

## Modeling H<sub>2</sub>S-Scavenger Efficiency Cuts Costs

The problems associated with production of H<sub>2</sub>S are well defined within the oil industry, with the major issues related to safety, corrosion integrity, and production deferment. Shell now has at its disposal a software model to predict H<sub>2</sub>S-scavenger efficiency in an effort to reduce costs and optimize chemical treatment regimes. The company also has available a test flow loop for evaluating scavenger performance under a wide range of simulated field conditions.

Phase 2 of a joint-industry project (JIP) with the Chicago-based Gas Technology Institute (GTI), which Shell recently completed, provided the basis for the company's advances. The

JIP work complements some extensive optimization work on a Shell field, where practical considerations to the chemical application had a proven significant effect on chemical use and subsequent reduction. This practical test work offshore clearly defined the many and varied considerations to the application technique required to achieve success. The results from one example are shown in **Table 1**.

Similar reductions in chemical use were noted for two other platforms in the field during this extensive offshore optimization study. The main factor contributing to this reduction was the relocation of the injection point. Further cost reductions of approxi-

mately 15% are feasible with a high probability of success through implementation of the following:

- Improved monitoring and measurement of H<sub>2</sub>S in the export gas, which would allow optimization and control of the scavenger-dosage regime by up to 15%

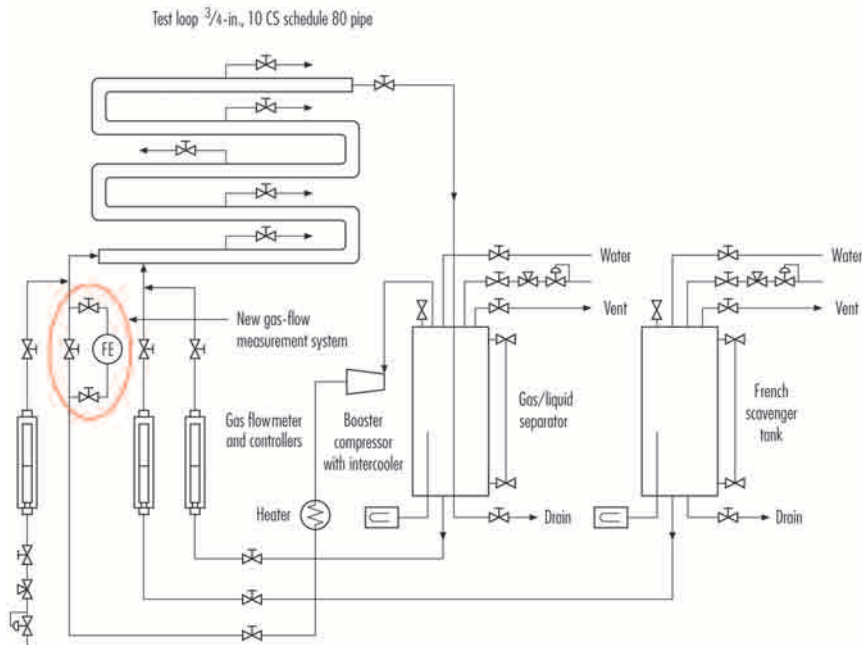
- Improved delivery of chemical by priming the pulsation dampener and using an appropriately sized atomization nozzle

- Maximized contact between the injected chemical scavenger and the sour gas from the low-pressure compressor, through use of an additional scavenger-injection point at the high-pressure separator discharge

**TABLE 1—H<sub>2</sub>S SCAVENGER USE OPTIMIZATION RESULTS**

Operating parameter	Units	Pre		Post	
		LP discharge	LP discharge	HP discharge	HP discharge
		Case 1 - Min consumption	Case 2 - Max consumption	Case 1 - Min consumption	Case 2 - Max consumption
Gas-flow rate	million m <sup>3</sup> /d	6.01	6.01	6.01	6.01
Pressure	bar	60	60	22.4	22.4
Temperature	°C	71	71	29	29
H <sub>2</sub> S initial in gas phase	ppm	4.3	4.3	4.3	4.3
H <sub>2</sub> S final	ppm	1.5	1.5	1.5	1.5
Pipe diameter - if Direct injection	in.	24	24	28	28
Pipe length	m	20	20	40	40
H <sub>2</sub> S partial pressure	psi	0.0046	0.0046	0.0023	0.0023
Scavenger used	water-soluble	HSW82165	HSW82165	HSW82165	HSW82165
Actual gas rate	m <sup>3</sup> /d	9.44E+0.4	9.44E+0.4	1.67E+0.5	1.67E+0.5
H <sub>2</sub> S to be removed	kg/d	24.50	24.50	24.50	24.50
Actual scavenger consumption	L/d	975	1351	605	740
<b>Scavenging efficiency</b>	<b>L/ppm H<sub>2</sub>S rem/million Nm<sup>3</sup></b>	<b>57.94</b>	<b>80.28</b>	<b>35.95</b>	<b>43.97</b>
Volume-to-surface ratio	ft <sup>3</sup> /sec/ft <sup>2</sup> /ft	6.14	6.14	9.33	9.33
Velocity	m/s	3.75	3.75	4.88	4.88
Ratio of V/V <sub>c</sub>		1.53	1.53	1.41	1.41
Transit time	seconds	5.34	5.34	8.20	8.20
Average scavenger consumption	L/d	1163		673	
Average treatment rate HSW82165	L/ppm H <sub>2</sub> S rem/million Nm <sup>3</sup>	69.11		39.96	

N=Normal LP=Low-Pressure HP=High-Pressure



**Fig. 1—A schematic and photograph of the scavenger test loop at the Gas Technology Institute are shown.**

- Use of a pump suitable for the volumetric injection rates

- Fitting the flowing system with a retrievable insertion probe for ease of maintenance and reduced downtime

Additional savings of more than 10% in chemical costs are achievable through automating the injection, with a payout period of less than 1 year projected for this.

Implementing the above recommendations will yield a positive environmental impact by achieving up to a 30% reduction in the concentration of unspent scavenger in the water that is discharged overboard.

### Adding Value to the Chemical Contract

On the basis of the optimization studies, the improved prediction of scavenger efficiency can add value to an operator's chemical contract from several standpoints:

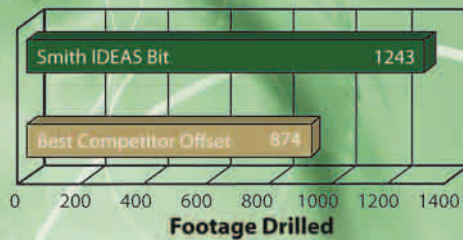
- Environmental
  - Better compliance with the United Kingdom's Petroleum Operations Notice 15D discharge limit through reduced chemical use

- Reduced tank movements, corresponding to reductions of approximately 50 per annum at each of the platforms in the studies



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**Additional Benefits to Platform Operations**

In addition to the above benefits, one of the platforms studied now has an optimized maximum dosage rate for total production vs. H<sub>2</sub>S volume produced. Information on each producing well's H<sub>2</sub>S loading is constantly updated. This has enabled the platform to set dosage rate on the basis of anticipated H<sub>2</sub>S, rather than relying on gas-export readings and then making manual pump adjustments to set dosage.

Cost and use levels of H<sub>2</sub>S scavenger now receive a much higher priority on the platform, with platform-to-shore

communication on these issues given a higher profile.

**Computer-Model Development**

During Phase 2, a new steady-state mechanistic model was implemented, based on more-rigorous modeling of the two-phase flow and mass transfer. The underlying equations developed were based on both theoretical and experimental work sponsored by GTI and participant members over the past 10 years. The model is programmed in Microsoft Visual Basic Software and has a graphical user interface. The calculation method is based on determining the mass-transfer rate of H<sub>2</sub>S from the gas to the liquid at each point along the flow path inside the length of the pipe or heat exchanger being modeled.

The rate of H<sub>2</sub>S absorption per unit length is expressed as a function of the local conditions at that point. The equation is then solved by use of a standard fourth-order Runge-Kutta method. The model has been validated

against hundreds of data sets from the GTI test loop, as well as from several commercial H<sub>2</sub>S-scavenging facilities.

A schematic and photograph of the GTI test loop are shown in **Fig. 1**. The pipe is made of ¾-in. 10 CS schedule-80 pipe with total contact length of 240 ft. The entire structure is housed inside a 20×12-ft fume hood equipped with a carbon adsorption bed. This unit has a maximum flow of 400 Mscf/D of gas under both once-through and recycled flow conditions at higher temperatures (function of gas-flow rate) and at pressures up to 1,200 psig. Testing in the scavenging loop can also be used to determine if proposed scavengers are sufficiently reactive to be capable of removing the H<sub>2</sub>S to the desired levels in the required pipe lengths. It can be used to compare the performance of scavengers against each other and against known scavengers, to determine the likelihood of achieving the performance specifications with each scavenger.

The activation energy, diffusion, viscosity, surface tension, and other mass-transfer phenomena, however, are dependent on the solvent (i.e., the scavenger being used). The model will be expanded and improved significantly during the Phase-3 effort. Several new features will be incorporated:

- Temperature-dependent chemical kinetics for different scavengers
- Vertical-upflow section calculations
- Diffusion effects
- A different set of flow-regime characteristics

These program features will increase the accuracy and robustness of the model to handle a wider range of operating conditions.

During Phase 2 of the JIP, experimental techniques were developed in the GTI vapor/liquid-equilibrium unit to measure kinetics along with the effects of mass transfer. A schematic and photograph of this unit are shown in **Fig. 2**. The kinetic data will be used to develop a more temperature-dependent kinetic model for each scavenger. In Phase 2, it was limited to a single scavenger and under a limited range of conditions. In Phase 3, this will be broadened to include scavengers of interest over a wide range of conditions.

Pseudofirst-order kinetics that was observed in Phase 2 for ethanol-based

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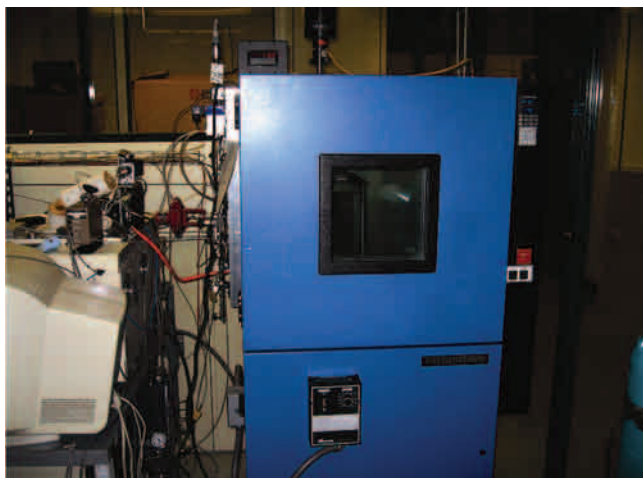
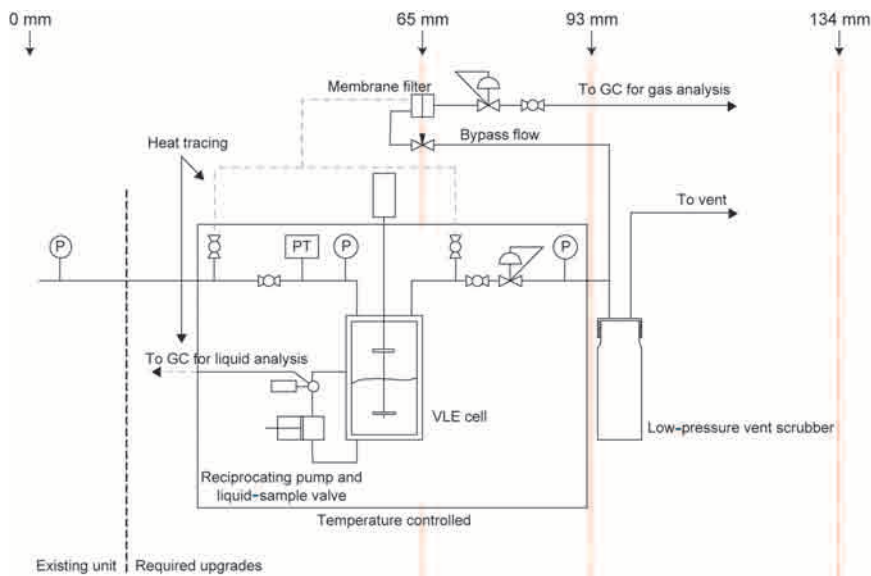
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**Fig. 2—A schematic and photograph of the vapor/liquid-equilibrium unit at the Gas Technology Institute are shown.**

triazine should apply across the entire range of ethanol-based H<sub>2</sub>S-scavenger products. If deviations are encountered, the product is considered suspect and could be contaminated. The level of residual intermediates and active ethanol/triazine purity will be considered in the work.

The temperature dependence will be sought for each scavenger, with the understanding that diffusion interference by the surrounding package (i.e., the type of surfactant added and/or the winterization additives that may be required) might cause a deviation of the observed activation energy from the predicted value with such additives.

The current model uses empirical relations for the diffusivity of H<sub>2</sub>S in water. Experiments will be set up to determine the gas/liquid diffusivity of

H<sub>2</sub>S in each scavenger. These data will be used to develop a liquid-mass-transfer coefficient based on the scavenger of interest.

### Looking Forward

The project will continue to evaluate the model performance as changes are made. The model predictions will be compared with experimental data from the laboratory and field-test data to quantify the prediction errors and identify operating regimes or physical conditions where modeling difficulties arise. The continual evaluation and validation of the model provide a measure of quality control and confidence, and a degree of safety factor, that is required for effective application.

**JPT**

*Information provided by Calum Buchan, Shell*

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