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THE TAYLOR WAVE CONFIGURATION DURING BOILING FROM A FLAT PLATE

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DURING the development of the hydrodynamic theory of the peak and minimum pool boiling heat flux there have lingered certain questions about the Taylor wavelength in the liquid–vapor interface and the spacing of the grid of jets or bubble release nodes.

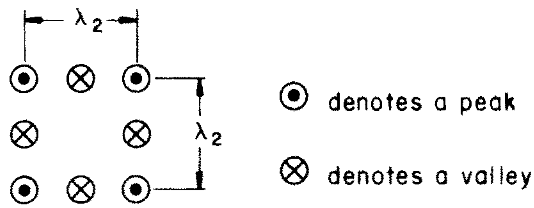
Zuber [1] originally used the most susceptible two-dimensional Taylor wavelength, λ_2, in his analysis. He envisioned that the vapor jets, which become Helmholtz unstable at the peak heat flux, were spaced on a square grid of dimensions $\lambda_2 \times \lambda_2$. His arrangement is shown in Fig. 1a. He envisioned that the minimum heat flux occurred when the cyclic release of bubbles from the peaks of such a grid reached its minimum stable frequency.

There are two problems with this formulation. One is the use of λ_2 instead of the correct three-dimensional wavelength. The other lies in counting the wave peaks for a particular grid. Let us consider the latter problem first.

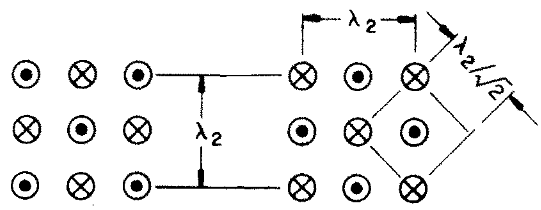
If two-dimensional waves are superposed orthogonally they will actually yield the configuration shown in Fig. 1b. We see that there should be an additional peak in the center. Thus Zuber's original conceptualization would appear to be correct only for a square grid of dimensions $\lambda_2/\sqrt{2}$ as shown in Fig. 1b.

Recently Sernas [2] derived the expression for the length of a true three-dimensional Taylor wave. He found that the interface took the form shown in Fig. 1c with a three dimensional wave of length, $\lambda_3 = \sqrt{2}\lambda_2$. This result is extremely fortuitous because it shows that the square grid corresponding with Zuber's assumption actually has peaks distributed just as he assumed they were—on a wavelength equal to λ_2 (see Fig. 1c). There exists one piece of experimental evidence to support this outcome for a flat plate. It is shown in the authors' closure of [3] that Hosler and Westwater's photographic results [4] give a wavelength almost exactly equal to λ_2 or $\lambda_3/\sqrt{2}$.

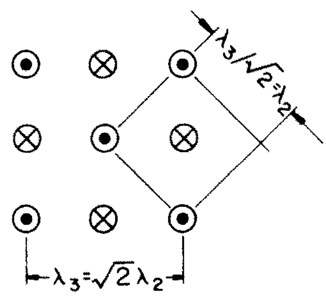
Thus it is correct to assume (as Zuber did) that there is one Helmholtz unstable jet per λ_2^2 at the peak heat flux and



(a) Zuber's two-dimensional model.



(b) Actual result of superposing two-dimensional waves. Two arrangements show the same interface, displaced one-half cycle in time.



(c) Dimensions of a true three-dimensional interface.

FIG. 1. Top views of liquid–vapor interfaces showing peak and valleys due to Taylor instability.

that 2 bubbles are released per λ_2^2 and per cycle during film boiling. It is not necessary to consider a second jet in the center of the grid as suggested by Fig. 1b. Statements by Dhir [5] and Lienhard [6] correcting the area from λ_2^2 to $\lambda_2^2/2$ are in fact not correct. And Sernas' [2] direct use of λ_3 in Zuber's flat plate model overestimated q_{min}.

There exist a number of papers dealing with the two-dimensional Taylor waves above horizontal cylinders (see e.g. [7]). These studies are unaffected by the present discussion since they involve a truly unidimensional configuration.

REFERENCES

1. N. Zuber, Hydrodynamic aspects of boiling heat transfer, AEC Rept. No. AECU-4439, Physics and Mathematics (1959).
2. V. Sernas, Minimum heat flux in film boiling—a three dimensional model, *Proc. Second Canadian Cong. of App. Mech.*, University of Waterloo, Canada, 19–23 May (1969).
3. J. H. Lienhard and V. E. Schrock, The effect of pressure, geometry, and the equation of state upon the peak and minimum boiling heat flux, *J. Heat Transfer* **85**, 261 (1963).
4. E. R. Hosler and J. W. Westwater, Film boiling on a horizontal plate, *ARS Jl* **32** (4), 553 (1962).
5. V. Dhir, Some notes on the development of the hydrodynamic theory of boiling, (based on 3 lectures by J. H. Lienhard), University of Kentucky, College of Engineering, Tech. Rept. UKY-19-70-ME-6 (March 1970).
6. V. Dhir and J. H. Lienhard, The influence of viscosity and other system variables upon the Taylor wavelength in pool boiling, XVth Siberian Thermophysical Seminar on Critical Phenomena in Two-Phase Systems, Novosibirsk, USSR (May 1972).
7. J. H. Lienhard and K. H. Sun, Effects of gravity and size upon film boiling from horizontal cylinders, *J. Heat Transfer* **92** (2), 292 (1970).