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LITERATURE SURVEY ON LIQUID METAL BOILING

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FOREWORD

This report was prepared in the College of Engineering, The University of Michigan, on Air Force Contract AF 33(616)-8277 under Task 314507 of Project 3145. The work was administered under the direction of the Flight Accessories Laboratory, Aeronautical Systems Division, Wright Patterson Air Force Base, Ohio. Lt. Lloyd Hedgepeth and Mr. Kenneth Hopkins were project engineers for ASD. The survey began in June 1961 as the initial phase of a program which is to include an experimental investigation of liquid-metal-boiling phenomena and associated two-phase-flow problems. Professor R. E. Balzhiser of the Department of Chemical Engineering is the Project Director at The University of Michigan. Professors J. A. Clark and Herman Merte, Jr., have specific interests in the agravic portion of the program, and Professor E. E. Hucke has particular interest in the relation of interfacial effects to boiling processes. Messrs. C. Phillip Colver, Lowell R. Smith, and A. S. Teller are graduate students in the Department of Chemical and Metallurgical Engineering at The University of Michigan. Messrs. S. Kim and W. A. Niethammer have worked long and diligently in organizing the extensive bibliography and physical property charts. This report is the culmination of a joint effort of the above individuals.

Appreciation is expressed to the following individuals and groups for permission to reproduce figures originating in their publications: The Oil and Gas Journal, published by the Petroleum Publishing Company; Dr. John Vohr of Columbia University; American Institute of Chemical Engineers; Professor C. F. Bonilla; Consultants Bureau Enterprises Inc.; and the Advanced Technology Laboratories, a division of American Standard. The authors also wish to extend appreciation to the many investigators who have contributed information for this survey.

This report concludes the work on Phase I of Contract No. AF 33(616)-8277. Work on Phase II involving the experimental investigations of liquid-metal-boiling systems is currently in progress.

ABSTRACT

Recent interest in high-temperature, high-flux, heat-transfer processes has focused considerable attention on liquid metals as heat-transfer media. This survey was originated for the purpose of collecting and evaluating information pertaining to the current status of liquid-metal-boiling technology. The sparsity of information specifically about liquid-metal-boiling programs prompted the inclusion of additional material pertaining to boiling and two-phase-flow phenomena in general. Existing correlations for predicting heat-transfer coefficients in the nucleate- and film-boiling regimes have been summarized and analyzed in the report. Likewise, correlations which predict the critical heat flux (or burnout flux) have been presented and compared with the experimental data available.

The use of liquid metals as fluids in space-oriented Rankin cycles necessitates a thorough understanding of quality and gravity effects on boiling phenomena. Each of these variables is treated in separate sections, with pertinent investigations and conclusions summarized. Interfacial considerations of possible importance are cited and discussed. Particular attention is called to the solid-liquid interfacial energy and its importance in limiting heat transfer across the interface.

The importance of two-phase-flow considerations in understanding the heat-transfer phenomena prompted the inclusion of additional sections regarding flow regimes and the pressure drops in flowing two-phase media. Both of these sections describe correlations presently used for water-steam or water-air two-phase mixtures. Little work has been reported to date regarding two-phase-flow phenomena in liquid metallic systems.

Appendix B is a summary of physical properties for various liquid metals and water. Examination of these physical properties suggests in many instances that existing correlations for aqueous systems might be used with reasonable confidence in predicting liquid-metal behavior. Appendix D is a comprehensive bibliography of all aspects of boiling heat transfer, fluid flow, and corrosion and circulation problems associated with liquid-metal fluids.

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INTRODUCTION

The literature on boiling heat transfer contains relatively little information on liquid-metal systems. Early interest in connection with the mercury-turbine and binary-power cycles produced some data for mercury systems. Subsequent interest prompted by the need for high-temperature coolants for nuclear reactors led to the development of several programs in the last decade. However, few results have yet reached the unclassified literature. Summaries and analyses of the available reports are included in this review. Special attention should certainly be called to the recent translation from Russian by Consultants Bureau Inc. of Liquid Metal Heat Transfer Media,[617*] edited by S. S. Kutateladze, which is devoted entirely to problems associated with utilizing liquid metals (up to 1958) and the recent paper of Gambill and Hoffman[369] which summarizes the field of boiling-metal heat transfer up to mid-1961.

The sparsity of information available for boiling-liquid-metal systems makes it extremely difficult to engineer such systems. The experimental difficulties associated with a precise evaluation of the effects of many important variables on the heat-transfer process in liquid-metal media reduce the probability of obtaining directly the needed information. Correlations and studies for nonmetallic fluids are certain to fill the many voids in the liquid-metal picture. Therefore, summaries of the present status of boiling heat transfer in general have been included. The authors have attempted to summarize in reasonable detail the results of these investigations.

The phenomenon of surface boiling exhibits the three separate regimes descriptively shown in Fig. 1. These modes are nucleate boiling, transitional boiling, and film boiling. Nucleate boiling (region AB) is characterized by the generation of vapor bubbles at selective locations on the surface. These bubbles either collapse back to the surface (as when the bulk liquid is sufficiently subcooled) or detach themselves and are carried by inertial and buoyant forces into the bulk liquid. During nucleate boiling, the heat-flux density is not directly proportional to the driving force, as in normal convective heat transfer, but to some power of the driving force. The heat-transfer mechanism in this regime is not well understood and several mechanisms have been proposed. As the heat flux density is further increased, the population of nucleating sites increases until the growing bubbles tend to coalesce to form an unstable vapor blanket. This point is shown by point B and is referred to as the critical heat flux density.**

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*Numbers in superscript after names refer to reference numbers listed in Appendix D.

**This condition is frequently referred to as the lower critical, the first crisis, or the burnout point.

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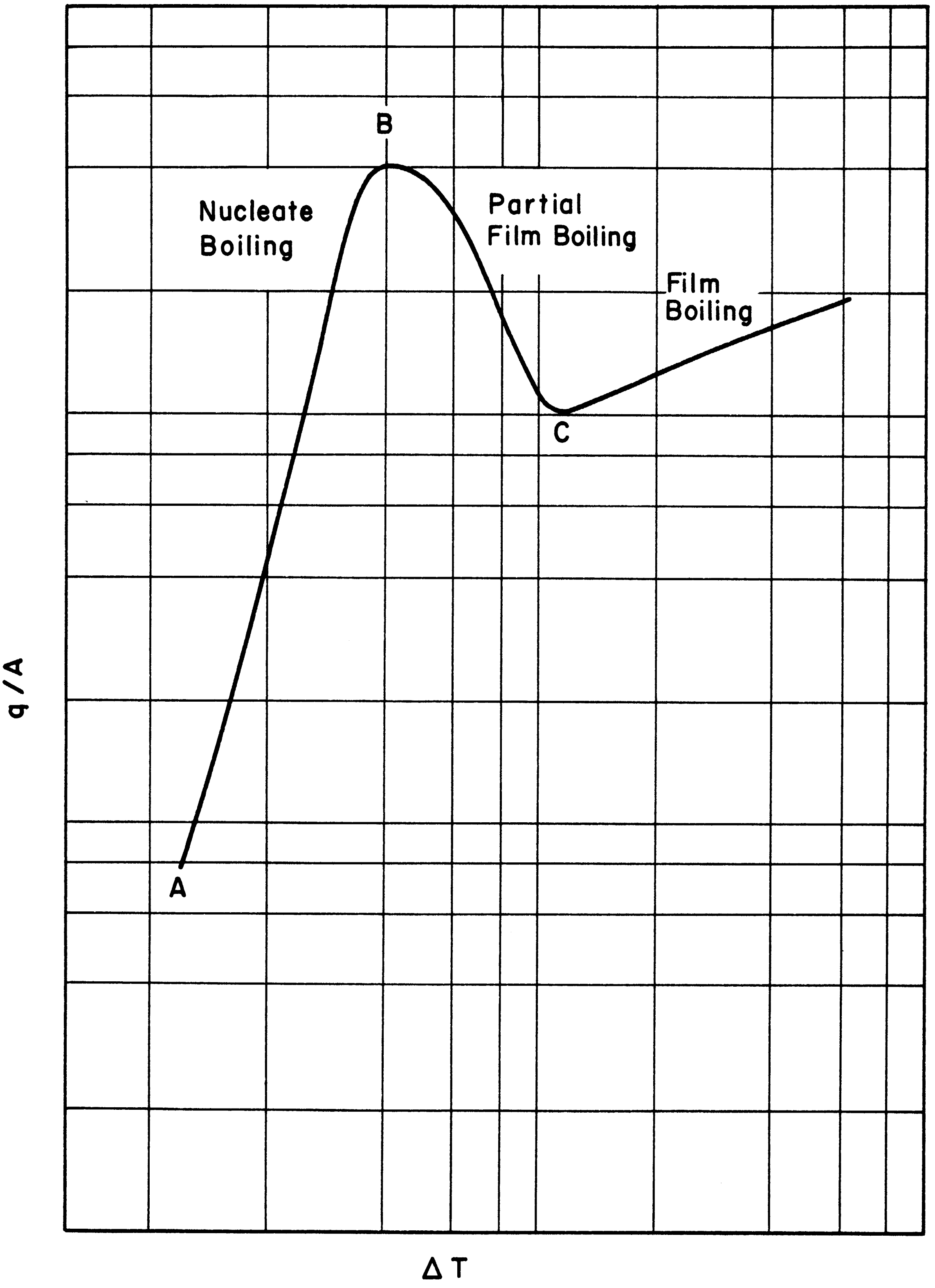

Fig. 1. Typical boiling curve.

The second regime (BC), partial-film boiling or transitional boiling, is characterized by the existence of an unstable vapor blanket that releases great patches of vapor at more or less regular frequencies. It is seen that the heat-transfer rate diminishes as a result of the insulating action of the vapor. As the temperature of the surface is increased, the heat flux is observed to pass through a minimum. At this temperature (C), a stable vapor film covers the entire surface and film boiling occurs. Heat transfer is accomplished principally by conduction and convection through the vapor film with radiative contributions becoming more significant as the surface temperature increases.

When ebullition is governed by the heat-flux density (electrical heating), as opposed to control by the temperature-driving force (condensing media), it is obvious that any increase of heat-flux density above the critical heat flux causes the surface temperature to rise rapidly in an effort to compensate for the decreasing coefficient. If this rise in temperature causes the surface to exceed the melting point of the surface, the phenomenon of "burnout" occurs. For this reason it is desirable to operate a boiling system as close to as possible, but without fear of exceeding, the critical heat-flux density.

MECHANISM OF NUCLEATE BOILING

A detailed knowledge of the heat-transfer mechanism for nucleate boiling is very important since it presumably would permit the calculation of heat-flux densities for various liquids at different pressures, forced convective velocities, superheats, surface conditions, agravic conditions, etc. A considerable amount of research has been performed in this area and several mechanisms have been suggested. In essence, however, each mechanism yet proposed has in some way been an alteration or extension of one or more of three intrinsic modes of transferring heat in nucleate boiling. These modes are: (1) microconvection heat transfer; (2) latent heat transport; and (3) vapor-liquid exchange.

(1) Microconvection heat transfer.—The rapid growth of the vapor bubble at a nucleation site imposes a quantum of kinetic energy to the surrounding liquid, thus accelerating the liquid to a velocity in excess of its natural convection velocity. This pulsating action at each site creates currents in the normally stagnant or laminar sublayer near the boiling surface.

(2) Latent heat transport.—This mechanism is essentially the transfer of latent heat from the boiling surface to the liquid to form and grow a vapor bubble. Heat may be transferred through the vapor bubble by mass transfer; i.e., some of the heat used to vaporize the liquid near the base of the vapor bubble is carried as vapor to the bubble cap where it is transferred to the liquid bulk by condensation of the vapor.

(3) Vapor-liquid exchange.—This mechanism allows the growing, collapsing, and departing vapor bubbles to act as heat pumps, first by pushing superheated liquid into the liquid bulk and then by allowing bulk liquid to replace the void left by the collapsed or departed vapor bubble. As the vapor bubble grows, it displaces the superheated liquid near the surface by pushing it into the liquid bulk. When the bubble either collapses back to the surface or departs from the surface, the liquid fills the void left by the vapor bubble thus allowing large amounts of heat to be transferred at each nucleation site. The cycle is repeated.

With the aid of photographic results, Jakob[521] and later Rohsenow and Clark[935] and Gunther and Kreith[420] concluded that only microconvection could account for the majority of the heat exchange during nucleate boiling. Edwards made calculations for subcooled liquids and found that mass transfer through a growing and collapsing vapor bubble could account for a major portion of the heat transfer to the liquid. Forster and Greif[344] have made speculative calculations and have concluded that "the amount of heat transferred by the liquid-vapor exchange taking place every time a bubble grows and then collapses on, or detaches from, the heating surface is by itself sufficient to account for the heat flux in nucleate boiling."

Treshchov,[1084] Zuber,[1180] and Chang[182] have recently proposed mechanisms including more than one intrinsic mode. Treshchov[1084] and Chang[182] have proposed a nucleate boiling-heat-transfer mechanism including all three modes. They state that at the initiation of nucleate boiling the greater part of the heat is transmitted by microconvection, but with an increase of heat-flux density the share of heat transmitted by microconvection is decreased. In turn, the heat transferred by the bubbles in both latent-heat and vapor-liquid exchange is increased to the point at which, when nucleate boiling is fully developed, all the heat is essentially transferred by the bubble. Zuber's analysis is similar; however, he neglects vapor-liquid exchange.

A more recent mechanism advanced by Moore and Mesler[791] postulates microlayer vaporization. These experimenters believe that as the vapor bubble grows on the surface it traps a very thin layer of liquid beneath it which rapidly evaporates, transferring great quantities of heat. With the aid of a thermocouple which measures transient temperatures on the surface, they were able to account for 70 to 90% of the heat transferred.

NUCLEATE-BOILING CORRELATIONS

Many investigators have suggested semi-empirical expressions relating the heat-flux density to various properties of nucleate-boiling systems. For the most part analysis has been made using dimensionless parameters and fitting the various empirical constants with experimental data.

Rohsenow[934] proposed the following expression for pool boiling:*

$$\frac{Cp_{\ell}\Delta T_W}{\lambda} = C\left[\frac{q/A}{\mu_{\ell}\lambda}\sqrt{\frac{g_c\sigma}{g(\rho_{\ell}-\rho_V)}}\right]^{0.33} Pr_{\ell}^{1.7} \qquad (1)$$

where C is a constant for a particular heating surface-fluid combination. He assumed that energy transfer occurs primarily from surface to liquid and extended the Nusselt analogy. He used bubble diameter as the characteristic system dimension for the Nusselt and Reynolds numbers and succeeded in correlating the data of Addoms,[7] Cichelli-Bonilla,[199] and Cryder-Finalborgo.[229] The above equation expressed explicitly in q/A follows:

$$q/A = C'\mu_{\ell}\lambda\left[\frac{Cp_{\ell}\Delta T_W}{\lambda}\right]^3 Pr_{\ell}^{-5.1}\left[\frac{g(\rho_{\ell}-\rho_V)}{g_c\sigma}\right]^{1/2} \qquad (2)$$

Application of this equation is somewhat restricted because of the need for experimental data to evaluate the constant.

Levy[658] derived a general equation to represent nucleate boiling of saturated liquids by postulating that as the generated bubbles attain their maximum diameter, they carry all heat transferred at the heat-transfer surface. His expression,

$$q/A = \frac{1}{B_L}\frac{k_{\ell}Cp_{\ell}\rho_{\ell}^2}{\sigma T_S(\rho_{\ell}-\rho_V)}\Delta T_W^3 \qquad (3)$$

is (except for secondary effects) independent of pressure and the heat surface-liquid combination. The constant B_L is empirically determined and found to be well represented by plotting it against $\lambda\rho_V$. This relationship correlates reasonably well the ethanol and normal heptane data of Cichelli-Bonilla[199] and the water data of Addoms.[7]

Forster and Grief[344] in their analysis decided which dimensionless parameters were significant and then correlated them with experimental data. The results produced two expressions. The first utilizes a specific coefficient for each liquid; the second expression employs the same constant for all liquid-surface combinations. This permits extension to systems previously unexplored, but some sacrifice in accuracy is inherent. This latter expression has been shown to correlate well with the boiling data for mercury in the range 1-3 atmospheres.[126] For liquid-metal-boiling systems where few data are available, the second form seems to possess greater utility. It is

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*Symbols and their definitions are given in Appendix A.

$$q/A = 4.3 \times 10^{-5} \frac{\alpha C p_{\ell} \rho_{\ell} T_s}{\sqrt{\sigma}\,(\lambda \rho_v)^{3/2}} \left[C p_{\ell} T_s \sqrt{\alpha} \right]^{1/4} \left[\frac{\rho_{\ell}}{\mu_{\ell}} \right]^{5/8} Pr_{\ell}^{1/3}\, \Delta p^2 \qquad (4)$$

This equation also correlates Lyon's sodium results.[696]

Chang and Snyder[185] applied dimensional analysis to the fundamental equations for motion and energy to produce parameters which characterize the nucleate-boiling phenomena. The concept of a thermal-eddy diffusivity was incorporated in their analysis. The following equation, which is good for vigorous boiling, resulted from this study:

$$q/A = 4 \times 10^{-4} \frac{k_{\ell} \Delta p^{1.4}}{(\rho_v \lambda)^{0.8} \sigma} \left[C p_{\ell} T_s (\rho_{\ell} - \rho_v) \right]^{0.4} \Delta T_w \qquad (5)$$

The authors state that this expression is directly applicable for liquid metals. Comparison with the data of Bonilla[126] supports this supposition.

From experiments with nonmetallic liquids, Kutateladze[617] has derived the following:

$$q/A = 0.44\, Pr_{\ell}^{0.35} \left[\frac{q/A\ p\ 10^{-4}}{\lambda \rho (\rho_{\ell} - \rho_v)} \right]^{1.7} \left[\frac{k_{\ell}^2 (\rho_{\ell} - \rho_v)}{\sigma} \right]^{0.5} \Delta T_w \qquad (6)$$

or explicitly in q/A

$$q/A = 0.76\, Pr_{\ell}^{1.17} \left[\frac{p\ 10^{-4}}{\lambda \rho_v (\rho_{\ell} - \rho_v)} \right]^{2.33} \left[\frac{k_{\ell} (\rho_{\ell} - \rho_v)}{\sigma} \right]^{1.67} \Delta T_w^{3.33} \qquad (7)$$

Borishanskii and Menchenko,[617] after experimenting with different liquids, concluded that for ordinary liquids the power on the Prandtl number of Kutateladze's first equation should be changed to 0.7 and the value of the coefficient changed to 0.55. The predictions of this correlation are compared with data for magnesium, mercury amalgams, and sodium in a later section of this report.

Mumm[803] proposed an interesting correlation that considered variations in vapor fraction. Four dimensionless parameters were selected to characterize the nucleate-boiling phenomena. The correlation was based on data obtained for the water-steam system and is supposedly applicable for qualities up to 40%.

$$q/A = \left[4.3 + 5 \times 10^{-4} \left(\frac{V_v}{V_{\ell}} \right)^{1.64} \chi \right] \left[\frac{q/A}{G \lambda} \right]^{0.46} \left[\frac{G d_e}{\mu_e} \right]^{0.8} \left[\frac{k_{\ell} \Delta T_w}{d_e} \right] \qquad (8)$$

In a recent publication Chang[183] employed theory developed from the Maxwell-Boltzman distribution law to derive the following empirical expression:

$$q/A = c \frac{\rho_\ell Cp_\ell \Delta T_W N_A (KT_S)^{3/2}}{H\sigma^{1/2}} \exp\left[-n \frac{lb\ \pi}{3}\left(\frac{\sigma}{\Delta P}\right)^2 \frac{\sigma}{KT_s}\left(\frac{\rho_\ell Cp_\ell \Delta T_W}{\rho_V \lambda}\right)^{-m}\right] \quad (9)$$

where m = 1 and 2 for organic and inorganic liquids respectively, and c and n represent dimensionless numbers whose values depend on the liquid and surface conditions. The equation is valid for liquids, including liquid metals, under the following conditions: saturated pool boiling from either rough or smooth surfaces; saturated or subcooled forced-convection boiling from rough surfaces; and early stages of forced-convection boiling (saturated or subcooled) from smooth surfaces. A comparison with Lyon's data showed good agreement.

CRITICAL HEAT-FLUX CORRELATIONS

At the upper limit of the nucleate-boiling regime, sufficient nucleation sites have become active to cover the surface. As the number of vapor columns emanating from the surface increases, the cross-sectional area remaining for liquid flow to the surface decreases. This necessitates an increased velocity if the liquid supply to the surface is to be replenished.

Early investigators of this type of phenomenon observed instabilities in the system when a certain relative velocity was achieved between the two phases in countercurrent flow. More recent theoretical attempts to relate this observed instability in two-phase flow to the critical heat-flux limitations have aroused much attention and have produced some encouraging results. Experimental verification of their predictions is difficult, particularly for liquid-metal media. However, some burnout data for water and organics are available and have been used to check (in part) some of the theoretical treatments. At the same time, it has led to empirical and semi-empirical correlations for the critical flux. Several of the more promising results are summarized along with a brief discussion of the effects of pressure, velocity, and subcooling on the location of the critical point. The effects of quality, interface conditions, and agravic considerations are treated in greater detail later in the report.

Numerous analytical expressions have been derived to predict the critical heat flux. Even though most expressions are limited to water, there are several with presumably general application. For saturated pool boiling, Rohsenow and Griffith[937] have proposed the following:

$$[q/A]_c = 143 g^{1/4}\ \rho\lambda \left[\frac{\rho_\ell - \rho_v}{\rho_v}\right]^{0.6} \quad (10)$$

This correlation was compared with the data of Cichelli and Bonilla[199] and produced approximate deviations of about ±11%.

Considering the critical heat flux as a phenomenon governed by hydrodynamic limitations, Kutateladze[624] employed dimensional analysis to derive the relationship:

$$[q/A]_c = K\lambda\rho_v \left[g^2\sigma\left(\frac{\rho_\ell-\rho_v}{\rho_v^2}\right)\right]^{1/4} \qquad (11)$$

When compared with water and some organic liquids for saturated pool boiling, the best value of K was found to be in the range 0.14 to 0.18. For subcooled pool boiling, K is no longer constant but a function of the groups,

$$\frac{\lambda}{Cp\Delta T_{sub}} \quad \text{and} \quad \frac{\rho_v}{\rho_\ell}$$

These give rise to a new expression:

$$[q/A]_{c,sub} = [q/A]_c \left\{1 + (1-n)\left[\frac{\rho_\ell}{\rho_v}\right] \frac{Cp_\ell\Delta T_{sub}}{\lambda}\right\} \qquad (12)$$

When correlated with data for water, alcohol, and isooctane, Eq. (13) resulted.

$$[q/A]_{c,sub} = [q/A]_c \left\{1 + 0.065\left[\frac{\rho_\ell}{\rho_v}\right]^{0.8} \frac{Cp_\ell\Delta T_{sub}}{\lambda}\right\} \qquad (13)$$

Zuber and Tribus[1175] considered the critical heat flux as a hydrodynamic limitation arising from Taylor-Helmholtz instabilities at the vapor liquid interface. Their expression,

$$[q/A]_c = \frac{\pi}{24}\lambda\rho_v \left[\frac{\sigma g(\rho_\ell-\rho_v)g_c}{\rho_v^2}\right]^{1/4} \left[\frac{\rho_\ell}{\rho_\ell+\rho_v}\right]^{1/2} \qquad (14)$$

is seen to differ slightly from Kutateladze's in the value of the constant and includes an additional term which is near unity. For subcooled liquids, Zuber and Tribus[1175] extend Eq. (14) to

$$[q/A]_{c,sub} = \frac{\lambda\pi}{24}\frac{\lambda_o}{\tau} + \frac{\pi}{24}\rho Cp_\ell(T_s-T_\ell)\frac{\lambda_o}{\tau} + \sqrt{2\pi}\,\frac{k}{\sqrt{\alpha\tau}}[T_s-T_\ell] \qquad (15)$$

where

$$= 2\pi\left[\frac{\sigma}{g(\rho_\ell-\rho_v)}\right]^{1/2}\left[\frac{\rho_v^2}{\sigma g(\rho_\ell-\rho_v)}\right]^{1/4}\left[\frac{\rho_\ell}{\rho_\ell+\rho_v}\right]^{1/2} \qquad (16)$$

and

$$\frac{\lambda_o}{\tau} = \left[\frac{\sigma g(\rho_\ell - \rho_v)}{\rho_v^2}\right]^{1/4} \left[\frac{\rho_\ell}{\rho_\ell + \rho_v}\right]^{-1/2} \tag{17}$$

This equation was compared to the critical heat flux data for water,[420] ammonia,[1175] and carbon tetrachloride[295] with fair agreement.

Griffith[409] has proposed an empirical equation applicable for different levels of subcooling, force convective velocities, and pressure. It is

$$[q/A]_{c,sub} = f\left[\frac{p}{p_c}\right](h_v - h_b)\,\rho_v\left[\left(\frac{\rho_\ell - \rho_v}{\mu_\ell}\right) g \left(\frac{k_\ell}{\rho_\ell C p_\ell}\right)^2\right]^{1/3} F \tag{18}$$

where

$$F = 1 + Re_\ell\, 10^{-6} + 0.014J + 5 \text{ x } 10^{-4}\,[J \text{ Re }]^{1/2} \tag{19}$$

and

$$J = \frac{\rho_\ell C p_\ell (T_s - T_b)}{\rho_v \lambda} \tag{20}$$

Over 300 data points from various liquids (including water, benzene, n-heptane, and ethane) have been correlated, with 94% of the points having less than a ±33% deviation.

At low pressures for saturated boiling, it has been experimentally shown that as the pressure is raised the critical heat flux markedly increases.[101,295,1081] Kazakova[622] has experimentally determined the critical heat flux for water boiling from flat disks. Her data indicate that the critical heat flux increases with pressures up to 30 to 40% of the critical pressure, then slowly decreases to zero as the pressure approaches the critical value. This behavior is in qualitative agreement with all the equations and with most investigations reviewed.

For saturated forced convection, Aladyev et al.[16] present data for water with flow rate as a separate parameter showing similar behavior to that described above. At higher flow rates the critical heat flux appeared less sensitive to pressure changes.

Subcooling has been shown to have a greater effect at low pressures, as demonstrated by the following relationship:

$$\left\{\frac{[q/A]_{c,sub}}{[q/A]_c}\right\}_{p_1,T} > \left\{\frac{[q/A]_{c,sub}}{[q/A]_c}\right\}_{p_2,T} \tag{21}$$

where $p_1 < p_2$.

Verification of this behavior is clearly shown by the data of Kutateladze and Shneiderman.[631]

For water and organic liquids, velocity increases have been shown to increase markedly the critical heat-flux density. The growing vapor bubbles on the surface are swept away at a smaller diameter by the flowing stream, thus permitting more nucleating sites to become active at the surface before coalescence results. Consequently, a greater ΔT is required to activate these sites. Since the heat transfer coefficient would not be expected to decrease, the critical heat flux must increase.

Aladyev et al.[16] found that for water at constant subcooling a change from 1 meter/sec to 2 meters/sec affected the critical heat flux insignificantly at 20 atm, but at 180 atm increased it approximately 50%. On the other hand, Torikai[1080] found that for water at 1 atm and constant subcooling the critical heat-flux density was increased as much as 50% for an increase in velocity from 1 meter/sec to 2 meters/sec. With an increase from 1.1 ft/sec to 5 ft/sec, at constant subcooling and 16 psia, Ellion[295] found that the critical heat-flux density was increased 100%.

Many investigators have shown that subcooling increases the critical heat-flux density above that in saturated boiling. In their experiments, Kutateladze and Shneiderman[631] have clearly shown that for pool boiling with ethanol, isooctane, and water, at constant pressure, the critical heat-flux density increases for a decrease in the bulk temperature.

Ellion[295] found, for water flowing at 1 ft/sec, that changing from 50°F to 100°F subcooling increased the critical heat-flux density approximately 50%. This behavior was confirmed by Aladyev et al.[16]

In their derivation of Eq. (15) for subcooled boiling, Zuber et al.[1177] assumed, for subcooled pool boiling, that the same hydrodynamic behavior is exhibited at the critical as for saturated boiling, but that an additional quantity of energy is transferred to the subcooled liquid.

FILM-BOILING CORRELATIONS

Unlike the forced-convection and nucleate-boiling regimes, the film-boiling region has been the subject of relatively few analytical studies and very few experimental investigations. However, today's technology includes areas where it is essential to transfer large quantities of heat across minimal surface areas, thus increasing the probability of encountering this phenomenon. The process is characterized physically by a layer of vapor that separates the liquid from the heat surface. The energy transfer through the vapor layer occurs by conduction, convection, and radiation processes. At reasonable temperature levels the attainable fluxes are substantially suppressed.

Several excellent literature surveys on film boiling have been compiled. Drew and Mueller[268] as part of a general review on boiling surveyed film-boiling literature up to 1937. Westwater[1145] reviewed the literature on film boiling up to 1955 and summarized the work in terms of description of photographic studies; theoretical treatments; and experimental results where the effects of type of liquid, type of solid and its surface texture, geometric arrangement, pressure, surface tension, agitation, and impurities were separately considered. McFadden and Grosh[750,751] extended the coverage to 1959 in their review. This summary includes findings discussed in these reviews and attempts to bring the subject up to date by including several of the more important recent contributions.

Although the first observation of the phenomenon of film boiling was made as early as 1746, an analytical development did not appear in the literature until 1950 when Bromley,[156] prompted by the earlier work of Colburn, presented a theory of stable laminar film boiling. Bromley based his derivation on Nusselt's derivation for heat transfer during laminar-film condensation. It treated specifically free-convection film boiling on the outside of an isothermal horizontal tube and incorporated the following assumptions: a vapor blanket exists between the liquid and the tube wall, heat is transferred through the film by conduction and radiation, the vapor rises due to buoyant forces, the liquid vapor interface is smooth, viscous drag retards the rise of the vapor, the enthalpy of vaporization is the major energy supplied to the film, the kinetic energy of the film is negligible, the liquid is at rest and saturated, and properties may be evaluated at an average temperature. The resulting theoretical equation is modified with an experimentally determined constant to fit the physical situation. Bromley's results can be expressed as

$$h_{co} = 0.62 \left[\frac{k_\ell^2 \rho_v (\rho_\ell - \rho_v) g \lambda' Cp_\ell}{d \, \Delta T_w \, Pr} \right]^{1/4} \tag{22}$$

where 0.62 is empirical, a compromise between 0.724 and 0.512. The former value corresponds to the situation in which the liquid is moving with the same velocity as the vapor (hence zero sheer stress at the vapor-liquid interface), and the second value arises where the liquid is considered to be at rest, thus producing a large sheer stress at the interface. Bromley corrected his heat-transfer coefficient for radiation by assuming infinite parallel-plane-plate radiation. The radiation coefficient was expressed as follows:

$$h_r = \left[\frac{\sigma'}{\frac{1}{\epsilon_w} + \frac{1}{\epsilon_\ell} - 1} \right] \left[\frac{T_w^4 - T_\ell^4}{\Delta T_w} \right] \tag{23}$$

The radiation coefficient was combined with the convection coefficient in the following manner to obtain a total heat-transfer coefficient.

$$h = h_{co} + h_r \left[\frac{3}{4} + \frac{1}{4} \, \frac{h_r}{h_{co}} \left(\frac{1}{2.62 + h_r/h_{co}} \right) \right] \tag{24}$$

For low wall temperatures the total coefficient was expressed as follows:

$$h = h_{co} + \frac{3}{4} h_r \qquad (25)$$

For vertical tubes Bromley used the same expression for the convection coefficient, but substituted the height, L, of the tube for D as the characteristic dimension in his expression. For such small values of L that the vapor film was laminar, this correlated the data satisfactorily. These correlations were substantiated with data taken on the following liquids: water, nitrogen, carbon tetrachloride, absolute ethyl alcohol, benzene, diphenol oxide, and normal pentane. Bromley's experimental program showed that the value of the coefficient was independent of the physical characteristics of the liquid although his experiments were limited to a rather narrow viscosity range. The physical or chemical character of the tube or tube surface appeared to have little or no effect as long as it was fairly round and smooth. The effect of diameter was as predicted in the equation. Total coefficients ranging from 18 to 80 Btu/hr (sq ft)(°F) were measured, and the following conclusions were obtained:

(1) The liquid vapor interface is substantially smooth along the bottom two thirds of the tube except at high heat fluxes. At the top it is always uneven due to bubble formation and departure.

(2) Heat-transfer coefficients are independent of the tube material except for the radiation contribution.

(3) The effect of variables such as pressure may be calculated from their effect on the physical properties of the liquid and its vapor.

(4) A decrease in surface tension does not affect the calculated coefficients, but the minimum critical heat flux and the corresponding temperature-heat difference are both decreased.

(5) Film boiling persists for subcooled liquids with higher coefficients resulting.

(6) Mercury was shown to exhibit film boiling at very low ΔT's. Bromley observed that the potassium additions did not substantially affect this behavior.

(7) Heat-transfer coefficient is increased for forced convection.

S. S. Kutateladze[626] summarized Russian efforts in the area of film-boiling heat transfer up through 1952. He considers the laminar flow of a vapor layer along a vertical plate, assuming that all vapor moves along the heated surface. He, too, considers the two extremes discussed by Bromley (above), and observes that the value of the coefficient differs by a factor of 1.59 for the two extremes. For free convection he presents the following correlation for the average value of the heat-transfer coefficient:

$$h = \beta^{3/4} \phi^{1/4} \left[\frac{k_\ell^2 Cp_\ell \lambda \rho (\rho_\ell - \rho_V)}{Pr \; \Delta T \; L} \right]^{1/4} \qquad (26)$$

where $\beta = 0.436 - 0.690$ and $\phi = 1 + (Cp/2\lambda)\Delta T$. For forced flow of a liquid such that

$$\frac{2\mu_\ell u_\ell}{(\rho_\ell - \rho_V)} \gg 1 \qquad (27)$$

the differential coefficient of heat transfer during film boiling is directly proportional to the liquid velocity. For situations in which radiative transfer must also be considered, the following expression results for the average heat-transfer coefficient:

$$h = \frac{4}{3} \beta' \left[\frac{k_\ell^2 Cp_\ell \phi \lambda \rho_V (\rho_\ell - \rho_V)}{Pr_\ell \; \Delta T_W L(1+\psi)} \right]^{1/4} \qquad (28)$$

where $\psi = h_r/h$ and $\beta' = 0.500 - 0.705$. For high liquid velocities with a constant ΔT_W, the following expression correlates the average heat-transfer coefficient.

$$h = \left[\frac{k_\ell \phi \lambda \rho_V u_\ell}{\Delta T_W L(1+\psi)} \right]^{1/2} \qquad (29)$$

As is evident, the heat-transfer coefficient for these conditions is proportional to the square root of the liquid velocity.

Kutateladze's summary mentions the early experimental work of Styrikovich and Semonovker,[1045] who studied the transfer of heat to boiling mercury. At about the same time, Kutateladze and Zysina[617] studied heat transfer to mercury boiling under conditions of free convection. In 1947 Lukomskii[688] measured the heat-transfer coefficient of carbon dioxide during film boiling in vertical tubes. Experimental data for the film-boiling of water at atmospheric pressure on a 3-mm vertical heater with a flux of 500,000 Kcal/meter^2/hr produced a vapor-film Reynold's number of 62, thus confirming the assumption of laminar flow within the film. Pressures up to 12 atmospheres were also studied with the water system. Equations (26) and (28) were shown to correlate the data very well. Equation (28) also does a satisfactory job of correlating Bromley's data. Subcooling is shown to increase the value of the average transfer coefficient. However, the effect of subcooling decreases with an increase in the absolute pressure of the system because of a decreasing density ratio.

In 1954 Ellion[295] analyzed an isothermal vertical plate with laminar stable film boiling. He made essentially the same assumptions as Bromley and arrived at a result approximating Bromley's. This correlation was substantiated with water data for a velocity range of 1.1-5 ft/sec, subcooling from 50 to 100°F and pressures from 16 to 60 psia. He reports film boiling to be independent of water pressure, velocity, and subcooling over these ranges.

Bromley[156] later analyzed a case of stable laminar film boiling for an isothermal horizontal cylinder for uniform, vertical, upward flow. For low water velocities his results were the same as for free convection. For high water velocities his results can be expressed as follows:

$$Nu = 2.7 \left[\frac{u\rho\lambda d}{k\ \Delta T}\right]^{1/2} \quad \text{or} \tag{30}$$

$$h = 2.7 \left[\frac{ku\rho\lambda}{d\ \Delta T}\right]^{1/2} \tag{31}$$

This study included four different liquids with velocities up to 14 ft/sec.

In 1958 Chang[186] presented his wave theory of heat transfer and film boiling from both horizontal and vertical isothermal surfaces. He considered heat transfer in both saturated and subcooled systems. He utilizes the concept of an equivalent thermal diffusivity to produce a generalized model. He generates a general formula for both convection and boiling. His results can be expressed as follows:

$$Nu = C\ [Pr_\ell Gr]^{1/3} \tag{32}$$

$$= \left[\frac{g(\rho_\ell - \rho_V)L^3}{8\pi^2\ \mu_\ell g_c \gamma_c}\right]^{1/3} \tag{33}$$

where γ_c is defined as follows:

$$\gamma_c = \frac{\Delta T_{sub}}{2(\lambda\rho_V + \Delta T_W Cp_\ell \rho_\ell)} \tag{34}$$

For vertical plates the value of the exponent for the product $(Pr_\ell Gr)$ is 1/4. Chang concludes that the heat-transfer coefficient for film boiling from the horizontal surface is in general higher than from a vertical plate. For boiling from tubes the reverse is observed to be true. He suggests that the effect of different variables be calculated from their effect on the physical properties of the liquid and vapor. Increases in pressure will increase the heat-transfer coefficient, but not as significantly as might be anticipated because the boiling point of the liquid will also increase with pressure. A higher wall temperature is then required to maintain film boiling which increases the radiative contribution.

McFadden and Grosh[750,751] performed an analytical study of stable, free convection, laminar film boiling in which they consider transfer by conductive and convective processes only. The boundary-layer equations were solved using transformation techniques for the following conditions: (1) compressible flow with variable specific heat; (2) variable specific heat and density variations considered only in the evaluation of the buoyant force; and (3) the case of constant properties. Numerical solutions were obtained for the following conditions: (1) water at 2800 and 3100 psia with wall-to-liquid temperature differences of 250, 500, and 1000°F; (2) for fluids with Prandtl numbers of 2/3, 1 and 2; and (3) for mercury and methanol film boiling at 1 atmosphere considering constant properties. An approximate analysis for nonisothermal wall condition, including radiation effects, was also performed. Radiation was shown to be the controlling factor in film boiling for high-emissivity walls at high temperatures.

The investigators concluded that for water at 2800 and 3100 psia, radiation is of more significance than the consideration of variable properties. They suggest, however, that as the critical pressure is approached, property variations will play a more important part in film-boiling heat transfer.

A comparison of Lyon's experimental data[695,696] for the film boiling of mercury with their theoretical results yielded satisfactory agreement. McFadden and Grosh pointed out that had Lyon chosen to measure his surface temperatures along the bottom 2/3 of the tube, better agreement would have been achieved. Their values for film boiling of methanol on the outside of a horizontal tube also yielded values slightly above the experimental data of Westwater and Santangelo.[1148] Again they postulate that the surface temperatures measured were not representative.

In 1960, Hsu and Westwater[1147] proposed an approximate theory for film boiling on vertical surfaces. The equation was developed for saturated liquids in the absence of forced flow and postulated the following conditions: (1) that vapor flow near the low end of the heating surface is viscous and Bromley's equation is applicable; (2) that turbulence develops with a local Reynolds number of about 100; and (3) that in the turbulent region of the heating surface thermal resistance is due entirely to the laminar sublayer. The results produced the following equation for the Nusselt number averaged over the upper and lower portions of the heating surface:

$$\mathrm{Nu} = \frac{2\lambda'\mu \mathrm{Re}^{*} k_{\ell}}{3L\,\Delta T_{w}} + \frac{B + 1/3}{A}\left\{\left[\frac{2}{3}\,\frac{A}{B+1/3}\,(L-L_{o}) + \left(\frac{1}{y^{*}}\right)^{2}\right]^{3/2} - \left(\frac{1}{y^{*}}\right)^{3}\right\} \qquad (35)$$

where Re* represents the vapor-film Reynolds number; y*, the critical vapor film thickness; and A and B are functions of the system properties and Re*. Experimental data were obtained for five liquids, methanol, benzene, carbon tetrachloride, nitrogen and argon. Tube lengths were varied from 2.0 to 6.3 inches. Hsu and Westwater's prediction appears to be much improved over Bromley's and Chang's, with the results being particularly good for nitrogen and argon, both of which have high ΔTs (560-780°F). For the organics with lower ΔTs (150-310°F) the correlation is not as reliable over the ΔT range investigated. The data that show h decreasing as ΔT increases are characteristic of the transitional region. Data at higher ΔTs, where film boiling is certain, might produce better agreement.

As the tube lengths increase from zero, the predicted heat-transfer coefficient passes through a minimum and then increases steadily. The minimum local heat-transfer coefficient occurs at the point where turbulence first develops. This value corresponds to 1.9 in. of water and about 1/2 in. for nitrogen for a ΔT of 700°F. The minimum heat-transfer coefficient averaged over the length occurs at greater lengths, 4.8 in. for water and 2.4 in. for nitrogen for the same ΔT. Bromley's equation predicts a decreasing value of h as L is increased. Increases in ΔT cause increases in the average heat-transfer coefficient for water, but the reverse is predicted for nitrogen. The Hsu-Westwater correlation produced an average deviation of about 32% for the predicted Nusselt number as compared to experimental values. This is shown to be an improvement over the predictions of Bromley or Chang. Recently Berenson[89] developed an analytical expression for the heat-transfer coefficient near the minimum in film pool boiling from a horizontal surface. He utilizes Taylor-Helmholtz hydrodynamic instability to formulate a model from which he derives the following expression for the heat-transfer coefficient:

$$h = 0.425 \left[\frac{k_{\ell} \lambda \rho_V (\rho_{\ell} - \rho_V) g}{\mu \; \Delta T_W \sqrt{\dfrac{g_c \sigma}{g(\rho_{\ell} - \rho_V)}}} \right]^{1/4} \tag{36}$$

A comparison of his expression with Bromley's shows that the diameter has been replaced with

$$\sqrt{\frac{g_c \sigma}{g(\rho_{\ell} - \rho_V)}}$$

as the geometrical scale factor for horizontal surfaces.

The applicability of Berenson's expression at fluxes substantially above the minimum flux is questionable. Radiation effects, which the author suggests become appreciable at temperature differences above 1000°F, and velocity effects would both tend to produce higher values of the coefficient. Berenson's article contains an expression for the minimum flux, which occurs at the onset of stable film boiling, and also the expression for the ΔT at which film boiling can occur. Experimental results obtained for normal pentane and carbon tetrachloride agree within 10% of his theoretical predictions.

Cess and Sparrow[180] investigated film boiling in forced-convection boundary-layer flow. Their results can be expressed in the following manner:

$$\frac{Nu}{\sqrt{Re}} \left(\frac{\mu_V}{\mu_{\ell}} \right) \left[1 + \sqrt{\pi \frac{Nu}{\sqrt{Re}} \; \frac{\mu_V}{\mu_{\ell}}} \right]^{1/2} = 0.5 \left[\frac{(\rho\mu)_{\ell} Cp \; \Delta T_W}{\rho_V \mu_V \; \lambda \; Pr_{\ell}} \right]^{-1/2} \tag{37}$$

A simplified, but less accurate, expression can be obtained by ignoring the square root bracket on the left side of the equation. It can be seen from this equation that the heat-transfer coefficient is inversely proportional to the square root of the temperature difference. Therefore, in the film-boiling regime at low fluxes, q is proportional to ΔT to the 1/2 power, which is a smaller ΔT dependence than exhibited by other convective-transfer phenomena. Cess and Sparrow extended their analysis to include subcooled liquids. Subcooling was shown to produce an appreciable increase in the heat-transfer coefficient. The effect is expected to be most pronounced for low Prandtl liquids, such as metals.

Lin et al.[664] performed experimental studies with pure mercury at 1 atmosphere. The system was observed to enter the film-boiling regime for very low temperature differences. As the flux increased, the coefficient was observed to decrease. An expression $h = 4850q^{-0.26}$ correlated their data. The experimental values correlated by this equation fell about 50% above the theoretical line corresponding to Bromley's prediction. These investigators observed that increases in pressure changed the boiling type from film to nucleate with corresponding increases in both heat-flux and heat-transfer coefficient. The experimental work of Lyon with mercury systems also confirmed the tendency of mercury under nonwetting conditions to exhibit film boiling at relatively low temperature differences. The addition of magnesium and titanium in very small quantities was observed to promote wetting. Coefficients and fluxes characteristic of the nucleate regime were then comparable for temperature differences. Preliminary calculations for sodium at temperatures where conduction would be expected to predominate yielded a value for the coefficient of 43 Btu/hr ft^2. This value is of the same magnitude as that observed by Bromley with other fluids. It appears that unless significant radiative contributions occur at higher ΔTs, the flux in the film-boiling regime will remain below the critical flux for reasonable values of ΔT.

Investigations to date have shed some light on the effect of certain variables. Liquids studied thus far have not indicated a radical difference for heat-transfer coefficients in the stable film-boiling regime. The main difference between liquids seems to be due to differences in wettability on particular surfaces. Film boiling will occur at smaller temperature differences for nonwetting fluids. Lyon's results with mercury demonstrated this phenomenon. Similarly, the surface from which heat is transferred has relatively little effect on the transfer coefficient. However, it should be remembered that extreme roughness might change the character of flow, producing changes in the coefficient. Likewise, at high temperatures the emissivity of the surface becomes important in determining relative importance of radiative contributions. Differences for horizontal and vertical surfaces have definitely been established. Likewise, cylinders have been observed to yield results differing from those obtained on plane surfaces. Most investigators observe h to increase as pressure increases. Likewise, liquid velocity increases produce increased coefficients, according to most investigators.

QUALITY EFFECTS IN BOILING HEAT TRANSFER

The influence of net vapor generation on the heat-transfer coefficient in the nucleate-boiling regime parallels forced-convection effects. In the low-quality regions the vapor phase will likely remain dispersed in the liquid matrix, thus resulting in a reduction of the average fluid density. Under these conditions slip can be considered negligible and an increase in the velocity will occur. The film at the heating surface will remain essentially the same, except that the boundary-layer thickness will decrease as the velocity is increased. Eventually a velocity will be reached at which the bubbles are sheared from the wall shortly after nucleating. At this point, the film thickness has been reduced to where it no longer offers the resistance to heat transfer that it would at lower velocities. A given heat flux can be sustained at lower ΔTs, and hence the surface temperature drops. This in turn deactivates sites and decreases the vapor generation at the surface. The effect of the growth and collapse of bubbles on the boundary layer becomes less significant.

Sterman and Styushin[1030] observed that the critical flux was increased by quality increases. Their observations with isopropyl alcohol in stainless steel tubes showed that the critical flux was always approached first in the low-quality regions. They postulate that since bubbles are removed from the surface at smaller diameters for increased flow rates, a greater number of sites can be activated before the growing bubbles begin to merge and blanket the surface. This requires a greater ΔT at the critical point, and hence a greater heat flux. Mumm[803] also observed that the heat-transfer coefficient increased with quality for qualities ranging up to 50%. For higher values a rapid decrease in the coefficient was observed, with burnout resulting for qualities of about 70%. His correlation for the Nusselt number includes quality as a parameter [see Eq. (8)]. McAdams <u>et al</u>.[734] and Rohsenow and Clark[938] observed an increase in h with quality increases.

Most investigators agree that for qualities below 50%, improved coefficients will be observed as χ increases. However, at higher qualities considerable disagreement exists as to the exact behavior to be expected. An examination of the flow pattern sheds some light on the heat-transfer phenomena. At low qualities the flowing stream is essentially liquid, with vapor dispersed as a discontinuous phase. At higher qualities the vapor coalesces, but liquid remains as the continuous phase. For sufficiently high vapor velocities such annular flow eventually develops that vapor with dispersed liquid droplets moves along the tube axis, while a liquid film flows along the tube wall. For liquids which wet the surface, high heat-transfer coefficients persist in this flow regime.

Forced-convection effects have probably suppressed any surface boiling, but the high velocity of the gas phase through the core removes all but a thin liquid film at the tube wall, thus reducing the resistance to heat transfer. Eventually the liquid film is reduced to a point where it is difficult to detect. This stage is referred to as fog or mist flow. However, the surface is still supplied with sufficient liquid to remove the necessary heat load by vaporization. As the quality continues to rise, a point is finally reached where insufficient liquid reaches the surface to dissipate the high energy fluxes. This "dry wall condition" results in rapid temperature increases at the surface, and burnout occurs. Investigators refer to this type of critical condition as two-phase burnout.

Several investigators have measured high quality heat-transfer coefficients. McAdams et al.[734] observed for water-steam a drop in the heat-transfer coefficient for qualities above 40% at 24 psi and 71 psi. Dengler[255] observed three mechanisms operative over the quality range he studied. At low qualities nucleate boiling seemed to control; at higher qualities forced convection effects appeared to dominate. For qualities from 47% ($G = .171 \times 10^6$ lb/hr ft^2) to 84% ($G = .044 \times 10^6$ lb/hr ft^2) sharp decreases in the heat-transfer coefficient were observed. This phenomenon was attributed to "dry wall conditions."

Parker and Grosh[833] studied the heat transfer characteristics in the mist-flow regime for steam and water droplets moving vertically upward in a tube. Heat flux was varied from 3,020 to 20,700 Btu/hr ft^2 with inlet qualities from 89-100%. Their results showed that equilibrium was not necessarily attained between the droplets and vapor, and that considerable superheating of the vapor was possible in the presence of droplets. They also observed the heat-transfer coefficient to be a strong function of surface temperature. Above a certain critical temperature, spheroidal behavior was observed with coefficients approximately the same as for dry steam. Surface temperatures below this critical produced coefficients 3 to 6 times greater than dry steam values. Flux and quality effects on this temperature appeared interrelated. Higher qualities and/or fluxes tend to promote the spheroidal state. Any method of directing the dispersed liquid phase toward the walls is likely to increase the heat-transfer coefficient in the very-high-quality regions.

Guerrieri and Talty[418] have attempted to separate the mechanisms of boiling and convection in high-quality heat transfer. They present the following expression for the two-phase heat-transfer coefficient:

$$h_c = 3.4\, h_\ell \left[\frac{1}{\chi_{tt}}\right]^{0.45} \qquad (38)$$

where h_ℓ is the single-phase liquid coefficient given by the Dittus-Boelter equation, and χ_{tt} is the Martinelli parameter. They relate boiling-film coefficients when superimposed on convective effects by the following formula:

$$h = 0.187\, h_c \left[\frac{r^*}{\delta}\right]^{-5/9} \qquad (39)$$

where r^* is the radius of a minimum-sized thermodynamically stable bubble and δ is the laminar film thickness.

These investigators, and others, concur in the conclusion that a convective mechanism becomes controlling for high-quality systems.

AGRAVIC EFFECTS IN BOILING HEAT TRANSFER

Space applications of small nuclear reactors cooled by boiling liquid media have necessitated a better understanding of gravity effects on the heat transfer process. Zero gravity conditions create rather unusual conditions for processes which function due to density differences. It becomes necessary to replace the normal gravitational forces with others, perhaps centrifugal, which will permit the mechanisms usually operative to function at or above their normal efficiency. Investigations using vortex tubes have already demonstrated tremendous increases in the maximum heat flux that can be transferred from surfaces to fluids without incurring burnout. A summary of the agravic work to date follows. Little has been done experimentally with liquid metal systems although several programs are currently underway.

Merte and Clark[766] made a study of the influence of system acceleration on pool boiling heat transfer in saturated distilled water, at approximately atmospheric pressure. The heating surface was a flat disc 3 in. in diameter, with the acceleration vector (1-21 g's) away and normal to it. At low constant values of the heat flux, ΔT_{sat} decreased as acceleration of the system increased. This is attributed to the increasing contribution of natural convection with acceleration. At high values of heat flux, ΔT_{sat} increased with increasing acceleration. Some data are presented showing the influence of subcooling with the system under acceleration. Nonboiling data in the same range of a/g is presented.

Costello and Tuthill[223] used a flat, electrically heated ribbon mounted near the periphery of a cylinder filled with distilled water at essentially atmospheric pressure. The system was spun about its axis producing effective accelerations normal to surface of $a/g = 20$ to $a/g = 40$. The heat flux varied from $q/A = 100{,}000$ Btu/hr ft^2 to 200,000 Btu/hr ft^2. It was found for the given heat flux that ΔT_{sat} increased with increasing acceleration, resulting in a decrease in the "heat-transfer coefficient." This increase in ΔT_{sat} amounted to approximately 5-7°F for an increase in a/g from 1 to 40.

Costello and Adams[222] have measured the maximum heat flux for water from a carbon cylinder at approximately one atmosphere for a/g from 1 to 44. The acceleration was normal to the axis of the cylinder which was electrically heated. In other respects their test apparatus was similar to that previously reported by Costello and Tuthill.[223] The relationship between $(q/A)c$ and a/g follows the 1/4-power law for a/g in the range from 10 to 44. Below a/g of 10 a power-law representation between these quantities was also found, but with an exponent somewhat less than 1/4.

Gambill and Greene[370,372] attained a critical heat flux of 55 x 10^6 Btu/hr ft^2 with water flowing in a vortex in an electrically heated tube. This was attributed to the effect of the centrifugal acceleration estimated to be 18,000 times normal gravity on the bubbles forming at the heating surface. However, the contribution of forced, as well as free, convection could not be isolated.

Siegel and Usiskin[997] performed a photographic study of boiling water at one atm from several heater configurations in the absence of a gravitational field. No attempts were made to measure heat flux or temperatures. The bubbles appeared to grow and remain in the vicinity of the heating surface.

Measurements of the critical heat flux from a platinum wire 0.0453 in. in diameter were made[1102] in saturated distilled water in various force fields of $0 \leqq a/g \leqq 1$. The burnout heat flux decreased with reduced force fields but still had a finite value at $a/g = 0$. Measurements were also made of bubble sizes at departure and of bubble rise velocities with reduced gravities.

Merte and Clark[765] have studied the boiling of saturated liquid nitrogen at atmospheric pressure from a 1-in.-diameter sphere for standard gravity and at near-zero gravity for 1.4 sec duration. The sphere is used as a dynamic calorimeter for continuous measurements from film through nucleate boiling. In the nucleate-boiling region, the characteristics are the same as at standard gravity, indicating perhaps that buoyant forces play a minor role in promoting the turbulence associated with boiling.

In Ref. 661 various liquid configurations, based on the principle of minimum energy, are presented for containers partially filled with a liquid and subjected to zero gravity. Consideration of tank outlet vents under this condition are examined. For liquids which wet the container wall, it is probable that the final zero gravity configuration is a wetted wall with an internally centered gas bubble. For nonwetting liquid, roughly the opposite effect is anticipated.

A feasibility study was made[911] for boiling and condensing mercury with zero gravity using parabolic flight of an aircraft. No quantitative heat transfer measurements were made. The authors discuss problems regarding slug motion of mercury in flow passages and undesired movement of condensed mercury back into the boiler which they encountered in their study.

Reference 1093 discusses general problem areas of heat transfer, and those anticipated in future space vehicles. Tests of the behavior of gases released in fluids and in mercury condensing tests are described. Presentation is qualitative.

INTERFACE CONSIDERATIONS IN BOILING HEAT TRANSFER

There is a substantial agreement, in the published works on boiling, that homogeneous nucleation, i.e., the nucleation of a bubble from within the bulk liquid is, in general, seldom obtained,[438] because the formation of a bubble must create surface at the expense of volume-free energy. Adequate quantitative treatments of this subject are available in the literature.[1094] They show that the superheat required to obtain a bubble by homogeneous nucleation is larger than that obtained experimentally. The critical size of the bubble nucleus is shown to be proportional to the liquid-vapor surface tension, and the free energy of activation to form the bubble is proportional to the surface tension cubed. The surface tensions of liquid metals are from 4 to 200 times greater than those of aqueous solutions and, therefore, the improbability of homogeneous nucleation of liquid metals is even greater than that of the systems that have received more attention.

To explain the relatively low superheats generally found in boiling systems, heterogeneous nucleation is indicated. In liquid-metal systems, the savings of energy through heterogeneous nucleation are even greater than those in aqueous or organic systems. The essential condition for the operation of an effective heterogeneous nucleation catalyst is that its surface be more susceptible to wetting by the newborn phase than by the mother phase.[1094] In short, a nonwetted surface would tend to promote nucleation in boiling. It is not necessary that lack of wetting be general over the whole surface, but rather that suitable specific locations, as discussed above, be provided. In the limiting case where the surface is completely nonwettable by the liquid, the vapor film would always exist and nucleation is unnecessary.

Unfortunately, the conditions for nucleation of the vapor bubbles and for the prevention of film boiling are diametrically opposed. For easier bubble detachment from the surface, the highest possible affinity of the liquid for the solid and the lowest possible affinity of the vapor for the solid are desired. These conditions would be met when the resultant force of the surface stress tensor would have its component at a given location under the liquid, pointing out of the surface, as opposed to a location under a vapor spot where it should point into the surface (see Appendix C).

Increasing the relative preference of liquid for solid has been shown to have the following effects on heat transfer. First, under conditions where convection is the predominant mode of transfer, a wetted condition at the wall gives higher heat transfer coefficients for a given ΔT.[438] Larson[644] has postulated that as the temperature differential is raised, a well-wetted surface, as opposed to a surface not so well wetted, has a slower rate of increase of heat flux. This would be due to the more difficult nucleation of bubbles. However, it has been shown[1150] that alteration of the surface energies will prolong the nucleate regime and give a higher critical heat flux. Russian workers[617] have shown that additions of magnesium to mercury in controlled amounts continue to raise both the critical heat flux and the corresponding critical temperature difference. Extension of the nucleate regime is to be expected from the more favorable conditions for bubble detachment, as opposed to the spreading of the vapor over the solid surface, which would result in the onset of film boiling.

To obtain maximum heat transfer from a surface, the following conditions should be met by the solid-liquid combination. First, the surface should be completely wetted by the liquid to an extent limited by loss of strength due to stress corrosion or penetration of grain boundaries (see Appendix C). Secondly, the surface should have a controlled amount and distribution of a very fine second phase chosen so that the liquid does not wet it. This phase will then serve as a nucleation catalyst. And finally, external stimuli such as the application of elastic stress might be used to increase further the degree of heterogeneity of the surface, allowing the more complete wetting of at least some of the grains.

SUMMARIES OF EXPERIMENTAL LIQUID-METAL-BOILING PROGRAMS

Considerable activity in liquid-metal-boiling heat transfer has taken place during the past decade. Earlier efforts associated with the mercury boiler had produced some results both in the United States and in Russia. However, the first comprehensive boiling study in which other metals were considered was performed by R. E. Lyon at The University of Michigan in 1953. Since that time C. F. Bonilla at Columbia has performed boiling studies on mercury and sodium-potassium systems. He has also contributed several other studies, including several liquid-metal-condensing investigations. Several other programs during this period have produced results which have appeared in the literature. Summaries of these are included in the following text.

The renewed emphasis on high-flux, high-temperature heat transfer has resulted in the establishment of experimental programs in laboratories throughout the world. Table I summarizes most of these programs. Some are designed to yield corrosion data and others to measure heat-transfer coefficients. Effects of pressure, velocity, subcooling, quality, surface characteristics, and fluid properties on heat-transfer characteristics are all receiving attention. Much of this work is in its early stages, and results are still unavailable.

The summaries which follow include a description of the equipment and the experimental procedure as well as an analysis of the results. Conflicting data and conclusions are reported. Subsequent results will undoubtedly clarify many of today's uncertainties.

KUTATELADZE, S. S.[617]

This book is a supplement to the Soviet Journal of Atomic Energy (1958) and is devoted entirely to the problems of utilizing liquid metals as heat-transfer

TABLE I

LIQUID-METAL EXPERIMENTAL PROGRAMS*

Organization	Test Fluid	Test Objective	Status
Aerojet-General Nucleonics	Rb, Cs	Operating Loops	---
AiResearch Manufacturing Co.	K	Materials	Fabrication
AiResearch Manufacturing Co.	K	0-g Boiling Exp.	Fabrication
Argonne National Laboratory	K	Boiling Heat Transfer	Design
Argonne National Laboratory	Cd	Boiling Heat Transfer	Operation
Argonne National Laboratory	$Hg-N_2$	Two-Phase Studies	---
Atomics International	Na-K(78)	Heat Transfer and Hydraulics	---
Atomics International	Hg	Boiling Heat Transfer	---
Atomics International	Na	Burnout Studies	---
Atomics International	Na	Condensing Studies	---
Brookhaven National Lab.	K	Boiling Heat Transfer	---
Columbia University	Na	Condensing Studies	---
Electro-Optical Systems, Inc.	Hg	Condensing 0-g Studies	---
General Electric	K, Na	Materials	Fabrication
General Electric	K, Na	Heat Transfer	Fabrication
General Electric	K	Turbine	Design
Marquandt Corporation	Li	---	---
The Martin Company	Li	Operating Loops	---
MSA	Na	Materials	Operating
NASA-Lewis	Na	Turbine	Design
NASA-Lewis	Na	Turbine	Fabrication
NASA-Lewis	Na	Pumps	Fabrication
NASA-Lewis	Na	Boiling Heat Transfer	Fabrication
NASA-Lewis	Na	Condensing Studies	Design
NASA-NDA	K, Na	Materials	Design
Nuclear Develop. Corp.	--	---	---
Oak Ridge National Laboratory	K	Boiling Heat Transfer	Operating
Pratt and Whitney Aircraft	Li, Na-K	Materials	Operating
Rocketdyne	K	Materials	Operating
Sundstrand Aviation	Rb	Condensing	Fabrication
Sundstrand Aviation	Rb	Boiling	Fabrication
Sundstrand Aviation	Rb	Heat Storage	Design

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*From Aeronautical Systems Division, Wright-Patterson Air Force Base.

media in nuclear power. It presumably contains all important liquid-metal heat-transfer data collected during the previous ten years in Russia as well as some from the United States and other countries. There are chapters covering selective liquid-metal properties, general areas of liquid-metal applicability, corrosion studies, and instrumentation in liquid-metal systems. The present summary covers only that portion dealing with heat transfer of liquid metals during boiling.

A discussion concerning wettability and the hydrodynamic characteristics in vapor-liquid mixtures is given. The degree of wettability as characterized by the premature origination of film boiling is qualitatively discussed. If the liquid does not wet the wall of the tube, it is pointed out that the flow pattern thus formed is one in which the vapor bubbles that form remain adjacent to the wall, retarding the heat transfer to the liquid. From an investigation by Lozhkin and Krol[684] for mercury boiling in a glass tube, the fraction of the surface covered by vapor varied from 34% to 78.5-87.5% for 10,000 Kcal/(m^2)(hr) and 25,000 Kcal/(m^2)(hr), respectively.

Several plots are given showing the fundamental hydrodynamic characteristic of two-phase flow as obtained by Gremilov.[403] The vapor fraction is shown as a function of the ratio of the reduced vapor velocity to the convective velocity with the Froude number (u^2/d) as a parameter. A separate plot is given, correcting for tube inclinations. For foreed-convective boiling Gremilov's results clearly show that the effect on the integral hydraulic characteristics of two-phase flow is small and that mercury-vapor systems behave much like steam-water systems. Pressure drop may be expressed to an accuracy of ±15% by the following:

$$\Delta p = \frac{f u_m \rho_\ell L}{2gd}\left[1 + \left(1 + \frac{\rho_v}{\rho_\ell}\right)\frac{u_v}{u_m}\right] \tag{40}$$

As further proof that nonwetting metals approximate the film-boiling regime of wetting metals, a number of investigations[403,545,591,626,683,684,1044,1046] are cited which agree with this hypothesis. It is shown from an investigation by Lozhkin[684] that turbulent promoters markedly improve the boiling heat-transfer coefficient. Two tables are given comparing the heat-transfer coefficients at three stages in the heat-transfer loop for baffled and nonbaffled flow. For example, in boiling at 25,400 Kcal/(m^2)(hr), the heat-transfer coefficients are 470 and 5640 Kcal/(m^2)(hr)(°C) for non-vortex and vortex flow, respectively. The most significant increases were observed in the upper portion of the tubes where boiling became more fully developed and net vapor generation resulted.

The effect of the tube diameter does not have any appreciable effect on the nucleate-boiling regime. This has been verified for diameters up to 40 mm.

The dependence of the heat-transfer coefficient on the heat-flux density is discussed. It is stated that when a liquid metal wets the heat-transfer surface and the heat load is below the critical, the following equation is applicable:

$$h = \phi \, (q/A)^{n} \qquad (41)$$

Korneev's data[591] on the boiling of a magnesium amalgam on a vertical steel tube placed in a large volume of liquid could be correlated with this equation with n equaling 0.59. His data also demonstrated that the above correlation was independent of magnesium concentration over the range of .01-.03%. However, an increased magnesium concentration was observed to shift the critical flux upwards (see Fig. 2).

Three semi-empirical equations derived from investigations with nonmetallic liquids are compared with data on liquid metal systems: (1) the equation of Averin and Kruzhilin,[45]

$$\frac{h}{k_{\ell}}\left[\frac{\sigma}{\rho_{\ell}-\rho_{v}}\right]^{1/2} = 0.082\ \mathrm{Pr}_{\ell}^{0.45}\left[\frac{\rho_{v}\lambda\ q/A}{AT_{s}k(\rho_{\ell}-\rho_{v})}\right]^{0.7}\left[\frac{c\sigma^{0.5}\ AT_{s}\rho_{\ell}(\rho_{\ell}-\rho_{v})^{0.5}}{(\lambda\rho_{v})^{2}}\right]^{0.333} \qquad (42)$$

(2) the equation of Kutateladze,[625]

$$\frac{h}{k_{\ell}}\left[\frac{\sigma}{\rho_{\ell}-\rho_{v}}\right]^{0.5} = 0.44\ \mathrm{Pr}_{\ell}^{0.35}\left[\frac{q/A\ p\ 10^{-4}}{\lambda\rho_{v}(\rho_{\ell}-\rho_{v})\nu}\right]^{0.7} \qquad (43)$$

(3) Borishanskii's and Minchenko's[131] alteration of Kutateladze's equation

$$\frac{h}{k_{\ell}}\left[\frac{\sigma}{\rho_{\ell}-\rho_{v}}\right]^{0.5} = 0.55\ \mathrm{Pr}_{\ell}^{0.7}\left[\frac{q/A\ p\ 10^{-4}}{\lambda\rho_{\ell}(\rho_{\ell}-\rho_{v})\nu}\right]^{0.7} \qquad (44)$$

The equations are compared with experimental data on magnesium-mercury, and sodium.[623,695,696,697,698] The results are reproduced in Table II. It is seen that Eq. (43) gives the best value for magnesium-mercury amalgams while Eqs. (43) and (44) show nearly equal deviations for sodium.

The data of Styrikovich, Semenovker, and Sovin[1045] on heat transfer to mercury during forced convection inside vertical steel tubes show an increase in h as velocity increases and as tube diameter decreases. Their fluxes ranged from 25,000-70,000 Kcal/(m^2)(hr) diameters from 21-40 mm and velocities up to 0.9 m/sec. Additional data for nonstratified flow in inclined tubes with fluxes extended to 98,000 produced coefficients up to 1100 Kcal/(m^2)(hr)(°C) for nonwetting mercury.

For nonstratified flow vertical and inclined tubes yield indistinguishable values. For stratified flow a reduction is observed in the coefficient, particularly at the top of the tube. For nonwetting fluids the decrease was observed to occur before boiling actually occurred, at about the point where the wall temperature reached the saturation temperature.

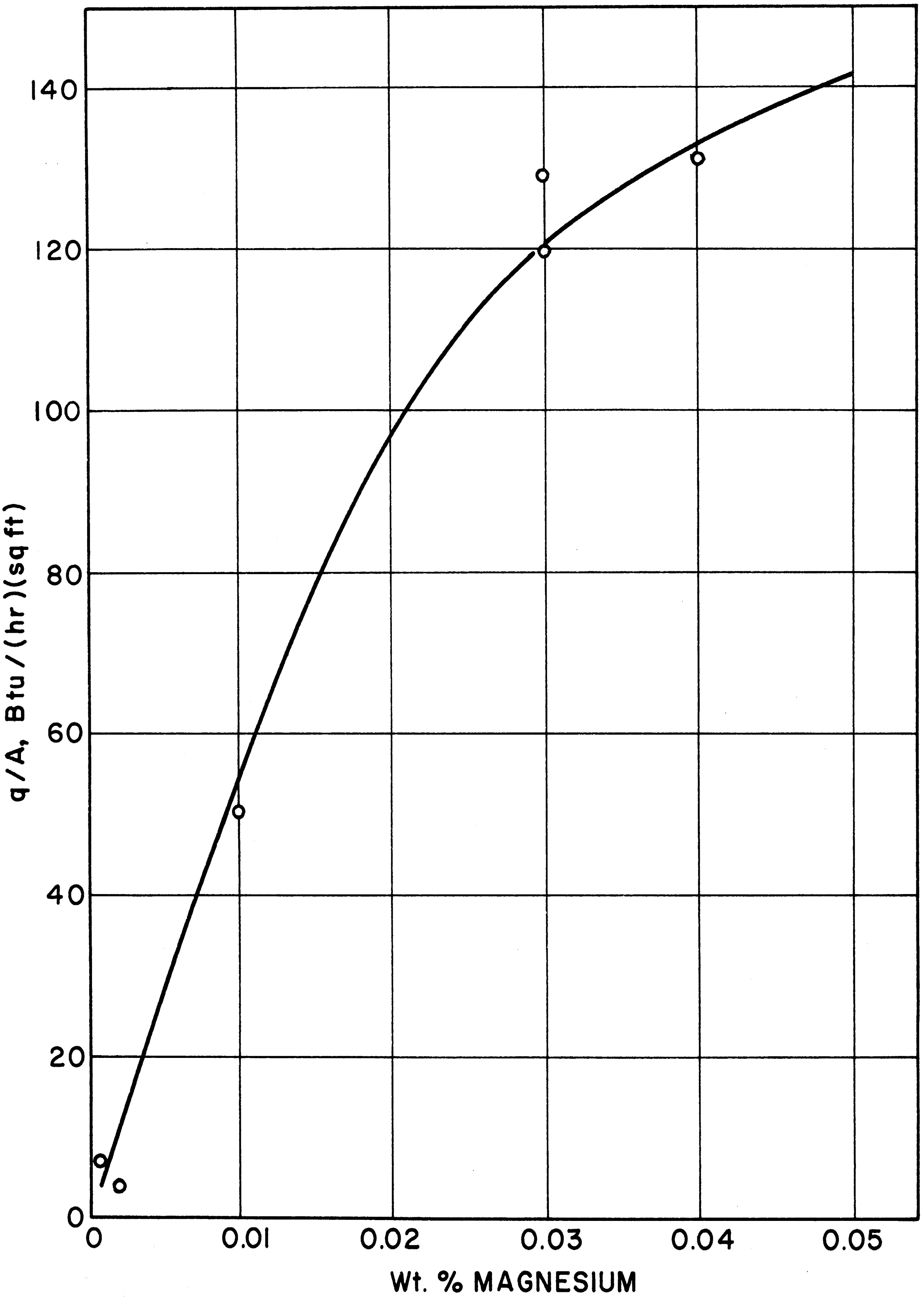

Fig. 2. Effect of magnesium concentration in mercury on the critical heat supply for boiling in a large volume (Kutateladze[617]).

TABLE II

COMPARISON OF THE EXPERIMENTAL VALUES OF THE COEFFICIENT IN EQ. (41); CALCULATED VALUES

Metal	Pressure (atm)	Experimental	$\phi = \frac{h}{q/A^{0.7}}$		
			Eq. (42)	Eq. (43)	Eq. (44)
Magnesium-mercury amalgam	1.03	3.30	24.6	5.19	1.1
Magnesium-mercury amalgam	10.3	$[q/A < 2 \times 10^{+5}]$ 4.75	27.5	6.42	1.5
Sodium	1.03	$[q/A < 1 \times 10^{5}]$ 8	56.6	22.6	3.72

Korneev's data[591,592] show the heat transfer coefficient of mercury as a function of velocity with parameters of the heat-flux density at the top, middle, and bottom of a horizontal boiling tube (see Fig. 3). As is evident from the figure, the velocity has a pronounced effect on the coefficient at the top of the tube. The velocity above which heat transfer in the upper portion of the tube remains at an almost constant level is given by the following:

$$u = 22 \times 10^{-5} \; q/A^{0.42} \; d^{0.76} \; \text{m/sec} \tag{45}$$

where q/A is in Kcal/(m^2)(hr) and d is in mm. The heat-transfer coefficient at this velocity level is

$$h = 12 \; q/A^{0.67} \; u^{0.3} \; d^{-0.45} \tag{46}$$

for $5000 < q/A < 70{,}000$ Kcal/(m^2)(hr); $13 \leqq d \leqq 40$ mm, $1 < p \leqq 12$ atm, $1 < u \leqq 19$ m/sec.

LYON, R. E.[695,696]

Lyon was the first investigator in the United States to make an extensive study of the heat-transfer characteristics of liquid metals in the boiling regime. The metals investigated were mercury, mercury containing 0.10% sodium, mercury containing 0.02% magnesium and 0.0001% titanium, sodium, sodium-potassium alloy (56-59 wt %K), and cadmium. Water was also boiled as a basis for comparison.

The experimental apparatus was constructed principally of 304 stainless steel with a 3/4-in. (OD), 16-gauge, type-316, stainless-steel boiler tube

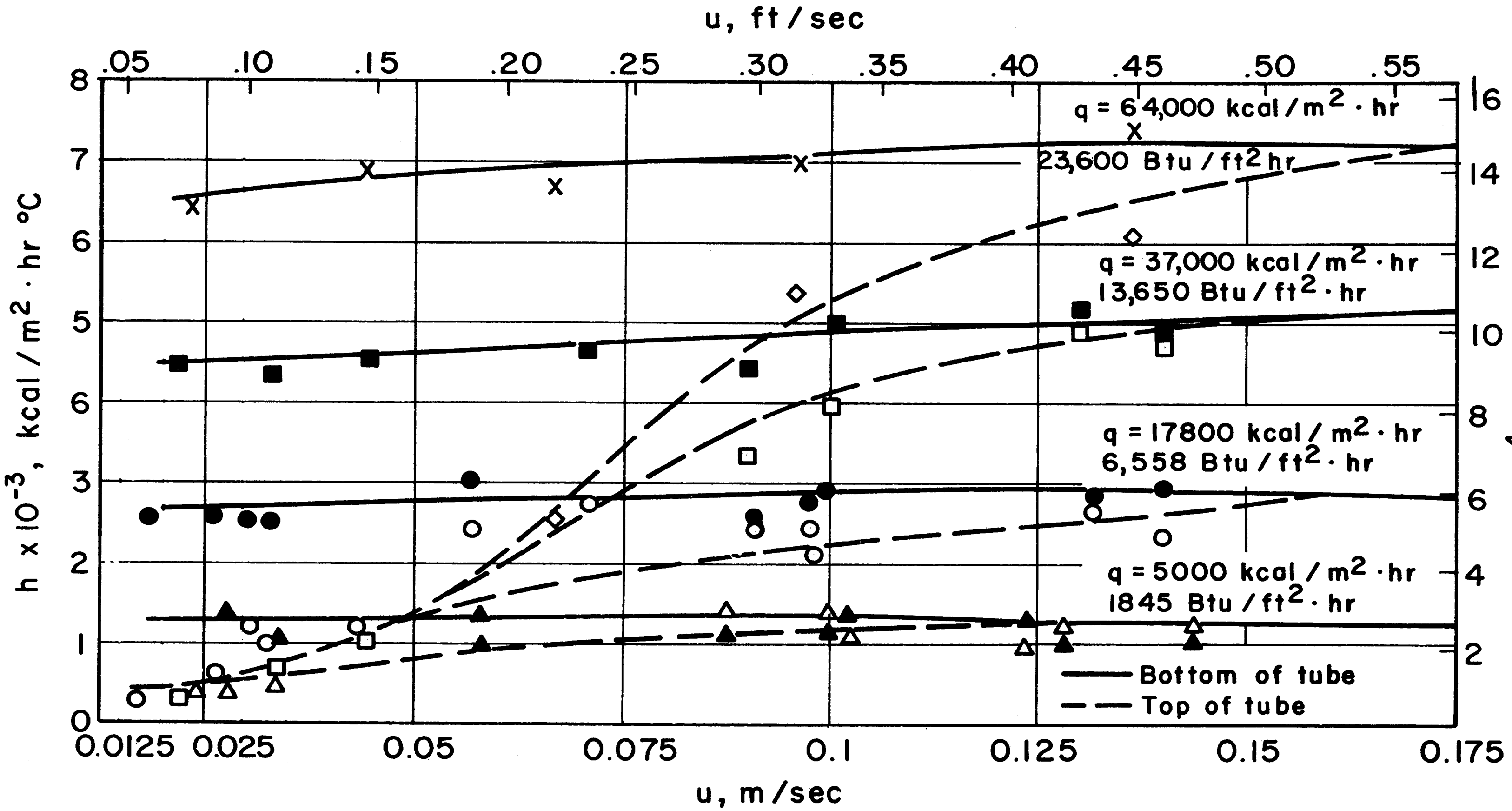

Fig. 3. Dependence of heat transfer from the wall to magnesium amalgam on the reduced velocity of the liquid u_0' and the heat supply q/A for a horizontally heated tube (D = 17.6 mm) with a vapor velocity u = 2 mm/sec (Kutateladze, *et al.*[617]).

five inches long. Chromel-alumel thermocouples imbedded in the wall of the heating tube measured temperatures that could be used to determine the boiling surface temperature. An electrical resistance element inserted inside the boiler tube supplied a heat source up to 130,000 Btu/(hr)(sq ft). All tests were performed at atmospheric pressure under conditions of natural convection with the entire system blanketed with nitrogen. Condensing of the bulk boiling metals was accomplished in an air-cooled condenser.

Before each liquid was boiled, the system was evacuated and re-pressurized with nitrogen. A known quantity of the test metal was emitted to the boiler and the heater element turned on and adjusted to the desired level. After steady-state conditions had been established, the required readings were recorded.

In the analysis of the experimental error, Lyon found the probable error in measuring the boiling surface temperature to be 3.2°F at 50,000 Btu/(hr)(sq ft), the error from potentiometer calibrations and readings to be ±0.4°F, yielding a probable error in the temperature difference of ±0.8°F; and the overall error in computing the heat flux density to be ±8% at 10,000 Btu/(hr)(sq ft) and ±6% at 100,000 Btu/(hr)(sq ft).

Figures 4, 5, and 6 show plots of the heat flux density (q/A) as a function of the temperature difference between the bulk liquid and the heat-transfer surface (ΔT) for all the test liquid metals. Figure 7 shows the heat-transfer coefficient (h) as a function of ΔT. It is seen that the sodium, sodium-potassium alloy, and mercury containing magnesium and titanium give extremely good heat-transfer characteristics. Nucleate-boiling heat-transfer coefficients of nearly 15,000 Btu/(hr)(sq ft)(°F) were found for both sodium boiling at 1620°F and sodium-potassium alloy boiling at 1500°F, for a ΔT of less than 10°F. For mercury with 0.02% magnesium and 0.0001% titanium, a heat flux of 100,000 Btu/(hr)(sq ft) at a ΔT equal to 12°F was attained with no apparent indication of the critical heat flux being reached.

Certain pertinent conclusions were drawn from the investigation. Cadmium and pure mercury experienced only film boiling upon reaching the saturation temperature. This effect was attributed to their nonwetting features. The effects of additives in mercury are to increase the heat-transfer coefficient (in the case of 0.10% sodium the heat-transfer coefficient reached ten times as high as with pure mercury) because they promote wetting. Temperature fluctuations at low heat fluxes were observed during the nucleate boiling of sodium-potassium alloy and mercury containing magnesium and titanium, and were explained on the basis of the high heat-transfer rates in the liquid metals.

With the exception of pure mercury and cadmium, there was no indication that the critical had been approached. The condensing capacity prohibited operation with higher fluxes.

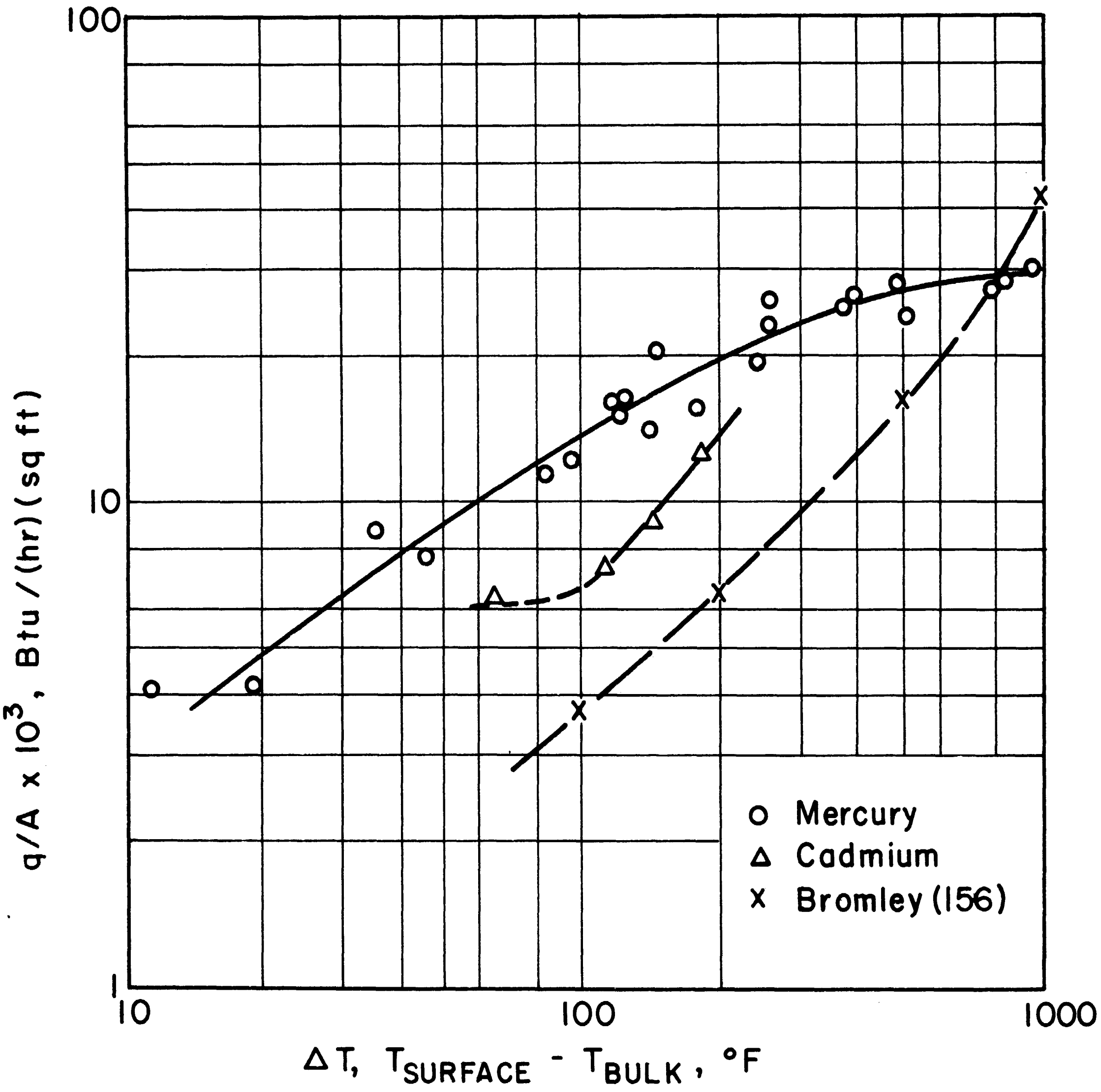

Fig. 4. Heat flux vs. temperature difference for film boiling of mercury and cadmium (Lyon[695,696]).

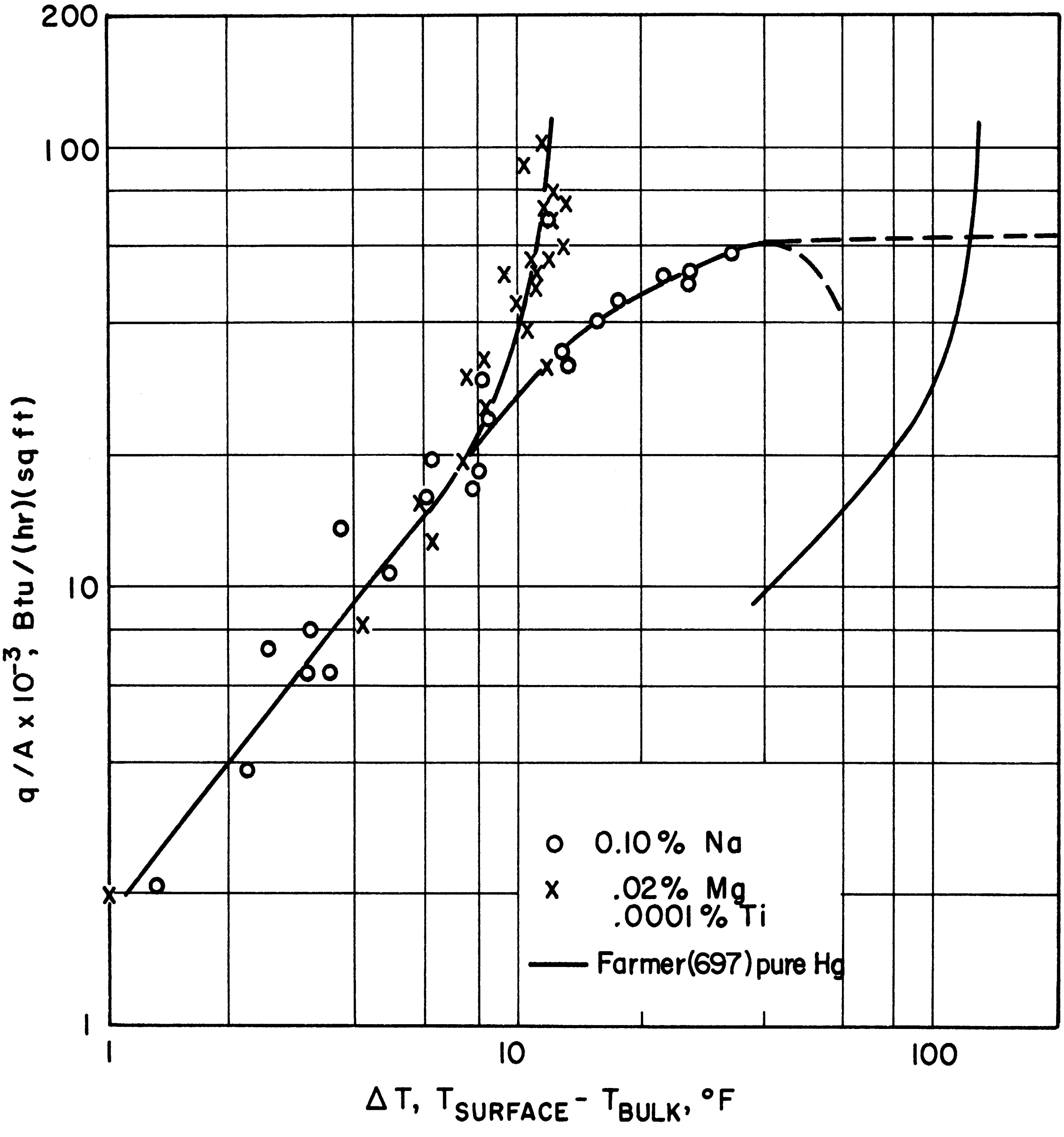

Fig. 5. Heat flux vs. temperature difference for boiling mercury with wetting agents (Lyon[695,696]).

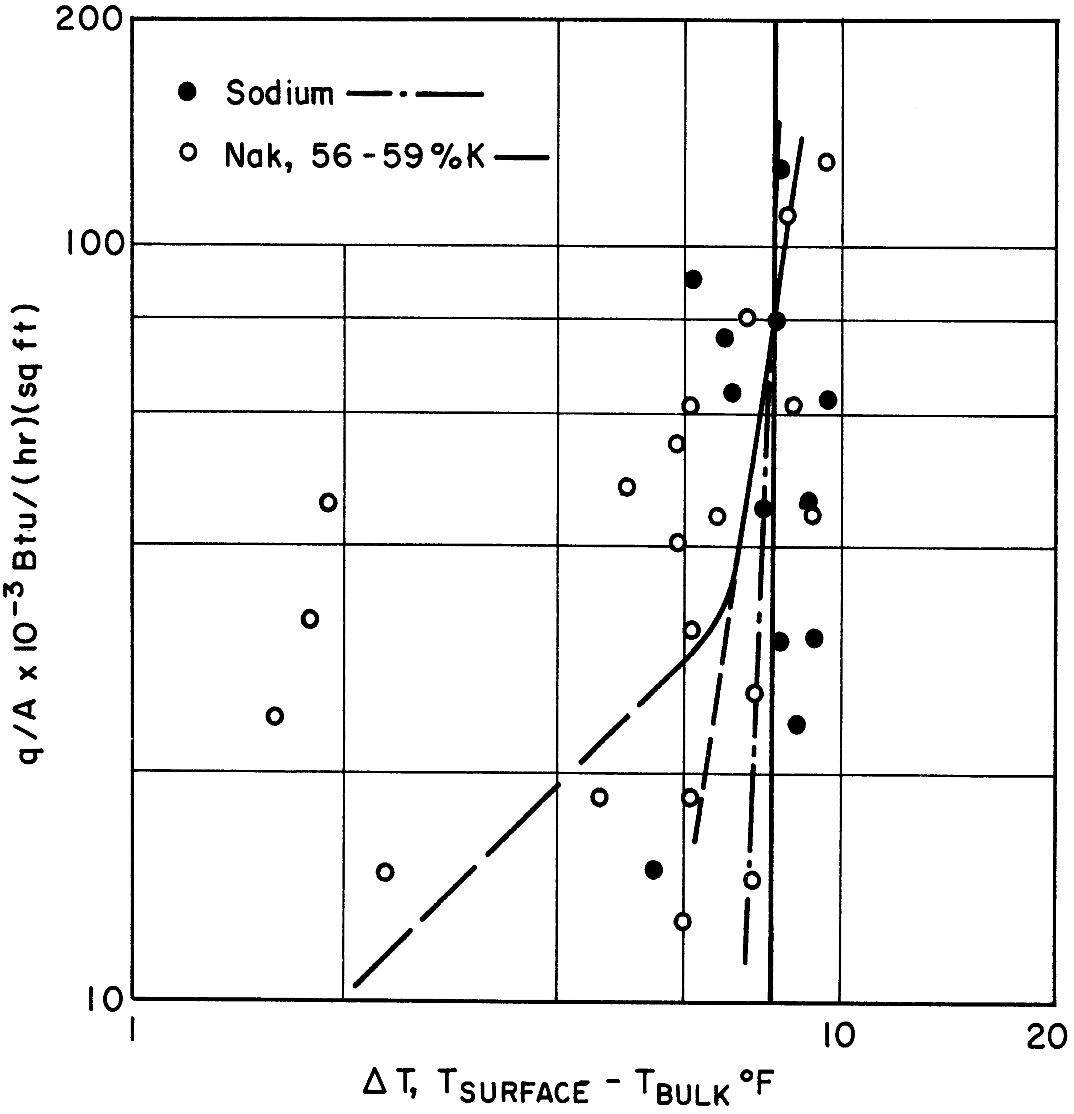

Fig. 6. Heat flux vs. temperature difference for boiling sodium and boiling NaK (Lyon, et al.[695,696]).

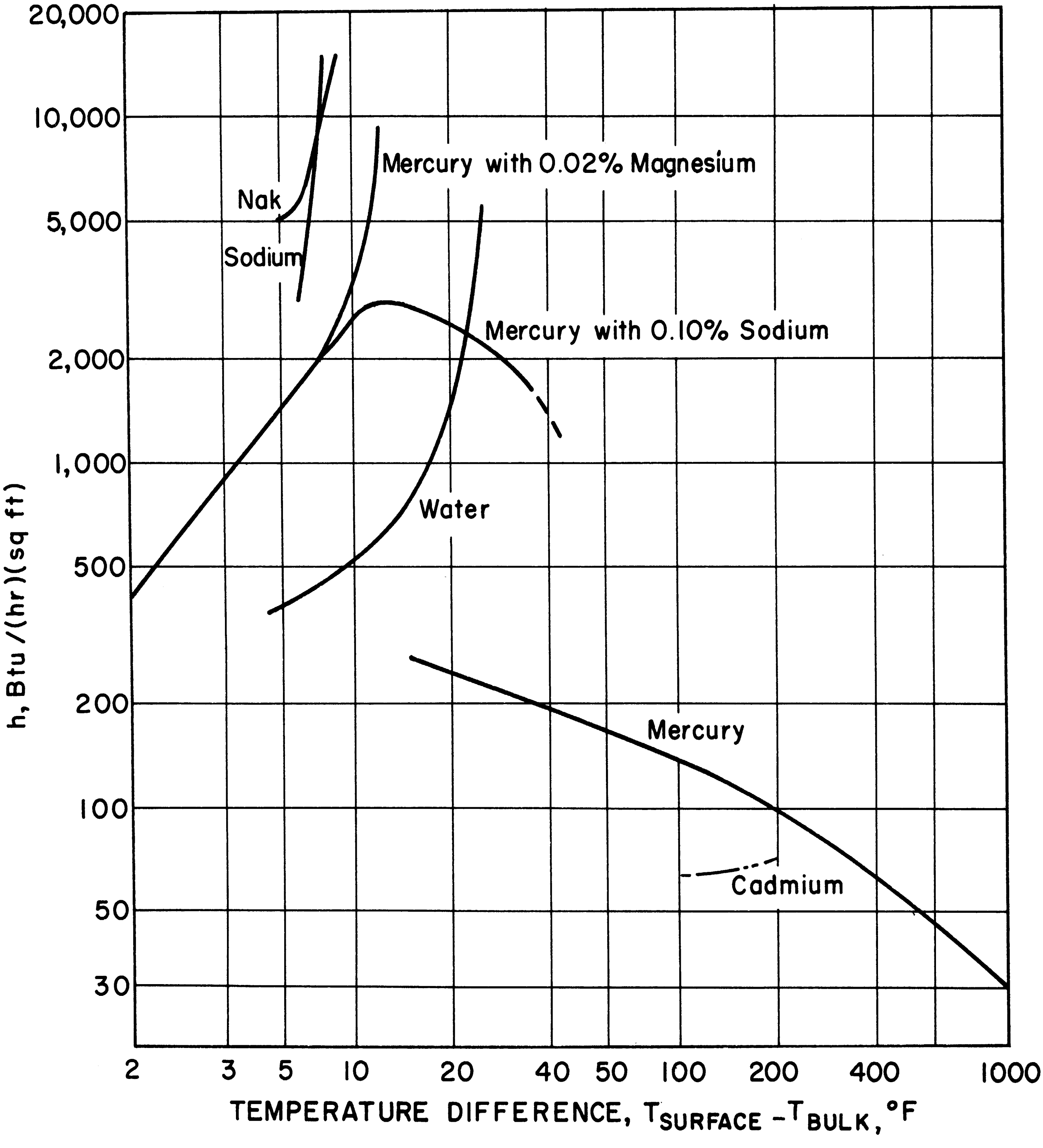

Fig. 7. Comparison of experimental boiling heat transfer coefficients for water and liquid metals (Lyon, et al.[695,696]).

BONILLA, C. F.[126]

Boiling of mercury was accomplished both with and without wetting agents. The apparatus consisted of a horizontal heating surface of low-carbon steel fitted with a 3-in.-OD stainless-steel tube. The upper portion of the tube served as the condenser. The main heater consisted of a wound Nichrome strip over mica on flat copper fins extending from the bottom of the heating surface plate. The system was blanketed with nitrogen and was operated at pressures from 4 mm mercury to 45 psia with heat-flux densities ranging from 4,000 to 200,000 Btu/(hr)(sq ft). The boiling pool depth varied from 2 to 10 cm. At various times 0.002% magnesium and 0.0001% titanium were added to the mercury to increase its wettability. A guard heater was used to minimize heat loss. The boiling-surface temperature was attained by extrapolating temperatures measured by iron-constantan thermocouples inserted in the boiling block at varied distances from the heating surface. Bulk boiling temperatures were measured using three iron-constantan thermocouples placed in the liquid.

The experimental procedure was quite simple. The apparatus was properly assembled, pressurized to check for leaks, filled with mercury (and additives), evacuated, refilled with nitrogen, and then the heater was turned on to the desired level. After steady-state conditions had been reached (15 to 30 min), the required temperature and power readings were recorded.

No mention was made of the experimental accuracy achieved in the apparatus.

Figures 8, 9, and 10 show the boiling curves for mercury boiled in 2- and 10-cm-deep pools; system pressure is the parameter. Data for each pressure run seem to correlate reasonably well. It can be seen that the effect of pressure diminished as the pool depth increased. It was stated that over a period of a few weeks of constant use, film boiling was not obtained with pure mercury systems. The authors attributed this to mechanical removal of oxygen or oxide from the surface. This may partially account for the fact that Lyon's pure mercury data deviate somewhat from the present data. Lyon experienced film boiling when mercury was boiled, thus yielding a boiling curve with a negative slope and displaced slightly to the right of the present data.[695,696]

Figure 11 shows the boiling curve for mercury with the addition of 0.02% magnesium and 0.0001% titanium. The heat flux at constant ΔT is increased some 25% over that obtained by boiling pure mercury. The agreement of Bonilla's data with those of Lyon[695,696] and Farmer[881] should be noted.

Conclusions reached are as follows:

(1) Prolonged boiling on stainless steel promotes wetting and increases the heat-flux density for the same temperature-driving force;

(2) Increasing the pressure of the system reduces the temperature-driving force for the same heat-flux density;

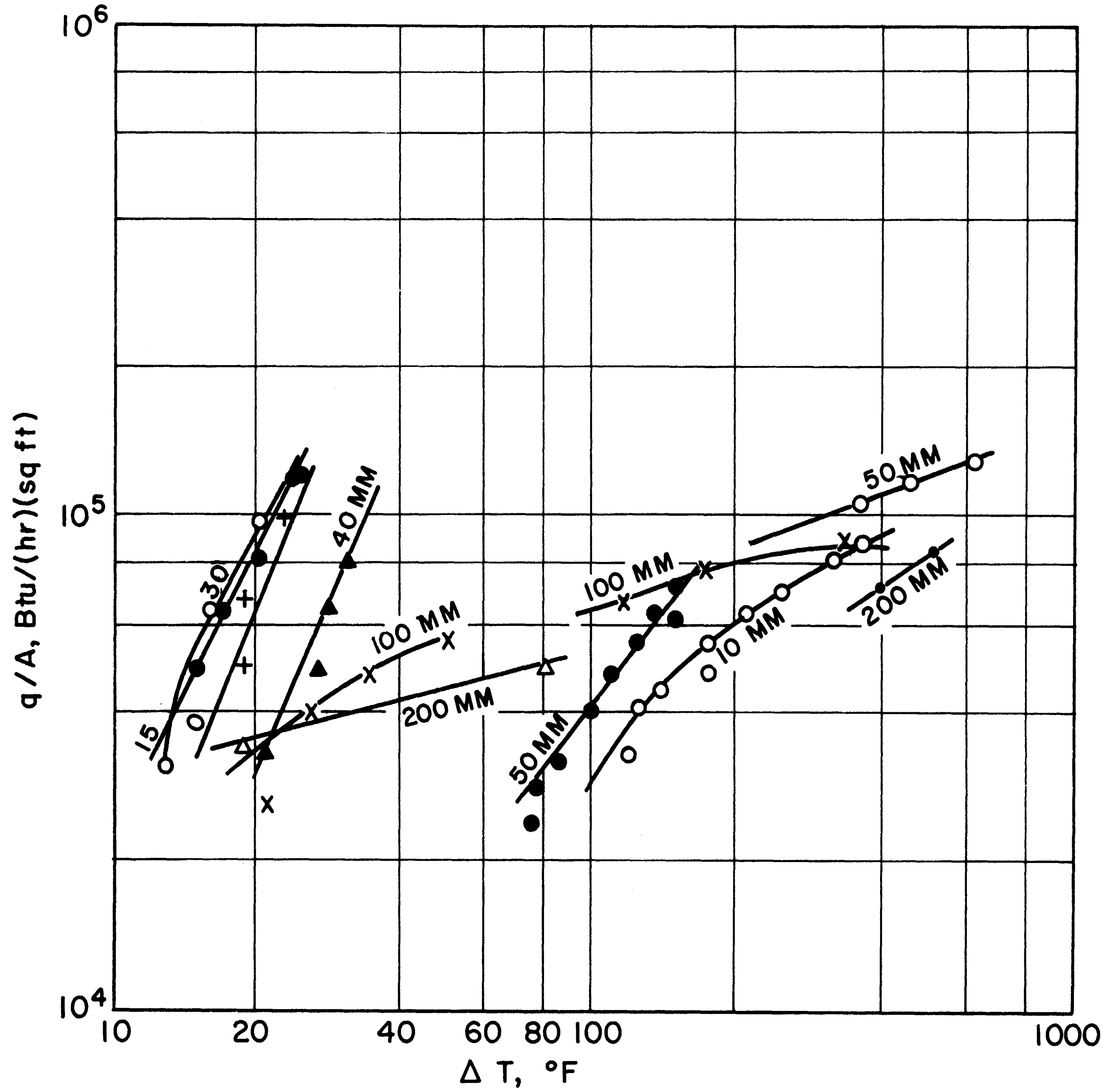

Fig. 8. Boiling of pure mercury 2 cm deep on a horizontal low-carbon-steel plate; parameter: pressure over the liquid in mm Hg absolute or in lb/sq in. gauge (Bonilla[126]).

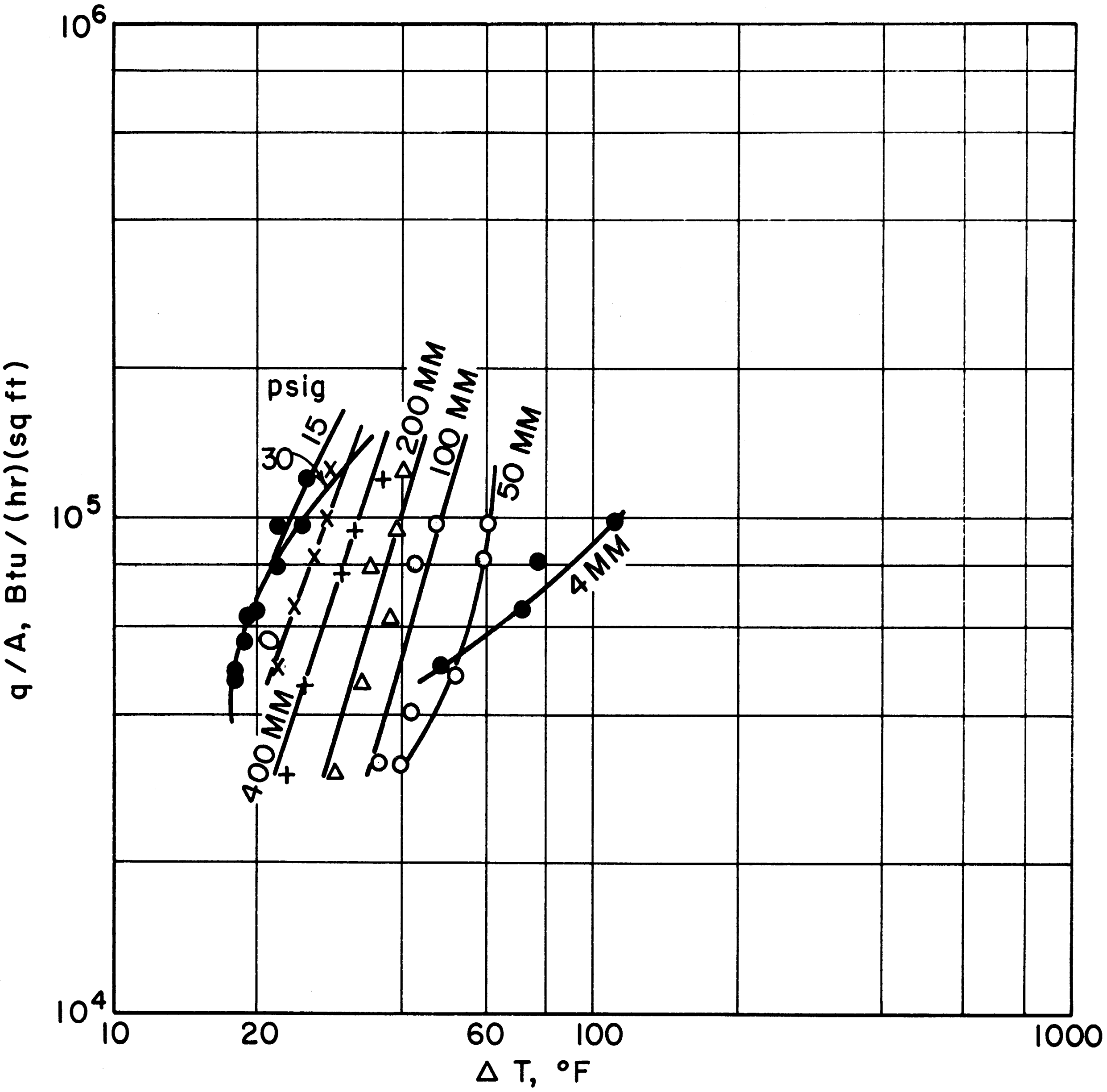

Fig. 9. Boiling of pure mercury 10 cm deep on a horizontal low-carbon-steel plate; parameter: pressure over the liquid in mm Hg absolute or in lb/sq in. gauge (Bonilla[126]).

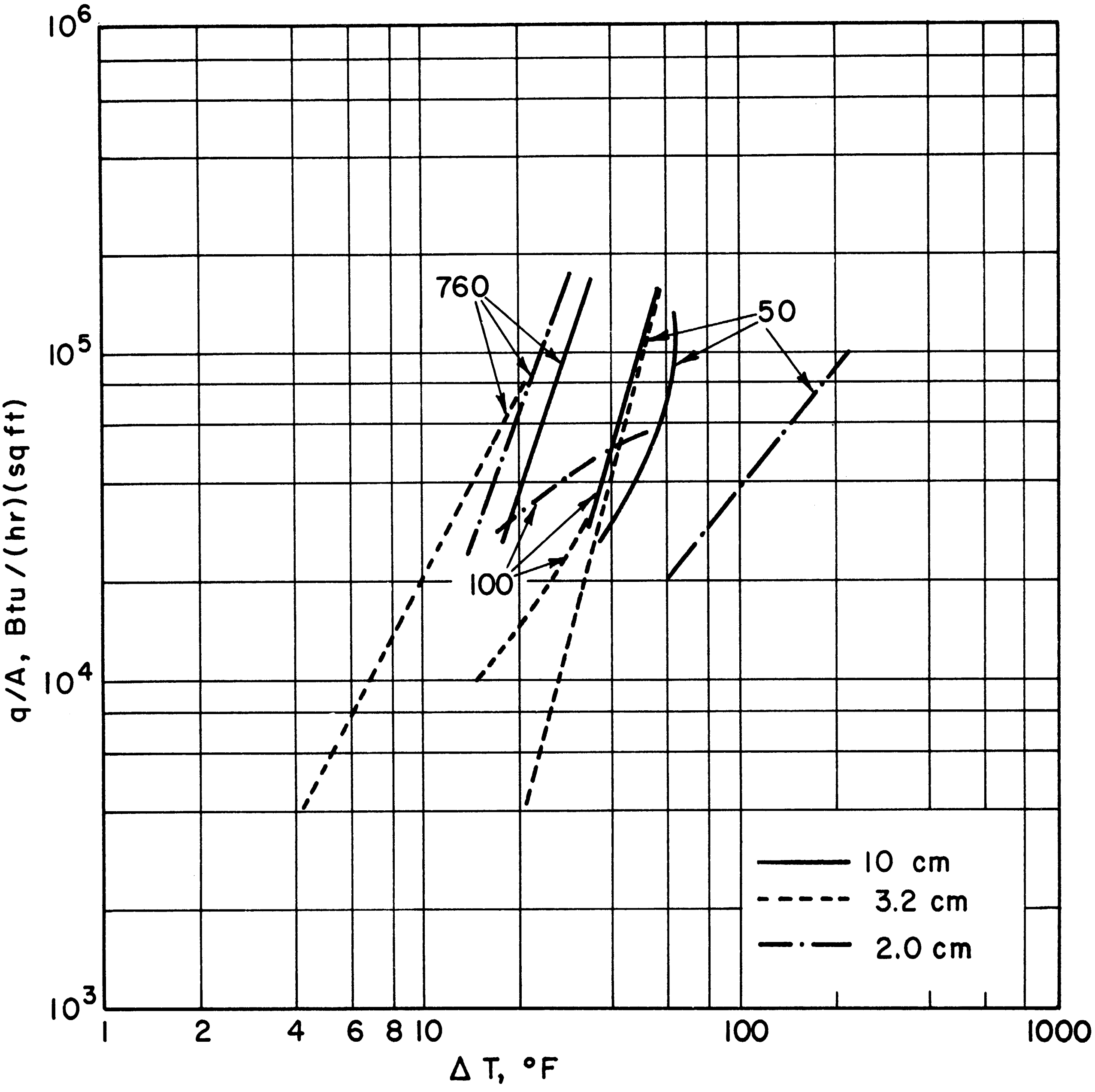

Fig. 10. Effect of depth on the nucleate boiling or pure mercury on a horizontal low-carbon-steel plate; parameter: pressure over the liquid in mm Hg absolute (Bonilla[126]).

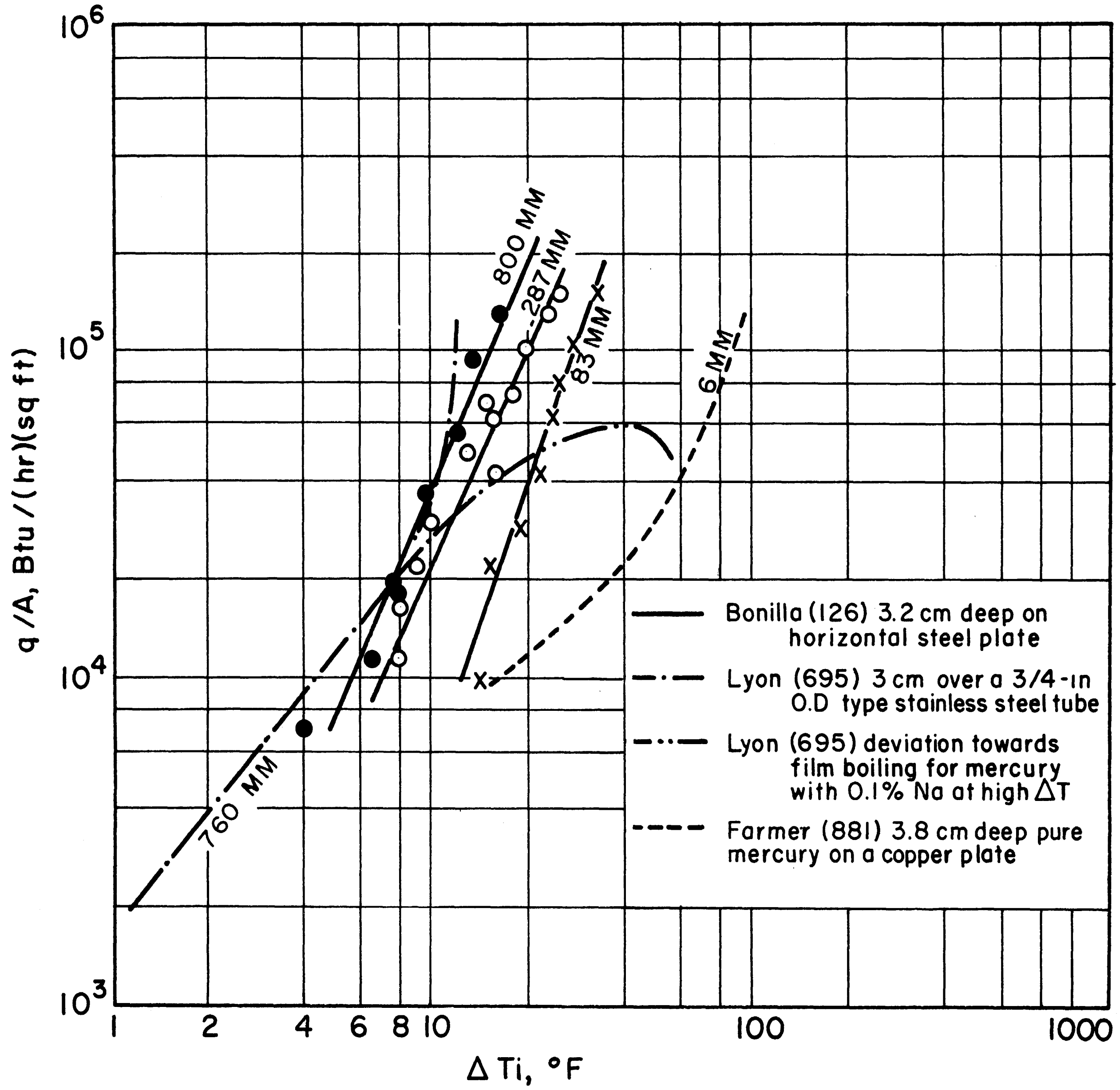

Fig. 11. Boiling of mercury containing 0.02% Mg and 0.0001% Ti; parameter: pressure over the liquid in mm (Bonilla, et al.[126]).

(3) Additives in mercury promote wetting;

(4) The liquid-metal pool temperature does not change with increased depth;

(5) Different noise levels are observed for different heat-flux densities.

LIN, C., ET AL.[664]

Boiling of mercury containing magnesium was accomplished for heat loads from 5,000 to 47,000 Kcal/(hr)(sq m) and pressures of 1 and 11 atmospheres. No mention is made in the article of the experimental apparatus, procedure, or experimental error.

For pure mercury boiling under atmospheric conditions, the authors found that the heat-transfer coefficient could be expressed by the following:

$$h = 4850 \quad q/A^{-0.26} \text{ Kcal/(hr)(sq in.)(°C)} \tag{47}$$

For boiling pure mercury under superatmospheric pressures, the authors give the following expression:

$$h = Ap^{b} \quad q/A^{0.46} \tag{48}$$

For the pressure interval 4-11 atm the equation gives:

$$h = 7p^{-0.29} \quad q/A^{0.46} \tag{49}$$

This indicates that increasing the pressure lowers the heat-transfer coefficient for pure mercury and gives a behavior different from ordinary liquids. Using $q/A = h\Delta T$ and eliminating h from the above equation gives:

$$q/A = 37 \quad p^{-0.537} \quad \Delta T^{1.85} \tag{50}$$

Comparing this equation for pure mercury with the one in identical form determined by Madsen and Bonilla[706] for Na-K, one finds that the powers of ΔT and the coefficient seem to be in accord, but the effect of pressure is inverted. The only major difference in behavior of the two metal systems is wettability, which, it is felt, could hardly account for this unusual behavior.

Mercury was then boiled with varied amounts of magnesium added (0.02 to 0.05%). The data indicated that the heat-transfer coefficient could be represented by the formula

$$h = A \quad q/A^{n} \tag{51}$$

where the constants A and n are given in Table III. It was stated that for the same heat-flux density, 0.05% magnesium results in a heat-transfer coefficient

15-50% higher than that for 0.02% magnesium. Variations in wettability accounted for this effect. Pressure had little or no effect on the heat-transfer characteristics.

TABLE III

CONSTANTS IN EQ. (51)

Magnesium Content (%)	A	B
0.02	13.7	0.43
0.05	2.43	0.63

ROMIE, F. E., BRORARNEY, S. W., AND GIEDT, W. H.[946]

Mercury with a small amount of magnesium and a trace of titanium was boiled in a thermal-syphon-type heat-transfer loop fabricated from 7/16-in.-OD, 304 stainless steel. A 4-in. heating section made of 7/16-in.-OD, 1018 steel served as the boiling surface. Electrical power was applied to the heating section giving heat-flux densities as high as 600,000 Btu/(hr)(sq ft) with a 5 mole percent vapor quality. Temperature of the heating surface was determined by measuring the outside wall temperature with a thermocouple and equating to the inner wall. It was found that by cleaning the surface and depositing a thin copper layer on the inside wall that the test fluid readily wet the surface.

Experimentation was begun by completely filling the loop with mercury and then draining out a specified amount of mercury. The pressure in the system could be changed by simply controlling the water rate to the condenser.

The test results are reproduced in Table IV. Probable error in determining the heat flux was estimated at ±20%. The exit quality of the mercury was calculated by means of an energy balance. During certain runs, hydrodynamic oscillations in the mercury flow were observed. In all cases these oscillations could be removed either by increasing the heat-flux density and/or increasing the pressure of the system.

Even though a heat-flux density of 600,000 Btu/(hr)(sq ft) was the maximum reached in these tests, it was emphasized by the authors that the thermal and hydrodynamic performance of the loop gave every indication that even higher heat-flux densities could be achieved before reaching the critical heat-flux density.

TABLE IV

RESULTS OF BOILING MERCURY WITH ADDITIONS IN A THERMO-SYPHON HEAT TRANSFER

Run	Heat Flux, q/A (Btu/hr-ft^2 x 10^{-3})	Test Section Pressure (psia)	Flow Velocity at Inlet to Test Section (ft/sec)	Inlet Temp. (°F)	Temp. Increase Through Test Section (°F)	Inside Wall Temp. (°F)	Inside Wall Temp. Less Saturation Temp. (°F)	$\frac{\text{Heat Out}}{\text{Heat In}}$	Exit Quality, (mole/mole)
1	--	--	--	--	--	--	--	--	--
2	24	--	2.9	66	137	647	--	2.16	--
3	92	--	0.67	282	169	468	--	1.65	--
4	150	--	1.0	256	217	504	--	2.0	--
5	190	--	1.1	293	227	562	--	1.78	--
6	230	--	1.9	320	221	587	--	2.50	--
7	260	--	1.5	355	221	629	--	1.66	--
8	400	--	1.3	386	240	701	--	1.0	--
9	460	10	1.1	392	249	741	100	--	0.015
10	67	--	--	247	214	453	--	--	--
11	--	--	--	--	--	--	--	--	--
12	210	--	1.3	480	135	674	--	1.03	--
13	280	10	1.4	488	153	710	69	--	0.001
14	340	14	1.1	506	122	759	88	--	0.032
15	470	17	0.89	524	168	776	84	--	0.061
16	550	19	0.74	536	165	776	75	--	0.10
17	600	33	1.5	649	112	825	64	--	0.049

AVERY, G. W.[47]

The effect of the surface geometry on boiling mercury and mercury with 0.1% sodium was studied. The experimental apparatus was similar to that used by Bonilla and co-workers[126] and consisted principally of a horizontal low-carbon steel boiling plate fitted with a 3-in.-diameter, 304 stainless-steel pipe 24 in. long. The heat supply was furnished by nichrome strips wound over 13 mica insulated copper fins brazed to the underside of the boiling plate. A guard heater and insulation surrounded the heater arrangement. Condensing of the metallic vapors was accomplished in 304 stainless-steel tubing extending from the top of the vapor chamber. For the most part, the system was operated at subatmospheric pressures under a cover of nitrogen gas.

The experimental procedure consisted of assembling the apparatus, calibrating the vessel for heat loss, filling with 125 cc of mercury, blanketing with nitrogen, and then setting the heat input to the desired level. After reaching equilibrium the required instrument readings were recorded. Upon completion of one set of runs the vessel was disassembled and the boiling surface grooved. This procedure was repeated.

During the course of the investigation two boiling plates were used. Data for boiling mercury from a smooth surface were obtained before burnout occurred. A similar plate was used to boil mercury and mercury with sodium additions first from a smooth surface and then from a surface milled with parallel, 0.003-in.-wide by 0.004-in.-deep, grooves both 3/8 in. and 1/8 in. apart. A groove spacing of 1/16 in. was also milled, but an equipment failure prevented obtaining data.

Figure 12 shows the data taken. It is seen from this plot that for any given surface, the surface geometry has a significant effect on boiling heat transfer to mercury both with and without additives. Unfortunately, the two different plates, despite efforts to reproduce initial surface conditions, gave considerably different heat-transfer coefficients. The first surface gave heat-transfer characteristics for pure mercury comparable to those obtained from the 1/8-in. grooved surface when boiling 0.1% sodium in mercury from the second plot. This fact leaves many questions unanswered. The author suggests that this may be due to the differences in the microscopic geometry of the surfaces.

The author concluded the following from this investigation:

(1) Heat-transfer coefficients can be improved by grooving the surface;

(2) Nitrogen cover gas does not appreciably affect the heat-transfer characteristics;

(3) "Bumping" is observed primarily during atmospheric nucleate boiling at 40,000 Btu/(hr)(sq ft) or greater;

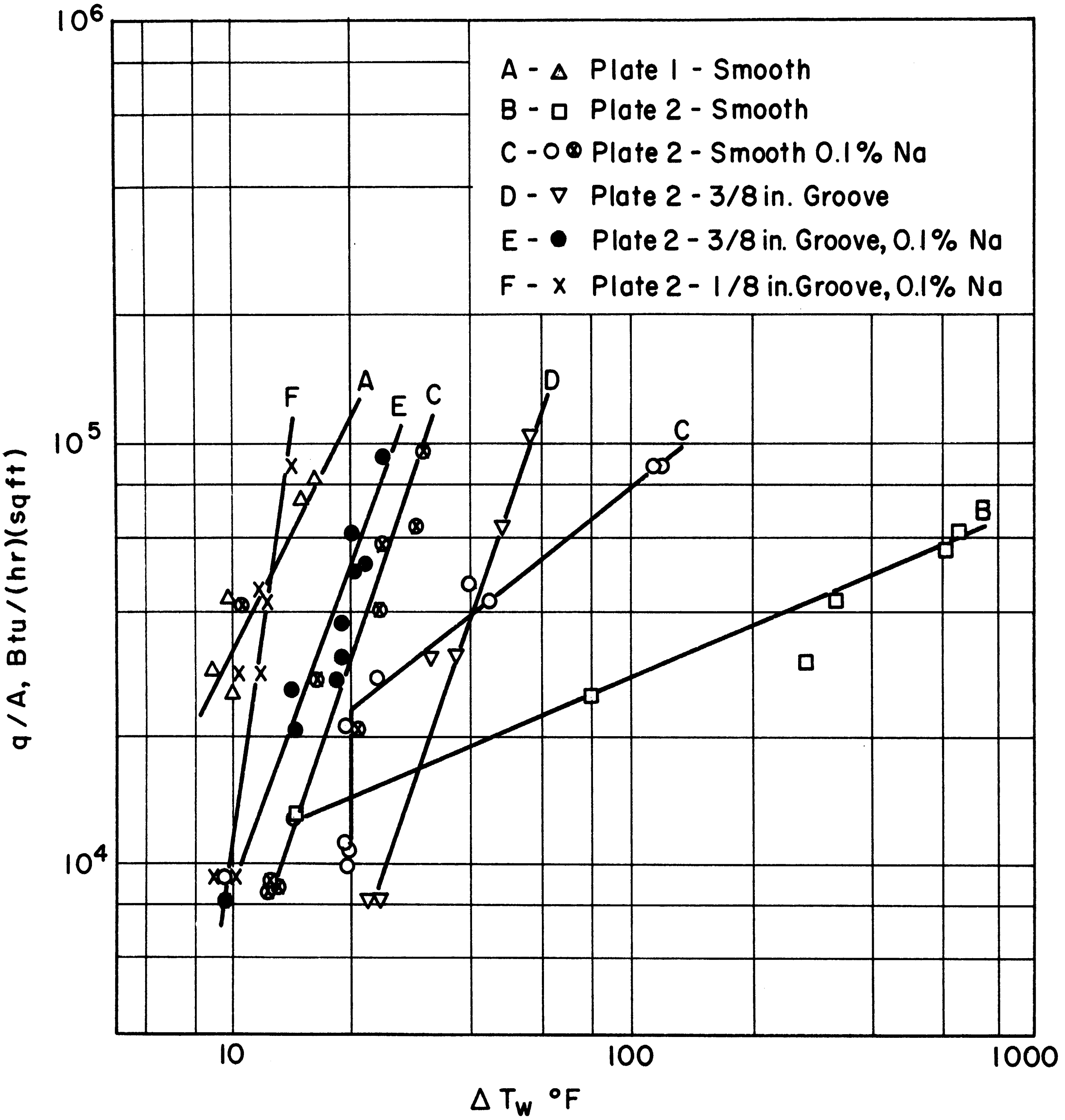

Fig. 12. Mercury boiling on smooth and grooved plates (Avery[47]).

(4) The effect of surface grooves increases percentagewise with increasing heat-flux density.

MADSEN, N., AND BONILLA, C. F.[706]

A sodium-potassium alloy (44 wt % potassium) was pool-boiled from a horizontal low-carbon nickel plate at temperatures in the neighborhood of 1600°F and pressures from 2 mm to 794 mm of mercury. The boiling chamber was fabricated from a 3.068-in.-ID stainless-steel pipe with a water-cooled stainless-steel plug at the top serving as the condensing surface and used to condense the metal vapor.

The vessel was constructed in such a way as to allow for a minimum number of welded joints, and hence reduce the possibility of sodium penetrating cracks or seams in the vessel. Heat to the boiling liquid metal was furnished by molybdenum resistance wire covered with alumina sleeves and wound around molybdenum fins brazed to the bottom of the heater plate. The entire system including the heater enclosure was blanketed with helium gas. Temperatures in the boiling plate were determined by six thermocouples inserted in holes radially drilled and at various depths from the boiling surface; a thermocouple inserted from the top of the boiling vessel measured liquid bulk temperatures.

After cleaning with concentrated hydrochloric acid and testing for leaks, the vessel was calibrated for heat loss and charged with Na-K under a helium blanket. Throughout the tests metal was maintained at a minimum of 900°F, thus reducing heater damage. After the desired heat flux density had been attained and steady state achieved, the necessary readings were taken.

Figure 13 shows all the experimental data taken. Even though the data are more or less random, the authors used the method of least squares twice to obtain the following empirical equation:

$$q/A = 134\ p^{0.25}\ \Delta T^{1.24} \tag{52}$$

where ΔT is the temperature difference between the heat-transfer surface and the liquid free surface equilibrium temperature. The probable error is estimated at +38 or -28% of the calculated value.

For a constant heat-flux density the heat-transfer coefficient can be estimated by the following:

$$h = C\ p^{0.20} \tag{53}$$

where C is a constant.

It was found that a temperature gradient existed in the bulk liquid throughout all runs. This presumably would account for the large temperature differences as compared to Lyon.[695,696] The authors suggest that the geometry of

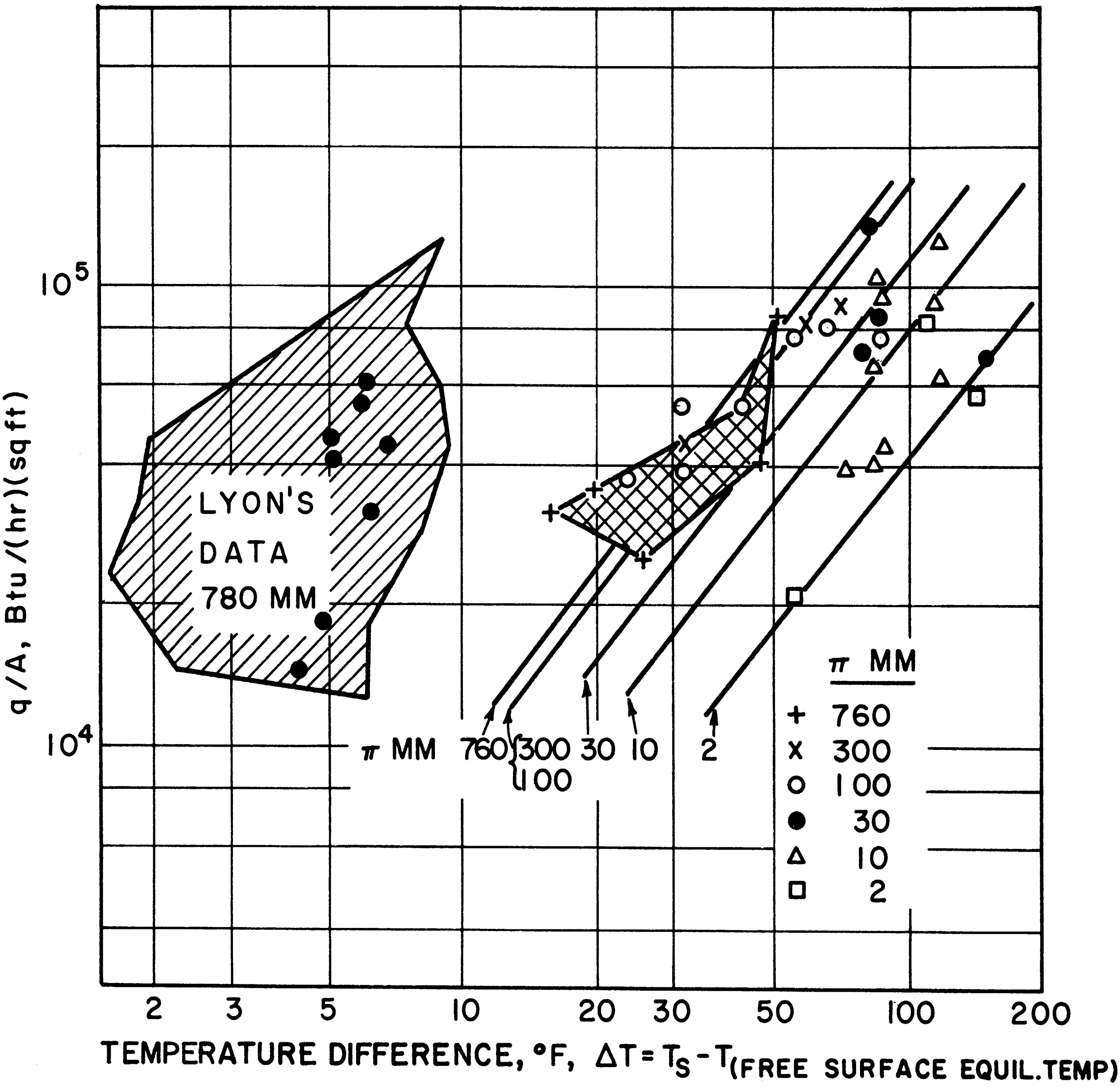

Fig. 13. Comparison of q/A vs. ΔT with Lyon's[695,696] data for boiling NaK (Madsen and Bonilla[706]).

Lyon's heater in a larger vessel may promote strong natural-convection currents, thus reducing temperature gradients in the pool.

It was noticed during the investigation that the temperature on the boiling plate near the surface fluctuated randomly, the amplitude of fluctuation changing slightly with different heat-flux densities. Moreover, it was observed that liquid-bulk temperatures and pressures fluctuated, but they were not as significant as the surface-temperature fluctuation. Finally, at low heat-flux densities distinct "bumps" were heard followed by a pronounced temperature drop.

TWO-PHASE FLOW REGIMES

Two-phase (gas-liquid) flow patterns have been studied by a number of investigators, most of whom have used visual means of observation. A recent literature survey on this subject is given by John H. Vohr,[1116] who presents a total reference list of 35 items.

Gas-liquid flows appear in a complex variety of forms, and visual observances have produced a wide variety of terminology. Vohr points out, however, that observers seem to agree as to the basic types of flow patterns that occur, although they differ in classifying subdivisions of the basic patterns. Flow regimes are usually studied in horizontal or vertical flow. The principal difference between these two situations arises when gravity forces cannot be neglected with respect to dynamic forces.

The basic horizontal flow patterns are:[1116]

(1) Bubble flow, in which gas bubbles flow along with the liquid;
(2) Plug flow, in which the gas bubbles coalesce to form long gas plugs;
(3) Stratified flow, in which the gas flows in a continuous stream above a smooth gas-liquid interface;
(4) Wavy flow, which is stratified flow with a wavy interface;
(5) Slug flow, in which periodic slugs of liquid rapidly travel the length of the duct, leading to pulsating gas-liquid flow;
(6) Annular flow, in which liquid flows in an annulus adjacent to the walls of the duct and the gas flows as a central core;
(7) Spray flow, in which the liquid flows as a spray carried by the gas stream.

The following table summarizes and compares the parameters some investigators used in correlating horizontal flow patterns. An obvious consistency in the tabulation is that all authors reported no information concerning the dependence of flow regime upon fluid physical properties.

TABLE V

SUMMARY AND COMPARISON OF PARAMETERS USED IN CORRELATING HORIZONTAL FLOW PATTERNS

Investigators	Parameters Plotted
Alves[25]	Superficial gas velocity vs. superficial liquid velocity
Bergelin and Gazley[93]	Water rate vs. air rate, both in lb/hr
White and Huntington[1154]	Liquid mass velocity vs. gas mass velocity, both in lb/hr ft^2
Johnson and Abou-Sabe[536]	Water rate vs. air rate, both in lb/hr
Krasiakova[599]	Water velocity vs. air velocity
Richardson[921]	Water wt. flow vs. air wt. flow, both in lb/hr

Kosterin[596] studied air-water flow patterns in tubes of various diameters, and he presented his findings in a separate plot for each tube. His plots give some indication of the effect of pipe diameter on two-phase flow pattern. Kosterin stated that the transition from divided (stratified or wavy) flow to plug flow should depend on the Froude number, u^2/gD, and that the strong dispersion of gas should depend on the Weber number, $L\rho u^2/\sigma g_c$, where L is a characteristic length associated with bubble size.

Baker[54] proposed a correlation in which the parameters attempted to account for the effect of fluid physical properties on flow regime. His coordinates were G/λ^B and $L\lambda^B\psi^B/G$ where G and L are gas and liquid mass velocities and λ^B and ψ^B are given by

$$\lambda^B = \left[\left(\frac{\rho_g}{0.075}\right)\left(\frac{\rho_\ell}{62.3}\right)\right]^{1/2} \tag{54}$$

$$\psi^B = \frac{73}{\sigma}\left[u\left(\frac{62.3}{\rho_\ell}\right)^2\right]^{1/3} \tag{55}$$

Baker's plot is shown in Fig. 14. The plot was developed from data on air-water systems, and the extension of the parameters λ^B and ψ^B for correlating two-phase flow regimes in other systems needs verification.

It should be questioned whether all regime transitions depend in the same manner on the same fluid properties. If different transitions depend on differ-

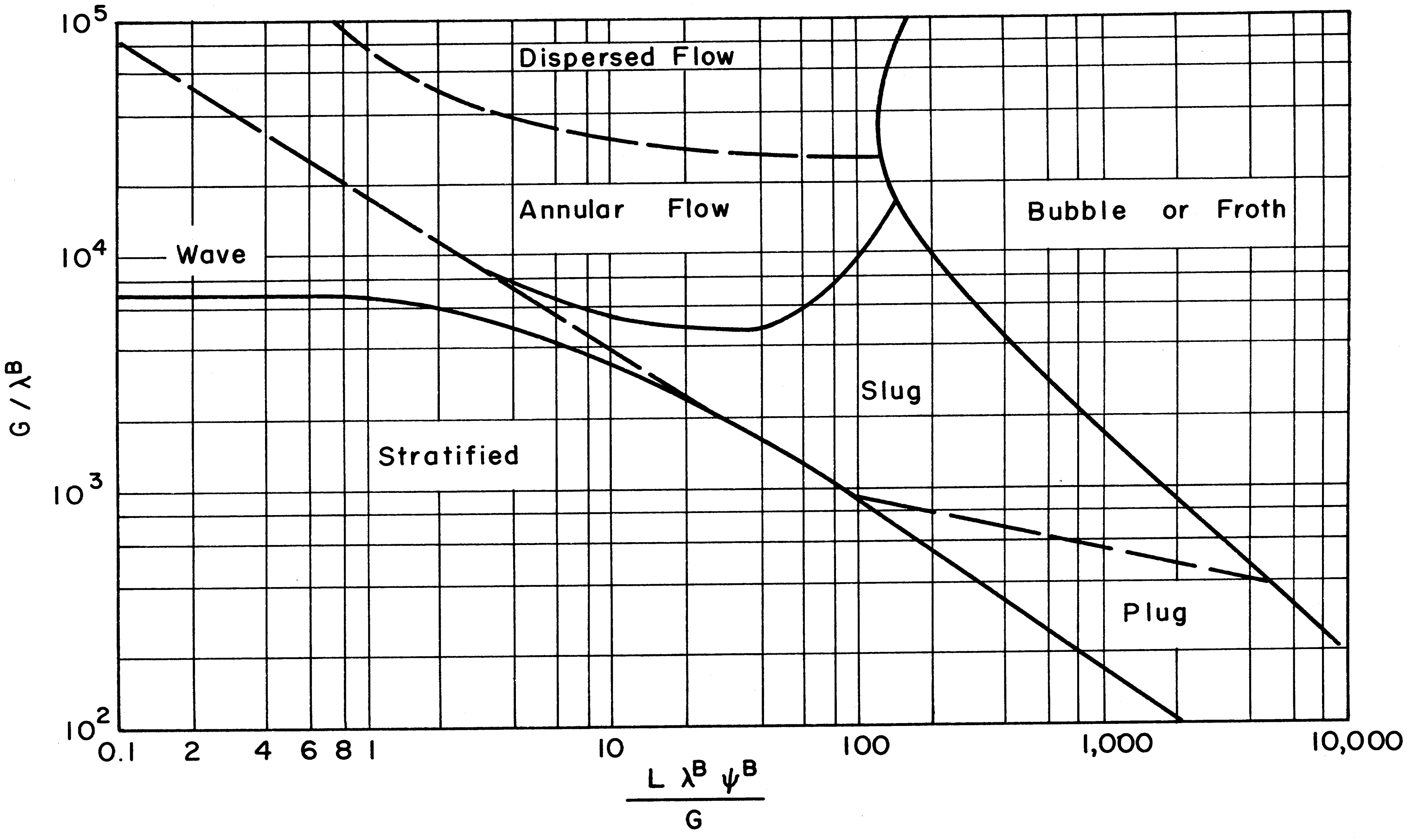

Fig. 14. Flow pattern correlation proposed by Baker.[54]

ent sets of physical properties, each transition might have to be correlated separately. Clearly, information on the relationship between fluid physical properties and stability of particular flow patterns should be important in gaining understanding of mechanics of two-phase flow regimes.

The flow-pattern plots given by various authors are dissimilar in appearance, and thus are difficult to compare quantitatively. Vohr compared the correlations of several observers by constructing a table, Fig. 15, in which the flow regimes were taken for a constant liquid velocity of 0.5 ft/sec with gas velocities ranging from 1 to 100 ft/sec.

Among those who studied vertical two-phase flow regimes were Govier, Radford, and Dunn,[395] Kosterin,[596] Dengler,[255] and Kozlov.[598]

Kosterin and Kozlov plotted vertical flow regimes using delivered volumetric gas content (C_{vd}) and mean mixture velocity (V_m). Kozlov also presented mathematical expressions for regime transition boundaries based on C_{vd} and the Froude number (N_F or Fr).

The basic vertical flow regimes are:[1116]

(1) Bubble flow, defined as for horizontal flow;
(2) Piston flow, in which gas flows up in periodic bullet-shaped slugs;
(3) A region between piston flow and fully developed annular flow in which flow is agitated and complex. Some of the terms for this range are dispersed-plug flow, emulsion flow, turbulent flow, semi-annular flow;
(4) Annular flow, defined as for horizontal flow;
(5) Spray flow, defined as for horizontal flow.

Some studies have been made of flow patterns in natural-circulation boiling, and the results are quite similar to those for nonboiling, vertical, two-phase flow. Apparently no studies have been made on forced-circulation boiling flow regimes, but these regimes are expected to differ widely from those in nonboiling two-phase flow due to induced agitation and rapid generation of vapor at fluid boundaries. Vohr is commencing a visual and photographic study of flow regimes in forced-circulation boiling. Wallis and Griffith[1123] studied gas and liquid distributions in a two-phase boiling analogy. Their results indicate that flow patterns may be most strongly affected by bubble-formation rate, and that nonboiling and natural-circulation boiling patterns do not apply.

No flow regime studies have been reported for two-phase flow in metallic systems.

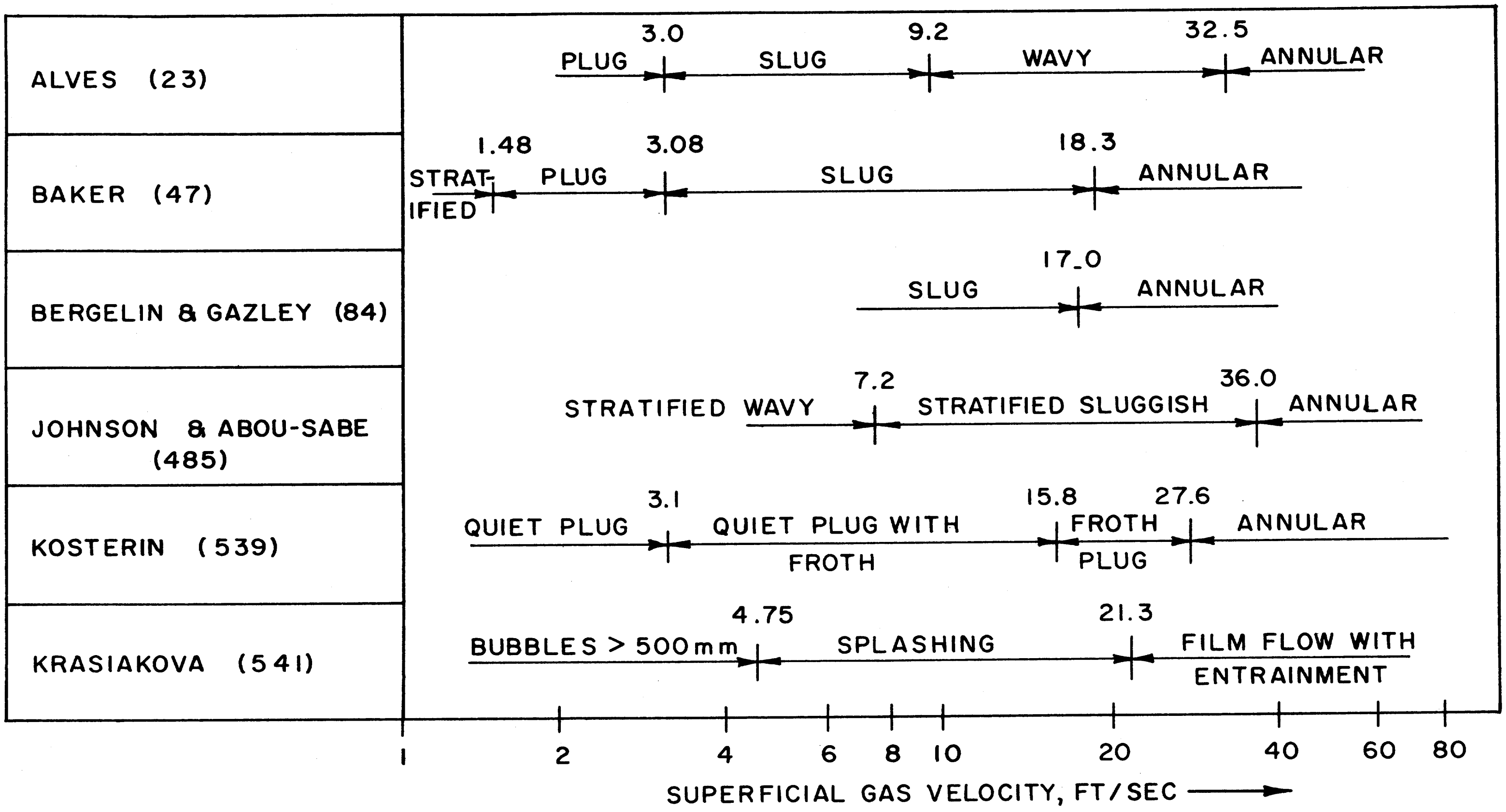

Fig. 15. Horizontal air-water flow pattern regimes for superficial water velocity = 0.5 ft/sec (Vohr[1116]).

TWO-PHASE PRESSURE DROP

The pressure drop occurring during flow of a boiling mixture includes, in addition to the frictional loss, a loss resulting from the rate of increase of momentum of the mixture as it flows through the tube and vaporizes. Such momentum pressure drops are often quite significant, and in order to predict them one needs to know true gas velocity which in turn demands knowledge of vapor volume fraction. Homogeneous flow should not be assumed.

The first significant two-phase pressure drop study in the United States was made by Boelter and Kepner[116] around 1939. In 1944 Martinelli and coworkers[721] proposed a method for predicting horizontal, isothermal, two-phase pressure drop. The Martinelli method assumes that the frictional pressure loss is the same for each phase and is equivalent to the static pressure drop, i.e., momentum and head losses are neglected. The method proposes a two-phase flow modulus χ, a function of fluid properties, which is used to correlate parameters ϕ.

$$\phi_g^2 = \frac{(\Delta P/\Delta L)_{TPF}}{(\Delta P/\Delta L)_g} \qquad (56)$$

$$\phi_\ell^2 = \frac{(\Delta P/\Delta L)_{TPF}}{(\Delta P/\Delta L)_\ell} \qquad (57)$$

where $(\Delta P/\Delta L)_{TPF}$ = two-phase frictional pressure drop and $(\Delta P/\Delta L)_{g(\text{or } \ell)}$ = pressure drop if gas (or liquid) phase were flowing alone in the tube.

Lockhart and Martinelli[670] improved the correlation in 1949 when they found that $(\Delta P/\Delta L)_\ell/(\Delta P/\Delta L)_g = X$ gave considerable improvement in the ϕ correlations. The Martinelli procedures utilize a notion of "flow type" based on whether laminar ($Re < 1000$) or turbulent ($Re > 2000$) flow would exist if the phase considered were flowing alone. Several attempts have been made to improve analytically the Martinelli method.[92,657] Some investigators feel the method could be improved by considering flow-pattern effects.

Friction factor models have been proposed for both horizontal and vertical two-phase flow. This concept was most recently used for horizontal flow by Bertuzzi, Tek, and Poettmann.[105] The authors claim that the variables which set the flow pattern also determine pressure drop, making possible a generalized solution independent of flow pattern. The development is based on a steady-state, total-energy balance, and the two-phase "f" factor is correlated against a two-phase Reynolds number function.

A recent approach to the problem of vertical two-phase pipe flow was given by Ros,[948] who utilized a dimensional analysis. He considered twelve independent variables which account for geometry, liquid and gas physical properties, flow properties, and interactions between phases. Ros used pressure gradient and liquid holdup as dependent variables, and he arrived at the following dimensionless groups:*

Diameter influence number	$N_d = d\sqrt{\rho_\ell g/\sigma}$
Relative roughness	ϵ/D
Pipe inclination	ϕ
Gas-liquid density ratio	$N_\rho = \rho_g/\rho_\ell$
Liquid viscosity-influence number	$N_\ell = u_\ell \sqrt[4]{g/\rho_\ell \sigma^3}$
Gas viscosity-influence number	$N_g = u_g \sqrt[4]{g/\rho_\ell \sigma^3}$
Liquid velocity-influence number	$N = V_{s\ell} \sqrt[4]{\rho_\ell/g\sigma}$
Gas-liquid velocity ratio	$R = V_{sg}/V_{s\ell}$
Wall contact angle	θ
Dimensionless-pressure gradient (dependent)	$G = (1/\rho_\ell g)(dP/dL)$

$V_{s\ell}$ and V_{sg} are superficial velocities.

By assumptions, Ros eliminated certain groups, and his experimental work was comprised of 4000 data runs which yielded 20,000 experimental points. His correlations for frictional-pressure gradient and liquid holdup involve a rather large number of constants which are related to the dimensionless groups. The prediction of pressure drop and liquid holdup by this method gives strong consideration to three flow regimes: liquid phase continuous, gas phase continuous, and alternating phases. The method gives impressive accuracy, the standard deviation between measured and predicted values in the three regimes being 3, 10, and 8%, respectively.

Ros's treatment is most significant in that he has used dimensionless parameters involving fluid physical properties, and that predictions of pressure drop depends on nature of the flow.

In 1948 Martinelli and Nelson[720] proposed a procedure for calculating pressure drop during forced-circulation of boiling water. The correlation is based on few data, but it represents one of the few attempts to estimate two-

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*Dimensionless groups given here are not to be confused with nomenclature in Appendix A.

phase pressure drop in situations where quality varies with flow length. The ϕ and χ values from the previous correlations,[670,721] derived from air-water data, were assumed valid for boiling water. The ϕ's were corrected in order to have proper empirical dependence on pressure, and working charts are given which can be used (with caution) in determining frictional and momentum pressure drops for flow of boiling water.

Soviet investigators have been interested in two-phase flow in boiling systems. Armand[35] correlated the ratio of two-phase pressure gradient to the liquid-pressure gradient as a function of volumetric steam content. He considered the ratio of volumetric steam content to fraction of pipe cross-section occupied by steam as a parameter. Bankoff[69] demonstrated the relationship between this parameter, the volume fraction, and the slip ratio. This relationship when combined with the void fraction and density ratio yields the quality which then allows prediction of pressure drop.

Two-phase pressure drop data for metallic systems are not available in the literature. In an AEC report[146] the authors derive a pressure drop equation in which they account for hydrostatic, friction, and acceleration losses. For friction losses they use the Lockhart-Martinelli-multiplier, modified for the mercury system at saturation temperatures. No data are given.

Kutateladze et al.[617] report the results of Lozhkin, Krol, and Gremilov, who studied two-phase mercury flow. They report that wetting has negligible effect on two-phase mercury flow systems, and they propose the following equation for pressure drop.

$$\Delta P = \frac{fu\rho_{\ell}L}{2g_c d}\left[1 + \left(1 - \frac{\rho_V}{\rho_{\ell}}\right)\frac{V}{V_{\ell}}\right] \tag{58}$$

No supporting data are given.

REMARKS ON TWO-PHASE METALLIC FLOW

Because the literature gives no information on two-phase flow behavior of metallic media, investigators and designers are compelled to extrapolate existing correlations (derived almost exclusively from air-water and steam-water data) for problems in metal flow. The reliability of such extrapolations has yet to be established.

Parameters involving physical properties will probably characterize flow regimes and also pressure-drop behavior. Ros's work in vertical two-phase flow is a clear illustration of the importance of physical properties. Experimentally, it would be desirable to approximate two-phase metallic flow by use of a more easily handled aqueous system. The physical properties of the steam-water system have been compared with those for the sodium and potassium systems on a basis of reduced temperature. For the density and viscosity of sodium vapor and water vapor, the properties are of the same order of magnitude—indeed, nearly equal—over a T_r range of 0.5 to 0.7. Liquid phase densities and viscosities also show an encouraging agreement over the same reduced temperature range. The meager amount of data for potassium also shows a favorable comparison with water-steam properties, although the applicable T_r range is not yet adequately known. Surface tensions for these three substances are of the same order of magnitude.

The above-mentioned correspondence in physical properties between water and two alkali metals, although preliminary, indicates that extrapolation of water-steam pressure drop methods to sodium and potassium systems may be valid. The Martinelli-Nelson method for forced-circulation boiling pressure drop has been used for sodium calculations on a reduced-pressure basis. The results cannot be substantiated because of lack of data, but using the method on a reduced-property basis is believed to give the best predictions currently possible.

There is disagreement in the literature as to whether a significant relationship exists between two-phase pressure drop and flow regimes. Recent investigations indicate that pressure drop depends on flow pattern, but this area needs further work. Data definitely are needed for metallic systems.

Two-phase flow data are sparse for forced-circulation boiling, and none is available presently for metallic systems. Work is being conducted in this area at the Argonne National Laboratory. Lunde[691] cites an instance where pressure-drop data provided the best basis for a quantitative estimation of heat transfer to liquids in an atomized state. Thus, the ability to accurately predict two-phase flow behavior should be a decided help in designing boiling heat-exchange systems.

APPENDIX A

NOMENCLATURE

a	Acceleration (Lt^{-2})*
A	Area (L^2); parameter defined in Eq. (35)
$A_{\alpha-\beta}$	Area of interface between phases α-β (L^2)
B	Parameter defined in Eq. (35)
B_L	Parameter defined by Eq. (3)
c, C	Constant
Cp	Heat capacity ($L^2t^{-2}\Theta^{-1}$)
C_{vd}	Volumetric gas content (dimensionless fraction)
d, D	Diameter (L)
f	Coefficient of resistance (dimensionless)
f^{α}, f^{β}	Helmholtz free energy per volume for phase α and β, respectively ($mt^{-2}L^{-1}$)
f^s	Helmholtz specific free energy (L^2t^{-2})
Fr (or N_F)	Froude number (dimensionless)
F^T	Total Helmholtz free energy (mL^2t^{-2})
g	Acceleration of gravity (Lt^{-2})
g_c	Gravitational conversion constant (32.17 ft/sec^2)
$g_{\mu\nu}$	Surface-stress tensor ($mt^{-2}L^{-1}$)
G	Mass flowrate ($mL^{-2}t^{-1}$); dimensionless pressure gradient
Gr	Grashof number, $L^3g\beta\Delta T/\nu^2$ (dimensionless)
h	Heat-transfer coefficient ($mt^{-2}\Theta^{-1}$)

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*Dimensions are given in the following system:
m = mass, L = length, t = time, Θ = temperature.

h_{co}	Local convection heat-transfer coefficient based on conduction ($mt^{-2}\Theta^{-1}$)
h_r	Local convection heat-transfer coefficient based on radiation ($mt^{-2}\Theta^{-1}$)
h	Enthalpy (mL^2t^{-2})
H	Planck's constant (6.624×10^{-27} erg·sec)
J	Defined by Eq. (20)
k	Thermal conductivity ($mLt^{-3}\Theta^{-1}$)
K	Boltzmann's constant (1.38×10^{-16} erg deg^{-1}); constant defined by Eq. (11)
L	Length (L); liquid mass flow rate ($mL^{-2}t^{-1}$)
L_o	Critical height of viscous-flow section of heat source (L)
m	Constant defined in Eq. (9)
n	Constant defined in Eq. (9)
N_A	Avogardro's number (6.023×10^{23} molecules/mole)
Nu	Nusselt number, hL/k (dimensionless
N_i^T	Total moles of component i
N_i^α, N_i^β	Moles of component i in α and β phases, respectively
p, P	Pressure ($mL^{-1}t^{-2}$)
Δp	Pressure drop ($mL^{-1}t^{-2}$)
$\Delta P/\Delta L$, dP/dL	Pressure gradient and local pressure gradient, respectively ($mL^{-2}t^{-2}$)
Pr	Prandtl number, $C_p\mu/k$ (dimensionless)
q, q/A	Heat-flux density (mt^{-3})
r	Radius (L)
Re	Reynolds number, $dv\rho/\mu$ (dimensionless)

Re^*	Vapor-film Reynolds number (dimensionless)
T	Temperature (Θ)
ΔT	Temperature difference (Θ)
ΔT_{sub}	Temperature difference between saturated vapor and bulk liquid temperature (Θ)
u	Velocity (Lt^{-1})
V^α, V^β	Volume of phase α and β, respectively (L^3)
V_m	Mean mixture velocity (Lt^{-1})
V_{sg}	Superficial gas velocity (Lt^{-1})
$V_{s\ell}$	Superficial liquid velocity (Lt^{-1})
X	Vapor quality (fractional, dimensionless); $(\Delta P/\Delta L)_\ell/(\Delta P/\Delta L)_g$
y^*	Critical vapor film thickness (L)
α	Thermal diffusivity, $k/Cp\ \rho$ (L^2t^{-1})
β	Constant; volumetric coefficient of expansion (Θ^{-1})
Γ	Defined in Eq. (C-3)
δ	Boundary-layer thickness (L)
$\delta_{\mu\nu}$	Denotes unit matrix
ϵ	Emissivity, strain (dimensionless)
Θ	Contact angle (dimensionless)
λ	Latent heat (Lt^{-2})
λ'	Latent heat using arithmetic mean vapor conditions (Lt^{-2})
λ_o	Defined by Eq. (17)
λ^β	Defined by Eq. (54)
μ	Viscosity $(mL^{-1}t^{-1})$

μ_i	Chemical potential of component i (L^2t^{-2})
ν	Kinematic viscosity (L^2t^{-1})
π	3.1416 (dimensionless)
ρ	Density (mL^{-3})
σ	Surface tension (mt^{-2})
σ'	Stefan-Boltzmann constant (5.672×10^{-5} erg $cm^{-2}deg^{-4}sec^{-1}$)
τ	Defined by Eq. (16)
ϕ	Constant defined by Eq. (26); pipe inclination angle (dimensionless); Martinelli two-phase flow correlation parameter [see Eqs. (56) and (57)]
χ or χ_{tt}	Martinelli's two-phase flow modulus
ψ^B	Defined by Eq. (55)
γ_c	Defined by Eq. (34)

Subscripts

1, 2	Denotes condition
b	Bulk
c	Critical; horizontal cylinder
e	Equivalent
fg	Change from; liquid to gas
g	Gas
ℓ	Liquid
m	Mean
s	Saturated; solid
sub	subcooled
v	Vapor
w	Wall
μ	1,2,3
ν	1,2
TPF	Two-phase frictional

APPENDIX B

REFERENCES TO TABLE VI

1. Dunning, E. L., The Thermodynamic and Transport Properties of Sodium and Sodium Vapor. ANL-6246, October, 1960.

2. Handbook of Chemistry and Physics, 36th Ed., Chemical Rubber Publishing Company, Cleveland, Ohio, 1954.

3. Gambill, W. R., et al., Boiling Liquid-Metal Heat Transfer. Space-Nuclear Conference, May 3-5, 1961. American Rocket Society, ORNL.

4. Lyon, R. N., Liquid Metals Handbook, Washington, D. C., AEC and Bureau of Ships, Department of the Navy, 1950.

5. Bradfute, J. O., An Evaluation of Mercury Cooled Breeder Reactors. AEC Report, ATL-A-102, October, 1959.

6. Whitman, J. J., et al., Boiling Rubidium as a Reactor Coolant Preparation of Rubidium Metal, Physical and Thermodynamic Properties and Compatibility with Inconel. CF-55-6-49 (Pt. 1), August, 1954.

7. MacKay, D. B., et al., Powerplant Heat Cycles for Space Vehicles. MD-60-177, June 30, 1960.

8. Keenan, J. H., and F. G. Keyes, Thermodynamic Properties of Steam, John Wiley and Sons, New York, 1936.

9. Evans, W. H., et al., Journal of National Bureau of Standards, 55, No. 2, 83-96, 1955.

10. Douglas, T. B., et al., The Heat Capacity of Lithium from 25 to 900°C, The Heat of Fusion and the Triple Point, Thermodynamic Properties of the Solid and Liquid. NBS-2879, October 16, 1953.

11. Perry, J. H., ed., Chemical Engineers' Handbook, 3rd Ed., McGraw-Hill, New York, 1950.

12. Inatomi, T. H., et al., Thermodynamic Diagram for Sodium. NAA-SR-62, July 13, 1950.

13. Shamrai, F. I., Lithium and Its Alloys. AEC-TR-3436, 1952.

14. Meisl, C. J., Thermodynamic Properties of Alkali Metal Vapors and Mercury, 2nd Revision, R 60 FPD 358-A, Flight Propulsion Div., GE Company.

15. Taylor, J. W., An Estimation of Some Unknown Surface Tensions for Metals. Metullurgia, 50, 164, 1954.

APPENDIX C

SUPPLEMENTARY DISCUSSION OF INTERFACE CONSIDERATIONS

Interfaces, whether liquid-vapor, solid-liquid, or solid-vapor are inherently very difficult to reproduce. Therefore, a major problem is encountered in the interpretation of experimental data where surface considerations are important. These difficulties often cause seemingly contradictory statements to be made concerning the effects of surface conditions on experimental results. The cause of the difficulties can be appreciated if the details of an interface are examined.

The simplest type of surface is that between a liquid and its vapor. Such a surface is very nearly smooth except when examined on the scale of atomic dimensions. Its energy and state-of-stress can be characterized by a single parameter dependent only on temperature, pressure, and composition of the liquid phase. This parameter, called the "surface tension" to be defined more specifically, can be directly measured. Interfaces involving a solid phase in contact with either a liquid or a vapor are by no means as simple. The geometrical surface is, even after very careful preparation, quite rough. The finest surface finishes on solids still give peak to valley roughness of from 2 to 5 microinches. In addition the solid is in general not homogeneous; that is, it will consist of grains each having different properties and property variations in different directions. In metals the very high affinity between the solid and ever present contaminants causes some degree of surface contamination. This contamination ranges from very lightly held, physically absorbed molecules to thin oxide layers. For most metals of engineering importance, the oxygen pressure necessary to avoid some form of oxygen contamination is far lower than the best obtainable vacuum. Thus, even with carefully cleaned surfaces the interface is generally covered with an oxygen-rich layer, on top of which is found a more weakly adsorbed stratum of other polar molecules.

The energies associated with metallic interfaces are in general much larger than those found for other types of materials such as organics and aqueous base solutions. The surface tensions of liquid metals range from several hundred to several thousand dynes/cm as compared to water with about 70 dynes/cm. The higher values of interfacial energy give rise to several problems since these energies can most easily be lowered by absorbing small amounts of a variety of elements present in the environment. This lowering of energy can take place rapidly or over a long period. It is often possible to replace one contaminant layer with another. The replacement may be accomplished by dissolution (atom-by-atom removal) or, in some cases by a tunneling of a liquid phase under a superficial oxide layer.

The above behavior has been summarized by Bikerman and is an excellent review of the technical literature.

Before discussing the specific effects of surface parameters on the boiling process, a short review of surface thermodynamics is in order. Much of the literature on boiling makes use of thermodynamic concepts used in situations where they need not apply. This is particularly the case for the so-called "contact angle." Most standard treatments of surface thermodynamics are evolved in terms of the "surface tension." Such treatments are quite adequate for liquid-vapor or liquid-liquid interfaces, but entirely inappropriate for interfaces involving solids. A rather complete discussion of this point is given by Herring.[458] In the case of interfaces involving a solid there are three distinct quantities that should be differentiated. The first is the Helmholtz specific free energy. It is defined in Eq. (C-1).

$$f^S = \frac{F^T - V^\alpha f^\alpha - V^\beta f^\beta}{A_{\alpha-\beta}} \qquad \text{(C-1)}$$

where F^T is the total Helmholtz free energy of the system comprised of phases α and β, and V^α, V^β are the volumes of the respective phases; f^α, f^β are the Helmholtz free energies per unit volume; and $A_{\alpha-\beta}$ is the area of the interface between the two phases.

The second quantity which is called, somewhat reluctantly, "surface tension" is defined in Eq. (C-2).

$$\sigma = f_s - \sum_i \Gamma_i \mu_i \qquad \text{(C-2)}$$

where μ_i is the chemical potential of component i and Γ is the "surface excess" defined by Eq. (C-3).

$$\Gamma_i = \frac{N_i^T - N_i^\alpha - N_i^\beta}{A_{\alpha-\beta}} \qquad \text{(C-3)}$$

where N_i^T is the total number of moles of component i, and N_i^α, N_i^β are respectively the moles of i in the alpha and beta phases.

The third quantity is the surface-stress tensor $g_{\mu\nu}$, where the individual components are forces per unit length acting at the surface and arising due to the presence of the surface. The surface stress for solids is not equal to the surface tension, as has been shown by Herring[458] and Shuttleworth.[995] The two quantities are related by Eq. (C-4).

$$g_{\mu\nu} = \sigma\,\delta_{\mu\nu} + \frac{\partial\sigma}{\partial\epsilon_{\mu\nu}} \qquad \text{(C-4)}$$

where $\mu = 1, 2, 3$; $\nu = 1, 2$, and $\delta_{\mu\nu}$ is a unit matrix. In general, an interface involving a solid will have a component of surface stress (tension or compression) acting in the plane of the surface, a shear component acting in the plane of the surface, as well as a component acting normal to the surface. This set of surface forces is illustrated in Fig. C-1. These forces vary in magnitude with direction in an individual grain, and from grain to grain across a metallic surface. For the special case of a liquid-vapor or a liquid-liquid interface, the surface stress tensor can be represented with a single tension component. The second term of Eq. (C-4) is zero, since, upon stretching, the interface extends itself not by altering the relative density of atoms in the surface, but by causing new atoms to come into the surface from the bulk liquid. In such a case the surface stress is indeed numerically equal to the surface tension as defined in Eq. (C-2), and it is quite appropriate to interchange the concepts of force per unit length and free energy per unit area. It is interesting to note that, even in this case, σ is not generally equal to f^s, the specific surface free energy. The two differ by the right-hand term of Eq. (C-2), which is zero only for one choice in the physical location of the dividing surface.

Recent work[483] has shown that the surface tension and the surface stress are functions of the elastic strain in a solid metal adjoining either a vapor or a liquid interface. When one analyzes the condition of adherence or spreading of a liquid on a polycrystalline solid the conditions on any individual grain are determined by the orientation of the crystallographic axis with respect to the surface area, the orientation of the area with respect to an external coordinate system, and the direction of all of the individual applied or induced strain components existing in the solid. Thus, the degree of macroscopic wetting of the surface is not truly indicative of the local conditions of wetting, which are much more appropriate in any discussion of nucleation.

Macroscopic contact angles are customarily defined in terms of the surface tensions. Such considerations lead to the often quoted equations for contact angle. These relations presume complete thermodynamic equilibrium. In particular, surfaces involved must be capable of migrating freely under the surface forces. In most cases σ is assumed to be independent of crystallographic orientation. Drops or bubbles in contact with solids virtually never come to complete equilibrium, as can be shown from the lack of balance of the vertical components of the "vectors" shown in Fig. C-1.

On the other hand, the equilibrium of surface forces acting at the junction of a mobile phase boundary (e.g., vapor-liquid on solid), is mechanical in nature and does not depend on the establishment of complete thermodynamic equilibrium. Thus, conditions for the movement of the phase boundaries shown in Fig. C-1 and the local contact angle are dependent on the existing state of balance of the sum of the components of the surface-stress tensor on the solid on either side of the liquid-vapor surface. At present there is no known experimental method for measuring directly the components of the surface stress tensor. However, it is possible to measure the change of the value in these components as the crystal is strained. Thus, it is found that a solid surface has a set of elastic moduli closely analogous to the elasticity coefficients for the bulk phase but differing markedly in value.

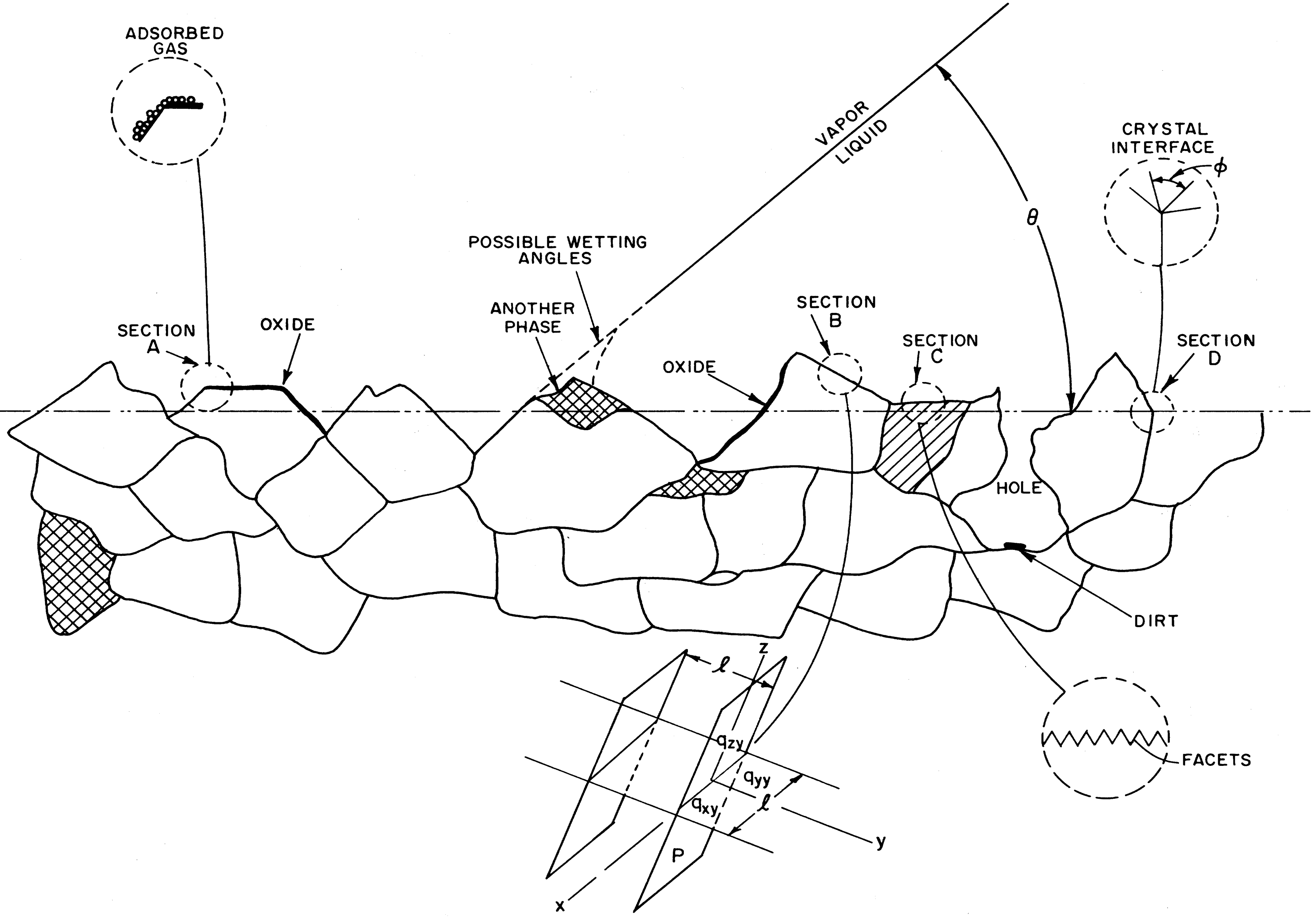

Fig. C-1. Typical heat transfer surface.

Figure C-1 has been drawn to indicate schematically the various types of behavior to be found when a vapor and a liquid is in contact with a solid crystalline substance such as a metal. The first feature is physical roughness. The second feature shows the possible presence of film or absorbed surface contaminance. It should be noted that almost all metals contain second phases introduced either from impurities or in many cases as a desirable feature of the metallic structure. Such phases are often present as extremely fine particles. They are often nonmetallic in character such as oxides or sulfides, and exhibit widely different surface characteristics than the parent metallic phase. The individual grains comprising the geometric surface will, in general, present a variety of crystallographic orientations to the environment. The grain boundaries between these grains will also have varying energies due to the mismatch differences exhibited from place to place across the surface. Surface damage in the form of deep recesses such as shown in Fig. C-1 are also common occurrences. They often contain minute particles of phases of nonmetallic character, i.e., dirt, oxide particles, etc.

For many considerations the features illustrated in Fig. C-1 are of no practical significance. When considering processes such as the nucleation of a new phase, however, the very nature of the process demands that attention be given to the conditions that exist on a very local scale. For example, the critical size required to nucleate bubbles is of the order of 1 micron, which is in general small compared to the grain size of most metals. Thus, the degree of wetting at individual locations on the surface is far more important than the degree of wetting of the gross surface.

The picture of a metallic surface that has been involved above then shows the surface conditions at any given time to be locally determined by the surface properties of the individual grains and minor phases as well as the bulk properties of the individual phases and the liquid or vapor. All these properties are, of course, functions of temperature, state-of-stress, and the usual composition variables. The effect of temperature may be particularly marked because heating of the metallic surface will in general cause changes in all the strain components in the individual grains due to thermal expansion. One must then think of the metallic surface as an aggregate of tiny areas displaying varying affinity for the liquid or the vapor, depending on the local magnitude of the components surface-stress tensor. That the various crystalline phases have different affinities for the liquid and the vapor has been demonstrated experimentally.[438] Experiments at The University of Michigan[651] have shown that elastic straining in the solid can also influence the macroscopic constant. The above ideas are quite consistent with the bulk of experimental findings on boiling heat transfer which indicate nucleation occurring at highly selective points with more and more additional points being activated as the temperature is raised. However, only in poorly wetting liquids will vapor trapped in surface cavities account for the nucleation phenomenon. In systems completely wetted by a liquid, such vapor would be excluded from the cavity walls by the intrusion of liquid.

There is another limitation in attempting to characterize the behavior of liquid-solid systems in boiling by use of a macroscopic contact angle; namely, that for many instances no such angle exists. The relationship between the three surface tensions and the macroscopic contact is often given as in Eq. (C-5):

$$\cos \Theta = \frac{\sigma_{s-v} - \sigma_{\ell-s}}{\sigma_{\ell-v}} \tag{C-5}$$

However, a contact angle, Θ, exists only for a special range of values of the surface tensions. In the case where,

$$\sigma_{s-v} - \sigma_{\ell-s} \geqq \sigma_{\ell-v} \tag{C-6}$$

Θ is zero and complete spreading occurs over the macroscopic surface. No further information can be obtained about the relative magnitudes of the three interfacial tensions. However, it is quite possible to have two systems, the first having the left side of Eq. (C-6) only slightly larger than $\sigma_{\ell-v}$; and the second having the left-hand member much larger than $\sigma_{\ell-v}$. In the second case, the relative preference of the liquid for the solid as opposed to the liquid for the vapor is much larger and could hardly be expected to behave in a similar fashion with respect to nucleation and bubble growth. In fact, the lowering of $\sigma_{\ell-s}$, that is, increasing the preference of liquid for solid might be expected to influence not only nucleation characteristics at the solid surface, but the transfer of heat across the solid surface to the liquid.

The case of complete spreading of a liquid metal on a solid metal is much more common than with organic or aqueous phases on solid metals. This spreading can in general be achieved by additives or other methods that influence one or all of the surface tensions. Quite commonly an additive to the liquid phase is made which exhibits quite strong bonding tendencies for the solid. Such an additive can decrease $\sigma_{\ell-s}$ without substantially affecting the other two values. In liquid metals such a procedure has distinct limitations. There is, indeed, another condition of spreading, that is, the spreading of the liquid metal along the grain boundaries of the solid metal which can result in complete deterioration or catastrophic fracture of the solid. The equilibrium condition for this spreading is that $\sigma_{\ell-s}$ be less than twice the grain-boundary energy σ_{bb}. Thus, the liquid-solid surface tension cannot be lowered without limit, without facing the consequences of complete grain-boundary penetration. Of course, such penetration is again a local affair, that is, the grain boundaries with the highest energies are those which fulfill the necessary conditions for a given liquid-solid energy. In this respect, certain heat-treatment steps can be taken in order to insure that the grain boundaries present in the solid are at relatively low energies. Metals that have undergone annealing tend to eliminate most of the high-energy grain boundaries. There are numerous examples of grain-boundary penetration by liquid metals. Among them are lithium on aluminum alloys, mercury on brasses, and bismuth on pure copper.

Another distressing factor associated with fully wetted metallic surfaces is the ability of the liquid to promote catastrophic fracture of the solid at low stress levels. Such embrittlement by liquid metals has been widely studied in recent years. As an example, copper at 650°F is in air a ductile material having a fracture strength exceeding 48,000 psi. When copper at the same temperature is immersed in liquid lead which only partially wets it, the fracture strength drops to 45,000 psi. As bismuth is added to the lead, the fracture strength and ductility drop rapidly. In pure bismuth the fracture strength is approximately 7,000 psi and the ductility is substantially zero. Similar losses of strength are encountered in many other solid-liquid metal combinations. In general the greater is the wetting tendency of the liquid for the solid, the greater influence will be exerted on the fracture strength.

APPENDIX D

BIBLIOGRAPHY

The compilation resulted from a thorough review of the Nuclear Science Abstract, Liquid Metal Abstracts, Technical Translations, numerous literature reviews on boiling and two-phase flow, and all the prominent heat-transfer periodicals. Articles pertaining to boiling heat transfer, two-phase flow, liquid-metal heat transfer, liquid-metal circulating systems and related problems, and physical properties of liquid-metal media have been included.

1
ABAS-ZADE, A.K. A NEW INSTRUMENT FOR MEASURING THE HEAT CONDUCTIVITY OF LIQUIDS AND VAPORS AT HIGH TEMPERATURES AND PRESSURES. 1959 AEC-TR-3796

2
ABBOTT, M.D., ET AL, HEAT TRANSFER COEFFICIENTS FOR A HORIZONTAL TUBE EVAPORATOR. MS THESIS M.I.T. 1938

3
ABRAMSON, H., W. CHU, AND J.C. COOK, STUDIES OF TRANSIENT HEAT CONDUCTION AT HIGH THERMAL FLUX. JAN, 1961 AD-260-248

4
ADAM, N, K., PHYSICS AND CHEMISTRY OF SURFACES 3RD ED. OXFORD U PRESS 1941

5
ADAMSON, G.M., ET AL, EXAMINATION OF SODIUM, BERYLLIUM, INCONEL PUMP LOOP. NUMBER LAND 2, CF-54-9-98 SEPT 13, 1954

6
ADDISON, C.C., ET AL, LIQUID METALS, PART 1, THE SURFACE TENSION OF LIQUID SODIUM, THE VERTICAL PLATE TECHNIQUE, J. CHEM. SOC., AUG, 1954

7
ADDOMS, J.H. HEAT TRANSFER AT HIGH RATES TO WATER BOILING OUTSIDE OF CYLINDERS. PHD THESIS M.I.T. 1948

8
ADMIRE, B.W., ET AL, A GAS SHAFT SEAL FOR HNPF SODIUM PUMP. JUNE, 1958 NAA-SR-MEMO-2616

9
AFFEL,R.G., CALIBRATION AND TESTING OF 2 AND 3 1/2 INCH MAGNETIC FLOWMETERS FOR HIGH-TEMPERATURE NAK SERVICE, MARCH 4, 1960, ORNL- 2793

10
AGRESTA, J., ET AL., FAST REACTOR SAFETY. NDA-2147-5 MARCH 15,1961

11
AKIN, G.A. HEAT TRANSFER TO SUBMERGED EVAPORATORS. THESIS M.I.T. 1942

12
AKIN, G.A. BOILING HEAT TRANSFER IN A NATURAL CONVECTION EVAPORATOR IND ENG CHEM 31,1939

13
AKSELROD , L.S., ET AL, SPECIFIC GRAVITY OF A BUBBLING GAS-LIQUID MIXTURE, KHIM PROM 1, 1954

14
AKSELROD, L.S., ET AL, BUBBLE CHARACTERISTICS AT LOW GAS VELOCITIES ZHUR PRIKLAD KHIM 27. 1954

15
ALADYEV,I.T.,ET AL., NEW METHODS OF STUDYING HEAT LOSS DURING BOILING OF LIQUIDS. DOKL AN SSSR 90 NO 5 775-776 1953

16
ALADYEV, I. T., ET AL., BOILING CRISIS IN TUBES. PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME

17
ALADYEV,I.T.,ET AL., HEAT TRANSFER IN TUBES WHEN UNDERHEATED WATER IS BOILING. DOKL AN SSSR 111 NO 3 593-595 NOV. 1956

18
ALADYEV,I.T., ET AL., EFFECT OF THE WETTABILITY ON THE HEAT EXCHANGE DURING EBULLITION (WITH SUMMARY IN ENGLISH) INZH. -FIZ. ZHUR. NO 7 11-17 JULY 1958

19
ALADYEV, I.T., ET AL. HEAT TRANSFER IN BOILING WATER IN TUBES. TEPLOENERGETIKA 4, NO 9, SEPT, 1957

20
ALADYEV, I.T., ET AL, CRITICAL HEAT FLUXES FOR WATER FLOWING IN TUBES. J NUCL ENERGY, PART B. REACTOR TECH 1, NO 3, 1960

21
ALEKSANDROV, Y.A., ET AL, THE GROWTH AND EMERGENCE RATE OF BUBBLES IN A PROPANE CHAMBER. PRIBORI I TEKH EKSPT, 6, NOV-DEC, 1960

22
ALIMOV, R.Z. HEAT TRANSFER DURING CROSS FLOW THROUGH CYCLINDRICAL RODS BY TWO PHASE STREAM. ZHUR TEKH FIZ 26, JUNE, 1956

23
ALLEN, W.F. FLOW OF FLASHING MIXTURE OF WATER AND STEAM THROUGH PIPES AND VALVES. T ASME 73. 1951

24
ALTMAN, M. HEAT TRANSFER IN REACTORS COOLED BY WATER. NUCLEONICS 14, 1956

25
ALVES, G.E. CO-CURRENT LIQUID GAS FLOW IN A PIPELINE CONTACTOR. CHEM ENG PROG 50, 1954

26
AMBROSE, T.W. LITERATURE SURVEY OF FLOW PATTERNS ASSOCIATED WITH TWO-PHASE FLOW. G.E. CO. HANFORD LABS OCT 8, 1957 HW-52927

27
ANDERSON, G.H., ET AL, TWO PHASE(GAS LIQUID) FLOW PHENOMENA, PART 1. PRESSURE DROP AND HOLD UP FOR TWO PHASE FLOW IN VERTICAL TUBES. CHEM ENG SCI 12,NO 2, 1960

28
ANDERSON, W.K., ET AL, CALCULATION OF ATTENUATION FACTORS AND PERCENT SIGNAL CHANGE FOR X-RAY VOID DETECTION METHOD IN THE LIMITING CASE OF LOW QUALITY MIXED PHASE WATER SYSTEMS, KAPL-M-WKA-15 JAN 11, 1960

29
ANDREEV, P.A., KANAEV, A.A., AND FEDOROVICH, E.D. LIQUID METAL COOLANTS IN NUCLEAR REACTORS. SELECTED PARTS. MCL-554/1+2 1961

30
ANDREEV , P.A., ET AL, LIQUID METAL COOLANTS IN NUCLEAR REACTORS. JUNE 21, 1961 AD-258-462

31
ANDREEV, P.A., LIQUID METAL COOLANTS IN NUCLEAR REACTORS NP-TR-642 1958

32
ANDREVSKII , A . A ., HEAT TRANSFER INTO A SINGLE PIPE IN THE TRANSVERSE CURRENT OF A LIQUID WITH LOW PRANDTL NUMBER MCL-753/1+2 DEC 5, 1960

33
ANDREVSKII,A.A. HEAT TRANSFER OF MOLTEN SODIUM FLOWING TRANSVERSELY ACROSS A SINGLE CYLINDER, ATOMNYA ENERG,7,254-6 (1959) SEPT

34
ANDREWS, R.C., ET AL, TEST RESULTS OF LIQUID METAL CLOSED CYCLE COOLANT SYSTEM. MSAR-TR-321-12 NOV 15, 1957

35
ARMAND, A.A.,ET AL, INVESTIGATION OF THE RESISTANCE DURING THE MOVEMENT OF STEAM - WATER MIXTURES IN A HEATER BOILER PIPE AT HIGH PRESSURES AERE-LIB/TRANS - 816, 1947

36
ARMAND,A.A., INVESTIGATION OF THE MECHANISM OF TWO-PHASE FLOW IN VERTICAL PIPES, ARTICLE IN THE BOOK ENTITLED, HYDRODYNAMICS AND HEAT TRANSFER WITH BOILING, EDITED BY M.A. STYRIKOVICH, ACAD,NAUK, SSSR., MOSCOW, 1954 AEC-TR-4490

37
ARMAND, A.A., ET. AL., INVESTIGATION OF THE MECHANISM OF TWO-PHASE FLOW IN VERTICAL PIPES, IZVEST. VSESOU. TEPLOTEK. INST., NO.2, 1950

38
ARMAND, A.A. THE RESISTANCE DURING THE MOVEMENT OF A TWO PHASE SYSTEM IN HORIZONTAL PIPES. MAR, 1959. AERE-TRANS-828

39
ASIJEE, J. STUDY OF HEAT REMOVAL FROM A FUEL ELEMENT OF A NUCLEAR REACTOR OF THE BOILING WATER TYPE, AEC-TR-4011

40
ASPDEN, R.L. A NEW HIGH SPEED PHOTOGRAPHIC TECHNIQUE APPLIED TO THE INVESTIGATION OF BUBBLES BURSTING AT AN AIR WATER INTERFACE, AD-40888 1954

41
ATZ, R.W. PERFORMANCE OF HNPF PROTOTYPE FREE SURFACE SODIUM PUMP. JUNE, 1960. NAA-SR-4336

42
ATZ, R.W. TESTING OF HNPF FREEZE SEAL PUMP. NOV, 1960. NAA-SR-4387

43
AUDETTE, R.F. BURNOUT PROTECTION REQUIREMENTS AND PRELIMINARY BURNOUT PROTECTION SYSTEM DESIGN NAA-SR-MEMO-4469 OCT 7, 1959

44
AVERIN, E.K.,ET.AL, HEAT TRANSFER IN THE BOILING OF WATER IN CONDITIONS OF FORCED CIRCULATION. TEPLOPEREDACHA TEPLOVOE MODELIROMNIE AERE-TRANS-847. 1959

45
AVERIN, E.K., ET AL, THE INFLUENCE OF SURFACE TENSION AND VISCOSITY OF THE CONDITIONS OF HEAT EXCHANGE IN THE BOILING OF WATER. 1955. AERE-TRANS-682

46
AVERIN, E.K. THE EFFECT OF THE MATERIAL AND THE MECHANICAL TREATMENT OF THE SURFACE ON THE HEAT EXCHANGE IN THE BOILING OF WATER. AERE-LIB/TRANS-562. 1954

47
AVERY, G. EFFECT OF SURFACE ROUGHNESS ON THE BOILING OF MERCURY. MS THESIS IN CHEM ENG 1960 COLUMBIA UNIV

48
AZER, N. Z., ET AL., TURBULENT HEAT TRANSFER IN LIQUID METALS-- FULLY DEVELOPED PIPE FLOW WITH CONSTANT WALL TEMPERATURE INT J OF HEAT AND MASS TRANSFER 3 NO 2 SEPT 1961

49
AZER, N.Z., ET AL, A MECHANISM OF TURBULENT HEAT TRANSFER IN LIQUID METALS INTERN J. HEAT AND MASS TRANSFER 1 AUG. 1960

50
BAGDANOV, V.V. INVESTIGATION OF THE EFFECT ON THE RATE OF MOTION OF THE WATER CURRENT ON THE HEAT EXCHANGE COEFFICIENT ON BOILING WATER IN AN INCLINED TUBE. 1955 AERE-LIB/TRANS-596

51
BAILEY, D.L.R., ET AL, HEAT TRANSFER TO MERCURY, NP-4010 JULY , 1952

52
BAILEY, R.V. HEAT TRANSFER TO LIQUID METALS IN CONCENTRIC ANNULI, ORNL-521 JUNE 13, 1950

53
BAKER, M., ET AL, HEAT TRANSFER FILM COEFFICIENTS FOR REFRIGERANTS BOILING INSIDE TUBES, REFRIG ENG 61, 1953

54
BAKER, O. DESIGN OF PIPELINES FOR THE SIMULTANEOUS FLOW OF OIL AND GAS. THE OIL AND GAS JOURNAL. JULY, 1954

55
BAKER,R.S., A LINEAR INDUCTION PUMP FOR LIQUID METALS, 1/15/60, NAA-SR-4388

56
BAKER, R.S. DESIGN OF AN EDDY CURRENT BRAKE FOR A SODIUM COOLED NUCLEAR POWER REACTOR, NAA-SR-2986 SEPT 15, 1958

57
BAKER, R.S., ET AL, DESIGN OF 2 ELECTROMAGNETIC PUMPS FOR NA-K ATOMICS INTERNATIONAL. NAA-SR-MEMO-5106 MARCH 25, 1960

58
BAKER, R.S., ET AL, ELECTRICAL HEATING METHODS FOR LIQUID METAL SYSTEMS. SEPT 15, 1959, NAA-SR-3882

59
BAKER, R.S., ET AL, NA-K PUMP EVALUATION. FEB, 1960. NAA-SR-MEMO-5004

60
BAKER, R., ET AL, THE DESIGN, CONSTRUCTION, AND TESTING OF A SYSTEM FOR THE STUDY OF BUBBLE FORMATION AT HIGH DENSITIES. KT-97. OCT 23, 1950

61
BAKER, R.S., ET AL, WOUND ROTOR ELECTROMAGNETIC PUMP FOR NA-K. JUNE, 1960 NAA-SR-MEMO-5433

62
BALHOUSE, H.J. FIRST INTERIM REPORT ON DURABILITY AND SEAT LEAKAGE ON LIQUID METAL VALVES. KAPL-585 AUG 3, 1951

63
BANCHERO, J.T., ET AL, STABLE FILM BOILING OF LIQUID OXYGEN OUTSIDE HORIZONTAL TUBES AND WIRES. CHEM ENG PROG SYM SER 51, NO 17. 1955

64
BANISTER, C.G., ET AL, A REPORT ON THE PROCEEDINGS OF THE LIQUID METAL UTILIZATION CONFERENCE HELD IN ABINGDON, MAY 16, 1953. AERE-X/R-1381

65
BANKOFF, S.G. EBULLITION FROM SOLID SURFACES IN THE ABSENCE OF A PREXISTING GASEOUS PHASE. HEAT TRANS AND FLUID MECH INST. STANFORD, 1956
TRANS ASME 78. 1957

66
BANKOFF, S.G.,ET.AL, BUBBLE GROWTH RATES IN HIGHLY SUBCOOLED NUCLEATE BOILING CEP 55, SYM. SER. NO. 29 1959

67
BANKOFF, S.G., ET AL, GROWTH OF BUBBLES IN A LIQUID OF INITIALLY NONUNIFORM TEMPERATURE. PAPER 58-A-105. ASME ANNUAL MEETING. 1958

68
BANKOFF, S.G., ET AL, SUMMARY OF CONFERENCE OF BUBBLE DYNAMICS AND BOILING HEAT TRANSFER HELD AT THE JET PROPULSION LABORATORY, JUNE 14 AND 15, 1956. JPL-MEMO-20-137

69
BANKOFF, S.G. A VARIABLE DENSITY SINGLE FLUID MODEL FOR TWO PHASE FLOW WITH PARTICULAR REFERENCE TO STEAM WATER FLOW. J HEAT TRANSFER 82, NOV 1960

70
BANKOFF, S.G. NATURAL CIRCULATION BOILING REACTOR WITH TAPERED COOLANT CHANNELS CEP 55, SYM. SER. NO. 27, 113-16(1959)

71
BANKOFF, S.G. ON THE MECHANISM OF SUBCOOLED NUCLEATE BOILING FEB 2, 59. JPL-MEMO-30-8

72
BANKOFF, S.G. THE ENTRAPMENT OF GAS IN THE SPREADING OF A LIQUID DROP OVER A ROUGH SURFACE, AMER INST OF CHEM ENGR NATL MEETING, MAY 6-9, 1956

73
BANKOFF, S.G. THE PREDICTION OF SURFACE TEMPERATURES AT INCIPIENT BOILING CHEM ENG PROG SYM SER 55, NO 29. 1959

74
BARKER, K.R. REMOVAL OF ENTRAINED GAS FROM SODIUM SYSTEM. MINE SAFETY APP. CO., TECH REPORT NO 50. JULY, 1956

75
BARTOLOME,G.G. ET AL., UTILIZATION OF GAMMA RADIATION IN THE STUDY OF THE BUBBLING PROCESS. AEC-TR-4206

76
BASHFORTH, F., ET AL, AN ATTEMPT TO TEST THE THEORIES OF CAPILLARY ACTION. CAMBRIDGE UNIV PRESS

77
BATEMAN, J.B., ET AL, FORMATION AND GROWTH OF BUBBLES IN AQUEOUS SOLUTIONS CAN J REASEARCH 23, E, 1945

78
BAUM, V.A., ET AL., HEAT DELIVERY OF MOLTEN METALS (UN-639) JUN 30 1955

79
BAUMEISTER, E. CALCULATED BURNOUT HEAT FLUXES FOR SANTONAX-R, NAA-SR-MEMO-3860 MAY 14, 1959

80
BAUMIER, J., ET AL, HEAT TRANSFER WITH HIGH HEAT FLUX DENSITY BETWEEN A WALL AND WATER WITH LOCAL BOILING AT THE WALL, CEA-846 (IN FRENCH) JUNE, 1958

81
BEAM, B.H. AN EXPLORATORY STUDY OF THERMOELECTROSTATIC POWER GENERATION FOR SPACE FLIGHT APPLICATIONS. 1960. NASA-TN-D-336

82
BECKERS, H.L. HEAT TRANSFER IN TURBULENT TUBE FLOW. APPL SCI RES 6A, 1956

83
BEHRINGER, P. VELOCITY OF STEAM BUBBLES IN BOILER PIPES. VDI FORSCHUNGSHEFT 365, 1934

84
BELL, D.W. CORRELATION OF BURNOUT HEAT FLUX DATA AT 2000 PSIA NUCLEAR SCI AND ENG 1, 245-51 (1960) MAR

85
BENJAMIN, J. E., ET AL., BUBBLE GROWTH IN NUCLEATE BOILING OF A BINARY MIXTURE. PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME

86
BENNETT, J.A., ET AL, HEAT TRANSFER TO TWO PHASE GAS LIQUID SYSTEMS. PART ONE. STEAM-WATER IN THE LIQUID-DISPERSED REGION IN AN ANNULUS. AERE-R-3159. 1959

87
BENNETT, J.A.R. TWO PHASE FLOW IN GAS LIQUID SYSTEMS. A LITERATURE SURVEY UNITED KINGDOM AT.EN.AUTH. RES GROUP AT.EN.RES.EST, HARWELL, BERKS, ENGLAND. BIS AERE-CE/R-2497 MARCH, 1958

88
BENTLEY, R., ET AL, PHYSICAL CONSTANTS OF PROPOSED COOLANTS, CP-3061 DEC 14, 1955

89
BERENSON, P. J., FILM-BOILING HEAT TRASFER FROM A HORIZONTAL SURFACE J HEAT TRANSFER VOL 83 SERIES C NO 3 AUG 1961

90
BERENSON, P.J. TRANSITION BOILING HEAT TRANSFER FROM A HORIZONTAL SURFACE NP-8415 M.I.T. MARCH 1, 1960

91
BERETSKY, I., ET AL, A BOILING WATER ANALYSIS CODE ON THE IBM-650-ABWAL-MNC PROGRAM NO 302, APAE-MEMO-181 MARCH 10, 1959

92
BERGELIN, O.P., ET AL, HEAT TRANSFER TO BOILING LIQUID UNDER CONDITIONS OF HIGH TEMPERATURE DIFFERENCE AND FORCED CONVECTION, UD-FB-7 UNIV OF DELWARE JUNE 5, 1956

93
BERGELIN, O.P. AND GAZLEY, CO-CURRENT GAS-LIQUID FLOW. FLOW IN HORIZONTAL TUBES. HEAT TRANS AND FLUID MECH INST., 5 - 18, CALIF. MEETING, ASME, 1949

94
BERGLES, A. E., MEMO 8767-1, PROJ. DSR, HEAT TRANS LAB., M.I.T., APR 1961

95
BERMAN, L. D., PROCESSING EXPERIMENTAL DATA ON COMMON COEFFICIENTS OF HEAT AND MASS EXCHANGE BETWEEN A LIQUID AND A GASEOUS (VAPOR) MEDIUM. ZHUR PRIKL KHIM 29 NO 1 138-140 JAN 1956

96
BERMAN, L. D., ET AL., EFFECT OF AN AIR ADMIXTURE ON HEAT EMISSION DURING CONDENSATION OF MOVING STEAM. IZV VTI 21 NO 11 11-18 NOV 1952

97
BERMAN ,L.D., ET AL., EXPERIMENTAL DATA ON THE EFFECT OF A FLOW OF SUBSTANCE ON THE HEAT AND MASS EXCHANGE DURING CONDENSATION. TEPLOENERGETIKA 4 NO 1 49-51 JAN 1957

98
BERNATH, L. A THEORY OF LOCAL BOILING BURNOUT AND ITS APPLICATION TO EXISTING DATA. CHEM ENG PROG SYM SER 56 , NO 30, 1960

99
BERNATH, L. EXTENSION OF THE METHOD OF BURNOUT PREDICTION, AECU-3901 1958

100
BERNATH, L. FORCED CONVECTION, LOCAL BOILING HEAT TRANSFER IN NARROW ANNULI - CEP 55, SYMPOSIUM SER. NO. 29 1959

101
BERNATH, L. PREDICTION OF HEAT TRANSFER BURNOUT. CHEM ENG PROG SYM SER 52 NO 18. 1956

102
BERNATH, L. THEORY OF BUBBLE FORMATION IN LIQUIDS, IND ENG CHEM 44, 1952

103
BERRY, V.J. EFFECT OF A LIQUID PHASE VELOCITY ON THE GROWTH AND COLLAPSE OF GAS BUBBLES, J CHE PHYS 20. JUNE, 1952

104
BERTANZA, L., ET AL, INFLUENCE OF IONS ON THE NUCLEATION PROCESS IN LIQUID. LIQUIDS UNDER POSITIVE PRESSURE IN METASTABLE THERMODYNAMICAL EQUILIBRIUM (OVERHEATED LIQUIDS), NVOVO CIMENTO 1, FEB, 1955

105
BERTUZZI, A.F., ET AL., SIMULTANEOUS FLOW OF LIQUIDS AND GAS THROUGH HORIZONTAL PIPE, J PET TECHNOLOGY, JAN 1956

106
BIKERMAN, J., SURFACE CHEMISTRY, ACADEMIC PRESS, NEW YORK, 1960

107
BILLURIS, G. EXPERIMENTAL INVESTIGATIONS OF THE REMOVAL OF SODIUM OXIDE FROM LIQUID SODIUM. JAN, 1960. GEAP-3328

108
BIRKHOFF, G. STABILITY OF SPHERICAL BUBBLES. QUART APP MATH 13, 1956

109
BIRKHOFF,G.,ET AL., RISING PLANE BUBBLES. J OF RATIONAL MECH AND ANALYSIS 6 1957

110
BIRKHOFF, G. TAYLOR INSTABILITY AND LAMINAR MIXING. U OF CAL. LOS ALMOS SCI LAB. 1955 LA-1862 AND LA-1927

111
BIRKHOFF, G., ET AL, SPHERICAL BUBBLE GROWTH. PHYS OF FLUIDS 1, 1958

112
BLACKMEYER, R.H. RESEARCH ON LIQUID METALS AS POWER TRANSMISSION FLUIDS. REPORT FOR MAY 56 - MAY 57 ON HYDRAULIC FLUIDS. WADC-TR-57-294 FEB, 1958 (PT. 1)

113
BLOOMFIELD, M., ET AL, BUBBLE FORMATION, A BIBLIOGRAPHY. JUNE, 1958 NAA-SR-2551

114
BOADLE, C.D. LIQUID METALS - 2 AND NUCLEAR POWER. ATOMICS 8, MARCH, 1957

115
BOARTS, R.M., ET AL, EFFECT OF WETTING ON HEAT TRANSFER CHARACTERISTICS OF LIQUID METALS, ORO-121 TENN UNIV. FEB, 1954

116
BOELTER, L.M.K., ET AL., PRESSURE DROP ACCOMPANYING TWO COMPONENT FLOW THROUGH PIPES, IEC, 31, 426, 1939

117
BOGART, N.T., ET AL, HEAT TRANSFER TO BOILING LIQUIDS UNDER PRESSURE. THESIS M.I.T. 1939

118
BOGDANOV, F.F. INVESTIGATION OF NATURAL CIRCULATION OF AN ORGANIC HEAT CARRIER WITH HIGH BOILING POINT.1950 AEC-TRANS-2881

119
BONILLA, C.F., ET AL, BOILING AND CONDENSING OF LIQUID METALS. FEB, 1952 NYO-3147

120
BONILLA, C.F., ET AL, BOILING AND CONDENSING OF LIQUID METALS, PROGRESS REPORT, NYO-3148 APR, 1952

121
BONILLA, C.F. BOILING AND CONDENSING OF LIQUID METALS, NYO-3150 OCT, 1952

122
BONILLA, C.F., ET AL, BOILING AND CONDENSING OF LIQUID METALS, NYO-3152 APR, 1953

123
BONILLA, C.F., ET AL, HEAT TRANSFER IN THE CONDENSATION OF METAL VAPORS,
MERCURY AND SODIUM UP TO ATMOSPHERIC PRESSURE,
CHEM ENG PROGR SYM SER 52, JULY 7, 1956

124
BONILLA, C.F., ET AL, HEAT TRANSFER TO BOILING STYRENE AND BUTADIENE AND
THEIR MIXTURES WITH WATER. IND ENG CHEM 40, 1948

125
BONILLA, C., ET AL, HEAT TRANSMISSION TO BOILING BINARY LIQUID MIXTURES.
TRAN AM INST CHEM ENG 37. 1941

126
BONILLA, C.F., POOL-BOILING HEAT TRANSFER WITH MERCURY,LIQUID METALS TECH.
PT 1, CEP SYMPOSIUM SERIES 1957 (ALSO REACTOR HEAT TRANSFER
CONFERENCE OF 1956, TID-7529, (PT.1)(P.324)(ALSO NYO-7638))

127
BONNET, W.E., ET AL, BOILING COEFFICIENTS OF HEAT TRANSFER.
CHEM ENG PROG 47. 1951

128
BOOTH, M. BEHAVIOR OF WATER MODERATED REACTORS DURING RAPID TRANSIENTS.
NDA-24

129
BORISHAKOV, A.G., ET AL., INVESTIGATION OF THE HEAT -TRANSFER PROCESS
DURING BUBBLING. ZAP. NAUCH. OD. POLITEKH. INST. NO 2 1954

130
BORISHANSKII,V.M., ET AL., EFFECT OF THE RATE OF FLOW ON THE CRITICAL
DENSITY OF HEAT FLOW DURING THE BOILING OF WATER.
ENERGOMASHINOSTROENIE 3 NO 2 10 FEB 1957

131
BORISHANSKII, V.M., ET AL., ON THE HEAT TRANSFER AND HYDRAULIC RESISTANCE
CALCULATIONS FOR THE FLOW OF LIQUID METALS IN PIPES. ENERGOMASHINOSTROENIE 3 NO 6 5-8 1957

132
BORISHANSKII, V.M. AN EQUATION GENERALIZING EXPERIMENTAL DATA ON THE
CESSATION OF BUBBLE BOILING IN A LARGE VOLUME OF LIQUID. J TECH PHYS.
26,NO 2. 1956

133
BORISHANSKII, V.M. INFLUENCE OF PRESSURE AND PROPERTIES OF THE LIQUID ON
THE CESSATION OF FILM BOILING WITH FREE CONVECTION IN A LARGE SPACE.
AEC-TR-3405 1953

134
BORISHANSKII, V.M. HEAT TRANSFER TO A LIQUID FREELY FLOWING OVER A SURFACE
HEATED TO A TEMPERATURE ABOVE THE BOILING POINT. AEC-TR-3405 1953

135
BORISHANSKII, V.M. ON THE PROBLEM OF GENERALIZING EXPERIMENTAL DATA ON THE
CESSATION OF BUBBLE BOILING IN A LARGE VOLUME OF LIQUIDS. TS K.T.I.
28. 1955

136
BORISHANSKII, V.M., ET AL, COLL., HEAT EXCHANGE PROBLEMS ARISING UPON
CHANGING OF THE AGGREGATE STATE OF MATTER. (IN RUSSIAN)
GOSENERGOIZDAT, LENINGRAD. 1953

137
BORISHANSKII, V.M. THE COEFFICIENTS OF THE TRANSFER OF HEAT TO BOILING
WATER AT EXCESSIVE PRESSURES. TRANS OF ENERGOMASHINOSTROYENIYE 4,
NO 7. 1958

138
BOSCOV, J.L. HEAT TRANSFER TO BOILING WATER UNDER PRESSURE.THESIS M.I.T. 1947

139
BOSNJAKOVIC, F. EVAPORATION AND LIQUID SUPERHEATING. NDA-24 TECHNISCHE MECHANICK UND THERMODYNAMIK 1, NO 10, 1930. TRANSLATED BY J.E. VISCARDI

140
BOSWORTH, R.C. DEMONSTRATION OF FILM AND NUCLEAR BOILING, J PROC ROY SOC N.S. WALES 80, 1946

141
BOSWORTH, R.C. HEAT TRANSFER PHENOMENA. JOHN WILEY AND SONS. NEW YORK. 1952

142
BOWERS, R.H. MECHANISM OF BUBBLE FORMATION, J APPL CHEM 5, AUG, 1955

143
BOWRING, R.W. BURNOUT IN HIGH PRESSURE WATER. AN APPRECIATION OF RECENT AMERICAN CORRELATIONS, AERE-R/R-2493 FEB, 1958

144
BOYD, L.R. ION CHAMBER CAN DETECT NUCLEATE BOILING, NUCLEONICS 17, NO 3, MAR, 1959

145
BOYD, L.R. NUCLEATE BOILING DETECTION SYSTEM DESIGN DESCRIPTION KAPL-M-SSD-46 FEB 19, 1957

146
BRADFUTE, J.O. AN EVALUATION OF MERCURY COOLED BREEDER REACTORS. AEC REPORT ATL-A-102 OCT, 1959

147
BRASUNAS, A. STATIC LIQUID METAL CORROSION. ORNL-1647 MAY 11, 1954

148
BRAUNLICH, R.H. POOL BOILING OF LIQUIDS AT REDUCED PRESSURES. MS THESIS M.I.T. 1941

149
BREAZEALE, W.M., ET AL, PRELIMINARY BOILING EXPERIMENT IN THE LITR, TID-5065 1953

150
BREAZEALE, W.M. FURTHER BOILING EXPERIMENTS IN THE LITR, AECD-3670 MARCH, 1955

151
BRESAN, V.P., ET AL., SWIRLING FLOW IN CYCLONES AND CYLINDERS. R.P.I.,1960

152
BROMBERG, R. DENSITY TRANSIENTS IN BOILING LIQUID SYSTEM, 1952, AECU-2169

153
BROMLEY, L.A., ET AL, HEAT TRANSFER IN CONDENSATION, IND ENG CHEM,44,1952

154
BROMLEY, L.A., ET AL, HEAT TRANSFER IN FORCED CONVECTION FILM BOILING. IND ENG CHEM 45, 1953 ALSO UCRL-1894

155
BROMLEY, L. HEAT TRANSFER IN FILM BOILING FROM HORIZONTAL TUBE, 1947, BC-86

156
BROMLEY, L.A. HEAT TRANSFER IN STABLE FILM BOILING. CHEM ENG PROG, 46, 1950

157
BROOKS, R.D., ET AL, NUCLEAR POWER PLANTS, DESIGN AND PERFORMANCE OF LIQUID METAL HEAT EXCHANGERS AND STEAM GENERATORS, MECH ENG 75, MAY, 1953, KAPL-P-888

158
BROOKS, R.O.R., ET AL, THE CONTROL OF MERCURY METAL IN THE CAB. JULY, 1957 AERE-MED/R-2350

159
BROTHERTON, T.D., ET AL, PROPERTIES AND HANDLING PROCEDURES FOR RUBIDIUM AND CESIUM METALS. TRONA RES LAB, AMER POTASH AND CHEM CORP. MAR, 61

160
BRUGGEMAN, W.H., ET AL, RECLEANING SODIUM HEAT TRANSFER SYSTEMS, KAPL-P-1511 1956

161
BRUGGEMAN, W.H. PURITY CONTROL IN SODIUM COOLED REACTOR SYSTEMS A. I. CH. E. JOURNAL 2, JUNE, 1956

162
BRUSH, E.G., ET AL, EVALUATION OF FERRITIC SUBSTITUTES FOR THE AUSTENITIC STAINLESS STEELS 1, RESISTANCE TO ATTACK BY SODIUM, KAPL-1103 APRIL 22, 1954

163
BRUSH, E.G., ET AL, LOW COST MATERIALS FOR SODIUM HEAT TRANSFER SYSTEMS. LIQ MET TECH, PT 1, CHEM ENG PROG SYM SER 53, NO 20. 1957

164
BUCHBERG, H. ET AL, HEAT TRANSFER, PRESSURE DROP, AND BURNOUT STUDIES WITH AND WITHOUT SURFACE BOILING FOR DE-AERATED AND GASSED WATER AT ELEVATED PRESSURES IN A FORCED FLOW SYSTEM. 1951 HEAT TRANS AND FLUID MECH INST. STANFORD

165
BUTENKO, G.F., ET AL, A MOLTEN METALS HEAT CONDUCTIVITY CALCULATION ATOMNAYA ENERG 6, FEB, 1959 NO 2

166
CAIRNS, R.C. DISCHARGE COEFFICIENTS FOR THE NO 1 SODIUM LOOP VENTURI METER AAEC/E-18 OCT, 1957

167
CALLAHAN, E.J., ET AL, EXAMINATION OF THE NATURAL CIRCULATION STEAM GENERATOR FROM THE LIQUID METAL HEAT TRANSFER TEST FACILITY AT ALPLAUS, NEW YORK. KAPL-M-WLF-5 SEPT 12, 1953

168
CALLINAN, J.P., ET AL, SOME RADIATOR DESIGN CRITERIA FOR SPACE VEHICLES. J HEAT TRANS 81. AUG, 1959

169
CALVERT, S. VERTICAL UPWARD ANNULAR TWO PHASE FLOW IN SMOOTH TUBES. PHD THESIS UNIV OF MICH 1952

170
CAMACK, W.G. A COMPARISON OF FORSTER AND ZUBERS THEORY OF BOILING HEAT TRANSFER WITH THE EXPERIMENTAL DATA ON POOL BOILING OF MERCURY BY BONILLA, ET AL. RESEARCH MEMO RM-62-20-10, 1956 LACKHEED AIR. CORP.

171
CAMACK, W.G. AND H.R. FORSTER, TEST OF A HEAT TRANSFER CORRELATION FOR BOILING LIQUID METALS. JET PROP 27, 1957

172
CAPPEL, H.H. RADIAL TEMPERATURE PROFILE OF SODIUM POOL BOILING HEATER ASSEMBLE NAA-SR-MENO-4914 FEB 26, 1960

173
CARBON, M.W. AND C.R. MCNUTT REACTOR COOLING BY BOILING. ENG DEPT. GE CO.

174
CARL, R., ET AL, LOCAL BOILING OF WATER IN AN ANNULUS. MS THESIS
M.I.T. 1948
175
CARLANDER, R., ET AL, COMPATIBILITY TESTS OF VARIOUS MATERIALS IN MOLTEN
SODIUM. OCT, 1959. CF-57-3-126
176
CARLANDER, R. THE HIGH TEMPERATURE CORROSION RESISTANCE OF HASTELLOY B
AND MO TO RUBIDIUM. CF-56-8-85 AUG 14, 1956
177
CARNIGLIA, S.C. LIQUID METAL SEAL FOR SODIUM PUMP SHAFTS. OCT, 1957
NAA-SR-MEMO-2184
178
CARTER, J.C. THE EFFECT OF FILM BOILING, ANL-4766 FEB 7, 1952
179
CASSIDY, J.F., ET AL, HIGH TEMPERATURE HEAT TRANSFER TO CYLINDERS.
MAY 29, 1961 AD-260-372
180
CESS, R.D., ET AL, FILM BOILING IN A FORCED CONVECTION BOUNDARY LAYER
FLOW. WESTINGHOUSE RESEARCH LAB. SCIENTIFIC PAPER 6-40509-1-PS 1960
181
CESS, R. D., ET AL., SUBCOOLED FORCED-CONVECTION FILM BOILING ON A FLAT
PLATE J HEAT TRANSFER VOL 83 SERIES C NO 3 AUG 1961
182
CHANG, Y. HEAT TRANSFER AND CRITICAL CONDITIONS IN NUCLEATE BOILING OF
SUBCOOLED AND FLOWING LIQUIDS TID-6045 1960
183
CHANG, Y.P., AN EMPIRICAL MODIFICATION OF NUCLEATION THEORY AND ITS APPLICATION TO BOILING HEAT TRANSFER, FEB.1961, ANL 6304
184
CHANG, Y.P. A THEORETICAL ANALYSIS OF HEAT TRANSFER IN NATURAL CONVECTION
AND IN BOILING. ASME TRANS 79. 1957
185
CHANG, Y.P., ET AL, HEAT TRANSFER IN SATURATED BOILING.
CHEM ENG PROG SYM SER 56, NO 30, 1960
186
CHANG, Y.P. WAVE THEORY OF HEAT TRANSFER IN FILM BOILING.
J HEAT TRANS 81. FEB, 1959
187
CHAUNCEY, G., HIGH-PRESSURE, HIGH-TEMP REACTOR SUITS. US PATENT 2745713
MAY 15,1956
188
CHELEMER,H. EFFECT OF GAS ENTRAINMENT ON THE HEAT TRANSFER CHARACTERISTICS
OF MERCURY UNDER TURBULENT FLOW CONDITIONS, ORO-139 JUNE, 1955
189
CHEMISTRY DIVISION ANNUAL PROGRESS REPORT FOR PERIOD ENDING JUNE 20, 1958
ORNL-2584
190
CHEMISTRY DIVISION, SECTION C-11 SUMMARY REPORT FOR APR, MAY, JUNE, 1948
ANL-4232(DEL.)
191
CHEN, M.M. AN ANALYTICAL STUDY OF LAMINAR FILM CONDENSATION. PART 1
FLAT PLATES. PART 2 - SINGLE AND MULTIPLE HORIZONTAL TUBES.
J HEAT TRANS 83, FEB, 1961

192
CHERNOBYLSKII, I.I., ET AL, AN INVESTIGATION OF THE HEAT TRANSFER TO
BOILING WATER FLOWING THROUGH NARROW ANNULAR OPENINGS IN THE PRESENCE
OF MODERATE HEAT FLUXES. IZV. KIYEVSK. POLITEKHN IN-TA. 17. 1956
193
CHERNOBYLSKII, I.I.,ET AL., DETERMINATION OF HEAT EMISSION COEFFICIENTS
IN THE BOILING OF BINARY MIXTURES. KHIM PROM NO 6, SEPT 1957
194
CHERNOBYLSKII, I.I., ET AL., EXPERIMENTAL INVESTIGATION OF THE COEFFICIENT
OF HEAT TRANSFER IN BOILING LARGE VOLUMES OF FREON-12.
KHOL TEKH 32 NO 3 48-51 1955
195
CHERNOBYLSKII, I.I., ET AL, INVESTIGATION OF HEAT TRANSFER IN BOILING
WATER IN AN ANNULAR SPACE AT MODERATE THERMAL FLOWS.
IZVEST KIEV POLITEKH INST 17, 1956
196
CHIRKIN, V.S., ET AL, CRITICAL POINT IN HEAT REMOVAL FROM BOILING WATER
FLOWING THROUGH AN ANNULAR GAP. J TECH PHYS 26, NO 7. 1957
197
CHOI, H. Y., TUFT UNIVERSITY MECHANICAL ENG REPT NO 60-2, MAY 1960
198
CICCHITTI, A., ET AL, CRITICAL SURVEY OF THE LITERATURE ON BUNOUT STUDIES
WITH WET STEAM ENERGIA NUCLEARE (MILAN) 6, 637-60 (1959)OCT
199
CICHELLI,M.T., ET AL, HEAT TRANSFER OF LIQUIDS BOILING UNDER PRESSURE
TRANS AM INST CHEM ENGRS 41, 1945
200
CLARK, H.B., ET.AL, ACTIVE SITES FOR NUCLEATE BOILING CEP 55, SYM.
SER. NO. 29,103-10(1959)
201
CLARK, J.A., ET AL, LOCAL BOILING HEAT-TRANSFER TO WATER AT LOW REYNOLDS
NUMBERS AND HIGH PRESSURE. T ASME 76. MAY, 1954
202
CLARK, J.A. HEAT TRANSFER TO WATER WITH SURFACE BOILING. DS THESIS
M.I.T. 1953
203
CLARK, J.A. THE THERMODYNAMICS OF BUBBLES. NP-6186 JAN, 1956
204
CLAUSEN, I.M. TRANSIENT AND STEADY STATE TEMPERATURES IN A LIQUID METAL
COOLING SYSTEM. KAPL-M-IMC-1 DEC, 1952
205
COHEN, P.D. HEAT TRANSFER COEFFICIENTS FOR CONDENSATION OF LIQUID METAL
VAPORS INSIDE THE VERTICAL TUBE. MS THESIS, OREGON STATE COLLEGE. 1959
206
COHEN, P., ET AL, THE EFFECT OF DISSOLVED GASES ON THE BUBBLE POINT OF H2O
WAPD-RM-7. FEB, 1950
207
COHEN, S. MEASUREMENT OF THE DENSITY OF LIQUID RUBIDIUM.
NUCLEAR SCI AND ENG 2, JULY, 57
208
COHN, P.D. HEAT TRANSFER AND THERMODYNAMIC PROPERTIES OF MERCURY
NAA-SR-MEMO-4666 NOV 18, 1959
209
COLBURN, A.P., ET AL, EFFECT OF LOCAL BOILING AND AIR ENTRAINMENT ON
TEMPERATURES OF LIQUID-COOLED CYLINDERS. 1948 NACA-TN-1498

210
COLE, R. A PHOTOGRAPHIC STUDY OF POOL BOILING IN THE REGION OF THE CRITICAL HEAT FLUX. AICHE JOURNAL 6, DEC, 1960
211
COLLIER, J.G., BURNOUT IN LIQUID-COOLED REACTORS-1 NUCL POWER 6 NO.62 JUNE 1961
212
COLLIER,J.G.,ET AL., HEAT TRANSFER TO HIGH PRESSURE SUPERHEATED STEAM IN AN ANNULUS.
PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME
213
COLLIER, J.G. A REVIEW OF TWO PHASE HEAT TRANSFER. AERE-CE/R-2496 MAY, 1958
214
COLVER, C.P. MEASUREMENTS OF THE TEMPERATURE PROFILES ADJACENT TO THE SURFACE DURING THE NUCLEATE BOILING OF WATER AND METHANOL. MS THESIS UNIV OF KANSAS. 1960. ALSO PROGRESS REPORT, UNIV OF KANSAS, 1960
215
CONTROL AND DYNAMIC PERFORMANCE OF A SODIUM COOLED REACTOR POWER SYSTEM, ALCO PRODUCTS, INC. SCHENECTADY, N.Y. 1960
216
COOK, W.H. BOILING DENSITY IN VERTICAL RECTANGULAR MULTICHANNEL SECTIONS WITH NATURAL CURCULATION, ANL-5621 1956
217
COOK, W.H. BOILING DENSITY STUDIES IN MULTIPLE RECTANGULAR CHANNELS. REACTOR HEAT TRANS SYM. BNL-2466 SEPT 30, 1954
218
CORE, T.C. DETERMAINATION OF BURNOUT LIMITS OF SANTOWAX OMP AGC-1672 SEPT 15, 1959
219
CORROSIVITY, HANDLING AND TRANSFER OF MOLTEN LITHIUM, NP-6598 FEB 14, 1958
220
CORTY, C., ET AL, SURFACE VARIABLE IN NUCLEATE BOILING, CHEM ENG PROG SYM SER 51, 1955
221
CORTY, C. SURFACE VARIABLES IN NUCLEATE BOILING. PHD DISS. U OF MICH 1952
222
COSTELLO,C.P., ET AL., BURNOUT HEAT FLUXES IN POOL BOILING AT HIGH ACCEL
PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME
223
COSTELLO,C.P., ET AL., EFFECTS OF ACCELERATION ON NUCLEATE POOL BOILING, PRESENTED AT AICHE-IMIQ JOINT MEETING, MEXICO CITY, JUNE 1960. TO BE PUBLISHED BY AICHE
224
COTTRELL,W.B. AIRCRAFT NUCLEAR PROPULSION PROJECT QUATERLY PROGRESS REPORT FOR PERIOD ENDING MAR 10, 1951 ANP-60-DEL
225
COTTRELL, W.B., ET AL, SODIUM PLUMBING. A REVIEW OF THE UNCLASSIFIED RESEARCH AND TECHNOLOGY INVOLVING SODIUM AT THE OAK RIDGE NATIONAL LAB ORNL-1688 AUG 14, 1953
226
CROCKER, A.R. ET AL., DESIGN AND OPERATION OF A SODIUM-TO-LITHIUM-TO-AIR HEAT TRANSFER SYSTEM. APEX-327 DEC, 1954
227
CROFTS, T. CALIBRATION OF USE OF ELECTROMAGNETIC FLOW METERS IN 1 INCH SS PIPE CIRCUITS PASSING LIQUID METALS, RDB(W)/TN-221 AUGUST, 1955

228
CROFTS, T.I.M. OPERATING EXPERIENCE WITH NO 1 400 GPM FLAT LINEAR INDUCTION PUMP, RDB(W)-TN-92 SEPT, 1953

229
CRYDER, D.S., ET AL, HEAT TRANSMISSION FROM METAL SURFACES TO BOILING LIQUIDS-EFFECT OF TEMPERATURE OF THE LIQUID ON THE LIQUID FILM COEFFICIENT . TRANS. AICHE 33. 1937

230
CRYDER, D.S., ET AL, HEAT TRANSMISSION FROM METAL SURFACES TO BOILING LIQUID. IND ENG CHEM 24, NO 12. 1932

231
CUNNINGHAM, J.E., RESISTANCE OF METALLIC MATERIALS TO CORROSION ATTACK BY HIGH TEMPERATURE LITHIUM. CF-51-7-135. JULY 23, 1951

232
CURTIS, R.L. SELECTED PHYSICAL PROPERTIES OF POTASSIUM AND POTASSIUM HYDROXIDE IN THE TEMPERATURE RANGE 100 TO 1000C, Y-B4-59 SEPT 23,1952

233
CUTLER, M., ET AL, THERMAL CONDUCTIVITY OF REACTOR MATERIALS. JAN. 1961 GA-1939

234
CYGAN,N. INITIAL TEST OF SODIUM PUMP AND INSTRUMENT LOOP, NAA-SR-MEMO-1178 DEC, 1954

235
DANA, A.W., ET AL, EROSION AND CORROSION STUDIES OF LIQUID METAL SYSTEMS INVESTIGATION OF CONSTANT TEMPERATURE, FORCED CIRCULATION LIQUID LITHIUM SYSTEMS, TECHNICAL REPORT III. DC-52-5-19 AUG 21, 1952

236
DANA, A.W., ET AL, EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER TO LIQUID LITHIUM AND CORROSION STUDIES OF LIQUID METAL SYSTEMS, PROGRESS REPORT JAN 15 TO FEB 15, 1952 , DC-52-2-24, ES-582-783
... DEC 15, 1951 TO JAN 15, 1952, DC-52-1-19, ES-782-783

237
DANA, A.W., ET AL, INVESTIGATION OF LARGE SCALE DYNAMIC LIQUID LITHIUM CORROSION APPARATUS, TECHNICAL REPORT IV, DC-52-25-66, APRIL 30, 1952

238
DANILOVA, G. A STUDY OF THE BOILING PROCESS OF CERTAIN REFRIGERANTS. UCRL-TRANS-280(L)

239
DARLING, G.B. HEAT TRANSFER TO LIQUIDS IN INTERMITTENT FLOW. PETROLEUM 22. 1959

240
DARRAS, R., COOLING BY LIQUID METALS, PROBLEMS OF COMPATIBILITY ENERGIE NUCLEAIRE (IN FRENCH) 3 MAR-APR 1961

241
DATTA, R.L., ET AL, THE PROPERTIES AND BEHAVIOR OF GAS BUBBLES FORMED AT A CIRCULAR ORFICE. TRANS INST CHEM ENG (LONDON) 28, 1950

242
DAVIDSON, W.F., ET AL, STUDIES OF HEAT TRANSMISSION THROUGH BOILER TUBING AT PRESSURE FROM 500-3000 POUNDS. T ASME 65, 1943

243
DAVIS, E. HEAT TRANSFER TO PRESSURE DROP IN ANNULI . ASME 65, 1943

244
DAVIS, E.J., ET AL., HEAT TRANSFER AND PRESSURE DROP FOR HIGH QUALITY STEAM-WATER MIXTURES FLOWING IN A HORIZONTAL,RECTANGULAR DUCT,HEATED ON ONE SIDE. U OF WASHINGTON, 1960

245
DAVIS, M., ET AL, COMPATIBILITY OF REACTOR MATERIALS IN FLOWING SODIUM
A/CONF.0.15/P/25
246
DAVIS, S.H. NUMERICAL MATHEMATICAL ANALYSIS. CHEM ENG 67, AUG 8, 1960
247
DAY, R.B., ET AL, TESTING AND EXAMINATION OF THERMAL CONVECTION LOOPS
OPERATED WITH LITHIUM AND LEAD, Y-F31-4 AUG 20, 1951
248
DEAN, R.B. THE FORMATION OF BUBBLES, J APPL PHYS 15, 1944
249
DEBORTOLI, R.A. DEPARTURE FROM NUCLEATE BOILING TESTS AT 2000 PSIA ON
RECTANGULAR CHANNELS WITH A FLUX PEAK IN THE CORNERS WAPD-AD-TH-529
JUNE, 1959
250
DEBORTOLI, R.A., ET AL, ATMOSPHERIC PRESSURE FREE CONVECTION BURNOUT TESTS
OCT, 1956. WAPD-TH-229
251
DEBORTOLI, R.A., ET AL, FORCED CONVECTION HEAT TRANSFER BURNOUT STUDIES
FOR WATER IN RECTANGULAR CHANNELS AND ROUND TUBES AT PRESSURES ABOVE
500 PSIA, NAPD-188 OCT, 1958
252
DEBORTOLI, R.A., ET AL, INVESTIGATION OF BURNOUT HEAT FLUX.
WESTINGHOUSE ATOMIC POWER DIV. ALSO TID-7529 (PT. 1)
253
DEISSLER, R.D. ANALYSIS OF FULLY DEVELOPED TURBULENT HEAT TRANSFER AT
LOW PECLET NUMBERS IN SMOOTH TUBES WITH APPLICATION TO LIQUID METALS
NACA-RM-ES2F05 AUG 11, 1952
254
DEISSLER, R.G. HEAT TRANSFER AND FRICTION FOR FLUIDS FLOWING OVER SURFACES
AT HIGH TEMPERATURES AND HIGH VELOCITIES. J HEAT TRANS 81. FEB, 1959
255
DENGLER, C.E. HEAT TRANSFER AND PRESSURE DROP FOR EVAPORATION OF WATER IN
A VERTICAL TUBE. THESIS IN CHEM ENG. M. I. T. 1952 ALSO CHEM ENG
PROG SYM SER 52, 1956
256
DENSITY TRANSIENTS IN BOILING LIQUID SYSTEMS, INTERIM REPORT, AECU-2169
JULY, 1952
257
DERGARABEDIAN, P. OBSERVATIONS ON BUBBLE GROWTHS IN VARIOUS SUPERHEATED
LIQUIDS, J FLUID MECH 9, 1960
258
DEGARABEDIAN, P. THE RATE OF GROWTH OF VAPOR BUBBLES IN SUPERHEATED
WATER. J APP MECH 20 1953
259
DERYUGIN, V.M., ET AL, HEAT TRANSFER DURING TRANSITION FLOW OF LIQUID
METALS IN PIPES INZHENER-FIZ ZHUR AKAD NAUK BELORUS SSR 2,3-18(1959)
260
DEWEES, N.B. DESIGN OF LIQUID COOLANT PUMPS, DESIGN REPORT 22463-D2 PARTS
1 AND 2, NEPA-1855 APRIL 30, 1951
261
DINGEE, D.A., ET AL, BURNOUT HEAT FLUX IN A RECTANGULAR CHANNEL.
JAN.1956 BMI-1065

262
DISKIND, T., ET AL. BASIC STUDIES IN HEAT TRANSFER AND FLUID FLOW
TID-6035 1960
263
DONALD, M.B., ET AL, THE MECHANISM OF THE TRANSITION FROM NUCLEATE TO
FILM BOILING. CHEM ENG SCI 8 1958
264
DOODY, T.C., ET AL, HEAT TRANSFER COEFFICIENTS FOR LIQUID MERCURY AND
DILUTE SOLUTIONS OF SODIUM IN MERCURY IN FORCED CONVECTION.
CHEM ENG PROG SYM SER 49, NO 5, 1953
265
DOUGLAS, T.B., ET AL, HEAT CAPACITY OF LIQUID MERCURY BETWEEN 0 AND 450C
CALCULATION OF CERTAIN THERMODYNAMIC PROPERTIES OF THE SATURATED
LIQUID AND VAPOR, J. RESEARCH NATL BUR STANDARDS 46, APR, 1951
266
DOUGLAS, T.B., ET AL, THE HEAT CAPACITY OF LITHIUM FROM 25 TO 900C, THE
HEAT OF FUSION AND THE TRIPLE POINT, THERMODYNAMIC PROPERTIES OF THE
SOLID AND LIQUID. NBS-2879 OCT 16, 1953
267
DOUGLAS, T.B. SPECIFIC HEATS OF LIQUIDS OF LIQUID METALS AND LIQUID SALTS.
FIRST NUCLEAR ENGIN AND SCIENCE CONGRESS 1, 1957
268
DREW, T., ET AL, BOILING. TRANS AM INST CHEM ENG 23, 1937
269
DROPKIN, D., ET AL, EFFECT OF SPIN ON NATURAL CONVECTION IN MERCURY HEATED
FROM BELOW. J APPL PHYS 30, NO1. 1959
270
DUDEK, R.F., ET AL, THE CORROSION TESTING OF VARIOUS MATERIALS IN SODIUM.
1957. BW-7020
271
DUKLER,A.E.,ET.AL., CHARACTERISTICS OF FLOW IN FALLING LIQUID FILMS,
CHEM.ENG.PROG. 48, 557 (1952)
272
DUKLER,A.E. FLUID MECHANICS AND HEAT TRANSFER IN VERTICAL FALLING FILM
SYSTEMS ASME AICHE THIRD NATL HEAT TRANSFER CONFERENCE AUG.,1959
273
DUNN, P.S., ET AL, STUDY OF HEAT TRANSFER FROM A HORIZONTAL METAL SURFACE
TO BOILING LIQUID. MS THESIS M.I.T. 1931
274
DUNNING, E.L. THE THERMODYNAMIC AND TRANSPORT PROPERTIES OF SODIUM AND
SODIUM VAPOR. ANL-6246 OCT, 1960
275
DUNSKUS, T.B., ET AL ., TRACE ADDITIVES IN BOILING LIQUIDS. UNIVERSITY OF
ILLINOIS, 1960
276
DURANT, W.S.,ET AL, ROUGHENING OF HEAT TRANSFER SURFACES AS A METHOD OF
INCREASING THE HEAT FLUX AT BURNOUT DP-380 JULY, 1959
277
DURHAM,N.C., SYMPOSIUM PROCEEDING ON THE CHEMISTRY OF SOLID SURFACES, HELD
AT DUKE UNIV, AD-235207 MARCH 26 - 27, 1958

278
DURKAN, F.P. RADIOLYTIC GAS BUBBLES IMPROVE CONVECTIVE HEAT TRANSFER IN SUPO. NUCLEONICS 13, NO 5. 1955

279
DVORAK, A. PROBLEMS OF CORRODING STRUCTURAL MATERIALS BY LIQUID METALS. JULY 11, 1961 AD-259-250

280
DVORAK, A. THE LIQUID METAL CORROSION PROBLEMS JADERNA ENERGIE 6 (IN CZECH 1960. AKIMOV STATE UNIV, PRAGUE

281
DWYER, O.E., ET AL, HEAT TRANSFER RATES FOR CROSSFLOW OF WATER THROUGH A TUBE BANK AT HIGH REYNOLDS NUMBERS. NOV, 1952. BNL-203

282
DWYER, O.E. HEAT EXCHANGE IN LMF POWER REACTOR SYSTEMS, NUCLEONICS 12, JULY, 1954

283
DZHANDAVA, S. G., FORMATION OF STEAM BUBBLES IN HEATING SURFACES. DOKL AKAD NAUK SSSR 70. 1950

284
DZHANDAVA , S. G., INVESTIGATION OF THE FORMATION OF BUBBLES AND OF THE SUPERHEAT. DOK AK NAUK SSSR 73, NO 3. 1950

285
ECKERT, E.R.G., ET AL, HEAT TRANSFER. IND ENG CHEM 49, MARCH, 1957

286
ECKERT, E.R.G., ET AL, HEAT TRANSFER, IEC 51, MAR, 1959

287
ECKERT, E.R.G., ET.AL. HEAT TRANSFER IEC 52,327-39(APR. 1960)

288
EDMONSON, R.B., ET AL, EXPERIMENTAL STUDIES ON HEAT TRANSFER AND FLUID FLOW SYSTEMS. AEC-AE-30 OCT - DEC, 1956

289
EDWARDS, D. K., HEAT TRANSFER IN LOW PRANDTL NUMBER FLOWS WITH VARIABLE THERMAL PROPERTIES AM ROCKET SOC J 31 MAY 1961

290
EDWARDS, D.K. THE ROLE OF INTERPHASE MASS TRANSFER IN THE MECHANISM OF NUCLEATE BOILING. MS THESIS UNIV OF CAL (BERKELEY) 1956

291
EGEN, R.E., ET AL, VAPOR FORMATION AND BEHAVIOR IN BOILING HEAT TRANSFER BMI-1163 FEB 4, 1957

292
EGGLETON, P. BOILING AND BUBBLING, CHEM PRODUCTS 8. 1945

293
EICHELBERGER,R.L. RECENT INFORMATION ON MODERATOR SHEATH CORROSION IN LIQUID SODIUM, BNL-489 NOV, 1957

294
ELDRED, V.W. INTERACTION BETWEEN SOLID AND LIQUID METALS AND ALLOYS AERE-INF/BIB-102 1953

295
ELLION, M.E. A STUDY OF THE MECHANISM OF BOILING HEAT TRANSFER. JPL-MEMO-20-88 MARCH, 1954

296
ELLION, M.E., ET AL, EXPERIMENTAL STUDIES ON HEAT TRANSFER AND FLUID FLOW SYSTEMS. AGC-1310-3 JAN - MAR, 1957

297
ELLIS, A.T. OBSERVATIONS ON CAVITATION BUBBLE COLLAPSE, AD-7615 1952
298
ELLIS, J.F. A DATA SHEET FOR LITHIUM. 1958. AD-212-943
299
ELROD, E.G., ET AL, EROSION AND HEAT TRANSFER WITH MOLTEN LITHIUM, FINAL
REPORT FOR JAN 1, 1950 TO APR 30, 1951. NEPA-1837
300
ELROD, H.G. TURBULENT HEAT TRANSFER IN POLYGONAL FLOW SECTIONS.
NDA-10-7.
301
ELSER,D., HEAT TRANSFER MEASUREMENTS WITH MERCURY,AEC-TR-2016 1948
302
EMMERSON, G.S. HEAT TRANSMISSION WITH BOILING. NUCLEAR ENG 5 NOV, 1960
303
ENGLISH, D., ET AL, BOILING AND DENSITY STUDIES AT ATMOSPHERIC PRESSURE
AERE-ED/M-20 1955
304
ENGLISH, D., ET AL, HEAT TRANSFER PROPERTIES OF MERCURY, AERE-E/R-547
JUNE, 1950
305
ENGLISH, R.E., ET AL, A 20,000 KILOWATT NUCLEAR TURBOELECTRIC POWER SUPPLY
FOR MANNED SPACE VEHICLES. MAR, 1959. NASA-MEMO-2-20-59E
306
EPSTEIN, L.F. AN OBJECTIVE STUDY OF BARRIER MATERALS FOR NA-H2O SYSTEMS
KAPL-M-LFE-16 NOV 17, 1955
307
EPSTEIN, L.F., ET AL, HEAT TRANSFER AND BURNOUT AT HIGH SUBCRITICAL
PRESSURES. BMI-1116 JULY 20, 1956
308
EPSTEIN, L.F., ET AL, PROBLEMS IN THE USE OF MOLTEN SODIUM AS A HEAT TRANS
FER FLUID, PARTS I AND II. TID-2501(DEL.), KAPL-139, AND KAPL-362
JULY, 1948 - JAN, 1951
309
EPSTEIN, L.F. STATIC AND DYNAMIC CORROSION AND MASS TRANSFER IN LIQUID
METAL SYSTEMS. CHEM ENG PROGR 53, SYM SER NO 20, 1957
310
EREMENKO, V.N., ET AL, WETTING THE SURFACE OF HIGH MELTING ALLOYS WITH
LIQUID METALS. KIEV VYD-VO AN VKRAYINS KOYI RSR. 1958
311
EROSION AND HEAT TRANSFER WITH LIQUID METALS, PROGRESS REPORT V, APR 16
TO MAY 17, 1950, NEPA-1423
312
ERVIN, G. LITERATURE SURVEY ON PROPERTIES OF SODIUM VAPOR. SEPT, 1959
NAA-SR-MEMO-4417
313
EUCKEN, A., ENERGY AND MATERIAL EXCHANGE ON BOUNDARY SURFACES,
NATURWISSESCHAFTEN 25 209-218, 1937
314
EUROLA, A.T. ON THE MEASUREMENT OF THE DYNAMIC PROPERTIES OF THE STEAM
VOID FRACTION IN BOILING WATER CHANNELS. ANL-6369 JUNE, 1961
315
EVANS, J.W. LIQUIDS METALS, NUCLEAR ENG 4, FEB, 1959
316
EVANS, W.H., ET AL, THERMODYNAMIC PROPERTIES OF THE ALKALI METALS.
U S NAT BUREAU OF STANDARDS. JOUR OF RESEARCH 55, NO 2. 1955

317
EVERSOLE, W.G., ET AL, RAPID FORMATION OF GAS BUBBLES IN LIQUIDS, IND ENG CHEM 33, 1941

318
EWING, C.T., ET AL, THE MEASUREMENT OF THE PHYSICAL AND CHEMICAL PROPERTY OF THE SODIUM POTASSIUM ALLOY. SEPT, 1946. PB-129268

319
EWING, C.T., ET AL, THERMAL CONDUCTIVITY OF LIQUID SODIUM AND POTASSIUM J AM CHEM 74, JAN 5, 1952

320
FALETTI, D. W., ET AL., TWO-PHASE CRITICAL FLOW OF STEAM-WATER MIXTURES. U OF WASHINGTON, 1959

321
FANEUFF, C.E. ,ET AL, SOME ASPECTS OF SURFACE BOILING, J APPL PHYS 29, JAN 1958

322
FARBER, E.A. FREE CONVECTION HEAT TRANSFER FROM ELECTRICALLY HEATED WIRES. J APP PHY 22, 1951

323
FARBER, E.A. HEAT TRANSFER TO WATER BOILING UNDER PRESSURE TRANS AM SOC MECH ENG 70, 1948

324
FASTOVSKIY, V.G., ET AL., BOILING OF FREON-11, METHYLENE CHLORIDE AND BENZENE IN A HORIZONTAL TUBE. TEPLOENERGETIKA 5 NO 2 , 1958

325
FEDYNSKIY, O.S. THE INFLUENCE OF THE THERMO PHYSICAL PROPERTIES OF THE HEAT CARRIERS ON HEAT TRANSFER UNDER NATURAL CONVECTION. MAY, 1960 RTS-1434. TECH TRANS

326
FILATKIN, V., HEAT EXCHANGE DURING THE BOILING OF AN AMMONIA-WATER SOLUTION. KHOL TEKH 34 NO 4 23-29 OCT-DEC., 1957

327
FIREY, J.C., ET AL, PRESSURE DROP AND CRITICAL FLOW FOR STEAM WATER MIXTURES. 1957 HW-47681

328
FIRMAN, E.C. ET AL. EXPERIENCE OBTAINED ON A LIQUID SODIUM HEAT TRANSFER RIG. AERE-R/R-2190 AUGUST, 1957

329
FIRSTENBERG, H., K. GOLDMAN, ET AL, COMPILATION OF EXPERIMENTAL FORCED-CONVECTION QUALITY BURNOUT DATA WITH REYNOLDS NUMBER. NDA-2131-16

330
FIRTZ, W., ET AL, STUDY OF EVAPORATION PROCESSES BY MEANS OF CINE RECORDS OF VAPOR BUBBLES. PHYS ZEIT 37. 1936

331
FISHER, E.S., ET AL, SILICONIZING OF METALS IN LIQUID NA-K. 1957. TID-7526

332
FISHER, R.W., ET AL, HIGH TEMPERATURE LOOP FOR CIRCULATING LIQUID METALS. CHEM ENG PROG SYM SER 53, NO 20. 1957

333
FLA, D. POWER REACTOR TECHNOLOGY, TECH PROG REVIEWS 2, 1959

334
FOGLIA, J.J., ET AL, BOILING WATER VOID DISTRIBUTION AND SLIP RATIO IN HEATED CHANNELS. MAY, 1961 BMI-1517

335
FOHRMAN,M.J.THE EFFECT OF THE LIQUID VISCOSITY IN TWO PHASE, TWO COMPONENT FLOW. NOV, 1960. ANL-6256

336
FOLTZ, H.L., ET AL, HEAT TRANSFER RATES TO BOILING FREON 114 IN VERTICAL COPPER TUBES. CEP 54 NO 10, OCT, 1958

337
FOLTZ, H.L., ET AL, HEAT TRANSFER RATES TO BOILING FREON 114 IN VERTICAL COPPER TUBES, CEP 55, SYM SER NO29, 79-86, 1959

338
FOLTZ, H.L., ET AL, TWO PHASE FLOW RATES AND PRESSURE DROPS IN PARALLEL TUBES. CHEM ENG PROG SYM SER 56, NO 30, 1960

339
FORSTER, H.K., ET AL., HEAT CONDUCTION IN A MOVING MEDIUM AND ITS APPLICATION TO LIQUID VAPOR SYSTEM. PRESENTED AT AICHE MEETING, NEW ORLEANS, LOUISIANA, MAY 2, 1956

340
FORSTER, H.K., ET AL, DYNAMICS OF VAPOR BUBBLES AND BOILING HEAT TRANSFER A.I.CH.E. JOURNAL 1, DEC, 1955

341
FORSTER, H.K., ET AL, GROWTH OF A VAPOR BUBBLE IN A SUPERHEATED LIQUID J APPL PHYS 25, APR, 1954

342
FORSTER, H.K. ON THE CONDUCTION OF HEAT INTO A GROWING VAPOR BUBBLE J APPL PHYS 25, AUG, 1954

343
FORSTER, K. CALCULATION OF HEAT FLUX IN SUPERHEATED LIQUIDS. REP. NO 59-63 DEP OF ENG, U OF CAL IN LOS ANGELES. 1959

344
FORSTER, K., ET AL., HEAT TRANSFER TO A BOILING LIQUID --- MECHANISM AND CORRELATIONS, ASME J HEAT TRANSFER 81 P 37 1959 (ALSO AECU3843)

345
FORSTER, K. HEAT CONDUCTION IN A LIQUID WITH EVAPORATION ON A BOUNDARY. REP NO 59-63, PART 2 OF PROGRESS REPORT. DEP OF ENG, U OF CAL, L. A.

346
FORTESCUE, P. ELECTROMAGNETIC PUMPS, NUC ENG 4, JULY THRU SEPT, 1959

347
FORTIER, R.E. HNPF SODIUM SYSTEM, STATIC AND DYNAMIC PERFORMANCE AUG 3, 1961 NAA-SR-M-5979

348
FORTIER, R.E. HNPE SODIUM SYSTEM IHX FREQUENCY RESPONSE. MARCH 27, 1961 NAA-SR-M-5980

349
FRASS, A.P., ET AL., HEAT TRANSFER MEANS. JULY 11, 1961

350
FRASS, A.P. FLOW STABILITY IN HEAT TRANSFER MATRICES UNDER BOILING CONDITIONS, CF-59-11-1 NOV 1, 1959

351
FRANK, S., J. JICHA, AND M. NORIA. LOCAL BOILING HEAT TRANSFER TESTS. SINGLE TUBE HEAT TRANSFER AND PRESSURE DROP TESTS. MND-M-1857 MAY, 1961

352
FRASER, J.P. CORRELATION OF FRICTION COEFFICIENT WITH SURFACE ROUGHNESS GEOMETRY, KAPL-2000-10

353
FRASER, J.P., ET AL, TURBULENT FREE CONVECTION HEAT TRANSFER RATES IN A HORIZONTAL PIPE, KAPL-1494 FEB 28, 1956

354
FRASER, J.P. LUMPED METAL HEAT CAPACITY. KAPL-M-RES-29 JULY 16, 1956

355
FRENKEL, J., KINETIC THEORY OF LIQUIDS . OXFORD (ENG) CLARENDON PRESS 1946

356
FRENKEL, IA. I., ET AL., BOILNG OF GAS-FILLED LIQUID. ZHUR TEKG FIZ 22 NO 9 1500-1505 SEPT 1952

357
FRIED, L. PRESSURE DROP AND HEAT TRANSFER FOR TWO PHASE, TWO COMPONENT FLOW. CHEM ENG PROG SYM SER 5D, NO 9

358
FRIEDLAND, A. J., ET AL., HEAT TRANSFER TO MERCURY IN PARALLEL FLOW THROUGH BUNDLES OF CIRCULAR RODS
PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 3 ASME

359
FROST, B.R.T., ET AL LIQUID METAL TECHNOLOGY, A/CONF.15/P/270

360
FROST, B.R.T. THE WETTING OF SOLIDS BY LIQUID METALS. ATOMICS 8, OCT, 1957

361
FRUMKIN, A. PHENOMENA OF WETTING AND THE ADHESION OF BUBBLES. ACTA PHYSICOHIM (URSS) 9. 1938

362
FUKAI, Y., ET AL, CALCULATIONS OF FLUX DISTRIBUTIONS IN A BOILING WATER REACTOR, NUCLEAR SCI AND ENG 6, OCT, 1959

363
GAERTNER, R.F.,ET AL, NOVEL METHOD FOR DETERMINING NUCLEATE BOILING SITES CEP,55,NO 10,58-61. OCT, 1959

364
GALSON, A.E., STEAM SLIP AND BURNOUT IN BULK SYSTEM. GEAP-1076 JUNE 5, 57

365
GAMBILL, W.R. A PRELIMINARY STUDY OF BOILING BURNOUT HEAT FLUXES FOR WATER IN VORTEX FLOW. CF-58-4-56 APRIL 12, 1958

366
GAMBILL,W.R. ET AL., A STUDY OF BURNOUT HEAT FLUXES ASSOC. WITH FORCED CONVECTION, SUBCOOLED, AND BULK NUCLEATE BOILING OF WATER IN SOURCE-VORTEX FLOW. CF-57-10-118.

367
GAMBILL, W.R., ET AL, HFIR HEAT TRANSFER STUDIES OF TURBULENT WATER FLOW IN THIN RECTANGULAR CHANNELS. ORNL-3079

368
GAMBILL, W. R., ET AL., AN EVALUATION OF THE PRESENT STATUS OF SWIRL-FLOW HEAT TRANSFER CF-61-4-61 APR 24 1961

369
GAMBILL, W.R., ET AL ., BOILING LIQUID-METAL HEAT TRANSFER SPACE-NUCLEAR CONFERENCE MAY 3-5 1961 AMERICAN ROCKET SOCIETY ORNL

370
GAMBILL, W. R., ET AL., BOILING BURNOUT WITH H2O(WATER) IN VORTEX FLOW CHEM ENG PROG 54 10 64-76 1958

371
GAMBILL, W.R., ET AL. BURNOUT HEAT FLUXES FOR LOW-PRESSURE WATER IN NATURAL CIRCULATION. DEC 20, 1960 ORNL-3026

372
GAMBILL, W.R. HEAT TRANSFER, BURNOUT, AND PRESSURE DROP FOR WATER IN SWIRL FLOW THROUGH TUBES WITH INTERNAL TWISTED TAPES. ORNL-2911. 1960

373
GARLID, K., N.R. AMUNDSON AND H.S. ISBIN. A THEORETICAL STUDY OF THE TRANSIENT OPERATION AND STABILITY OF TWO-PHASE NATURAL CIRCULATION LOOPS. ANL-6381 JUNE, 1961

374
GARY, ET AL, INEXPENSIVE WAY TO CONTROL OXYGEN IN NA HEAT TRANSFER SYSTEMS. NUCLEONICS 14, OCT, 1956

375
GASSER, E.R. OPERATIONAL PERFORMANCE OF MAGNETIC FLOW METERS ON A SODIUM COOLED REACTOR, AECU-3853 1957

376
GEGUZIN, IA. E., INVESTIGATION OF CERTAIN PHYSICAL PROCESSES OCCURRING ON METAL SURFACES AT HIGH TEMP. I. NATURAL ROUGHNESS OF POLYCRYSTAL SURFACE. IZV AN SSSR OTD TEKH NAUK 108-118 JAN 1956

377
GELMAN ,L.I., HEAT TRANSFER DURING DROP CONDENSATION OF MERCURY VAPOR. TEPLOENERGETIKA 5 NO 3 47-50 MAR 1958

378
GELPERIN ,N.I., ET AL., DETERMINATION OF HEAT-TRANSFER COEFFICIENTS BETWEEN CONDENSING VAPORS AND LIQUIDS. TRUDY MITKT IM M.V. LOMONOSOVA, NO 5 18-26 1955 (ABST)

379
GILL, W.N., ET AL., MASS TRANSFER IN LIQUID LI AND OTHER MEDIA. SYRACUSE U 1960

380
GILMORE, F., THE DYNAMICS OF CONDENSATION AND VAPORIZATION, THESIS CALIF INST TECH 1951

381
GILMOUR, C.H. NUCLEAR BOILING A CORRELATION, CEP 54, NO 10, OCT, 1958

382
GLASSTONE S. QUARTERLY STATUS REPORT ON LAMPRE PROGRAM FOR THE PERIOD ENDING MAY 20, 1960. LAMS-2438

383
GLASSTONE, S. QUARTERLY STATUS REPORT ON LAMPRE PROGRAM FOR PERIOD ENDING AUG 20, 60, LAMS-2462

384
GLEIM, V. G., ET AL., PHENOMENA OCCURRING AT THE PHASE BOUNDARIES OF BOILING SOLUTIONS . ZHUR PRIKL KHIM 31 NO 1 32-37 JAN 1957

385
GLEIM ,V. G. RATIONAL PROCESS OF BOILING OF SOLUTIONS AND FACTORS OF ITS DETERMINATION ZHUR PRIKL KHIM 26 1157-1165 1953

386
GOLDMAN,K. ET AL., BURNOUT IN TURBULENT FLOW - A DROPLET DIFFUSION MODEL. PRESENTED AT THE 1960 ASME-AICHE HEAT TRANSFER CONF. BUFFALO, N.Y.

387
GOLDMAN, K. IMPROVED HEAT TRANSFER BY APPLICATION OF CENTRIFUGAL FORCES NDA-2-79 JUNE 25, 1958

388
GOLDMAN, K. SPECIAL HEAT TRANSFER PHENOMENA FOR SUPERCRITICAL FLUIDS NDA-2-31 1956

389
GOLDSTEIN, M.B. AND M.E. LAPIDES. HEAT TRANSFER SOURCE FILE DATA. APEX-425 G.E. CO., ATOMIC PRODUCTS DIV, AIRCRAFT NUCLEAR PROD DEPT. SEPT, 1957

390
GOODMAN, E.L., ET AL, THE DESIGN AND CONSTRUCTION OF A TEST LOOP FOR THE STUDY OF AN ELECTROMAGNETIC PUMP AND FLOWMETER ON LITHIUM SYSTEMS. SEPT, 1950. AECU-3622

391
GOSE, E.E., ET AL., HEAT TRANSFER TO LIQUID WITH GAS INJECTION THROUGH THE BOUNDARY LAYER. U OF CALIF. PAPER PRESENTED AT AICHE MEXICO CITY MEETING, JUNE 1960

392
GOULARD, R. LIEBMANNS HEAT TRANSFER METHOD IN AEROTHERMOCHEMISTRY. PURDUE RES FOUNDATION. RES PROJ NO 1717. REP NO A-59-5. 1959

393
GOUSE,S.W.DESIGN OF A TEST SECTION FOR LOOP 1,BOILING HEAT TRANSFER STUDIES. NOV. 1960 NAA-SR-M-5651

394
GOUSE, S.W. METHODS OF MEASURING VOID FRACTIONS, NAA-SR-MEMO-5597 SEPT 29, 1960

395
GOVIER, G.W.,ET AL., THE UPWARDS VERTICAL FLOW OF AIR-WATER MIXTURES, EFFECT OF AIR AND WATER RATES ON FLOW PATTERN, HOLD-UP AND PRESSURE DROP. THE CANADIAN JOURN. OF CHEM. ENG. 58-70, AUG. 1957

396
GRACHEV, N.S., AND P.L. KIRILOV, EXPERIMENTAL DETERMINATION OF POTASSIUM VAPOR PRESSURE IN THE 550-1280 C TEMPERATURE RANGE. AD-260-009

397
GRASS, G., ET AL, SYSTEMATIC EXAMINATION OF THE HEAT TRANSFER AND RESISTANCE TO FLOW OF FINNED TUBES. 1959 BISITS-1382 TECH TRANS

398
GRASSMAN, P. MASS AND HEAT TRANSFER BETWEEN TWO FLUID PHASES. 1959 ATS-68L33G TECH TRANS 2, NO 10

399
GRAY, I.L., ET AL, CONTROL OF OXYGEN IN SODIUM HEAT TRANSFER SYSTEMS CHEM ENG PROG SYM SER 53, NO 20. 1957

400
GREEN, L. TABLE OF REACTOR COOLANT PROPERTIES. BNL-661 (T-215)

401
GREEN, S.J. PRELIMINARY INVESTIGATION OF THE EFFECTS OF VERTICALLY DOWNWARD FLOW ON BURNOUT FLUX. WESTINGHOUSE ATOMIC POWER DIV. NDA APRIL, 1956

402
GREENFIELD, M.L., ET AL, STUDIES ON DENSITY TRANSIENTS IN VOLUME HEATED BOILING SYSTEMS FINAL REPORT, AECU-2950 OCT, 1954

403
GREMILOV, D.I. COLL., COMBINATION POWER ENGINES AND CYCLES. (IN RUSSIAN) TRUDY TSKTI BOOK 23. MASHGIZ, LENINGRAD. 1952

404
GRESHAM, W.A., ET AL, REVIEW OF THE LITERATURE ON TWO-PHASE (GAS-LIQUID) FLUID FLOW IN PIPES. JUNE, 1955 WADC TECH REPT 55-422

405
GRIFFITH, P. A DIMENSIONAL ANALYSIS OF THE DEPARTURE FROM NUCLEATE BOILING HEAT FLUX IN FORCED CONVECTION WAPD-TM-210 DEC, 1959

406
GRIFFITH, P. BUBBLE GROWTH RATES IN BOILING. TRANS ASME 80, 721. 1958

407
GRIFFITH, P., ET AL, THE ROLE OF SURFACE CONDITIONS IN NUCLEATE BOILING. CHEM ENG PROG SYM SER 56, NO 30, 1960

408
GRIFFITH, P. AND J.D. WALLIS, THE ROLE OF SURFACE CONDITIONS IN NUCLEATE BOILING. PB-157-286

409
GRIFFITH,P. THE CORRELATION OF NUCLEATE BOILING BURNOUT DATA. NP-6446 MARCH, 1957

410
GRIFFITH, P. THE DYNAMICS OF BUBBLES ON NUCLEATE BOILING. SCD THESIS M.I.T. JUNE, 1956

411
GRIMALDI, J. SPACE HANDBOOK TURBINES 8/29/60, NAA-SR-MEMO-5615

412
GRINDELL, A.F. CORRELATION OF CAVITATION INCEPTION DATA FOR A CENTRIFIGAL PUMP OPERATING IN WATER AND IN SODIUM POTASSIUM ALLOY, ORNL-2544 DEC 11, 1958

413
GROHSE, E.W., ET AL, FUNDAMENTAL INVESTIGATION OF BOILING HEAT TRANSFER AND TWO PHASE FLOW, KAPL-M-EWG-1 OCT 17, 1958

414
GROOTHUIS, H. HEAT TRANSFER IN TWO PHASE FLOW. CHEM ENG SCI 11, NO 3. 1959

415
GROSSMANN, U. MASS AND HEAT TRANSFER BETWEEN LIQUID AND RISING STEAM BUBBLES IN TWO PHASE MIXTURES, CHEM TECH 28, 1956

416
GROSUENOR, W.M. A SURFACE TENSION EFFECT, SCIENCE 72, 1930

417
GRUZDEV, V. A., ET AL., HEAT TRANSFER AND HIGH-TEMP PROPERTIES OF LIQUID ALKALI METALS. ATOM ENERG, USSR (ENGL TRANSL) 1 NO 4 (PUBL IN J. NUCLEAR ENERGY 4) 387-408 1957

418
GUERRIERI, S.A., ET AL., A STUDY OF HEAT TRANSFER TO ORGANIC LIQUIDS IN SINGLE-TUBE, NATURAL-CIRCULATION, VERTICAL-TUBE BOILERS, HEAT TRANSFER CHEM E PROG SYM SERIES NO 18 VOL 52 1956 AICHE

419
GUNTHER, F.C. BOILING HEAT TRANSFER TO WATER AND FORCED CONVECTION. T ASME 73, NO 2. FEB, 1951

420
GUNTHER, F.C., ET AL, PHOTOGRAPHIC STUDY OF BUBBLE FORMATION IN HEAT TRANSFER TO SUBCOOLED LIQUIDS. HEAT AND FLUID MECH INST . BERKELEY. 1949 ALSO JET PROP LAB PROGRESS REPORT 4-120

421
GUNTHER, F.C. PHOTOGRAPHIC STUDY OF SURFACE BOILING HEAT TRANSFER TO WATER WITH FORCED CONVECTION. J APPL PHYS, 1950

422
HAAG, F.G. MATERIAL TRANSPORT IN SODIUM SYSTEMS. CHEM ENG PROG SYM SER 53 NO 20. 1957

423
HAGE, H.J., ET AL, RATE OF HEAT TRANSFER FROM A HORIZONTAL, HEATED COPPER TUBE IN BOILING LIQUID HYDROGEN OR OXYGEN. NOV, 1942 NBS-A-366

424
HALBERSTADT, S., ET AL, ON THE SIZE OF GAS BUBBLES AND DROPLETS IN LIQUIDS DTMB-TRANS-108 1930

425
HALL, W.B.,ET AL, HEAT TRANSFER EXPERIMENTS WITH SODIUM RDB(W)- 8054 JUNE, 1953

426
HALL, W.B., ET AL, HEAT TRANSFER EXPERIMENTS WITH SODIUM AND SODIUM POTASSIUM ALLOY. J NUCLEAR ENERGY 1, JUNE, 1955

427
HALL, W.B., ET AL, THE USE OF SODIUM AND OF SODIUM POTASSIUM ALLOY AS A HEAT TRANSFER MEDIUM I, ATOMICS 7, MAY, 1956

428
HALL, W.B., ET AL, THE USE OF SODIUM AND OF SODIUM POTASSIUM ALLOY AS A HEAT TRANSFER MEDIUM II, ATOMICS 7. JUNE, 1956

429
HALL, W.B., ET AL, THE USE OF SODIUM AND OF SODIUM POTASSIUM ALLOY AS A HEAT TRANSFER MEDIUM III, ATOMICS 7, AUG, 1956

430
HAMMITT, F.G. LIQUID METAL CAVITATION EROSION RESEARCH INVESTIGATION. FINAL REPORT. JAN, 1960. U OF M RES INST. ...STATUS REPORT NO 1 APR 1960

431
HAMMITT, F.G. SELECTION OF LIQUID METAL PUMPS. U. OF MICH. CHEM ENG PROG 53, 1957

432
HANDLING AND USES OF THE ALKALI METALS, ADVANCES IN CHEMISTRY SERIES 19, WASHINGTON, A.C.S., 1957

433
HARBOURNE, B.L. SODIUM REACTOR COOLANT, CHEM AND PROG ENG 40, OCT, 1959

434
HARDEN, H., DIGITAL COMPUTER PROGRAM TO CALCULATE BOILING HEAT TRANSFER OF STEAM GENERATORS KAPL-M-NPA-22 MAR 15 1961

435
HARDEN, H. AN IBM DIGITAL COMPUTER PROGRAM TO CALCULATE BOILING HEAT TRANSFER OF STEAM GENERATORS, KAPL-M-NPA-15 JULY 7, 1960

436
HARRISON, W.B., ET AL, WETTING EFFECTS ON BOILING HEAT TRANSFER. NP-5713 MARCH, 1954 - MAY 31, 1955

437
HARRISON, W.B. FORCED CONVECTION HEAT TRANSFER IN THERMAL ENTRANCE REGIONS PART 3. HEAT TRANSFER TO LIQUID METALS, ORNL-915 JUNE , 1954

438
HARRISON, W. B., WETTING EFFECTS ON HEAT TRANSFER, (FINAL REPT) PROJECT NO A252, CONTRACT DA-01-009-ORD-444 US ARMY RES OFFICE SEPT 30 1957

439
HARRISON, W.B. HEAT TRANSFER IN MANHATTAN DISTRICT AND ATOMIC ENERGY COMMISSION LABORATORIES. A CRITICAL SURVEY. ORNL-156 OCT 1, 1948

440
HARTNETT,J.P. ET AL., NUSSELT VALUES FOR ESTIMATION TURBULENT LIQUID METAL
HEAT TRANSFER IN NONCIRCULAR DUCTS., AICHE JOURNAL 3 SEPT. 1957

441
HARVEY, E.N., ET AL., ON CAVITY FORMATION IN WATER. J. APPL PHY VOL 18
1947 P. 162

442
HARVEY, E.N., ET AL, BUBBLE FORMATION FROM CONTACT OF SURFACES.
J AM CHEM SOC 68, 1946

443
HASLAM, F. A STUDY OF THE MECHAMISM OF BOILING. PHD THESIS, LONDON 1956

444
HAWKINS, G.A. A BRIEF REVIEW OF THE LITERATURE ON BOILING HEAT TRANSFER
COO-23 JUNE, 1950

445
HAYASHI, S., ET AL, EXPERIMENTAL STUDY OF THE TEMPERATURE OVERSHOOT AND
THE DELAY TIME OF THE TRANSIENT BOILING, J ATOMIC ENERGY SOC JAPAN 2
DEC, 1960

446
HAYES, W.C. COMMENTS ON THE APPLICATION OF ASME AND ASA BOILER AND PIPING
CODES TO SODIUM SYSTEMS, NAA-SR-4102 SEPT 15, 1959

447
HAYES, W.C.,ET AL, CORROSION AND DECARBURIZATION OF THE FERRITIC
CHROMIUM MOLYBDENUM STEELS IN SODIUM COOLANT SYSTEMS, NAA-SR-2973
DEC 1, 1958

448
HEAT TRANSFER. BIBLIOGRAPHY COMPILED BY INSTITUT ENERGETIKI AN BSSR,
MINSK, 1960. RTS-1659. TECH TRANS 5, NO 7

449
HECKEL, V.K., ET AL, EMERGENCY SEAL FOR LIQUID SODIUM, NP-5292 AUG , 1954

450
HEDGEPETH, L.M. ZERO GRAVITY BOILING AND CONDENSING. NY-ARS-1960
SEPT 27 - 30, 1960

451
HELLMAN, S.K., ET AL, REPORT ON COMPLETED WORK ON TRANSIENT BOILING
WAPD-V(FBE)-115 APRIL 9, 1959

452
HELLMAN, S.K., ET AL, COMPILATION OF CURRENT WORK IN TRANSIENT BOILING
WAPD-V(FBE)-25 1958

453
HELLMAN, S.K., ET AL, SECOND COMPILATION OF CURRENT WORK ON TRANSIENT
BOILING, WAPD-V(FBE)-159 1959

454
HELLMAN, S.K., ET AL, THIRD COMPILATION OF CURRENT WORK ON TRANSIENT
BOILING, WAPD-V(FBE)-226 1959

455
HENRY, G. ET AL, BOILING HEAT TRANSFER PROJECT PROGRESS REPORT MAY 1953,
NP-4713,,, ...ALSO ANOTHER REPORT - NP-4723

456
HENRY, G., ET AL, BOILING HEAT TRANSFER PROJECT MONTHLY PROGRESS REPORT
NP-4501 MAR, 1953

457
HENRY, G., ET AL, BOILING HEAT TRANSFER PROJECT, MONTHLY PROGRESS REPORT
NP-4230 ALSO REPORTS NP-4218 AND NP-4987 NOV, 1952

458
HERRING , C., THE USE OF CLASICAL MACROSCOPIC CONSEPTS IN SURFACE-ENERGY PROBLEM, IN TEXT STRUCTURE AND PROPRETIES OF SOLID SURFACES, GOMER AND SMITH, U OF CHICAGO PRESS, 1953

459
HERSHMAN, A., ET AL., THE EFFECT OF LIQUID PROPERTIES ON THE INTERACTION BETWEEN A TURBULENT AIR STREAM AND A FLOWING LIQUID FILM. U OF ILLINOIS, 1960

460
HEWITT, G.F. ANALYSIS OF ANNULAR TWO PHASE FLOW. APPLICATION OF THE DUKLER ANALYSIS TO VERTICAL UPWARD FLOW IN A TUBE. JAN, 1961 PHOENIX LIB. U OF M AERE-R3680

461
HEWITT, G.F. SOME EXPERIMENTS ON THE FLOW OF MERCURY THROUGH A FINE CAPILLARY. DEC, 1958. AD-210-811L

462
HICKEY, J.S. HEAT TRANSFER AT HIGH POWER DENSITIES. J APPL PHYS 24, OCT, 1953

463
HIGUCHI, I., ET AL, LIMITING CONCENTRATION OF BUBBLE FORMATION IN THE LIQUID PHASE. J CHEM SOC JAPAN, PURE CHEM SECT 76, 1955

464
HILDITCH, J.A.S. THE ELECTROMAGNETIC PUMPING OF LIQUID METALS, ATOMICS AND NUCLEAR ENERGY 9, APR, 1958

465
HILL, P.L. ALKALI METALS AREA SAFETY GUIDE. MAY, 1951 Y-811

466
HILL, P.L. ALKALI METALS AREA SAFETY GUIDE (SUPPLEMENTAL ISSUE) UNION CARBIDE NUCLEAR COMPANY, DIVISION OF UNION CARBIDE CO. Y-811 AUGUST 15, 1951

467
HILL, T.L. CONCERNING THE DEPENDENCE OF THE SURFACE ENERGY AND SURFACE TENSION OF SPHERICAL DROPS AND BUBBLES ON RADIUS, U-16990 1951

468
HIRONO, F., ET AL, THEORETICAL INVESTIGATION ON HEAT TRANSFER BY NUCLEATE BOILING. APP MECH REVIEW 7. 1954

469
HIRONO, J., ET AL, TIME VARIATION OF NUCLEATE BOILING HEAT TRANSFER OF WATER. BULL JAPAN SOC MECH ANG 2, NO 7 1959

470
HOE, I.R.J., ET AL, HEAT TRANSFER RATES TO CROSS FLOWING MERCURY IN A STAGGERED TUBE BANK. TRANS AM SOC MECH ENG 79, MAY, 1957 BNL-2446

471
HOFFMAN, B., ET AL, THE EFFECT OF GAS ENTRAINMENT ON THE HEAT TRANSFER CHARACTERISTICS OF LIQUID MERCURY. BNL-2446 DEC, 1955

472
HOFFMAN, E.E. CORROSION OF MATERIALS BY LITHIUM AT ELEVATED TEMPERATURES 1000-1900F, ORNL-2924 OCT 27, 1960

473
HOFFMAN, K.C., R.J. ISLER, ET AL, LIQUID METAL FUEL REACTOR, FOUR INCH UTILITY TEST LOOP--DESIGN, CONSTRUCTION, AND EXPERIMENTAL RESULTS. JULY 14, 1960 BNL-619-(T-187)

474
HOGAN, J.M., ET AL, JOINT BETTIS-KAPL NUCLEATE BOILING DETECTION
EXPERIMENT, WAPD-168 FEB, 1957

475
HOGLUND, B.M., ET AL, TWO PHASE PRESSURE DROP IN A NATURAL CIRCULATION
BOILING CHANNEL. 1960 ANL-5760

476
HOLMAN,W. MATERIALS FOR LIQUID METAL SYSTEMS ASAE-26 OCT 28, 1957

477
HOOKER, H.H., ET AL, A GAMMA RAY ATTENUATION METHOD FOR VOID FRACTION
DETERMINATIONS IN EXPERIMENTAL BOILING HEAT TRANSFER TEST FACILITIES
ANL-5766 NOV, 1958

478
HORNING, W.A., ET AL, THEORY OF POWER TRANSIENTS IN THE SPERT I REACTOR.
RAMO-WOOLDRIDGE CORP. L.A., CAL. 1957 ERL-109

479
HORSLEY, G.W. MASS TRANSPORT AND CORROSION OF IRON-BASED ALLOYS IN LIQUID
METALS, REACTOR TECH 1, 84-91 (1959) AUG

480
HORVAY, G., ET AL., THE INTERFACE TEMPERATURE OF TWO MEDIA IN POOR
THERMAL CONTACT. AIME MET SOC TRANS 218, NO 5, 927 1960

481
HSU, S.T., ET AL.,MEASURED VARIATIONS IN LOCAL SURFACE TEMPERATURES IN
POOL BOILING OF WATER J HEAT TRANSFER VOL 83 SERIES C NO 3 AUG 1961

482
HUBER, D.A. EXPERIMENTAL SYSTEMS AND PROCEDURES UTILIZED IN STUDYING
THE PHENOMENA OF NUCLEATE BOILING AND BURNOUT NAA-SR-MEMO-4553
OCT 22, 1959

483
HUCKE, E. E., D. V. RAGONE, D.A. KRAAI, ET AL., THE EFFECT OF SURFACE
TENSION OF LIQUID METAL ENVIRONMENT ON THE FRACTURE STRENGTH OF SOLID
METALS, U OF MICHIGAN TECH REPT NO 2782-1-F, 1960

484
HUMPHREYS, J.R. SAMPLING AND ANALYSIS FOR IMPURITIES IN LIQUID SODIUM
SYSTEMS. CHEM ENG PROG SYM SER 53, NO 20. 1957

485
HUNT, T.W., ET AL, AN INVESTIGATION OF SUBCOOLED AND QUALITY BURNOUT
IN CIRCULAR CHANNELS. WESTINGHOUSE ATOMIC POWER DIV.
JAN 26, 1955. WAPD-LSR(IM)-1

486
HURST, R., ET AL, PROGRESS IN NUCLEAR ENERGY . SERIES IV. TECHNOLOGY AND
ENGINEERING. NEW YORK. MCGRAW-HILL, 1956

487
HYMAN, S.C., ET AL, HEAT TRANSFER BY NATURAL CONVECTION FROM HORIZONAL
CYLINDERS TO LIQUID METALS, SECOND QUARTERLY RROGRESS REPORT FOR OCT 1
TO DEC 31, 1950 NYO-562

488
HYMAN, S.C., ET AL, HEAT TRANSFER BY NATURAL CONVECTION FROM HORIZONTAL
CYLINDERS TO LIQUID METALS. PROGRESS REPORT FOR JULY 1, TO SEPTEMBER
30, 1949, NYOO-77,,, ..., THIRD QUARTERLY PROGRESS REPORT FOR JAN
1, TO MARCH 31, 1950, NYO-559

489
HYMAN, S.C., ET AL, HEAT TRANSFER BY NATURAL CONVECTION FROM HORIZONTAL
CYLINDERS TO LIQUID METALS, FINAL REPORT FOR JULY 1 TO JUNE 30, 1950
NYO-560

490
HYMAN, S.C., ET AL, NATURAL CONVECTION TRANSFER PROCESS. I. HEAT TRANSFER
TO LIQUID METALS AND NON-METALS AT HORIZONTAL CYLINDERS.
CHEM ENG PROG SYM SER 49, NO 5. 1953

491
HYMAN, S.C. HEAT TRANSFER COEFFICIENTS OBSERVED IN SMALL SODIUM EXCHANGERS
CEP, 54, NO 10, 81-2, 1958, OCT

492
IMAI, Y., ET AL, CORROSION OF IRON AND STEELS IN LIQUID METALS
J. ATOMIC ENERGY SOC JAPAN 2,96-101(1960) IN JAPANESE

493
IMAI, Y., ET AL, TRIAL MANUFACTURE OF AN EXPERIMENTAL NAK SYSTEM
J. ATOMIC ENERGY SOC. JAPAN,2,127-35 (1960)MAR (IN JAPANESE)

494
INATOMI, T.H. AND A. BENTON, THE THERMODYNAMIC PROPERTIES OF SODIUM VAPOR
NAA, INC. DOWNEY, CAL. NAA-SR-141 OCT 8, 1951

495
INATOMI, T.H., W.C. PARRISH, THERMODYNAMIC DIAGRAMS FOR SODIUM.
NAA-SR-62 JULY, 13, 1950

496
INSINGER, T.H., ET AL, TRANSMISSION OF HEAT TO BOILING LIQUIDS.
TRAN AM INST CHEM ENG 36. 1940

497
IRANORSKII, M.N., ET AL, A FAST METHOD FOR MEASURING THE HEAT EXCHANGE IN
A PIPE, A/CONF.15/P/2475

498
IRASHTEVICH, A.A. BURNOUT HEAT FLOW DURING FORCED CONVECTION OF FLUIDS IN
CHANNELS ATOMNAYA ENERG 8,51-4 (1960) JAN IN RUSSIAN

499
IRVINE, T.F. ROCKET HEAT TRANSFER LITERATURE. A SIX PART SURVEY
J HEAT TRANSFER 82, 1960

500
ISAKOFF, S. E., EFFECT OF AN ULTRASONIC FIELD ON BOILING HEAT TRANSFER,
HEAT TRANSFER AND FLUID MECHANICS INST STANFORD U PRESS 1956

501
ISAKOFF, S.E., ET AL, HEAT AND MOMENTUM TRANSFER IN TURBULENT FLOW OF
MERCURY, AECU-1199 1950. COLUMBIA UNIV AND BROOKHAVEN NATL LAB

502
ISBIN, H.S. CRITICAL TWO PHASE, STEAM WATER FLOW. TID-11061 NOV, 1960

503
ISBIN, H.S., ET AL, A MODEL FOR CORRELATING TWO PHASE STEAM WATER BURNOUT
HEAT TRANSFER FLUXES. J HEAT TRAN 83. MAY, 1961

504
ISBIN, H.S. TWO PHASE HEAT TRANSFER, TWO PHASE BURNOUT, AECU-4305
AUGUST 26, 1959

505
ISBIN, H.S., ET AL, TWO PHASE PRESSURE DROPS. NOV, 1954. AECU-2994

506
ISBIN, H.S., ET AL, TWO PHASE STEAM WATER CRITICAL FLOW. AICHE JOUR. 3,
NO.3, 1957

507
ISBIN, H.S., ET AL, TWO-PHASE, STEAM-WATER PRESSURE DROPS. CHEM ENG PROG SYM SER 55, NO 23. 1959

508
ISBIN, H.S., ET AL, VOID FRACTIONS IN TWO PHASE FLOW. J AMER INST CHEM ENG 5, NO 4. 1959

509
ISHIGAI, S., ET AL., BOILING HEAT TRANSFER FROM A FLAT SURFACE FACING DOWNWARD. PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME

510
ISMAILOV, M.I. THE THEORY OF CONVECTIVE HEAT EXCHANGE DURING EVAPORIZATION IZO AKAD NAUK USSR, SER FIZ MATER NAUK NO 3, 1957

511
IVANOV, M.E., ET AL., HEAT EMISSION DURING THE BOILING OF OXYGEN AND NITROGEN KISLOROD 11 NO 3 19-28 1958

512
IVANOVSKII, M.N., V.I. SUBBOTIN, AND P.A. USHAKOV. THE FAST METHOD FOR MEASURING THE HEAT EXCHANGE IN A PIPE. IN RUSSIAN A/CONF.15/T-2475

513
JACKET, H.S. BOILING PRESSURE DROP IN RECTANGULAR CHANNELS, WAPD-TH-204 1956

514
JACKET, H.S., ET AL, INVESTIGATION OF BURNOUT HEAT FLUX IN RECTANGULAR CHANNELS AT 2000 PSIA. AM SOC OF MECH ENG, TRANS 80, 1958

515
JACKSON, C.B. LIQUID METALS HANDBOOK. SODIUM NA-K SUPPLEMENT. JULY, 1955. AEC AND DEPART OF NAVY

516
JACOBI, W.M. THERMAL DESIGN CRITERIA FOR PRESSURIZED WATER REACTORS NUCLEONICS,16, NO 11, NOV, 1958

517
JACOBS, J.M., ET AL, HEAT TRANSFER, A BIBLIOGRAPHY OF UNCLASSIFIED REPORT LITERATURE. TID-3305 MARCH, 1957

518
JACOBS, J.M. LIQUID METAL TECHNOLOGY. LIT. SEARCH, TID-3544 1960

519
JACOBS, R.T., ET AL, THE APPLICATION OF STATISTICAL METHODS OF ANALYSIS FOR PREDICTING BURNOUT HEAT FLUX, NUCLEAR SCI. AND ENG 8, DEC, 1960

520
JAKOB, M. CONDENSATION AND EVAPORATION, NEW CONCEPTIONS AND EXPERIMENTS Z VER DENT ING 76, 1932

521
JAKOB, M. HEAT TRANSFER. VOL 1. JOHN WILEY, NEW YORK. 1949

522
JAKOB, M. HEAT TRANSFER IN EVAPORATION AND CONDENSATION, MECH ENG 58, 1936

523
JAKOB, M. THE INFLUENCE OF PRESSURE ON HEAT TRANSFER IN EVAPORATION. PROC 5TH INT CONG APP MECH. 1938

524
JAMES, W., ET AL, TWO-PHASE FLOW STUDIES IN HORIZONTAL PIPES WITH SPECIAL REFERENCE TO BUBBLY MIXTURES. U OF MINN., ST. ANTHONY FALLS HYDRAUL. LAB., TECH PAPER NO 26, SERIES B. 1958

525
JANSEN, G. BEHAVIOR OF A BOILING METAL THERMOSIPHON LOOP HW-63052 DEC 1, 1959

526
JANSEN, G. BOILING OF LIQUID METAL AMALGAMS. ,(MOTION PICTURE) SEPT 4, 1959. HW-61795

527
JARNER, F.H. SURFACE ACTIVE EFFECTS WITHIN BUBBLES, CHEM AND IND, FEB 19, 1955

528
JEFFERY, R.W. VISUAL STUDY OF WATER FLOWING OVER FLAT PLATE AT HIGH RATES OF HEAT TRANSFER WITH SURFACE BOILING. M.I.T. NP-4348 NOV 1, 1952

529
JENKINS, A.E., ET AL, HEAT TRANSFER EXPERIMENTS WITH NA-K, RDB(W)/TN-198 MAR, 1955

530
JENS, W.H., ET AL, ANALYSIS OF HEAT TRANSFER, BURNOUT PRESSURE DROP AND DENSITY DATA FOR HIGH PRESSURE WATER, ANL-4627 1951

531
JENS, W.H. BOILING HEAT TRANSFER. MECH ENG 76, NO 12. 1954

532
JENS, W.H., ET AL, RECENT DEVELOPMENTS IN BOILING RESEARCH, J AM SOC NAVAL ENGR 67, 1955

533
JENS, W.H., ET AL, TWO PHASE PRESSURE DROP AND BURNOUT USING WATER FLOWING IN ROUND AND RECTANGULAR CHANNELS, ANL-4915

534
JICHA, J.J., ET AL. NUCLEATE BOILING LITERATURE SEARCH. MND-1062-1 APRIL, 1957

535
JOHNSON, H.A.,ET AL., TRANSIENT POOL BOILING OF WATER AT ATMO PRESSURE PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME

536
JOHNSON, H.A., ET AL, HEAT TRANSFER AND PRESSURE DROP FOR TURBULENT FLOW OF AIR WATER MIXTURES IN A HORIZONTAL PIPE. T ASME 74, 1952

537
JOHNSON H.A., ET AL, HEAT TRANSFER TO LEAD BISMUTH AND MURCURY IN LAMINAR AND TRANSITION PIPE FLOW, AECU-2637 AUG, 1953

538
JOHNSON, H.A., ET AL, HEAT TRANSFER TO MERCURY IN TURBULENT PIPE FLOW AECU-2627 JULY, 1953

539
JOHNSON, S.O. SIMULATION OF HOT CHANNEL BOILING, WAPD-BT-8 JUNE, 1958

540
JONES, R.H., ET AL, HEAT TRANSFER AND CORROSION TESTS FOR A SODIUM-COOLED FAST BREEDER REACTOR. BNL-2446 DEC, 1955

541
JONES, E.A., ET AL, OVERALL HEAT FLUX VALUES FROM CONDENSING STEAM TO BOILING LIQUIDS, CHEM ENG SCI 2. 1953

542
JONTZ, P.D., ET AL, THE EFFECT OF DYNAMIC SURFACE TENSION ON NUCLEATE BOILING COEFFICIENTS. J AMER INST CHEM ENG 6, NO 1. 1960

543
JORDAN, D.P., ET AL, NUCLEATE BOILING CHARACTERISTICS OF ORGANIC REACTOR COOLANTS. NUC SCI ENG 5, NO 6. 1959

544
KAMINSKY, S. STUDY OF NUCLEATION AND BUBBLE DYNAMICS TO EVALUATE VOID SHUT DOWN MECHANISM IN A HETEROGENEOUS WATER MODERATED REACTOR, KLX-1809 VITRO ENG CO. NEW YORK MAY 4, 1959

545
KANAEV, A.A. KOTLOTURBOSTROENIE 2, NO 18. 1953

546
KANE, D.E. HEAT TRANSFER TO BOILING LIQUIDS FROM ELECTRICALLY HEATED HOLLOW RODS, SM THESIS IN CHEM ENG. M.I.T. 1951

547
KARETNIKOV, IU.P., INVESTIGATION OF HEAT TRANSFER TO THE FILM OF A BOILING FLUID. ZHUR TEKH FIZ 24 193-199 1954

548
KARPLUS, H.B. PROPAGATION OF PRESSURE WAVES IN A MIXTURE OF WATER AND STEAM. JAN, 1961 ARF-4132-12

549
KATZ, D.L., ET AL, BOILING AND CONDENSING FILM COEFFICIENTS FOR WATER FOR NORMAL HEXANE. PET REFINER 25, NO 9. 1946

550
KATZ, D.L., ET AL, BOILING, OUTSIDE FINNED TUBES, PETROL REFINER 34, 1955

551
KATZ, K., ET AL, EFFECT OF IN PILE LOCAL BOILING ON SURFACE DEPOSITION AND CORRISION, NUCLEAR SOC AND ENG 4, 673-89, 1958, NOV

552
KATZ, K. NUCLEATE BOILING DETECTION TECHNIQUES. WAPD-T-588 1957

553
KATZ, D.L. NUCLEATION AND RATE OF BUBBLE GROWTH IN HOMOGENEOUS REACTOR EXPERIMENT, CF-51-8-266 1951

554
KAUFMANN, A.R., ET AL, REACTOR COOLED BY BOILING METAL, 1953, TID-2010 (CLASSIFIED)

555
KAUFMANN, A.R., ET AL, REACTOR COOLED BY BOILING METAL. TID-2504(DEL.) 1953

556
KAULAKIS, A.F., ET AL, EFFECT OF PRESSURE ON HEAT TRANSFER TO BOILING LIQUIDS, SB THESIS, M.I.T. 1938

557
KAYS, W.M. AN INVESTIGATION OF THE EFFECT OF FIN SPACING ON THE PERFORMANCE OF LOUVERED PLATE AND FIN HEAT EXCHANGE SURFACES. DEC 15, 1948 PB-157-275

558
KAYS, W.M. THE HEAT TRANSFER FLOW FRICTION PERFORMANCE OF THREE COMPACT PLATE-FIN HEAT EXCHANGER SURFACES. AUG 15, 1961 PB-157-276

559
KAYS, W.M. THE BASIC HEAT TRANSFER AND FLOW FRICTION CHARACTERISTICS OF PLAIN-FIN HEAT EXCHANGER SURFACES. AUG 15, 1961 PB-157-277

560
KAZAKOVA, E.A., THE INFLUENCE OF PRESSURE ON THE APPEARANCE OF THE FIRST CRISIS DURING BOILING OF WATER ON A HORIZONTAL PLATE. COLLECTION OF QUESTIONS ABOUT THE HEAT-EXCHANGE DURING AGGREGATE STATE CHANGE OF A SUBSTANCE. GOSENERGOIZDAT 1953

561
KAZAKOVA, E., THE PHYSICS OF BOILING . TEKH MOL 23 NO 4 16 APR 1955

562
KAZAKOVA, E.A. THE INFLUENCE OF PRESSURE ON THE FIRST CRISIS IN BOILING WATER FROM A HORIZONTAL SURFACE. IN PROBLEMS OF HEAT TRANSFER WITH CHANGE OF PHASE. GEI, MOSCOW. 1953 AEC-TR-3045

563
KEEN, R.D. HIGH TEMPERATURE LIQUID METAL CIRCULATING SYSTEM, NAA-SR-985 AUGUST 1, 1954

564
KELMAN, L.R., ET AL, RESISTANCE OF MATERIALS TO ATTACK BY LIQUID METALS ANL-4417 JULY, 1950

565
KENDALL, W.W., ET AL, GUIDE TO ALKALI METALS HANDLING, AECU-3143 JULY 1, 1954

566
KENNISON, R.G. VORTICITY HEAT TRANSFER IN MOLTEN METALS, AECU-2010 AUG 11, 1952

567
KEZIOS, S.P., ET AL ., BURNOUT IN CROSSED-ROD MATRICES UNDER FORCED CONVECTION FLOW OF WATER.
PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME

568
KEZIOS, S.P., ET AL, HEAT TRANSFER FROM RODS NORMAL TO SUBCOOLED WATER FLOW FOR NONBOILING AND SURFACE BOILING CONDITIONS UP TO AND INCLUDING BURNOUT. JAN, 1958 ANL-5822

569
KHABAKHPASHEVA, E.M., ET AL, HEAT TRANSFER TO AN NA-K ALLOY IN AN ANNULUS ATOMNAYA ENERG 9, DEC, 1960

570
KHOLODOVSKI, G. E., NEW METHOD FOR CORRELATING EXPERIMENTAL DATA FOR THE FLOW OF STEAM-WATER MIXTURES IN VERTICAL PIPE,TEPLOENERGETIKA, VOL4, NO.7, 1957, P.68-72.

571
KIENTZLU, C.F. PHOTOGRAPHIC INVESTIGATION OF THE PROJECTION OF DROPLETS BY BUBBLES BURSTING AT A WATER SURFACE, AD-20215 FEB, 1954

572
KING, E.C., ET AL, GENERATION OF STEAM FROM LIQUID METAL AT HIGH HEAT FLUXES. CHEM ENG PROG SYM SER 51, NO 17. 1955

573
KIRILLOV, P.L., ET AL, HEAT TRANSFER IN TUBES TO MERCURY AND TO A SODIUM POTASSIUM ALLOY. ATOMNAYA ENERG 6, APR, 1959. (IN RUSSIAN)

574
KIRILLOV, P.L., ET AL, THE DESIGN AND OPERATION OF SOME PUMPS FOR SODIUM AND SODIUM-POTASSIUM ALLOYS. SOVIET JOURNAL OF ATOMIC PHYSICS 7, NO 1. DEC, 1960 CONSULTANTS BUREAU

575
KIRILLOV, P.L., ET AL, PURIFICATION OF SODIUM FROM OXIDES AND METHODS OF OXIDE CONTENT CONTROL. ATOMNAYA ENERG 8, JAN, 1960. (IN RUSSIAN)

576
KIRILLOV, P.L., ET AL, DETERMINATION OF SODIUM VAPOR PRESSURE AT TEMPERATURES FROM 880 TO 1300C. INZHENER FIZ ZHUR AKAD NAUK BELORUS SSR 2. MAY, 1959

577
KIRK, D.A. THE EFFECT OF GRAVITY ON FREE CONVECTION HEAT TRANSFER.
THE FEASIBILITY OF USING AN ELECTROMAGNETIC BODY FORCE. AUGUST, 1960
WAPD TECH REPT 60-303 PART I

578
KITZES, A.S. A DISCUSSION OF LIQUID METALS AS PILE COOLANTS, ORNL-360
AUGUST 10, 1949

579
KLOPP, W.D. REVIEW OF RECENT DEVELOPMENTS ON OXIDATION RESISTANT COATINGS
FOR REFACTORY METALS. APR. 26, 1961 AD-255-278

580
KLOPP, W.D. REVIEW OF RECENT DEVELOPMENTS ON OXIDATION-RESISTANT COATINGS
FOR REFRACTORY METALS. JULY 31, 1961 AD-261-293

581
KNAPP, R.T., ET AL., LAB INVESTIGATIONS OF THE MECHANISM OF CAVITAION,
T ASME 70 NO 5 419-435 1948

582
KNOWLES,J.W. HEAT TRANSFER WITH SURFACE BOILING.CANADIAN J OF RESEARCH 26.
1948

583
KNOX, W.M. PRESSURE RISE IN A CONFINED VOLUME OF MOLTEN NA UPON ADDITION
OF HEAT. KAPL-M-WMK-2 MAY 20, 1953

584
KOENIG, R.F., ET AL, SODIUM, A NONCORROSIVE COOLANT, AECU-1495
ALSO IN METAL PROGRESS 61, 1952

585
KOERPER, E.C. LIQUID METAL COOLANT HEAT EXCHANGER, PROGRESS FOR PERIOD
ENDING JULY 15, 1950, NEPA-1491, ARL-HE-102

586
KOERPER, E.C. LIQUID METAL COOLANT HEAT EXCHANGERS, PROGRESS FOR MONTH
ENDING MARCH 15, 1951, NEPA-1782, ARL-HE-110

587
KOLACH, T.A., ET AL., INFLUENCE OF CERTAIN FACTORS ON THE HEAT
TRANSFER FROM BOILING LIQUIDS IN TUBES. TRUDY MOSK ENERG., IN-TA,
24 41-63 1956 RZ-K NO 19, 1956 63911(ABST)

588
KORNBICULER, H., ET AL, HEAT TRANSFER IN BOILING. AEG. MITT. 48, JAN, 58

589
KORNEEV, M.I. TEPLOENERGETIKA 7, NO 30. 1955

590
KORNEEV, M.I. HEAT TRANSFER IN MERCURY AND MAGNESIUM AMALGAMS DURING
BOILING UNDER CONDITIONS OF FREE CONVECTION. TEPLOENERGETIKA 2, NO 4.
1955 NOT TRANSLATED

591
KORNEEV, M.I. TEPLOENERGETIKA 4, NO 44. 1955

592
KORNEEV , M. I.,INVESTIGATION OF HEAT TRANSFER OF MERCURY AND MAGNESIUM
AMALGAMS UNDER NATURAL CIRCULATION CONDITIONS. TEPLOENERGETIKA 2 NO 7
25-29 JULY 1955

593
KORNEEV, M.I., ET AL, AN INVESTIGATION OF HEAT EXCHANGE IN HORIZONTAL PIPES CARRYING A VAPOR LIQUID MIXTURE. TEPLOENERGETIKA 3, NO 6. TRANSLATED BY SLA 1955

594
KORNEEV, M. I., ET AL, INVESTIGATION OF HEAT EXCHANGE PHENOMENA I5 HORIZONTAL TUBES DURING FLOW OF A STEAM LIQUID MIXTURE. JUNE, 1960. RTS-1173 TECH TRANS

595
KOROLKOV, A.M. ON THE VISCOSITY OF LIQUID METALS. OCT , 1960. AEC-TR-4202

596
KOSTERIN, S. I., STUDY OF INFLUENCE OF TUBE DIAMETER AND POSITION UPON HYDRAULIC RESISTANCE AND FLOW STRUCTURE OF GAS-LIQUID MIXTURE. IZVESTIYA AKADEMII NAUK SSSR. O.T.N., NO.12, 1824-1831 USSR 1949 HENRY BRUTCHER TECHNICAL TRANSLATION, PO BOX 157, ALTADENA, CALIF.

597
KOVALENKA, V.F. AN EXPERIMENTAL INVESTIGATION OF THE VIBRATION EFFECT ON HEAT TRANSFER IN THE PROCESS OF BOILING. (IN RUSSIAN) TEPLOENERGELIKA 2. 1958

598
KOZLOV, B.K. FORMS OF FLOW OF GAS-LIQUID MIXTURES AND THEIR STABILITY LIMITS IN VERTICAL TUBES. ZHUR TEKH FIZ 24, NO 12, 1954

599
KRASIAKOVA, L.I. SOME CHARACTERISTICS OF THE FLOW OF A TWO PHASE MIXTURE IN A HORIZONTAL PIPE. AERE-LIB/TRANS-695 1952

600
KREITH, F., ET AL, INVESTIGATION OF HEAT TRANSFER AT HIGH HEAT FLUX DENSITIES. EXPERIMENTAL STUDY WITH WATER OF FRICTION DROP AND FORCED CONVECTION WITH AND WITHOUT SURFACE BOILING IN TUBES. JPL-PR-4-68

601
KREITH, F., ET AL, HEAT TRANSFER TO WATER AT HIGH FLUX DENSITIES WITH AND WITHOUT SURFACE BOILING. TRANS ASME 71, NO 7. OCT, 1949

602
KREITH, F., ET AL, INVESTIGATION OF HEAT TRANSFER AT HIGH HEAT FLUX DENSITIES. LITERATURE SURVEY AND EXPERIMENTAL STUDY IN ANNULUS. FEB 20, 1948. JPL-P4- 4- 65

603
KRUZHILIN, G.N. GENERALIZATION OF THE EXPERIMENTAL DATA ON THE HEAT TRANSMISSION AT THE BOILING OF LIQUIDS UNDER THE CONDITIONS OF FREE CONVECTION. AEC-2000 1949

604
KRUZHILIN, G.N. CORRELATION OF EXPERIMENTAL DATA ON HEAT TRANSFER TO BOILING LIQUIDS IN FREE CONVECTION. 1949 AEC-TR-2542

605
KRUZHILIN, G.N. HEAT TRANSMISSION FROM A HEATING SURFACE TO A BOILING ONE-COMPONENT LIQUID AT FREE CONVECTION, AEC-TR-2060 1948

606
KUCHEROV, Y., ET AL, ON HYDRODYNAMIC BOUNDARY CONDITIONS FOR EVAPORATION AND CONDENSATION. SOVIET PHYS - J OF EXPER AND THEOR PHYS 37, NO 1 1960

607
KUCZEN, K.D., ET AL, MEASUREMENT OF LOCAL HEAT TRANSFER COEFFICIENTS WITH SODIUM POTASSIUM EUTECTIC IN TURBULENT FLOW. NUCLEAR SCI AND ENG 2 APR, 1957

608
KULAKOV, I.G., ET AL, ELECTRON BOMBARDMENT HEATING FOR CRITICAL BOILING
STUDIED, INZHENER FIZ ZHUR AKAD NAUK BSSR 1, NO 3, MAR, 1958

609
KUMPITSCH, R.C. RESEARCH ON LIQUID METALS AS POWER TRANSMISSION FLUIDS.
PROGRESS REPORT NO 1. FOR SEPT 1 TO DEC 15, 1958, R58APS116

610
KUMPITSCH, R.C. REASEARCH ON LIQUID METALS AS POWER TRANSMISSION FLUIDS
FEB 1, 59. WADC-TR-57-294(PT.II)

611
KURIHARA, H.M. FUNDAMENTAL FACTORS AFFECTING BOILING COEFFICIENTS.
PHD DISS. PURDUE UNIV. 1956

612
KURIHARA, H.M., ET AL, FUNDAMENTAL FACTORS AFFECTING BOILING COEFFICIENTS.
PAPER NO 20. AICHE ATLANTIC CITY MEETING. MARCH, 1959

613
KUTATELADZE, S.S., ET AL, HEAT TRANSFER AND HYDRAULIC RESISTANCE DURING
FLOW OF LIQUID METALS IN CIRCULAR TUBES. SOVIET PHYS - J TECH PHYS 3,
NO 4. 1958

614
KUTATELADZE, S.S., ET AL, HEAT TRANSFER TO LIQUID METALS. ATOMNAYA ENERG 4
MAY, 1958. TRANSLATED BY CONSULTANTS BUREAU, INC. 4, NO 5

615
KUTATELADZE, S.S., ET AL, HYDRAULICS OF GAS LIQUID SYSTEMS. NP-TR-550
1958

616
KUTATELADZE, S.S., ET AL, HYDRODYNAMICS OF A TWO COMPONENT LAYER AS
RELATED TO THE THEORY OF CRISES IN THE PROCESS OF BOILING.
SOVIET FIZ-TEKH FIS 4, NO 9. 1960

617
KUTATELADZE, S.S., ET AL, LIQUID METAL HEAT TRANSFER MEDIA
ATOMNAYA ENERG, SUPPL NO 2, 1958, N.Y. CONSULTANTS BUREAU, INC. 1959
TRANSLATED BY CONS. BUR., 1960

618
KUTATELADZE, S.S., ET AL, LIQUID METAL HEAT TRANSFER AGENTS. 1959
F-TS-9721/V TECH TRANS.

619
KUTATELADZE, S.S., ET AL, SIMILITUDE METHODS APPLIED TO GENERALIZATION OF
THE EXPERIMENTAL RESULTS ON CRITICAL HEAT FLUXES FOR BOILING LIQUIDS
ATOMNAYA ENERG 9, DEC, 1960

620
KUTATELADZE, S.S., ET AL, THERMAL EXCHANGE BY LIQUID METALS, CEA-TR-R-565
(IN FRENCH) 1958

621
KUTATELADZE, S.S., ET AL, UTILIZATION OF THE GAMMA SCOPE METHOD OF
STUDYING THE HYDRODYNAMIC REGIME OF A LIQUID-LIQUID SYSTEM.
AEC-TR-4206 1957

622
KUTATELADZE, S.S. EXPERIMENTAL STUDY OF THE INFLUENCE OF TEMPERATURE OF
THE LIQUID ON A CHANGE IN THE RATE OF BOILING. AEC-TR-3405 1953

623
KUTATELADZE, S.S. FUNDAMENTALS OF HEAT EXCHANGE THEORY. (IN RUSSIAN)
MASHGIZ, LENINGRAD 1957

624
KUTATELADZE, S.S. HEAT TRANSFER DURING BOILING AND CONDENSATION.
(IN RUSSIAN) MASHGIZ, LENINGRAD. 1949 AND 1952
625
KUTATELADZE, S.S. HEAT TRANSFER DURING FLOW OF LIQUID METALS IN TUBES AND
ON PLANE PLATES. SOVIET PHYS - J TECH PHYS NAUK SSSR 28, NO 4. 1958
626
KUTATELADZE, S.S. HEAT TRANSFER IN CONDENSATION AND BOILING,2ND ED,
AEC-TR-3770 1952
627
KUTATALADZE, S.S. HEAT TRANSFER IN LIQUID METAL PIPE FLOWING ,
A/CONF.15/P/2210 1955
628
KUTATELADZE, S.S. HYDRODYNAMIC THEORY OF CHANGE IN THE REGION OF BOILING
OF A LIQUID WITH FREE CONVECTION. 1951 AEC-TRANS-1441
629
KUTATELADZE, S.S. HYDROMECHANICAL MODEL OF THE CRITICAL CONDITION OF
HEAT TRANSFER IN BOILING LIQUIDS FOR THE CASE OF FREE CONVECTION
AEC-TR-1858 1950
630
KUTATELADZE, S.S. ON THE TRANSITION TO FILM BOILING UNDER NATURAL
CONVECTION. KOTLOTURBOSTROENIE, NO 3. 1948
631
KUTATELADZE, S.S. PROBLEMS OF HEAT TRANSFER DURING A CHANGE OF STATE, A
COLLECTION OF ARTICLES, AEC-TR-3405 1953
632
KUTATELADZE, S.S. THE INFLUENCE OF PRESSURE ON THE MECHANISM OF STEAM
FORMATION. J TECH PHY 20. 1950
633
KUTATELADZE, S. S., ET AL., EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER
WHILE BOILING MERCURY, SKTS, 8, 1939 REPORT OF THE KIROVGRAD
ALLOY PLANT
634
LABUNTSOV , D.A. GENERALIZED DEPENDENCIES FOR HEAT TRANSFER DURING
BUBBLE BOILING OF LIQUIDS. TEPLOENERGETIKA NO 5, 1960
635
LABUNTSOV, D.A., EFFECT OF CONVECTIVE HEAT TRANSFER AND THE FORCES OF
INERTIA ON HEAT EXCHANGE DURING LAMINAR FLOW OF CONDENSATE FILM.
TEPLOENERGETIKA 3 NO12 47-50 DEC 1956
636
LAMB, H. HYDRODYNAMICS. DOVER PUBL., NEW YORK. 1957
637
LANCE, R.P. AND J.E. MYERS, LOCAL BOILING COEFFICIENTS ON A HORIZONTAL
TUBE. AICHE JOUR 4, NO 1. MARCH, 1958
638
LANTRATOV, M. F., THERMODYNAMIC PROPERTIES OF LIQUID METAL SOLUTIONS IN THE
SODIUM-LEAD SYSTEM.ZHUR NEORG KHIM 4, 2043-5 1959
639
LANTRATOV, M.F., ET AL, THE THERMODYNAMIC PROPERTIES OF LIQUID METALLIC
SOLUTIONS OF POTASSIUM WITH THALLIUM, LEAD, AND BISMUTH.
ZHUR, FIZ KHIM 33, 1959
640
LANTRATOV, M.F., ET AL, THERMODYNAMIC PROPERTIES OF LIQUID SOLUTIONS IN THE
SYSTEM POTASSIUM MERCURY. ZHUR PRIKLAD KHIM 33, 1960

641
LARSEN, F.W., ET AL, EFFECT OF ASPECT RATIO AND TUBE ORIENTATION ON FREE CONVECTION HEAT TRANSFER TO WATER AND MERCURY IN INCLOSED CIRCULAR TUBES. J HEAT TRANS 83. FEB, 1961

642
LARSON,H.C., VOID FRACTIONS OF TWO-PHASE STEAM-WATER MIXTURE, MS THESIS, U. OF MINNESOTA, 1957

643
LARSON, H.C. VOID FRACTIONS OF TWO PHASE STEAM WATER MIXTURES. PHD THESIS UNIV OF MINN. 1958

644
LARSON, R.F. FACTORS AFFECTING BOILING IN A LIQUID, IND ENG CHEM 37, 1945

645
LARSON , R. F., 1953 HEAT TRANSFER AND FLUID MECHANICS INST., STANFORD U PRESS 163-172

646
LARSON, R.F. FACTORS THAT INFLUENCE HEAT TRANSFER IN BOILING, CF-52-8-178 AUGUST 15, 1952

647
LATZKO, D.G.H. BURNOUT IN LIQUID COOLED POWER REACTORS , ATOMENERGIE 2 SEPT, 1960

648
LAVROVA, V., EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER TO BOILING FREON-12 KHOL TEKH 34 NO 3 55-61 1957

649
LAYMAN,D.C., HEAT TRANSFER TEST PROGRAM EVALUATION FLOW STABILITY IN NUCLEATE SURFACE BOILING. KAPL-M-SAR-RES-2 MARCH 13, 1957

650
LEBEDEV, P. D.,ET AL., MECHANISM OF HEAT AND MASS TRANSFER IN BOILING SOLUTIONS. IZV VYS UCHEB ZAV, ENERG NO 1 80-85 JAN 1958

651
LEE, B., HUCKE, E.E., UNPUBLISHED MATERIAL, U OF MICHIGAN, 1960

652
LEPPERT, G. PRESSURE DROP DURING FORCED CIRCULATION BOILING. PHD THESIS ILL INST TECH 1954

653
LEPPERT, G., ET AL, BOILING HEAT TRANSFER TO WATER CONTAINING A VOLATILE ADDITIVE, TRANS. ASME, 80, OCT, 1958

654
LETOURNEA, B.W., ET AL, AN ANALYSIS OF FUEL PLATE TEMPERATURE RISE DURING A BURNOUT TRANSIENT. WESTINGHOUSE ATOMIC POWER DIV. NOV, 1956

655
LETOURNEA, B.W., ET AL, HEATING, LOCAL BOILING, AND TWO-PHASE DROP FOR VERTICAL UPFLOW OF WATER AT PRESSURES BELOW 1850 PSIA, TEST DATA AND CORRELATIONS. 1958 WAPD-TH-410

656
LEVY, S., STEAM SLIP--THEORETICAL PREDICTION FROM MOMENTUM MODEL, J. HEAT TRANSFER, TRANS. ASME, SERIES C, VOL. 82, 1960 P.113

657
LEVY,S., THEORY OF PRESSURE DROP AND HEAT TRANSFER FOR TWO PHASE COMPONENT ANNULAR FLOW IN PIPES, OHIO STATE U.,ENGINEERING EXPERIMENTAL STATION BULLETIN NO.149, PROCEEDINGS OF SECOND MIDWESTERN CONFERENCE OF FLUID MECHANICS, 337, 1952

658
LEVY, S. GENERALIZED CORRELATION OF BOILING HEAT TRANSFER.
J HEAT TRANS 81. FEB, 1959
659
LEWIS, D.J. THE INSTABILITY OF LIQUID SURFACES WHEN ACCELERATED IN A
PERPENDICULAR TO THE PLANES,PT2. PROC ROY SOC, LONDON 1950 A-202
660
LEWIS, W.Y. AND S.A. ROBERTSON. THE CIRCULATION OF WATER AND STEAM IN
WATER TUBE BOILERS, AND THE RATIONAL SIMPLIFICATION OF BOILIER DESIGN.
PROC INST MECH ENG 143, 1940
661
LI, T., CRYOGENIC LIQUIDS IN THE ABSENCE OF GRAVITY, PAPER NO A-2,
PRESENTED AT 1961 CRYOGENIC ENGINEERING CONFERENCE, ANN ARBOR MICH
TO BE PUBLISHED IN ADVANCES IN CRYOGENIC ENGINEERING, VOL 7
662
LIEBERMAN, E., ET AL, PROGRAM FOR THE INVESTIGATION OF CORROSION AND CRUD
DEPOSITION UNDER NUCLEATE BOILING, WAPD-ALW (PCH)-69
663
LIELPETERIS,J., ON THE THERMAL PROCESSES IN AN ELECTROMAGNETIC INDUCTION
PUMP, LATVIFAL PSR ZINATNU AKAD VESTIS,NO.9, 91-100,1959,JPRS-2397
664
LIN, C., ET AL, BOILING HEAT TRANSFER OF LIQUID METALS JPRS-3512(OR3531)
TRANSLATED BY OTS. 1959
665
LIPKIS, R.P., ET AL, MEASUREMENT AND PREDICTION OF DENSITY TRANSIENTS IN A
VOLUME-HEATED BOILING SYSTEM. BNL-2446 DEC, 1955
666
LIPKIS, R.P. DENSITY TRANSIENTS IN VOLUME-HEATED BOILING SYSTEMS.
CHEM ENG PROG SYM SER 52, NO 18. 1956
667
LIQUID METALS. AUG, 1960 SELECTIVE BIBLIOGRAPHY. OTS-SB-424
668
LIQUID METAL PURIFIER,B AND W CO, FEB 25,1959
669
LITERATURE SURVEY ON TWO PHASE FLOW OF GAS AND LIQUID. AUGUST, 1958.
MND-1062-1
670
LOCKHART, R.W., ET AL, PROPOSED CORRELATION OF DATA FOR ISOTHERMAL, TWO
PHASE, TWO COMPONENT FLOW IN PIPES. CHEM ENG PROG 45, 1949
671
LONGO, J. CONTINUATION OF KAPL (DIG) INVESTGATION OF BURNOUT, KAPL-M-DIG-
TD-2 JUNE 16, 1958
672
LONGO, J. A STATISTICAL INVESTIGATION OF SUBCOOLED BURNOUT WITH UNIFORM
AND LOCALLY PEAKED HEAT FLUXES, KAPL-1744 OCT 22, 1957
673
LOSHKIN, A.N., ET AL, CHARACTERISTICS OF MERCURY BOILING IN THE TUBES OF A
MERCURY VAPOR GENERATOR. TR-NDA-28. REACTOR HEAT TRANS PROG 10,
JUNE 10, 1956
674
LOTTES, P.A. BOILING STUDIES AT ARGONNE RELATIVE TO BOILING REACTORS,
PROC CONF NUCL ENGR, 1955
675
LOTTES, P.A. EFFECTS OF CHANNEL GEOMETRY ON THE POWER DENSITY OF A
NATURAL CIRCULATION BOILING CHANNEL AT 300 PSIA. ANL QUARTERLY REPT.
JAN-MARCH, 1955

676
LOTTES, P.A., ET AL, A METHOD OF ANALYSIS OF NATURAL CIRCULATION BOILING SYSTEMS. NUC SCI AND ENG 1, DEC, 1956

677
LOTTES, P.A., ET AL, EXPERIMENTAL STUDIES OF NATURAL CIRCULATION BOILING AND THEIR APPLICATION TO BOILING REACTOR PERFORMANCE. A/CONF.15/P/1983 1958

678
LOTTES, P.A., ET AL, LECTURE NOTES ON HEAT EXTRACTION FROM BOILING WATER POWER REACTORS, ANL-6063 OCT, 1959

679
LOW, G.M. BOUNDARY LAYER TRANSITION AT SUPERSONIC SPEEDS. NACA-RM-E56E10 1956

680
LOWDERMILK, W. H., ET AL., NAT ADVISORY COMM AERONAUT. TECH. NOTE 4382 SEPT 1958

681
LOWDERMILK, W.H., ET AL, SOME MEASUREMENTS OF BOILING BURNOUT NACA-RM-E54K10 NOV, 1954

682
LOWERY, A.J., ET AL, HEAT TRANSFER TO BOILING METHANOL EFFECT OF ADDED AGENTS. IND ENG CHEM 49. 1957

683
LOZHKIN, A.J., ET AL, J TECH PHYS 8, NO 21. 1938

684
LOZHKIN, A.J., ET AL, BINARY HEAT ENGINES. (IN RUSSIAN) MASHGIZ, LENINGRAD 1946

685
LU, P.C. COMBINED FREE AND FORCED CONVECTION HEAT GENERATING LAMINAR FLOW INSIDE VERTICAL PIPES WITH CIRCULAR SECTOR CROSS SECTIONS. J HEAT TRANS 82. AUG, 1960

686
LUBARSKY, B., ET AL, REVIEW OF EXPERIMENTAL INVESTIGATIONS OF LIQUID METAL HEAT TRANSFER. NACA-TN-3336 NOV 4, 1954

687
LUKOMSKII, S.M., INVESTIGATION OF MAX HEAT FLOW WHEN WATER IS BOILED IN VERTICAL TUBES. DOKL AN SSSR 80 NO 1 53-56 1951

688
LUKOMSKII, S. M., HEAT TRANSFER WHILE BOILING CARBON DIOXIDE IN TUBES AT HIGH PRESSURE. IZVESTIYA AN SSSR, OTN, 8, 1947

689
LUKOMSKII, S.M., HEAT TRANSFER TO BOILING ETHYL ALCOHOL INSIDE TUBES WITH NATURAL CIRCULATION. IZV AN SSSR OTD TEKH NAUK 1306-1320 1951

690
LUKOMSKII, S.M. HEAT TRANSFER IN BOILING, IZVEST AKAD NAUK SSR OTDEL TEKH NAUK, NO 2, 1946

691
LUNDE, K.E., HEAT TRANSFER AND PRESSURE DROP IN TWO PHASE FLOW, YUBA CONSOLIDATED INDUSTRIES, PALO ALTO, CALIFORNIA

692
LYASHENKO, V.S., ET AL, ON THE CORROSION RESISTANCE OF SOME MATERIALS IN SODIUM AND LITHIUM. A/CONF.15/P/2194

693
LYKOUDIS, P.S. , ET AL, HEAT TRANSFER IN LIQUID METALS. TRANS AM SOC MECH-ENGRS 80, APR 1958

694
LYKOV, A.V. HEAT AND MASS TRANSFER IN DISPERSE MEDIA WITH PHASE CHANGES.
TRANS OF INZH. FIZ. ZH. 1, NO 6. 1958
695
LYON, R.E. BOILING HEAT TRANSFER WITH LIQUID METALS. THESIS. U OF MICH 53
696
LYON, R.E., ET AL, BOILING HEAT TRANSFER WITH LIQUID METALS.
CHEM ENG PROG SYM SER 51, 1955, NO 17
697
LYON, R.N. LIQUID METALS HANDBOOK, WASH., AEC AND BUREAU OF SHIPS,
DEPT. OF NAVY, 1950
698
LYON, R.N. LIQUID METAL HEAT TRANSFER COEFFICIENTS, CHEM ENG PROGRESS 47,
FEB, 1951
699
LYON, R.N. PRELIMINARY REPORT ON THE 1953 LOS ALMOS BOILING REACTOR
EXPERIMENTS, CF-53-11-210 1953
700
MABUCHI, I., HEAT TRANSFER BY FILM CONDENSATION- AN APPROXIMATE THEORY OF
LAMINAR FILM CONDENSATION TRANS JAPAN SOC MECH ENGRS, 26,1131 1960
701
MACH, J.E. OPTICAL METHODS AND INSTRUMENTS. MISCELLANEOUS PHYSICAL AND
CHEMICAL TECHNIQUES OF THE LOS ALAMOS PROJECT, NEW YORK, MCGRAW-HILL,
1952
702
MACKAY, D.B. THERMAL EFFICIENCY OF RANKINE CYCLE SPACE POWERPLANTS.
JUNE 30, 1960 MD-60-178
703
MACKAY, D.B. POWERPLANT HEAT CYCLES FOR SPACE VECHICLES. JUNE 30, 1960
MD-60-177
704
MACKAY, D.B., ET AL, SOLAR TURBO POWERPLANT DESIGN. AUGUST 22, 1958.
MD-58-215
705
MACKAY, D.B. SECONDARY POWER SYSTEMS FOR SPACE VEHICLES, MISSLE DIV.
NAA INC. PREPRINT FOR SAE NATIONAL AERONAUTIC MEETING. LOS ANGLELES,
CAL. OCT 10-14, 1960
706
MADSEN, N., ET AL, HEAT TRANSFER TO SODIUM POTASSIUM ALLOY IN POOL BOILING
CHEM ENG PROG SYMP SER, 56, 1960
707
MAGLADRY, R. TRANSIENT NONCONDUCTIVE HEAT TRANSFER AND STEAM FORMATION
MND-E-2155 OCT, 1959
708
MANLY, W.D. FUNDAMENTALS OF LIQUID METAL CORROSION, CORROSION 12, JULY,56
709
MARCHATERRE, ET AL, NATURAL AND FORCED CIRCULATION BOILING STUDIES
ANL-5735 MAY, 1960
710
MARCHATERRE, J.F. THE EFFECT OF PRESSURE ON THE BOILING DENSITY IN
MULTIPLE RECTANGULAR CHANNELS 1956 ANL-5522
711
MARCHATERRE, J.F., ET AL, THE PREDICTION OF STEAM VOLUME FRACTIONS IN
BOILING SYSTEMS, NUCLEAR SCI AND ENG 2, NO 1, JUNE, 1959

712
MARGULOVA, T.KH., ED., PROBLEMS OF CORROSION AND HEAT EXCHANGE IN LIQUID METALS .TRANSLATIONS FROM AMERICAN AND BRITISH SOURCES.MOSKVA, GOS ENERG IZD-VO, 1958 P.39

713
MARTENSON, A.J., ET AL, MECHANISM OF VOID FORMATION TEST FACILITY, WAPD-V(FBE)-274 AUGUST 20, 1959

714
MARTIN, A.V. HEAT FLOW FROM A FIN TO A BOILING LIQUID, AECD-2968, CP-2995 MAY 11, 1945

715
MARTIN, L.J., ET AL, ADVANCED HEAT TRANSFER FLUIDS. MARCH 15, 1961 WADD TECH REPT 61-186. FD-61-121

716
MARTIN, W.L., ET AL, DENSITY TRANSIENTS IN BOILING LIQUID SYSTEMS. INTERIM REPORT, AECU-2169

717
MARTIN, W.L. TRANSIENT BEHAVIOR OF BUBBLES, CF-52-4-197 1952

718
MARTINELLI, R.C. HEAT TRANSFER TO MOLTEN METALS. NOV, 1944. T ASME OR REPRINT IN APEX-425

719
MARTINELLI, R.C., ET AL, TWO PHASE, TWO COMPONENT FLOW IN THE VISCOUS REGION. TRAN AM INST CHEM ENG 42, 1946

720
MARTINELLI, R.C., ET AL, PREDICTION OF PRESSURE DROP DURING FORCED CIRCULATION BOILING OF WATER. T. ASME 70, 1948

721
MARTINELLI, R.C., ET AL, ISOTHERMAL PRESSURE DROP FOR TWO PHASE TWO COMPONENT FLOW IN A HORIZONTAL PIPE. T. ASME 66, 1944

722
MARON, F.S., ET AL, PRODUCING A EUTECTIC POTASSIUM SODIUM ALLOY. TRUDY URAL NAUCH ISSLEDOUATEL KHIM INST NO 5, AUG, 1957

723
MARX, J.W., ET AL, FILM BOILING TERMINATION MECHANISM, J APPL PHYS 23, DEC, 1952

724
MASNOVI, R. LITERATURE SURVEY OF TWO PHASE FLUID FLOW. WESTINGHOUSE. MAY, 1957 WAPD-TH-360

725
MASNOVI, R., ET AL, DEPARTURE FROM NUCLEATE BOILING DATA FOR 0.097 IN BY 1 IN BY 12.36 IN FINNED RECTANGULAR CHANNEL TEST SECTION, WAPD-TH-458 DEC, 1958

726
MATZNER, B. BASIC EXPERIMENTAL STUDIES ON BOILING FLUID FLOW AND HEAT TRANSFER AT ELEVATED PRESSURES. TID-11061 OCT, 1960

727
MAUNG-MYINT, M. A LITERATURE SURVEY ON TWO-PHASE FLOW OF GAS AND LIQUID. BS THESIS M.I.T. JUNE, 1959

728
MAURER, G.W. VAPOR FRACTION EQUATIONS AND DEFINITIONS. FEB, 1960 WAPD-AD-TH-568

729
MAURER, G.W. A METHOD FOR PREDICTING BOILING VAPOR FRACTIONS IN
RECTANGULAR COOLANT CHANNELS. NOV, 1959 WAPD-AD-TH-556
730
MAURER, G.W. BIBLIOGRAPHY ON TWO PHASE HEAT TRANSFER. WAPD-TM-249
AUGUST, 1960
731
MAUSTELLER, J.W. PROGRESS REPORT NO 29 FOR JUNE AND JULY 1955. NP-5739
732
MAUSTELLER, J.W., ET AL, EFFECT OF 1200F SODIUM ON AUSTENITIC AND FERRITIC
STEELS, MSAR-59-99 SEPT 16, 1959
733
MAYER, S.W. THEORY OF METAL SURFACE TENSIONS. AN IONIC-SALT MODEL FOR
LIQUID METALS. NAA-SR-6385 JUNE, 1961
734
MCADAMS, W.H., ET AL, VAPORIZATION INSIDE HORIZONTAL TUBES. TASME 63, 1941
735
MCADAMS, W.H. HEAT TRANSMISSION. 3RD ED., MCGRAW-HILL, NEW YORK, 1954
736
MCADAMS, W.H., ET AL, HIGH DENSITIES OF HEAT FLUX FROM METAL TO WATER.
HEAT TRANS LECTURES 1. DEC, 1948
737
MCADAMS, W.H., ET AL, HEAT TRANSFER TO SUPERHEATED STEAM AT HIGH PRESSURES
TRANS ASME. MAY, 1950
738
MCADAMS, W.H., ET AL, HEAT TRANSFER RATES TO WATER WITH SURFACE BOILING.
AECU-200
739
MCADAMS, W.H., ET AL, HEAT TRANSFER AT HIGH RATES TO WATER WITH SURFACE
BOILING. 1945 ANL-4268
740
MCADAMS, W.H., ET AL, HEAT TRANSFER FROM SINGLE HORIZONTAL WIRES TO
BOILING WATER. CHEM ENG PROG 44, 1948
741
MCCOY, H.E., ET AL, HANDLING TECHNIQUES FOR RUBIDIUM. ORNL-1991
DEC 12, 1955
742
MCDONALD, J.S., ET AL, INVESTIGATION OF NATURAL CONVECTION HEAT TRANSFER
IN LIQUID SODIUM, NUCLEAR SCI AND ENGINERING 8, NOV, 1960
743
MCDONALD, J.S. EXPERIMENTAL EVALUATION OF A NA-NA HELIFLOW HEAT EXCHANGER
AT TEMPERATURES UP TO 1200 F, FEB.1961, NAA-SR- 5661
744
MCDONALD, J. S., VALVE STEM FREEZE SEAL FOR HIGH-TEMPERATURE SODIUM.
ATOMICS INTERNATIONAL, DIV. OF NAA, CANOGA PARK, CALIF NAA-SR-4869
JULY 1960
745
MCDONALD, J.S. INVESTIGATION OF VARIABLES AFFECTING BELLOWS LIFE IN
LIQUID SODIUM. JAN, 1958. NAA-SR-MEMO-2414
746
MCDONALD, P.H. LUBRICATION BEHAVIOR OF LIQUID METALS. WADC-TR-59-764
JAN 15, 1960

747
MCDONALD , W.C., ET AL, CRITICAL ANALYSIS OF METAL WETTING AND GAS ENTRAINMENT IN HEAT TRANSFER TO MOLTEN METALS. CHEM ENG PROG SYM SER 50, NO 9. 1954

748
MCDONOUGH, J.B., ET AL, AN EXPERIMENTAL STUDY OF PARTIAL FILM BOILING REGION WITH WATER AT ELEVATED PRESSURES IN A ROUND VERTICAL TUBE MSAR-60-30 TECH REPT 71. MSA RESEARCH CORP. MARCH 16, 1960

749
MCDONOUGH, J.B. ,ET AL, PARTIAL FILM BOILING WITH WATER AT 2000 SIG IN A ROUND VERTICAL TUBE, NP-6976 OCT 8, 1958

750
MCFADDEN, P.W., ET AL, AN ANALYSIS OF LAMINAR FILM BOILING WITH VARIABLE PROPERTIES. INTER J OF HEAT AND MASS TRAN 1, NO 4. JAN, 1961

751
MCFADDEN , P.W., ET AL, HIGH FLUX HEAT TRANSFER STUDIED. AN ANALYTICAL INVESTIGATION OF LAMINAR FILM BOILING ANL-6060 OCT, 1959

752
MCLEAN, E.A., ET AL, FILM BOILING OF WATER BY PULSE HEATING SMALL WIRES J APPL PHYS 27, 1956

753
MCNEILLIS, J. REVIEW OF BOILING HEAT TRANSFER WITH PARTICULAR REFERENCE TO UNSTABLE FLOW. ENGINEERING 183, NO 4760. MAY 31, 1957

754
MCNELLY, M.T. A CORRELATION OF THE RATES OF HEAT TRANSFER TO NUCLEATE BOILING LIQUIDS, J IMP COLL CHEM ENG SOC 7, 1953

755
MCNUTT, C.R. PRESSURE DROP IN TWO PHASE ANNULAR FLOW, HW-35065TH 1955

756
MCPHERSON, R.E., ET AL, DEVELOPMENT TESTING AND PERFORMACE EVALUATION OF LIQUID METAL AND MOLTEN SALT HEAT EXCHANGERS. MAR, 1960, CF-60-3-164

757
MCPHERSON, R.E., ET AL, DEVELOPMENT TESTING OF LIQUID METAL AND MOLTEN SALT HEAT EXCHANGERS, NUCLEAR SCIENCE AND ENGIN 8, JULY, 1960

758
MEAD, B.R., ET AL, LIQUID SUPERHEAT AND BOILING HEAT TRANSFER. PROC OF HEAT TRAN AND FLUID MECH INST 1951 STANFORD

759
MEISL, C.J. THERMODYNAMIC PROPERTIES OF ALKALI METAL VAPORS AND MERCURY SECOND REVISION, R60FPD 358-A FLIGHT PROPULSION DIVISION, GE CO.

760
MELLEN, R.H. AN EXPERIMANTAL STUDY OF THE COLLAPSE OF A SPHERICAL CAVITY IN WATER, J ACOUST SOC AM 28, NO 3. 1956

761
MENDLER, O.J. ESTIMATED FILM BOILING HEAT TRANSFER COEFFICIENTS. WAPD-TH-404 MARCH 26, 1958

762
MENEGUS, R.L. BURNOUT OF HEATING SURFACES IN WATER. MARCH, 1959 DP-363

763
MENKE, J.R. SODIUM-RUBIDIUM ALLOYS. CNL-5 DEC 21, 1955

764
MEOVEDEV, S.A. TRANSFER OF MERCURY. TSVETNYE METALLY 31, NO 1, 1958

765
MERTE, H., ET AL., BOILING HEAT TRANSFER DATA FOR LIQUID NITROGEN AT STANFORD AND NEAR-ZERO GRAVITY PAPER G-8, PRESENTED AT 1961 CRYOGENIC ENGINEERING CONFERENCE ANN ARBOR MICH TO BE PUBLISHED IN ADVANCES IN CRYOGENIC ENGINEERING VOL 7

766
MERTE, H., ET AL., POOL BOILING IN AN ACCELERATING SYSTEM TRANS ASME SERIES C J HEAT TRANSFER VOL 83 NO 3, AUG 1961

767
MERTE, H. REVIEW OF RUSSIAN LITERATURE PERTAINING TO FORCED CONVECTION. OCT, 1959 WAPD-AD-TH-539

768
MERTE, H. ET AL., POOL BOILING IN AN ACCELERATING SYSTEM. PRESENTED AT THE 1960 HEAT TRANSFER CONF. BUFFALO N.Y. PAPER 60-HT-22

769
MESLER, R.B. THE EFFECTS OF SUPERATMOSPHERIC PRESSURES ON NUCLEATE BOILING. PHD THESIS UNIV OF MICH 1955

770
METALLURGY INFORMATION MEETING, AMES LABORATORY, IOWA STATE COLLEGE, MAY 2,3,4, 1956. TID-7526(PT.1)

771
METZNER, A.B., ET AL, HEAT TRANSFER OF NON NEWTONIAN FLUIDS, NP-5967 1956

772
MEYER, L. A THERMAL ANALYTICAL STUDY OF THE EQUILIBRIUM BETWEEN A BOILING LIQUID AND ITS VAPOR, Z PHYSIK CHEM A175, 1936

773
MIKHEYEU, M.A., ET AL, HEAT TRANSFER BY MOLTEN METALS. REAKTOROSTROYENIYE I TEORIYA REAKTOROV, 1955

774
MIKHEYEU, M.A. HEAT TRANSFER IN TURBULENT MOTION OF LIQUID IN TUBES. JULY, 1959. AEC-TR-3760

775
MILICH, W., ET AL, TEST LOOP FOR DETERMINING BURNOUT HEAT FLUX, NUCLEONICS 16, NO 4, APR, 1958

776
MILICH, W.,ET AL, TEST OF THIRD FLUID VALUE FOR USE WITH NA-K, N7-7404 JUNE 14, 1955

777
MILLER, W.R. HIGH TEMPERATURE PRESSURE TRANSMITTER EVALUATION. ORNL-2483 ALSO INSTRUMENTS. TID-4500 13TH ED.

778
MILLER, D.R. COMPARISON OF COOLANTS. OCT, 1946. KAPL-M-DRM-1

779
MILLER, R.I. STEADY STATE TWO DIMENSIONAL FLOW OF WATER WITH BOILING IN NON-UNIFORMLY HEATED RECTANGULAR DUCTS WAPD-BT-18

780
MILNE-THOMSON, L. M., THEORETICAL HYDRODYNAMICS . NEW YORK MACMILLAN CO 1955

781
MINASHIN, V. E., ET AL MICRO-THERMOCOUPLES USED FOR RESEARCH ON HEAT TRANSFER JULY 1961 RTS-1874

782
MIROPLSKII, Z.L., ET AL, MEASURING THE VOLUMETRIC CONTENT OF STEAM-GENERATING ELEMENTS BY MEANS OF GAMMA RADIATION. 1958 AEC-TR-4206

783
MIRSHAK, S. AND R.H. TOWELL, HEAT TRANSFER BURNOUT OF A SURFACE CONTACTED BY A SPACER RIB. APRIL, 1961 DP-562

784
MIRSHAK, S., ET AL, HEAT FLUX AT BURNOUT, DP-355 FEB, 1959

785
MIZUSHINA, T., ET AL, THERMAL CONTACT RESISTANCE BETWEEN MERCURY AND A METAL SURFACE. INTER J OF HEAT AND MASS TRANS 1, NO 2/3. AUG, 1960

786
MOEN,R.H., AN INVESTIGATION OF THE STEAM-WATER SYSTEM AT HIGH PRESURES AND HIGH TEMPERATURES, PHD THESIS, U. OF MINN., 1956

787
MOLOGIN, M.A. FLOW PATTERNS, LIMITS, AND CRITICAL VELOCITIES OF SEPARATION OF STEAM AND GAS-LIQUID MIXTURES IN HORIZONTAL PIPES. IZVESTIYA AKADEMII NAUK SSSR O.T.N., NO 3 MARCH, 1956

788
MONAGHAN, R.J. A SURVEY AND CORRELATION OF DATA ON HEAT TRANSFER BY FORCED CONVECTION AT SUPERSONIC SPEEDS. ARC TECH REPORT. HER MAJESTYS STATIONERY OFFICE, LONDON. 1958

789
MONRAD, C.C. AND J.F. PELTON, HEAT TRANSFER BY CONVECTION IN ANNULAR SPACES. TRANS AMER INST CHEM ENG 38, NO 3, 1942

790
MONTHLY REPORT NO. 1, JULY 1953, TO DETROIT EDISON COMPANY,,, ... NO. 2, OCTOBER, ... ,,, ...NO. 3, NOVEMBER, ... NP-5477,5478,5479

791
MOORE, F.D. AND R.B. MESLER, MICRO-LAYER VAPORIZATION. PRESENTED AT AICHE MEETING, CLEVELAND, 1961 ALSO UNIV OF KANSAS DEC, 1960

792
MOORE, W.T. HEAT TRANSFER IN MERCURY SYSTEMS. MECH ENG 55, 1933

793
MORGAN, A.I., ET AL, EFFECT OF SURFACE TENSION ON HEAT TRANSFER IN BOILING IND ENG CHEM 41, DEC, 1949

794
MOROZOV, V. G., AN EXPERIMENTAL STUDY OF CRITICAL HEAT LOADS AT BOILING OF ORGANIC LIQUIDS ON A SUBMERGED HEATING SURFACE. J HEAT TRANSFER APRIL 1961

795
MORPHEW, A.T. HEAT TRANSFER, A BIBLIOGRAPHY OF UNCLASSIFIED REPORT LITERATURE, TID-3022 MARCH 18, 1952

796
MOSCIKI, I., ET AL., J. ROSZNICKI CHEMJE, 6 319-354 1926 (DISCUSSION OF HEAT TRANSFER FROM A PLATINUM WIRE SUBMERGED IN WATER, ON FILE AT ENGINEERING RES LAB EXPERIMENTAL STATION, E. I. DUPONT DE NEMOURS AND CO., COMPLETE ENGLISH TRANSL.WILMINGTON DEL)

797
MOTTE, E.I., FILM BOILING OF FLOWING SUBCOOLED LIQUIDS, UCRL-2511 JUNE, 1954

798
MOTTE,E.I. ET AL., FILM BOILING OF FLOWING SUBCOOLED LIQUIDS. IND ENG CHEM 49. NOV,1957

799
MOYER, W.J., ET AL, HEAT TRANSFER MEASUREMENTS AT SODIUM STAINLESS STEEL INTERFACE, KAPL-567 JUNE 1, 1951

800
MUELLER, G.O. A REVIEW AND ASSESSMENT OF BOILING HEAT TRANSFER AND THE DEPARTURE FROM NUCLEATE BOILING, KAPL-M-GOM-2 AUG 19, 1958

801
MULLER, G.L. EXPERIMENTAL FORCED CONVECTION HEAT TRANSFER WITH ADIABATIC WALLS AND INTERNAL HEAT GENERATION IN LIQUID METAL, OR5L - 2669 AUGUST 28, 1959

802
MUMM, J.F. HEAT TRANSFER TO BOILING WATER FORCED THROUGH AN ELECTRICALLY HEATED TUBE. OCT, 1954. BNL-2446

803
MUMM, J.F. HEAT TRANSFER TO BOILING WATER FORCED THROUGH A UNIFORMLY HEATED TUBE, ANL-5276

804
MURGATROID, W. CIRCULATING LIQUID METAL FUEL REACTORS. LMFS/P-1 JULY, 1956

805
MURGATROID, W. SOME ASPECTS OF THE HIGH PRESSURE WETTED WALL EVAPORATOR. AERE-X/M-124

806
MERKULOV, U.I. HEAT EXCHANGE BETWEEN A LIQUID AND A HEAT EMMITTING ROD. FEB 13, 1961 AD-257-697

807
MUSSER, R.J., ET AL, HEAT TRANSFER TO MERCURY, NP-3579 M.I.T. MAY, 1947

808
MYERS, J.E., ET AL, BOILING COEFFICIENTS OUTSIDE HORIZONTAL TUBES. CHEM ENG PROG SYM SER 49, NO 5. 1953

809
NAYSMITH,A., MEASUREMENTS OF HEAT TRANSFER IN BUBBLES OF SEPARATED FLOW IN SUPERSONIC AIR STREAMS .
PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME

810
NESIS, E.J. BOILING UNDER REAL CONDITIONS. ZH TEKH FIZ 22. 1952

811
NEVZOROV, B. A., ON THE ELECTROLYTIC TRANSFER OF OXYGEN IN LIQUID SODIUM AID REPT 61-75 MAY 22, 1961

812
NGUSTRUEVA, E.I. INVESTIGATION OF VAPOR-CONTENT DISTRIBUTION IN BOILING BOUNDARY LAYERS BY THE BETA-RADIOSCOPY METHOD. SOVIET FIZ DOKL 5, NO 1. 1960

813
NICHOLSON, R.B. SODIUM BOILING CALCULATIONS. AECU-3698 AECU-3699 JULY 2, 1957

814
NICKELSON, R.L., ET AL, OBSERVATION ON BOILING CARBON TETRACHLORIDE FROM SURFACES. J CHEM ENG DATA 5, JULY, 1960

815
NIKOLSKIY, N.A., ET AL, THE THERMAL PHYSICAL PROPERTIES OF MOLTEN METALS. TEPLOENERGETIKA NO 2. 1959

816
NISHIBAYASHI, M. DENSITY AND VISCOSITY OF MOLTEN MATERIALS PART 1, DENSITY OF SODIUM AND SODIUM HYDROXIDE. NOV, 1953 WADC-TR-53-308(PT.1)

817
NISHIWAKI, I. BRIEF SURVEY OF GROWTH AND COLLAPSE OF STEAM BUBBLE. UNIV MINNESOTA, OCT, 1960

818
NISHIKAWA, K. HEAT TRANSFER IN NUCLEATE BOILING. MEM FAL ENG KYOSHO UNIV
16, 1956
819
NISHIKAWA, K. HEAT TRANSFER IN BOILING WITH FORCED CONVECTION. PARTS I ,
AND II. 1958 TECH TRANS 1, NO 4
820
NISHIKAWA, K, ET AL, PHOTOGRAPHIC STUDIES OF SATURATED FILM BOILING. 1958
TECH TRANS 1, NO 4
821
NISHIKAWA, K. ET AL., ON THE CORRELATION OF NUCLEATE BOILING HEAT
TRANSFER. INTERN J HEAT AND MASS TRANSFER 1, AUG, 1960.
822
NODEN, J.D., ETAL, THE SOLUBILITY OF OXYGEN IN SODIUM AND SODIUM POTASSIUM
ALLOY. AD-213-341 JULY 20, 1954
823
NORMAN, W. S., ET AL., HEAT TRANSFER TO A LIQUID FILM ON A VERTICAL
SURFACE TRANS INST CHEM ENG 38 1960
824
NOVIKOV,I.I., HEAT LOSS AND THERMOPHYSICAL PROPERTIES OF FUSED ALKALI
METALS. ATOM ENERG 4 92-106 1956
825
NOYES, R.E., ET AL., A NON-DIMENSIONAL METHOD FOR DIGITAL COMPUTER
CALCULATION OF STEADY STATE TEMPERATURE, PRESSURE, AND VOID FRACTION
IN PIPE FLOW WITH OR WITHOUT BOILING NAA-SR-5958 MAY 30 1960
826
NUKIYAMA, S. EXPERIMENTS ON THE DETERMINATION OF THE MAXIMUM AND MINIMUM
VALUES OF THE HEAT TRANSFERRED BETWEEN A METAL SURFACE AND BOILING
WATER. AERE-TRANS-854 1934
827
OPPENHEIMER,E. THE EFFECT OF SPINNING FLOW ON BOILING BURNOUT IN TUBES
NDA-80-1 JULY 30, 1957
828
OWENS, J. E., ET AL PERFORMANCE OF THE SODIUM REACTOR EXPERIMENT.
ATOMICS INT DIV OF NAA CANOGA PARK, CALIF POWER APP AND SYSTEMS
NO. 42 1959
829
OWENS,W.L. JR., TWO-PHASE PRESSURE GRADIENT.
PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME
830
PANCHINKOV,G.M., THE VISCOSITY OF MOLTEN METALS. DOKL AN SSSR 79 1951
831
PAPERS PRESENTED AT ANP MATERIALS MEETING, OAK RIDGE NATL LAB, ORNL-2685
MARCH 21, 1959
832
PARKIN, B.R., SCALE EFFECTS IN CAVITATING FLOW. REPT NO 21-8 HYDRODYNAMICS
LAB CALIF INST TECH JULY 1952
833
PARKER, J.D., ET AL, HEAT TRANFER TO A MIST FLOW. JAN, 1961. ANL-6291
834
PARKMAN, M.F. A STUDY OF THE FUNDAMENTALS OF MASS TRANSFER BY LITHIUM,
DEVELOPMENT OF APPARATUS. JULY 24, 1961 AD-259-882
835
PASET, M., LIQUID METAL RESEARCH IN THE INSTITUTE OF NUCLEAR RESEARCH IN
1956-58, NP-TR-615, 1959

836
PASTERNAK, I. S., ET AL., TURBULENT HEAT AND MASS TRANSFER FROM STATIONARY PARTICLES. CANADA J. CHEM ENG 38, NO 2, 1960

837
PATTEN, T.D. A REVIEW OF HEAT TRANSFER DATA ON THE EVAPORATION OF LIQUIDS AT SUB-ATMOSPHERIC PRESSURES. RAE FARNBOROUGH TECH NOTE NO MECH ENG 216, 1956

838
PEAK, K.D. THERMOCOUPLE LIQUID LEVEL INDICATOR USED ON COLD TRAP STANDS CF-58-10-13 OCT 3, 1958

839
PEEBLES, F.N., ET AL, STUDIES ON THE MOTION OF GAS BUBBLES IN LIQUIDS. CHEM ENG PROG 49. 1953

840
PENNER,S., ON THE KINETICS OF EVAPORATION, J. PH. CHEM., VOL 56 1952

841
PERRINE, H.E. COLLECTED METHODS FOR ANALYSIS OF SODIUM METAL. GEAP-3273 OCT 15, 1959

842
PETERSON, N.L. DIFFUSION IN REFRACTORY METALS. JUNE 20, 1961 AD-257-860

843
PETRICK, M. TWO-PHASE, AIR WATER FLOW PHENOMENA. 1958 ANL-5787

844
PETRICK, M., ET AL, A RADIATION ATTENUATION METHOD OF MEASURING DENSITY OF TWO PHASE FLUID. REV SCI INSTR 29, 1958

845
PETROV, P.A. BOILING LIQUID PULSATION IN NUCLEAR REACTOR CHANNELS A/CONF.15/P/2210 APRIL, 1958

846
PETROVICHEV, ET AL, HEAT TRANSFER TO LIQUID METALS IN TURBULENT FLOW WHEN THE THERMAL LOAD IS DISTRIBUTED SINUSOIDALLY ALONG THE LENGTH OF THE PIPE. AEC-TR-4218 1959

847
PETROVICHEV, V.I. HEAT TRANSFER IN MERCURY FLOW THROUGH ANNULAR CHANNELS. SOVIET JOURNAL OF ATOMIC ENERGY 1, NO 4 MARCH, 1961. CONSULTANTS BUR

848
PETROVICHEV, V.I. HEAT TRANSFER TO MERCURY IN A CIRCULAR TUBE AND ANNULAR CHANNELS WITH SINUSOIDAL HEAT LOAD DISTRIBUTION. INTER J OF HEAT AND MASS TRANS 1, NO 2/3. AUG, 1960

849
PETUKHOV, B. S., ET AL., HEAT EXCHANGE DURING THE FLOW OF LIQUID METAL IN THE LAMINAR AND TRANSITION REGIONS NP-TR-676 1961

850
PETUKHOV, B.S., ET AL, THE PROBLEM OF HEAT EXCHANGE IN THE TURBULENT FLOW OF LIQUID IN TUBES. MAY, 1959. TECH TRANS 5, NO 8

851
PETUKHOV, B.S., ET AL, HEAT EXCHANGE IN THE INITIAL PART OF A TUBE WHEN THERE IS A MIXED BOUNDARY LAYER. JULY, 1960 RTS-1435 TECH RANS

852
PFISTER, C.G. ET AL., D-C MAGNETIC FLOW METER FOR LIQUID SODIUM LOOPS. NUCLEONICS 15, OCT. 1957.

853
PIERCE, R.D., ET AL, HEAT TRANSFER AND FLUID DYNAMICS IN MERCURY WATER SPRAY COLUMNS. 1955. BNL-2433, OR J AMER INST CHEM ENG 5, NO 2. 1959

854
PIKE, J.T., ET AL, EFFECT OF GAS EVOLUTION ON SURFACE BOILING AT WIRE COILS. CHEM ENG PROG SYM SER 51, NO 17. 1955

855
PIRET, E.L. TWO PHASE HEAT TRANSFER IN NATURAL CIRCULATION EVAPORATION, AM INST CHEM ENG HEAT TRANS SYM, PAPER NO 4, 1953

856
PIROGOV, M.S. HEAT TRANSFER TO SODIUM AT LOW RE NUMBERS. SOVIET JOURNAL OF ATOMIC ENERGY 8, NO 4. JUNE, 1961. CONSULTANTS BUREAU

857
PLACZKOWSKI, E.J. EXAMINATION OF THE FORCED CIRCULATION STEAM GENERATOR FROM THE LIQUID METAL HEAT TRANSFER TEST FACILITY AT ALPLAUS, NEW YORK. KAPL-M-EJP-2 APRIL 11, 1954

858
PLANOVSKII, A.N., ET AL., PRACTICAL EQUATION FOR DETERMINING THE COEFFICIENT OF HEAT EMISSION IN BOILING LIQUIDS. KHIM PROM NO 5 287-290 1955

859
PLESSET, M.S. AND P.S. EPSTEIN, ON THE STABILITY OF GAS BUBBLES IN LIQUID-GAS SOLUTIONS. J CHEM PHYS 18. 1950

860
PLESSET, M.S., ET AL, A NON-STEADY DIFFUSION PROBLEM WITH SPHERICAL SYMMETRY. J APP PHYS 23. 1952

861
PLESSET, M.S., ET AL, ON THE DYNAMICS OF VAPOR BUBBLES IN LIQUIDS. J MATH AND PHYS 33. 1955

862
PLESSET, M.S., ET AL, THE GROWTH OF VAPOR BUBBLES IN SUPERHEATED LIQUIDS AD-19784 J APPL PHYS 25. 1954

863
PLESSET, M.S. NOTE ON THE FLOW OF VAPOR BETWEEN LIQUID SURFACES. J CHEM PHYS 20, 1952

864
PLESSET, M.S. RATE OF FORMATION OF VAPOR IN A UNIFORMLY HEATED LIQUID NAA-SR-53 1949

865
PLESSET, M.S. THE DYNAMICS OF CAVITATION BUBBLES, J APPL MECH 16, 1949

866
PLYSHCHEV, V.E., ET AL, DEVELOPMENT AND RECENT STATE OF TECHNOLOGY OF RUBIDIUM AND CESUIM AND OF THEIR COMPOUNDS. AEC-TR-3820 1957

867
POKROVSKIY, N.L., ET AL, AN APPARATUS FOR MEASURING SURFACE TENSION AND DENSITY OF LIQUID METALS IN VACUUM. 1957 TECH TRANS 5, NO 10

868
POLETAVKIN, P.G. ET AL. A NEW METHOD FOR THE INVESTIGATION OF HEAT TRANSFER IN THE BOILING OF LIQUIDS. DKLADY AKAD NAUK SSSR 90. NO 5. 1953. ALSO NP-TR-1

869
POLETAVKIN, P. G., ET AL, HEAT TRANSFER IN SURFACE BOILING OF WATER, AERE-LIB/TRANS-813 1958

870
POLETAVKIN, P.G., ET AL, TAGGED ATOM METHOD OF INVESTIGATING WATER AND STEAM CONTENT DURING SURFACE BOILING OF LIQUIDS. AEC-TR-4206 1958

871
POLETAVKIN, P.G., ET AL, WATER AND STEAM CONTENTS IN SURFACE BOILING OF WATER, AERE-LIB/TRANS-804 1958

872
POLETAVKIN, P.G. HYDRAULIC RESISTANCE WITH SURFACE BOILING OF WATER.
NOV, 1960. RTS-1513 TECH TRANS
873
POLOMIK, E. E., VAPOR VOIDS IN FLOW SYSTEMS FROM A TOTAL ENERGY
BALANCE GEAP-3214 AUG 1959
874
POLOZHII, S.V. LIQUID BOILING WITH HEAT SUPPLY THROUGH THE WALL
AERE-LIB/TRANS-814 1955
875
POLYAKOV, G. M., ET AL., CRITICAL THERMAL LOAD DURING BOILING OF A
LIQUID IN LARGE VOLUME. IZV AN SSSR OTD TEKH NAUK NO 5 1951
876
POLYAKOV, G.M., CRITICAL THERMAL LOAD OF LIQUID BOILING IN A LARGE VOLUME
AND A VERTICAL TUBE. TRUDY SARATOV AUTO.-DOROZH INST NO 12 141-152
1953 RZ-K 1954 NO 49270(ABST)
877
POPOV, B.G., ET AL., STUDY OF HEAT EXCHANGE IN BOILING AQUEOUS
SOLUTIONS OF MINERAL SALTS . IZV VYS UCHEB ZAV KHIM I KHIM TEKH
NO 1 173-182 1958
878
POPPENDIEK, H.F., ET AL, THERMAL ENTRANCE REGION HEAT TRANSFER IN LIQUID
METAL SYSTEMS. CHEM ENG PROG SYM SER 51, NO 17. 1955
879
POPPENDIEK, H.F. FORCED CONVECTION HEAT TRANSFER IN THERMAL ENTRANCE
REGIONS. MAR, 1951 ORNL-913
880
POPPENDIEK, H.F. HEAT TRANSFER IN LIQUID METAL FLOWING TURBULENTLY THROUGH
A CHANNEL WITH A STEP FUNCTION BOUNDARY TEMPERATURE NASA-M-2-5-59W
MARCH, 1959
881
POPPENDIEK, H.F. HEAT TRANSFER SYMPOSIUM AT THE UNIVERSITY OF MICHIGAN.
UNIV OF MICH PRESS, ANN ARBOR MICHIGAN. 1953
882
POPPENDIEK, H.F. TURBULENT LIQUID METAL HEAT TRANSFER IN CHANNELS
NUCLEAR SCI AND ENG 5, 390-434, 1959,JUNE
883
POSEY, W.J. PROGRESS REPORT NO 30 FOR AUGUST AND SEPTEMBER 1955, NP-5779
884
POSEY, W.J. PROGRESS REPORT NO. 33 FOR FEBRUARY AND MARCH 1956, NP-5921
885
POSEY, W.J. PROGRESS REPORT NO 36 FOR AUGUST AND SEPT, 1956. NP-6132
886
POSEY, W.J. PROGRESS REPORT NO 37 FOR OCTOBER AND NOV 1956.
MINE SAFETY APPLIANCES CO.
887
POSEY,W.J. PROGRESS REPORT NO 48 FOR AUGUST AND SEPTEMBER 1958, N7-6985
888
POSEY, W.J. PROGRESS REPORT NO 49 FOR OCTOBER AND NOVEMBER 1958, NP-7101
889
POSEY, W.J. FINAL REPORT (A REVIEW OF THE WORK FROM DEC 1953 TO DEC 1958
WITH ABSTRACTS OF REPORTS ISSUED. MSAR-59-29 MARCH 20, 1959 (ON
LIQ METAL TECHNOLOGY)
890
POWELL, R.W. THE THERMAL AND ELECTRICAL CONDUCTIVITY OF LIQUID MERCURY
PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 4 ASME

891
PRAMOK, F.S., ET AL, EFFECT OF AGITATION ON THE CRITICAL TEMPERATURE DIFFERENCE FOR A BOILING LIQUID. CHEM ENG PROG SYM SER 52, NO 18. 1956
892
PRIOGOV, M.S. HEAT TRANSFER TO SODIUM AT SMALL VALUES OF REYNOLDS NUMBER ATOMNAYA ENERG. 8, 367-8(APR 1960) (IN RUSSIAN)
893
PROPERTIES OF INORGANIC WORKING FLUIDS AND COOLANTS FOR SPACE APPLICATION, SOUTHWEST RESEARCH INST, WADC TECH REPORT 59-598, DEC, 59
894
PROPOSAL FOR A LIQUID METAL HEAT TRANSFER LOOP NP-7323
895
PUGACHEVICH, P.P., EXPERIMENTAL STUDY OF THE SURFACE TENSION OF METALLIC SOLUTIONS. I. TEMPERATURE DEPENDENCE OF THE SURFACE TENSION OF MERCURY AND OF SODIUM AND POTASSIUM AMALGAMS. ZHUR FIZ KHIM 25 NO 11 1365-1373 1957
896
PUMPS AND ELECTROMAGNETIC FLOWMETERS FOR LIQUID METALS, BIBLIOGRAPHY MAY, 1959. AERE-BIB-120, AERE-INF/BIB-93(4TH ED.)
897
PURSEL, C.A. TUBE BURNOUT AS A LIMIT TO IN-PILE BOILING, HW-32820 1954
898
QUARTERLY STATUS REPORT ON LAMPRE PROGRAM FOR PERIOD ENDING MAY 20, 1961 LAMS-2564
899
RADCHENKO, I. V. THE STRUCTURE OF LIQUID METALS AEC-TR-3971 1957
900
RALKO, A. V., ANALYSIS OF STUDIES ON UNSTABLE HEAT AND MASS TRANSFER IN PHASE AND CHEMICAL TRANSFORMATIONS. TRUDY MTIPP NO 8 1957
901
RANKIN, S., HEAT TRANSFER TO BOILING LIQUIDS UNDER CONDITIONS OF HIGH TEMPERATURE DIFFERENCE AND FORCED CONVECTION. UD-FB-13 FEB 20, 1958
902
RATHBUN, A.S. FLOW DISTRIBUTION IN A PARALLEL CHANNEL PRESSURIZED WATER REACTOR. BETTIS TECH REVIEW MAY, 1959
903
RATHBUN, A.S., ET AL, NATURAL CIRCULATION OF WATER AT 1200 PSIA UNDER HEATED LOCAL BOILING AND BULK BOILING CONDITIONS, TEST DATA AND ANALYSIS, WAPD-AD-7H-470 DEC, 1958
904
RATIANI,G.V., HEAT TRANSMISSION DURING BOILING FROM SURFACES PROVIDED WITH RIBS OF SMALL DIMENSIONS. SOOB AN GRUZ SSR19 NO 3 321-327 SEPT 1957
905
REACTOR ENGINEERING DIVISION QUARTERLY REPORT JUNE 1 THROUGH AUG 31, 53 ANL-5134
906
REACTOR DEVELOPMENT PROGRAM PROGRESS REPT FOR AUGUST, 1960 ANL-6215 16 SEPT 1960
907
REACTOR HEAT TRANSFER CONFERENCE OF 1956, TID-7529(PT.1)

908
REACTOR HEAT TRANSFER INFORMATION MEETING HELD AT BROOKHAVEN NATIONAL LABORATORY OCTOBER 18-19, 1954, BNL-2446

909
REICHARDT, C.L. HEAT TRANSFER RATES TO CROSS-FLOWING MERCURY IN STAGGERED TUBE BANK II. TRANS ASME. APRIL, 1958

910
REICHARDT, H. THE PRINCIPLES OF TURBULENT HEAT TRANSFER, NACA-TM-1408. 1951

911
REITZ, J.G. ZERO GRAVITY MERCURY CONDENSING RESEARCH. ZERO SPACE ENG 19, NO 9. 1960

912
REITZ, J.G. INTERIM REPORT ON FIRST ZERO G MERCURY CONDENSING TEST, THOMPSON RAMO WOOLDRIDGE NEW DEVICES LAB

913
RENALDO, P.M. EFFECTS OF DIAMETER ON BOILING OUTSIDE TUBES. THESIS M.I.T. 1947

914
REYNOLDS, J.M., BURNOUT IN FORCED CONVECTION NUCLEATE BOILING OF WATER. JULY 1, 1957 PB-157-688 AD-235-387

915
REYNOLDS, J., ET AL, TUBE FAILURES DURING BOILING. NDA-24 FEB 23, 1956

916
REYNOLDS, J.B. LOCAL BOILING PRESSURE DROP, ANL-5178 1954

917
REYNOLDS, J.M., BURNOUT IN FORCED CONVECTION NUCLEATE BOILING OF WATER NP-6476 M.I.T. JULY, 1957

918
REYNOLDS, W.C. HEAT TRANSFER TO FULLY DEVELOPED LAMINAR FLOW IN A CIRCULAR TUBE WITH ARBITRARY CIRCUMFERENTIAL HEAT FLUX. J HEAT TRANS 82, MAY, 1960

919
RHODES, F.H., ET AL, HEAT TRANSFER TO BOILING LIQUID. TRANS AMER INST CHEM ENG 35. 1939

920
RHODES, J.E. HEAT TRANSFER TO A BOILING LIQUID, AM J PHYS 21, JAN, 1953

921
RICHARDSON, B.L. SOME PROBLEMS IN HORIZONAL TWO PHASE TWO COMPONENT FLOW ANL-5949 DEC, 1958

922
ROBERTS, H.A. A REVIEW OF NET BOILING HEAT TRANSFER AND PRESSURE DROP FROM THE LITERATURE, AERE-ED/M-22 1955

923
ROBERTS,H.A., ET AL, BOILING EFFECTS IN LIQUID COOLED REACTORS NUCLEAR POWER J, NO 39, 96-101, MAR, 1959

924
ROBIN, M., ET AL, INSTALLATION FOR THE STUDY OF HEAT TRANSFER WITH HIGH FLUX DENSITY, LEA-703 1957

925
ROBIN, V. A., NEW HEAT TRANSFER AGENTS FOR INDUSTRIAL HEAT EXCHANGERS. TEPLOENERGETIKA 5 NO 5 61-63 MAY 1958

926
ROBIN, V.A., USING A MIXTURE OF ALUMINUM CHLORIDE AND ALUMINUM BROMIDE AS A HEAT TRASFER AGENT TEPLOENERGETIKA 3 NO 7 27-34 JULY 1956

927
ROBINSON, D.B., ET AL, EFFECT OF VAPOR AGITATION ON BOILING COEFFICIENTS CHEM ENG PROGR 47, 1951

928
ROCKOW, R.A. SURVEY OF THE LITERATURE PERTAINING TO THE PHENOMENA OF NUCLEATE BOILING NAA-SR-MEMO-4160 AUG 14, 1957

929
RODABAUGU, R. TWO PHASE FLOW AND ACOUSTIC PHENOMENA IN GASES AND LIQUIDS JPLAI-LS-177 JULY, 1960

930
RODEBUSH, W.H. SPONTANEOUS NUCLEATION IN SUPERSATURATED WATER VAPOR. IND ENG CHEM 44, PT. 1. 1952

931
ROEBUCK, A.H. BIBLIOGRAPHIES OF CORROSION PRODUCTS. CORROSION 13, FEB, 57

932
ROHRMANN, C.A. REACTOR HEAT TRANSFER BY BOILING MERCURY 204, HW-60564 JUNE 1, 1959

933
ROHSENOW, W.M. A METHOD OF CORRELATING HEAT TRANSFER DATA FOR SURFACE BOILING OF LIQUIDS, NP-3443 M.I.T. JULY, 1951

934
ROHSENOW, W.M. CORRELATING HEAT TRANSFER DATA FOR SURFACE BOILING LIQUIDS. TRANS ASME 74, 1952

935
ROHSENOW, W.M., ET AL, A STUDY OF THE MECHANISM OF BOILING HEAT TRANSFER TRANS AM SOC MECH ENGRS 73, JULY, 1951

936
ROHSENOW, W.M., ET AL CONSTRUCTION AND OPERATION OF APARATUS FOR STUDY OF HEAT TRANSFER WITH SURFACE BOILING, NP-3543 M.I.T. JULY, 1950

937
ROHSENOW, W.M., ET AL, CORRELATION OF MAXIMUM HEAT FLUX DATA FOR BOILING OF SATURATED LIQUIDS, NP-5738 M.I.T. 1955

938
ROHSENOW, W. M., ET AL ., HEAT TRANSFER AND PRESSURE DROP DATA FOR HIGH HEAT FLUX DENSITIES TO DATE AT HIGH SUBCRITICAL PRESSURES, HEAT TRANSFER AND FLUID MECHANICS INSTITUTE STANFORD U PRESS, 193 1951

939
ROHSENOW, W.M., AND H.Y. CHOI, HEAT, MASS AND MOMENTUM TRANSFER. PRENTICE-HALL 1961

940
ROHSENOW, W. M., HEAT TRANSFER, A SYMPOSIUM 1952, ENG RES INST., U OF MICH

941
ROHSENOW, W. M., ET AL ., DISCUSSION, TRANS ASME 80, 716-17 APR, 1958

942
ROHSENOW, W.M. HEAT TRANSFER ASSOCIATED WITH NUCLEATE BOILING. HEAT TRAN AND FLUID MECH INST. 1953 STANFORD

943
ROHSENOW, W.M. HEAT TRANSFER AND TEMPERATURE DISTRIBUTION IN LAMINAR-FILM CONDENSATION. TRANS ASME 78, 1956

944
ROHSENOW, W. PRESENT STATUS OF BOILING HEAT TRANSFER. SEMINAR, DEPT OF ENG., UNIV OF CAL IN LOS ANGELES. NOV, 1959

945
ROMANOV, A.G. AN INVESTIGATION OF HEAT EXCHANGE IN CLOSED TUBES UNDER NATURAL CONVECTION CONDITIONS. 1957 TECH TRANS 2, NO 9

946
ROMIE, F.E., ET AL, HEAT TRANSFER TO BOILING MERCURY.
J HEAT TRANS 82, NOV, 1960 ALSO ATL-A-102

947
ROMIE, F. THE GROWTH OF BUBBLES IN SUPERHEATED LIQUID.
DEPT OF ENG, UNIV OF CAL IN LOS ANGELES. 1952

948
ROS, N.C.J., SIMULTANEOUS FLOW OF GAS AND LIQUID AS ENCOUNTERED IN OIL WELL
KONINKLIJKE / SHELL EXPLORATIE EN PRODUCTIE LABORATORIUM,
AICHE MEETING , TULSA, SEPT 25-28, 1960

949
ROSENTHAL, M.W., ET AL, AN EXPERIMENTAL STUDY OF TRANSIENT BOILING.
NUC SCI AND ENG 2. 1957

950
ROSENTHAL, M.W. TRANSIENT BOILING INVESTIGATION. APRIL, 1956 NDA-26

951
ROSS, D.P. THERMODYNAMIC PROPERTIES OF MERCURY, NP-7016 MAR 20, 1956

952
ROSTOKER, W., ET AL, EMBRITTLEMENT OF LIQUID METALS. REINHOLD PUBLISHING
CORP., NEW YORK, 1960

953
ROUNTHWAITE, C., ET AL.,HEAT TRANSFER DURING EVAPORATION OF HIGH QUALITY
WATER-STEAM MIXTURES FLOWING IN HORIZONTAL TUBES.
PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 1 ASME

954
RUCKENSTEIN, E. ON HEAT TRANSFER IN REACTORS. 1959. AEC-TR-3609

955
RUCKENSTEIN,E. HEAT TRANSFER IN THE CASE OF BOILING, ACAD REP POPULARE
ROMINE INST ENERGET STUDII CERCETARI ENERGET,8, 1958

956
RUMFORD, F. HEAT TRANSFER THROUGH BOILING LIQUID FILMS,
J SOC CHEM IND 66, 1947

957
RYAN,S.A. COMPILATION OF EXPERIMENTAL BURNOUT DATA AS OF MARCH 1958
KAPL-M-DIG-TD-4(PT-1)

958
RYNCHKOV,A.I. ET AL. AN EQUATION FOR DETERMINING COEFFICIENTS OF HEAT
TRANSFER FOR BOILING LIQUIDS. NP-TR-40 1955

959
RYNCHKOV, A.I. THE RELATIONSHIP BETWEEN HEAT EXCHANGE DURING BOILING AND
INNER (MOLECULAR) PRESSURE OF A LIQUID FIZ. ZHUR., AKAD. NAUK
BELORUS. SSR NO. 11,63-71 (1959)NOV IN RUSSIAN

960
SABERSKY, R.H., ET AL, ON THE RELATIONSHIP BETWEEN FLUID FRICTION AND HEAT
TRANSFER IN NUCLEATE BOILING. JET PROP 25, 1955

961
SABERSKY, R.H., ET AL, ON THE START OF NUCLEATION IN BOILING HEAT TRANSFER
JET PROP 25. 1955

962
SABERSKY, R.H., ET AL, ON THE EFFECT OF NUCLEATION IN BOILING HEAT
TRANSFER. JET PROP 25. 1955

963
SACHS, P., ET AL, A CORRELATION FOR HEAT TRANSFER IN STRATIFIED TWO
PHASE FLOW WITH VAPORIZATION. INTER J OF HEAT AND MASS TRANS 2, NO 3.
APR, 1961

964
SAITO, R., ET AL, EXPERIMENTAL STUDIES OF THE BOILING PHENOMENA PT. 1. THE
JAPAN 1, JUNE, 1959
DENSITY DISTRIBUTION OF STEAM WATER MIXTURE IN THE MULTIPLE
RECTANGULAR CHANNELS UNDER ATMOSPHERIC PRESSURE, J. ATOMIC ENERGY SOC.
965
SALMON, D.F. TURBULENT HEAT TRANSFER FROM A MOLTEN FLUORIDE SALT MIXTURE
TO SODIUM-POTASSIUM ALLOY IN A DOUBLE-TUBE HEAT EXCHANGER, ORNL-1716
NOV 3, 1954
966
SALMON, O.N., ET AL, SOLUBILITY OF SODIUM MONOXIDE IN LIQUID SODIUM,
KAPL-1653 NOV 30, 1956
967
SANEYOSHI, J., ET AL, GROWTH AND EXTINCTION OF BUBBLES IN WATER,
OYO BUTSURI 12. 1943
968
SANI, R.L., DOWNFLOW BOILING AND NONBOILING HEAT TRANSFER IN A UNIFORMLY
HEATED TUBE, UCRL-9023 DEC, 1959
969
SARUKHANIAN, G. HEAT TRANSFER ON EVAPORATION, AEC-TR-2063. OR CHEM ENG
TECH 25, 1953
970
SAUER, E.T. HEAT TRANSFER TO BOILING LIQUIDS. THESIS M.I.T. 1937. OR
MECH ENG 60, 1938
971
SAVIC, P. THE COOLING OF A HOT SURFACE BY DROPS BOILING IN CONTACT WITH IT
NAT. RES. COUN. OF CANADA. DIV OF MECH ENG. REPT. MT-37. 1958
972
SCHERER, V.E., ET AL, STUDY OF BOILING PROCESS. NDA-24 FEB 23, 1956
973
SCHORR, M.M. BOILING HEAT TRANSFER CORRELATIONS, KAPL-M-MMS-1 JUNE 1, 1958
974
SCHRIVEN, L.E. ON THE DYNAMICS OF PHASE GROWTH. CHEM ENG SCE 10, NO 1/2,
1959
975
SCHRIVEN, L.E. ON THE DYNAMICS OF PHASE GROWTH. REPT. P-659.
SHELL DEVELOP CO. EMERYVILLE, CAL. 1958
976
SCHROCK, V.E., ET AL, LOCAL HEAT TRANSFER COEFFICIENTS AND PRESSURE DROP
IN FORCED CONVECTION BOILING. U OF CAL RADIATION LAB. LIVERMORE,
CAL. SEPT 30, 1957
977
SCHROEDER, R. W., ET AL DESCRIPTION OF INTERMEDIATE HEAT EXCHANGER AND
STEAM GENERATOR SELECTIONS FINAL REPT TID-6881 FEB 25 1958
978
SCHURIG, W. WATER CIRCULATION IN STEAM BOILERS AND THE MOTION OF LIQUID
GAS MIXTURES IN TUBES. VDI FORSCHUNGSHEFT 365, 1934
979
SCHWEPPE, J.L., ET AL EFFECT OF FORCED CIRCULATION RATE ON BOILING HEAT
TRANSFER AND PRESSURE DROP IN A SHORT VERTICAL TUBE.
CHEM ENG PROG SYM SER 49, NO 5. 1953
980
SCORAH, R.L. HEAT TRANSFER FROM METAL TO BOILING WATER. DEC, 1948
AECU-116 OR NEPA-804

981
SCOTT, A.B. THE SURFACE ENERGY OF SODIUM. PHIL MAG 45, 1954
982
SCOTT, A. W., ET AL., HEAT TRANSFER INVESTIGATIONS FOR THE FLOW
OF STEAM RANGING UP TO SONIC VELOCITY .
PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME
983
SEEVOLD, R.E., ET AL, THERMAL CONDUCTIVITY OF MERCURY. NRL-4506 MAR, 1955
984
SELBY, J.D. A COMPARATIVE ANALYSIS OF THE LIQUID METAL HEAT TRANSFER
SYSTEMS FOR WMA. KAPL-M-JDS-1 APR 20, 1949
985
SEMENCHENKO, V.K. SURFACE EFFECTS IN METALS AND ALLOYS. (IN RUSSIAN)
GOSTEKHIZDAT, MOSCOW 1957
986
SHAMRAI, F.I. LITHIUM AND ITS ALLOYS. 1952. AEC-TR-3436
987
SHARLOVSKAIA,M.S., STUDYING HEAT TRANSFER IN A BOILING LAYER BY THE METHOD
OF A QUASI-STATIONARY CONDITION. IZV SIB OTD AN SSSR NO 7 1958
988
SHELDON, L.A. THERMODYNAMIC PROPERTIES OF MERCURY VAPOR. ASME-PAPER
NO. 49-A-30. JAN 10, 1950
989
SHEPARD, O.C. WETTING OF HEAT TRANSFER SURFACES WITH LIQUIFIED METAL HEAT
TRANSFER MEDIA, U S PATENT 2,763,570. SEPT 18, 1956
990
SHER, N.C. LIQUID HOLDUP IN TWO PHASE, STEAM WATER FLOW. M.S. THESIS
UNIV OF MINN. 1955
991
SHER, N.C., ET AL, BOILING PRESSURE DROP IN THIN RECTANGULAR CHANNELS
REPRINT 146, SESSION 24. A.I.CH.E., 1958
992
SHERMAN, A., ET AL, THERMODYNAMIC AND ELECTRICAL PROPERTIES OF HG VAPOR
AT PRESSURES BELOW ATMOSPHERIC (10 MINUS 4 TO 1 ATM) AND HIGH TEMPERATURES (UP TO 15000K) AFOSR-TN-60-657 FEB, 1959 - FEB, 1960
993
SHEYN, V.B., CONVECTIVE PHENOMENA DURING EVAPORATION OF WATER FROM
VERTICAL TUBES. UCH ZAP MOLOTOVSK UN-T NO 4 85-92 1955
RZ-F NO 12 1956 34410 (ABST)
994
SHRAGE, R.W., A THEORETICAL STUDY OF INTERPHASE MASS TRANSFER. NEW YORK
COLUMBIA U PRESS 1953
995
SHUTTLEWORTH, R., PRO PHYS SOC , 63A, 1950
996
SIEDER, E.N., ET AL, HEAT TRANSFER AND PRESSURE DROP OF LIQUIDS IN TUBES.
IND ENG CHEM 28, 1936
997
SIEGEL, R., ET AL, A PHOTOGRAPHIC STUDY OF BOILING IN THE ABSENCE OF
GRAVITY. ASME PAPER 59-AV-37. NASA LEWIS RESEARCH INST
ALSO TRANS ASME, JOUR OF HEAT TRANS 81, 1959
998
SIEGEL, R., ET AL, TURBULENT FLOW IN A CIRCULAR TUBE WITH ARBITRARY
INTERNAL HEAT SOURCES AND WALL HEAT TRANSFER. J HEAT TRANS 81. NOV, 59

999
SIEGEL, R., ET AL, UNSTEADY TURBULENT HEAT TRANSFER IN TUBES.
J HEAT TRANS 82, AUG, 1960

1000
SIEMES, W. GAS BUBBLES IN LIQUIDS. I. FORMATION OF GAS BUBBLES FROM
VERTICAL CIRCULAR JETS, CHEM ENG TECH 26, 1954

1001
SILVESTRI,M., TWO-PHASE (STEAM AND WATER) FLOW AND HEAT TRANSFER
PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME

1002
SINGH, K.P., ET AL, TRANSPORT OF HEAT BY CONVECTION AND BOILING IN LIQUIDS
ENCLOSED IN VERTICAL TUBES. PROCEEDINGS OF THIRD CONGRESS THEOR APPL
MECH BAGALORE. INDIAN SOC THEOR APPL MECH. KHARAGPUR 1957

1003
SITTIG, M. SODIUM. ITS MANUFACTURE, PROPERTIES, AND USES. REINHOLD PUBL
CORP, NEW YORK, 1956 QD / 181 / .N2 / S62

1004
SKAPERDAS, G.T. HEAT TRANSFER, IND ENG CHEM 44, JAN, 1952

1005
SMIRNOV , A.G., FREE THERMAL CONVECTION OF MERCURY IN CLOSED CIRCULAR
TUBES. ZHUR TEKH FIZ 27 NO 10 2373-2380 OCT 1957

1006
SMITH, A. A., ET AL., SOME OBSERVATIONS ON THE INTERACTION OF LIQUID
SODIUM WITH CAST IRONS AND PLAIN CARBON STEELS U OF CAMBRIDGE,
ENG J IRON STEEL INST (LONDON) 196 1960

1007
SMITH, E.S. THE CALCULATION OF THE VISCOSITY OF LIQUID METALS (WITH
SPECIAL REFERENCE TO LITHIUM). RBD(R)/TN-1 JAN, 1952

1008
SODIUM. AERE-ED/D-10(ISSUE 2)

1009
SOKOLSKAIA, L. A., CONVECTION IN MOLTEN METALS. IZV AN SSSR OTD TEKH NAUK
NO 9 1365-1371 1949

1010
SOLDAINI, G. SURVEY OF HEAT TRANSFER STUDIES BY MEANS OF BOILING WATER IN
THE UNITED STATES, ENERGIA NUCLEARE (MILAN) 1, MAR, 1960 (IN ITALIAN)

1011
SONGINA, O.A. RUBIDIUM AND CESIUM. 1959. F-TS-9782/III TECH TRANS 3, NO1

1012
SONNEMANN, G. A METHOD OF CORRELATING BURNOUT HEAT FLUX DATA
NUCLEAR SCE AND ENG 5, 242-7,1959, APR

1013
SOO, S.L. EFFECT OF THE WALL ON TWO-PHASE TURBULENT MOTION.
J APPL MECH ENG 27, NO 1. 1960

1014
SOO, S.L., ET AL, DETERMINATION OF TURBULENCE CHARACTERISTICS OF SOLID
PARTICLES IN A TWO-PHASE STREAM BY OPTICAL AUTOCORRELATION.
REV SCI INSTRUM 30, NO 9. 1959

1015
SOROKIN, A. F., APPLYING G.N.KRUZHILINS CRITERIONAL RELATIONSHIP TO
THE HEAT EXCHANGE DURING THE BOILING OF SOLUTIONS. NAUK DOKL VYS
SHKOLY ENERG NO1 151-154 1958

1016
SOVIET RESEARCH AND DEVELOPMENTS IN THE CHEMICAL ENGINEERING UNIT OPERATION
OF HEAT TRANSFER. A BIBLIOGRAPHY. JAN, 1960. PAL-60-14. TECH TRANS.

1017
SPARROW, E.M., ET AL, A BOUNDARY LAYER TREATMENT OF LAMINAR FILM CONDENSATION. J HEAT TRANS. 81. FEB, 1959

1018
SPIEGL, C.J. THE INDUSTRIAL HYGIEN AND TOXICOLOGY OF MERCURY. UR-469 NOV 6, 1956

1019
STALEY, C.F. AND M. BAKER, A.S.H.R.A.E.J. 1, 83, 1959

1020
STANISZEWSKI, B.E. NUCLEATE BOILING BUBBLE GROWTH AND DEPARTURE, NP-7984 AUGUST, 1959

1021
STEIN, R.P., ET AL, PRESSURE DROP AND HEAT TRANSFER TO NON-BOILING AND BOILING WATER IN TURBULENT FLOW IN AN INTERNALLY HEATED ANNULUS. NUCLEAR ENG SYM, PART I

1022
STEIN, R. P., CRITICAL REVIEW OF ZUBER AND ZUBER-TRIBUS THEORIES OF TRANSLATION BOILING. DEPT. OF CHEM ENG ENG RES LAB COLUMBIA UNIVERSITY TECH NOTE IX TN-3-58 OCT 8 1959

1023
STEINER, J., ET AL, ELECTROMAGNETIC PUMPS WITHOUT MOVING PARTS FOR THE CONDUCTION OF LIQUID METALS. AEC-TR-3200 1956

1024
STEINLE, H.F. AN EXPERIMENTAL STUDY OF THE TRANSITION FROM NUCLEATE TO FILM BOILING UNDER ZERO GRAVITY CONDITIONS. 1960 HEAT TRANSFER AND FLUID MECH TUST, STANFORD UNIV JUNE 15 - 17, 1960

1025
STERMAN,L.S. ET AL., AN INVESTIGATION INTO THE INFLUENCE OF SPEED OF CIRCULATION ON THE VALUES OF CRITICAL HEAT FLOWS FOR LIQUID BOILING IN TUBES. IGRL-T/W-60 1952

1026
STERMAN, L.S., ET AL, INVESTIGATION OF HEAT TRANSFER DURING BOILING OF WATER AND ETHYL ALCOHOL IN PIPES FIZ ZHUR, AKAD NAUK BELORUS SSR 2,NO 10, 40-5(1959)OCT IN RUSSIAN

1027
STERMAN, L.S. INVESTIGATION OF HEAT EXCHANGE IN THE BOILING OF A LIQUID IN PIPES. AERE-LIB/TRANS-565 1954

1028
STERMAN, L.S. ON THE THEORY OF HEAT EXCHANGE ON BOILING IN PIPES AERE-LIB/TRANS-579 1954

1029
STERMAN, L.S. ON THE THEORY OF THE HEAT TRANSFER FROM A BOILING LIQUID CTS-62 DEPT OF SCIENTIFIC AND INDUSTRIAL RESEARCH. CHARLES HOUSE, C-11 REGENT ST., LONDON, SW-1, ENGLAND 1953

1030
STERMAN, L.S. THE EFFECT OF VELOCITY OF MOTION OF A FLUID ON HEAT TRANSFER DURING BOILING. AEC-TR-1781 1951

1031
STIUSHIN, N. G., INVESTIGATION OF THE INFLUENCE OF RATE OF FORCED MOVEMENT OF FLUID ON HEAT EXCHANGE IN BOILING UNDER PRESSURE. ZHUR EKS I TEOR FIZ 25 NO 11 1920-1930 1953

1032
STOCK, B.J. OBSERVATIONS ON TRANSITION BOILING HEAT TRANSFER PHENOMENA JUNE 1960 ANL-6175

1033
STRACHAN, J.F., ET AL, THE EFFECT OF MERCURY ON THE CORROSION AND MECHANICAL PROPERTIES OF VARIOUS MATERIALS. PART 2. MATERIALS EXPOSED TO STATIC LIQUID MERCURY AT 300C TO 500C. AERE-X/R-1229 AUG 11, 1953
1034
STRACHAN,J.F., ET AL, THE EFFECT OF MERCURY ON THE CORRISION AND PROPERTIES OF VARIOUS MATERIALS. FINAL REPORT PART 3. A SURVEY OF THE INTERACTION OF THE METALLIC ELEMENTS WITH STATIC LIQUID MERCURY AT ROOM TEMP. AND 500C, AERE-X/R-1503 JULY 19, 1954
1035
STRACHAN, J.F., ET AL, THE ATTACK OF UNSTRESSED METALS BY LIQUID MERCURY J INST METALS 85, 1956-57
1036
STRAHL,H., THE LARGE COMPONENT TEST LOOP 3/1/60, NAA-SR-4386
1037
STROMQUIST, W.K. EFFECT OF WETTING ON HEAT TRANSFER CHARACTERISTICS OF LIQUID METALS, SECOND QUARTERLY REPORT, ORO-52 OCT 31, 1951
1038
STUDIES IN BOILING HEAT TRANSFER. MAR, 1951. U OF CAL FOR AEC. COO-24
1039
STUDIES OF DENSITY TRANSIENTS IN VOLUME HEATER BOILING SYSTEMS. AECU-2529 JULY, 1953
1040
STUDIES OF LIQUID METALS, BULL INFORM SIC ET TECH (PARIS) NO 31 JULY, 1959
1041
STUMPF, H.J., ET AL, TEST RESULTS AND DESIGN COMPARISONS FOR LIQUID METAL-TO-AIR RADIATORS. ORNL, TENNESSEE CF-54-7-187.JULY 19, 1954 DECL. 9 OCT 1959
1042
STYRIKOVICH, M.A., ET AL, CRITICAL THERMAL LOADING WHEN A LIQUID BOILS IN LARGER VOLUME. IZVEST AKAD NAUK SSSR OTDEL. TEKH NAUK NO 5. 1951
1043
STYRIKOVICH, M. A., ET AL., OBSERVATIONS OF HEAT TRANSFER IN BOILING UNDER FORCED CIRCULATION, ZHTF 16, 1940
1044
STYRIKOVICH , M.A., ET AL, J TECH PHYS 10, NO 16. 1940
1045
STYRIKOVICH, M.A.,ET AL, SOME RELATIONSHIPS IN HEAT TRANSFER TO BOILING MERCURY IN FORCED CONVECTION, ZHUR. TEKH. FIZ. 10,1331-9 (1940) AEC-TR-3868
1046
STYRIKOVICH, M.A., ET AL, SOVETSKOE KOTLOLURBOSTROENIE 9. 1940
1047
STYRIKOVICH, M.A., ET AL, THE INFLUENCE OF NONUNIFORM HEATING OF THE PERIMETER OF A TUBE ON THE CRITICAL HEAT FLOW. SOVIET PHYS DOKLADY 4, NO 4, 1960
1048
STYRIKOVICH, M.A., ET AL., ON THE EFFECT OF ANGLE OF SLOPE ON THE TEMPERATURE STATE OF THE WALL OF STEAM GENERATING TUBES AT HIGH PRESSURES. DOKL AN SSSR 80 NO 1 57-60 1951
1049
STYRIKOVICH, M.A. HYDRODYNAMICS AND HEAT TRANSFER DURING BOILING IN HIGH PRESSURE BOILERS. JUNE, 1961. AEC-TR-4490

1050
STYRIKOVICH, M.A., G.E. KHOLODOVSKII, AND M.S. FOMICHEV. HEAT ENGINERING AND HYDRODYNAMICS. VOL 4. AEC-TR-4206 1958

1051
STYRIKOVICH, M.A. THE EFFECT OF SUPERIMPOSED ELEMENTS ON THE BEGINNING OF BOILING IN THE STEAM GENERATING PIPES. TEPLOENERGETIKA NO 5. 1960

1052
SUBBOTIN, V.I., ET AL, HEAT TRANSFER BETWEEN MERCURY AND WATER FLOWING IN A CLOSELY PACKED ASSEMBLY OF RODS ATOMNAYA ENERG 9, DEC, 1960

1053
SUBBOTIN, V.I., ET AL, HEAT TRANSFER TO MERCURY FLOWING TURBULENTLY IN AN ANNULUS. ATOMNAYA ENERG 9, OCT, 1960

1054
SUBBOTIN, V.I., ET AL., CRITICAL HEAT FLUX IN WATER UNDER CONDITIONS OF RESTRICTED FLOW. ATOM ENERG 3 NO8 149-151 AUG 1957

1055
SUSSKIND, H. A SURVEY OF BULK BOILING STUDIES IN PRESSURIZED WATER REACTOR SYSTEMS. AUG, 1960 BNL-636

1056
TACHIBANA, F., ET AL., HEAT TRANSFER IN FILM BOILING TO SUBCOOLED LIQUIDS PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME

1057
TAGAKI, S. THEORY OF FORMATION OF BUBBLES. J APP PHYS 24 DEC, 1953

1058
TANANAIKO, IU. M., HEAT EXCHANGE DURING BOILING OF WATER IN A DRAINING FILM . IZV KIEVSK POLITEKHN IN-TA 17 75-82 1956
RZ-F NO3 MAR 1957 6333 (ABST)

1059
TAO, L.N. ON COMBINED FREE AND FORCED CONVECTION IN CHANNELS. J HEAT TRANS 82. AUG, 1960

1060
TATARINOV, B.P., SOME CHARACTERISTICS OF BOILING LIQUIDS. TRUDY MIIT NO 17 3-15 1953

1061
TAYLOR, G.I. THE INSTABILITY OF LIQUID SURFACES WHEN ACCELERATED IN A DIRECTION PERPENDICULAR TO THEIR PLANE. PROC ROY SOC, LONDON. 1950 A-201

1062
TAYLOR, J.W., ET AL, SOLID METAL-LIQUID INTERACTION STUDIES. PART II. CONTACT ANGLE RELATIONSHIPS FOR SODIUM ON SOLIDS. NOV, 1955. AERE-M/R-1729

1063
TAYLOR, J.W. WETTING BY LIQUIDS METALS, PROG IN NUCL ENERGY, SERIES V, MET AND FUELS. VOL 2

1064
TAYLOR, L.E., ET AL, HIGH FLUX BOILING HEAT TRANSFER FROM A FLAT PLATE, UCRL-5414 NOV 25, 1958

1065
TAYLOR, J.W. AN ESTIMATION OF SOME UNKNOWN SURFACE TENSIONS FOR METALS. METULLURGIA, 50, 1954

1066
TEK, M.R. TOPICS IN MULTIPHASE FLOW. UNIV OF MICH. COLL OF ENG. 1961

1067
THOMAS, D.G., ET AL, NUCLEATE BOILING STUDIES WITH AQUEOUS TH-02 SLURRIES ORNL-2722 FEB 8, 1960

1068
THOMSON, G.W., ET AL, PHYSICAL AND THERMODYNAMIC PROPERTIES OF SODIUM. A CRITICAL REVIEW. ETHYL CORP. RES AND ENG DEPART. NOV, 1955

1069
THORPE, P.E., ET AL, CALIBRATION OF THE MERCURY VAPOUR DETECTOR TYPE B AERE-ES/R-2124 JAN, 1957

1070
TIDBALL, R.A., ET AL, FINAL REPORT ON THE 100KW AIR COOLED, LIQUID METAL HEAT TRANSFER LOOP. NP-5751 AUG 16, 1955

1071
TIDBALL, R.A., ET AL, FLOW DECAY IN A SODIUM HEAT TRANSFER SYSTEM, NP-5491 JAN 11, 1955

1072
TIDBALL, R.A. LIQUID METAL HEAT EXCHANGERS. POWER 104, 82. 1960

1073
TIDBALL, R.A. PERFORMACE OF SMALL LIQUID METAL HEAT EXCHANGERS. CHEM ENG PROG SYM SER 49, NO 5. 1953

1074
TIM, D.P. FREE CONVECTION IN NARROW VERTICAL LIQUID METAL ANNULI. BNL-2446 OCT, 1954

1075
TIMCHUCK, B.J. STUDY OF HEAT EXCHANGE IN LIQUID METALS DURING PHASE TRANSFORMATION. INZH FIZ ZH NO 11, 1959

1076
TIMMERHAUS, K. D., ET AL., AN EXPERIMENTAL INVESTIGATION OF OVER-ALL HEAT TRANSFER COEFFICIENTS FOR CONDENSING AND BOILING HYDROGEN FILMS PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME

1077
TIMO, D.P. FREE CONVECTION IN NARROW VERTICAL SODIUM ANNULI, KAPL-1082 MARCH 5, 1954

1078
TOBILEVICH, N.Y., ET AL, THE STUDY OF THE CHARACTERISTICS OF THE HEAT TRANSFER PROCESS DURING BOILING IN PIPES. V SB GIDRODINAMIKA I TEPLOOBMEN PRI KIPENII J KITLAKH VYSOKOGO DAVLENIYA AKAD. NAUK SSSR, 1955

1079
TOLUBINSKII,V. I., HEAT TRANSFER DURING BOILING OF WATER IN VERTICAL TUBES AT LOW HEAT FLUXES. TRUDY INST TEPLO NO 10 12-14 1953 RZ-K 1955

1080
TORIKAI, K., ET AL, THE FLUID FLOW RESISTANCE THROUGH THE ROUND TUBE IN NET BOILING. J ATOMIC ENERGY SOC JAPAN 2, NOV, 1960

1081
TORIKAI, K. HYDRODYNAMIC STUDY OF BURNOUT IN BOILING. 1961 J AERI 1017

1082
TRAMONTINI, V.N.,ET AL, STUDIES IN BOILING HEAT TRANSFER. LOS ANGELES DEPT. OF ENG., U. OF CALIF., MAR., 1951

1083
TREFETHEN, L.M. HEAT TRANSFER PROPERTIES OF LIQUID METALS, NP-1788 JULY 1, 1950

1084
TRESHCHOV, G.G. EXPERIMENTAL INVESTIGATION OF THE MECHANISMS OF HEAT TRANSFER WITH SURFACE BOILING OF WATER. TECH TRANS 3, NO 8 1958

1085
TRETYAKOV, A.P. EFFECT OF ULTRASOUND ON THE INTENSIFICATION OF HEAT EXCHANGE. AD-259-609

1086
TROCKI, T., ET AL, LIQUID METAL HEAT TRANSFER SYSTEM FOR NUCLEAR POWER PLANTS. A REPORT ON THE DEVELOPMENT OF SUITABLE HEAT EXCHANGERS AND STEAM GENERATORS, MECH ENG 75, JUNE, 1953

1087
TROCKI, T. ENGINEERING ASPECTS OF THE USE OF LIQUID METALS FOR HEAT TRANSFER, AECU-1608 1952

1088
TROY,M. ANALYSIS OF MSAR TRANSITION BOILING AND FILM BOILING DATA FOR WATER AT 2000 PSIA, WAPD-AD-TH-492 APRIL, 1959

1089
TROY, M.T. LITERATURE SEARCH ON BOILING OF WATER. BETTIS LIB. MAR 10, 59

1090
TROY, M. NATURAL CONVECTION OF WATER AT 2000 PSIA WITH BOILING IN VERTICAL RECTANGULAR CHANNELS UNDER CONDITIONS OF ZERO-NET THROUGH FLOW, WAPD-TM-456 OVT, 1958

1091
TROY,M. UPFLOW BURNOUT DATA FOR WATER AT 2000,1200,800, AND 600 PSIA IN VERTICAL 0.07 IN BY 2.25 IN BY 72 IN LONG STAINLESS STEEL RECTANGULAR CHANNELS, WAPD-TH-408 JULY, 1958

1092
TRUMMEL, J.M. SOME OBSERVATIONS MADE ON CAVTATING SODIUM FLOWS IN A VENTURI CF-54-8-225 AUG 31, 1954

1093
TRUSELA, R.A., ET AL, HEAT TRANSFER PROBLEMS OF SPACE VEHICLE POWER SYSTEM WRIGHT-PATTERSON SAE PAPER 154C, 1960

1094
TURNBULL, D., ET AL., HOMOGENEOUS NUCLEATION, IN TEXT THE PHYSICS OF POWDER METALLURGY, KINGSTON , W.E., MCGRAW-HILL, NEW YORK, N.Y. 1951

1095
TURNER, G.E. AN INVESTIGATION OF POSSIBLE FLOWMETER TYPES FOR THE LARGE HNPF PIPING. DEC, 1958. NAA-SR-MEMO-3407

1096
ULUGOL, V.L. PRESSURE GRADIENTS ASSOCIATED WITH NON-ADIABATIC TWO-PHASE FLOW. HEAT TRANSFER AND THERMODYNAMICS LAB. U OF MICH. 1961

1097
UNGAR, E. W., PARTICLE IMPACTS ON MELT LAYER OF ABLATING BODY. J AMER ROCKET SOC 30, NO. 9, 799 1960

1098
UNTERMEYER, S. BOILING REACTORS. DIRECT STEAM GENERATION FOR POWER. NUCLEONICS 12, NO 7. 1954

1099
URAZOVSKIY, S.S., ET AL, A NEW EFFECT IN THE TEMPERATURE DEPENDENCE OF SURFACE TENSION. JUNE, 1950. TECH TRANS 3, NO 1.

1100
UREY, H.C. BOILING WATER EXPERIMENTS RELATIVE TO BOILING REACTORS CF-51-8-45 1951

1101
USISKIN, C. M., ET AL., ASME PAPER 60-HT -10, 1960

1102
USISKIN,C,M., ET AL., AN EXPERIMENTAL STUDY OF BOILING IN THE ABSENCE OF GRAVITY J HEAT TRANSFER TRANS ASME SERIES C VOL 83 1961

1103
USISKIN,C.M. ET AL. AN EXPERIMENTAL STUDY OF BOILING IN REDUCED AND ZERO
GRAVITY FIELDS. ASME-AICHE HEAT TRANSFER CONF. AUG. 1960 BUFFALO,N.Y.
1104
VANDERWATER, R.G. BOILING LIMITS, 1952, HW-23251
1105
VAUTREY, L. ET AL., STUDIES OF LIQUID METALS.BULL. INFORM. SCI. ET TECH.
(PARIS), NO. 59, APRIL, 1961 (IN FRENCH)
1106
VELTISHCHEVA, V.A., ET AL., THERMAL CONDUCTIVITY OF MERCURY
TEPLOENERGETIKA 5 NO 10 80-82 OCT 1958
1107
VERSCHOR, H. SOME ASPECTS OF THE MOTION OF A SWARM OF GAS BUBBLES RISING
THROUGH A VERTICAL LIQUID COLUMN. TRANS INST CHEM ENG 28. 1950
1108
VEST, R.W. THE ELECTRICAL BEHAVIOR OF REFACTORY OXIDES. AD-260-194
1109
VEYNIK, A.I. A METHOD FOR THE DETERMINATION OF THE INTENSITY OF HEAT
EXCHANGE IN MOLTEN METALS BY FREE CONVECTION TRUDY INST ENERGET
AKAD NAUK BELORUSS SSR 3,62-7 (1957)
1110
VISCARDI, J.E., REACTOR HEAT TRANSFER PROGRESS. NDA-29 AUG. 31, 1956
1111
VISCARDI, J.E. REACTOR HEAT TRANSFER PROGRESS. NDA-28 JULY 10, 1956
ALSO NDA-29, AUGUST, 1956
1112
VISCARDI, J.E. BOILING BURNOUT NEWSLETTER NO 4, NDA-6,, ...ISSUE NO 5
NDA-8... ...PROGRESS NO 5, NDA-9... ...PROGRESS NO 8, NDA-24
1113
VISCARDI, J.E. REACTOR HEAT TRANSFER CONFERENCE OF 1956, TID-75 9(PT.1)
1114
VISHNEV,I.P.,ET.AL HEAT TRANSFER DURING THE BOILING OF LIQU9DS IN TUBES
FIZ ZHUR AKAD NAUK BELORAS, SSR 3 MAY, 1960
1115
VISKANTA, R., ET AL, HEAT TRANSFER TO LIQUID METALS WITH VARIABLE
PROPERTIES. J HEAT TRANSF 82, NOV, 1960
1116
VOHR, J.H. FLOW PATTERNS OF TWO-PHASE FLOW - A SURVEY OF LITERATURE.
DEC 15, 1960 TID-11514
1117
VOLMER, M., ET AL, ABOUT THE COEFFICIENT OF VAPORIZATION OF SOLID AND
LIQUID MERCURY, PHYSIK. Z 7, 1921
1118
VOS, A.S. SUPERHEATING AND DISTRIBUTION OF THE TEMPERATURE IN THE LIQUID
AND VAPOR OF BOILING LIQUIDS. (IN DUTCH) INGENIEUR 71, NO 7. 1959
1119
VOS, A.S., ET AL, HEAT TRANSFER TO BOILING METHYLETHYLKETONE MIXTURES
WITH WATER. CHEM ENG SCI 5. 1956
1120
VOSKRESENSKII, R.D.,ET AL, APPROXIMATE CALCULATIONS OF LIQUID METAL HEAT
TRANSFER, TEPLOPENEDACHA I TEORIYA TEPLA, ACAD. OF SC USSR, MOSCOW,
IGIS-53,RD/W) TRANSLATED TECH TRANS 5, NO 15 61-13027 1959

1121
WAHL, M.H. WETTING WITH SODIUM, NP-5811 NOV 7, 1955
1122
WALKER, K.W. HEAT TRANSFER TO WATER BOILING UNDER VACUUM. THESIS M.I.T.
1940
1123
WALLIS, G.B., ET AL, LIQUID AND GAS DISTRIBUTIONS IN A TWO PHASE BOILING
ANALOGY, NP-7204 M.I.T. DSR PROJECT NO 7-7673 DEC 1, 1958
1124
WALLIS, G. B., ET AL., OSCILLATIONS IN TWO-PHASE FLOW SYSTEMS J HEAT TRAN
VOL 83 SERIES C NO 3 AUG 1961
1125
WALLIS, G. B., GAS-LIQUID ANALOGUE OF NUCLEATE BOILING, NUCL POWER 5
NO 52, 99 1960
1126
WALLIS, G.B., SOME HYDRODYNAMIC ASPECTS OF TWO-PHASE FLOW AND BOILING
PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME
1127
WALLIS,G.B. THE ANALOGY BETWEEN THE BUBBLING OF AIR INTO WATER AND NUCLE
ATE BOILING AT SATURATION TEMPERATURE. 1960. AEEW-R-28
1128
WALSH, J.B. M.I.T. BOILING HEAT TRANSFER PROJECT PROGRESS REPORT.
JUNE 7, 1953 NP-4925. ALSO AUGUST 9, 1953 NP-4926
1129
WARD, A.G., ET AL, METALLURGICAL INVESTIGATIONS OF SODIUM HEAT TRANSFER RIG
AERE-M/M-148 FEB, 1957
1130
WATT, D.A. A SINGLE PHASE ANNULAR INDUCTION PUMP FOR LIQUID METALS.
AERE-ED/R-1844 JAN 21, 1953
1131
WATT, D.A. THE DESIGN OF ELECTROMAGNETIC PUMPS FOR LIQUID METALS.
PROC INST ELEC ENGR (LONDON) PT. A, APR, 1959
1132
WATT, D.A. DESIGN OF TRAVELING FIELD INDUCTION PUMPS FOR LIQUID METALS.
SEPT, 1957. AERE-R/M-144
1133
WATT, D.A. DIRECT CURRENT PUMPING OF LIQUID METALS, AERE-CE/R-757
SEPT 28, 1951
1134
WATT, J.S., ET AL, MEASUREMENT OF CONCENTRATION OF TUNGSTEN SUSPENSIONS
AND DENSITY OF LIQUID SODIUM BY GAMMA RAY ABSORPTION,
AUSTRALIAN ATOMEI ENERGY SYMPOSIUM, 1958
1135
WEATHERFORD, W. D., ET AL., PROPERTIES OF INORGANIC WORKING FLUIDS AND
COOLANTS FOR SPACE APPLICATIONS WADC-TR-59-598 DEC 1959
1136
WEECH, M. AND FLUKE, G. HOW TO TAKE SAMPLES FROM LIQUID METAL LOOPS.
U. OF MICH., NUCLEONICS 15, NO 10. OCT, 1957
1137
WEIL, L. HEAT TRANSFER IN BOILING FLUIDS. KALTETECK 5. 1953
1138
WEILLS, J.T. STEAM BUBBLE SIZE AND RATE OF RISE THROUGH WATER AT ITS
NORMAL BOILING POINT. 1956 CT-910
1139
WEISS, D.H. PRESSURE DROP IN TWO-PHASE FLOW. OCT 20, 1952 ANL-4916

1140
WELSER, D. HEAT TRANSFER MEASUREMENTS WITH MERCURY. AEC-TR-2016 1948
1141
WERNER, R.C. LIQUID METAL TECHNOLOGY FINAL REPORT. NP-5614
MINE SAFETY CO. MARCH 29, 1955
1142
WESTMORELAND, J.C. NATURAL CIRCULATION STEAM GENERATORS FOR NUCLEAR POWER.
NUC SCI AND ENG 2. 1957
1143
WESTMORELAND, J.C. PREDICTION OF THE PRESSURE LOSS AND DENSITY FACTORS FOR
TWO-PHASE ANNULAR FLOW WITH OR WITHOUT HEAT GENERATION. KAPL-1792
FEB, 1957
1144
WESTWATER, J.W. AND R.F. GAERTNER. POPULATION OF ACTIVE SITES IN NUCLEATE
BOILING HEAT TRANSFER. AICHE PAPER NO 105. AICHE AND ASME TRANS
CONFERENCE. STORRS, CONN. AUGUST, 1959
1145
WESTWATER, J. W., BOILING OF LIQUIDS, PART 1, IN ADVANCES IN CHEM ENG
VOL 1 ED. T.B. DREW ACADEMIC PRESS INC NEW YORK 1956
1146
WESTWATER, J.W. BOILING HEAT TRANSFER. AMER SCIENTIST 47. 1959
1147
WESTWATER, J.W., ET AL, APPROXIMATE THEORY FOR FILM BOILING ON VERTICAL
SURFACES. CHEM ENG PROG SYM SER 56, NO 30. 1960
1148
WESTWATER, J.W., ET AL, MEASUREMENTS OF BUBBLES FORMED IN BOILING METHANOL
AICHE JOUR 2. 1956
1149
WESTWATER, J.W., ET AL, SOUND OF BOILING. SCI 122. 1955
1150
WESTWATER, J.W., ET AL, THE EFFECT OF TRACE ADDITIVES ON THE HEAT TRANSFER
TO BOILING ISOPROPANOL. U OF ILLINOIS
1151
WESTWATER, J.W. PHOTOGRAPHIC STUDY OF BOILING, IND ENG CHEM 47, 1955
1152
WESTWATER, J.W. THE BOILING OF LIQUIDS, SCI AMER 190, 1954
1153
WHINERY, L.A., 2000 KW SODIUM TEST FACILITY. LAMS-2541 MARCH, 1961
1154
WHITE, P.D., ET AL., HORIZONTAL CO-CURRENT TWO-PHASE FLOW OF FLUIDS IN
PIPELINES, THE PET. ENG., D-40---D-46 AUG. 1955
1155
WHITMAN, M. J.,ET AL, BOILING RUBIDIUM AS A REACTOR COOLANT.PREPARATION OF
RUBIDIUM METAL, PHYSICAL AND THERMODYNAMIC PROPERTIES AND COMPATIBIL-
ITY WITH INCONEL. CF-55-6-49 (PT.1) AUG, 1954
1156
WICKS,M.,ET.AL., AM. INSTITUTE CHEM. ENG. JOUR. 6NO.3 P.463 1960
1157
WILKINSON, W.D., ET AL, ATTACK ON METALS BY LITHIUM. ANL-49-0 OCT 13, 1950
1158
WILSON, R.H. LITERATURE SURVEY RE, BUBBLE FORMATION, CF-50-4-148
APRIL 27, 1950
1159
WINKLER, H.H., ET AL, METHOD AND RESULTS OF SODIUM WETTING TESTS
KAPL-P-231 DEC 27, 1949

1160
WISSLER, E.H., ET AL, OSCILLATORY BEHAVIOR OF A TWO PHASE NATURAL
CIRCULATION LOOP. A I CH E JOURNAL 2 JUNE, 57
1161
WOODRUFF, O.J., ET AL, COOLANTS, NUCLEONICS 11, NO. 6, JUNE, 1953
1162
YAGGEE, F.L., ET AL, THE RELATIVE THERMAL CONDUCTIVITIES OF LIQUID LITHIUM
SODIUM, AND EUTECTIC NA-K, AND THE SPECIFIC HEAT OF LIQUID LITHIUM
ANL-4458 APR 21, 1950
1163
YAGI, S., ET AL, NUCLEATE BOILING HEAT TRANSFER ON HORIZONTAL FLAT SURFACE
THE SOCIETY OF CHEM ENG, JAPAN. CHEM ENG VOL 25, NO 1. 1961
1164
YAMAGATA, K., ET AL, NUCLEATE BOILING OF WATER ON THE HORIZONTAL HEATING
SURFACE. MEMOIRS OF THE FACULTY OF ENG. KYUSHU UNIV 15, NO 1. 1955
1165
YAROSH, M.M. EVALUATION OF THE PERFORMANCE OF LIQUID METAL AND MOLTEN SALT
HEAT EXCHANGERS. NUC SCI ENG 8, NO 1. 1960
1166
YEREMENKO, V.N, ET AL, THE WETTING OF BORIDES AND CARBIDES BY LIQUID METALS
1960 TECH TRANS 4, NO 7
1167
ZADUMKIN, S.N. APPROXIMATE ESTIMATION OF CRITICAL TEMPERATURES OF METALLIC
LIQUIDS AEC-TR-4404 1960
1168
ZADUMKIN, S.N. SURFACE TENSION AND HEAT OF VAPORIZATION OF METALS
DOKLADY AKAD NAUK SSSR 92, SEPT 1, 1953
TRANSLATED. TECH TRANS 2, NO 9 CCT-222TT
1169
ZENKEVICH, B.A. THE CORRELATION OF THE EXPERIMENTAL DATA ON CRITICAL
HEAT LOADS IN FORCED CONVECTION OF WATER HEATED BELOW THE BOILING
TEMPERATURE. SOVIET JOURNAL OF ATOMIC ENERGY 6, NO 2. SEPT, 1960
CONSULTANTS BUREAU
1170
ZERBY, C.D. DESIGN OF SMOOTHLY FLOWING GAS AND LIQUID MIXTURES
CF-51-10-130 OCT 11, 1951
1171
ZMOLA, P.C., ET AL, POWER REMOVAL FROM BOILING NUCLEAR REACTORS.
DEC, 1954 MEETING OF ASME
1172
ZMOLA, P.C. AN INVESTIGATION OF THE MECHANISM OF BOILING IN LIQUIDS.
THESIS. PURDUE UNIV, 1950
1173
ZOZULIA, M.V., HEAT TRANSMISSION DURING THE CONDENSATION OF VAPOR AS
AFFECTED BY THE CONDENSATE VISCOSITY (WITH SUMMARY IN ENGLISH)
DOP AN URSR NO 3 272-275 1958
1174
ZOZULIA, M.V. INVESTIGATION OF HEAT TRANSFER DURING CONDENSATION OF VAPOUR
ON VERTICAL TUBES. JUNE, 1960. RTS-1438 TECH TRANS
1175
ZUBER, N., ET AL, FURTHER REMARKS ON THE STABILITY OF BOILING HEAT
TRANSFER. AECU-3631 JAN, 1958
1176
ZUBER, N., A NOTE ON THE CORRELATION OF DATA IN NUCLEATE POOL BOILING
FROM A HORIZONTAL SURFACE, JUNE 1956

1177
ZUBER, N., AND TIBUS, THE HYDRODYNAMIC CRISIS IN POOL BOILING OF SATURATED AND SUBCOOLED LIQUIDS.
PREPRINT 1961 INTERNATIONAL HEAT TRANSFER CONFERENCE PART 2 ASME
1178
ZUBER, N., ET AL, ON THE PROBLEM OF LIQUID ENTRAINMENT. OCT, 1960 ANL-6244
1179
ZUBER, N. HYDRODYNAMIC ASPECTS OF BOILING HEAT TRANSFER AECU-4439
JUNE, 1959
1180
ZUBER, N. HYDRODYNAMIC ASPECTS OF NUCLEATE POOL BOILING. PART I. THE REGION OF ISOLATED BUBBLES. RW-RL-164 RAMO WOOLDRIDGE, DIV OF THOMPSON-RAMO-WOOLDRIDGE INC JAN 27, 1960
1181
ZUBER, N. J AMER INST CHEM ENG 3. 1957
1182
ZUBER, N. ON THE MAXIMUM HEAT FLUX IN POOL NUCLEATE BOILING TO SUBCOOLED LIQUIDS. MEMOR, DEPT OF ENG, UNIV OF CAL AT LOS ANGELES. 1957
1183
ZUBER, N. ON THE STABILITY OF BOILING HEAT TRANSFER. TRANS AM SOC MECH ENGRS 80, APR, 1958
1184
ZUBER, N. ON THE VARIABLE DENSITY SINGLE FLUID MODEL FOR TWO PHASE FLOW. J HEAT TRANS 82. AUG. 1960
1185
ZUBER, N. REPORT ON BOILING HEAT TRANSFER. AECU-3569 SEPT, 1957
1186
ZUBER, N. THE DYNAMICS OF VAPOR BUBBLES IN NONUNIFORM TEMPERATURE FIELDS. INT J OF HEAT AND MASS TRANSFER 2, NO 1/2 MARCH 1961
1187
ZUBER, N. THE RATE OF GROWTH OF A VAPOUR BUBBLE IN A SUPERHEATED LIQUID. MS THESIS UNIV OF CAL AT LOS ANGLES COLLEGE OF ENGIN 1954
1188
ZWICK, E.B., ET AL, SPACE VEHICLE POWER SYSTEMS. AMER ROCKET SOC. PAPER 867-59. PRESENTED AT SEMIANNUAL MEETING IN SAN DIEGO. JUNE, 59
1189
ZWICK,S.A., ET AL, NOTE ON THE DYNAMICS OF SMALL VAPOR BUBBLES IN LIQUIDS AD-40932 CAL INST OF TECH FEB, 1954
1190
ZWICK, S.A. GROWTH OF VAPOR BUBBLES IN A RAPIDLY HEATED LIQUID. PHYS FLUIDS 3, SEPT OCT, 1960
1191
ZWICK, S.A. THE GROWTH AND COLLAPSE OF VAPOR BUBBLES, AD-54059 PHD THESIS. CAL TECH. ALSO HYDR LAB REPT NO 21-19 AT CAL TECH DEC, 1954

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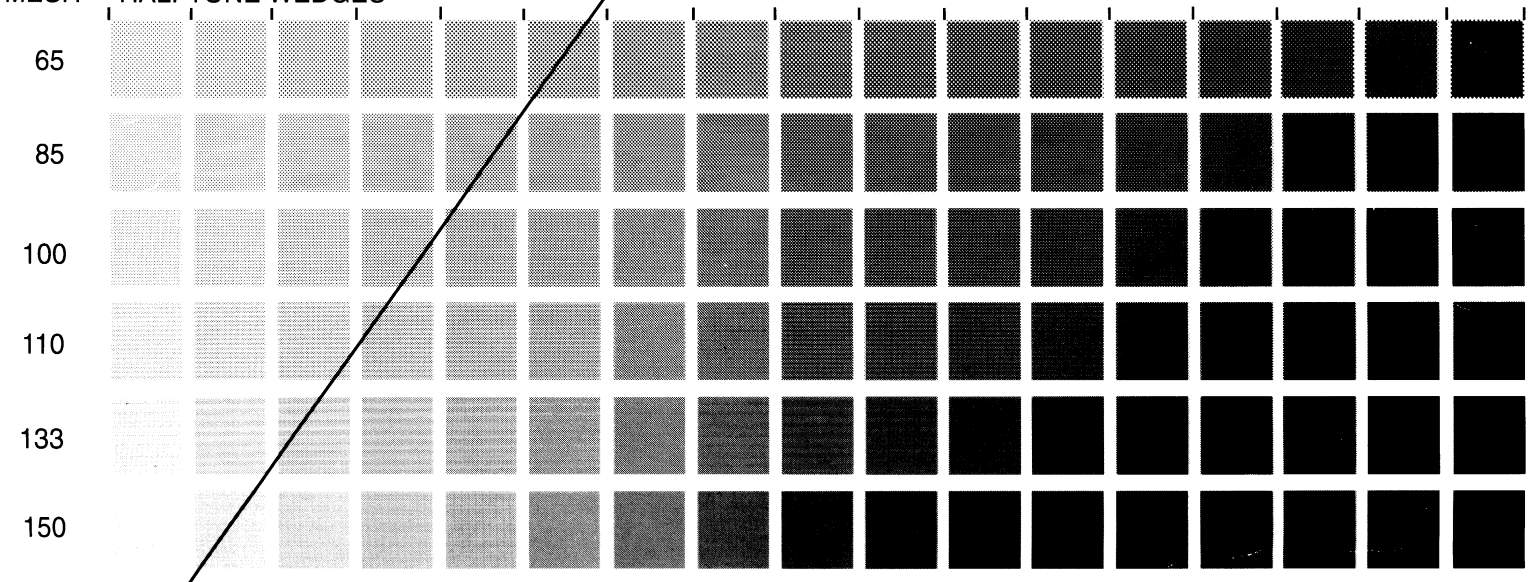

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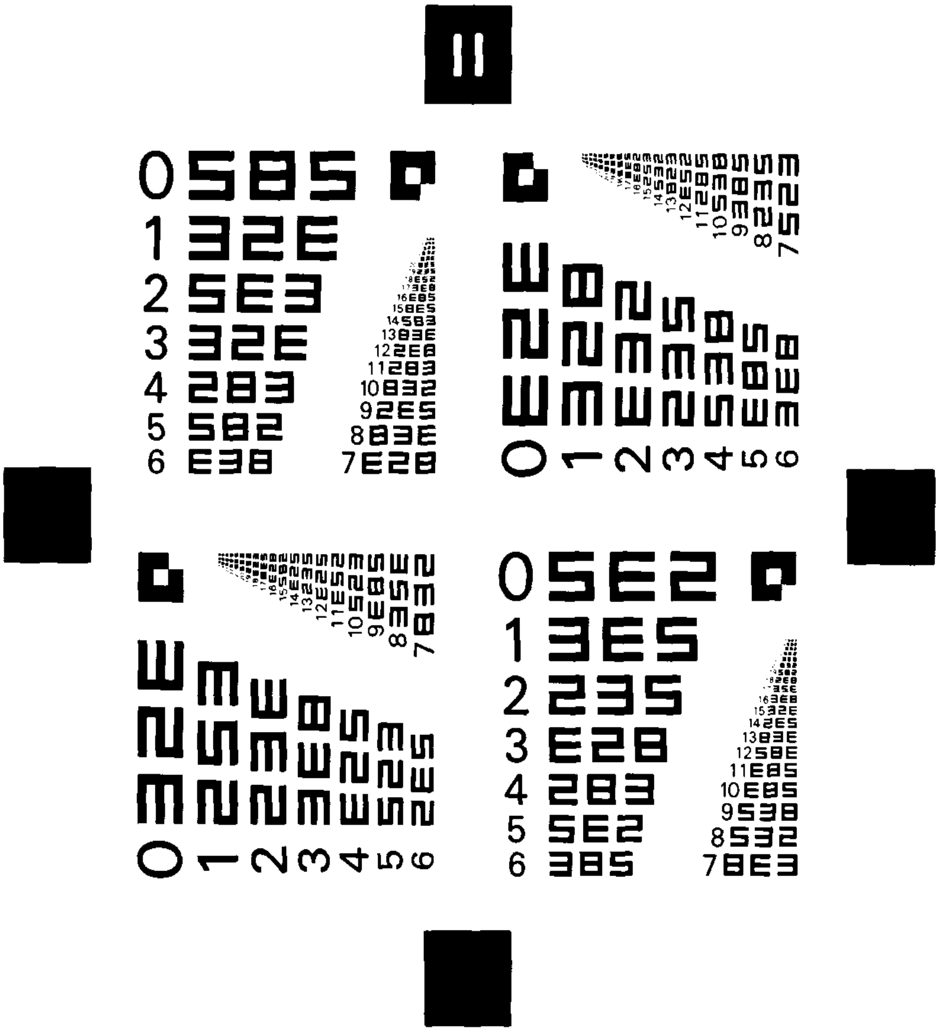

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