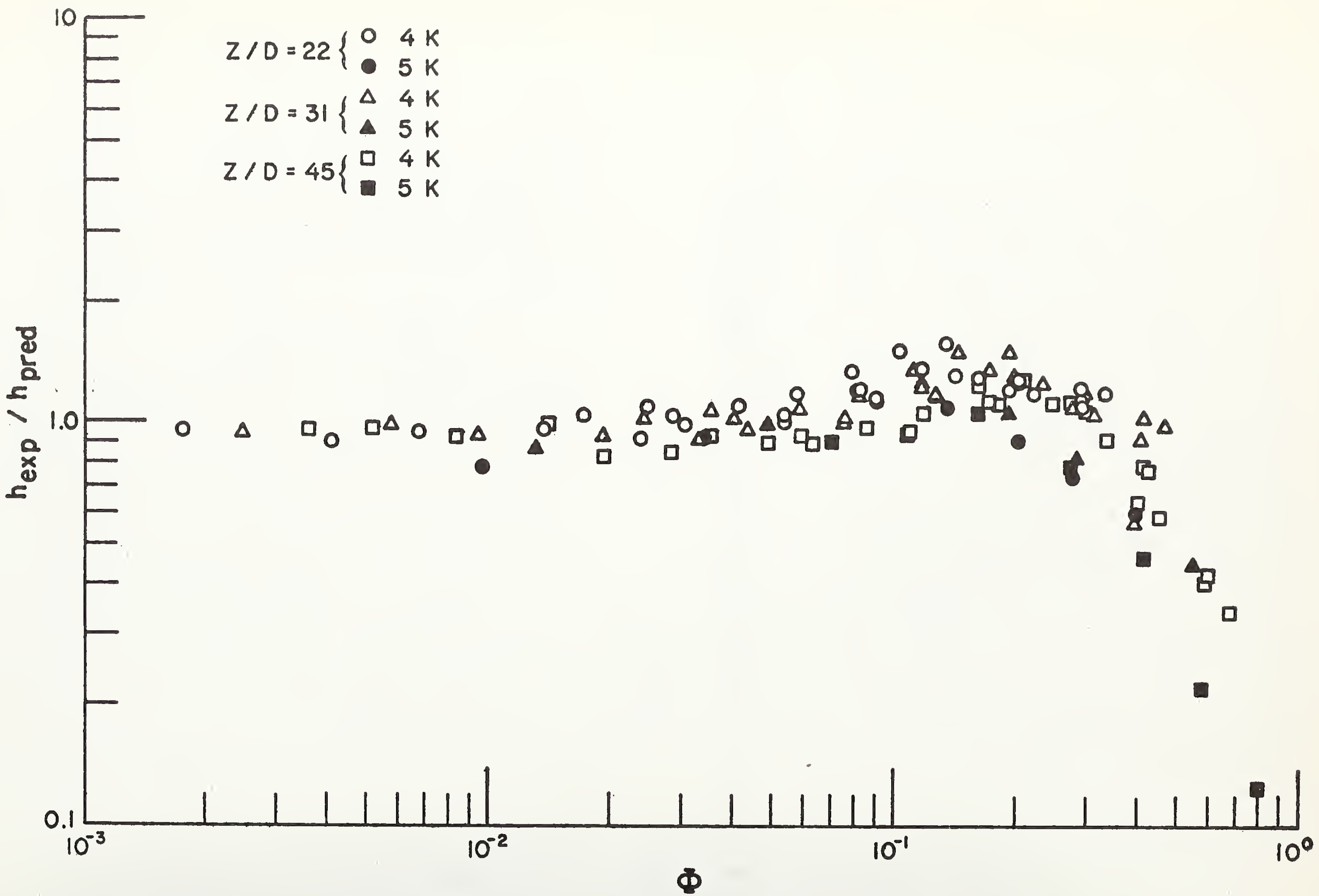

Figure 4. Ratio of experimental to predicted heat transfer coefficients (h_{exp}/h_{pred}) versus correlating parameter, Φ.

be achieved even under low heat flux (i. e. homogeneous) conditions and significant deviation from equation (1) would not be expected. For the range of the present inlet conditions table 1 contains the maximum heat fluxes above which departures of more than 20 percent from equation (1) were observed (i. e. $\Phi > 0.3$).

Table 5. Experimental values of q where $0.8 < h_{exp}/h_{calc} < 1.2$.

G g/s-cm²	$T_{B\ INLET}$ K	q W/cm²
5.7 - 7.6	4.056 - 4.064	less than 0.177
6.8 - 7.6	5.038 - 5.043	less than 0.187
11.2 - 12.5	4.047 - 4.085	less than 0.345
20.5 - 24.3	4.047 - 4.085	less than 0.582

We were not able to run the apparatus with $\Phi > 1$ for reasons which are not entirely clear. Several things happened simultaneously as the fluid approached the transposed critical temperature, including the problem that the superconducting power leads to the test section went normal. It should be noted that similar experiences occurred in our subcritical experiments in film boiling once the heat flux exceeded about 1.1 W/cm² and this may simply be a limitation imposed by the transition temperature of the superconducting leads.

An unexpected feature of Figure 4 is the region $0.07 < \Phi < 0.3$ which shows clear enhancement above the value of h given by equation (1). It should be remembered that equation (1) already accounts fairly well at higher pressures for enhancement due to the temperature dependence of the fluid properties as well as the non-linearity of the heat transfer process indicated by the term $(T_W/T_B)^{0.716}$.

In view of the apparent significance of the parameter Φ for the present study at 2.5 atm it is natural to inquire as to the values obtained in the experiments of [14] since the correlation developed there seems to represent the low heat flux limit. Table 6 lists the maximum values of Φ for the pressures investigated for those runs in which the fluid entered below the transposed critical temperature. A value of Φ for each thermometer is given.

Table 6. Values of Φ from [14]

Pressure (atm)	T_{INLET}/T_{TC}	Φ_1 (z/D=20)	Φ_2 (z/D=40)
3	.88	0.048	0.096
4	.88	0.37	0.74
5	.97	0.64	1.28
7	.86	0.37	0.74
8	.69	0.077	0.15
9	.91	0.104	0.208
10	.76	0.160	0.320
14-15	.44	0.96	1.92
19-20	.97	0.40	0.80

Since substantial values of Φ were achieved in [12] at higher pressures one can only surmise that degradation of heat transfer was not significant and perhaps this is of concern only quite close to the critical pressure as is here the case. Further experiments along the lines of those reported here would be required to clarify this point. Judging from these observations at 2.5 atm, a safe range of application of equation (1) would be given by values of T_{INLET}/T_{TC} greater than those shown in table 6 with corresponding values of Φ less than those shown in table 6

2.3 Conclusions

The experiments reported here for heat transfer to supercritical helium in forced flow at 2.5 atm lead to the following conclusions:

1. For supercritical helium, both enhancement and deterioration in heat transfer can occur as observed with other fluids. In general the criteria quoted from Shiralkar and Griffith for the existence of an impaired heat transfer coefficient are verified. A good quantitative indicator of the particular behavior

to be expected for the inlet conditions of this experiment at 2.5 atm is given by the value of the dimensionless parameter Φ defined in the text.

2. At 2.5 atm and conditions noted with heat fluxes below those given by $\Phi = \leq 0.3$ equation (1) gives heat transfer coefficients within $\pm$ 20 percent of the experiments.

3. For $0.3 < \Phi < 1.0$ the experimental heat transfer coefficient deteriorates to as low as 12 percent of that given by equation (1), the value $\Phi = 1.0$ appearing to be somewhat of a heat transfer crisis.

4. There is a strong indication from earlier results that this type of behavior may not be observable at 4 atm and above. The estimated range of applicability of equation (1) is given by information contained in table 6.

3. FORCED CONVECTION HEAT TRANSFER TO SUBCRITICAL HELIUM I

Patricia J. Giarratano, R. C. Hess, and M. C. Jones

3.1 Introduction

The intensive development of superconducting technology for electrical power equipment calls for a good knowledge of heat transfer to helium. Traditionally, simple bath cooling is used to provide the necessary rates of heat transfer to stabilize the conductor, and this appears still to be quite adequate in d. c. applications. However, in a. c. applications and various applications where large field sweep rates are experienced, either in normal operation or under fault conditions, losses occur and there may be design benefits from circulating the helium.

In a previous study at the Cryogenics Division of the National Bureau of Standards, by Giarratano et al. [21]. heat transfer coefficients for forced flow of <u>supercritical</u> helium were measured and a correlation was developed to predict the heat transfer in this region. As an extension of that study we have measured heat transfer coefficients under conditions of forced flow of <u>subcritical</u> helium. Particular emphasis has been placed on determination of conditions under which a transition from nucleate boiling to film boiling occurs (critical heat flux) since an unacceptable rise in wall temperature may occur at this point (from the point of view of cooling superconductors).

It is hoped that the information developed in our program will go some way towards broadening the designers choice and permitting closer design. The data presented herein are a summary of over two hundred experimental runs, including seventy four transition observations.

3.2 Description of Experimental Apparatus and Measurement

A schematic of the boiling heat transfer flow loop is shown in figure 5.† A centrifugal pump, previously described in [23], circulates the liquid around the flow loop. To maintain a constant inlet temperature to the test section, heat is removed from the liquid as it passes through approximately 13 meters of 0.32 cm i.d. copper tubing located in a heat exchanger reservoir of approximately 2.5 liter capacity. The heat exchanger reservoir is continuously supplied with liquid helium from a storage dewar.

Test Section

The test section is a 0.213 cm i.d. x 20 cm long stainless steel tube with a wall thickness of 0.016 cm. It is resistance heated along 10 cm of its length (L/D = 50). A stainless steel-pyrex seal located in the bottom of the loop provides electrical isolation of the test section. A wire wound preheater upstream of the test section allows variation of quality at the inlet of the tube. Accurate measurement of the current and potential drop across the two heaters is used in the calculation of heat flux. At the lowest power levels the uncertainty is less than 2 percent.

Temperature Measurement

Outside tube wall temperatures are measured at ten points along the heated test section length with calibrated carbon resistance thermometers. One lead of the carbon resistor is soldered to a small copper block which also provides a tempering post for the resistor's electrical leads. The block

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† Identification of any materials or their manufacturer by the National Bureau of Standards in no way implies a recommendation or endorsement by the Bureau. Furthermore, use of other trade names in this paper is for the sake of clarity and does not in any way imply a recommendation or endorsement by the Bureau.

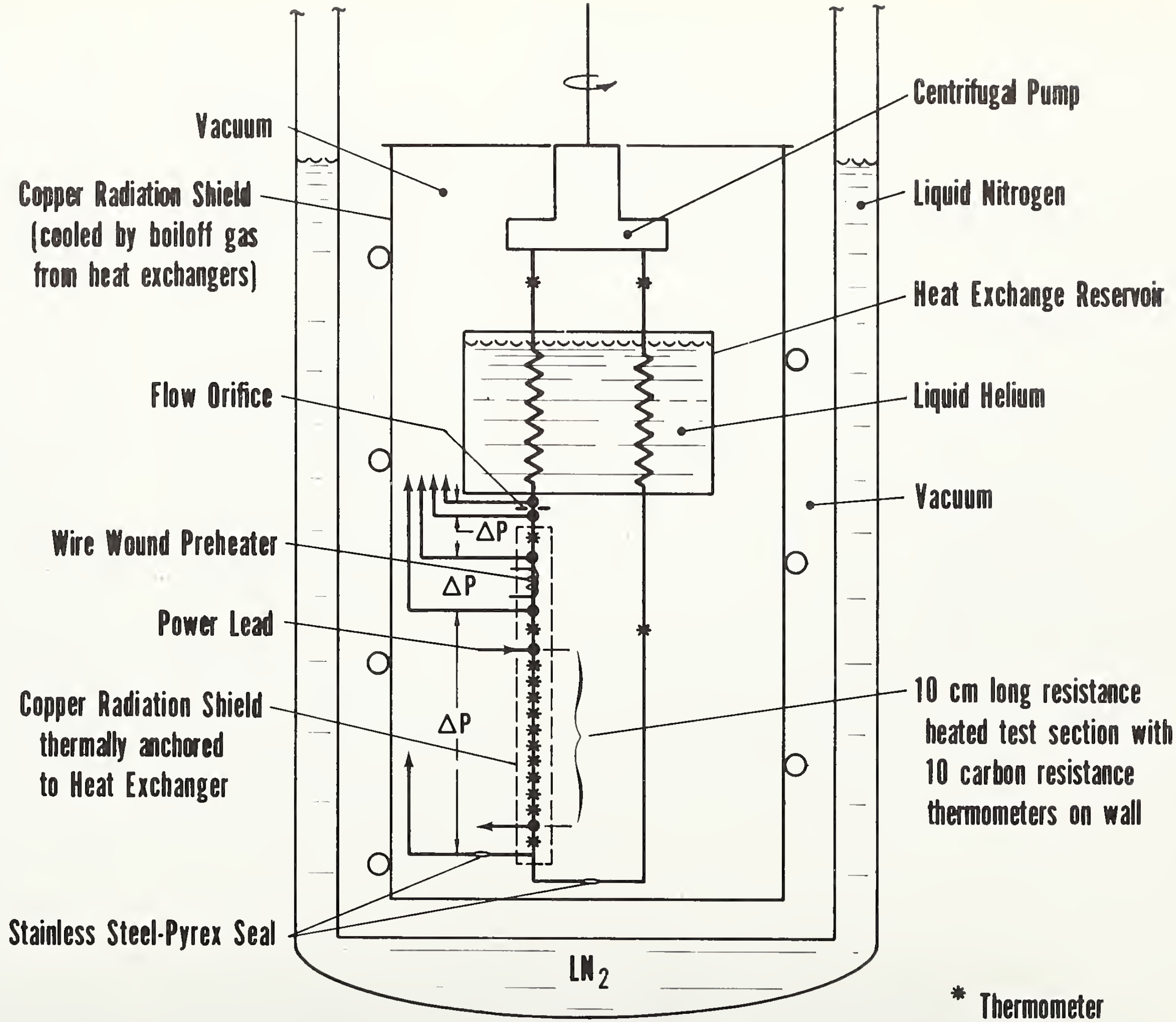

Figure 5. Schematic of experimental apparatus.

is thermally clamped to the test section but is electrically isolated from it by a thin (0.0127 cm) Mylar film. The thermometers are positioned one cm apart with the first thermometer located 0.6 cm from the inlet. Inside wall temperatures are obtained by calculation of the temperature drop through the tube wall using the thermal conductivity of stainless steel given by equation (A1) in the appendix of reference [24]. Bulk fluid temperatures are measured at four points along the flow loop (upstream of preheater, upstream of test section and two measurements downstream of the test section) with germanium resistance thermometers. These thermometers are potted with vacuum grease in copper wells which are soldered to the tube.

The carbon resistance thermometers and the germanium resistance thermometers used in this study were calibrated in a separate apparatus, over the range 4 - 20 K, against three germanium resistance thermometers (GT 1011, 1027 and 1024). These three germanium thermometers had been previously calibrated against NBS secondary standard germanium thermometers (GT 722 and 734).

In our calibration, over the range 4 - 9 K the agreement between GT 1011, 1027, and 1024 was within 0.01 K for the worst case and was generally within 0.005 K. Above 9 K the agreement was within 0.05 K. An average value of the three germanium thermometer readings was taken to be the true temperature.

The calibration data for each thermometer were fit with a curve of the form:

$$\mathrm{Log}\ T = \sum_{N=0}^{N=7} A(N)(\mathrm{Log}\ R)^N$$

with an rms percent error of 0.06 in temperature over the range 4 - 19 K. This corresponds to approximately 0.003 K at 4.2 K and 0.01 K at 19 K.

However, in the heat transfer apparatus during preliminary runs, it became apparent that there were carbon thermometry errors that were bulk temperature dependent and which partially decayed in time (time constant of the order of hours). Extensive tests indicated that the time dependence of the error was probably due to residual spurious radiation heat leaks, not evident in the calibration apparatus but impossible to totally eliminate in the heat transfer apparatus, and the bulk temperature dependence was probably due to shifts in calibration. Therefore, we adopted an in situ re-calibration procedure which allowed correction of the carbon thermometers on the basis of the germanium thermometer readings taking into account both time and bulk temperature dependence.

The estimated uncertainty in outside wall temperature after correction is at most 0.02 K (the maximum shift in calibration of the germanium thermometers upon which corrections for carbon thermometers were based). However, the error in temperature difference between the inside wall and the bulk temperature, due to uncertainty in the thermal conductivity of the stainless steel wall, the wall thickness and bulk temperature, is of the order 0.05 K at heat fluxes of 0.02 W/cm^2 and is of the order 0.15 K at heat fluxes of 0.2 W/cm^2.

In the two-phase region, since the pressure drop across the test section was of the order of a few mm Hg for the data presented, the intermediate bulk temperatures were taken to be the saturation temperatures corresponding to the inlet static pressures. This approximation was within experimental error.

Pressure and Flow Measurement

Provision was made to measure pressure drop across the flow orifice, preheater, and test section and the static test section inlet pressure using calibrated pressure transducers and a static Bourdon tube pressure gauge accurate to 0.01 atm located outside the cryostat at room temperature.

The pressure transducers were located at room temperature which resulted in large temperature gradients along the pressure tap lines. Consequently the pressure drop readings across the test section were unsteady (noise of the same order as the pressure drop itself). However, generally when there was no surging the ΔP across the test section was less than 7 mm Hg.

Since the fluid at the outlet of the preheater was slightly subcooled for much of the data presented a calorimetric method determined the flow rate under these conditions. The calorimetric flow rate from the preliminary runs was also used to determine a discharge coefficient for the flow orifice so that the orifice may be used for flow measurement when calorimetric flow determination is not possible, i. e. , two-phase out of the preheater. The discharge coefficient so obtained agrees with that of an identical orifice section which was calibrated in a separate apparatus.

For the calorimetric method, applicable for 75 percent of the runs, accuracy of the flow rate ranges from 2 percent to 9 percent (more uncertainty at the lower operating pressures due to less subcooling available). This is due to uncertainty in measuring the temperature rise of the bulk fluid through the preheater section. For 25 percent of the runs where the orifice was used there is an additional maximum uncertainty of 35 percent (3σ limits) due to fluctuations in the readings of pressure drop across the orifice.

Extraneous Heat Exchange

To minimize heat leak from room temperature to the test section by conduction, all electrical leads and the thin walled, 0.317 cm diam, stainless steel pressure transmission lines are thermally anchored to the outside copper surface of the liquid helium heat exchanger. A length of multifilament niobium-titanium superconducting wire is used for power leads between the heat exchanger and the preheater. The small diameter and low thermal conductivity of this wire further minimizes heat leak due to conduction and joule heating in the leads is eliminated. Error in heat flux due to axial conduction from the ends is less than 2 percent for the worst condition. Extraneous heat to and from the test section is therefore considered negligible. Boil-off from the liquid helium heat exchanger is routed through coils soldered to the pump housing and the radiation shield. This arrangement minimizes heat leak from room temperature via conduction along the pump housing and provides a low temperature radiation shield around the flow loop. The test section portion is further protected from radiation by a copper shield thermally anchored to the heat exchanger. The evacuated copper enclosure (vacuum less than 10^{-7} mm Hg) which is submerged in a bath of liquid nitrogen provides first stage radiation shielding from room temperature.

Experimental Measurement

For a fixed system pressure, pump speed and quality at the inlet of the test section, the power to the test section was increased in steps from zero. At a certain power level a discontinuous rise in the wall temperature occurred at the outlet end of the test section (critical heat flux). Further increase in power caused the discontinuity to move up the test section toward the inlet. The upper limit of power was usually determined by excessive wall temperatures at the outlet. After a change in test section power, thermometer voltages stabilized generally within a few seconds and were recorded by a digital voltmeter and automatically punched on paper tape together with all other pertinent voltages and run information.

Since the flow loop is a closed system, as power was applied it was necessary to vent the system to maintain a constant test pressure and conversely a decrease in power applied required adding and condensing gas in the loop to maintain the pressure.

This procedure was repeated for different pump speeds, inlet quality and pressure.

During a measurement the temperatures and pressure were stable to within their accuracy prior to a transition in the heat transfer mechanism (critical heat flux exceeded). When a transition occurred, it was accompanied by fluctuations in temperature (for the wall stations in the transition region) of a rather random nature, and an amplitude of the order of 0.5 K. Oscillations in pressure were not noticeable but this was at least partly due to the pressure transmission line being heavily damped.

We have attempted to establish the variability of our data from day to day by limited repetition of a measurement under the same set of conditions (e. g. same pressure, pump speed and inlet quality). For heat fluxes below the critical heat flux typical deviations in wall temperatures, at a given position on the test section, were 0. 02 K. For heat fluxes above the critical heat flux the wall temperature deviations were of the order of 0. 05 K and the position of the transition was repeatable to the nearest thermometer, i. e. to within 1 cm.

3. 3 Heat Transfer Results

Temperature profiles along the wall for subcritical helium heat transfer are shown in figures 6 and 7 for pressures from 1. 1 to 2. 0 atm* and mass velocities from 4. 5 to 63 g/s-cm^2. A typical profile is extremely flat up to some point at which a sharp rise is observed for the higher heat fluxes. This we identify, with reference to a vast body of literature on boiling heat transfer, as indicating a hydrodynamic transition from wetted-wall, e. g. , nucleate boiling, to dry-wall, e. g. , film boiling, heat transfer. Thus, at a particular point along the test section there is a critical heat flux above which the wall temperature rises quite steeply with heat flux.

Below the critical heat flux, heat transfer is very high as evidenced by the wall temperatures being nowhere more than about 0. 3 K above the bulk fluid temperature. Indeed this behavior is strongly reminiscent of boiling heat transfer without forced convection, i. e. , pool boiling. In figure 4 we plot the heat flux q against the difference between the wall and bulk fluid temperatures ΔT. The ΔT plotted is an average of the ΔT's for all positions on the tube having an $L/D > 20$ to preclude possible entrance effects. Furthermore since the wall temperature profile is so flat in this nucleate boiling region and since the bulk temperature is not changing, such a plot gives an indication of the average heat transfer in the nucleate boiling region. We have plotted as solid lines, the nucleate pool boiling correlation of Kutateladze [25] for 1. 1 and 2. 0 atm and indicated at the upper extremities the critical heat flux for pool boiling given by a second correlation due to Kutateladze [25]. As shown for

* 1 atm = 0. 1013 MN/m^2

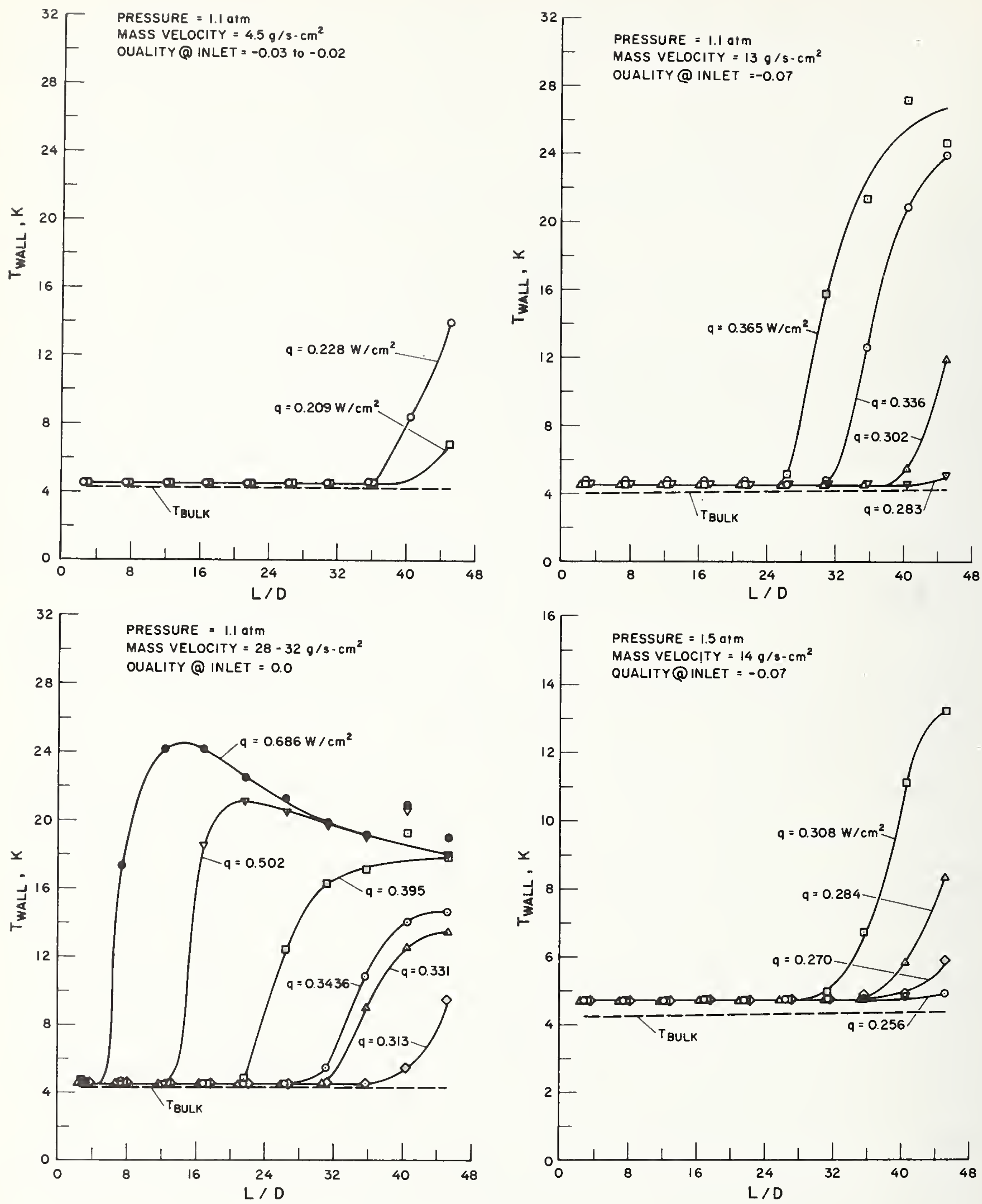

Figure 6. Typical wall temperature profiles for various inlet conditions. (pressure: 1.1 and 1.5 atm)

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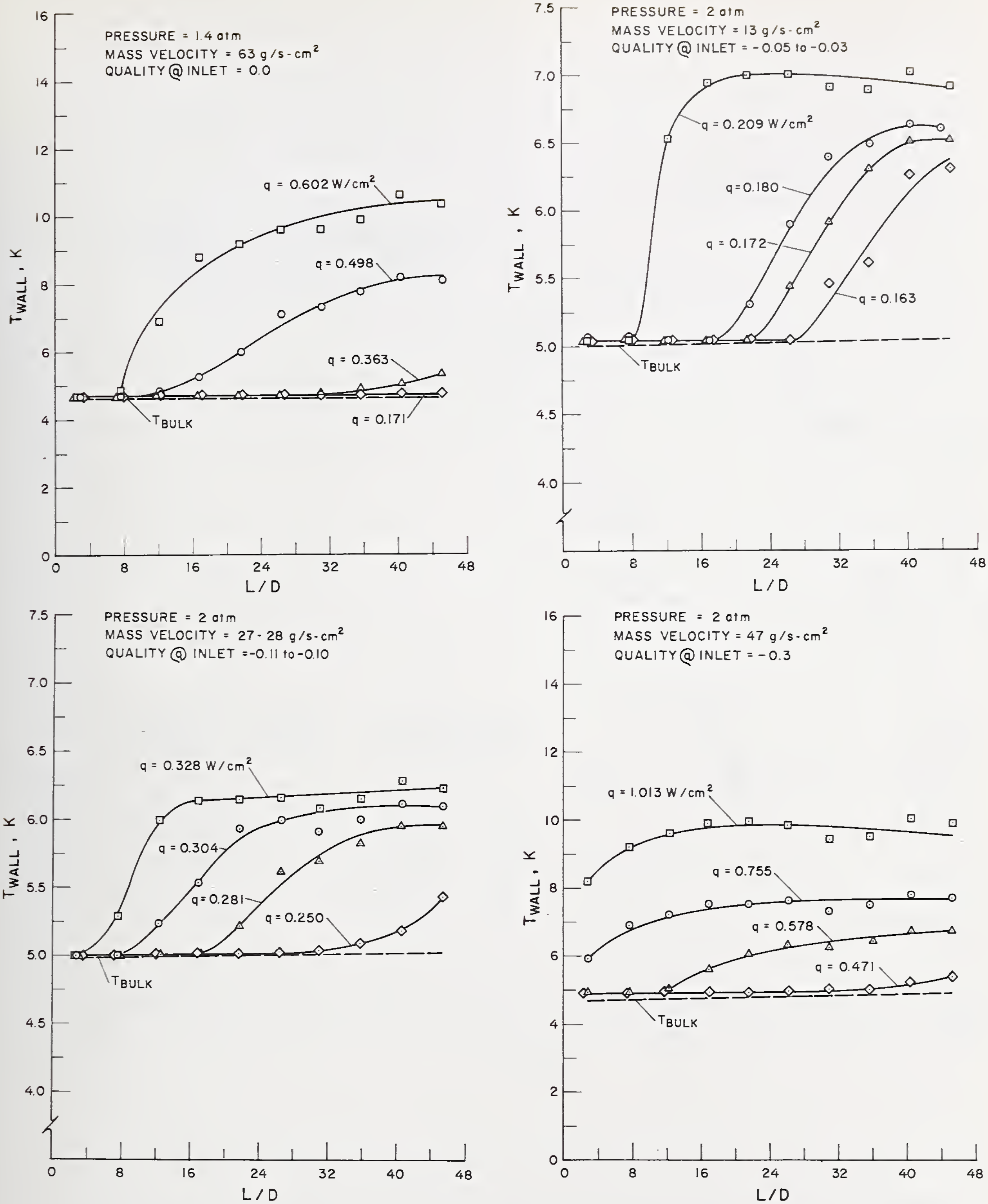

Figure 7. Typical wall temperature profiles for various inlet conditions (pressure: 1.4 and 2 atm).

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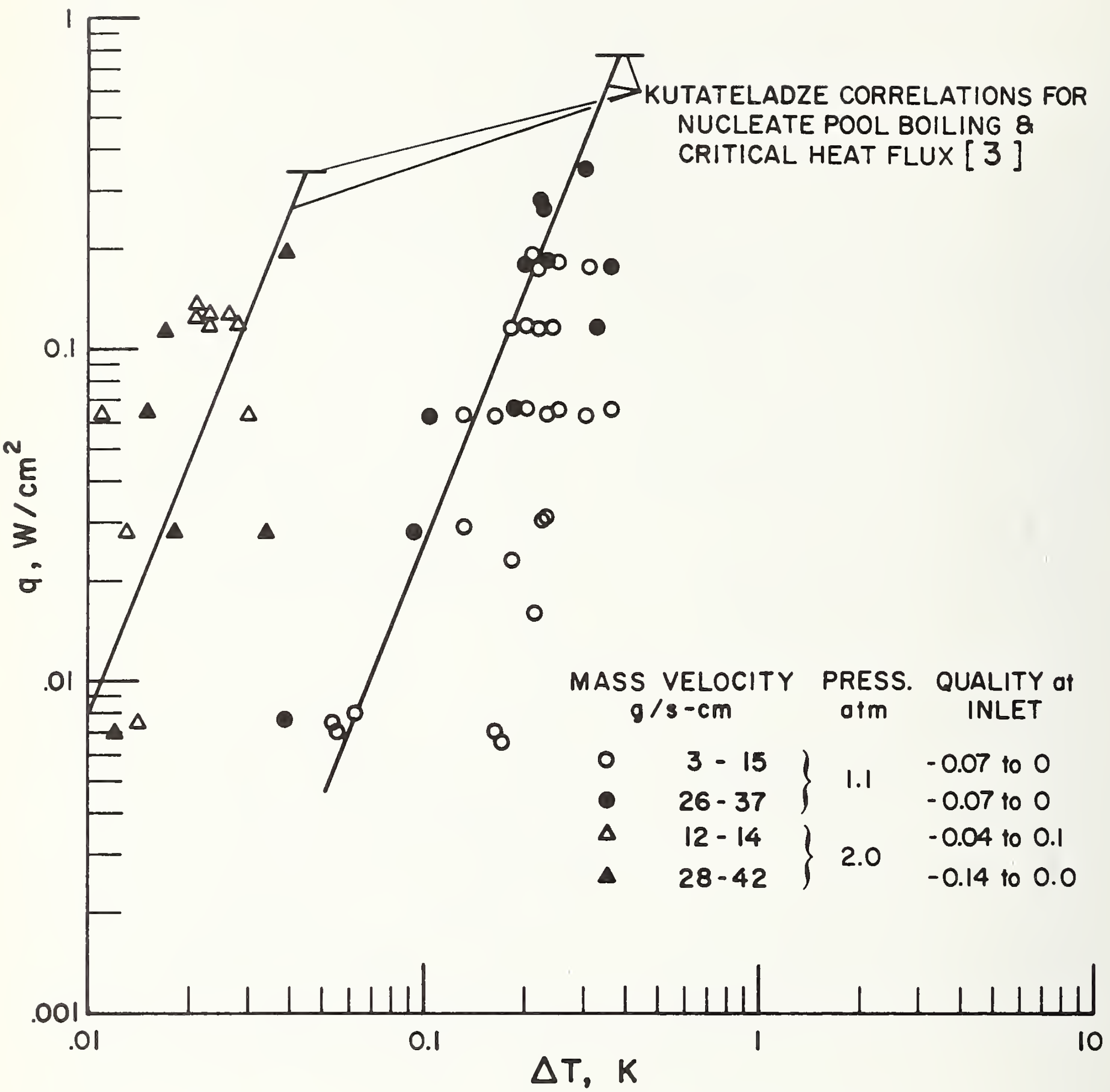

Figure 8. Heat flux (q) vs temperature difference ($T_{wall} - T_{bulk}$) in the nucleate boiling region under forced flow conditions.

example by Brentari et al. [26] these correlations give a good average representation of nucleate pool boiling data for cryogenic fluids. The present data for forced convection heat transfer are represented by the first of these correlations below the critical heat flux as well as any given set of pool boiling data, which are notorious for their sensitivity to the precise nature and preparation of the boiling surface, as well as its heating history (a strong hysteresis effect is often observed).

The lack of reproducibility in the present data in this region is quite in character with nucleate pool boiling data and has apparently masked any trend with mass velocity. We conclude that forced convection has had no significant effect on the rate of heat transfer below the critical heat flux and that the boiling mechanism itself is the primary determinant.

Above the critical heat flux wall temperatures are quite high and are now a strong function of the mass velocity in addition to heat flux and pressure. At 1.1 atm the wall temperatures rise to unacceptable values from the point of view of cooling of superconductors even at the highest mass velocities. At 2 atm, however, it is clear that the temperature excursion above the critical heat flux has reached a limit which is of some practical value and at the highest mass velocity (47 $g/s\text{-}cm^2$) it is even possible for the whole test section to be in film boiling below 8 K, with a heat flux of 0.755 W/cm^2. Even at 1.4 atm and 63 $g/s\text{-}cm^2$ a very useful heat flux can be supported while wall temperatures remain in a useful range. It is noticed too that when film boiling is well established throughout a good proportion of the test section, wall temperatures tend to fall again toward the outlet. This may be due to an increase in velocity as more vapor is generated as the fluid moves down the section.

We have not been able to find a suitable correlation to give a unique representation of the film boiling heat transfer coefficient even when we confined our attention to data for fully developed film boiling. This we defined as data for which the given thermometer was downstream of the maximum wall temperature. Correlations which were investigated for subcritical hydrogen in reference [26] could not represent the available data to better than an rms deviation of about 100 percent. We therefore have to rely for the present on the data alone to describe the film boiling region for helium.

Our primary interest in the present work has been in the nucleate-to-film boiling transition itself. The point of transition on the test section is quite clearly indicated on the temperature profiles to the nearest wall thermometer station. We take a point mid-way between two adjacent thermometers where one shows no significant temperature rise, and therefore presumably is still in nucleate boiling, while the next thermometer does indeed show a significant rise. In this way we have recorded 74 data points for the point of transition. Our goal has been to provide a means of predicting the transition, that is: given the state of the fluid at entry to the heated section, i. e. enthalpy and pressure, the flow rate and the heat flux, we wish to know at what position downstream the transition will occur. Alternatively, given the state and flow rate we wish to know the heat flux - the critical heat flux - at which the transition will occur at a certain position. Here we list the observed trends. In the next section we discuss the rationale for a correlation and describe the correlations that represent our data.

The first and most obvious trend is that, for a given pressure and mass velocity the critical heat flux is a function of distance from the inlet to the heated section. In experiments on heat transfer to subcritical helium under conditions of natural convection Johannes and Mollard [27] found that most of their data could be represented by a single curve when the critical heat flux was plotted against the distance from the inlet to the heated section in diameters (the equivalent diameter D_e was used for rectangular cross section, where D_e = 4x cross-sectional area/heated perimeter). The equation which represented their data was

$$\frac{1}{q_{cr}} = 1.7 + 0.125(L/D_e)^{0.88} \qquad (2)$$

where q_{cr} is the critical heat flux, L the tube length at which transition ocurred, and D_e the equivalent diameter based on the heated perimeter. Under conditions of natural circulation the mass velocities obtained by Johannes and Mollard were from 2 to 3 g/s-cm^2. For our lowest mass velocities (4.5 g/s-cm^2) at 1.1 atm pressure our critical heat fluxes are only about 10 percent higher than given by equation (2). However, a cursory examination of our data showed that there are considerable departures which may be summarized as follows.

i. Critical heat fluxes may be as much as a factor 2 or 3 times higher when mass velocities are in the range 30 - 60 g/s-cm^2.

ii. Critical heat fluxes may be as much as a factor of 2 lower at 2 atm pressure.

iii. Critical heat fluxes are enhanced by subcooling the liquid helium at the inlet to the test section.

There are thus at least five interdependent variables which characterize the transition: the heat flux, the thermodynamic state (2 variables), the mass velocity and the position in the tube.

Critical Heat Flux Correlation

Two factors have influenced our approach to correlation of our transition data. The first is that considerable simplification of the problem is possible if we adopt a local hypothesis. That is, we assume that transition occurs at a point in the tube under conditions of local hydrodynamic similarity. The second is the success which has been achieved for a very wide range of liquids (from helium to water) in correlating the pool boiling transition on the basis of the similarity criterion derived first by Kutateladze [25]. This criterion

$$\frac{q_{cr}}{\lambda \rho_v^{1/2} \left[\sigma g(\rho_\ell - \rho_v)\right]^{1/4}} = KU = \text{constant} \tag{3}$$

was derived from an analysis of the equations of motion of the two phases and equations for the dynamic interaction at the vapor-liquid interface when turbulent transport predominates. In equation (3) λ is the latent heat of vaporization, σ the surface tension, ρ_v and ρ_ℓ are vapor and liquid densities respectively and g is the gravitational acceleration. The essential point in the derviation of (3) is that in pool boiling the only scale of the velocity is the quantity $q/\rho_v\lambda$ and there is no scale for the pressure difference between phases, ΔP. We have taken the point of view that in forced convection boiling a well defined scale of velocity exists also in the direction of the tube axis as does a pressure drop. Further, we require an added parameter to complete the hydrodynamic description, namely the void fraction, or, equivalently, the quality x and the ratio ρ_ℓ/ρ_v. It is then straight forward to show that similarity in forced convection boiling can be specified by the following groups:

$$\left\{ \frac{G^2}{\rho_\ell^{\,2}\, gD} , \frac{DG^2}{\sigma \rho_\ell} , \frac{\rho_\ell \Delta P}{G^2} , x , \frac{\rho_\ell}{\rho_v} , KU \right\}$$

G is the mass velocity or mass flow per unit area. Now the ratio $\rho_\ell \Delta P/G^2$ for given L/D is determined by a Reynolds number which we define as $Re = \dfrac{GD}{\mu_\ell}$ where μ_ℓ is the liquid viscosity. Noting also that the first and second groups are the Froude number and Weber number respectively we arrive at the following equivalent set of dimensionless groups.

$$\left\{ Fr, \; We, \; Re, \; x , \; \frac{\rho_\ell}{\rho_v} , \; KU \right\}$$

This is as far as the local hypothesis takes us and the above groups should be adequate provided the point under consideration is remote from any flow perturbing geometry eg: the entrance to this heated section. This would be indeed a non-local effect. Now because some of our transitions were observed as close as three diameters distance from the entrance we included the group $\left(1 + \frac{D}{L}\right)$ where L is again, as in (2), the length up to the transition point. Since in the absence of forced convection we must again recover the criteria (3) the following form suggests itself

$$KU = C_1 + C_2 \left[Fr^{C_3} \cdot We^{C_4} . (1 + D/L)^{C_5} \cdot (1-x)^{C_6} \cdot \left(\frac{\rho_\ell}{\rho_v}\right)^{C_7} \cdot Re^{C_8} \right] \quad (4)$$

We have replaced x by 1-x to avoid a negative term in the subcooled region. Using non linear least squares fitting techniques [28] and the helium properties data given by McCarty [29], it was possible to determine the constants, C_j, in equation (4). The experimental data of Johannes and Mollard [27], with the equivalent diameter D_e based on the wetted perimeter instead of the heated perimeter, were used to supplement our own. Those data provided low mass velocity input (natural circulation with G's of the order 2g/s-cm^2). The standard deviation for the fit was 0.017 in units of KU, which was approximately 19 percent for an average value of KU. The constants obtained were

$C_1 = 0.04$

$C_2 = 0.36$

$C_3 = 0.40$

C_4 = essentially zero

$C_5 = -0.73$

$C_6 = 2.72$

$C_7 = 0.11$

$C_8 = -0.30$

Owing to the complexity of equation (4) and to the fact that some of the exponents were quite small, suggesting some redundancy, we experimented with several variants of (4) in which terms were removed. A good compromise between simplicity and goodness of fit was achieved with the expression

$$KU = C_1 + C_2 \, [1-x]^{C_3} \tag{5}$$

where

$C_1 = 0.031$

$C_2 = 0.078$

$C_3 = 3.92$

and the standard deviation was 0.02 (approximately 22% for an average of KU).

In arriving at a final selection of a correlation we plotted in addition three data points of Jergel and Stevenson [30] and two of Keilin et al. [31]. The latter are particularly significant, because in their work these authors observed transition under rather different circumstances; their L/D was 278 and transition occurred at a quality of about 0.4 (e.g. our L/D < 48 and x < 0.2 for similar pressures and mass velocities). It was found that some variants of (4) fitted to our own data and those of Johannes and Mollard were quite unable to predict the Keilin et al. data to better than an order of magnitude, whereas equation (5) came within 5 percent. Equation (5) and all the data discussed are shown plotted in figure 9.

To more pointedly illustrate the effects of mass velocity pressure and inlet conditions on critical heat flux we have constructed table 1 for a 10 centimeter long x 0.2 cm i.d. tube using equation (5) in the calculations. It is apparent that, for a given pressure, increasing the mass velocity from natural convection rates (2 g/s-cm^2) to reasonable forced convection rates (50 g/s-cm^2) results in a threefold increase in critical heat flux. Furthermore for a given pressure the effect of increased subcooling at the inlet also results in an increased critical heat flux. The maximum benefit from subcooling is obtained at 2 atm where it is seen that for an inlet temperature of 4 K and mass velocity of 50 g/s-cm^2 the critical heat flux is approximately three times that at saturated inlet conditions. Note that at 2 atm equation (5) predicts that transition can occur at negative values of x representing subcooled helium. Such a circumstance has been observed in our experiments; it is possible to have subcooled film boiling under forced convection conditions. Table 7 can be taken as a reasonable representation of the experimental results on transition of this and other work.

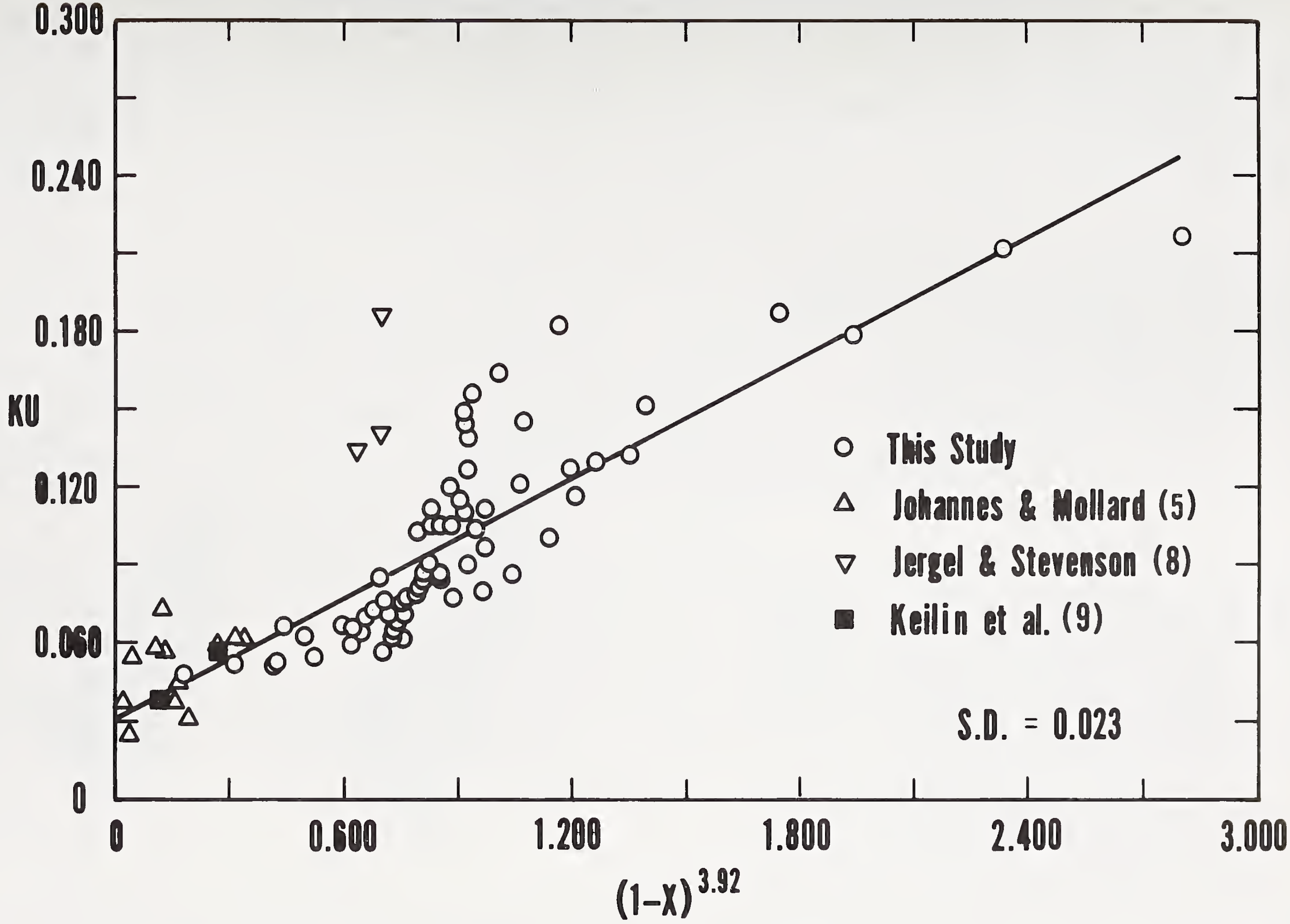

Figure 9. Dimensionless critical heat flux, $KU = q_{cr}/\lambda\rho_v^{1/2}\,[\sigma g(\rho_\ell - \rho_v)]^{1/4}$ vs correlating parameter $(1-x)^{3.92}$.

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TABLE 7

Example of Variation of Critical Heat Flux and Critical Quality, at L/D of 50, with Pressure, Mass Velocity and Inlet Conditions (using equation 5)

L = 10 cm

D = 0.2 cm

G = Mass Velocity, g/s-cm^2

q_{cr} = Critical Heat Flux, W/cm^2

x_{cr} = Critical Quality

Sat. Inlet Conditions	P = 1 atm				P = 1.6 atm				P = 2 atm			
G	2	5	30	50	2	5	30	50	2	5	30	50
q_{cr}	0.15	0.20	0.37	0.41	0.12	0.15	0.29	0.32	0.07	0.09	0.17	0.19
x_{cr}	0.73	0.38	0.12	0.08	0.73	0.38	0.12	0.08	0.64	0.34	0.11	0.07

Inlet Temp. = 4 K	P = 1 atm				P = 1.6 atm				P = 2 atm			
G	2	5	30	50	2	5	30	50	2	5	30	50
q_{cr}	0.15	0.20	0.40	0.46	0.13	0.19	0.46	0.55	0.09	0.15	0.47	0.62
x_{cr}	0.69	0.35	0.08	0.04	0.53	0.21	-0.07	-0.13	0.19	-0.09	-0.35	-0.42

Inlet Sub-Cooling = 0.224 K	P = 1 atm				P = 1.6 atm				P = 2 atm			
G	2	5	30	50	2	5	30	50	2	5	30	50
q_{cr}	0.15	0.20	0.40	0.46	0.12	0.17	0.34	0.40	0.08	0.11	0.25	0.30
x_{cr}	0.69	0.35	0.08	0.04	0.65	0.31	0.04	0.00	0.50	0.21	-0.05	-0.10

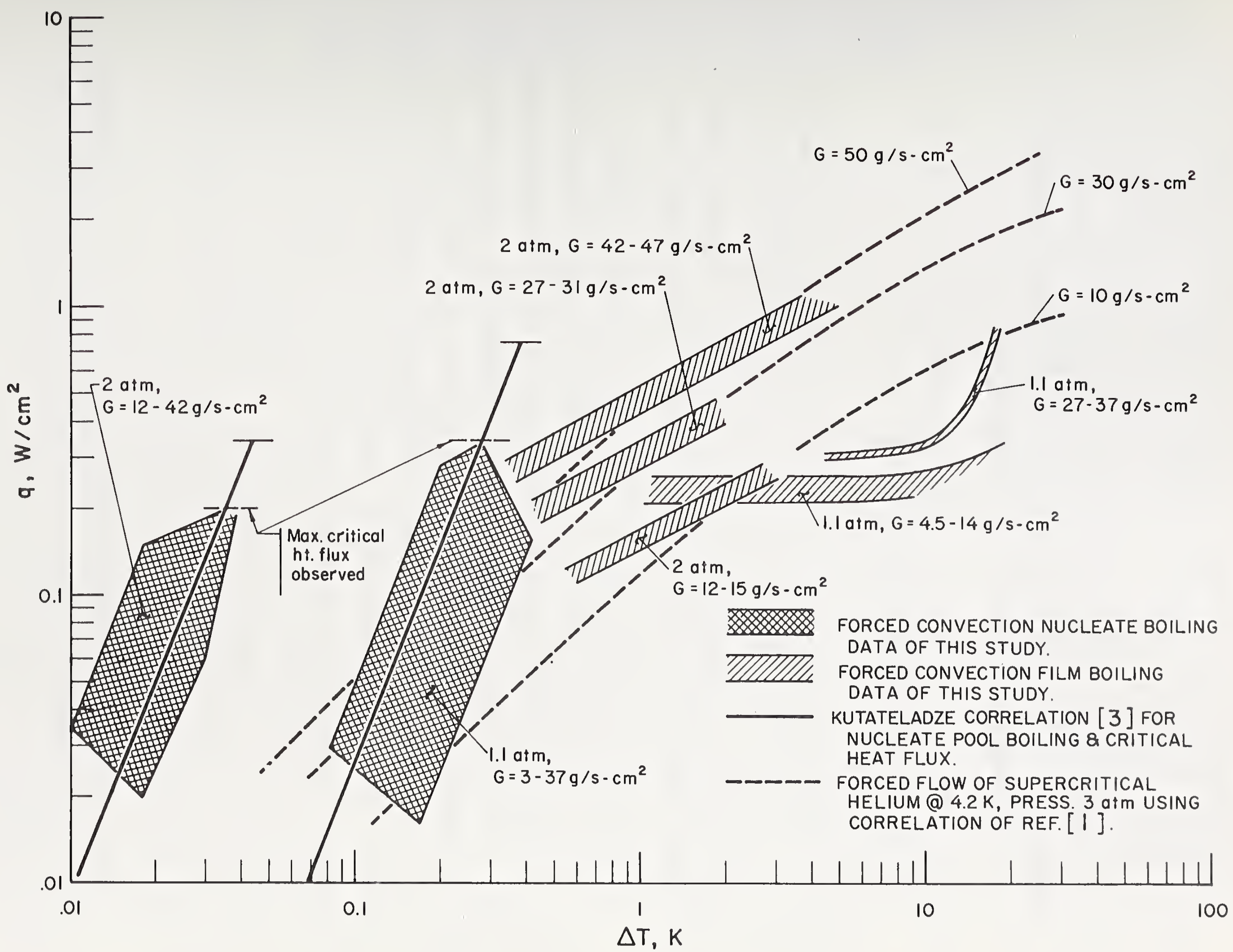

Figure 10. Comparison of various modes of helium heat transfer.

Comparison of Modes of Heat Transfer

In figure 6 the present results of heat flux q as a function of wall temperature rise ΔT for L/D = 48 are represented by shaded areas for comparison with other modes of heat transfer. We have included calculated values of the nucleate pool boiling correlations of Kutateladze and calculated values of q vs. ΔT for supercritical helium heat transfer at 3 atm and at mass velocities of 10, 30, and 50 g/s-cm^2. These were computed from

$$Nu = 0.0259\ Re^{0.8}\ Pr^{0.4}\left(\frac{T_W}{T_B}\right)^{-0.716} \tag{6}$$

where Nu is the Nusselt number, Re the Reynolds number, Pr the Prandtl number, T_W the inside wall temperature, and T_B is the bulk fluid temperature. The above correlation was developed in reference[24] which represented the data of that reference (L/D = 20 and 40) with an rms deviation of 8.5 percent.

We conclude from this comparison that for heat fluxes between 0.01 and 0.3 W/cm^2 subcritical pressures are preferable to supercritical pressures for equivalent mass velocities in forced convection. Above these heat fluxes, up to about 1 W/cm^2 and at pressures near one atmosphere, supercritical heat transfer is superior to subcritical, which is now in a dry-wall regime and shows very steep temperature rise for a small heat flux increment. However, at subcritical pressures approaching the critical pressure (e.g. 2 atm), and the highest flow rates observed the heat transfer rates are better or equivalent for the whole range of heat flux (.01-1 W/cm^2). We note that even though critical heat fluxes at 2 atm are relatively low, compared to 1 atm, the temperature excursion after transition is moderate if a reasonable flow rate is used (see last wall temperature profile in figure 3).

Finally, judging by the slopes of the curves in figure 10, at heat fluxes beyond the range of the present data (> 1 W/cm^2) supercritical heat transfer should be superior.

3.4 Conclusions

i. The usual transition from wetted-wall to dry-wall heat transfer is observed in heat transfer to subcritical helium I under forced convection.

ii. Below the transition, forced convection has little effect on heat transfer and the pool boiling correlation of Kutateladze for the heat flux vs. temperature rise of the wall is sufficient.

iii. Above the transition, the heat transfer coefficient falls off drastically. For superconductivity applications and low operating pressure (e. g. 1 atm) this will usually have to be avoided except at mass velocities of the order of 60 g/s-cm^2 or higher; but may be tolerated if higher operating pressures are used (e. g. 2 atm).

iv. Transition is a function of many variables (see discussion of correlation) but may be predicted by a relatively simple function of quality (equation 4) which implicitly contains those variables.

v. At heat fluxes between 0. 01 and 0. 3 W/cm^2 subcritical heat transfer is superior to supercritical for the same mass velocity. Above about 0. 3 W/cm^2 the reverse is true, for an operating pressure of 1 atm, and for an operating pressure of 2 atm the heat transfer rates are comparable.

3.5 Appended Experimental Data

For possible future reference in testing other methods of analysis, the uncorrected data are given in the following table.

<u>List of Symbols Used</u>

P	System pressure
Q	Wall heat flux
G	Mass velocity
X_{INLET}, X	Quality at the test section inlet and local quality
4_D	Length to diameter ratio (position in the test section)
T_W	Local inside wall temperature
T_B	Local bulk fluid temperature
H	Local heat transfer coefficient
*	Due to uncertainty in temperature measurement (discussed in text) in some instances a negative experimental heat transfer coefficient is indicated. This obviously unrealistic situation is denoted by an asterisk.

Table A1.

P(ATM) = 1.66 G(G/S-CM2) = 7.7
Q(W/CM2) = 0.032 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.813	4.811	0.00	19.092
7.5	4.806	4.811	0.01	******
12.2	4.802	4.811	0.01	******
16.9	4.801	4.811	0.02	******
21.6	4.800	4.811	0.02	******
26.3	4.858	4.811	0.03	0.674
31.0	4.800	4.811	0.03	******
35.7	4.802	4.811	0.04	******
40.4	4.804	4.811	0.04	******
45.1	4.809	4.811	0.05	******

P(ATM) = 1.70 G(G/S-CM2) = 7.3
Q(W/CM2) = 0.054 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.852	4.842	0.01	5.641
7.5	4.857	4.842	0.02	3.614
12.2	4.816	4.842	0.02	******
16.9	4.819	4.842	0.03	******
21.6	4.856	4.842	0.04	3.782
26.3	4.836	4.842	0.05	******
31.0	4.852	4.842	0.06	5.440
35.7	4.858	4.842	0.07	3.440
40.4	4.868	4.842	0.08	2.113
45.1	4.870	4.842	0.09	1.964

P(ATM) = 1.76 G(G/S-CM2) = 7.2
Q(W/CM2) = 0.085 XINLET = -0.02

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.888	4.866	-0.01	3.888
7.5	4.888	4.879	0.00	10.354
12.2	4.884	4.879	0.02	19.131
16.9	4.885	4.879	0.04	14.302
21.6	4.885	4.879	0.05	14.481
26.3	4.887	4.879	0.07	10.964
31.0	4.866	4.879	0.08	******
35.7	4.886	4.879	0.10	13.100
40.4	4.895	4.879	0.11	5.377
45.1	4.897	4.879	0.13	4.988

P(ATM) = 1.70   G(G/S-CM2) = 11.4
Q(W/CM2) = 0.099   XINLET = -0.03

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.739	4.806	-0.02	******
7.5	4.737	4.821	-0.01	******
12.2	4.735	4.837	-0.00	******
16.9	4.740	4.838	0.01	******
21.6	4.739	4.838	0.02	******
26.3	4.737	4.838	0.03	******
31.0	4.732	4.838	0.04	******
35.7	4.737	4.838	0.05	******
40.4	4.753	4.838	0.07	******
45.1	4.751	4.838	0.08	******

P(ATM) = 1.77   G(G/S-CM2) = 11.2
Q(W/CM2) = 0.099   XINLET = -0.05

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.779	4.832	-0.05	******
7.5	4.777	4.847	-0.04	******
12.2	4.774	4.862	-0.02	******
16.9	4.780	4.877	-0.01	******
21.6	4.778	4.892	-0.00	******
26.3	4.776	4.892	0.01	******
31.0	4.771	4.892	0.02	******
35.7	4.774	4.892	0.04	******
40.4	4.795	4.892	0.05	******
45.1	4.792	4.892	0.06	******

P(ATM) = 1.01   G(G/S-CM2) = 3.1
Q(W/CM2) = 0.007   XINLET = -0.03

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.271	4.129	-0.03	0.046
7.5	4.292	4.135	-0.02	0.042
12.2	4.335	4.142	-0.02	0.034
16.9	4.314	4.148	-0.02	0.039
21.6	4.318	4.155	-0.02	0.040
26.3	4.332	4.161	-0.02	0.038
31.0	4.335	4.168	-0.01	0.039
35.7	4.341	4.174	-0.01	0.039
40.4	4.365	4.181	-0.01	0.035
45.1	4.375	4.187	-0.01	0.035

P(ATM) = 0.98 G(G/S-CM2) = 3.1
Q(W/CM2) = 0.016 XINLET = -0.02

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.413	4.135	-0.02	0.057
7.5	4.378	4.155	-0.01	0.071
12.2	4.410	4.176	-0.01	0.068
16.9	4.373	4.196	-0.00	0.089
21.6	4.376	4.207	0.00	0.094
26.3	4.402	4.207	0.01	0.081
31.0	4.426	4.207	0.01	0.073
35.7	4.420	4.207	0.02	0.074
40.4	4.382	4.207	0.02	0.091
45.1	4.388	4.207	0.03	0.087

P(ATM) = 1.01 G(G/S-CM2) = 4.1
Q(W/CM2) = 0.031 XINLET = -0.03

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.399	4.118	-0.03	0.111
7.5	4.402	4.148	-0.02	0.123
12.2	4.458	4.179	-0.01	0.112
16.9	4.408	4.209	-0.01	0.157
21.6	4.420	4.232	0.00	0.166
26.3	4.447	4.232	0.01	0.145
31.0	4.473	4.232	0.02	0.130
35.7	4.450	4.232	0.02	0.143
40.4	4.427	4.232	0.03	0.160
45.1	4.450	4.232	0.04	0.143

P(ATM) = 1.04 G(G/S-CM2) = 4.3
Q(W/CM2) = 0.069 XINLET = -0.04

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.477	4.134	-0.03	0.200
7.5	4.469	4.197	-0.02	0.253
12.2	4.538	4.260	-0.00	0.247
16.9	4.459	4.268	0.01	0.342
21.6	4.475	4.268	0.03	0.331
26.3	4.509	4.268	0.04	0.285
31.0	4.522	4.268	0.06	0.271
35.7	4.499	4.268	0.07	0.298
40.4	4.506	4.268	0.09	0.289
45.1	4.539	4.268	0.10	0.254

P(ATM) = 0.96 G(G/S-CM2) = 3.5
Q(W/CM2) = 0.007 XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.306	4.179	-0.00	0.056
7.5	4.320	4.186	0.00	0.053
12.2	4.322	4.186	0.00	0.052
16.9	4.337	4.186	0.00	0.047
21.6	4.369	4.186	0.01	0.039
26.3	4.348	4.186	0.01	0.044
31.0	4.345	4.186	0.01	0.045
35.7	4.351	4.186	0.01	0.043
40.4	4.373	4.186	0.01	0.038
45.1	4.372	4.186	0.02	0.038

P(ATM) = 1.00 G(G/S-CM2) = 3.9
Q(W/CM2) = 0.023 XINLET = -0.02

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.373	4.174	-0.01	0.114
7.5	4.378	4.196	-0.01	0.125
12.2	4.373	4.219	-0.00	0.148
16.9	4.384	4.225	0.00	0.143
21.6	4.390	4.225	0.01	0.138
26.3	4.412	4.225	0.01	0.122
31.0	4.432	4.225	0.02	0.109
35.7	4.427	4.225	0.03	0.112
40.4	4.400	4.225	0.03	0.130
45.1	4.410	4.225	0.04	0.123

P(ATM) = 1.04 G(G/S-CM2) = 4.3
Q(W/CM2) = 0.063 XINLET = -0.03

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.459	4.183	-0.02	0.228
7.5	4.455	4.240	-0.01	0.294
12.2	4.439	4.262	0.01	0.358
16.9	4.456	4.262	0.02	0.326
21.6	4.456	4.262	0.04	0.309
26.3	4.493	4.262	0.05	0.273
31.0	4.509	4.262	0.06	0.256
35.7	4.484	4.262	0.08	0.284
40.4	4.487	4.262	0.09	0.281
45.1	4.519	4.262	0.10	0.246

P(ATM) = 1.04 G(G/S-CM2) = 3.9
Q(W/CM2) = 0.116 XINLET = -0.03

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.495	4.228	-0.01	0.435
7.5	4.481	4.264	0.02	0.536
12.2	4.461	4.264	0.05	0.588
16.9	4.471	4.264	0.07	0.560
21.6	4.465	4.264	0.10	0.576
26.3	4.510	4.264	0.13	0.471
31.0	4.525	4.264	0.16	0.445
35.7	4.494	4.264	0.18	0.505
40.4	4.513	4.264	0.21	0.467
45.1	4.546	4.264	0.24	0.412

P(ATM) = 1.07 G(G/S-CM2) = 10.7
Q(W/CM2) = 0.176 XINLET = -0.05

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.518	4.122	-0.04	0.445
7.5	4.503	4.187	-0.03	0.557
12.2	4.476	4.252	-0.01	0.786
16.9	4.485	4.298	0.00	0.938
21.6	4.482	4.298	0.02	0.957
26.3	4.528	4.298	0.04	0.765
31.0	4.535	4.298	0.05	0.740
35.7	4.522	4.298	0.07	0.785
40.4	4.548	4.298	0.08	0.704
45.1	4.576	4.298	0.10	0.633

P(ATM) = 1.12 G(G/S-CM2) = 8.3
Q(W/CM2) = 0.030 XINLET = -0.05

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.417	4.167	-0.05	0.119
7.5	4.412	4.184	-0.04	0.130
12.2	4.446	4.202	-0.04	0.121
16.9	4.466	4.219	-0.04	0.120
21.6	4.457	4.237	-0.03	0.129
26.3	4.482	4.254	-0.03	0.130
31.0	4.503	4.272	-0.03	0.128
35.7	4.491	4.289	-0.02	0.147
40.4	4.505	4.307	-0.02	0.150
45.1	4.519	4.324	-0.02	0.152

P(ATM) = 1.13 G(G/S-CM2) = 8.8
Q(W/CM2) = 0.062 XINLET = -0.05

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.479	4.166	-0.05	0.199
7.5	4.443	4.193	-0.04	0.248
12.2	4.472	4.220	-0.04	0.246
16.9	4.492	4.246	-0.03	0.253
21.6	4.495	4.273	-0.02	0.281
26.3	4.532	4.300	-0.02	0.267
31.0	4.574	4.326	-0.01	0.251
35.7	4.525	4.353	-0.00	0.362
40.4	4.537	4.359	0.01	0.348
45.1	4.577	4.359	0.01	0.285

P(ATM) = 1.11 G(G/S-CM2) = 8.8
Q(W/CM2) = 0.114 XINLET = -0.05

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.497	4.177	-0.04	0.357
7.5	4.444	4.226	-0.03	0.524
12.2	4.469	4.275	-0.02	0.587
16.9	4.486	4.324	-0.00	0.694
21.6	4.490	4.335	0.01	0.733
26.3	4.537	4.335	0.02	0.563
31.0	4.561	4.335	0.03	0.506
35.7	4.530	4.335	0.05	0.586
40.4	4.538	4.335	0.06	0.561
45.1	4.587	4.335	0.07	0.452

P(ATM) = 1.11 G(G/S-CM2) = 8.8
Q(W/CM2) = 0.180 XINLET = -0.05

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.507	4.197	-0.04	0.580
7.5	4.452	4.274	-0.02	1.008
12.2	4.483	4.341	0.00	1.268
16.9	4.513	4.341	0.02	1.044
21.6	4.517	4.341	0.04	1.023
26.3	4.532	4.341	0.06	0.944
31.0	4.554	4.341	0.08	0.844
35.7	4.530	4.341	0.10	0.954
40.4	4.571	4.341	0.12	0.781
45.1	4.604	4.341	0.14	0.683

P(ATM) = 1.12 G(G/S-CM2) = 92.5
Q(W/CM2) = 0.043 XINLET = -0.05

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.441	4.168	-0.05	0.175
7.5	4.456	4.174	-0.05	0.170
12.2	4.416	4.180	-0.05	0.202
16.9	4.419	4.186	-0.05	0.205
21.6	4.424	4.192	-0.05	0.206
26.3	4.408	4.198	-0.05	0.228
31.0	4.419	4.204	-0.04	0.223
35.7	4.405	4.210	-0.04	0.245
40.4	4.429	4.216	-0.04	0.225
45.1	4.432	4.222	-0.04	0.228

P(ATM) = 1.12 G(G/S-CM2) = 58.8
Q(W/CM2) = 0.113 XINLET = -0.04

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.484	4.196	-0.04	0.391
7.5	4.485	4.202	-0.04	0.398
12.2	4.468	4.208	-0.04	0.434
16.9	4.480	4.214	-0.03	0.423
21.6	4.484	4.220	-0.03	0.427
26.3	4.488	4.225	-0.03	0.430
31.0	4.507	4.231	-0.03	0.409
35.7	4.485	4.237	-0.03	0.456
40.4	4.518	4.243	-0.03	0.411
45.1	4.532	4.249	-0.02	0.399

P(ATM) = 1.09 G(G/S-CM2) = 34.8
Q(W/CM2) = 0.258 XINLET = -0.02

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.512	4.273	-0.01	1.078
7.5	4.497	4.299	-0.01	1.311
12.2	4.497	4.321	0.00	1.473
16.9	4.516	4.321	0.01	1.330
21.6	4.510	4.321	0.02	1.371
26.3	4.520	4.321	0.02	1.302
31.0	4.526	4.321	0.03	1.265
35.7	4.568	4.321	0.04	1.047
40.4	7.210	4.321	0.04	0.090
45.1	10.312	4.321	0.05	0.043

P(ATM) = 1.12 G(G/S-CM2) = 86.0
Q(W/CM2) = 0.067 XINLET = -0.02

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.487	4.263	-0.02	0.301
7.5	4.463	4.270	-0.02	0.347
12.2	4.430	4.276	-0.02	0.313
16.9	4.502	4.282	-0.02	0.307
21.6	4.485	4.289	-0.02	0.343
26.3	4.485	4.295	-0.02	0.355
31.0	4.489	4.302	-0.02	0.360
35.7	4.429	4.308	-0.02	0.558
40.4	4.427	4.315	-0.02	0.597
45.1	4.456	4.321	-0.02	0.497

P(ATM) = 1.52 G(G/S-CM2) = 7.2
Q(W/CM2) = 0.007 XINLET = -0.09

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.549	4.494	-0.09	0.127
7.5	4.548	4.498	-0.08	0.139
12.2	4.563	4.502	-0.08	0.112
16.9	4.563	4.505	-0.08	0.118
21.6	4.568	4.509	-0.08	0.117
26.3	4.574	4.513	-0.08	0.111
31.0	4.578	4.516	-0.08	0.111
35.7	4.581	4.520	-0.08	0.112
40.4	4.593	4.524	-0.08	0.100
45.1	4.592	4.527	-0.08	0.106

P(ATM) = 1.52 G(G/S-CM2) = 7.2
Q(W/CM2) = 0.028 XINLET = -0.09

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.693	4.497	-0.08	0.140
7.5	4.713	4.509	-0.08	0.134
12.2	4.736	4.520	-0.08	0.128
16.9	4.749	4.532	-0.07	0.127
21.6	4.744	4.544	-0.07	0.138
26.3	4.758	4.556	-0.06	0.136
31.0	4.770	4.567	-0.06	0.135
35.7	4.765	4.579	-0.05	0.148
40.4	4.781	4.591	-0.05	0.145
45.1	4.796	4.603	-0.05	0.142

P(ATM) = 1.49 G(G/S-CM2) = 7.1
Q(W/CM2) = 0.065 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.753	4.508	-0.07	0.265
7.5	4.742	4.533	-0.06	0.310
12.2	4.757	4.557	-0.05	0.325
16.9	4.772	4.582	-0.04	0.343
21.6	4.757	4.607	-0.03	0.434
26.3	4.777	4.632	-0.02	0.448
31.0	4.777	4.657	-0.01	0.540
35.7	4.778	4.675	0.00	0.629
40.4	4.803	4.675	0.01	0.508
45.1	4.812	4.675	0.02	0.473

P(ATM) = 1.49 G(G/S-CM2) = 7.2
Q(W/CM2) = 0.116 XINLET = -0.08

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.744	4.515	-0.07	0.507
7.5	4.731	4.559	-0.05	0.674
12.2	4.752	4.603	-0.03	0.777
16.9	4.770	4.647	-0.01	0.941
21.6	4.750	4.676	0.01	1.587
26.3	4.769	4.676	0.02	1.254
31.0	4.769	4.676	0.04	1.251
35.7	4.769	4.676	0.06	1.258
40.4	4.810	4.676	0.08	0.871
45.1	4.815	4.676	0.09	0.837

P(ATM) = 1.49 G(G/S-CM2) = 7.2
Q(W/CM2) = 0.175 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.728	4.539	-0.06	0.930
7.5	4.715	4.606	-0.03	1.604
12.2	4.740	4.672	-0.00	2.561
16.9	4.763	4.675	0.03	1.993
21.6	4.736	4.675	0.05	2.867
26.3	4.757	4.675	0.08	2.128
31.0	4.759	4.675	0.11	2.097
35.7	4.756	4.675	0.13	2.156
40.4	4.814	4.675	0.16	1.263
45.1	4.817	4.675	0.19	1.234

P(ATM) = 1.52 G(G/S-CM2) = 14.8
Q(W/CM2) = 0.029 XINLET = -0.09

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.605	4.485	-0.09	0.241
7.5	4.620	4.491	-0.09	0.225
12.2	4.626	4.497	-0.08	0.224
16.9	4.641	4.502	-0.08	0.209
21.6	4.643	4.508	-0.08	0.215
26.3	4.650	4.514	-0.08	0.213
31.0	4.654	4.520	-0.08	0.216
35.7	4.663	4.526	-0.07	0.212
40.4	4.678	4.532	-0.07	0.199
45.1	4.686	4.538	-0.07	0.196

P(ATM) = 1.52 G(G/S-CM2) = 15.1
Q(W/CM2) = 0.065 XINLET = -0.09

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.738	4.484	-0.09	0.258
7.5	4.745	4.498	-0.08	0.266
12.2	4.747	4.512	-0.08	0.279
16.9	4.756	4.526	-0.07	0.285
21.6	4.753	4.540	-0.07	0.306
26.3	4.759	4.554	-0.06	0.304
31.0	4.771	4.568	-0.06	0.322
35.7	4.768	4.581	-0.05	0.351
40.4	4.786	4.595	-0.05	0.343
45.1	4.797	4.609	-0.04	0.348

P(ATM) = 1.48 G(G/S-CM2) = 14.6
Q(W/CM2) = 0.116 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.758	4.499	-0.07	0.448
7.5	4.755	4.521	-0.06	0.495
12.2	4.756	4.543	-0.05	0.546
16.9	4.768	4.565	-0.04	0.572
21.6	4.761	4.586	-0.03	0.665
26.3	4.768	4.608	-0.02	0.728
31.0	4.767	4.630	-0.02	0.849
35.7	4.766	4.652	-0.01	1.021
40.4	4.797	4.669	0.00	0.904
45.1	4.802	4.669	0.01	0.871

P(ATM) = 1.48 G(G/S-CM2) = 14.2
Q(W/CM2) = 0.256 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.730	4.533	-0.06	1.293
7.5	4.727	4.581	-0.04	1.757
12.2	4.730	4.630	-0.02	2.551
16.9	4.746	4.670	0.00	3.369
21.6	4.737	4.670	0.02	3.855
26.3	4.744	4.670	0.04	3.474
31.0	4.748	4.670	0.06	3.296
35.7	4.738	4.670	0.08	3.756
40.4	4.799	4.670	0.10	1.983
45.1	4.889	4.670	0.12	1.168

P(ATM) = 1.47 G(G/S-CM2) = 14.1
Q(W/CM2) = 0.250 XINLET = -0.06

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.727	4.534	-0.05	1.298
7.5	4.724	4.583	-0.03	1.763
12.2	4.727	4.630	-0.01	2.604
16.9	4.741	4.664	0.01	3.273
21.6	4.734	4.664	0.03	3.611
26.3	4.741	4.664	0.04	3.284
31.0	4.743	4.664	0.06	3.198
35.7	4.734	4.664	0.08	3.592
40.4	4.793	4.664	0.10	1.954
45.1	4.814	4.664	0.12	1.676

P(ATM) = 1.48 G(G/S-CM2) = 14.3
Q(W/CM2) = 0.180 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.744	4.515	-0.06	0.787
7.5	4.742	4.549	-0.05	0.934
12.2	4.743	4.583	-0.03	1.129
16.9	4.753	4.618	-0.02	1.327
21.6	4.748	4.652	-0.01	1.889
26.3	4.753	4.668	0.01	2.121
31.0	4.754	4.668	0.02	2.101
35.7	4.749	4.668	0.04	2.222
40.4	4.793	4.668	0.05	1.440
45.1	4.800	4.668	0.06	1.365

P(ATM) = 1.48 G(G/S-CM2) = 14.5
Q(W/CM2) = 0.115 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.757	4.500	-0.07	0.449
7.5	4.757	4.522	-0.06	0.491
12.2	4.757	4.544	-0.05	0.542
16.9	4.754	4.566	-0.04	0.582
21.6	4.763	4.587	-0.03	0.659
26.3	4.770	4.609	-0.02	0.718
31.0	4.766	4.631	-0.02	0.855
35.7	4.764	4.652	-0.01	1.035
40.4	4.795	4.670	0.00	0.924
45.1	4.802	4.670	0.01	0.876

P(ATM) = 1.52 G(G/S-CM2) = 14.8
Q(W/CM2) = 0.028 XINLET = -0.09

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.597	4.487	-0.09	0.256
7.5	4.613	4.493	-0.09	0.234
12.2	4.622	4.499	-0.08	0.229
16.9	4.633	4.505	-0.08	0.220
21.6	4.639	4.511	-0.08	0.219
26.3	4.646	4.517	-0.08	0.218
31.0	4.650	4.522	-0.07	0.221
35.7	4.655	4.529	-0.07	0.224
40.4	4.672	4.534	-0.07	0.206
45.1	4.677	4.541	-0.07	0.206

P(ATM) = 1.32 G(G/S-CM2) = 60.2
Q(W/CM2) = 0.030 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.554	4.507	-0.01	0.628
7.5	4.559	4.510	-0.01	0.605
12.2	4.560	4.513	-0.01	0.628
16.9	4.558	4.515	-0.01	0.700
21.6	4.560	4.518	-0.01	0.723
26.3	4.562	4.521	-0.01	0.726
31.0	4.561	4.524	-0.01	0.798
35.7	4.560	4.527	-0.01	0.903
40.4	4.575	4.530	-0.01	0.658
45.1	4.575	4.533	-0.01	0.712

P(ATM) = 1.31   G(G/S-CM2) = 60.9
Q(W/CM2) = 0.117   XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.632	4.512	-0.00	0.978
7.5	4.643	4.518	-0.00	0.932
12.2	4.645	4.522	0.00	0.953
16.9	4.646	4.522	0.00	0.947
21.6	4.639	4.522	0.00	1.008
26.3	4.644	4.522	0.01	0.965
31.0	4.639	4.522	0.01	1.005
35.7	4.636	4.522	0.01	1.028
40.4	4.657	4.522	0.01	0.812
45.1	4.667	4.522	0.01	0.811

P(ATM) = 1.33   G(G/S-CM2) = 58.5
Q(W/CM2) = 0.262   XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.657	4.532	-0.00	1.940
7.5	4.669	4.544	-0.00	2.101
12.2	4.662	4.545	0.00	2.247
16.9	4.673	4.545	0.01	2.054
21.6	4.670	4.545	0.01	2.100
26.3	4.676	4.545	0.02	2.008
31.0	4.671	4.545	0.02	2.081
35.7	4.657	4.545	0.03	2.148
40.4	4.727	4.545	0.03	1.444
45.1	4.735	4.545	0.04	1.380

P(ATM) = 1.32   G(G/S-CM2) = 59.4
Q(W/CM2) = 0.361   XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.646	4.532	-0.00	3.160
7.5	4.649	4.532	0.01	3.094
12.2	4.640	4.532	0.01	3.329
16.9	4.657	4.532	0.02	2.893
21.6	4.650	4.532	0.02	3.066
26.3	4.656	4.532	0.03	2.904
31.0	4.659	4.532	0.04	2.836
35.7	4.658	4.532	0.04	2.855
40.4	4.747	4.532	0.05	1.674
45.1	4.767	4.532	0.06	1.533

P(ATM) = 1.33 G(G/S-CM2) = 60.5
Q(W/CM2) = 0.363 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.651	4.526	-0.00	2.915
7.5	4.650	4.538	0.00	3.226
12.2	4.642	4.538	0.01	3.481
16.9	4.662	4.538	0.01	2.921
21.6	4.651	4.538	0.02	3.207
26.3	4.661	4.538	0.03	2.955
31.0	4.673	4.538	0.03	2.683
35.7	4.667	4.538	0.04	2.808
40.4	4.757	4.538	0.05	1.658
45.1	4.794	4.538	0.05	1.416

P(ATM) = 1.33 G(G/S-CM2) = 59.2
Q(W/CM2) = 0.254 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.671	4.526	-0.01	1.753
7.5	4.665	4.538	-0.00	1.998
12.2	4.659	4.544	0.00	2.204
16.9	4.677	4.544	0.01	1.905
21.6	4.671	4.544	0.01	2.009
26.3	4.677	4.544	0.02	1.918
31.0	4.675	4.544	0.02	1.940
35.7	4.673	4.544	0.02	1.978
40.4	4.738	4.544	0.03	1.312
45.1	4.743	4.544	0.03	1.278

P(ATM) = 1.32 G(G/S-CM2) = 62.0
Q(W/CM2) = 0.113 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.638	4.504	-0.01	0.846
7.5	4.645	4.509	-0.01	0.835
12.2	4.645	4.515	-0.01	0.866
16.9	4.654	4.520	-0.00	0.839
21.6	4.645	4.525	-0.00	0.937
26.3	4.652	4.530	-0.00	0.925
31.0	4.653	4.532	0.00	0.936
35.7	4.645	4.532	0.00	1.003
40.4	4.682	4.532	0.00	0.751
45.1	4.686	4.532	0.01	0.735

P(ATM) = 1.32 G(G/S-CM2) = 60.9
Q(W/CM2) = 0.029 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.555	4.513	-0.01	0.684
7.5	4.561	4.515	-0.01	0.620
12.2	4.556	4.517	-0.01	0.733
16.9	4.562	4.519	-0.01	0.675
21.6	4.569	4.521	-0.01	0.607
26.3	4.559	4.523	-0.01	0.788
31.0	4.560	4.525	-0.01	0.824
35.7	4.562	4.527	-0.01	0.826
40.4	4.586	4.529	-0.00	0.504
45.1	4.592	4.531	-0.00	0.476

P(ATM) = 1.08 G(G/S-CM2) = 4.0
Q(W/CM2) = 0.008 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.335	4.266	-0.01	0.117
7.5	4.308	4.273	-0.01	0.231
12.2	4.353	4.281	-0.01	0.112
16.9	4.361	4.288	-0.01	0.111
21.6	4.323	4.296	-0.00	0.298
26.3	4.388	4.303	-0.00	0.095
31.0	4.387	4.310	-0.00	0.106
35.7	4.363	4.311	0.00	0.155
40.4	4.380	4.311	0.00	0.118
45.1	4.377	4.311	0.01	0.122

P(ATM) = 1.08 G(G/S-CM2) = 4.2
Q(W/CM2) = 0.029 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.405	4.266	-0.01	0.209
7.5	4.368	4.291	-0.00	0.379
12.2	4.416	4.307	0.00	0.267
16.9	4.427	4.307	0.01	0.243
21.6	4.393	4.307	0.02	0.337
26.3	4.443	4.307	0.02	0.214
31.0	4.486	4.307	0.03	0.162
35.7	4.441	4.307	0.04	0.216
40.4	4.454	4.307	0.04	0.197
45.1	4.461	4.307	0.05	0.188

P(ATM) = 1.07 G(G/S-CM2) = 4.3
Q(W/CM2) = 0.062 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.442	4.276	-0.01	0.375
7.5	4.392	4.302	0.01	0.694
12.2	4.439	4.302	0.02	0.454
16.9	4.446	4.302	0.03	0.431
21.6	4.408	4.302	0.05	0.589
26.3	4.513	4.302	0.06	0.295
31.0	4.541	4.302	0.07	0.261
35.7	4.473	4.302	0.09	0.365
40.4	4.480	4.302	0.10	0.350
45.1	4.509	4.302	0.11	0.301

P(ATM) = 1.10 G(G/S-CM2) = 4.7
Q(W/CM2) = 0.117 XINLET = -0.02

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.504	4.290	-0.01	0.547
7.5	4.434	4.323	0.02	1.056
12.2	4.494	4.323	0.04	0.686
16.9	4.509	4.323	0.06	0.632
21.6	4.471	4.323	0.09	0.790
26.3	4.568	4.323	0.11	0.479
31.0	4.563	4.323	0.13	0.489
35.7	4.537	4.323	0.16	0.548
40.4	4.558	4.323	0.18	0.498
45.1	4.580	4.323	0.21	0.456

P(ATM) = 1.08 G(G/S-CM2) = 4.3
Q(W/CM2) = 0.180 XINLET = -0.02

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.493	4.308	0.01	0.971
7.5	4.421	4.308	0.05	1.594
12.2	4.490	4.308	0.09	0.989
16.9	4.512	4.308	0.12	0.884
21.6	4.470	4.308	0.16	1.109
26.3	4.551	4.308	0.20	0.741
31.0	4.545	4.308	0.24	0.761
35.7	4.524	4.308	0.28	0.833
40.4	4.563	4.308	0.32	0.706
45.1	4.581	4.308	0.36	0.660

P(ATM) = 1.08   G(G/S-CM2) = 4.5
Q(W/CM2) = 0.180   XINLET = -0.02

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.503	4.304	0.01	0.904
7.5	4.436	4.304	0.04	1.365
12.2	4.482	4.304	0.08	1.012
16.9	4.496	4.304	0.12	0.937
21.6	4.472	4.304	0.16	1.070
26.3	4.542	4.304	0.20	0.756
31.0	4.541	4.304	0.23	0.761
35.7	4.527	4.304	0.27	0.808
40.4	4.565	4.304	0.31	0.690
45.1	4.587	4.304	0.35	0.636

P(ATM) = 1.10   G(G/S-CM2) = 10.7
Q(W/CM2) = 0.008   XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.322	4.275	-0.01	0.157
7.5	4.324	4.277	-0.01	0.159
12.2	4.333	4.280	-0.01	0.140
16.9	4.339	4.283	-0.01	0.132
21.6	4.336	4.286	-0.01	0.149
26.3	4.340	4.288	-0.01	0.144
31.0	4.343	4.291	-0.01	0.143
35.7	4.348	4.294	-0.01	0.137
40.4	4.361	4.297	-0.01	0.115
45.1	4.360	4.299	-0.01	0.123

P(ATM) = 1.07   G(G/S-CM2) = 11.0
Q(W/CM2) = 0.066   XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.485	4.280	-0.01	0.320
7.5	4.468	4.300	0.00	0.391
12.2	4.478	4.300	0.01	0.369
16.9	4.486	4.300	0.01	0.353
21.6	4.488	4.300	0.02	0.350
26.3	4.506	4.300	0.02	0.318
31.0	4.528	4.300	0.03	0.288
35.7	4.501	4.300	0.03	0.327
40.4	4.516	4.300	0.04	0.304
45.1	4.529	4.300	0.05	0.287

P(ATM) = 1.07 G(G/S-CM2) = 10.5
Q(W/CM2) = 0.113 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.513	4.298	0.00	0.527
7.5	4.485	4.298	0.01	0.604
12.2	4.494	4.298	0.02	0.576
16.9	4.501	4.298	0.03	0.557
21.6	4.498	4.298	0.04	0.564
26.3	4.532	4.298	0.05	0.484
31.0	4.543	4.298	0.06	0.461
35.7	4.521	4.298	0.07	0.507
40.4	4.543	4.298	0.08	0.461
45.1	4.562	4.298	0.09	0.428

P(ATM) = 1.07 G(G/S-CM2) = 10.4
Q(W/CM2) = 0.180 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.523	4.300	0.00	0.811
7.5	4.493	4.300	0.02	0.936
12.2	4.505	4.300	0.04	0.879
16.9	4.514	4.300	0.05	0.842
21.6	4.508	4.300	0.07	0.867
26.3	4.534	4.300	0.08	0.771
31.0	4.536	4.300	0.10	0.763
35.7	4.526	4.300	0.12	0.798
40.4	4.566	4.300	0.13	0.679
45.1	4.576	4.300	0.15	0.653

P(ATM) = 1.07 G(G/S-CM2) = 10.4
Q(W/CM2) = 0.177 XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.516	4.295	0.01	0.797
7.5	4.483	4.295	0.02	0.936
12.2	4.482	4.295	0.04	0.945
16.9	4.473	4.295	0.05	0.993
21.6	4.475	4.295	0.07	0.977
26.3	4.530	4.295	0.09	0.750
31.0	4.533	4.295	0.10	0.741
35.7	4.518	4.295	0.12	0.792
40.4	4.527	4.295	0.13	0.761
45.1	4.566	4.295	0.15	0.651

P(ATM) = 1.07 G(G/S-CM2) = 10.8
Q(W/CM2) = 0.113 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.472	4.292	-0.00	0.628
7.5	4.445	4.296	0.01	0.762
12.2	4.444	4.296	0.02	0.767
16.9	4.432	4.296	0.03	0.835
21.6	4.429	4.296	0.04	0.849
26.3	4.511	4.296	0.05	0.527
31.0	4.536	4.296	0.06	0.472
35.7	4.485	4.296	0.07	0.600
40.4	4.467	4.296	0.08	0.663
45.1	4.525	4.296	0.09	0.495

P(ATM) = 1.07 G(G/S-CM2) = 10.6
Q(W/CM2) = 0.054 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.419	4.282	-0.00	0.463
7.5	4.405	4.300	0.00	0.599
12.2	4.425	4.300	0.01	0.507
16.9	4.397	4.300	0.01	0.652
21.6	4.390	4.300	0.02	0.700
26.3	4.445	4.300	0.02	0.437
31.0	4.500	4.300	0.03	0.316
35.7	4.428	4.300	0.03	0.494
40.4	4.417	4.300	0.04	0.542
45.1	4.457	4.300	0.05	0.403

P(ATM) = 1.10 G(G/S-CM2) = 11.0
Q(W/CM2) = 0.007 XINLET = -0.02

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.317	4.263	-0.02	0.131
7.5	4.321	4.267	-0.02	0.130
12.2	4.326	4.270	-0.02	0.126
16.9	4.334	4.274	-0.01	0.116
21.6	4.331	4.277	-0.01	0.131
26.3	4.339	4.280	-0.01	0.120
31.0	4.339	4.284	-0.01	0.128
35.7	4.338	4.287	-0.01	0.140
40.4	4.341	4.291	-0.01	0.141
45.1	4.348	4.294	-0.01	0.130

P(ATM) = 1.10 G(G/S-CM2) = 27.5
Q(W/CM2) = 0.008 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.315	4.275	-0.01	0.193
7.5	4.316	4.277	-0.01	0.194
12.2	4.319	4.279	-0.01	0.190
16.9	4.321	4.280	-0.01	0.191
21.6	4.322	4.282	-0.01	0.196
26.3	4.322	4.284	-0.01	0.202
31.0	4.323	4.286	-0.01	0.209
35.7	4.323	4.288	-0.01	0.218
40.4	4.327	4.290	-0.01	0.206
45.1	4.327	4.292	-0.01	0.219

P(ATM) = 1.07 G(G/S-CM2) = 27.0
Q(W/CM2) = 0.066 XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.480	4.288	-0.00	0.346
7.5	4.475	4.297	-0.00	0.372
12.2	4.478	4.298	0.00	0.367
16.9	4.482	4.298	0.00	0.360
21.6	4.476	4.298	0.01	0.370
26.3	4.490	4.298	0.01	0.362
31.0	4.483	4.298	0.01	0.358
35.7	4.476	4.298	0.01	0.372
40.4	4.496	4.298	0.02	0.333
45.1	4.497	4.298	0.02	0.332

P(ATM) = 1.05 G(G/S-CM2) = 27.4
G(W/CM2) = 0.177 XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.507	4.289	0.00	0.814
7.5	4.488	4.289	0.01	0.891
12.2	4.488	4.289	0.01	0.893
16.9	4.495	4.289	0.02	0.862
21.6	4.491	4.289	0.03	0.878
26.3	4.521	4.289	0.03	0.764
31.0	4.526	4.289	0.04	0.747
35.7	4.508	4.289	0.04	0.808
40.4	4.540	4.289	0.05	0.707
45.1	4.551	4.289	0.06	0.652

P(ATM) = 1.07 G(G/S-CM2) = 26.7
Q(W/CM2) = 0.262 XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.515	4.299	0.00	1.216
7.5	4.495	4.299	0.01	1.340
12.2	4.498	4.299	0.02	1.324
16.9	4.509	4.299	0.03	1.250
21.6	4.506	4.299	0.04	1.272
26.3	4.520	4.299	0.05	1.189
31.0	4.522	4.299	0.06	1.176
35.7	4.511	4.299	0.07	1.241
40.4	4.572	4.299	0.08	0.962
45.1	4.580	4.299	0.09	0.935

P(ATM) = 1.07 G(G/S-CM2) = 27.6
Q(W/CM2) = 0.274 XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.511	4.298	0.00	1.287
7.5	4.492	4.298	0.01	1.412
12.2	4.492	4.298	0.02	1.416
16.9	4.504	4.298	0.03	1.333
21.6	4.502	4.298	0.04	1.347
26.3	4.514	4.298	0.05	1.267
31.0	4.515	4.298	0.06	1.260
35.7	4.506	4.298	0.07	1.320
40.4	4.568	4.298	0.08	1.015
45.1	4.622	4.298	0.09	0.846

P(ATM) = 1.07 G(G/S-CM2) = 28.3
Q(W/CM2) = 0.179 XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.495	4.292	0.00	0.883
7.5	4.466	4.292	0.01	1.028
12.2	4.459	4.292	0.01	1.073
16.9	4.462	4.292	0.02	1.052
21.6	4.464	4.292	0.03	1.043
26.3	4.519	4.292	0.03	0.787
31.0	4.527	4.292	0.04	0.762
35.7	4.506	4.292	0.04	0.837
40.4	4.508	4.292	0.05	0.826
45.1	4.555	4.292	0.06	0.681

P(ATM) = 1.07 G(G/S-CM2) = 27.9
Q(W/CM2) = 0.063 XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.397	4.291	-0.00	0.599
7.5	4.385	4.297	0.00	0.726
12.2	4.385	4.297	0.00	0.721
16.9	4.384	4.297	0.00	0.730
21.6	4.378	4.297	0.01	0.781
26.3	4.406	4.297	0.01	0.581
31.0	4.441	4.297	0.01	0.441
35.7	4.401	4.297	0.01	0.613
40.4	4.404	4.297	0.02	0.596
45.1	4.428	4.297	0.02	0.484

P(ATM) = 1.10 G(G/S-CM2) = 27.3
Q(W/CM2) = 0.008 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.324	4.284	-0.01	0.195
7.5	4.323	4.286	-0.01	0.205
12.2	4.327	4.288	-0.01	0.194
16.9	4.332	4.290	-0.01	0.183
21.6	4.331	4.292	-0.01	0.198
26.3	4.332	4.294	-0.01	0.202
31.0	4.330	4.296	-0.01	0.224
35.7	4.332	4.298	-0.01	0.223
40.4	4.343	4.300	-0.01	0.177
45.1	4.342	4.302	-0.01	0.189

P(ATM) = 1.93 G(G/S-CM2) = 13.1
Q(W/CM2) = 0.119 XINLET = -0.03

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.994	5.022	-0.02	******
7.5	4.967	5.030	-0.00	******
12.2	5.010	5.032	0.01	******
16.9	5.040	5.032	0.03	15.464
21.6	4.998	5.032	0.04	******
26.3	5.030	5.032	0.06	******
31.0	5.026	5.032	0.07	******
35.7	5.025	5.032	0.09	******
40.4	5.097	5.032	0.10	1.830
45.1	5.099	5.032	0.12	1.784

P(ATM) = 1.98 G(G/S-CM2) = 13.1
Q(W/CM2) = 0.128 XINLET = -0.03

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.995	5.024	-0.02	******
7.5	4.969	5.034	-0.00	******
12.2	5.011	5.036	0.01	******
16.9	5.041	5.036	0.03	27.465
21.6	5.001	5.036	0.04	******
26.3	5.034	5.036	0.06	******
31.0	5.030	5.036	0.08	******
35.7	5.027	5.036	0.09	******
40.4	5.102	5.036	0.11	1.948
45.1	5.104	5.036	0.13	1.891

P(ATM) = 1.99 G(G/S-CM2) = 13.1
Q(W/CM2) = 0.134 XINLET = -0.04

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.010	5.025	-0.03	******
7.5	4.990	5.034	-0.02	******
12.2	5.015	5.043	0.00	******
16.9	5.039	5.043	0.02	******
21.6	5.013	5.043	0.04	******
26.3	5.032	5.043	0.05	******
31.0	5.029	5.043	0.07	******
35.7	5.028	5.043	0.09	******
40.4	5.103	5.043	0.11	2.252
45.1	5.106	5.043	0.12	2.122

P(ATM) = 2.01 G(G/S-CM2) = 28.1
Q(W/CM2) = 0.198 XINLET = -0.14

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.005	4.959	-0.14	4.309
7.5	4.995	4.967	-0.12	7.064
12.2	5.007	4.974	-0.11	6.037
16.9	5.028	4.981	-0.10	4.234
21.6	5.006	4.989	-0.09	11.268
26.3	5.019	4.996	-0.07	8.596
31.0	5.017	5.003	-0.06	14.691
35.7	5.012	5.011	-0.05	******
40.4	5.089	5.018	-0.04	2.807
45.1	5.091	5.025	-0.02	3.000

P(ATM) = 2.01 G(G/S-CM2) = 27.7
Q(W/CM2) = 0.135 XINLET = -0.14

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.024	4.958	-0.14	2.055
7.5	5.012	4.964	-0.13	2.796
12.2	5.024	4.969	-0.12	2.455
16.9	5.046	4.975	-0.11	1.895
21.6	5.025	4.980	-0.10	3.026
26.3	5.020	4.985	-0.10	3.961
31.0	5.017	4.991	-0.09	5.187
35.7	5.018	4.996	-0.08	6.272
40.4	5.098	5.002	-0.07	1.409
45.1	5.098	5.007	-0.06	1.497

P(ATM) = 2.02 G(G/S-CM2) = 45.3
Q(W/CM2) = 0.374 XINLET = -0.34

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.939	4.736	-0.33	1.842
7.5	4.912	4.753	-0.32	2.353
12.2	4.929	4.770	-0.30	2.345
16.9	4.963	4.786	-0.29	2.119
21.6	4.942	4.803	-0.27	2.696
26.3	4.960	4.820	-0.26	2.674
31.0	4.965	4.837	-0.24	2.927
35.7	4.953	4.854	-0.23	3.759
40.4	5.066	4.871	-0.21	1.913
45.1	5.071	4.888	-0.20	2.041

P(ATM) = 1.99 G(G/S-CM2) = 13.3
Q(W/CM2) = 0.125 XINLET = -0.04

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.966	5.021	-0.03	******
7.5	4.930	5.030	-0.02	******
12.2	5.002	5.039	-0.00	******
16.9	5.043	5.039	0.02	32.981
21.6	4.976	5.039	0.03	******
26.3	5.033	5.039	0.05	******
31.0	5.029	5.039	0.06	******
35.7	5.030	5.039	0.08	******
40.4	5.107	5.039	0.10	1.825
45.1	5.105	5.039	0.11	1.905

P(ATM) = 2.01 G(G/S-CM2) = 27.7
Q(W/CM2) = 0.135 XINLET = -0.14

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.024	4.958	-0.14	2.055
7.5	5.012	4.964	-0.13	2.796
12.2	5.024	4.969	-0.12	2.455
16.9	5.046	4.975	-0.11	1.895
21.6	5.025	4.980	-0.10	3.026
26.3	5.020	4.985	-0.10	3.961
31.0	5.017	4.991	-0.09	5.187
35.7	5.018	4.996	-0.08	6.272
40.4	5.098	5.002	-0.07	1.409
45.1	5.098	5.007	-0.06	1.497

P(ATM) = 2.02 G(G/S-CM2) = 45.3
Q(W/CM2) = 0.374 XINLET = -0.34

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.939	4.736	-0.33	1.842
7.5	4.912	4.753	-0.32	2.353
12.2	4.929	4.770	-0.30	2.345
16.9	4.953	4.786	-0.29	2.119
21.6	4.942	4.803	-0.27	2.696
26.3	4.960	4.820	-0.26	2.674
31.0	4.965	4.837	-0.24	2.927
35.7	4.953	4.854	-0.23	3.759
40.4	5.066	4.871	-0.21	1.913
45.1	5.071	4.888	-0.20	2.041

P(ATM) = 1.99 G(G/S-CM2) = 13.3
Q(W/CM2) = 0.125 XINLET = -0.04

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.966	5.021	-0.03	******
7.5	4.930	5.030	-0.02	******
12.2	5.002	5.039	-0.00	******
16.9	5.043	5.039	0.02	32.981
21.6	4.976	5.039	0.03	******
26.3	5.033	5.039	0.05	******
31.0	5.029	5.039	0.06	******
35.7	5.030	5.039	0.08	******
40.4	5.107	5.039	0.10	1.825
45.1	5.105	5.039	0.11	1.905

P(ATM) = 1.98 G(G/S-CM2) = 13.4
Q(W/CM2) = 0.119 XINLET = -0.03

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.981	5.019	-0.02	******
7.5	4.950	5.027	-0.01	******
12.2	5.004	5.032	0.01	******
16.9	5.039	5.032	0.02	14.848
21.6	4.988	5.032	0.04	******
26.3	5.032	5.032	0.05	******
31.0	5.029	5.032	0.07	******
35.7	5.027	5.032	0.08	******
40.4	5.103	5.032	0.10	1.664
45.1	5.105	5.032	0.11	1.634

P(ATM) = 1.98 G(G/S-CM2) = 13.4
Q(W/CM2) = 0.064 XINLET = -0.04

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.021	5.009	-0.04	5.306
7.5	5.002	5.014	-0.03	******
12.2	5.025	5.019	-0.02	9.230
16.9	5.047	5.023	-0.01	2.701
21.6	5.022	5.028	-0.01	******
26.3	5.040	5.032	0.00	7.665
31.0	5.035	5.032	0.01	20.693
35.7	5.037	5.032	0.02	10.776
40.4	5.098	5.032	0.03	0.966
45.1	5.098	5.032	0.03	0.956

P(ATM) = 2.00 G(G/S-CM2) = 47.3
Q(W/CM2) = 0.028 XINLET = -0.32

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.726	4.716	-0.32	2.697
7.5	4.721	4.717	-0.32	6.221
12.2	4.739	4.718	-0.32	1.345
16.9	4.751	4.718	-0.32	0.876
21.6	4.742	4.720	-0.32	1.261
26.3	4.750	4.720	-0.32	0.966
31.0	4.749	4.721	-0.32	1.021
35.7	4.753	4.722	-0.32	0.917
40.4	4.790	4.723	-0.32	0.423
45.1	4.794	4.724	-0.31	0.408

P(ATM) = 2.00 G(G/S-CM2) = 46.6
Q(W/CM2) = 0.118 XINLET = -0.32

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.827	4.719	-0.32	1.095
7.5	4.826	4.724	-0.32	1.158
12.2	4.855	4.729	-0.31	0.943
16.9	4.883	4.735	-0.31	0.798
21.6	4.854	4.740	-0.30	0.947
26.3	4.888	4.745	-0.30	0.826
31.0	4.891	4.750	-0.29	0.838
35.7	4.892	4.755	-0.29	0.862
40.4	4.960	4.760	-0.29	0.591
45.1	4.957	4.765	-0.28	0.586

P(ATM) = 2.00 G(G/S-CM2) = 46.4
Q(W/CM2) = 0.183 XINLET = -0.31

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.906	4.740	-0.31	1.106
7.5	4.903	4.748	-0.30	1.180
12.2	4.930	4.756	-0.29	1.049
16.9	4.959	4.764	-0.29	0.934
21.6	4.936	4.771	-0.28	1.100
26.3	4.958	4.779	-0.27	1.023
31.0	4.959	4.787	-0.27	1.065
35.7	4.959	4.795	-0.26	1.113
40.4	5.042	4.802	-0.25	0.763
45.1	5.046	4.810	-0.25	0.777

P(ATM) = 2.00 G(G/S-CM2) = 46.6
Q(W/CM2) = 0.250 XINLET = -0.31

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.931	4.742	-0.31	1.317
7.5	4.911	4.753	-0.30	1.575
12.2	4.936	4.764	-0.29	1.453
16.9	4.965	4.775	-0.28	1.314
21.6	4.941	4.786	-0.27	1.612
26.3	4.961	4.797	-0.26	1.527
31.0	4.962	4.808	-0.25	1.628
35.7	4.956	4.819	-0.24	1.837
40.4	5.050	4.831	-0.23	1.140
45.1	5.054	4.842	-0.22	1.179

P(ATM) = 2.00 G(G/S-CM2) = 47.4
Q(W/CM2) = 0.373 XINLET = -0.32

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.919	4.728	-0.31	1.953
7.5	4.898	4.745	-0.30	2.438
12.2	4.921	4.763	-0.29	2.353
16.9	4.956	4.780	-0.27	2.123
21.6	4.923	4.797	-0.26	2.968
26.3	4.948	4.815	-0.25	2.801
31.0	4.951	4.832	-0.23	3.123
35.7	4.940	4.849	-0.22	4.122
40.4	5.063	4.867	-0.21	1.899
45.1	5.070	4.884	-0.19	2.008

P(ATM) = 1.50 G(G/S-CM2) = 62.9
Q(W/CM2) = 0.029 XINLET = -0.05

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.602	4.564	-0.05	0.773
7.5	4.566	4.566	-0.05	******
12.2	4.603	4.567	-0.05	0.814
16.9	4.627	4.568	-0.05	0.501
21.6	4.603	4.570	-0.05	0.864
26.3	4.607	4.571	-0.05	0.816
31.0	4.597	4.573	-0.05	1.196
35.7	4.597	4.574	-0.05	1.238
40.4	4.621	4.575	-0.05	0.635
45.1	4.653	4.577	-0.05	0.381

P(ATM) = 1.35 G(G/S-CM2) = 64.6
Q(W/CM2) = 0.171 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.668	4.557	0.00	1.537
7.5	4.651	4.557	0.00	1.810
12.2	4.667	4.557	0.01	1.556
16.9	4.691	4.557	0.01	1.278
21.6	4.661	4.557	0.01	1.640
26.3	4.686	4.557	0.02	1.326
31.0	4.687	4.557	0.02	1.311
35.7	4.680	4.557	0.02	1.390
40.4	4.732	4.557	0.02	0.976
45.1	4.738	4.557	0.03	0.942

P(ATM) = 1.37 G(G/S-CM2) = 61.2
Q(W/CM2) = 0.305 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.669	4.575	0.00	3.252
7.5	4.654	4.575	0.01	3.868
12.2	4.666	4.575	0.01	3.361
16.9	4.695	4.575	0.02	2.552
21.6	4.687	4.575	0.02	2.729
26.3	4.702	4.575	0.03	2.411
31.0	4.706	4.575	0.03	2.330
35.7	4.721	4.575	0.04	2.087
40.4	4.804	4.575	0.04	1.335
45.1	4.839	4.575	0.05	1.156

P(ATM) = 1.36 G(G/S-CM2) = 61.2
Q(W/CM2) = 0.141 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.693	4.570	0.00	1.156
7.5	4.671	4.570	0.00	1.410
12.2	4.677	4.570	0.01	1.326
16.9	4.682	4.570	0.01	1.263
21.6	4.677	4.570	0.01	1.318
26.3	4.706	4.570	0.01	1.045
31.0	4.702	4.570	0.02	1.076
35.7	4.693	4.570	0.02	1.152
40.4	4.732	4.570	0.02	0.871
45.1	4.737	4.570	0.02	0.847

P(ATM) = 1.06 G(G/S-CM2) = 33.5
Q(W/CM2) = 0.075 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.464	4.283	0.00	0.414
7.5	4.461	4.283	0.00	0.420
12.2	4.486	4.283	0.01	0.368
16.9	4.487	4.283	0.01	0.367
21.6	4.456	4.283	0.01	0.433
26.3	4.474	4.283	0.01	0.393
31.0	4.478	4.283	0.01	0.384
35.7	4.471	4.283	0.02	0.397
40.4	4.500	4.283	0.02	0.344
45.1	4.498	4.283	0.02	0.348

P(ATM) = 1.06 G(G/S-CM2) = 28.5
Q(W/CM2) = 0.243 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.479	4.285	0.00	1.251
7.5	4.452	4.285	0.01	1.451
12.2	4.473	4.285	0.02	1.296
16.9	4.493	4.285	0.03	1.168
21.6	4.464	4.285	0.04	1.357
26.3	4.512	4.285	0.04	1.072
31.0	4.515	4.285	0.05	1.055
35.7	4.503	4.285	0.06	1.116
40.4	4.559	4.285	0.07	0.886
45.1	4.570	4.285	0.08	0.854

P(ATM) = 1.98 G(G/S-CM2) = 13.7
Q(W/CM2) = 0.008 XINLET = 0.11

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.050	5.035	0.11	0.496
7.5	5.052	5.035	0.11	0.436
12.2	5.050	5.035	0.11	0.491
16.9	5.050	5.035	0.11	0.501
21.6	5.049	5.035	0.11	0.545
26.3	5.050	5.035	0.11	0.491
31.0	5.050	5.035	0.11	0.484
35.7	5.050	5.035	0.11	0.480
40.4	5.049	5.035	0.12	0.540
45.1	5.046	5.035	0.12	0.655

P(ATM) = 1.99 G(G/S-CM2) = 14.0
Q(W/CM2) = 0.028 XINLET = 0.09

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.045	5.036	0.09	3.044
7.5	5.039	5.036	0.10	7.545
12.2	5.042	5.036	0.10	4.348
16.9	5.044	5.036	0.10	3.380
21.6	5.043	5.036	0.11	4.115
26.3	5.046	5.036	0.11	2.852
31.0	5.047	5.036	0.11	2.580
35.7	5.046	5.036	0.12	2.744
40.4	5.052	5.036	0.12	1.705
45.1	5.052	5.036	0.12	1.712

P(ATM) = 1.99 G(G/S-CM2) = 13.2
Q(W/CM2) = 0.064 XINLET = 0.13

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.044	5.039	0.13	12.902
7.5	5.034	5.039	0.14	******
12.2	5.041	5.039	0.15	23.070
16.9	5.045	5.039	0.16	9.590
21.6	5.040	5.039	0.17	44.410
26.3	5.044	5.039	0.17	11.505
31.0	5.046	5.039	0.18	8.689
35.7	5.044	5.039	0.19	11.465
40.4	5.058	5.039	0.20	3.378
45.1	5.058	5.039	0.21	3.324

P(ATM) = 1.96 G(G/S-CM2) = 30.8
Q(W/CM2) = 0.065 XINLET = 0.03

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.016	5.020	0.03	******
7.5	5.020	5.020	0.04	******
12.2	5.011	5.020	0.04	******
16.9	5.009	5.020	0.04	******
21.6	5.014	5.020	0.05	******
26.3	5.015	5.020	0.05	******
31.0	5.015	5.020	0.05	******
35.7	5.011	5.020	0.06	******
40.4	5.022	5.020	0.06	27.620
45.1	5.024	5.020	0.06	15.796

P(ATM) = 1.93 G(G/S-CM2) = 31.4
Q(W/CM2) = 0.007 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.012	5.004	0.00	0.880
7.5	5.013	5.004	0.00	0.790
12.2	5.011	5.004	0.00	1.013
16.9	5.010	5.004	0.00	1.121
21.6	5.014	5.004	0.00	0.710
26.3	5.013	5.004	0.00	0.807
31.0	5.012	5.004	0.00	0.887
35.7	5.011	5.004	0.00	1.103
40.4	5.010	5.004	0.00	1.199
45.1	5.012	5.004	0.00	0.965

P(ATM) = 1.95   G(G/S-CM2) = 30.7
Q(W/CM2) = 0.028   XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.035	5.016	0.00	1.489
7.5	5.033	5.016	0.00	1.671
12.2	5.031	5.016	0.00	1.870
16.9	5.033	5.016	0.01	1.658
21.6	5.030	5.016	0.01	1.978
26.3	5.031	5.016	0.01	1.881
31.0	5.033	5.016	0.01	1.678
35.7	5.031	5.016	0.01	1.956
40.4	5.037	5.016	0.01	1.338
45.1	5.039	5.016	0.01	1.239

P(ATM) = 1.95   G(G/S-CM2) = 31.6
Q(W/CM2) = 0.064   XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.023	5.012	0.00	5.880
7.5	5.020	5.012	0.01	8.085
12.2	5.018	5.012	0.01	10.628
16.9	5.025	5.012	0.01	4.715
21.6	5.022	5.012	0.01	6.108
26.3	5.022	5.012	0.02	6.440
31.0	5.025	5.012	0.02	5.043
35.7	5.021	5.012	0.02	6.817
40.4	5.031	5.012	0.03	3.380
45.1	5.036	5.012	0.03	2.708

P(ATM) = 1.88   G(G/S-CM2) = 56.4
Q(W/CM2) = 0.003   XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.958	4.964	0.00	******
7.5	4.965	4.964	0.00	2.596
12.2	4.990	4.964	0.00	0.105
16.9	4.962	4.964	0.00	******
21.6	4.990	4.964	0.00	0.106
26.3	4.973	4.964	0.00	0.298
31.0	4.974	4.964	0.00	0.288
35.7	4.965	4.964	0.00	6.334
40.4	4.960	4.964	0.00	******
45.1	4.976	4.964	0.00	0.234

P(ATM) = 1.90　　G(G/S-CM2) = 42.2
Q(W/CM2) = 0.007　　XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.007	4.980	0.00	0.275
7.5	4.991	4.980	0.00	0.683
12.2	4.984	4.980	0.00	1.770
16.9	4.987	4.980	0.00	1.096
21.6	4.985	4.980	0.00	1.653
26.3	4.998	4.980	0.00	0.419
31.0	4.989	4.980	0.00	0.805
35.7	4.995	4.980	0.00	0.506
40.4	4.983	4.980	0.00	2.199
45.1	4.996	4.980	0.00	0.462

P(ATM) = 1.90　　G(G/S-CM2) = 42.1
Q(W/CM2) = 0.029　　XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.029	4.980	0.00	0.594
7.5	5.013	4.980	0.00	0.875
12.2	5.010	4.980	0.00	0.968
16.9	5.025	4.980	0.00	0.651
21.6	5.011	4.980	0.00	0.952
26.3	5.017	4.980	0.01	0.799
31.0	5.006	4.980	0.01	1.123
35.7	5.013	4.980	0.01	0.876
40.4	5.014	4.980	0.01	0.873
45.1	5.023	4.980	0.01	0.672

P(ATM) = 2.00　　G(G/S-CM2) = 45.3
Q(W/CM2) = 0.064　　XINLET = -0.10

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.3	5.021	4.982	-0.10	1.655
7.5	5.003	4.983	-0.10	3.172
12.2	5.000	4.984	-0.10	3.895
16.9	5.016	4.984	-0.09	2.029
21.6	5.004	4.985	-0.09	3.328
26.3	5.013	4.986	-0.09	2.313
31.0	5.013	4.986	-0.09	2.367
35.7	5.007	4.987	-0.08	3.229
40.4	5.017	4.988	-0.08	2.154
45.1	5.024	4.989	-0.08	1.803

P(ATM) = 2.00 G(G/S-CM2) = 47.6
Q(W/CM2) = 0.117 XINLET = -0.11

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.007	4.975	-0.11	3.681
7.5	4.994	4.976	-0.10	6.304
12.2	4.998	4.977	-0.10	5.461
16.9	5.015	4.977	-0.10	3.129
21.6	5.003	4.978	-0.09	4.699
26.3	5.000	4.979	-0.09	5.624
31.0	5.003	4.980	-0.08	5.110
35.7	4.998	4.981	-0.08	6.872
40.4	5.019	4.981	-0.07	3.093
45.1	5.020	4.982	-0.07	3.086

P(ATM) = 1.93 G(G/S-CM2) = 41.6
Q(W/CM2) = 0.266 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.992	5.000	0.01	******
7.5	4.988	5.000	0.02	******
12.2	5.009	5.000	0.03	27.314
16.9	5.059	5.000	0.04	4.487
21.6	5.055	5.000	0.05	4.789
26.3	5.106	5.000	0.06	2.490
31.0	5.097	5.000	0.07	2.728
35.7	5.148	5.000	0.08	1.789
40.4	5.217	5.000	0.09	1.219
45.1	5.250	5.000	0.10	1.059

P(ATM) = 1.97 G(G/S-CM2) = 11.9
Q(W/CM2) = 0.123 XINLET = 0.02

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.015	5.026	0.03	******
7.5	4.970	5.026	0.05	******
12.2	5.008	5.026	0.07	******
16.9	5.029	5.026	0.08	43.497
21.6	5.001	5.026	0.10	******
26.3	5.022	5.026	0.12	******
31.0	5.022	5.026	0.13	******
35.7	5.024	5.026	0.15	******
40.4	5.081	5.026	0.17	2.264
45.1	5.114	5.026	0.19	1.403

P(ATM) = 1.50 G(G/S-CM2) = 15.8
Q(W/CM2) = 0.008 XINLET = -0.21

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.073	4.026	-0.21	0.175
7.5	4.071	4.029	-0.21	0.194
12.2	4.083	4.032	-0.21	0.160
16.9	4.090	4.035	-0.21	0.151
21.6	4.089	4.038	-0.21	0.161
26.3	4.095	4.041	-0.21	0.153
31.0	4.098	4.044	-0.21	0.155
35.7	4.101	4.047	-0.21	0.153
40.4	4.108	4.051	-0.21	0.142
45.1	4.111	4.054	-0.21	0.144

P(ATM) = 1.50 G(G/S-CM2) = 15.4
Q(W/CM2) = 0.034 XINLET = -0.21

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.220	4.032	-0.21	0.182
7.5	4.223	4.044	-0.21	0.191
12.2	4.264	4.055	-0.20	0.164
16.9	4.288	4.067	-0.20	0.155
21.6	4.287	4.079	-0.20	0.165
26.3	4.305	4.091	-0.20	0.160
31.0	4.314	4.102	-0.19	0.162
35.7	4.329	4.114	-0.19	0.160
40.4	4.357	4.126	-0.19	0.148
45.1	4.365	4.137	-0.19	0.151

P(ATM) = 1.50 G(G/S-CM2) = 16.0
Q(W/CM2) = 0.065 XINLET = -0.21

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.390	4.037	-0.21	0.185
7.5	4.402	4.059	-0.20	0.191
12.2	4.466	4.081	-0.20	0.170
16.9	4.503	4.103	-0.19	0.163
21.6	4.505	4.124	-0.19	0.172
26.3	4.534	4.146	-0.19	0.168
31.0	4.551	4.167	-0.18	0.171
35.7	4.575	4.189	-0.18	0.169
40.4	4.626	4.211	-0.17	0.158
45.1	4.636	4.233	-0.17	0.162

P(ATM) = 1.50   G(G/S-CM2) = 15.9
Q(W/CM2) = 0.115   XINLET = -0.21

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.652	4.046	-0.21	0.190
7.5	4.653	4.082	-0.20	0.201
12.2	4.721	4.117	-0.19	0.190
16.9	4.752	4.152	-0.18	0.191
21.6	4.725	4.188	-0.17	0.213
26.3	4.752	4.223	-0.17	0.217
31.0	4.750	4.258	-0.16	0.233
35.7	4.756	4.294	-0.15	0.248
40.4	4.813	4.329	-0.14	0.237
45.1	4.813	4.365	-0.13	0.255

P(ATM) = 1.50   G(G/S-CM2) = 16.2
Q(W/CM2) = 0.253   XINLET = -0.21

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.726	4.067	-0.20	0.384
7.5	4.647	4.130	-0.18	0.490
12.2	4.710	4.194	-0.16	0.490
16.9	4.745	4.257	-0.15	0.518
21.6	4.707	4.320	-0.13	0.654
26.3	4.738	4.383	-0.11	0.715
31.0	4.736	4.447	-0.09	0.874
35.7	4.733	4.510	-0.08	1.134
40.4	4.818	4.573	-0.06	1.036
45.1	4.819	4.637	-0.04	1.385

P(ATM) = 1.50   G(G/S-CM2) = 33.9
Q(W/CM2) = 0.063   XINLET = -0.21

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.205	4.029	-0.21	0.360
7.5	4.212	4.039	-0.21	0.365
12.2	4.241	4.050	-0.21	0.329
16.9	4.261	4.060	-0.20	0.314
21.6	4.261	4.070	-0.20	0.329
26.3	4.280	4.080	-0.20	0.316
31.0	4.287	4.090	-0.20	0.321
35.7	4.296	4.100	-0.20	0.323
40.4	4.329	4.110	-0.19	0.289
45.1	4.338	4.121	-0.19	0.290

P(ATM) = 1.50　　G(G/S-CM2) = 33.6
Q(W/CM2) = 0.113　　XINLET = -0.21

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.340	4.033	-0.21	0.367
7.5	4.352	4.050	-0.21	0.374
12.2	4.404	4.068	-0.20	0.336
16.9	4.435	4.086	-0.20	0.323
21.6	4.432	4.104	-0.19	0.343
26.3	4.467	4.121	-0.19	0.327
31.0	4.477	4.139	-0.19	0.334
35.7	4.490	4.157	-0.18	0.340
40.4	4.548	4.175	-0.18	0.303
45.1	4.563	4.192	-0.18	0.305

P(ATM) = 1.50　　G(G/S-CM2) = 33.9
Q(W/CM2) = 0.251　　XINLET = -0.21

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.677	4.044	-0.21	0.397
7.5	4.651	4.080	-0.20	0.440
12.2	4.695	4.117	-0.19	0.435
16.9	4.723	4.153	-0.18	0.441
21.6	4.699	4.190	-0.17	0.493
26.3	4.720	4.226	-0.17	0.509
31.0	4.713	4.262	-0.16	0.552
35.7	4.715	4.299	-0.15	0.604
40.4	4.799	4.336	-0.14	0.542
45.1	4.802	4.372	-0.13	0.584

P(ATM) = 1.50　　G(G/S-CM2) = 34.0
Q(W/CM2) = 0.512　　XINLET = -0.21

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.678	4.062	-0.20	0.833
7.5	4.611	4.123	-0.18	1.051
12.2	4.657	4.184	-0.17	1.084
16.9	4.697	4.245	-0.15	1.133
21.6	4.659	4.306	-0.13	1.451
26.3	4.689	4.367	-0.12	1.592
31.0	4.694	4.428	-0.10	1.931
35.7	4.678	4.489	-0.08	2.715
40.4	4.824	4.550	-0.07	1.873
45.1	4.838	4.611	-0.05	2.261

P(ATM) = 1.50 G(G/S-CM2) = 45.0
Q(W/CM2) = 0.112 XINLET = -0.17

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.383	4.213	-0.16	0.661
7.5	4.391	4.222	-0.16	0.663
12.2	4.418	4.231	-0.16	0.599
16.9	4.436	4.240	-0.16	0.573
21.6	4.437	4.249	-0.15	0.595
26.3	4.449	4.258	-0.15	0.587
31.0	4.458	4.267	-0.15	0.587
35.7	4.449	4.276	-0.14	0.647
40.4	4.495	4.285	-0.14	0.534
45.1	4.506	4.294	-0.14	0.529

P(ATM) = 1.50 G(G/S-CM2) = 45.6
Q(W/CM2) = 0.212 XINLET = -0.17

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.544	4.219	-0.16	0.651
7.5	4.559	4.236	-0.16	0.655
12.2	4.601	4.253	-0.15	0.609
16.9	4.628	4.270	-0.15	0.591
21.6	4.626	4.287	-0.14	0.625
26.3	4.644	4.304	-0.14	0.623
31.0	4.654	4.321	-0.13	0.636
35.7	4.643	4.338	-0.13	0.693
40.4	4.721	4.355	-0.12	0.579
45.1	4.732	4.372	-0.12	0.588

P(ATM) = 1.50 G(G/S-CM2) = 45.5
Q(W/CM2) = 0.416 XINLET = -0.16

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.652	4.235	-0.16	0.999
7.5	4.618	4.266	-0.15	1.184
12.2	4.640	4.297	-0.14	1.214
16.9	4.673	4.329	-0.13	1.209
21.6	4.648	4.360	-0.12	1.444
26.3	4.663	4.391	-0.11	1.530
31.0	4.668	4.422	-0.10	1.692
35.7	4.648	4.453	-0.09	2.137
40.4	4.763	4.484	-0.08	1.490
45.1	4.758	4.515	-0.07	1.647

P(ATM) = 1.50 G(G/S-CM2) = 44.4
Q(W/CM2) = 0.557 XINLET = -0.16

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.638	4.250	-0.15	1.434
7.5	4.595	4.284	-0.14	1.793
12.2	4.619	4.319	-0.12	1.858
16.9	4.659	4.354	-0.11	1.828
21.6	4.634	4.388	-0.10	2.270
26.3	4.652	4.423	-0.08	2.428
31.0	4.658	4.458	-0.07	2.775
35.7	4.633	4.492	-0.05	3.954
40.4	4.785	4.527	-0.04	2.162
45.1	4.796	4.561	-0.03	2.379

P(ATM) = 1.36 G(G/S-CM2) = 57.7
Q(W/CM2) = 0.113 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.675	4.566	0.00	1.033
7.5	4.666	4.566	0.00	1.131
12.2	4.678	4.566	0.01	1.006
16.9	4.658	4.566	0.01	1.225
21.6	4.665	4.566	0.01	1.143
26.3	4.655	4.566	0.01	1.269
31.0	4.657	4.566	0.01	1.245
35.7	4.649	4.566	0.02	1.368
40.4	4.675	4.566	0.02	1.034
45.1	4.682	4.566	0.02	0.975

P(ATM) = 1.36 G(G/S-CM2) = 57.3
Q(W/CM2) = 0.385 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.660	4.565	0.00	4.070
7.5	4.640	4.565	0.01	5.171
12.2	4.657	4.565	0.02	4.209
16.9	4.662	4.565	0.03	3.971
21.6	4.652	4.565	0.03	4.438
26.3	4.711	4.565	0.04	2.644
31.0	4.711	4.565	0.05	2.630
35.7	4.709	4.565	0.05	2.681
40.4	4.860	4.565	0.06	1.307
45.1	4.897	4.565	0.07	1.160

P(ATM) = 1.44 G(G/S-CM2) = 37.0
Q(W/CM2) = 0.114 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.740	4.632	0.00	1.056
7.5	4.730	4.632	0.01	1.163
12.2	4.735	4.632	0.01	1.105
16.9	4.739	4.632	0.01	1.062
21.6	4.740	4.632	0.02	1.059
26.3	4.740	4.632	0.02	1.053
31.0	4.740	4.632	0.02	1.057
35.7	4.740	4.632	0.03	1.052
40.4	4.759	4.632	0.03	0.898
45.1	4.763	4.632	0.03	0.865

P(ATM) = 1.43 G(G/S-CM2) = 23.4
Q(W/CM2) = 0.114 XINLET = 0.13

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.726	4.628	0.13	1.155
7.5	4.720	4.628	0.14	1.231
12.2	4.726	4.628	0.14	1.160
16.9	4.735	4.628	0.15	1.063
21.6	4.731	4.628	0.15	1.101
26.3	4.738	4.628	0.16	1.034
31.0	4.736	4.628	0.16	1.057
35.7	4.735	4.628	0.17	1.066
40.4	4.756	4.628	0.17	0.887
45.1	4.759	4.628	0.18	0.868

P(ATM) = 1.10 G(G/S-CM2) = 36.9
Q(W/CM2) = 0.028 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.111	4.027	-0.07	0.340
7.5	4.116	4.032	-0.07	0.338
12.2	4.127	4.037	-0.07	0.315
16.9	4.134	4.042	-0.07	0.310
21.6	4.139	4.047	-0.07	0.308
26.3	4.151	4.052	-0.07	0.285
31.0	4.151	4.057	-0.07	0.300
35.7	4.152	4.062	-0.07	0.314
40.4	4.170	4.066	-0.07	0.274
45.1	4.173	4.071	-0.06	0.280

P(ATM) = 1.44 G(G/S-CM2) = 37.0
Q(W/CM2) = 0.114 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.740	4.632	0.00	1.056
7.5	4.730	4.632	0.01	1.163
12.2	4.735	4.632	0.01	1.105
16.9	4.739	4.632	0.01	1.062
21.6	4.740	4.632	0.02	1.059
26.3	4.740	4.632	0.02	1.053
31.0	4.740	4.632	0.02	1.057
35.7	4.740	4.632	0.03	1.052
40.4	4.759	4.632	0.03	0.898
45.1	4.763	4.632	0.03	0.865

P(ATM) = 1.43 G(G/S-CM2) = 23.4
Q(W/CM2) = 0.114 XINLET = 0.13

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.726	4.628	0.13	1.155
7.5	4.720	4.628	0.14	1.231
12.2	4.726	4.628	0.14	1.160
16.9	4.735	4.628	0.15	1.063
21.6	4.731	4.628	0.15	1.101
26.3	4.738	4.628	0.16	1.034
31.0	4.736	4.628	0.16	1.057
35.7	4.735	4.628	0.17	1.066
40.4	4.756	4.628	0.17	0.887
45.1	4.759	4.628	0.18	0.868

P(ATM) = 1.10 G(G/S-CM2) = 36.9
Q(W/CM2) = 0.028 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.111	4.027	-0.07	0.340
7.5	4.116	4.032	-0.07	0.338
12.2	4.127	4.037	-0.07	0.315
16.9	4.134	4.042	-0.07	0.310
21.6	4.139	4.047	-0.07	0.308
26.3	4.151	4.052	-0.07	0.285
31.0	4.151	4.057	-0.07	0.300
35.7	4.152	4.062	-0.07	0.314
40.4	4.170	4.066	-0.07	0.274
45.1	4.173	4.071	-0.06	0.280

P(ATM) = 1.12   G(G/S-CM2) = 32.5
Q(W/CM2) = 0.112   XINLET = -0.08

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.348	4.029	-0.08	0.349
7.5	4.370	4.047	-0.07	0.346
12.2	4.408	4.066	-0.07	0.326
16.9	4.429	4.084	-0.07	0.323
21.6	4.439	4.103	-0.06	0.332
26.3	4.456	4.121	-0.06	0.334
31.0	4.467	4.140	-0.06	0.341
35.7	4.478	4.159	-0.05	0.349
40.4	4.522	4.177	-0.05	0.323
45.1	4.532	4.196	-0.05	0.332

P(ATM) = 1.10   G(G/S-CM2) = 32.8
Q(W/CM2) = 0.175   XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.476	4.037	-0.07	0.399
7.5	4.465	4.061	-0.06	0.435
12.2	4.478	4.086	-0.06	0.448
16.9	4.492	4.111	-0.05	0.461
21.6	4.486	4.136	-0.05	0.501
26.3	4.504	4.161	-0.04	0.511
31.0	4.514	4.186	-0.04	0.534
35.7	4.517	4.211	-0.03	0.572
40.4	4.553	4.235	-0.03	0.536
45.1	4.561	4.260	-0.02	0.584

P(ATM) = 1.05   G(G/S-CM2) = 31.7
Q(W/CM2) = 0.340   XINLET = -0.06

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.437	4.048	-0.05	0.758
7.5	4.466	4.092	-0.04	0.909
12.2	4.483	4.135	-0.03	0.980
16.9	4.506	4.179	-0.02	1.040
21.6	4.490	4.223	-0.01	1.274
26.3	4.501	4.267	-0.00	1.451
31.0	4.502	4.276	0.01	1.506
35.7	4.496	4.276	0.02	1.550
40.4	4.587	4.276	0.03	1.092
45.1	4.592	4.276	0.04	1.077

P(ATM) = 1.26 G(G/S-CM2) = 30.4
Q(W/CM2) = 0.113 XINLFT = -0.12

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.270	4.042	-0.12	0.495
7.5	4.291	4.055	-0.11	0.481
12.2	4.313	4.068	-0.11	0.465
16.9	4.334	4.082	-0.10	0.450
21.6	4.344	4.095	-0.10	0.457
26.3	4.356	4.109	-0.10	0.459
31.0	4.371	4.122	-0.09	0.456
35.7	4.377	4.135	-0.09	0.470
40.4	4.426	4.149	-0.09	0.409
45.1	4.437	4.162	-0.08	0.413

P(ATM) = 1.10 G(G/S-CM2) = 13.5
Q(W/CM2) = 0.065 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.420	4.034	-0.07	0.167
7.5	4.457	4.057	-0.07	0.161
12.2	4.484	4.080	-0.06	0.160
16.9	4.499	4.102	-0.06	0.162
21.6	4.500	4.125	-0.05	0.172
26.3	4.511	4.148	-0.05	0.177
31.0	4.519	4.170	-0.04	0.185
35.7	4.516	4.193	-0.04	0.199
40.4	4.550	4.216	-0.03	0.193
45.1	4.553	4.238	-0.03	0.205

P(ATM) = 1.08 G(G/S-CM2) = 13.9
Q(W/CM2) = 0.116 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.523	4.041	-0.06	0.241
7.5	4.509	4.075	-0.05	0.268
12.2	4.515	4.108	-0.05	0.286
16.9	4.528	4.142	-0.04	0.301
21.6	4.523	4.176	-0.03	0.335
26.3	4.544	4.210	-0.02	0.348
31.0	4.544	4.244	-0.01	0.386
35.7	4.541	4.278	-0.01	0.441
40.4	4.580	4.307	0.00	0.427
45.1	4.580	4.307	0.01	0.426

P(ATM) = 1.08 G(G/S-CM2) = 13.7
Q(W/CM2) = 0.175 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.519	4.051	-0.06	0.374
7.5	4.503	4.103	-0.05	0.438
12.2	4.511	4.155	-0.04	0.493
16.9	4.527	4.207	-0.02	0.548
21.6	4.520	4.259	-0.01	0.670
26.3	4.539	4.306	0.00	0.753
31.0	4.537	4.306	0.01	0.761
35.7	4.534	4.306	0.03	0.770
40.4	4.590	4.306	0.04	0.618
45.1	4.590	4.306	0.05	0.618

P(ATM) = 1.10 G(G/S-CM2) = 14.5
Q(W/CM2) = 0.063 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.406	4.037	-0.07	0.172
7.5	4.418	4.059	-0.07	0.177
12.2	4.417	4.081	-0.06	0.189
16.9	4.409	4.104	-0.06	0.207
21.6	4.408	4.126	-0.05	0.225
26.3	4.443	4.149	-0.05	0.215
31.0	4.454	4.171	-0.04	0.223
35.7	4.451	4.193	-0.04	0.245
40.4	4.455	4.215	-0.04	0.264
45.1	4.473	4.238	-0.03	0.269

P(ATM) = 1.95 G(G/S-CM2) = 7.2
Q(W/CM2) = 0.160 XINLET = -0.14

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.986	4.909	-0.12	2.070
7.5	4.988	4.940	-0.08	3.377
12.2	4.983	4.972	-0.04	14.499
16.9	4.988	5.003	-0.01	******
21.6	4.986	5.011	0.03	******
26.3	4.991	5.011	0.06	******
31.0	4.969	5.011	0.10	******
35.7	5.784	5.011	0.13	0.207
40.4	7.564	5.011	0.17	0.063
45.1	7.869	5.011	0.20	0.056

P(ATM) = 1.97 G(G/S-CM2) = 7.2
Q(W/CM2) = 0.165 XINLET = -0.16

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.012	4.914	-0.14	1.695
7.5	5.014	4.946	-0.10	2.441
12.2	5.008	4.978	-0.06	5.480
16.9	5.014	5.010	-0.03	38.991
21.6	5.013	5.031	0.01	******
26.3	5.021	5.031	0.05	******
31.0	6.762	5.031	0.09	0.095
35.7	7.676	5.031	0.13	0.063
40.4	8.093	5.031	0.17	0.054
45.1	8.113	5.031	0.20	0.054

P(ATM) = 1.15 G(G/S-CM2) = 9.5
Q(W/CM2) = 0.256 XINLET = -0.05

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.508	4.222	-0.04	0.897
7.5	4.451	4.322	-0.01	1.977
12.2	4.488	4.372	0.01	2.200
16.9	4.524	4.372	0.04	1.691
21.6	4.527	4.372	0.06	1.652
26.3	4.529	4.372	0.09	1.628
31.0	4.556	4.372	0.12	1.396
35.7	4.589	4.372	0.14	1.184
40.4	7.810	4.372	0.17	0.075
45.1	13.303	4.372	0.19	0.029

P(ATM) = 1.50 G(G/S-CM2) = 7.1
Q(W/CM2) = 0.253 XINLET = -0.08

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.720	4.559	-0.05	1.566
7.5	4.708	4.654	-0.01	4.655
12.2	4.734	4.687	0.03	5.444
16.9	4.759	4.687	0.07	3.549
21.6	4.733	4.687	0.11	5.514
26.3	4.764	4.687	0.14	3.312
31.0	7.556	4.687	0.18	0.088
35.7	12.640	4.687	0.22	0.032
40.4	16.831	4.687	0.26	0.021
45.1	18.559	4.687	0.30	0.018

P(ATM) = 1.47 G(G/S-CM2) = 14.1
Q(W/CM2) = 0.270 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.682	4.533	-0.05	1.822
7.5	4.664	4.585	-0.03	3.458
12.2	4.714	4.637	-0.01	3.511
16.9	4.729	4.663	0.01	4.091
21.6	4.666	4.663	0.03	******
26.3	4.799	4.663	0.05	1.981
31.0	4.759	4.663	0.07	2.822
35.7	4.876	4.663	0.09	1.268
40.4	4.900	4.663	0.12	1.141
45.1	5.905	4.663	0.14	0.218

P(ATM) = 1.48 G(G/S-CM2) = 14.5
Q(W/CM2) = 0.284 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.728	4.528	-0.06	1.421
7.5	4.725	4.582	-0.04	1.982
12.2	4.727	4.635	-0.02	3.089
16.9	4.744	4.672	0.01	3.990
21.6	4.736	4.672	0.03	4.467
26.3	4.742	4.672	0.05	4.094
31.0	4.747	4.672	0.07	3.814
35.7	4.794	4.672	0.09	2.334
40.4	5.769	4.672	0.11	0.259
45.1	8.253	4.672	0.14	0.079

P(ATM) = 1.48 G(G/S-CM2) = 14.4
Q(W/CM2) = 0.308 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.722	4.533	-0.06	1.623
7.5	4.718	4.591	-0.03	2.409
12.2	4.721	4.649	-0.01	4.279
16.9	4.739	4.671	0.01	4.569
21.6	4.730	4.671	0.04	5.210
26.3	4.739	4.671	0.06	4.579
31.0	4.914	4.671	0.09	1.265
35.7	6.755	4.671	0.11	0.148
40.4	11.103	4.671	0.13	0.048
45.1	13.196	4.671	0.16	0.036

P(ATM) = 1.34 G(G/S-CM2) = 56.3
Q(W/CM2) = 0.446 XINLET = -0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.637	4.547	-0.00	4.936
7.5	4.637	4.551	0.01	5.191
12.2	4.633	4.551	0.01	5.467
16.9	4.653	4.551	0.02	4.380
21.6	4.654	4.551	0.03	4.356
26.3	4.690	4.551	0.04	3.219
31.0	4.766	4.551	0.05	2.077
35.7	4.969	4.551	0.05	1.068
40.4	5.331	4.551	0.06	0.573
45.1	5.561	4.551	0.07	0.442

P(ATM) = 1.31 G(G/S-CM2) = 61.2
Q(W/CM2) = 0.530 XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.616	4.528	0.00	6.053
7.5	4.615	4.528	0.01	6.139
12.2	4.627	4.528	0.02	5.402
16.9	4.803	4.528	0.03	1.933
21.6	5.522	4.528	0.04	0.533
26.3	6.507	4.528	0.05	0.268
31.0	7.287	4.528	0.06	0.192
35.7	7.945	4.528	0.06	0.155
40.4	8.452	4.528	0.07	0.135
45.1	8.428	4.528	0.08	0.136

P(ATM) = 1.08 G(G/S-CM2) = 4.6
Q(W/CM2) = 0.212 XINLET = -0.02

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.486	4.304	0.01	1.163
7.5	4.417	4.304	0.05	1.877
12.2	4.488	4.304	0.10	1.152
16.9	4.509	4.304	0.14	1.031
21.6	4.466	4.304	0.18	1.307
26.3	4.541	4.304	0.23	0.893
31.0	4.535	4.304	0.27	0.915
35.7	4.518	4.304	0.31	0.989
40.4	4.584	4.304	0.36	0.756
45.1	8.135	4.304	0.40	0.055

P(ATM) = 1.13 G(G/S-CM2) = 4.5
Q(W/CM2) = 0.228 XINLET = -0.03

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.486	4.349	-0.00	1.672
7.5	4.416	4.360	0.05	4.021
12.2	4.480	4.360	0.09	1.886
16.9	4.501	4.360	0.14	1.612
21.6	4.468	4.360	0.19	2.100
26.3	4.535	4.360	0.24	1.297
31.0	4.531	4.360	0.29	1.331
35.7	4.522	4.360	0.34	1.407
40.4	8.370	4.360	0.38	0.057
45.1	13.961	4.360	0.43	0.024

P(ATM) = 1.07 G(G/S-CM2) = 4.6
Q(W/CM2) = 0.209 XINLET = -0.02

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.493	4.302	0.01	1.093
7.5	4.427	4.302	0.05	1.660
12.2	4.484	4.302	0.09	1.145
16.9	4.502	4.302	0.14	1.040
21.6	4.473	4.302	0.18	1.222
26.3	4.536	4.302	0.22	0.883
31.0	4.534	4.302	0.27	0.898
35.7	4.521	4.302	0.31	0.952
40.4	4.578	4.302	0.35	0.756
45.1	6.791	4.302	0.40	0.084

P(ATM) = 1.07 G(G/S-CM2) = 10.5
Q(W/CM2) = 0.247 XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.515	4.299	0.01	1.147
7.5	4.485	4.299	0.03	1.336
12.2	4.502	4.299	0.05	1.224
16.9	4.507	4.299	0.07	1.192
21.6	4.506	4.299	0.10	1.196
26.3	4.524	4.299	0.12	1.101
31.0	4.526	4.299	0.14	1.092
35.7	4.514	4.299	0.16	1.151
40.4	4.594	4.299	0.19	0.840
45.1	6.233	4.299	0.21	0.128

P(ATM) = 1.07 G(G/S-CM2) = 9.8
Q(W/CM2) = 0.257 XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.522	4.296	0.01	1.137
7.5	4.483	4.296	0.04	1.373
12.2	4.494	4.296	0.06	1.300
16.9	4.511	4.296	0.08	1.195
21.6	4.498	4.296	0.11	1.276
26.3	4.519	4.296	0.13	1.154
31.0	4.520	4.296	0.16	1.151
35.7	4.505	4.296	0.18	1.229
40.4	4.853	4.296	0.21	0.462
45.1	10.010	4.296	0.23	0.045

P(ATM) = 1.07 G(G/S-CM2) = 10.3
Q(W/CM2) = 0.245 XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.517	4.301	0.01	1.139
7.5	4.489	4.301	0.03	1.306
12.2	4.500	4.301	0.05	1.232
16.9	4.512	4.301	0.08	1.162
21.6	4.502	4.301	0.10	1.218
26.3	4.527	4.301	0.12	1.085
31.0	4.529	4.301	0.14	1.077
35.7	4.633	4.301	0.17	0.740
40.4	4.571	4.301	0.19	0.907
45.1	5.401	4.301	0.21	0.223

P(ATM) = 1.07 G(G/S-CM2) = 27.1
Q(W/CM2) = 0.297 XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.509	4.296	0.00	1.397
7.5	4.488	4.296	0.01	1.544
12.2	4.492	4.296	0.03	1.519
16.9	4.505	4.296	0.04	1.418
21.6	4.502	4.296	0.05	1.443
26.3	4.513	4.296	0.06	1.369
31.0	4.514	4.296	0.07	1.359
35.7	4.502	4.296	0.08	1.440
40.4	4.866	4.296	0.09	0.520
45.1	8.666	4.296	0.10	0.068

P(ATM) = 1.98 G(G/S-CM2) = 13.1
Q(W/CM2) = 0.163 XINLET = -0.03

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.990	5.025	-0.02	******
7.5	4.963	5.035	0.00	******
12.2	5.004	5.035	0.02	******
16.9	5.036	5.035	0.04	******
21.6	4.995	5.035	0.07	******
26.3	5.042	5.035	0.09	24.878
31.0	5.459	5.035	0.11	0.383
35.7	5.598	5.035	0.13	0.289
40.4	6.246	5.035	0.15	0.134
45.1	6.305	5.035	0.17	0.128

P(ATM) = 1.99 G(G/S-CM2) = 13.3
Q(W/CM2) = 0.172 XINLET = -0.05

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.991	5.020	-0.04	******
7.5	4.967	5.033	-0.02	******
12.2	5.005	5.044	0.00	******
16.9	5.035	5.044	0.03	******
21.6	5.021	5.044	0.05	******
26.3	5.433	5.044	0.07	0.442
31.0	5.918	5.044	0.09	0.197
35.7	6.296	5.044	0.12	0.138
40.4	6.508	5.044	0.14	0.118
45.1	6.491	5.044	0.16	0.119

P(ATM) = 1.98 G(G/S-CM2) = 27.8
Q(W/CM2) = 0.250 XINLET = -0.11

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.019	4.957	-0.10	4.058
7.5	5.012	4.968	-0.09	5.688
12.2	5.016	4.979	-0.07	6.748
16.9	5.034	4.990	-0.06	5.677
21.6	5.010	5.001	-0.04	26.575
26.3	5.028	5.012	-0.03	15.356
31.0	5.047	5.023	-0.01	10.358
35.7	5.085	5.034	0.00	4.837
40.4	5.186	5.034	0.02	1.644
45.1	5.448	5.034	0.03	0.603

P(ATM) = 1.97 G(G/S-CM2) = 27.4
Q(W/CM2) = 0.281 XINLET = -0.10

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.004	4.964	-0.09	7.075
7.5	4.992	4.977	-0.07	18.828
12.2	5.002	4.989	-0.06	20.947
16.9	5.034	5.001	-0.04	8.532
21.6	5.211	5.014	-0.02	1.420
26.3	5.622	5.026	-0.01	0.472
31.0	5.703	5.030	0.01	0.418
35.7	5.836	5.030	0.03	0.349
40.4	5.971	5.030	0.05	0.299
45.1	5.971	5.030	0.06	0.299

P(ATM) = 1.98 G(G/S-CM2) = 28.0
Q(W/CM2) = 0.276 XINLET = -0.12

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.059	4.956	-0.11	2.687
7.5	5.067	4.968	-0.09	2.799
12.2	5.024	4.980	-0.07	6.214
16.9	5.070	4.992	-0.06	3.532
21.6	5.202	5.004	-0.04	1.398
26.3	5.113	5.016	-0.02	2.850
31.0	5.317	5.028	-0.01	0.957
35.7	5.382	5.034	0.01	0.795
40.4	5.857	5.034	0.03	0.336
45.1	5.927	5.034	0.04	0.309

P(ATM) = 1.96 G(G/S-CM2) = 27.1
Q(W/CM2) = 0.246 XINLET = -0.09

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.008	4.966	-0.08	5.888
7.5	4.992	4.977	-0.06	16.008
12.2	5.003	4.988	-0.05	15.689
16.9	5.031	4.999	-0.03	7.535
21.6	5.011	5.009	-0.02	******
26.3	5.010	5.020	-0.00	******
31.0	5.030	5.024	0.01	38.789
35.7	4.989	5.024	0.02	******
40.4	5.312	5.024	0.04	0.853
45.1	5.297	5.024	0.05	0.901

P(ATM) = 2.01 G(G/S-CM2) = 45.3
Q(W/CM2) = 0.455 XINLET = -0.33

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.921	4.742	-0.32	2.538
7.5	4.899	4.762	-0.30	3.320
12.2	4.919	4.781	-0.28	3.311
16.9	4.956	4.801	-0.26	2.931
21.6	4.927	4.821	-0.25	4.276
26.3	4.951	4.841	-0.23	4.142
31.0	4.958	4.861	-0.21	4.691
35.7	4.960	4.880	-0.19	5.711
40.4	5.200	4.900	-0.18	1.517
45.1	5.275	4.920	-0.16	1.281

P(ATM) = 1.98 G(G/S-CM2) = 13.4
Q(W/CM2) = 0.171 XINLET = -0.04

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.961	5.016	-0.03	******
7.5	4.925	5.029	-0.01	******
12.2	4.994	5.034	0.01	******
16.9	5.037	5.034	0.03	71.248
21.6	4.976	5.034	0.06	******
26.3	5.060	5.034	0.08	6.723
31.0	5.300	5.034	0.10	0.644
35.7	5.949	5.034	0.12	0.187
40.4	6.442	5.034	0.14	0.122
45.1	6.423	5.034	0.16	0.123

P(ATM) = 2.00 G(G/S-CM2) = 47.0
Q(W/CM2) = 0.471 XINLET = -0.31

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.907	4.749	-0.30	2.967
7.5	4.882	4.768	-0.28	4.124
12.2	4.908	4.787	-0.27	3.907
16.9	4.949	4.807	-0.25	3.312
21.6	4.921	4.826	-0.23	4.984
26.3	4.960	4.846	-0.21	4.119
31.0	4.992	4.865	-0.20	3.708
35.7	5.000	4.885	-0.18	4.084
40.4	5.230	4.904	-0.16	1.442
45.1	5.405	4.924	-0.14	0.978

P(ATM) = 2.00 G(G/S-CM2) = 46.9
Q(W/CM2) = 0.578 XINLET = -0.31

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.895	4.755	-0.29	4.125
7.5	4.897	4.775	-0.27	4.767
12.2	5.060	4.796	-0.25	2.193
16.9	5.589	4.817	-0.23	0.748
21.6	6.037	4.838	-0.21	0.482
26.3	6.328	4.858	-0.19	0.393
31.0	6.205	4.879	-0.17	0.436
35.7	6.406	4.900	-0.15	0.384
40.4	6.704	4.921	-0.12	0.324
45.1	6.695	4.941	-0.10	0.329

P(ATM) = 1.36 G(G/S-CM2) = 61.3
Q(W/CM2) = 0.363 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.651	4.567	0.00	4.324
7.5	4.632	4.567	0.01	5.611
12.2	4.656	4.567	0.02	4.084
16.9	4.689	4.567	0.02	2.963
21.6	4.658	4.567	0.03	3.981
26.3	4.711	4.567	0.03	2.515
31.0	4.734	4.567	0.04	2.171
35.7	4.874	4.567	0.05	1.180
40.4	5.055	4.567	0.05	0.742
45.1	5.328	4.567	0.06	0.476

P(ATM) = 1.06 G(G/S-CM2) = 31.5
Q(W/CM2) = 0.298 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.469	4.285	0.01	1.617
7.5	4.446	4.285	0.01	1.842
12.2	4.476	4.285	0.02	1.555
16.9	4.500	4.285	0.03	1.384
21.6	4.462	4.285	0.04	1.677
26.3	4.502	4.285	0.05	1.369
31.0	4.506	4.285	0.06	1.347
35.7	4.493	4.285	0.07	1.428
40.4	5.440	4.285	0.08	0.258
45.1	9.505	4.285	0.08	0.057

P(ATM) = 1.06   G(G/S-CM2) = 30.0
Q(W/CM2) = 0.313   XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.463	4.285	0.01	1.763
7.5	4.437	4.285	0.02	2.057
12.2	4.469	4.285	0.03	1.698
16.9	4.496	4.285	0.04	1.486
21.6	4.458	4.285	0.04	1.805
26.3	4.498	4.285	0.05	1.468
31.0	4.503	4.285	0.06	1.434
35.7	4.875	4.285	0.07	0.530
40.4	9.357	4.285	0.08	0.062
45.1	11.579	4.285	0.09	0.043

P(ATM) = 1.06   G(G/S-CM2) = 29.4
Q(W/CM2) = 0.331   XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.460	4.286	0.01	1.903
7.5	4.435	4.286	0.02	2.221
12.2	4.470	4.286	0.03	1.801
16.9	4.498	4.286	0.04	1.560
21.6	4.458	4.286	0.05	1.926
26.3	4.497	4.286	0.06	1.570
31.0	4.586	4.286	0.07	1.102
35.7	8.969	4.286	0.08	0.071
40.4	12.564	4.286	0.09	0.040
45.1	13.543	4.286	0.10	0.036

P(ATM) = 1.06   G(G/S-CM2) = 29.0
Q(W/CM2) = 0.343   XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.454	4.288	0.01	2.072
7.5	4.431	4.288	0.02	2.395
12.2	4.465	4.288	0.03	1.940
16.9	4.494	4.288	0.04	1.667
21.6	4.453	4.288	0.05	2.084
26.3	4.492	4.288	0.06	1.685
31.0	5.451	4.288	0.07	0.295
35.7	10.928	4.288	0.08	0.052
40.4	14.151	4.288	0.10	0.035
45.1	14.745	4.288	0.11	0.033

P(ATM) = 1.06 G(G/S-CM2) = 28.7
Q(W/CM2) = 0.350 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.457	4.291	0.01	2.104
7.5	4.434	4.291	0.02	2.455
12.2	4.469	4.291	0.03	1.963
16.9	4.499	4.291	0.04	1.683
21.6	4.456	4.291	0.05	2.116
26.3	4.503	4.291	0.06	1.648
31.0	7.493	4.291	0.08	0.109
35.7	12.179	4.291	0.09	0.044
40.4	15.364	4.291	0.10	0.032
45.1	15.636	4.291	0.11	0.031

P(ATM) = 1.99 G(G/S-CM2) = 12.3
Q(W/CM2) = 0.113 XINLET = 0.18

L/D	TW (K)	TB (K)	X	H (W/CM2-K
2.8	5.036	5.043	0.19	******
7.5	5.026	5.043	0.20	******
12.2	5.034	5.043	0.22	******
16.9	5.043	5.043	0.24	******
21.6	5.041	5.043	0.25	******
26.3	5.167	5.043	0.27	0.915
31.0	5.220	5.043	0.28	0.643
35.7	5.363	5.043	0.30	0.354
40.4	5.583	5.043	0.32	0.210
45.1	5.616	5.043	0.33	0.198

P(ATM) = 1.96 G(G/S-CM2) = 29.8
Q(W/CM2) = 0.193 XINLET = 0.01

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.012	5.018	0.02	******
7.5	5.004	5.018	0.03	******
12.2	5.021	5.018	0.04	73.916
16.9	5.050	5.018	0.05	5.980
21.6	5.111	5.018	0.06	2.075
26.3	5.179	5.018	0.07	1.201
31.0	5.184	5.018	0.08	1.166
35.7	5.241	5.018	0.09	0.865
40.4	5.390	5.018	0.10	0.519
45.1	5.437	5.018	0.11	0.461

P(ATM) = 1.43   G(G/S-CM2) = 18.7
Q(W/CM2) = 0.356   XINLET = -0.20

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.708	4.069	-0.19	0.557
7.5	4.625	4.136	-0.17	0.727
12.2	4.688	4.203	-0.15	0.734
16.9	4.729	4.270	-0.13	0.774
21.6	4.688	4.337	-0.10	1.014
26.3	4.722	4.404	-0.08	1.119
31.0	4.723	4.471	-0.06	1.410
35.7	4.718	4.538	-0.04	1.977
40.4	4.885	4.605	-0.02	1.258
45.1	6.950	4.669	0.00	0.156

P(ATM) = 1.47   G(G/S-CM2) = 14.5
Q(W/CM2) = 0.350   XINLET = -0.20

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.706	4.067	-0.19	0.548
7.5	4.636	4.152	-0.16	0.724
12.2	4.689	4.238	-0.13	0.776
16.9	4.726	4.323	-0.11	0.868
21.6	4.689	4.409	-0.08	1.250
26.3	4.718	4.494	-0.05	1.567
31.0	4.718	4.580	-0.03	2.536
35.7	4.711	4.665	0.00	7.526
40.4	4.827	4.665	0.03	2.154
45.1	5.032	4.665	0.05	0.952

P(ATM) = 1.48   G(G/S-CM2) = 14.6
Q(W/CM2) = 0.366   XINLET = -0.20

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.708	4.073	-0.19	0.576
7.5	4.641	4.161	-0.16	0.763
12.2	4.690	4.250	-0.13	0.831
16.9	4.727	4.338	-0.10	0.941
21.6	4.692	4.426	-0.08	1.377
26.3	4.718	4.515	-0.05	1.794
31.0	4.719	4.603	-0.02	3.152
35.7	4.725	4.670	0.01	6.591
40.4	5.189	4.670	0.03	0.705
45.1	12.238	4.670	0.06	0.048

P(ATM) = 1.47 G(G/S-CM2) = 14.5
Q(W/CM2) = 0.431 XINLET = -0.20

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.696	4.084	-0.18	0.703
7.5	4.629	4.189	-0.15	0.981
12.2	4.679	4.294	-0.11	1.121
16.9	4.718	4.400	-0.08	1.352
21.6	4.687	4.505	-0.05	2.363
26.3	5.333	4.610	-0.02	0.596
31.0	15.343	4.662	0.02	0.040
35.7	20.195	4.662	0.05	0.028
40.4	27.678	4.662	0.08	0.019
45.1	26.334	4.662	0.11	0.020

P(ATM) = 1.50 G(G/S-CM2) = 33.9
Q(W/CM2) = 0.558 XINLET = -0.21

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.668	4.065	-0.20	0.925
7.5	4.603	4.126	-0.18	1.170
12.2	4.648	4.186	-0.16	1.209
16.9	4.590	4.247	-0.14	1.261
21.6	4.649	4.307	-0.13	1.634
26.3	4.681	4.368	-0.11	1.784
31.0	4.686	4.429	-0.09	2.167
35.7	4.676	4.489	-0.07	2.978
40.4	5.504	4.550	-0.05	0.585
45.1	11.555	4.610	-0.03	0.080

P(ATM) = 1.43 G(G/S-CM2) = 33.8
Q(W/CM2) = 0.703 XINLET = -0.18

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.645	4.078	-0.17	1.242
7.5	4.581	4.153	-0.14	1.642
12.2	4.625	4.227	-0.12	1.766
16.9	4.705	4.301	-0.10	1.742
21.6	13.009	4.375	-0.08	0.082
26.3	18.470	4.450	-0.05	0.050
31.0	21.038	4.524	-0.03	0.043
35.7	23.051	4.598	-0.01	0.038
40.4	28.122	4.629	0.01	0.030
45.1	24.420	4.629	0.04	0.035

P(ATM) = 1.50 G(G/S-CM2) = 44.5
Q(W/CM2) = 0.620 XINLET = -0.16

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.629	4.254	-0.15	1.655
7.5	4.590	4.288	-0.13	2.053
12.2	4.609	4.322	-0.12	2.157
16.9	4.650	4.356	-0.10	2.108
21.6	4.623	4.390	-0.09	2.662
26.3	4.642	4.424	-0.07	2.843
31.0	4.651	4.458	-0.06	3.210
35.7	4.624	4.492	-0.04	4.688
40.4	4.814	4.526	-0.02	2.150
45.1	5.409	4.560	-0.01	0.730

P(ATM) = 1.36 G(G/S-CM2) = 43.0
Q(W/CM2) = 0.675 XINLET = -0.10

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.624	4.288	-0.09	2.010
7.5	4.576	4.340	-0.07	2.860
12.2	4.600	4.391	-0.06	3.231
16.9	4.644	4.443	-0.04	3.372
21.6	4.616	4.495	-0.02	5.567
26.3	4.638	4.547	-0.01	7.413
31.0	4.766	4.570	0.01	3.439
35.7	6.550	4.570	0.03	0.341
40.4	10.737	4.570	0.04	0.110
45.1	11.912	4.570	0.06	0.092

P(ATM) = 1.36 G(G/S-CM2) = 44.3
Q(W/CM2) = 0.712 XINLET = -0.10

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.611	4.266	-0.09	2.065
7.5	4.569	4.320	-0.08	2.857
12.2	4.587	4.373	-0.06	3.338
16.9	4.635	4.427	-0.04	3.432
21.6	4.604	4.481	-0.03	5.799
26.3	4.682	4.535	-0.01	4.824
31.0	6.261	4.566	0.01	0.420
35.7	10.570	4.566	0.02	0.119
40.4	13.101	4.566	0.04	0.084
45.1	13.985	4.566	0.06	0.076

P(ATM) = 1.36 G(G/S-CM2) = 43.6
Q(W/CM2) = 0.825 XINLET = -0.10

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.606	4.290	-0.09	2.616
7.5	4.562	4.353	-0.07	3.949
12.2	4.580	4.415	-0.05	5.016
16.9	5.680	4.478	-0.03	0.686
21.6	12.571	4.540	-0.01	0.103
26.3	15.571	4.570	0.01	0.075
31.0	17.262	4.570	0.03	0.065
35.7	19.104	4.570	0.05	0.057
40.4	22.734	4.570	0.07	0.045
45.1	18.878	4.570	0.09	0.058

P(ATM) = 1.36 G(G/S-CM2) = 59.5
Q(W/CM2) = 0.456 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.651	4.564	0.00	5.295
7.5	4.625	4.564	0.01	7.559
12.2	4.642	4.564	0.02	5.909
16.9	4.761	4.564	0.03	2.318
21.6	4.919	4.564	0.04	1.287
26.3	5.145	4.564	0.04	0.786
31.0	5.232	4.564	0.05	0.684
35.7	5.409	4.564	0.06	0.540
40.4	5.785	4.564	0.07	0.374
45.1	6.037	4.564	0.08	0.310

P(ATM) = 1.43 G(G/S-CM2) = 23.8
Q(W/CM2) = 0.277 XINLET = 0.13

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.705	4.627	0.13	3.536
7.5	4.689	4.627	0.15	4.456
12.2	4.701	4.627	0.16	3.708
16.9	4.717	4.627	0.17	3.079
21.6	4.719	4.627	0.18	2.998
26.3	5.000	4.627	0.20	0.743
31.0	4.946	4.627	0.21	0.868
35.7	5.197	4.627	0.22	0.486
40.4	5.589	4.627	0.23	0.288
45.1	5.892	4.627	0.25	0.219

P(ATM) = 1.05 G(G/S-CM2) = 31.1
Q(W/CM2) = 0.404 XINLET = -0.06

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.484	4.053	-0.05	0.937
7.5	4.457	4.106	-0.04	1.152
12.2	4.471	4.159	-0.03	1.295
16.9	4.496	4.212	-0.01	1.421
21.6	4.476	4.265	-0.00	1.915
26.3	4.488	4.277	0.01	1.915
31.0	4.490	4.277	0.02	1.896
35.7	4.481	4.277	0.03	1.979
40.4	6.224	4.277	0.05	0.207
45.1	12.975	4.277	0.06	0.046

P(ATM) = 1.08 G(G/S-CM2) = 13.2
Q(W/CM2) = 0.283 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.506	4.072	-0.05	0.653
7.5	4.487	4.159	-0.03	0.864
12.2	4.496	4.246	-0.01	1.131
16.9	4.517	4.307	0.01	1.348
21.6	4.512	4.307	0.03	1.378
26.3	4.522	4.307	0.05	1.313
31.0	4.521	4.307	0.07	1.322
35.7	4.513	4.307	0.09	1.373
40.4	4.594	4.307	0.11	0.987
45.1	5.091	4.307	0.13	0.361

P(ATM) = 1.08 G(G/S-CM2) = 13.3
Q(W/CM2) = 0.302 XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.504	4.075	-0.05	0.704
7.5	4.484	4.167	-0.03	0.952
12.2	4.494	4.258	-0.01	1.285
16.9	4.515	4.306	0.01	1.447
21.6	4.510	4.306	0.03	1.487
26.3	4.519	4.306	0.05	1.420
31.0	4.518	4.306	0.07	1.426
35.7	4.510	4.306	0.10	1.486
40.4	5.471	4.306	0.12	0.260
45.1	11.871	4.306	0.14	0.040

P(ATM) = 1.10   G(G/S-CM2) = 12.5
Q(W/CM2) = 0.365   XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.495	4.091	-0.06	0.902
7.5	4.476	4.208	-0.03	1.360
12.2	4.486	4.324	-0.00	2.255
16.9	4.510	4.327	0.03	1.995
21.6	4.506	4.327	0.05	2.038
26.3	5.120	4.327	0.08	0.459
31.0	15.778	4.327	0.11	0.032
35.7	21.403	4.327	0.14	0.021
40.4	27.204	4.327	0.16	0.016
45.1	24.544	4.327	0.19	0.018

P(ATM) = 1.10   G(G/S-CM2) = 12.6
Q(W/CM2) = 0.336   XINLET = -0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.499	4.086	-0.06	0.814
7.5	4.479	4.193	-0.03	1.178
12.2	4.486	4.301	-0.01	1.812
16.9	4.508	4.324	0.02	1.829
21.6	4.509	4.324	0.05	1.822
26.3	4.514	4.324	0.07	1.775
31.0	4.788	4.324	0.10	0.726
35.7	12.704	4.324	0.12	0.040
40.4	20.931	4.324	0.15	0.020
45.1	24.033	4.324	0.17	0.017

P(ATM) = 1.07   G(G/S-CM2) = 13.5
Q(W/CM2) = 0.268   XINLET = -0.06

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.365	4.072	-0.05	0.918
7.5	4.328	4.152	-0.03	1.531
12.2	4.392	4.233	-0.02	1.682
16.9	4.405	4.300	0.00	2.554
21.6	4.367	4.300	0.02	4.010
26.3	4.430	4.300	0.04	1.415
31.0	4.456	4.300	0.06	1.719
35.7	4.542	4.300	0.08	1.107
40.4	5.189	4.300	0.10	0.302
45.1	6.185	4.300	0.12	0.143

P(ATM) = 1.98 G(G/S-CM2) = 13.1
Q(W/CM2) = 0.180 XINLET = -0.04

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.993	5.023	-0.02	******
7.5	4.970	5.036	0.00	******
12.2	5.007	5.036	0.02	******
16.9	5.039	5.036	0.05	57.442
21.6	5.314	5.036	0.07	0.647
26.3	5.892	5.036	0.09	0.210
31.0	6.394	5.036	0.12	0.132
35.7	6.482	5.036	0.14	0.124
40.4	6.631	5.036	0.16	0.113
45.1	6.582	5.036	0.18	0.116

P(ATM) = 2.00 G(G/S-CM2) = 13.2
Q(W/CM2) = 0.209 XINLET = -0.05

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.001	5.028	-0.03	******
7.5	5.082	5.044	-0.01	5.501
12.2	6.527	5.047	0.02	0.141
16.9	6.948	5.047	0.05	0.110
21.6	6.986	5.047	0.08	0.108
26.3	6.985	5.047	0.10	0.108
31.0	6.907	5.047	0.13	0.112
35.7	6.892	5.047	0.16	0.113
40.4	7.020	5.047	0.19	0.106
45.1	6.926	5.047	0.21	0.111

P(ATM) = 1.97 G(G/S-CM2) = 27.5
Q(W/CM2) = 0.304 XINLET = -0.10

L/D	TW (K)	TB (K)	X	(W/CM2-K)
2.8	5.009	4.964	-0.09	6.703
7.5	5.033	4.977	-0.07	5.435
12.2	5.240	4.990	-0.05	1.215
16.9	5.535	5.004	-0.04	0.571
21.6	5.935	5.017	-0.02	0.331
26.3	5.992	5.030	0.00	0.316
31.0	5.919	5.030	0.02	0.342
35.7	5.996	5.030	0.04	0.315
40.4	6.129	5.030	0.06	0.276
45.1	6.109	5.030	0.07	0.281

P(ATM) = 1.97 G(G/S-CM2) = 27.6
Q(W/CM2) = 0.328 XINLET = -0.10

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.047	4.964	-0.09	3.957
7.5	5.282	4.978	-0.07	1.080
12.2	5.996	4.992	-0.05	0.327
16.9	6.137	5.007	-0.03	0.290
21.6	6.142	5.021	-0.01	0.293
26.3	6.167	5.029	0.01	0.288
31.0	6.072	5.029	0.03	0.315
35.7	6.151	5.029	0.05	0.292
40.4	6.282	5.029	0.07	0.262
45.1	6.236	5.029	0.09	0.272

P(ATM) = 2.01 G(G/S-CM2) = 50.3
Q(W/CM2) = 0.601 XINLET = -0.32

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.942	4.748	-0.31	3.105
7.5	5.179	4.771	-0.29	1.474
12.2	6.375	4.794	-0.27	0.380
16.9	6.596	4.817	-0.25	0.338
21.6	6.638	4.840	-0.23	0.334
26.3	6.646	4.863	-0.21	0.337
31.0	6.568	4.886	-0.19	0.357
35.7	6.384	4.909	-0.16	0.407
40.4	6.956	4.932	-0.14	0.297
45.1	6.864	4.955	-0.12	0.315

P(ATM) = 1.97 G(G/S-CM2) = 13.3
Q(W/CM2) = 0.207 XINLET = -0.03

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.955	5.019	-0.02	******
7.5	4.911	5.030	0.01	******
12.2	5.160	5.030	0.03	1.588
16.9	6.465	5.030	0.06	0.144
21.6	6.850	5.030	0.08	0.114
26.3	6.958	5.030	0.11	0.108
31.0	6.894	5.030	0.14	0.111
35.7	6.933	5.030	0.16	0.109
40.4	7.097	5.030	0.19	0.100
45.1	6.995	5.030	0.21	0.105

P(ATM) = 1.36 G(G/S-CM2) = 61.3
Q(W/CM2) = 0.498 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.624	4.567	0.01	8.711
7.5	4.616	4.567	0.01	10.198
12.2	4.798	4.567	0.02	2.157
16.9	5.191	4.567	0.03	0.798
21.6	5.986	4.567	0.04	0.351
26.3	7.086	4.567	0.05	0.198
31.0	7.346	4.567	0.06	0.179
35.7	7.776	4.567	0.06	0.155
40.4	8.159	4.567	0.07	0.139
45.1	8.066	4.567	0.08	0.142

P(ATM) = 1.36 G(G/S-CM2) = 62.8
Q(W/CM2) = 0.602 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.600	4.570	0.01	19.474
7.5	4.868	4.570	0.02	2.014
12.2	6.854	4.570	0.03	0.263
16.9	8.758	4.570	0.04	0.144
21.6	9.177	4.570	0.05	0.131
26.3	9.582	4.570	0.06	0.120
31.0	9.538	4.570	0.07	0.121
35.7	9.851	4.570	0.08	0.114
40.4	10.614	4.570	0.09	0.100
45.1	10.290	4.570	0.10	0.105

P(ATM) = 1.07 G(G/S-CM2) = 28.5
Q(W/CM2) = 0.395 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.455	4.293	0.01	2.437
7.5	4.434	4.293	0.02	2.805
12.2	4.471	4.293	0.03	2.226
16.9	4.502	4.293	0.05	1.888
21.6	4.818	4.293	0.06	0.752
26.3	12.366	4.293	0.07	0.049
31.0	16.318	4.293	0.09	0.033
35.7	17.137	4.293	0.10	0.031
40.4	19.313	4.293	0.11	0.026
45.1	17.844	4.293	0.12	0.029

P(ATM) = 1.06 G(G/S-CM2) = 33.3
Q(W/CM2) = 0.431 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.440	4.291	0.01	2.882
7.5	4.420	4.291	0.02	3.331
12.2	4.458	4.291	0.03	2.577
16.9	4.528	4.291	0.04	1.821
21.6	13.095	4.291	0.06	0.049
26.3	18.372	4.291	0.07	0.031
31.0	18.266	4.291	0.08	0.031
35.7	18.203	4.291	0.09	0.031
40.4	20.475	4.291	0.10	0.027
45.1	18.107	4.291	0.12	0.031

P(ATM) = 1.06 G(G/S-CM2) = 30.5
Q(W/CM2) = 0.502 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.443	4.286	0.01	3.185
7.5	4.410	4.286	0.02	4.045
12.2	4.462	4.286	0.04	2.851
16.9	18.457	4.286	0.06	0.035
21.6	21.054	4.286	0.07	0.030
26.3	20.452	4.286	0.09	0.031
31.0	19.665	4.286	0.10	0.033
35.7	19.092	4.286	0.12	0.034
40.4	20.659	4.286	0.13	0.031
45.1	17.990	4.286	0.15	0.037

P(ATM) = 1.06 G(G/S-CM2) = 31.9
Q(W/CM2) = 0.686 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.403	4.289	0.01	6.018
7.5	17.286	4.289	0.03	0.053
12.2	24.182	4.289	0.05	0.034
16.9	24.158	4.289	0.07	0.034
21.6	22.611	4.289	0.09	0.037
26.3	21.288	4.289	0.11	0.040
31.0	19.750	4.289	0.13	0.044
35.7	19.053	4.289	0.15	0.047
40.4	20.891	4.289	0.17	0.041
45.1	19.015	4.289	0.19	0.047

P(ATM) = 1.07 G(G/S-CM2) = 31.9
Q(W/CM2) = 0.705 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.450	4.293	0.01	4.483
7.5	20.303	4.293	0.03	0.044
12.2	24.292	4.293	0.05	0.035
16.9	24.402	4.293	0.07	0.035
21.6	22.713	4.293	0.10	0.038
26.3	21.331	4.293	0.12	0.041
31.0	19.834	4.293	0.14	0.045
35.7	19.162	4.293	0.16	0.047
40.4	21.106	4.293	0.18	0.042
45.1	19.234	4.293	0.20	0.047

P(ATM) = 1.07 G(G/S-CM2) = 30.5
Q(W/CM2) = 0.419 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.479	4.295	0.01	2.272
7.5	4.473	4.295	0.02	2.353
12.2	4.475	4.295	0.03	2.314
16.9	4.500	4.295	0.05	2.040
21.6	10.381	4.295	0.06	0.069
26.3	17.194	4.295	0.07	0.033
31.0	18.404	4.295	0.08	0.030
35.7	18.012	4.295	0.10	0.030
40.4	20.470	4.295	0.11	0.026
45.1	18.289	4.295	0.12	0.030

P(ATM) = 1.98 G(G/S-CM2) = 14.7
Q(W/CM2) = 0.193 XINLET = 0.07

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.019	5.034	0.08	******
7.5	5.949	5.034	0.10	0.211
12.2	6.423	5.034	0.12	0.139
16.9	6.484	5.034	0.15	0.133
21.6	6.457	5.034	0.17	0.136
26.3	6.410	5.034	0.19	0.140
31.0	6.326	5.034	0.21	0.149
35.7	6.316	5.034	0.23	0.150
40.4	6.393	5.034	0.26	0.142
45.1	6.329	5.034	0.28	0.149

P(ATM) = 1.91 G(G/S-CM2) = 35.2
Q(W/CM2) = 0.208 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.974	4.988	0.01	******
7.5	5.083	4.988	0.01	2.199
12.2	5.205	4.988	0.02	0.960
16.9	5.358	4.988	0.03	0.563
21.6	5.453	4.988	0.04	0.447
26.3	5.507	4.988	0.05	0.401
31.0	5.432	4.988	0.06	0.469
35.7	5.487	4.988	0.07	0.417
40.4	5.552	4.988	0.08	0.369
45.1	5.534	4.988	0.09	0.381

P(ATM) = 1.96 G(G/S-CM2) = 30.7
Q(W/CM2) = 0.244 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.012	5.023	0.01	******
7.5	5.110	5.023	0.02	2.813
12.2	5.422	5.023	0.03	0.612
16.9	5.638	5.023	0.05	0.397
21.6	5.668	5.023	0.06	0.378
26.3	5.669	5.023	0.07	0.378
31.0	5.596	5.023	0.09	0.426
35.7	5.648	5.023	0.10	0.390
40.4	5.722	5.023	0.11	0.349
45.1	5.701	5.023	0.12	0.360

P(ATM) = 1.95 G(G/S-CM2) = 30.5
Q(W/CM2) = 0.301 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.073	5.016	0.01	5.298
7.5	5.818	5.016	0.03	0.375
12.2	5.948	5.016	0.04	0.323
16.9	5.995	5.016	0.06	0.308
21.6	5.969	5.016	0.08	0.316
26.3	5.957	5.016	0.09	0.320
31.0	5.866	5.016	0.11	0.354
35.7	5.897	5.016	0.12	0.342
40.4	5.982	5.016	0.14	0.312
45.1	5.946	5.016	0.15	0.324

P(ATM) = 1.35 G(G/S-CM2) = 59.2
Q(W/CM2) = 0.551 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.637	4.563	0.01	7.389
7.5	4.644	4.563	0.02	6.797
12.2	5.224	4.563	0.03	0.833
16.9	6.156	4.563	0.03	0.346
21.6	7.513	4.563	0.04	0.187
26.3	7.924	4.563	0.05	0.164
31.0	7.716	4.563	0.06	0.175
35.7	7.835	4.563	0.07	0.168
40.4	8.084	4.563	0.08	0.157
45.1	8.078	4.563	0.09	0.157

P(ATM) = 1.43 G(G/S-CM2) = 42.2
Q(W/CM2) = 0.323 XINLET = -0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.696	4.626	0.00	4.616
7.5	4.681	4.626	0.01	5.875
12.2	4.698	4.626	0.02	4.527
16.9	4.840	4.626	0.03	1.512
21.6	5.037	4.626	0.04	0.786
26.3	5.751	4.626	0.04	0.287
31.0	6.405	4.626	0.05	0.182
35.7	6.916	4.626	0.06	0.141
40.4	7.215	4.626	0.07	0.125
45.1	7.275	4.626	0.08	0.122

P(ATM) = 1.44 G(G/S-CM2) = 34.4
Q(W/CM2) = 0.467 XINLET = 0.03

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.675	4.632	0.04	10.959
7.5	5.234	4.632	0.06	0.705
12.2	8.380	4.632	0.07	0.124
16.9	9.716	4.632	0.08	0.092
21.6	10.296	4.632	0.10	0.082
26.3	10.663	4.632	0.11	0.077
31.0	10.902	4.632	0.13	0.074
35.7	11.177	4.632	0.14	0.071
40.4	12.165	4.632	0.16	0.062
45.1	12.083	4.632	0.17	0.063

P(ATM) = 1.05 G(G/S-CM2) = 30.4
Q(W/CM2) = 0.529 XINLET = -0.06

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	4.468	4.064	-0.05	1.309
7.5	4.441	4.135	-0.03	1.726
12.2	4.453	4.206	-0.02	2.144
16.9	4.485	4.276	0.00	2.530
21.6	6.466	4.276	0.02	0.241
26.3	19.545	4.276	0.03	0.035
31.0	20.259	4.276	0.05	0.033
35.7	20.501	4.276	0.07	0.033
40.4	23.396	4.276	0.08	0.028
45.1	20.592	4.276	0.10	0.032

P(ATM) = 1.99 G(G/S-CM2) = 13.2
Q(W/CM2) = 0.260 XINLET = -0.04

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	6.832	5.029	-0.02	0.144
7.5	7.990	5.038	0.02	0.088
12.2	8.143	5.038	0.05	0.084
16.9	8.277	5.038	0.08	0.080
21.6	8.238	5.038	0.12	0.081
26.3	8.153	5.038	0.15	0.083
31.0	8.027	5.038	0.18	0.087
35.7	7.955	5.038	0.22	0.089
40.4	8.110	5.038	0.25	0.085
45.1	7.963	5.038	0.28	0.089

P(ATM) = 1.97 G(G/S-CM2) = 27.5
Q(W/CM2) = 0.394 XINLET = -0.10

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.839	4.969	-0.08	0.453
7.5	6.520	4.986	-0.06	0.257
12.2	6.622	5.003	-0.04	0.243
16.9	6.738	5.020	-0.01	0.229
21.6	6.723	5.029	0.01	0.232
26.3	6.703	5.029	0.04	0.235
31.0	6.570	5.029	0.06	0.256
35.7	6.606	5.029	0.08	0.250
40.4	6.751	5.029	0.11	0.229
45.1	6.674	5.029	0.13	0.239

P(ATM) = 2.00 G(G/S-CM2) = 46.3
Q(W/CM2) = 0.755 XINLET = -0.30

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	5.959	4.760	-0.29	0.630
7.5	6.922	4.781	-0.26	0.353
12.2	7.219	4.802	-0.23	0.313
16.9	7.520	4.823	-0.20	0.280
21.6	7.533	4.843	-0.17	0.281
26.3	7.596	4.864	-0.15	0.277
31.0	7.329	4.885	-0.12	0.309
35.7	7.495	4.906	-0.09	0.292
40.4	7.847	4.926	-0.06	0.259
45.1	7.755	4.947	-0.03	0.269

P(ATM) = 1.86 G(G/S-CM2) = 43.7
Q(W/CM2) = 1.013 XINLET = -0.15

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	8.227	4.789	-0.13	0.295
7.5	9.226	4.831	-0.10	0.231
12.2	9.576	4.873	-0.07	0.215
16.9	9.935	4.914	-0.03	0.202
21.6	9.863	4.955	0.00	0.207
26.3	9.798	4.955	0.03	0.209
31.0	9.366	4.955	0.07	0.230
35.7	9.510	4.955	0.10	0.222
40.4	10.049	4.955	0.13	0.199
45.1	9.911	4.955	0.17	0.204

P(ATM) = 1.37 G(G/S-CM2) = 62.8
Q(W/CM2) = 0.985 XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	10.114	4.576	0.01	0.178
7.5	14.952	4.576	0.03	0.095
12.2	16.673	4.576	0.04	0.081
16.9	18.693	4.576	0.06	0.070
21.6	19.203	4.576	0.08	0.067
26.3	18.626	4.576	0.09	0.070
31.0	17.487	4.576	0.11	0.076
35.7	16.719	4.576	0.13	0.081
40.4	17.538	4.576	0.14	0.076
45.1	15.053	4.576	0.16	0.094

P(ATM) = 1.06   G(G/S-CM2) = 37.6
Q(W/CM2) = 0.853   XINLET = 0.00

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	20.100	4.290	0.01	0.055
7.5	26.927	4.290	0.03	0.038
12.2	25.153	4.290	0.06	0.041
16.9	24.908	4.290	0.08	0.042
21.6	23.498	4.290	0.10	0.045
26.3	22.663	4.290	0.12	0.047
31.0	21.368	4.290	0.14	0.051
35.7	21.010	4.290	0.16	0.052
40.4	23.848	4.290	0.18	0.044
45.1	21.910	4.290	0.21	0.049

P(ATM) = 1.98   G(G/S-CM2) = 14.4
Q(W/CM2) = 0.244   XINLET = 0.08

L/D	TW (K)	TB (K)	X	H (W/CM2-K)
2.8	6.520	5.035	0.10	0.165
7.5	7.150	5.035	0.12	0.115
12.2	7.181	5.035	0.15	0.114
16.9	7.212	5.035	0.18	0.112
21.6	7.140	5.035	0.21	0.116
26.3	7.060	5.035	0.24	0.121
31.0	6.948	5.035	0.27	0.128
35.7	6.927	5.035	0.29	0.129
40.4	7.030	5.035	0.32	0.122
45.1	6.943	5.035	0.35	0.128

4. Notation

Symbol	Denotes	Units
D	Inside tube diameter	cm
C_p	Specific heat at const. pressure	J/g-K
i_{IN}	Enthalpy at $T_{B\ INLET}$, P	J/g
i_{TC}	Enthalpy at T_{TC}, P	J/g
G	Mass velocity	g/s-cm^2
h	Heat transfer coefficient	W/cm^2-K
k	Thermal conductivity	W/cm-K
z	Length along test section	cm
P	Pressure	atm
$\dot{m}$	Mass flow rate	g/s
Q	Total heat added to fluid	W
q	Heat flux	W/cm^2
T_B	Bulk fluid temperature	K
$T_{B\ INLET}$	Fluid temperature at test section inlet	K
$T_{B\ OUTLET}$	Fluid temperature at test section outlet	K
T_{TC}	Transposed critical temperature	K
T_W	Inside wall temperature	K
Φ	$\dfrac{4zq}{D[(i_{TC} - i_{IN})G]}$	–
μ	Viscosity	g/cm-s

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16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

The first section of this report summarizes design problems for the development of advanced superconducting pulse magnets, leading to recommendations for future work, primarily in (1) evaluation of eddy-current, hysteresis, and frictional losses, and (2) transient heat transfer between the superconductor and the helium. Two subsequent sections report measurements of forced convection heat transfer respectively to subcooled liquid helium and to supercritical helium just above the critical pressure.

17. KEY WORDS (Alphabetical order, separated by semicolons) Forced convection heat transfer; pulsed power systems; pulsed superconducting magnets; superconductor losses; supercritical helium; transient heat transfer.

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