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SHORTER COMMUNICATIONS

POOL BOILING CRITICAL HEAT FLUXES IN SLOWLY VARIABLE TRANSIENT STATES

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NOMENCLATURE

R_s, resistance of the sample;
V_s, voltage drop in the sample;
τ_p, permanence time of nucleate boiling;
τ_r, rise time;
φ, heat flux;
φ_{cr}, critical heat flux;
φ_{st}, critical heat flux in steady state conditions.

INTRODUCTION

THE CRITICAL heat flux under transient conditions has been recently investigated by several authors [1–9]. In these studies, the experiments have been carried out with the power increasing in different ways (linear, exponential, or even in more sophisticated ways), and values of φ_{cr} higher than those observed in steady state conditions have been reported. However, in all cases involving pool boiling conditions, [1–6], the duration of the transient investigated has been relatively short (with a maximum of a few tenths of seconds).

Some of the results obtained in a previous study [10], have suggested that a similar increase of φ_{cr} exists even for power transients of longer duration; that is, of the order of tens of seconds. The purpose of the present work is to confirm such an indication.

MATERIALS AND METHODS

The experiments have been performed in distilled, deaerated and saturated water, at atmospheric pressure. The test section was made of horizontally orientated, calibrated wires of constantan, diameter 0·25 mm and length 200 mm. The power supply is designed to produce a linear increase in time of the d.c. voltage applied to the sample, according to the desired increase rate, so obtaining a quadratic increase of the power with time. The latter was estimated by measuring the resistance R_s and recording the voltage drop V_s between the extremities of the sample.

Each sample was used for several tests (no more than ten) but, since the values of φ_{cr} for the first crisis are remarkably different from those for the following crises [10, 11], the values for the first crisis were disregarded. However, care was taken that, during the first crisis, film boiling encompassed the entire wire.

The critical heat flux was tested by increasing the power supplied to the sample from zero.

The beam of a gas laser was oriented on the wire in such a way that it was almost completely intercepted; the fraction of the beam which was not intercepted was monitored by a photoelectric cell. As soon as the thermal crisis happened and the temperature started to increase the wire started to lengthen and to bend simultaneously due to the increase in temperature. Consequently, the fraction of the laser beam intercepted lessens and the cell signal rises; the power supply is then switched off. The records of V_s and of the cell signal are synchronized; the value of the power at the time of starting rise of the cell signal has been employed for the φ_{cr} computations.

Several determinations of the "steady state" critical flux φ_{st} were also carried out. They were obtained by increasing the power in discreet increments of less than 2 per cent of the expected value of φ_{st} and at intervals of 2 min.

The overall error for φ_{cr} measurement can be assumed at less than 5 per cent.

RESULTS

The results are shown in Fig. 1, where the values of φ_{cr} are reported as a function of the rise time τ_r from $\varphi = 0$ to $\varphi = \varphi_{cr}$. In the same figure, the results of the tests for the "steady state" critical heat flux φ_{st} are reported in the form of a histogram. The figure shows a large spread ($\pm$10–15 per cent) of the values observed for both φ_{cr} and φ_{st}. However, both the mean and the minimal values of φ_{cr} decrease with the increasing of τ_r up to values of 2 min; thereafter φ_{cr} remains constant around values quite similar to the steady-state values.

There is a decrease of 25 per cent of the (mean and minimal) values of φ_{cr} with τ_r varying from 10 to 130 s.

Further tests have been performed for three different voltage increment rates (Fig. 1, curves a, b, c). In these tests, the value of the heat flux was arrested and maintained at values of φ between the highest values observed of φ_{st} and the lowest of φ_{cr} for the given voltage increment rate, and the permanence time τ_p of the nucleate boiling before the crisis was measured. The τ_p value varies in a nearly random way, for all cases tested, from few tenths to a few tens of seconds.

CONCLUSIONS

Under the described experimental conditions, it seems that the values of the critical heat flux are on average higher than those relative to the steady state if the duration of the transient is of 2 min or less. For the shortest transients tested (10 s) the difference between the transient and steady values of φ_{cr} reaches 25 per cent.

However, if the power rise is stopped and heat flux maintained at values between the highest steady values and the lowest observed values of φ_{cr} for the given increment rate, there is not any reliable significant permanence time of nucleate boiling. Therefore, it should be concluded that the observed trend for φ_{cr} are of little relevance for practical applications; on the contrary, it seems to be important mainly with regard to the problems of critical heat flux measurements.

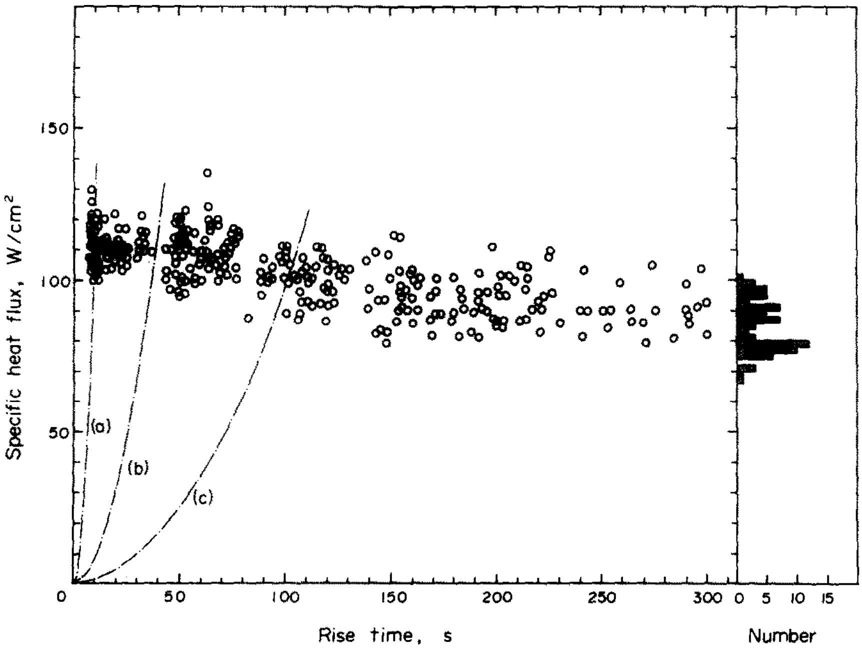

FIG. 1. Plot of φ_{cr} as a function of τ_r. The histogram shows the values of φ_{st}.

REFERENCES

1. R. Cole, Investigation of transient pool boiling due to sudden large power surge, NACA Technical Note No. 3885 (1956).
2. W. B. Hall and W. G. Harrison, Transient boiling of water at atmospheric pressure, Proc. 3rd Int. Heat Transfer Conf., Abstract 11, Chicago (1966).
3. H. Kawamura, F. Tachibana and M. Akiyama, Heat transfer and DNB heat flux in transient boiling, Proc. 4th Int. Heat Transfer Conf., Abstract B3.3, Paris (1970).
4. M. W. Rosenthal and R. L. Miller, An experimental study of transient boiling, Oak Ridge Nat. Lab. Publication No. 2294, Oak Ridge, Tenn. (1957).
5. A. Sakurai, K. Mizukami and M. Shiotsu, Experimental studies on transient boiling heat transfer and burnout, Proc. 4th Int. Heat Transfer Conf., Abstract B3.4, Paris (1970).
6. F. Tachibana, M. Akiyama and H. Kawamura, Heat transfer and critical heat flux in transient boiling, *J. Nucl. Sci. Technol.* **5**, 3 (1968).
7. H. A. Johnson, Transient boiling heat transfer, Proc. 4th Int. Heat Transfer Conf., Abstract B3.1, Paris (1970).
8. D. P. Jordan, The pressure drop and void volume during subcooled boiling of water with forced convection at atmospheric pressure, Ph.D. Thesis, Stanford University (1961).
9. R. Roemer, The effect of power transients on the peak heat flux, *Int. J. Heat Mass Transfer* **12**, 953–964 (1969).
10. D. M. Fontana, Ebollizione su fili metallici: Influenza della natura del materiale metallico sul flusso di burnout nella ebollizione satura in convezione naturale, Ricerche di Termotecnica No. 20 (1971).
11. L. S. Tong, *Boiling Heat Transfer and Two-Phase Flow*. John Wiley, New York (1965).