INVESTIGATION OF SCALE INHIBITION USING PHOSFLOW® TECHNOLOGY

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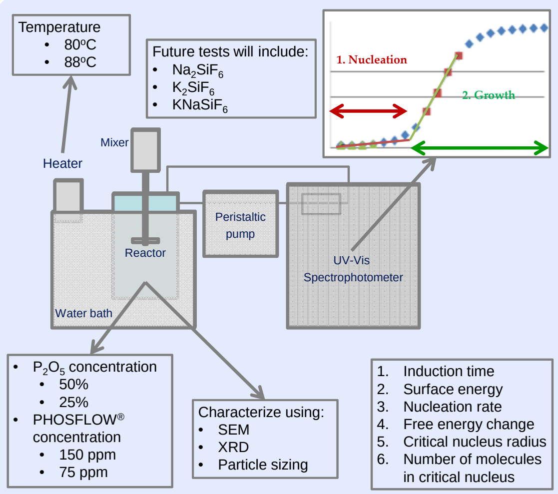
Objective: The goal of this study is to understand the mechanisms that govern the effect of various surfactants including PHOSFLOW® reagents developed by Cytec-Solvay Group on inhibition of scale formation.

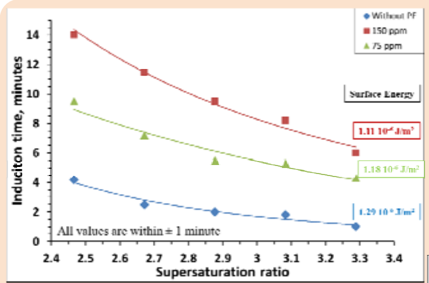
Industrial Relevance: Scale formation reduces plant throughput and heat transfer and increases energy consumption maintenance/labor costs and safety hazards[1].
Broad Appeal: Understanding the mechanics of antiscaling can be applied to other areas such as reverse osmosis and nano-filtration systems[2] as well as in the oil and gas industry[3].

Materials and Methods: PHOSFLOW®, phosphoric and sulfuric acids, and calcium hydrogen phosphate monobasic ($CaH_4(PO_4)_2 \cdot H_2O$). Characterization of scale with SEM, XRD, and FTIR. Further testing will include turbidity measurements using the HACH 2100A Turbidimeter, size distribution using the Coulter Laser Diffraction Analyzer model LS13320 or the Coulter Rapidvue, the calculation of inhibition efficiency, and adhesion force measurements using AFM.

Experiment Setup



Results

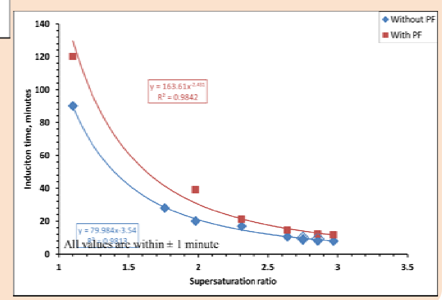


PHOSFLOW® decreases surface energy at both tested dosages. This causes nuclei to be more stable and to form more readily.

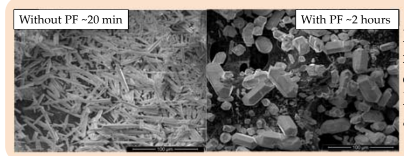
Figure 2- High supersaturation hemihydrate turbidity data collected from HACH 2100A Turbidimeter

PHOSFLOW® increases induction times at all supersaturations tested. This shows that PHOSFLOW® delays crystal growth in both calcium sulfate species tested.

Figure 3- Dihydrate turbidity data collected from HACH 2100A Turbidimeter



Morphology Changes



Morphology changes in hemihydrate crystals upon PHOSFLOW® addition (150 ppm).

Summary

- Results thus far are in agreement with Industry observations
  - More effective combating hemihydrate compared to dihydrate
  - Inhibition is due to a decrease in surface energy causing nuclei to be more stable and to form more readily
- PHOSFLOW® modifies crystal morphology

Specific tasks for next reporting period and anticipated outcomes

- Transition to a continuous flow system
  - Simulate real system conditions
  - Automate procedure
- Investigate $CaSO_4$ formation in the presence of:
  - Na_2SiF_6
  - K_2SiF_6
  - $NaKSiF_6$

$CaSO_4$ Dihydrate System

Supersat. Ratio (S)	Induction time, min		Nucleation rate J, nuclei/cm³s x 10^{28}		Free energy change for formation of critical nucleus ΔG_{cr}, J x 10^{-20}	
	without	150 ppm	without	150 ppm	without	150 ppm
2.31	17.00	21	15.40	22.48	0.91	0.73
2.64	10.50	14.5	24.86	32.95	0.68	0.54
2.86	8.50	12	30.49	38.77	0.58	0.46
2.97	8.00	11.5	33.06	41.35	0.54	0.43
				x1.33		

$CaSO_4$ Hemihydrate System

Supersat. Ratio, S	Induction time, min			Nucleation rate J, nuclei/cm³s x 10^{28}			Free energy change for formation of critical nucleus ΔG_{cr}, J x 10^{-20}		
	without	75 ppm	150 ppm	without	75 ppm	150 ppm	without	75 ppm	150 ppm
2.466	4.2	9.5	14.0	9.19	16.59	22.43	1.19	0.90	0.75
2.6715	2.5	7.2	11.5	13.35	21.96	28.33	1.00	0.76	0.63
2.877	2.0	5.5	9.5	17.53	26.96	33.60	0.87	0.65	0.54
3.0825	1.8	5.3	8.2	21.56	31.51	38.25	0.76	0.58	0.48
					x1.5	x2			

Nuclei are more stable and form at a faster rate in the presence of PHOSFLOW. PHOSFLOW is more effective at inhibiting hemihydrate compared to dihydrate.

References

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2. Myles M. Jordan, Ian R. Collins, and Eric J. Mackay. *SPE Production & Operations* 23.02 (2008): 192-209.
3. Neville, Anne. *Energy & Fuels Energy Fuels*26.7 (2012): 4158-166.

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