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ON THE HEAT-FLUX/EXIT-QUALITY TYPE CORRELATION OF CHF OF FORCED CONVECTION BOILING IN UNIFORMLY HEATED VERTICAL TUBES

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Abstract—In this paper, it is attempted to use generalized correlation equations of CHF proposed recently by the author for predicting the well-known relation which appears between critical heat flux q_c and exit quality χ_{ex} when tube length l and inlet subcooling enthalpy ΔH_i are varied for fixed pressure p, mass velocity G and tube diameter d. Numerical calculation is made for water under the conditions of p = 29.5–196 bar, G = 750–4000 kg/m² s, d = 0.008 m, l/d = 10–793, and ΔH_i = 0–400 kJ/kg. Then, the result is compared with the standard table of $q_c - \chi_{ex}$ published recently by Heat Mass Transfer Section, Academy of Sciences, U.S.S.R., for water in uniformly heated tubes of d = 0.008 m, and thereby the characteristics of $q_c - \chi_{ex}$ type correlation are discussed.

NOMENCLATURE

- C, constant, equation (3);
- d, I.D. of heated tube [m];
- G, mass velocity [kg m^{-2} s^{-1}];
- H_{fg}, latent heat of evaporation [J kg^{-1}];
- ΔH_i, enthalpy of inlet subcooling [J kg^{-1}];
- K, parameter for the effect of inlet subcooling, equation (2);
- l, length of heated tube [m];
- p, absolute pressure [bar];
- q_c, critical heat flux [W m^{-2}];
- q_{co}, q_c for $\Delta H_i = 0$ [W m^{-2}].

Greek symbols

- ρ_l, density of liquid [kg m^{-3}];
- ρ_v, density of vapor [kg m^{-3}];
- σ, surface tension [N m^{-1}];
- χ_{ex}, quality at the exit end of heated tube.

1. INTRODUCTION

IT HAS long been known that if experimental data of critical heat flux q_c, obtained within a range of inlet subcooling enthalpy ΔH_i for uniformly heated tubes with various lengths, are plotted against exit vapor quality χ_{ex} for fixed pressure p, mass velocity G and tube diameter d, it gives a single line in an approximate sense (cf. Collier [1] for example). From this empirical fact, the concept of local conditions hypothesis, namely $q_c = f(p, G, d, \chi_{ex})$, was born (Barnett [2]), but a little later, it was found that the local conditions hypothesis deteriorated either if l was very short and G was high, where q_c depended not only on χ_{ex} but also on l, or if l was very long, where χ_{ex} was kept nearly constant independently of q_c (cf. Stevens *et al.* [3], Lee and Obertelli [4], Lee [5] etc.). However, CHF/exit-quality ($q_c - \chi_{ex}$) type correlation of experimental data is convenient, so that, even now, it still constitutes the main current of correlation along with the correlation based on the boiling length concept (cf. Hewitt [6]). In addition, Heat Mass Transfer Section, Academy of Sciences, U.S.S.R. [7, 8], surveying CHF data of water (obtained in U.S.S.R. mainly), has recently given a standard table for $q_c - \chi_{ex}$ correlation of water in uniformly heated tubes of d = 0.008 m within the range of p = 29.5–196 bar and G = 500–5000 kg/m² s.

On the other hand, analyzing CHF data for uniformly heated tubes with subcooled inlet conditions, the author [9–13] presented correlation equations of simple form made up of five dimensionless groups; q_c/GH_{fg}, $\sigma\rho_l/G^2 l$, ρ_v/ρ_l, l/d and $\Delta H_i/H_{fg}$, and it was shown [12] that these equations could outline general features of existing experimental data fairly well. The relation of the boiling length concept to the author's correlation equations mentioned above has been studied in [11, 13], accordingly the $q_c - \chi_{ex}$ type correlation will be investigated in the present paper on the basis of the author's correlation equations.

2. CORRELATION EQUATIONS OF CHF

For uniformly heated tubes, the following equation holds generally via the heat balance:

$$\chi_{ex} = \frac{4q_c}{GH_{fg}}\frac{l}{d} - \frac{\Delta H_i}{H_{fg}}. \tag{1}$$

Then, if q_c on the RHS of equation (1) is written as:

$$q_c = q_{co}\left(1 + K\frac{\Delta H_i}{H_{fg}}\right) \tag{2}$$

q_{co} is the critical heat flux for $\Delta H_i = 0$, and K is the dimensionless parameter for the effect of ΔH_i on critical heat flux.

2.1. *Correlation equations of* q_{co}

From [13], the author's correlation equations of q_{co}

are given as follows, being classified into four characteristic regimes called L, H, N and HP, where L-regime is the regime mainly corresponding to the so-called dryout, N-regime is the regime mainly corresponding to the so-called DNB (departure from nucleate boiling), H-regime is the intermediate regime between L- and N-regime, and HP-regime is a special regime replacing N-regime when the system pressure is extremely high.

L-regime*:

$$\frac{q_{co}}{GH_{fg}} = C\left(\frac{\sigma\rho_l}{G^2 l}\right)^{0.043}\frac{1}{l/d} \tag{3}$$

where $C = 0.25$ for $l/d < 50$, $C = 0.34$ for $150 < l/d$, and

$$C = 0.25 + \frac{(l/d) - 50}{150 - 50}(0.34 - 0.25) \text{ for } 50 < l/d < 150.$$

H- and N-regime:

$$\frac{q_{co}}{GH_{fg}} = 0.10\left(\frac{\rho_v}{\rho_l}\right)^{0.133}\left(\frac{\sigma\rho_l}{G^2 l}\right)^{1/3}\frac{1}{1 + 0.0031 l/d} \tag{4}$$

and

$$\frac{q_{co}}{GH_{fg}} = 0.098\left(\frac{\rho_v}{\rho_l}\right)^{0.133}\left(\frac{\sigma\rho_l}{G^2 l}\right)^{0.433}\frac{(l/d)^{0.27}}{1 + 0.0031 l/d}. \tag{5}$$

HP-regime

$$\frac{q_{co}}{GH_{fg}} = 0.0384\left(\frac{\rho_v}{\rho_l}\right)^{0.60}\left(\frac{\sigma\rho_l}{G^2 l}\right)^{0.173} \times \frac{1}{1 + 0.280(\sigma\rho_l/G^2 l)^{0.233} l/d}. \tag{6}$$

2.2. *Equations for evaluating* K

According to [11, 13], K on the RHS of equation (2) is derived theoretically from equations (3)–(6) by taking into consideration the linear $q_c - \Delta H_i$ relationship and the boiling length concept, to give the following equations.

L-regime: corresponding to q_{co} of equation (3),

$$K = \frac{1.043}{4C(\sigma\rho_l/G^2 l)^{0.043}}. \tag{7}$$

H-regime: corresponding to q_{co} of equation (4),

$$K = \frac{5}{6}\frac{0.0124 + d/l}{(\rho_v/\rho_l)^{0.133}(\sigma\rho_l/G^2 l)^{1/3}} \tag{8}$$

and corresponding to q_{co} of equation (5),

$$K = 0.416\frac{(0.0221 + d/l)(d/l)^{0.27}}{(\rho_v/\rho_l)^{0.133}(\sigma\rho_l/G^2 l)^{0.433}} \tag{9}$$

HP-regime: corresponding to q_{co} of equation (6),

$$K = 1.12\frac{1.52(\sigma\rho_l/G^2 l)^{0.233} + d/l}{(\rho_v/\rho_l)^{0.60}(\sigma\rho_l/G^2 l)^{0.173}}. \tag{10}$$

For N-regime, the linear $q_c - \Delta H_i$ relationship does not hold, accordingly the equation of evaluating K in this regime has not been determined.

2.3. *Characteristic CHF-regime maps*

Figure 1 shows characteristic CHF-regime maps determined in the author's preceding study [13], indicating the extent of L-, H-, N- and HP-regime for the respective cases of density ratio $\rho_v/\rho_l = 0.01787$, 0.04847, 0.1351, and 0.3216 (corresponding to the pressure $p = 29.5$, 69, 137, and 196 bar in the case of water). Equations of q_{co} and K, which are used to estimate CHF in each regime, are denoted by numbers in Fig. 1. As mentioned in Section 2.2, there is no equation of evaluating K in N-regime. However, if it is limited to the range of small ΔH_i within N-regime near H-regime, equation (9) may probably be used to evaluate approximately the effect of subcooling on CHF in N-regime without serious error. In this sense, approximate evaluation of CHF in N-regime will be made in this paper employing equation (9), and this is the reason why equation (9) is denoted in N-regime as well in Fig. 1.

3. PREDICTION OF $q_c - \chi_{ex}$ RELATION

3.1. *Method of calculation*

For fixed p, G, and d, the relation of $q_c - \chi_{ex}$ can be evaluated in the following way for uniformly heated tubes with various lengths within a range of inlet subcooling enthalpy. First, each diagram of Fig. 1 is in the form of l/d against $\sigma\rho_l/G^2 l$, so that if l changes for fixed d, σ, ρ_l and G, it determines an oblique line on the diagram. Three oblique lines for $G = 750$, 2000 and 4000 kg/m^2 s shown in each diagram of Fig. 1 are those thus obtained for water flowing in tubes of $d = 0.008$ m at the pressure indicated in each diagram. It is noted that as the pressure increases, the location of oblique line for the same magnitude of G moves to the left due to the decrease of σ and ρ_l; and even at the same pressure, if G increases, the oblique line moves to the left, making the change of characteristic regime through which the oblique line passes. For example, in the case of $G = 750$ kg/m^2 s in the top diagram of Fig. 1, the oblique line passes through N, H and L successively as increasing l (that is l/d), whereas in the cases of $G = 2000$ and 4000 kg/m^2 s, the oblique lines pass through N and H alone. Then, employing a set of two equations denoted in each characteristic CHF-regime, q_{co} and K can be evaluated for a given value of l (or l/d), and accordingly the relation of $q_c - \chi_{ex}$ is obtained through equations (1) and (2) for a given set of l and ΔH_i.

3.2. *Result of calculation*

In this paper, the relation of $q_c - \chi_{ex}$ for a given value of l/d is evaluated for the range of $\Delta H_i = 0$ to

*$q_{co}/GH_{fg} = 0.25/(l/d)$, which holds in L-regime for $l/d > 100$ and $\sigma\rho_l/G^2 l > 7.84 \times 10^{-4}$, is omitted here because it is unnecessary for the range dealt with in this paper.

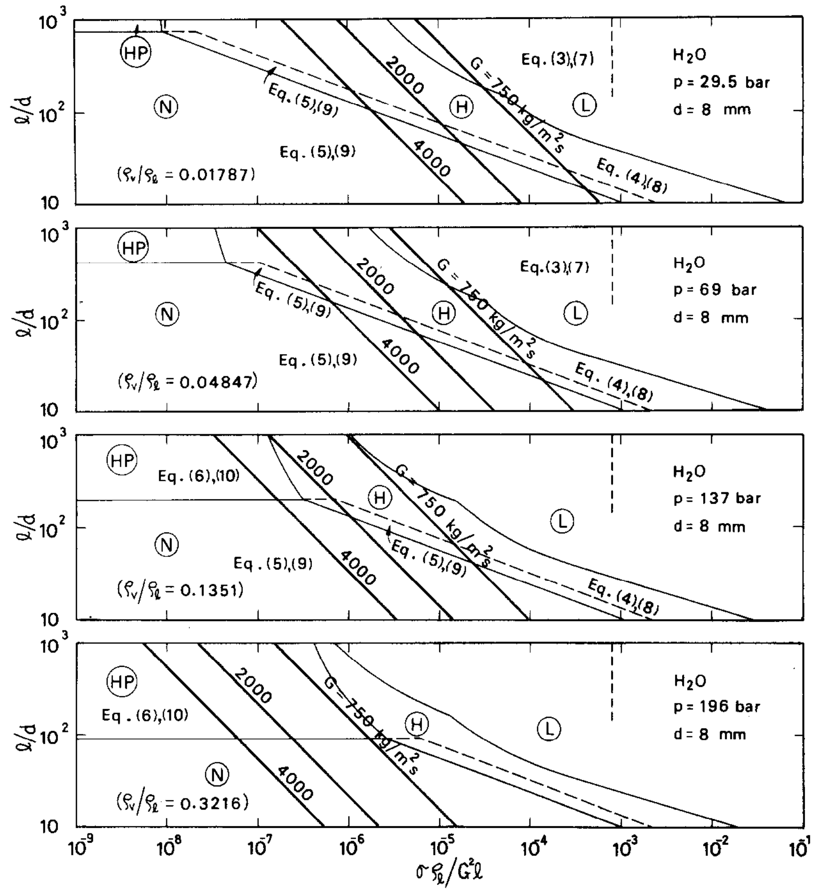

FIG. 1. CHF-regime maps for ρ_v/ρ_l = 0.01787, 0.04847, 0.1351 and 0.3216.

400 kJ/kg, with reference to the range of inlet subcooling enthalpy encountered ordinarily in the experiment of water; and the $q_c - \chi_{ex}$ relation thus determined is illustrated in the $q_c - \chi_{ex}$ diagram by a short segment of line for every prescribed value of l/d.

Now, the relations of $q_c - \chi_{ex}$ obtained for discrete values of l/d between 10 and 793 are shown in Figs. 2–5 corresponding to the respective diagrams of Fig. 1, where broken lines show CHF belonging to N-regime, thin lines to H-regime, thick lines to L-regime, and chain lines to HP-regime. In case of $G = 4000\,kg/m^2\,s$ in Fig. 4, it is noted that there is a discontinuous gap between the predictions of CHF in N-regime (l/d = 10–148) and those in HP-regime (l/d = 207–793), and it results from the author's correlation equations determined with discontinuous values of q_c and K above and below the horizontal lines separating HP- and N-regime in Fig. 1. On the other hand, in Fig. 5 are shown the prediction of $q_c - \chi_{ex}$ in HP-regime alone, because experimental data of CHF in N-regime have not yet been published for water at p = 196 bar.

4. DISCUSSION

(I) As for the relation of $q_c - \chi_{ex}$ predicted by the author's generalized correlation equations, it is noted first in Figs. 2–4 that in N-regime, where l/d is small, q_c is not a single-valued function of χ_{ex}, and the degree of dispersion of $q_c - \chi_{ex}$ relation due to l/d becomes higher as G is increased.* Second, the relation of $q_c - \chi_{ex}$ in H-regime can constitute a continuous curve approximately, and the curve has a trend to bend downward when l/d becomes very large. It may be of interest to note that all the characteristics mentioned above of N- and H-regime agree with those found by Stevens *et al.* [3] in the experiment for boiling of R-12.

Meantime, L-regime has little chance to appear in the range of conditions dealt with in this paper, only taking place when l/d is very large in case of p = 29.5–69 bar and $G = 750\,kg/m^2\,s$.

As for HP-regime, it is noted in Fig. 5 that roughly speaking, q_c has a trend of being approximately a single-valued function of χ_{ex}, and besides, q_c has a very simple relation to χ_{ex} decreasing monotonously as increasing χ_{ex}.

(II) Solid circular symbols plotted in Figs. 2–5 come

*It has been known (cf. Lee and Obertelli [4] for example) that the linear $q_c - \Delta H_i$ relationship does not hold in the range of this dispersion. Meanwhile, the author's definition of N-regime (cf. [9]) is based on the non-linear $q_c - \Delta H_i$ relationship. Thus the two ranges are identical.

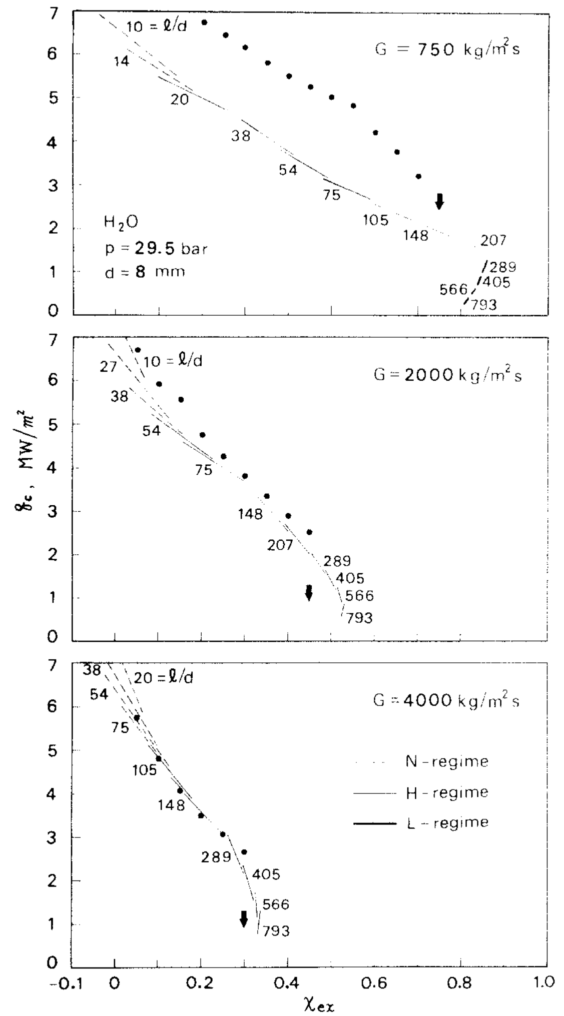

FIG. 2. Relation of $q_c - \chi_{ex}$ for water at $p = 29.5$ bar in tubes of $d = 0.008$ m.

from the U.S.S.R. standard table for the relation of $q_c - \chi_{ex}$ given for water in tubes of $d = 0.008$ m [7, 8], and χ_{ex} indicated by an arrow pointing downward in Figs. 2–4 is called "the limiting quality", depending on the assumption [8] that the relation of $q_c - \chi_{ex}$ has a flection point near this position.

Then, if the relation of $q_c - \chi_{ex}$ given by the U.S.S.R. standard table is compared with the predicted relation of $q_c - \chi_{ex}$, it is firstly noticed that disagreement is noticeable in case of $G = 750\,\mathrm{kg/m^2\,s}$ for both Figs. 2 and 3. In connection with this matter, Milan reproducibility test data for $d = 0.01$ m and $l/d = 200$ [15], which is regarded as very reliable, are shown by crosses in Fig. 3, suggesting the possibility that the standard table may give a little too high values for q_c at $G = 750\,\mathrm{kg/m^2\,s}$ of Figs. 2 and 3. Second, in case of $G = 750\,\mathrm{kg/m^2\,s}$ in Fig. 4, the arrow indicating the limiting quality is located considerably apart from the position where the predicted $q_c - \chi_{ex}$ curve bends downward, but the cause is unknown at present. Third, it is noted in Fig. 5 for HP-regime that the deviation increases to some extent between the predicted and the standard value as increasing G, and the cause is also unknown.

However, excepting the matter mentioned above, we can see a general trend that the author's generalized correlation equations may be a match for the U.S.S.R. standard table for water; and this fact may be regarded as a kind of certification to the availability of the author's generalized correlation.

(III) However, there is a problem whether the change of CHF mechanism takes place or not near the so-called limiting quality indicated by arrows in Figs. 2–4. It is postulated in the papers [7, 8, 14] that CHF which takes place in the range of χ_{ex} less than the limiting quality, shown by solid circles in Figs. 2–4, is of DNB, but near the limiting quality the mechanism of CHF changes to the dryout of liquid film on the tube wall. However, it must be noted in Figs. 2 and 3 (G = 2000–4000 kg/m² s) and in Fig. 4 (G = 2000 kg/m² s) that the q_c–χ_{ex} relation predicted by the author's correlation equations bends downward

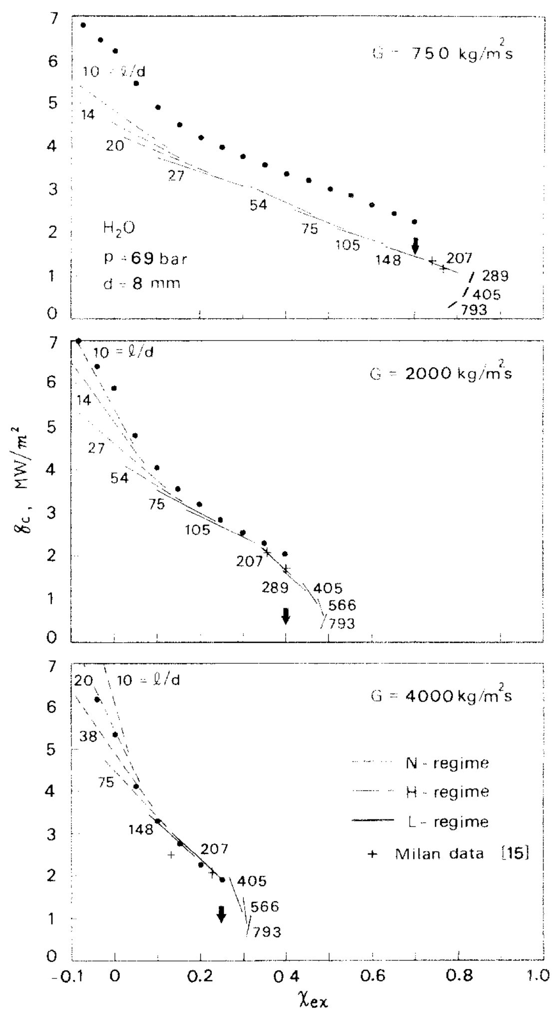

FIG. 3. Relation of $q_c - \chi_{ex}$ for water at $p = 69$ bar in tubes of $d = 0.008$ m.

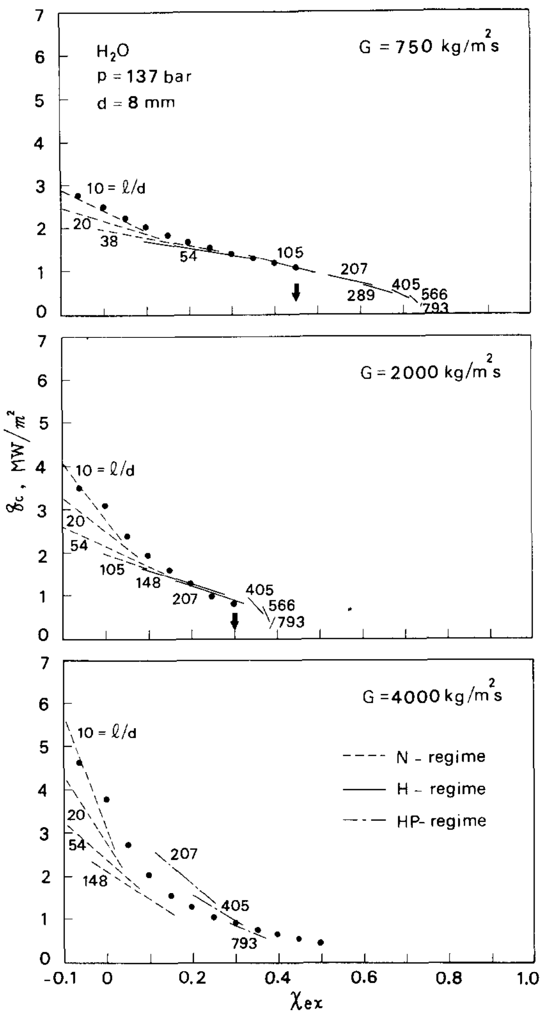

FIG. 4. Relation of $q_c - \chi_{ex}$ for water at p = 137 bar in tubes of d = 0.008 m.

near the so-called limiting quality, but H-regime remains up to l/d = 793 showing no change of CHF-regime. In addition, as mentioned in Section 2, H-regime is the regime lying between N-regime (mainly corresponding to DNB) and L-regime (mainly corresponding to dryout).

Therefore, further studies are necessary on the contradiction mentioned above, but it may not be useless to point out the following fact. Namely, as for the experiments of CHF with subcooled (and saturated in the limit) inlet conditions, there are very few existing data in H-regime for l/d > 400 (cf. [12]); and therefore, almost all experiments connecting with the concept of limiting quality are presumed to be made by employing tubes of l/d < 400 with mixed inlet conditions. In this respect, Hewitt [6] has mentioned that the generality may be questionable for the conclusions drawn from the experiments of mixed inlet conditions.

(IV) It seems customary to assume that if the length of heated tube l is increased fixing all other conditions, the rise of χ_{ex} takes place along with the fall of q_c so as to enter the state of dryout, and finally the curve of $q_c - \chi_{ex}$ should approach the point of $\chi_{ex} = 1$ and $q_c = 0$. However, there is an empirical fact relating to the study of CHF based on $q_c - \chi_{ex}$ diagram that the high χ_{ex} region such as mentioned above is rarely entered with tubes of practicable lengths in case of the subcooled inlet conditions (cf. Bennett [17], Lee [5] etc.). Besides, according to the prediction of the author's correlation equations, the relation of $q_c - \chi_{ex}$ for fixed p, G and d always, except in HP-regime, has a bend which is convex to the right (see Figs. 2–4). Therefore, there is a possibility that the customary view mentioned at the beginning of this item may not be correct in case of the subcooled inlet conditions. On this point, it should be noted that according to equation (1), when $q_c l \to 0$ for fixed d, G and H_{fg}, the exit quality $\chi_{ex} \to -\Delta H_i/H_{fg}$, where $\Delta H_i/H_{fg}$ does not become negative for subcooled or saturated inlet conditions. Thus the $q_c - \chi_{ex}$ relation predicted by the author's correlation equations in Figs. 2–5 interprets the fact that $q_c l$ tends to vanish as increasing l for L- and H-regime, whereas $q_c l$ does not vanish as increasing l for HP-regime.

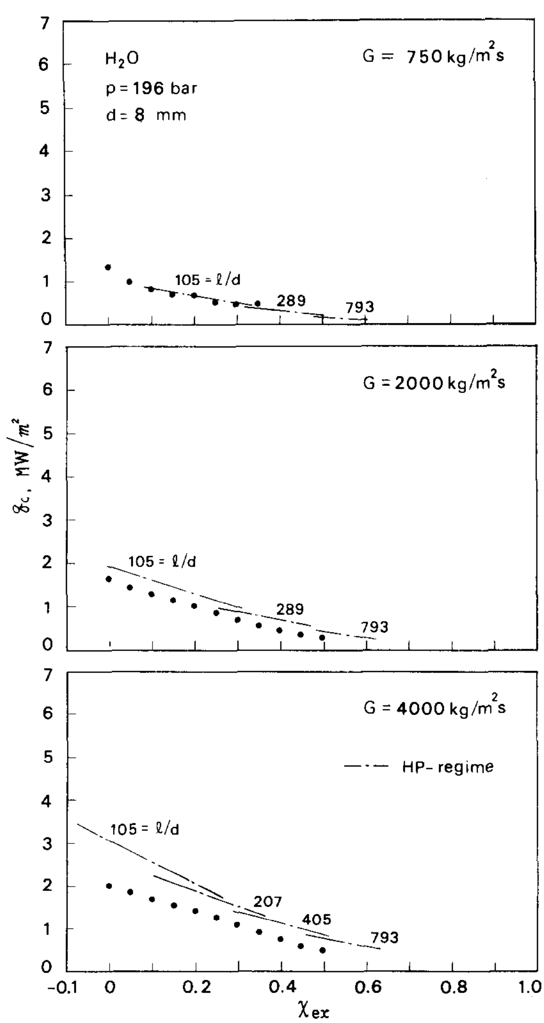

FIG. 5. Relation of $q_c - \chi_{ex}$ for water at p = 196 bar in tubes of d = 0.008 m.

5. CONCLUSIONS

With respect to the heat-flux/exit-quality type correlation of CHF, the following conclusions follow from the present study.

(i) The author's correlation equations of CHF seem available for outlining the characteristics of $q_c - \chi_{ex}$ type correlation in case of subcooled inlet conditions.

(ii) There are a few contradictions or disagreements between the customary views related to the $q_c - \chi_{ex}$ type correlation and the prediction of the author's correlation equations.

(iii) The $q_c - \chi_{ex}$ type correlation may not be a way adequate for presuming the mechanism of CHF, because it is subject to the ambiguity due to the intrinsic dependence of χ_{ex} upon q_c as seen in equations (1) and (2).

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REFERENCES

1. J. C. Collier, *Convective Boiling and Condensation*, p. 246. McGraw-Hill, New York (1972).
2. P. G. Barnett, An investigation into the validity of certain hypothesis implied by various burnout correlations, UKAEA, AEEW-R 214 (1963).
3. G. F. Stevens, D. F. Elliott and R. W. Wood, An experimental investigation into forced convection burn-out in Freon, with reference to burn-out in water, uniformly heated round tubes with vertical up-flow, UKAEA, AEEW-R 321 (1964).
4. D. H. Lee and J. D. Obertelli, An experimental investigation of burn-out with forced convection high-pressure water, *Proc. Instn Mech. Engrs* **180**(3C), 27–36 (1965–66).
5. D. H. Lee, Prediction of burnout, in *Two-Phase Flow and Heat Transfer*, edited by D. Butterworth and G. F. Hewitt, p. 295. Oxford University Press, Oxford (1977).
6. G. F. Hewitt, Critical heat flux in flow boiling, in *Heat Transfer 1978*, Vol. 6, pp. 143–171. National Research Council of Canada (1978).
7. Heat Mass Transfer Section, Scientific Council, Academy of Sciences, U.S.S.R., Tabular data for calculating burnout when boiling water in uniformly heated round tubes, *Thermal Engng* **23**(9), 77–79 (1977).
8. Scientific Council of U.S.S.R. Academy of Sciences, Recommendations on calculating burnout when boiling water in uniformly heated round tubes, BTD OKB IVTAN, Moscow (1975). (In Russian.)
9. Y. Katto, A generalized correlation of critical heat flux for the forced convection boiling in vertical uniformly heated round tubes, *Int. J. Heat Mass Transfer* **21**, 1527–1542 (1978).
10. Y. Katto, A generalized correlation of critical heat flux for the forced convection boiling in vertical uniformly heated round tubes — a supplementary report, *Int. J. Heat Mass Transfer* **22**, 783–794 (1979).
11. Y. Katto, An analysis of the effect of inlet subcooling on critical heat flux of forced convection boiling in vertical uniformly heated tubes, *Int. J. Heat Mass Transfer* **22**, 1567–1575 (1979).
12. Y. Katto, General features of CHF of forced convection boiling in uniformly heated vertical tubes with zero inlet subcooling, *Int. J. Heat Mass Transfer* **23**, 493–504 (1980).
13. Y. Katto, Critical heat flux of forced convection boiling in uniformly heated vertical tubes (Correlation of CHF in HP-regime and determination of CHF-regime map), *Int. J. Heat Mass Transfer* **23**, 1573–1580 (1980).
14. V. E. Doroschuk, L. L. Levitan and F. P. Lantzman, Investigation into burnout in uniformly heated tubes, ASME Paper, No. 75-WA/HT-22 (1975).
15. Exercise on reproducibility of critical heat flux data, in 1970 Meeting of the European Two-Phase Flow Group (8–11 June, 1970). As quoted in [16].
16. K. M. Becker, J. Bager and D. Djursing, Burnout correlations in simple geometrics: most recent assessments, in Seminar on Two-Phase Flow Thermodynamics, Rome, pp. 51–91 (9 June, 1972).
17. A. W. Bennett, G. F. Hewitt, H. A. Kearsey, R. K. F. Keeys and D. J. Pulling, Studies of burnout in boiling heat transfer, *Trans. Instn Chem. Engrs* **45**, T319–T333 (1967).

SUR LA RELATION TYPE DE CHF FLUX THERMIQUE/QUALITE DE LA VAPEUR A LA SORTIE POUR L'EBULLITION AVEC CONVECTION FORCEE DANS DES TUBES CHAUFFES ET VERTICAUX

Résumé — On essaie d'utiliser des formules générales de CHF proposées récemment par l'auteur pour prédire les relations classiques entre le flux thermique critique q_c et la qualité en sortie χ_{ex} quand la longueur du tube 1 et l'enthalpie de sous-refroidissement ΔH_i à l'entrée varient, la pression p, la vitesse massique G et le diamètre de tube d étant fixée. Un calcul numérique est fait pour l'eau sous les conditions p = 29,5 à 196 bar, G = 750 à 4000 kg/m^2 s, d = 0,008 m, $1/d$ = 10 à 793 et ΔH_i = 0 à 400 kJ/kg.

Le résultat est comparé avec la table standard de $q_c - \chi_{ex}$ publiée récemment par la Section de transfert de chaleur et de masse de l'Académie des Sciences U.R.S.S. pour l'eau dans des tubes chauffés uniformément avec d = 0,008 m; on discute la relation type $q_c - \chi_{ex}$.

BERECHNUNG DER KRITISCHEN WÄRMESTROMDICHTE BEIM STRÖMUNGSSIEDEN IN GLEICHMÄßIG BEHEIZTEN SENKRECHTEN ROHREN MIT GLEICHUNGEN, BEI DENEN DIE WÄRMESTROMDICHTE VON DAMPFGEHALT AM ROHRAUSTRITT ABHÄNGT

Zusammenfassung—In diesem Aufsatz wird versucht, verallgemeinerte Gleichungen zur Berechnung der kritischen Wärmestromdichte anzuwenden. Die Gleichungen hat der Autor in jüngster Zeit vorgeschlagen, um den bekannten Zusammenhang anzugeben, welcher zwischen der kritischen Wärmestromdichte q_c und dem Dampfgehalt am Rohraustritt χ_{ex} besteht, wenn die Rohrlänge L und die Unterkühlungsenthalpie ΔH_i

verändert werden, bei gleichbleibenden Werten des Druckes p, der Massenstromdichte G und des Rohrdurchmessers d.

Numerische Berechnungen werden für Wasser durchgeführt; die Bedingungen sind $29{,}5 < p < 196$ bar, $750 < G < 4000$ kg/m^2 s, $d = 0{,}008$ m, $10 < L/D < 793$ und $0 < \Delta H_i < 400$ kJ/kg. Anschließend werden die Ergebnisse verglichen mit den Werten der Tabelle für q_c (χ_{ex}), welche kürzlich von der Wärme- und Stoffübertragungsabteilung der Sowjetischen Akademie der Wissenschaften veröffentlicht wurde. Sie gilt für Wasser in gleichmäßig beheizten Rohren mit $d = 0{,}008$ m. Es werden die Eigenschaften des Gleichungstyps $q_c f(\chi_{ex})$ diskutiert.

О ЗАВИСИМОСТИ ТИПА «ПЛОТНОСТЬ ТЕПЛОВОГО ПОТОКА — ПАРОСОДЕРЖАНИЕ НА ВЫХОДЕ» ДЛЯ КРИТИЧЕСКОГО ТЕПЛОВОГО ПОТОКА В СЛУЧАЕ КИПЕНИЯ ПРИ ВЫНУЖДЕННОЙ КОНВЕКЦИИ В РАВНОМЕРНО НАГРЕВАЕМЫХ ВЕРТИКАЛЬНЫХ ТРУБАХ

Аннотация — Предпринята попытка использовать обобщенные соотношения для критического теплового потока, предложенные ранее автором для расчета зависимости критического теплового потока q_c от паросодержания на выходе χ_{ex} в случае, когда длина трубы l и энтальпия недогрева на входе ΔH_i изменяются при постоянных давлении, массовой скорости и диаметре трубы d. Проведены численные расчеты для воды в следующих диапазонах изменения величин: $p = 29{,}5$–196 бар, $G = 750$–4000 кг/м^{2}сек, $d = 0{,}008$ м, $l/d = 10$–793 и $\Delta H_i = 0$–400 кДж/кг. Дано сравнение полученных значений со стандартной таблицей $q_c - \chi_{ex}$, опубликованной недавно Отделением тепломассообмена АН СССР для воды в равномерно нагреваемых трубах диаметром $d = 0{,}008$ м. Тем самым проведена оценка зависимостей типа $q_c - \chi_{ex}$.