EXPERIMENTAL STUDY OF BINARY FLUID CONVECTION IN A QUASI 1-DIMENSIONAL CELL WITHOUT REFLECTIONS FROM THE SIDEWALLS

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With properly chosen parameters, convection in binary fluid mixtures sets in via a Hopf bifurcation leading to travelling waves. In this case one has to distinguish between a convectively unstable and an absolutely unstable situation. We present an observation in a cell where the fluid becomes unstable at the absolute instability point, not at the convective one as in most other experiments. This is done by preventing the sides of the cell from reflecting the travelling wave.

The experimental setup has been described elsewhere (Rehberg et al., 1987, Rehberg et al., 1988). The convection channel is cut out of a copper plate (Fig. 1). The bulk part of the channel is 3 mm high, 1.5 mm thick, and 18 mm long. The ramps adjacent to this central part decrease the height of the channel from 3 mm to 1 mm over a length of 26 mm by means of a parabolic curvature of the top and bottom. The bottom of the copper plate is heated by an electric heater and the top of the cell is kept at a constant temperature by a water circuit controlled better than ±0.01 °C. We have chosen such a thin cell in order to prevent three dimensional

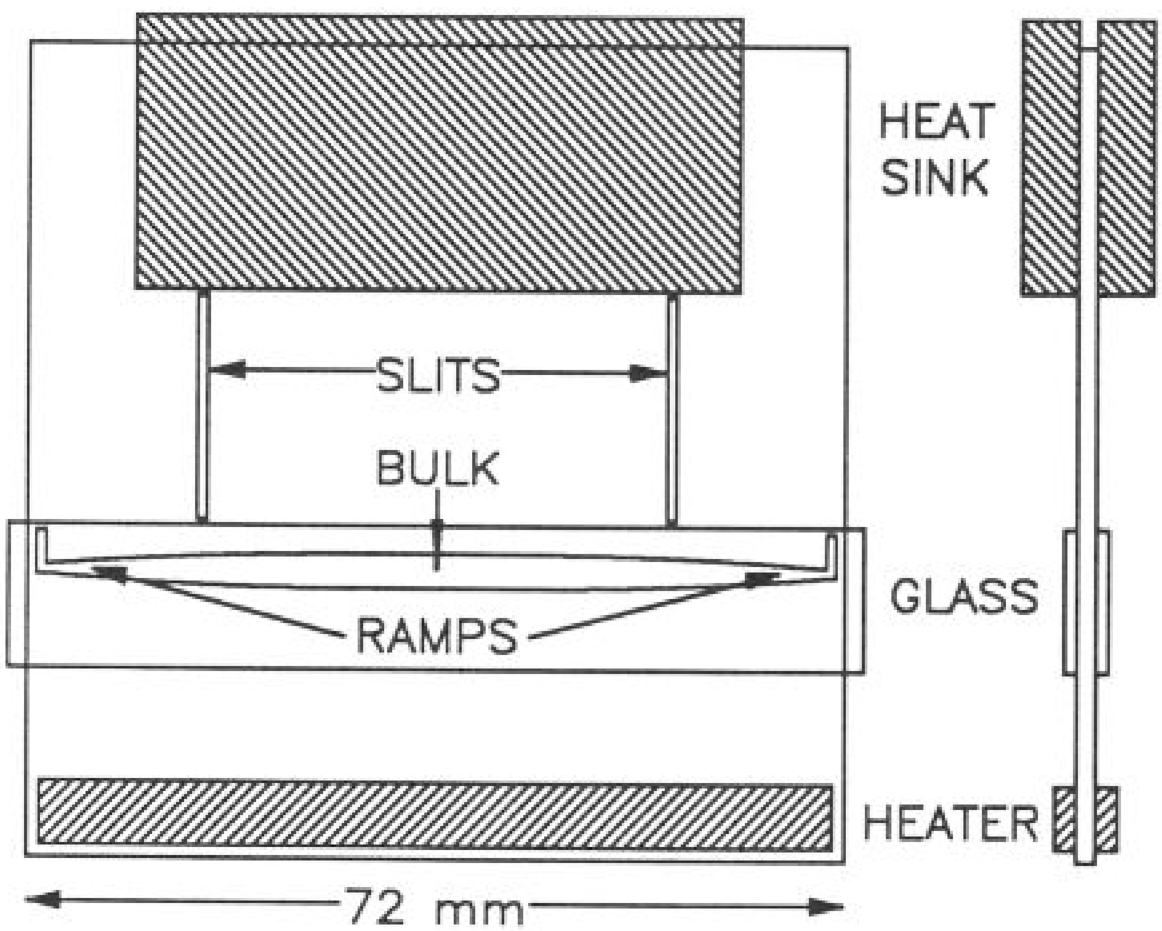

Fig. 1. The convection channel is cut out of a copper plate of $72x72x1.5\ mm^3$.

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effects. The purpose of the parabolic subcritical ramps in this experiment is to decrease the amplitude of the waves travelling into this ramp smoothly to zero because the systems becomes subcritical near the right and left sidewalls. So the convection dies out and we got no hint for any reflection from these walls. Our working fluid is a mixture of 16.98 wt.% of ethanol in water at a mean temperature of about 30 °C. To visualize the flow field we used the shadowgraph technique (Rasenat et al., 1989).

When heating from below convection sets in via a backward Hopf bifurcation as is well understood (Schöpf 1988, Schöpf et al., 1989). This leads to a hysteresis in the bifurcation diagram as shown in Fig. 2. Here the amplitude of the convection is shown as a function of the temperature difference between the top and the bottom of the convection channel. When increasing the applied temperature difference, stability is lost with respect to overturning convection at ΔT = 10.12 K, and cooling down again the convection vanishes at the saddle node at ΔT = 8.84 K. The important feature of this picture is the fact that this convection onset is well above the convective instability point, which is the generic one from linear stability analysis of the fundamental hydrodynamic equations (Knobloch et al., 1988, Cross et al., 1988, Schöpf 1988). This convective instability point is observed in most of the experiments, where small disturbances are able to grow and finally the entire convection cell is filled with rolls (Kolodner et al., 1986, Moses et al., 1986, Heinrichs et al., 1987, Kolodner et al., 1988). We are able to determine it by measuring the growth rate of pulses of travelling waves which are the answer of the system to applied heat pulses, similar to the procedure described by Kolodner et al. (1987). The system gets convectively unstable at a zero growth rate, and this point is approximately at 9.6 K. In our experimental situation all small disturbances are carried away and die out due to the nonreflecting sidewalls until the absolute instability point is reached. This point is characterized by a local increase of small disturbances, so that the onset of overturning convection can no longer be prevented. This feature can be understood theoretically by analysing the suitable amplitude equation and the absolute instability point is determined by the linear coefficients of this equation (Huerre, 1987).

The novel feature that we like to present here occurs in the range between the convective instability and the absolute instability point

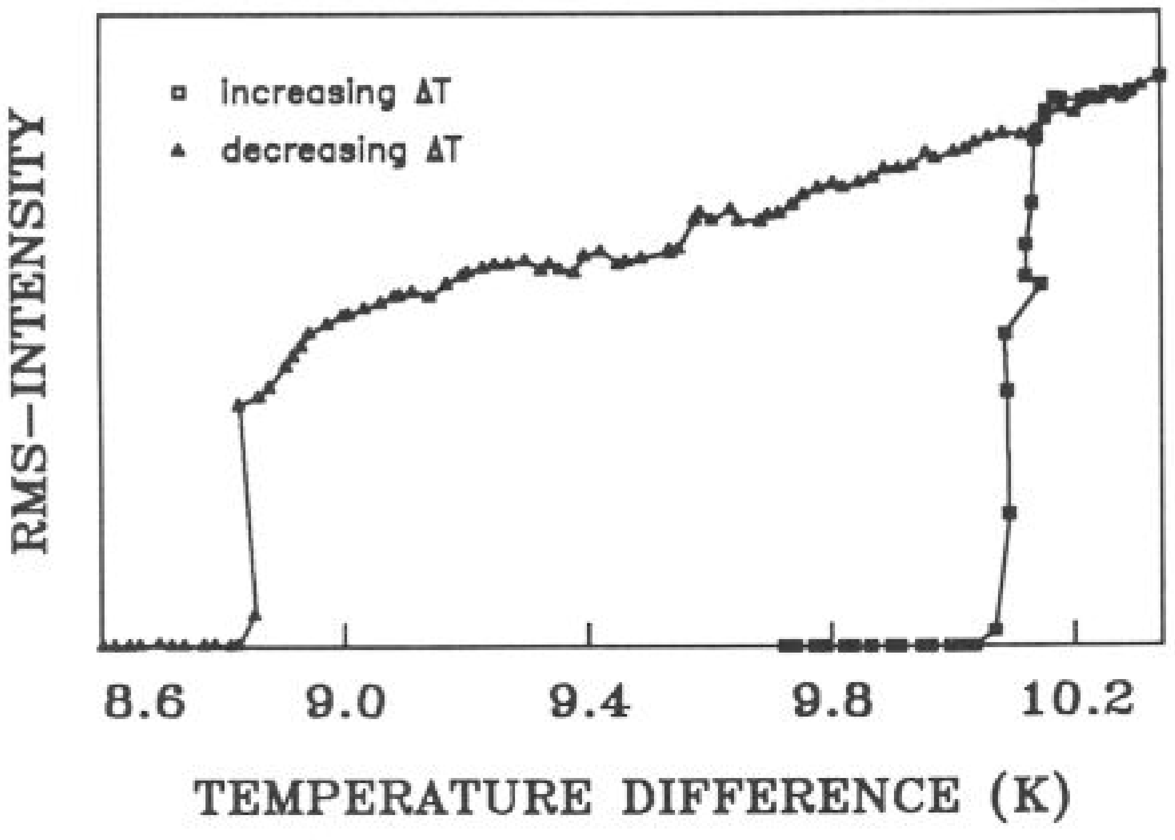
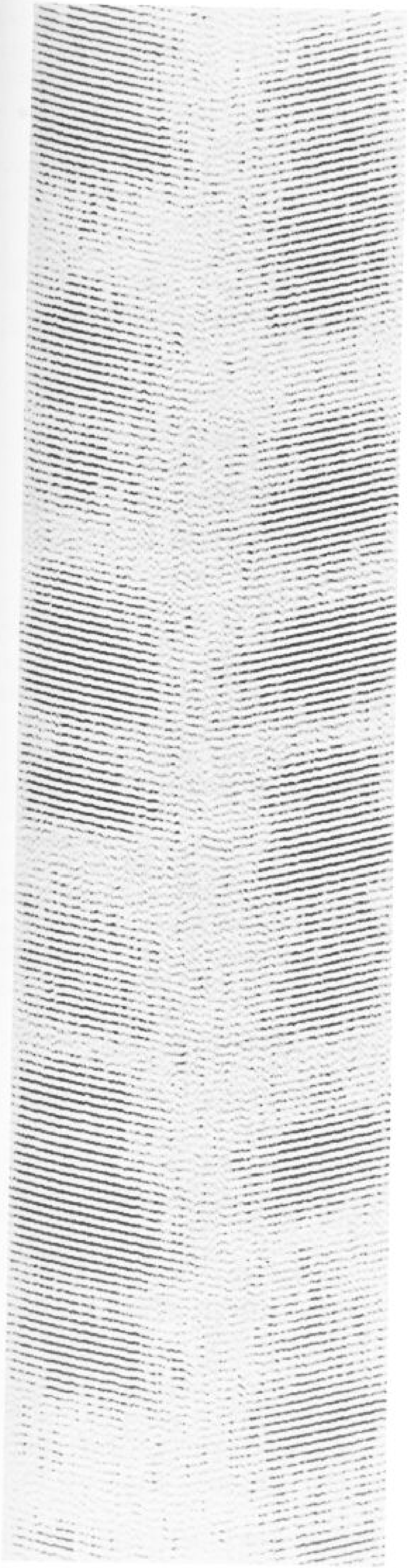
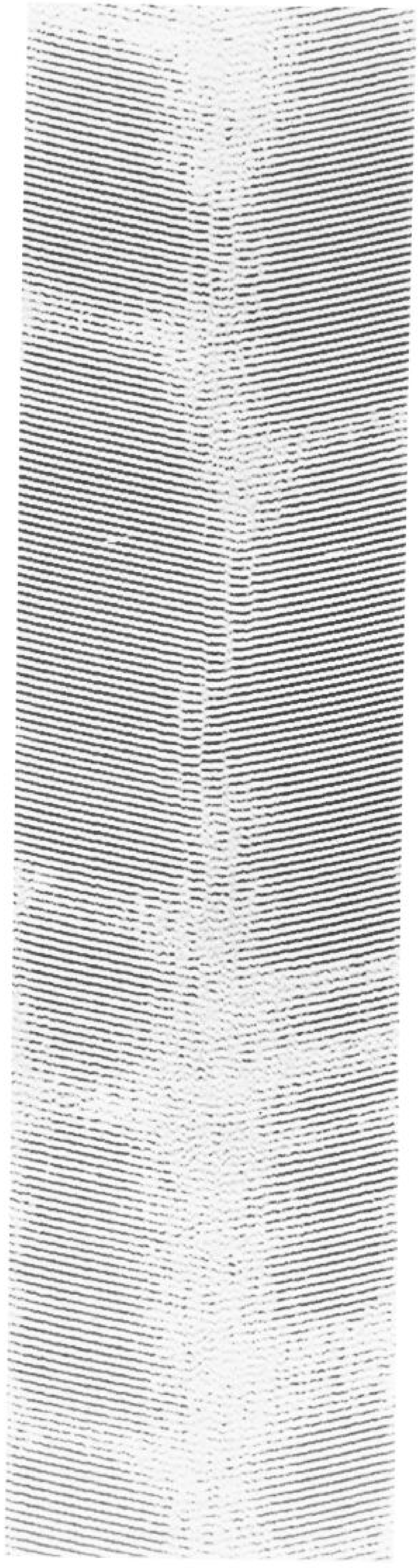


Fig. 2. Intensity of the convection image versus temperature difference. Convection sets in at ΔT = 10.12 K and vanishes at ΔT = 8.84 K.



a) ΔT = 10.02 K.



b) ΔT = 10.09 K.

Fig. 3. Time series of the small amplitude 'Blinking Convection'. Time goes upwards (4096 seconds) and the x-direction shows about 50 mm of the long dimension of the cell.

close to the second one. Here we observe the blinking behaviour illustrated by Fig. 3a) and b) which is a 4096 sec. time series of intensity lines along the long dimension of the cell. Time goes upwards and about 50 mm of the cell are shown. Randomly occuring islands of convection with the linear frequency can be seen in the left and right part of the cell. This state is no transient - our longest run was about ten days and no change was observed within this period. The amplitude of this kind of convection is less than 1% of the fully developed convection on the upper branch of Fig. 2. Fig. 3a) is taken at $\Delta T = 10.02$ K and Fig. 3b) at $\Delta T = 10.09$ K. It seems that the convection periods become longer with increasing temperature difference and also the amplitude of the structure increases. Further study of this state is in progress.

Acknowledgement

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