New Experiments on Convection: The Formation of Ring Cells

By H. v. Tippelskirch*)

Summary

The following investigation was carried out for the *Flug-meteorologisches Institut der Deutschen Forschungsanstalt für Segelflug* in Munich-Riem which is under the direction of Prof. H. Koschmieder. It is concerned with the experimental demonstration of a convectional motion, hitherto not investigated, about which Zierep first reported on the basis of a special solution of the Rayleigh-Jeffreys theory. The particular feature of this motion is its appearance when local instability acts together with instability extended over an area in a fluid layer covering the plane.

Zierep considered a fluid layer with critical vertical temperature gradient. In this layer he obtained a system of concentric annular (toroid) cells around the point of instability which was situated at the lower boundary. The flow in the cells is in the same direction at the common boundary surfaces, and the velocity decreases with increasing distance from the point of instability. The diameter of the cells can be found by an eigen value problem.

The purpose of this investigation was to demonstrate this flow experimentally. Further, observations have been made which are no longer based on Zierep's theory, but which concern uniquely the same flow problem. These observations show that the annular cells represent a special case of a convection current system for which the notation "toroid cells" introduced by Zierep will be used generally. In particular it could be shown:

1) The geometric from of the toroid cells is determined by the form of the local instability area, that is by the geometric configuration of the heat source activating the instability.

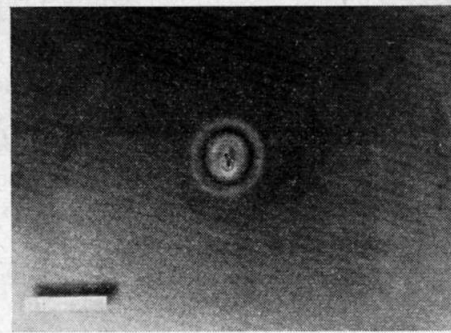2) The flow in the toroid cells has the properties assumed by Zierep.
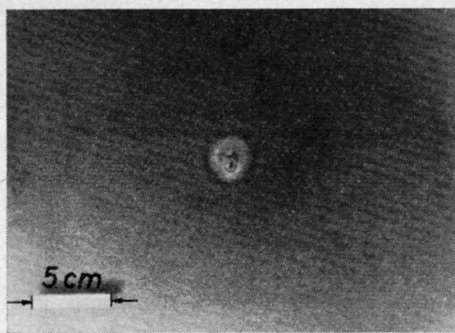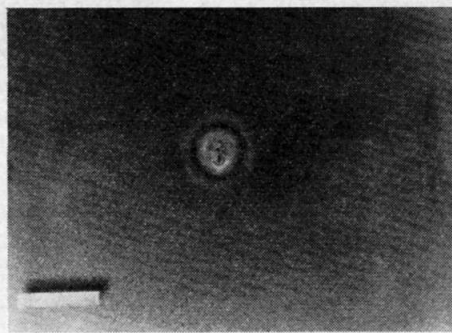
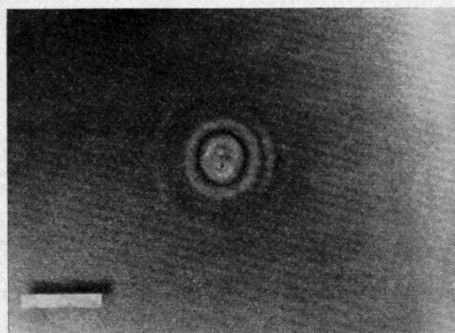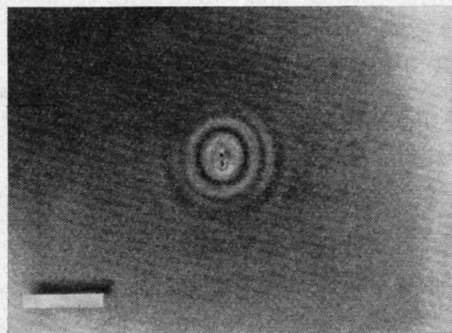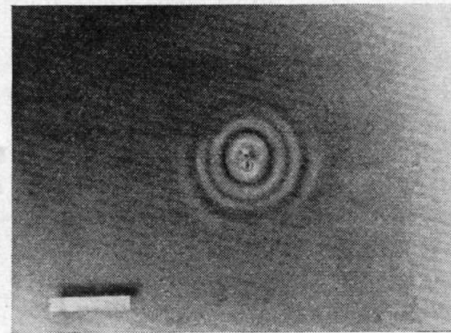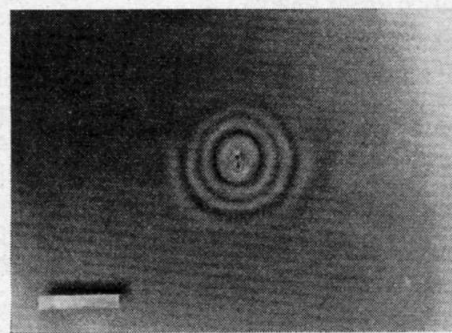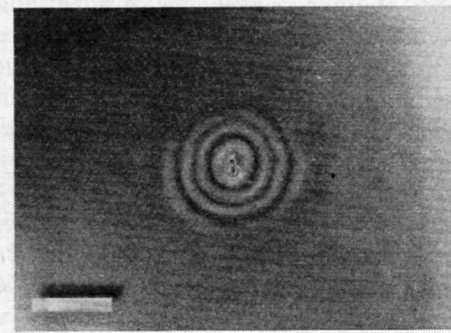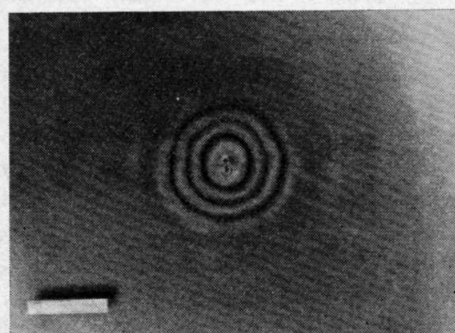The development of ring alls over a heated point source. Duration: 49 minutes. Fixed boundaries on top and bottom. Layer depth = 10 mm. Mean temperature = 25° C Temperature difference between top and bottom = 3° C. Paraffin oil

3) With less than critical stratification according to Rayleigh the horizontal temperature gradient determines the onset of the toroid flow.

The magnitude of the vertical temperature gradient determines the number of cells and the speed of their formation. Above the critical vertical temperature gradient according to Rayleigh the flow is not persistent, but changes into the Bénard flow as far as the experiments show. Also below this gradient the flow cannot persist when the horizontal temperature gradient is below a certain not yet determined value which depends on the magnitude of the vertical gradient (see fig.).

Reference: J. Zierep, Zur Theorie der Zellularkonvektionsströmung. Beitr. Phys. Atmos. 32 (1959).