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A DIAMETRAL EFFECT ON VAPOUR COLUMN FORMATIONS IN FILM BOILING IN CARBON DIOXIDE NEAR THE CRITICAL STATE

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1. INTRODUCTION

IN A RECENT article [1] conclusions were drawn and interesting photographic evidence produced concerning the phenomena of uprising vapour in columns. The present communication describes early visual observations of an ongoing investigation, and the authors feel obliged to comment on the conflicting evidence of the diametral effect on the dominant Taylor wavelength λ, which is the measured distance between rising vapour columns in film boiling.

2. EXPERIMENT

The present note reports on one geometry, namely a horizontal stainless steel tube, arranged in a cylindrical test chamber which incorporates glass windows so situated as to enable flow visualization. The optical arrangement adopted for the schlieren type experiment is shown in Fig. 1. Light is transmitted from a simple filament source through a collimating lens, to provide a light beam which is transmitted through the fluid and a second lens, and finally on to a knife edge positioned to eliminate the direct image of the source; the desired image is focussed in the camera.

Carbon dioxide is supplied from commercial bottles, equipped with a syphon tube, and warm water is passed through passages in the test vessel until the pressure reaches some predetermined level. A standard Bourdon type test gauge is used to measure gauge pressure, and the bulk temperature is measured by a number of chromel/alumel thermocouples. The tube surface temperature is determined by monitoring the tube internal temperature history using fine chromel/alumel thermocouples, and computing the external surface temperature in both radial and axial directions. The thermocouple outputs are recorded on a Tinsley potentiometer.

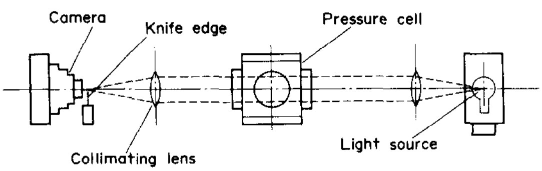

FIG. 1. Simple Schlieren optical arrangement.

3. RESULTS

It is well known that film boiling in the critical region results in various characteristic shapes of the uprising vapour: bubbles, columns and sheets, and that the characteristic Taylor wavelength is strongly dependent on the pressure and wire diameter. The authors wish to draw attention to the latter effect. The photograph, Fig. 2, shows vapour column formations in bulk conditions of 0·98 reduced pressure and 30·5°C on a stainless steel tube 1·07 mm dia., it is regretted that the heat flow data were not available. The significant feature is the uniformity of the column spacing λ, which appears to contradict the observations of [1] in which it was concluded that the observed column spacing was quite uniform for the smaller 0·1 mm dia. wire and irregular for the largest, 0·38 mm wire. The same uniformity as exemplified in Fig. 2 was achieved at various other bulk conditions, and the formation of the columns followed closely Zuber's idealized model in which columns of vapour, formed by the coalescence of a large number of

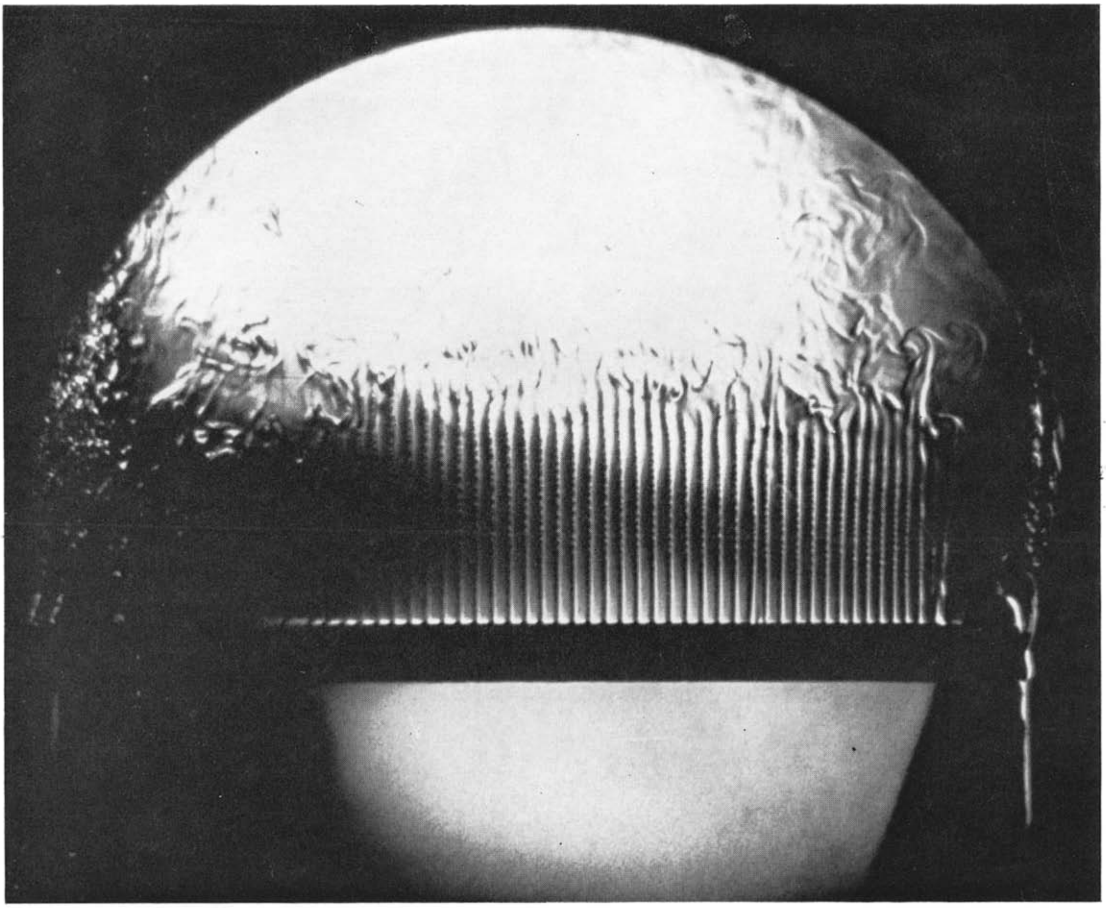

FIG. 2. Vapour column formations in film boiling heat transfer to carbon dioxide near the critical point. Reduced pressure—0·98 Bulk temperature—30·5°C

bubbles, rise from the heated surface to be replaced by a liquid jet. The condition is hydrodynamically unstable and the Taylor and Helmholtz's instability criteria serve to establish the separation of the columns and the critical velocity for mass balance.

4. CONCLUSION

This note describes early visual observations of the phenomenon of uprising vapour columns in near-critical, two-phase carbon dioxide. The authors feel that, although the investigation is not complete, the contribution illustrates evidence of regular column formations for a wire diameter larger than investigated in [1], suggesting a diametral effect which contradicts the relevant conclusion drawn in that paper.

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