FIG. 1.

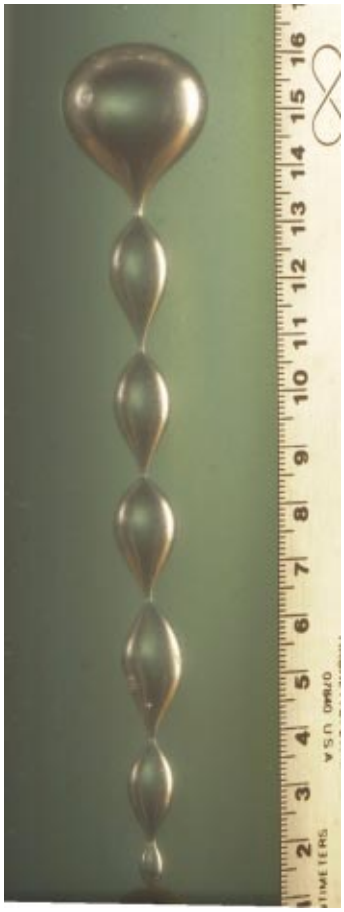

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 1. Formation of the chain of large bubbles in a very viscous mineral oil polymer solution. The marks on the ruler are 1 cm apart.
FIG. 2. Fast formation of the chain of bubbles in 2% methocel solution in water.
FIG. 3. Chain of bubbles in 2% methocel (hydroxypropyl methylcellulose) solution in water.
FIG. 4. Chain of bubbles in red-colored hand soap. Most commercially available hand soaps contain polymers (methocel and/or others).

Chain of Bubbles in Polymer Solution

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Everyday experience shows that a stream of air in a Newtonian liquid (water) breaks down into bubbles through the Rayleigh–Taylor instability. However, in concentrated polymer solutions (such as hand soap) the elastic properties of the polymers can alter the development of the Rayleigh–Taylor instability. In particular, the breakdown of the air stream can be arrested and, as a result, instead of individual bubbles, a long chain of bubbles forms. The bubbles in the chain are connected by thin necks. There is relatively fast motion of the polymer liquid near the necks of rising bubbles. The presence of polymers prevents the necks from collapsing. The complete structure is very stable and can be observed in a broad variety of polymer solutions, both water-based and organic. The phenomenon does not appear in diluted polymer solutions. There is a minimal concentration threshold for the chain formation. For aqueous methocel solutions, the minimal concentration is 2%. Also, there is a minimal air flow rate necessary to support the chain; for a very small flow rate, the air stream breaks down even in concentrated polymer solutions. For 2% aqueous methocel solution, the minimal flow rate is about 3.7 cm^3/s.