

FIG. 1.



FIG. 2.



FIG. 3.

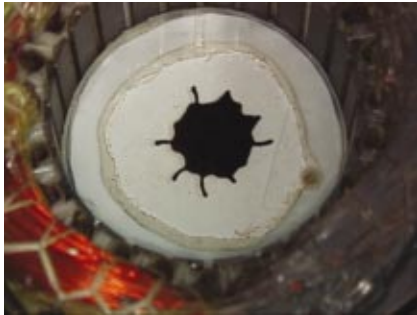


FIG. 4.



FIG. 5.



FIG. 6.

## Hele-Shaw Ferrohydrodynamics for Rotating and dc Axial Magnetic Fields

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We examine the response of a fluorocarbon based ferrofluid, with about 400 G saturation magnetization and low field magnetic susceptibility of 3, contained in a glass Hele-Shaw cell of 1.1 mm gap with simultaneously applied in-plane clockwise rotating and dc axial magnetic fields. The ferrofluid is surrounded by a 50/50 mixture of isopropyl alcohol and deionized water, which prevents ferrofluid wetting of the glass plates. In all cases the rotational field strength is 20 G rms and the frequency is 25 Hz.

In the pictures above, we see two experiments. The first experiment, Figs. 1–3, uses 50  $\mu\text{l}$  of ferrofluid and the dc axial field is first increased to 100 G and then the clockwise rotating field is turned on. Figure 1 shows the circular ferrofluid drop before the magnetic field is applied, while Fig. 2 shows the spiking labyrinth pattern formed by the ferrofluid after only the dc axial field has been applied. Then the clockwise rotating field is applied and the spikes begin to curl in

on themselves, eventually forming the smooth spiral pattern shown in Fig. 3 after some of the spikes are absorbed into the larger structure. The smooth spirals form from viscous shear as the clockwise rotating magnetic field causes counter-clockwise flow on the outside ferrofluid surfaces which return on the inside surfaces.

The second experiment, with 200  $\mu\text{l}$  of ferrofluid, is seen in Figs. 4–6. The test cell is first placed in the clockwise rotating field which causes a counter-clockwise flow that holds the fluid drop together without spikes. Then a 100 G dc axial field is gradually applied. This results in the ferrofluid drop appearing to expand before the phase-like transition to Fig. 5 at a critical dc magnetic field strength around 100 G. Careful observations show that the pattern of Fig. 5 forms at slightly less than 100 G dc field under a thin ferrofluid coating on the top glass plate, like that in Fig. 4, which then abruptly peels away at slightly increased dc axial magnetic field. In Fig. 6 the magnetic field is increased from 100 G to 250 G.

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