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# Critical Thresholds for CO2 Foam Generation in Homogeneous Porous Media

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Long-distance propagation of foam is one key to deep gas mobility control for CO2 sequestration (Rossen et al., 2022). It depends on two processes: convection of bubbles and foam generation at the displacement front. Prior studies with N2 foam show the existence of a critical threshold for foam generation in terms of a minimum pressure gradient ( $\nabla$ pmin) or minimum velocity (vt,min), beyond which strong-foam generation is triggered. Yu et al. (2020) show that the same mechanism controls foam propagation. There are few data for  $\nabla$ pmin or vt,min for CO2 foam.

We conduct extensive experiments to quantify  $\nabla$ pmin and vt,min for CO2 foam generation, and quantify the correlations of  $\nabla$ pmin and vt,min with factors including injected foam quality (gas fraction)–fg, surfactant concentration–Cs, and permeability–K. In each experiment, steady-state pressure gradient is measured at fixed injection rate and quality, with velocity increasing in a series of steps. The abrupt jump in  $\nabla$ p against vt marks the trigger of strong foam generation (see graphical abstract: N2 data on top, schematic in middle, data for  $\nabla$ pmin on bottom).

In most cases, the experimental results for  $\nabla p$  as a function of vt identify three regimes: coarse foam at low  $\nabla p$ , an abrupt jump in  $\nabla p$  (point B in graphical abstract) and strong foam at high  $\nabla p$ . The abrupt jump in  $\nabla p$  upon foam generation demonstrates the existence of  $\nabla p$ min and vt,min for CO2 foam. We further show how  $\nabla p$ min and vt,min scale with fg, Cs and K. The effect of K is dominant over the effects of fg and Cs. Specifically, both  $\nabla p$ min and vt,min increase with foam quality: e.g. for fg over a range 0.5 –0.9,  $\nabla p$ min rises by a factor ~ 2 –4 and vt,min by a factor ~ 4. Increasing Cs leads to decrease in both  $\nabla p$ min and vt,min by factors of less than three.  $\nabla p$ min changes considerably with permeability. Our results in consolidated sandpacks show that  $\nabla p$ min for CO2 foam scales with K as K-2, in comparison to N2 foam, where  $\nabla p$ min scales as K-1 in unconsolidated homogeneous sand or bead packs. However, the data of Gauglitz et al. (2002) for CO2 foam in Boise sandstone do not show a dependence of  $\nabla p$ min on K. The difference may be a result of the impact of heterogeneity of the Boise sandstone, since foam generation is easier in heterogeneous media.

 $\nabla$ pmin is about 0.17 bar/m (~ 0.75 psi/ft) for K ~ 270 mD, 2 to 3 orders of magnitude less than for N2 foam. This pressure gradient is easily attainable deep in formations. This suggests that generation is much less of a restriction for long-distance CO2 foam propagation than with N2. Foam propagation could still be challenging in low-permeability reservoirs ( $\nabla$ pmin ~ 10 bar/m for K = 27 mD). Nevertheless, realistic formations are heterogeneous and field application deploys alternating-slug injection. Both factors help foam generation and thus reduce the value of  $\nabla$ pmin. More research is needed to determine conditions for CO2 foam propagation under those conditions.

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#### References

Gauglitz, P. A., Friedmann, F., Kam, S. I., & Rossen, W. R. (2002). Foam generation in homogeneous porous media." Chemical Engineering Science 57, 4037-4052. https://doi.org/10.2118/75177-MS. - Rossen, W. R., Farajzadeh, R., Hirasaki, G. J., and Amirmoshiri M. (2022) Potential and challenges of foam-assisted CO2 sequestration, SPE paper 209371, presented at the SPE Improved Oil Recovery Conference, Tulsa, OK, 25-29 April 2022. https://doi.org/10.2118/209371-MS - Yu, G., Vincent-Bonnieu, S., & Rossen, W. R. (2020). Foam propagation at low superficial velocity: implications for long-distance foam propagation. SPE Journal, 25(06), 3457-3471. https://doi.org/10.2118/201251-PA

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