Natural Gas Hydrates *in* Flow Assurance

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Jefferson Creek holds a BS degree from Middle Tennessee State University, and MS and PhD (1976) degrees from Southern Illinois University at Carbondale. Jeff has worked in phase behavior and fluid analysis since joining Chevron Oil Field Research Company in La Habra, California, in 1977 after a two-year postdoctoral fellowship at UCLA. He continues to work with the flow assurance core team in fluid analysis and phase behavior as integrated with multiphase flow.

Michael Eaton is a senior research engineer with the ExxonMobil Upstream Research Company. His work has focused on the performance of kinetic hydrate inhibitors and the modeling of hydrate-related phenomena. He has a BS and MS in chemical engineering from the Colorado School of Mines, and a PhD in materials science and engineering from the State University of New York at Stony Brook.

Carolyn Koh is associate professor and codirector of the Colorado School of Mines Hydrate Center. She is a fellow of the Royal Society of Chemistry and recipient of the Young Scientist Award of the British Association for Crystal Growth.

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Norm McMullen retired from his senior advisor position at BP America in July 2008. At present, he is working as a flow assurance consultant. Before joining BP in 1997, he was president of PipeSoft Corporation for 4 years and held many positions in Chevron Corporation over the previous 20 years. McMullen holds a BS and MS from the University of Washington, both in mechanical engineering. He is a member of SPE.

Thierry Palermo after a PhD in physical chemistry, entered (IFP) in 1989. He was in charge of the hydrates project and at the head of the complex fluids department for more than 10 years. He then became leader of the flow assurance project, and left IFP in May 2009 to join the production department at TOTAL E&P.

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Larry Talley after a PhD in physical chemical physics at the University of California, Riverside, joined Exxon as a research scientist in 1980. He has worked on enhanced oil recovery and flow assurance during his career. He is a coinventor of many kinetic hydrate inhibitors and of a hydrate cold flow process using static mixers.

LIST OF FIGURES

PREFACE

This is a condensed, updated version of earlier works to enable the flow assurance engineer to quickly answer seven questions:

(1) How do hydrate plugs form?
(2) How can hydrate plugs be prevented from forming?
(3) How to deal safely with hydrate plugs?
(4) How to remove a hydrate plug once it has formed?
(5) How can kinetic inhibitors be certified?
(6) What is the mechanism for naturally inhibited oils?
(7) What are industrial hydrate case studies?

Our focus is offshore systems, from the reservoir to the platform, because these lines are the most inaccessible and, thus, the most problematic. However, almost all of the content can be applied to onshore processes and export lines from platforms.

The intent was to combine eight industrial flow assurance perspectives (from British Petroleum [BP], Chevron, ExxonMobil, and the Total Petroleum) with three perspectivs from the Colorado School of Mines to enable resolution of hydrate design and operating problems. In a few pages the coauthors encapsulated knowledge from their careers to provide a basis for advancement by flow assurance engineers.

The trend over the last decade has focused on risk management to manage hydrates in field developments. Thus, the technical perspective of hydrate flow assurance is changing significantly, from avoidance to risk management. While industry previously chose to avoid having transportation equipment operate in the hydrate formation region of pressure and temperature (i.e., by inhibitor injection), a change in that earlier concept is to allow hydrate particles to form, while preventing hydrate plug formation. As this book illustrates, both economic and technical incentives are provided by adding new hydrate risk management tools to the existing tools of hydrate avoidance.

Our intention was to combine the practical experience of industry together with the concepts generated in academia, to state in this concise volume the basics of the new risk-management methods. We gratefully acknowledge the flow assurance engineers who contributed to enable this book: John Abrahamson, Alex Alverado, Guro Aspenes, Torstein Austvik, Ray Ayres, Jim Bennett, Gary Bergman, Phaneendra Bollavaram, John

Boxall, Jep Bracey, Ricardo Carmargo, Richard Christiansen, Jim Chitwood, Mike Conner, Chris Cooley, Simon Davies, Emmanuel Dellecasse, Laura Dieker, Mark Ehrhardt, Havard Eidsmoen, Douglas Estanga, Erik Freer, John Fulton, Jim Grant, David Greaves, Kathy Greenhill, Arvind Gupta, Ronny Hanssen, Greg Hatton, Chris Haver, Blake Hebert, Pål Hemmingsen Prof. Jean-Michel Herri, Scott Hickman, Nikhil Joshi, Sanjeev Joshi, Bob Kaminsky, Moussa Kane, Sam Kashou, Aftab Khokhar, Dean King, Keijo Kinnari, Veet Kruka, Roar Larsen, Joe Lederhos, Emile LePorcher, Jin-Ping Long, Susan Lorimer, Taras Makogon, Patrick Matthews, Ajay Mehta, Dave Miller, Kelly Miller, Pierre Montaud, Alberto Montesi, Julie Morgan, Alex Mussumeci, Bob Newton, Lewis Norman, Phil Notz, Bill Parrish, David Peters, Mike Phillips, David Qualls, Kevin Renfro, Kevin Rider Jeremy Rohan, Laura Rovetto, Allan Rydahl, Mike Scribner, Prof. Sami Selim (deceased), Don Shatto, Rob Sirco, Prof. Johan Sjöblom, Chris Smith, Mark Stair, Tim Strobel, Dan Subik, Siva Subramanian, Craig Taylor, Saadedine Tebbal, Troy Trosclar, Doug Turner, Mike Volk, Sung Oh Wang, and Nick Wolf.

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