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FLUID-TO-FLUID MODELING AND CORRELATION OF FLOW BOILING CRISIS IN HORIZONTAL TUBES

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Abstract—Parameters for fluid-to-fluid modeling of critical heat flux in horizontal tubes have been obtained using the method of compensated distortion. The fluids used were water and Freon-12. The modeling parameter obtained differs from the one applicable to vertical flow by the addition of a term representing the effects of gravity. The mass flux scaling factor for modeling water with Freon-12 in horizontal flow is generally higher than that for vertical flow, and it shows a greater sensitivity to pressure. A dimensionless correlation for CHF in horizontal tubes, which describes the available data with an r.m.s. error of 9.1%, is also presented.

1. INTRODUCTION

Boiling crisis is an important consideration in the design of heat exchange equipment operating with evaporating coolants. If this condition is reached, the sharply reduced heat transfer coefficient could lead to potentially detrimental temperature excursions on the heater surface. It is therefore important to be able to predict the critical heat flux (CHF) at which boiling crisis occurs.

Much work has been done on boiling crisis under conditions of vertical flow, however, comparatively little information is available for horizontal flow; a condition encountered in boiler tubes, refrigeration equipment and nuclear fuel channels.

Though some success has recently been achieved in the mathematical description of horizontal annular flow (e.g. Hutchinson *et al.* 1974; Fisher *et al.* 1978), the complexity of the phenomena involved has so far precluded the development of an entirely satisfactory prediction tool for horizontal flow boiling crisis. It is therefore necessary, for design purposes, to obtain measurements on individual systems. Generally, for steam–water systems, which are encountered in nuclear reactors and boilers, the large physical size, high pressure, high temperature and large power requirements make this work costly and cumbersome.

Modeling is one method which has been used successfully to alleviate high testing costs in other fields of engineering since the beginning of the century. By this technique, a model of a physical system is used to obtain quantitative information about the behavior of the original system, or prototype. Dimensional analysis is commonly used to obtain the scaling laws which relate these systems.

In experimental studies of two-phase flow and heat transfer, it has been found expedient to replace water, which has a high latent heat, with lower latent heat fluids, such as the fluorocarbons. In evaporating systems, this can result in considerably lower power requirements. Further, since the liquid–vapor density ratio is normally kept the same in both the model and the prototype, and since the critical pressures are much lower in the fluorocarbons than in water, experiments can be performed at considerably lower pressures and temperatures.

Fluid-to-fluid modeling has so far been applied to critical heat flux in vertical channels (e.g. Barnett 1964; Ahmad 1973), pressure drop (e.g. Bruce 1972; Friedel 1974), and parallel channel instabilities (e.g. Harvie 1974; Crowley & Bergles 1970).

No quantitative study has been performed to date on modeling of CHF in horizontal channels, though qualitative work has been done by Fisher & Yu (1975) in serpentine evaporators.

Recent experiments by Merilo (1977) have shown that vertical CHF modeling criteria are not applicable to horizontal flow. It is, therefore, the purpose of the present work to extend fluid-to-fluid modeling to conditions where the flow is horizontal.

2. THEORY

When a small number of dimensionless groups describes the behavior of a physical system, it is possible to obtain an exact model by ensuring that all the dimensionless groups for both the model and prototype are identical. In this case, there is a complete correspondence of events in both the model and the prototype. As the complexity of the physical phenomena occurring in the system increases, it becomes impossible to maintain the values of all the corresponding dimensionless groups the same, and, therefore, this requirement must be relaxed. In this situation, we have an incomplete simulation or a "distorted model".

To extract pertinent information from distorted models, attention is focused on only one phenomenon or aspect of the system behavior at the expense of excluding others. An example of this occurs when modeling boiling crisis and pressure drop in vertical geometries by using Freon-12 to simulate steam–water. While Ahmad (1973) obtains a mass flux scaling factor of 1.4 for modeling CHF, Bruce (1972) obtains a mass flux scaling factor of approx. 1.0 for modeling pressure drop. Under these circumstances, the pressure drop and CHF cannot both be modelled simultaneously.

Many techniques have been proposed, with varying degrees of success, to compensate for incomplete modeling of flow boiling crisis. These have been reviewed by Lawther & Miles (1973) who state that the "potentially most useful adaptation of Barnett's dimensional analysis approach is that proposed by Ahmad". The method of compensated distortion originally described by Ahmad (1973) is considered here in greater detail.

2.1 *The method of compensated distortion*

Consider a physical phenomenon for which a relationship of the following kind can be written

$$\zeta(x_1, x_2, \ldots, x_\alpha) = 0. \tag{1}$$

Here $x_1, \ldots, x_\alpha$ are all the "important" dimensional variables describing the phenomenon. By means of dimensional analysis and the theorem of Vaschy (1892), it is possible to reduce the number of variables and to write in dimensionless form

$$\xi(\pi_1, \pi_2, \ldots, \pi_\beta) = 0 \tag{2}$$

where the number of dimensionless groups in a complete set is equal to the total number of dimensional variables minus the rank of the dimensional matrix.

There are infinitely many sets of dimensionless groups which can be written; however, for convenience of application, some care must be exercised in their choice. The independent variables which can easily be controlled should not appear in combination with each other and preferably should appear just once. Similarly, the dependent variable should appear in only one group, though it can appear in combination with some independent variables. It is also good practice to use classical dimensionless groups whose physical significance are known and extend beyond a single problem.

In the present analysis, we let Θ represent the group which contains the dependent variable. The independent groups can be divided into two categories: those which the experimenter is free to control, Λ_i, and those which are subsequently determined by the system and therefore cannot be controlled, Γ_i. It is not always clear whether a particular dimensionless group can or cannot be controlled. Therefore, its classification is to some extent a matter of expediency.

The equation describing the behavior of the system can be written as:

$$\Theta = f(\Lambda_1, \Lambda_2, \ldots, \Lambda_\gamma, \Gamma_1, \Gamma_2, \ldots, \Gamma_\delta). \quad [3]$$

For modeling purposes, we require

$$\Theta_m = \Theta_p \quad [4]$$

where the subscripts m and p refer to the model and prototype respectively.

Since the Λ_i can be adjusted experimentally, we choose all, except one, to be identical in the model and the prototype. Thus,

$$\Lambda_{im} = \Lambda_{ip} \quad i = 2, \gamma. \quad [5]$$

The remaining Λ_1 is chosen as a "compensator" for the distortions introduced in the Γ_i since

$$\Gamma_{im} \neq \Gamma_{ip} \quad i = 1, \delta. \quad [6]$$

For the concept of compensated distortion to succeed, it must be possible to express [3] as

$$\Theta = f[g(\Lambda_2, \ldots, \Lambda_\gamma), \psi(\Lambda_1, \Gamma_1, \ldots, \Gamma_\delta)]. \quad [7]$$

From [5] we can then write

$$g(\Lambda_{2m}, \ldots, \Lambda_{\gamma m}) = g(\Lambda_{2p}, \ldots, \Lambda_{\gamma p}) \quad [8]$$

and therefore to satisfy [4], it is only necessary to ensure that

$$\psi(\Lambda_{1m}, \Gamma_{1m}, \ldots, \Gamma_{\delta m}) = \psi(\Lambda_{1p}, \Gamma_{1p}, \ldots, \Gamma_{\delta p}). \quad [9]$$

For this reason, ψ is called the modeling parameter. Its value is adjusted in the model to satisfy [9] by varying the compensator, Λ_{1m}. If this methodology is successful, the data for different fluids should collapse onto a single curve when Θ is plotted as a function of ψ at constant $g(\Lambda_i)$. The end result of this procedure to satisfy [9] is a functional relationship between Λ_{1m} and Λ_{1p}.

The modeling parameter can easily be related to the commonly used scaling factor through Λ_1. The scaling factor for a dimensional quantity, say x_1, is defined as

$$F_{x_1} \equiv \frac{x_{1p}}{x_{1m}}. \quad [10]$$

Since the dimensionless compensator, Λ_1, can be written in the form

$$\Lambda_1 = x_1^{\alpha_1} x_2^{\alpha_2} \ldots x_n^{\alpha_n} \quad [11]$$

it follows immediately that

$$F_{x_1} = \left\{ \frac{\Lambda_{1p}}{\Lambda_{1m}} \left(\frac{x_{2m}}{x_{2p}}\right)^{\alpha_2} \cdots \left(\frac{x_{nm}}{x_{np}}\right)^{\alpha_n} \right\}^{1/\alpha_1}. \quad [12]$$

When no theory exists to give an indication of the functional form of [3] or [7], experimental data must be resorted to.

The main advantage of compensated distortion modeling rests in the fact that there is no need to determine the function of $g(\Lambda_2,\ldots,\Lambda_\gamma)$, but only $\psi(\Lambda_1, \Gamma_1,\ldots,\Gamma_\delta)$.

3. APPLICATION TO FLOW BOILING CRISIS IN VERTICAL FLOW

To describe flow boiling crisis, Ahmad (1973) suggests that [1] can be written in terms of dimensional variables as follows:

$$F(\phi, G, \Delta H, L, D, g, \lambda, \rho_L, \rho_v, \mu_L, \mu_v, C_{PL}, C_{Pv}, k_L, k_v, \sigma, \gamma, \beta) = 0 \qquad [13]$$

where ϕ is the critical heat flux (W/m^2), G is the mass flux (kg/m^{2}s), ΔH is the inlet subcooling (J/kg), L is the length (m), D is the diameter (m), g is the acceleration of gravity (m/s^2), λ is the latent heat of vaporization (J/kg), ρ is the density (kg/m^3), μ is the viscosity (Ns/m^2), C_P is the specific heat (J/kg K), k is the thermal conductivity (W/m K), and σ is the surface tension (N/m). The subscripts v and L refer to vapor and liquid, respectively. The parameters γ and β are defined as

$$\gamma \equiv \frac{\partial(\rho_L/\rho_v)}{\partial P}\bigg]_{\text{saturation}}$$

and

$$\beta \equiv \frac{\partial \theta}{\partial \rho}\bigg]_{\text{saturation}}$$

where P is the pressure (Pa) and θ is the temperature (K).

If the conversion of heat into mechanical energy or vice versa can be neglected, the five fundamental dimensions of mass, length, time, temperature, and enthalpy are pertinent. There are then 13 dimensionless products required in [2].

The quantity of interest for flow boiling crisis is the critical heat flux, and a number of dimensionless groups which include it have been proposed (e.g. Barnett 1963). The most useful form is probably obtained from the dimensionless energy equation

$$\frac{\phi}{G\lambda} = \frac{1}{4}\frac{D}{L}(X - X_{\text{in}}) \qquad [14]$$

where X is the thermodynamic quality defined as

$$X \equiv \frac{H - H_{\text{sat}}}{\lambda} \qquad [15]$$

and X_{in} is the inlet quality.

Therefore, the dependent variable is chosen to be

$$\Theta \equiv \frac{\phi}{G\lambda} \quad \text{(Boiling number)} \qquad [16]$$

and the groups D/L and X_{in} appear in the remaining twelve dimensionless groups. The local or critical quality does not have to be included since it is determined by [14].

The most convenient quantity to use in the compensator, Λ_1, is the mass flux because it is easy to control and can generally be varied over a wide range. Therefore, the liquid Reynolds number is used

$$\Lambda_1 = \frac{GD}{\mu_L} = \text{Re}. \quad \text{(Reynolds number)}$$

The other controlled groups are:

$$\Lambda_2 = \frac{\Delta H}{\lambda} = -X_{\text{in}} \quad \text{(Inlet quality)}$$

$$\Lambda_3 = \frac{\rho_L}{\rho_v} \quad \text{(Density ratio)}$$

$$\Lambda_4 = \frac{\text{L}}{\text{D}}. \quad \text{(Geometry)}$$

The uncontrolled groups are

$$\Gamma_1 = \frac{\mu_L}{(\sigma D \rho_L)^{1/2}} = Z \quad \text{(Ohnesorge number)}$$

$$\Gamma_2 = \frac{\mu_L}{\mu_v} \quad \text{(Viscosity ratio)}$$

$$\Gamma_3 = \frac{g D^3 \rho_L{}^2}{\mu_L{}^2} = \text{Ga} \quad \text{(Galileo number)}$$

$$\Gamma_4 = \frac{C_{PL}\mu_L}{k_L} = \text{Pr}_L \quad \text{(Liquid Prandtl number)}$$

$$\Gamma_5 = \frac{C_{Pv}\mu_v}{k_v} = \text{Pr}_v \quad \text{(Vapor Prandtl number)}$$

$$\Gamma_6 = \frac{k_L}{k_v} \quad \text{(Conductivity ratio)}$$

$$\Gamma_7 = \frac{\gamma \mu_L{}^2}{\rho D^2} \quad \text{(Barnett number)}$$

$$\Gamma_8 = \frac{\beta C_p}{\gamma \lambda}. \quad \text{(Ahmad number)†}$$

Through physical arguments and considering results of CHF experiments on water, potassium and carbon dioxide, Ahmad (1973) concluded that parameters Γ_3 to Γ_8 are not important for an adequate description of boiling crisis. He then assumed that the modeling parameter could be expressed as a power law.

$$\psi_{\text{CHF}} = \Lambda_1 \Gamma_1{}^{n_1} \Gamma_2{}^{n_2}. \quad [17]$$

The values of n_1 and n_2 were determined from experimental data. To obtain n_1, Θ was plotted as a function of Λ_1 for two different values of Γ_1, resulting in two curves displaced from each other. All other independent dimensionless groups were maintained constant. The value of n_1 was adjusted to make the two curves coincide. In a similar fashion, n_2 was obtained by plotting Θ as a function of $\Lambda_1 \Gamma_1{}^{n_1}$ for two different values of Γ_2 and forcing those two curves to coincide.

†This dimensionless group has been named the Ahmad number by the author in recognition of his work on compensated distortion.

The resulting values were $n_1 = 4/3$ and $n_2 = -1/5$.

One advantage to the power law formulation becomes apparent when we determine the scaling factor for mass flux. We get from [9] and [17] that

$$\frac{\Lambda_{1p}}{\Lambda_{1m}} = \left(\frac{\Gamma_{1m}}{\Gamma_{1p}}\right)^{4/3} \left(\frac{\Gamma_{2m}}{\Gamma_{2p}}\right)^{-1/5} \qquad [18]$$

and therefore substituting into [12]

$$F_G = \frac{G_p}{G_m} = \left(\frac{\Gamma_{1m}}{\Gamma_{1p}}\right)^{4/3} \left(\frac{\Gamma_{2m}}{\Gamma_{2p}}\right)^{-1/5} \left(\frac{D_m}{D_p}\right) \left(\frac{\mu_{Lp}}{\mu_{Lm}}\right). \qquad [19]$$

From here we see that the mass flux scaling factor depends only on the properties of the fluids and the geometry. If the geometries of the model and prototype are identical, as recommended by Stevens & Macbeth (1970), it turns out that for a particular modeling fluid, since the fluid properties are calculated at saturation, the scaling factor is a function of the pressure only.

If a more complicated expression for the modeling parameter is required to satisfy [9], it is possible that

$$\frac{\Lambda_{1p}}{\Lambda_{1m}} = f(\Lambda_{1p}). \qquad [20]$$

In this case, the mass flux scaling factor depends on the mass flux in the prototype. This results in an acceptable, though somewhat inconvenient, modeling criterion and has been used by Dix (1970). There is clearly a subjective judgment as to whether a power law for the modeling parameter, and hence a constant mass flux scaling factor is adequate. In view of Ahamad's success with the power law form, this seems to be a satisfactory formulation.

4. APPLICATION TO FLOW BOILING CRISIS IN HORIZONTAL FLOW

Boiling crisis in horizontal and vertical tubes, with water and Freon-12 as coolant, has been studied by Merilo (1977). It was found that modeling criteria for critical heat flux in vertical flow were not applicable to horizontal flow. This is illustrated in figure 1 where good agreement can be seen for vertical modeling, but large discrepancies appear when vertical modeling criteria are used for horizontal flow. The vertical and horizontal flow conditions differ because the gravity force causes an asymmetric vapor/liquid distribution in horizontal flow.

Ahmad (1973) included gravity in his initial list of important variables; however, on the basis of upflow and downflow tests carried out by Papell *et al.* (1966) and Lee & Obertelli (1963), he concluded that gravity was not important in vertical flow at the mass fluxes tested. It is clear, however, that in horizontal flow a term including gravity must be included in the modeling parameter.

Initially, it had been hoped that it would be possible to relate vertical and horizontal CHF by the addition, to a vertical correlation or modeling parameter, of a dimensionless group characterizing the transverse vapor or liquid velocity, such as the Froude number

$$\mathrm{Fr} = \frac{G}{\rho (gD)^{1/2}}$$

or the Kutateladze number

$$\mathrm{K} = \frac{G}{\rho_L}\left\{\frac{\rho_L^2}{\sigma g(\rho_L - \rho_v)}\right\}^{0.25}.$$

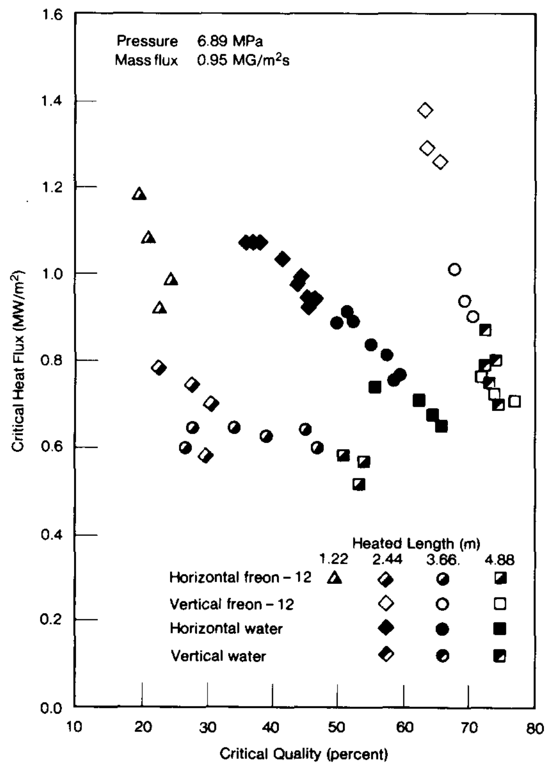

Figure 1. Comparison of water and Freon-12 CHF data for vertical and horizontal tubes. The Freon-12 data is in terms of water equivalent values calculated by vertical modeling criteria (Merilo 1977).

This was not feasible, however, because to account for the difference between vertical and horizontal CHF requires all the dimensionless groups which are needed to correlate horizontal CHF independently. This effort was therefore abandoned in favor of deriving a new modeling parameter applicable to horizontal CHF alone.

Because of Ahmad's success with his modeling parameter, we choose a similar power law form, modified, however, by the inclusion of a term representing gravity.

Instead of the Galileo number, however, we use the Bond number

$$\mathrm{Bo} = (\rho_L - \rho_v) g D^2 / \sigma$$

which can be obtained from Ahmad's original list of dimensionless parameters by combining the Ohnesorge number and the Galileo number to eliminate the viscosity. The Bond number was chosen because its inclusion gives a lower rms error in the final correlation.

The postulated modeling parameter for horizontal CHF, ψ_H, then has the form

$$\psi_H = \mathrm{Re}\,\mathrm{Bo}^{n_1} Z^{n_2} \left(\frac{\mu_L}{\mu_v}\right)^{n_3} \qquad [21]$$

where the coefficients n_1, n_2, and n_3 are to be determined from the data.

Three sources of data were used to determine the modeling parameter. These, with the range of the experiments, are shown in table 1. The graphical technique to determine the arbitrary powers of the modeling parameter could not be used here because the Bond and Ohnesorge numbers could not be varied independently. In this situation, other, less direct techniques must be resorted to. One possible method consists of deriving an overall dimensionless correlation in the form of [7] such that the functions ψ and g can be separated. The

Table 1. Range of experimental parameters

Data	Fluid	Tube diameter, mm	L/D	ρ_l/ρ_v	Mass flux, Mg/m^2s	X_{in} %
Merilo (1977)	Freon-12	12.6	193–387	13–20.5	0.7–5.4	−35– 0
Merilo (1977)	Water	12.6	193–387	13–20.5	1.0–5.7	−30– 0
Robertson (1973)	Water	19.1	112–160	20.5	0.7–1.4	−29–−7
Merilo & Ahmad (1979)	Freon-12	5.3	193–571	13–20.5	1.6–8.1	−35– 0

drawback of this technique is that it depends on the ability to correlate for the effect of $g(\Lambda_2,\ldots,\Lambda_\gamma)$, and uncertainties in this portion of the correlation propagate as uncertainties of $\psi(\Lambda_1,\Gamma_i)$. It is also necessary to assume a functional form for $\Theta(\psi)$, which is not essential for the graphical technique. Further, since in the graphical method $g(\Lambda_2,\ldots,\Lambda_\gamma)$ is maintained constant, it is not necessary to correlate for its effect.

Nevertheless, in spite of its deficiencies, the overall correlation method was used here. Consistent with Ahmad's results for vertical flow, the parameters Γ_4–Γ_8 were assumed to be unimportant for horizontal flow. A power law form was therefore chosen for the remaining parameters, and fitted, by minimizing the rms error, to all the data specified in table 1 consisting of 605 data points.

This correlation is

$$\frac{\phi}{G\lambda} = 575\,\mathrm{Re}_L^{-0.340}\{Z^3 B_0\}^{0.358}\left(\frac{\mu_L}{\mu_v}\right)^{-2.18}\left(\frac{L}{D}\right)^{-0.511}\left(\frac{\rho_L}{\rho_v}-1\right)^{1.27}(1-X_{in})^{1.64}. \qquad [22]$$

It correlates 462 Freon-12 and 143 water data points with rms errors of 9.12 and 9.07%, respectively. Graphical comparisons between the experiments and the correlation are shown in figures 2 and 3. Considering that the data come from three different laboratories, this can be considered to be satisfactory agreement.

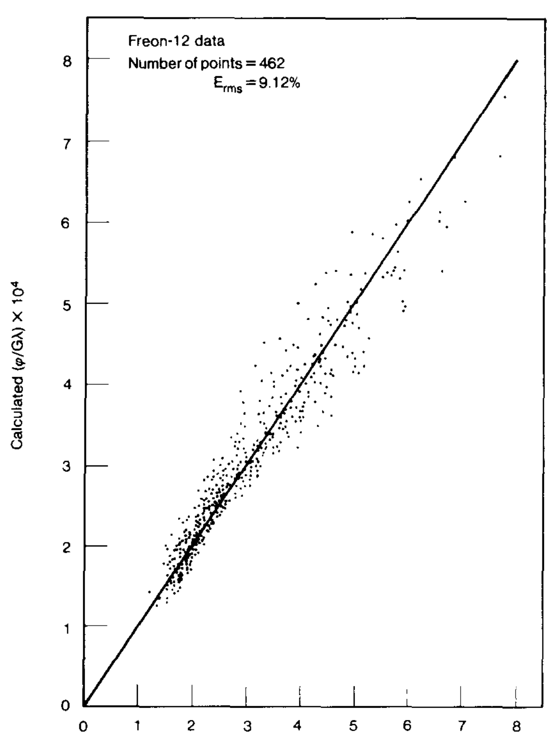

Figure 2. Measured vs calculated critical boiling number for Freon-12.

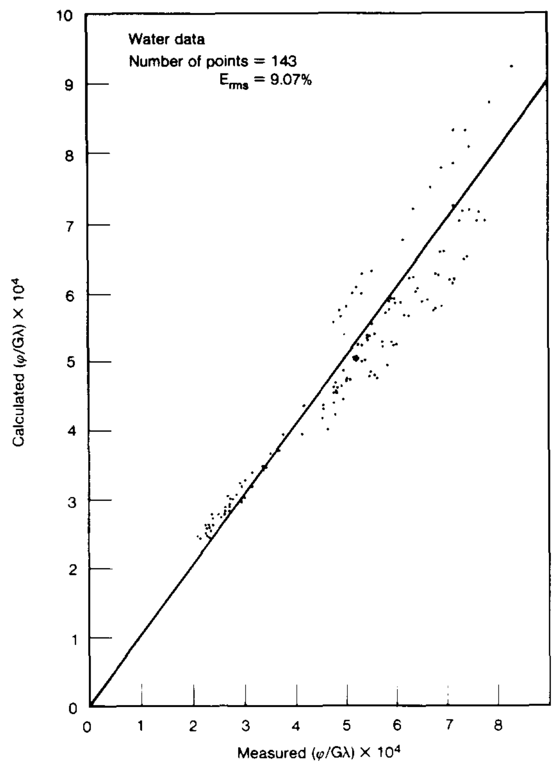

Figure 3. Measured vs calculated critical boiling number for water.

From [22], the horizontal CHF modeling parameter can easily be deduced to be

$$\psi_H = \mathrm{Re}_L\{Z^3\,\mathrm{Bo}\}^{-1.05}\left(\frac{\mu_L}{\mu_v}\right)^{6.41}. \qquad [23]$$

The success of the proposed modeling technique can be assessed by plotting the Boiling number as a function of the modeling parameter, with the remaining dimensionless groups being held constant. Typical results are shown in figures 4–6, for various values of the density ratio, length to diameter ratio, and the inlet subcooling. It can be seen that the data for different experiments falls essentially on the same curve, as fitted by eye.

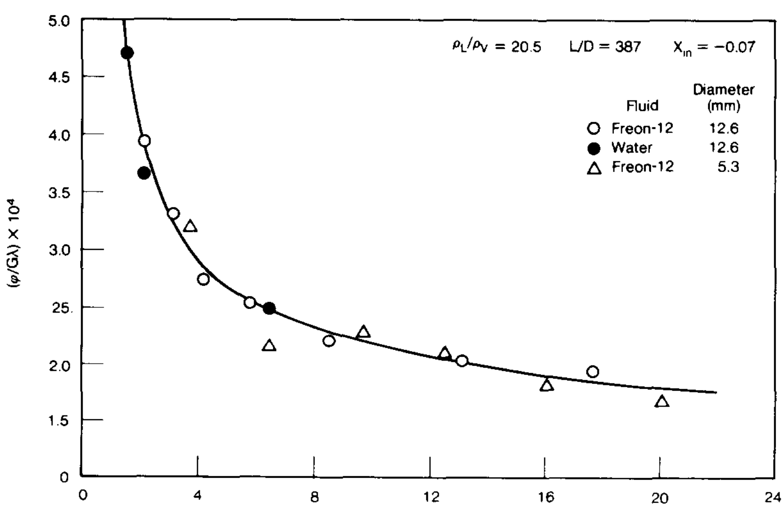

Figure 4. Boiling number as a function of the horizontal CHF modeling parameter.

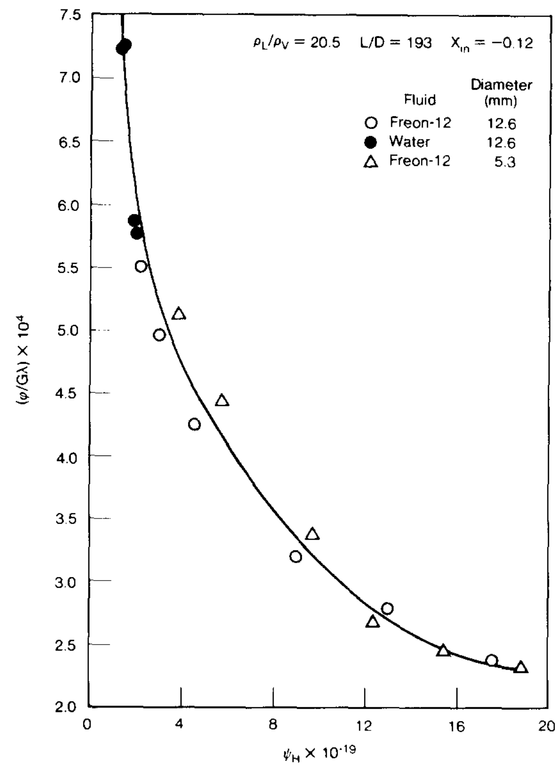

Figure 5. Boiling number as a function of the horizontal CHF modeling parameter.

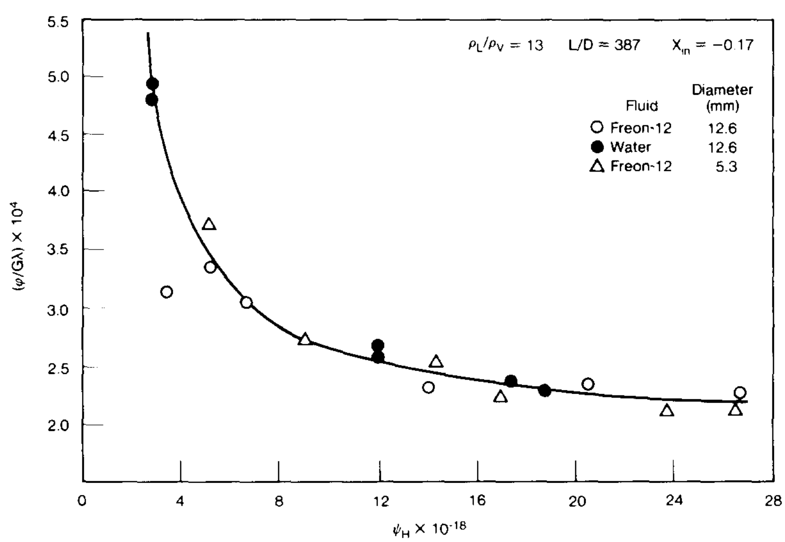

Figure 6. Boiling number as a function of the horizontal CHF modeling parameter.

The mass flux scaling factor implied by [23] is given in table 2 for Freon-12 and water. It is considerably more sensitive to pressure than the vertical mass flux scaling factor, probably reflecting the role of the transverse buoyancy forces.

An interesting illustration of the compensated distortion concept can be made by assuming that the length to diameter ratio, which previously could be controlled, is now an uncontrolled parameter. In this case, the modeling parameter becomes

$$\psi_{H,L/D} = \text{Re}\{Z^3 \,\text{Bo}\}^{-1.05}\left(\frac{\mu_L}{\mu_v}\right)^{6.41}\left(\frac{L}{D}\right)^{1.50}. \qquad [24]$$

Table 2. Mass flux scaling factor for horizontal flow CHF using Freon-12 to model water

ρ_L/ρ_v	13	16.2	20.5
F_G	1.69	1.93	2.12

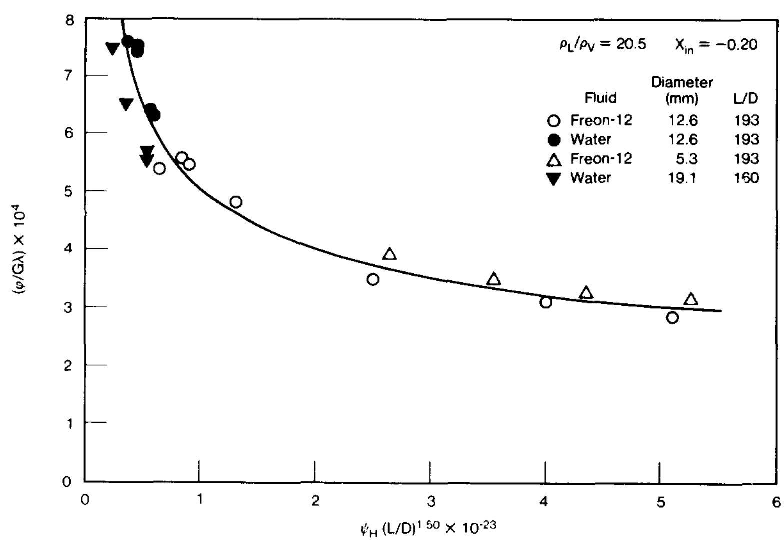

Figure 7. Boiling number as a function of the modified horizontal CHF modeling parameter.

It is now possible to include Robertson's (1973) data in the comparison, and the result is shown in figure 7. In spite of the fact that the water and Freon-12 data do not overlap, they can be seen to fall on the same curve.

5. DISCUSSION

It has been pointed out by Merilo (1977) that, for both water and Freon-12, at mass fluxes greater than approx. 4.2 Mg/m^2s differences in critical heat flux between vertical and horizontal flow disappear. In view of this observation, one could legitimately ask why the mass flux scaling factors at high mass flux are not the same for vertical and horizontal flow. The answer lies essentially in the insensitivity of the Boiling number to the mass flux at high mass flux, as can be seen in figures 4–6. This is consistent with Groeneveld's (1969) observation that for Freon-12 in tubes, varying the mass flux scaling factor from 1.4 to 2.5 resulted in only a 0.7% increase in the rms error for CHF.

Dix (1970) proposed a mass flux scaling factor which is a function of the mass flux, length to diameter ratio, and density ratio. For a mass flux of 4.2 Mg/m^2s, length to diameter ratio of 380 and a density ratio of 20.6, his formulation gives a mass flux scaling factor of 2.0 which is close to the present value of 2.1. At a density ratio of 13.6 for the same length to diameter ratio and mass flux, Dix's value is 1.8 which again compares favorably with the present value of 1.7. Thus, the present results for the mass flux scaling factors in horizontal flow are not inconsistent with available information for vertical flow.

The correlation for CHF in horizontal tubes [22], which has been developed here, is clearly applicable only over the range of conditions tested and it should therefore not be extrapolated. However, it is important to note that the modeling parameter itself [23] which forms part of the correlation is not necessarily restricted in validity to the range of applicability of the correlation. All that is required for the validity of the modeling parameter is that the critical heat flux data be expressible in the functional form

$$\frac{\phi}{G\lambda} = f(\psi_H, g[L/D, \rho_L/\rho_v, X_{in}])$$

where ψ_H is defined by [23].

It is not possible to know *a priori* what the range of applicability of the horizontal CHF modeling parameter is. However, considering Ahmad's (1973) success with a similar modeling parameter for CHF in vertical flow, there is cause for optimism that the range of validity for the horizontal CHF modeling parameter may extend beyond the range of the correlation from which it was derived.

From the present application of compensated distortion modeling to horizontal CHF, we can see that the determination of the modeling parameter consists of a manipulation of sets of experimental data, expressed in dimensionless form, to obtain a correlation for parameters which cannot be controlled. As such, it is not based on a mathematical description of the physics involved. Since some of the dimensionless groups in the model and prototype are not identical, clearly all of the physical processes are not equivalent. The degree to which the physical processes in the model and prototype differ is a function of how important the distorted groups are and the extent of their discrepancies; however, this cannot be determined *a priori*.

In view of these comments, it may be more appropriate to describe the method as one of modeling by partial correlation.

6. CONCLUSIONS

The compensated distortion modeling technique, which was originally proposed by Ahmad (1973), has been derived in a more rigorous fashion and applied to flow boiling crisis in horizontal flow using Freon-12 to model water. The mass flux scaling factor, obtained from the modeling parameter, is higher for horizontal flow than vertical and shows a greater sensitivity to the pressure. A dimensionless CHF correlation for flow of water and Freon-12 in horizontal tubes was developed in the process of obtaining the modeling parameter. It describes the available data with an rms error of 9.1%.

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