# APPENDICES

## Nomenclature

| | |
|---|---|
| $E_{act}$ | activation energy |
| $\gamma_i$ | activity coefficient of *i*-th species |
| $a_i$ | activity of *i*-th species |
| L, $L_{Capillary}$ | capillary length |
| $\beta$ | collision efficiency |
| $K_{ij}$ | collision kernel |
| $C_i$ | concentration of *i*-th species |
| $\rho$ | density of barium sulfate |
| $L_{Deposit}$ | deposit length |
| $M_{Deposit}$ | deposit mass |
| D | diameter |
| $k_D$ | disappearance rate constant |
| $\mu$ | dynamic viscosity of medium |
| A | empirical constant |
| $r_{Deposit}$ | final capillary radius |
| r, $r_0$ | initial capillary radius |
| $\Delta P$ | pressure drop across capillary |
| $\Delta P_0$ | pressure drop at the steady state before detect deposition |
| $D_p$ | primary particle diameter |
| m | reaction order |
| SI | saturation index |
| SR | saturation ratio |
| $K_{SP}$ | solubility product |
| T | temperature |
| $R_g$ | universal gas constant ($8.314 \frac{J}{mol \cdot K}$) |
| Q | volumetric flow rate |

## Appendix A: Capillary Length Experiment

To further understand the barium sulfate deposition mechanism, a long capillary deposition experiment was performed with a length of 9 ft. An increase in the pressure drop with time of 9 ft was compared with that of 3 ft, as shown in Figure A.1.

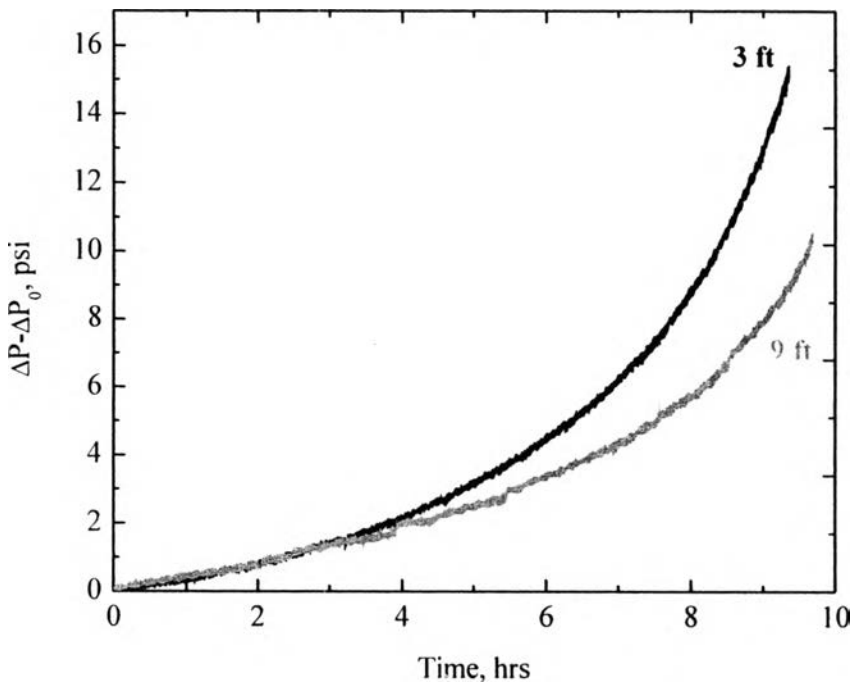


Figure A.1 The pressure drop vs. time plot comparing an experiment conducted with the long capillary to the one conducted with the short capillary.

If the deposit were forming only in the 3 ft section of the capillary as shown in Figure A.2, there would be no effect of an increase in the pressure drop due to the deposition at later 6 ft section. Therefore, an increase in the pressure drop which is subtracted the steady state pressure drop ($\Delta P$-$\Delta P_0$) of 9 ft would be the same trend as the one of 3 ft.

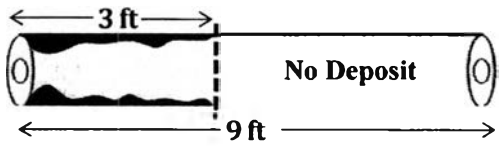


Figure A.2 Proposed deposition mechanism only at first 3 ft section.

The pressure drop of 9 ft run was in good agreement with the 3 ft capillary at the beginning of experiment. Afterward, the pressure drop of 3 ft became greater than the one of 9 ft. However, in theory, the long capillary should always gives either equal or higher pressure drop compared to a short capillary. One possibility could be an error in the experimental technique. The current experimental apparatus has a 1/16 inches diameter outlet tee at the capillary outlet. Because of the diameter difference between the capillary and outlet tee, there may be a flow interruption or a change in flow pattern that could change the deposition tendency. Also, at the connection, there could be a dead zone. Consequently, barium sulfate could be greatly precipitating and depositing at the outlet of the capillary which contributes to an increase in the pressure drop.

In order to solve this issue, an additional experiment was conducted with a 0.02 inches diameter outlet tee. An increase of the pressure drop of 9 ft was expected to be higher or equal to the one of 3 ft, if this technique was able to neglect the flow interruption or flow pattern change. Unfortunately, the increase in the pressure drop of 9 ft was still lower than the one of 3 ft, similar to the result shown in Figure A.1.

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