Convection Currents in an Unstable Layer of Fluid studied by Optical Methods.

THE convection currents set up in a thin horizontal layer of a liquid by an unstable distribution of density have been studied experimentally by many investigators. Following Bénard, the usual method of making the movements visible is to mix with the liquid fine particles of some shining substances such as aluminium or "gold" paint. Simple optical methods enable the phenomena to be studied in much greater detail.

A horizontal layer of liquid is obtained by floating it on clean mercury. The surface of a volatile liquid like ether or alcohol cools rapidly by evaporation resulting in an unstable distribution of density. With less volatile liquids, instability can be produced by placing the tray of mercury on a flat heater. If we reflect the divergent beam of light coming from a point source of light at the mercury surface at nearly normal incidence and receive the reflected beam on a screen, a pattern is formed on the screen showing the local deviations of optical thickness of the evaporating layer. Bright points and lines correspond to convergence of beam (cooler liquid or increased thickness) and dark points and lines to divergence. The liquid behaves as a composite lens backed by a plane reflector.

Figs. 1 to 5 show the successive stages of the appearance of the pattern on the screen as a layer of ether floating on mercury gradually gets thinner. When the layer is more than 4 mm. thick, prominent dark canals and rapidly moving thin bright filaments make their appearance. The former are regions at which the liquid ascends. When the thickness is 2–3 mm., the bright filaments converge to a series of lines or points surrounded by the dark canals. As the film gets thinner, the movement becomes less brisk, the dark canals get narrower and the bright spots in the middle of the cells get more concentrated and become connected together by bright lines. After a certain stage, the dark lines become invisible, but

Fig. 1.
Ether; thickness c, 7 mm.

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Fig. 2.
Ether, thickness c. 3 mm.

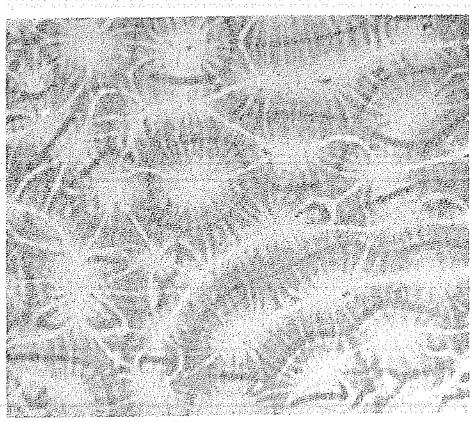

Fig. 3.
Ether; thickness c. 2 mm.

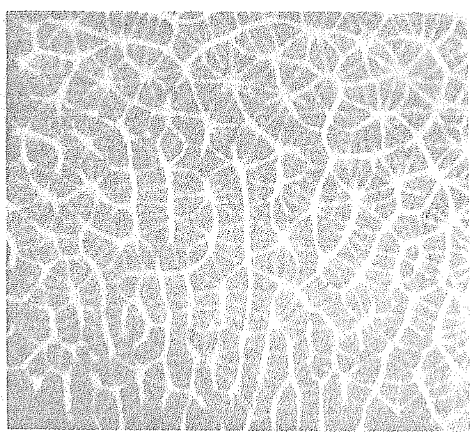

Fig. 4.
Ether; thickness c. 1 mm,

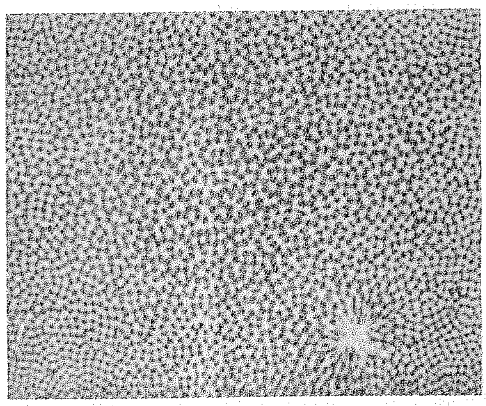

Fig. 5.
Ether; thickness c. 0·2 mm.

in this condition also, we have ascending movement in the middle of each bright-bordered cell and convergence and descending movement at the boundaries. A noteworthy feature of the vertical circulation in each individual cell is that the movement in the upper level is much more rapid than in the lower. This is easily verified by observation of floating specks of dust. As the film approaches the vanishing stage, the field is covered by a net-work of alternately bright and dark cells and just before vanishing, the film becomes continuous.

If instead of ether, we use a less volatile (and also more viscous) liquid like carbon tetrachloride, the movements are generally more sluggish but the sequence of changes is essentially the same; when the liquid layer is very thin, it divides itself into remarkably regular hexagons (Fig. 6). The regularity is

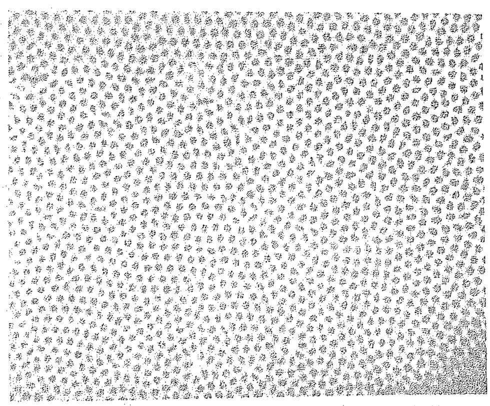

Fig. 6.
Carbon tetrachloride; thickness c. 0·2 mm.

dependent on a proper balance between density-gradient and viscosity.

If the unstable liquid has a translatory movement, the cells arrange themselves along the line of movement accompanied by characteristic changes of shape. Figs. 7 and 8 obtained with carbon tetrachloride

Fig. 7.

CCl_4 moving towards the right.

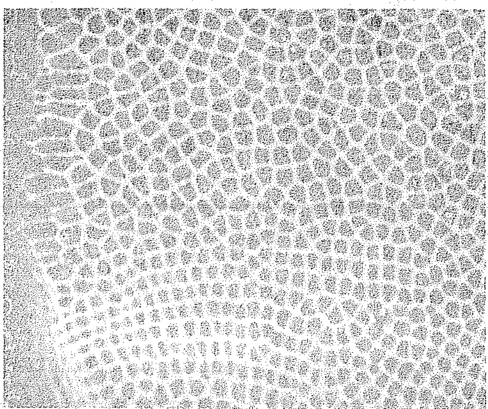

Fig. 8.

CCl_4 moving towards the right.

illustrate this. Their similarity to cloud forms has been studied by Mal, Walker, Phillips and others.

The influence of temperature-gradient, viscosity and heat-conditions of the liquid in determining the instability and the patterns of cell-structure is being investigated in the light of theories developed by Lord Rayleigh and H. Jeffreys. The Schlieren method can also be used to show up the cells, but the shadow method is simpler. Attempts are being made to apply these methods to study the vortices in gases.

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