Fluctuating Foam State in Flow Through Porous Media

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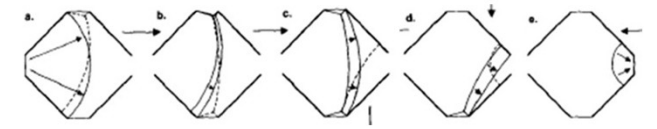
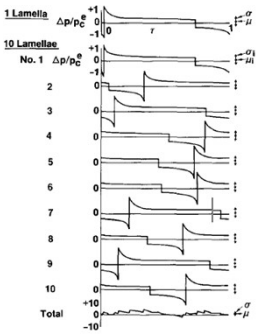
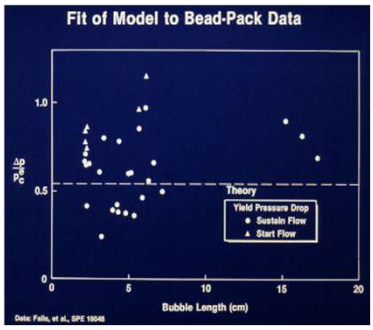
In foam coreflood experiments, pressure gradient ∇p fluctuates significantly over time. There are several reasons for this. The capillary resistance to bubble movement fluctuates with the shape of films, or lamellae, between bubbles during movement through the complex porespace. In addition, flow pathways through trapped gas open and close in response to fluctuating ∇p, further magnifying the fluctuations. Foam generation and propagation depend on ∇p and are likely affected by these fluctuations.

Why does ∇p fluctuate in foam flow?[1]

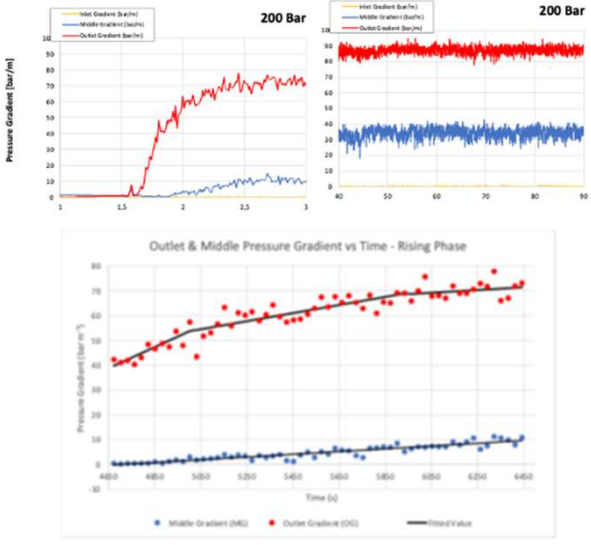
The curvature of a soap film (lamella) in a pore gives a significant Δp between bubbles across the lamella. As the lamella travels through the porespace, this Δp shifts up and down. Along a train of flowing bubbles, the fluctuations add up, as illustrated below.



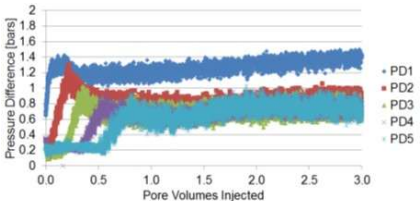




N_2 foam coreflood data: fluctuating ∇p[4]



Similar N_2 foam coreflood data



Results for N_2 Foam Coreflood[4]

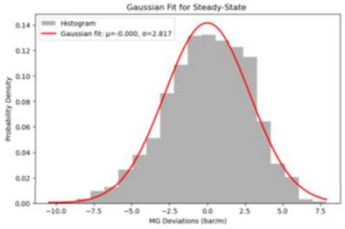
During the period of rising ∇p, **∇p in the middle section fluctuates ~1.2 bar/m around mean. In the outlet section, ~ 3.2 bar/m.**

In the steady-state period, **∇p in the middle section fluctuates ~ 2.8 bar/m around the mean. In the outlet section, ~ 1.9 bar/m.**

In the steady-state period, the **fluctuations** in the outlet section appear to **last ~30 - 90 s**. In the middle section, fluctuations last **> 1 minute**.

Fluctuating outlet pressure may play a role. Coreflood back-pressure fluctuated ~ 0.3 bar in rising period; 0.7 bar in steady-state period. Capillary end effect at outlet may also play a role.

Middle section ∇p, steady-state period

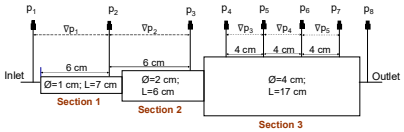


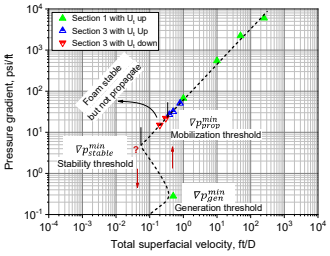
Why does fluctuating p matter?[2,3]

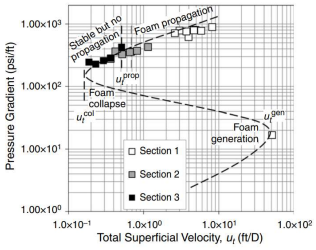
Foam generation in steady flow and propagation and stability in place depend on ∇p. Experiments with multi-diameter cores can measure all three thresholds. (**See talk session MS01, 10:50 Friday**)

Fluctuating ∇p could cause or slow foam generation and propagation. Fluctuating ∇p reflects fluctuation gas mobility. As gas mobility changes, saturations and capillary pressure change. Fluctuating capillary pressure is essential for foam generation by snap-off.

Experimental Apparatus







References

1. Rossen, W.R., *J. Colloid Interface Sci.* **139**: 457-468 (1990). https://doi.org/10.1016/0021-9797(90)90118-8
2. Gauglitz, P.A. et al., *Chem. Eng. Sci.* **57**: 4037-4052 (2002). https://doi.org/10.2118/75177-MS
3. Yu, G., et al., *SPE Journal* **25**: 3457–347 (2020). https://doi.org/10.2118/201251-PA
4. Louter, M., BSc thesis, Delft U. of Technology, 2025. (Available from w.r.rossen@tudelft.nl)

5. Rossen, W.R., Session MS01, 10:50 Friday.

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