Notes on the $CaCO_3$ Scale Block Test

A. Whittington

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1 Introduction

The $CaCO_3$ scale block (aka 'tube-blocking') test models the performance of scale inhibitors.

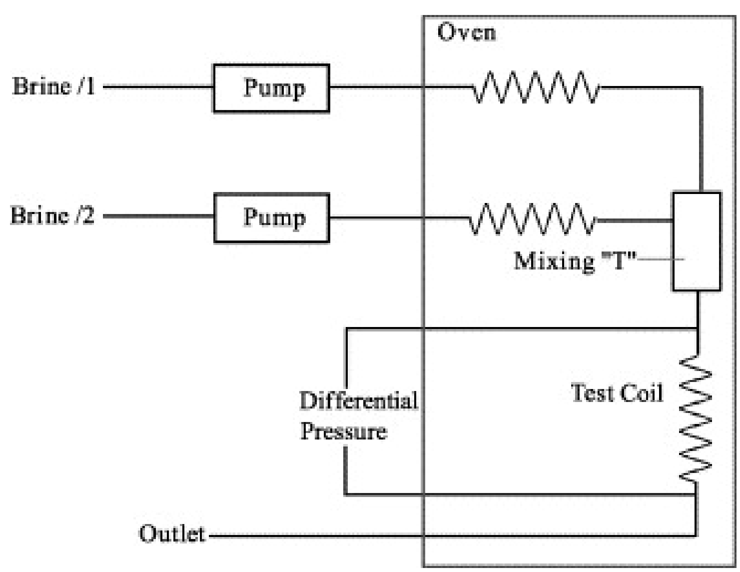
A pair of reciprocating (constant-volume) pumps are used to push synthetic brines through a system of tubes housed in a heated oven. The brines will become mixed at a point in the tubing, after which the applied heat promotes scale formation. This scale formation restricts flow and leads to a buildup of pressure in the system. The rate of scale formation is inferred by integrating a series of pressure measurements over time.

The experiment consists of taking a series of pressure measurements over an interval of time. The experiment ends once the interval has elapsed or a designated pressure threshold is reached, whichever comes first.

2 Apparatus

A diagram of the apparatus is given in Figure 1.

Figure 1: Diagram of the apparatus[1]



At time of writing, the pumps used are MX-class HPLC pumps from Teledyne Scientific Systems Inc., and the software used to manage experiments and interact with these pumps is ScaleWiz from Premier Chemical Technologies, LLC.

3 Procedure

Given information: test temperature, failing pressure threshold, brine composition.
Before beginning an experiment: verify that the oven is at its setpoint, and that both pumps are set to the desired flowrate.

1. Prepare two brine solutions according to the synthetic brine composition provided; one brine will contain all of the Ca^{2+} ions, and the other will contain all of the ${CO_3}^{2-}$ ions (in the form of ${HCO_3}^{-}$)
2. Degasify the brines in an ultrasonic bath for a few seconds
3. Flush the system with 20% acetic acid until stable pressure readings are observed, then flush the system with deionized water for at least 2 minutes
4. Conduct at least two “opening blanks” to get an idea of how long it should take the system to reach the failing pressure threshold
5. Take note of and record the “baseline pressure” for the brine; this is easily determined from the average pressure reading over the interval 0.25-1 minute while the system is at the testing temperature
6. Treat an aliquot of brine with a volume of inhibitor such that the desired treating rate will be achieved upon mixing, then conduct the trial
7. Repeat steps (2) and (5) until sufficient data is collected
8. Collect a “closing blank” to verify the scaling behavior observed in the opening blanks

3.1 Notes

- Brines should be freshly prepared the day of testing; atmospheric CO_2 equilibration alters the bicarbonate concentration and may lead to variance in the results
- Brines should be formulated such that they are of comparable density; this will facilitate better mixing at the ‘T’
- Historically, most tests are conducted in the range 180-200°F, the pumps have been operated at 10 ml min^{-1}, the failing pressure threshold for the test has been 1500 psi, and test is allowed to run for a maximum of 90 minutes
  Inline vaporization may occur at higher temperatures and damage the apparatus
- Sometimes the requested treating rate is unusually high (a %volume concentration); in these cases it may be beneficial to treat both brines equally rather than “double-dosing” one of them

4 Analysis of Results

All pressure units are psi and all time units are seconds unless otherwise stated.
The performance of an inhibitor is determined by integrating the series of pressure measurements over time. Analysis begins by determining the available area A_{avail} which represents how much scale could be formed over the duration of the test.

Let F be the failing pressure threshold, and B be the baseline pressure. Let T be the time limit, and let t_f be the duration of a particular trial. The value of $P(t)$ is the measured pressure of the system at some time t.

$$\begin{aligned} A_{avail} &= \int_0^T (F - B)\ \mathrm{d}t \\ &= (F - B) \times T \end{aligned}$$

The area over the blank A_{blank} for a particular trial is determined from

$$\begin{aligned} A_{blank} &= F \times t_f - \int_0^{t_f} P(t)\,\mathrm{d}t \\ &= F \times t_f - \sum_0^{t_f} P(t) \end{aligned}$$

The average protectable area $\bar{A}_p$ is A_{avail} minus the average area over the blanks $A_{\bar{blank}}$.

$$\bar{A}_p = A_{avail} - A_{\bar{blank}}$$

The scale area A_{scale} for a particular run is determined from

$$\begin{aligned} A_{scale} &= \int_0^{t_f} P(t)\,\mathrm{d}t - B \times T \\ &= \sum_0^{t_f} P(t) - B \times T \end{aligned}$$

Where the quantity $B \times T$ represents the cumulative baseline area over the course of the trial. The % protection for a particular trial is then found from

$$\%\ \text{protection} = 1 - \frac{A_{scale}}{\bar{A}_p} \times 100$$

Analysis of the data is automatically performed within the ScaleWiz application.
Consult the application's documentation to view individual calculation steps during analysis.

5 References

(1) Waleed, A. N.; Yasser, A. J. *Chemical Engineering Research and Design* **2020**, DOI: https://doi.org/10.1016/j.cherd.2020.02.012.