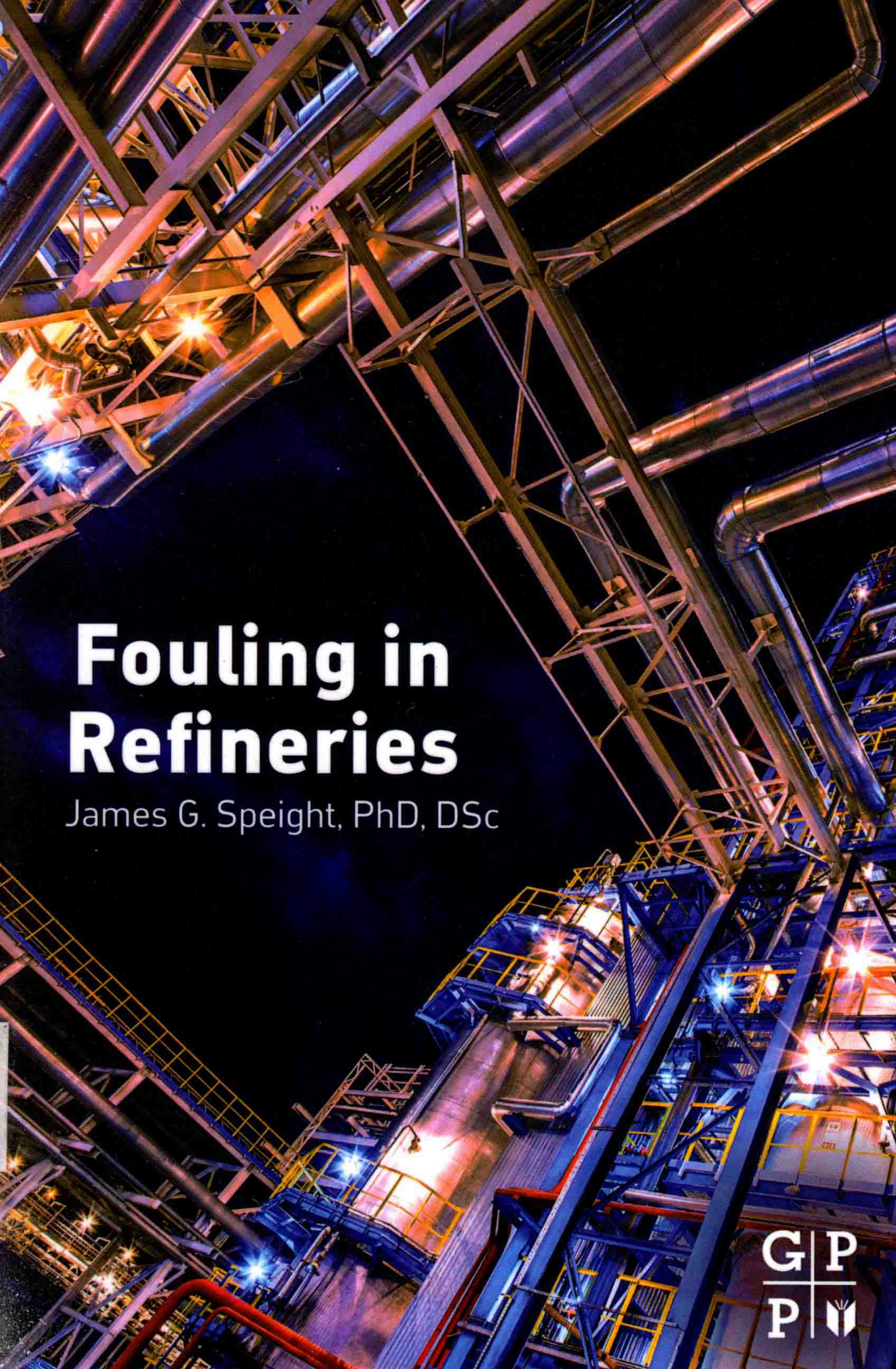

Fouling in Refineries

James G. Speight, PhD, DSc

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By

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Preface

Fouling (solids deposition and phase separation) can occur throughout the refinery and can affect almost every unit. Initially, fouling impacts mostly on the crude unit and other units where the whole crude is the feedstock. These units experience the highest feed rates and temperature increases. The battle to maintain heat through the preheat network of exchangers and furnace inlet temperatures is a constant issue. Traditionally (in the refining sense), the fouling is caused by the instability of asphaltene constituents, which can manifest itself as early as the tank farm through incompatible crude storage. In the refinery, exposure of the asphaltene constituents to heat changes the stability of the asphaltene constituents leading to agglomeration and deposition. Broadly, this can result in flow restrictions and harder furnace firing rates (more refinery fuel gas is consumed) in order to maintain temperatures at the distillation column or to reduce the crude throughput. In addition, nonasphaltene products formed during thermal processes can also give rise to phase separation and fouling.

In addition to fouling caused by the presence of asphaltene constituents, the wax constituents of crude oil (and crude oil products) are also capable of contributing the fouling. The presence of the constituents of wax increases fluid viscosity and its accumulation on the walls reduces the flow line section, causing the blockage of filters, valves and even pipelines, increasing pumping costs, and reducing or even having an adverse effect on crude oil production, storage, and transport. Thus, constituents of wax present in petroleum mixtures—as well as in petroleum products—can separate and form a precipitate when the temperature decreases during oil production, storage, and transport.

More specifically, wax may be deposited on the components of the production system by various mechanisms and causes loss of production, reduced pipe diameter, and increased horsepower requirements, and negatively impacts production economics. The available remedial measures include mechanical, chemical, and thermal techniques. Temperature reduction/heat loss is a dominant factor in wax problems, as wax begins to precipitate from crude when the temperature falls to or below the cloud point (wax appearance temperature). However, other factors such as pressure, oil composition, gas-oil ratio, water-oil ratio, flow rate, well completion, and pipe-surface roughness also contribute to the problem of wax deposition.

Over time, fouling (whatever the cause—asphaltene constituents or wax constituents—leads to higher energy consumption, higher maintenance costs, reduced feed rates, and shorter intervals between turnaround. This can result in severe economic penalties, as well as significant safety and environmental concerns.

This book covers the various aspects of fouling during production and in refinery units and describes how the fouling rate can be greatly influenced by the crude type or blend as well as the effects of using opportunity and high acid crudes, although these crude do offer an economic incentive to the refinery that can process them. The book will also assist the reader to develop an analysis-based strategy to operate production and refining equipment below the threshold fouling conditions as well as create a knowledge-based system for understanding and predicting the potential of crude oil to contribute to the fouling phenomenon.

The book will be valuable to production personnel, pipeline personnel, and refinery personnel—researchers, process engineers, process chemists, and managers—as well as to nonrefinery personnel—analysts and researchers—who need to understand the chemical and physical mechanisms of fouling.

Dr. James G. Speight
Laramie, WY, USA

Biography

Dr. James G. Speight, who has doctorate degrees in Chemistry, Geological Sciences, and Petroleum Engineering, is the author of more than 60 books in petroleum science, petroleum engineering, and environmental sciences. He has served as Adjunct Professor in the Department of Chemical and Fuels Engineering at the University of Utah and in the Departments of Chemistry and Chemical and Petroleum Engineering at the University of Wyoming. In addition he has been a Visiting Professor in Chemical Engineering at the following universities: the University of Missouri-Columbia, the Technical University of Denmark, and the University of Trinidad and Tobago.

As a result of his work, Dr. Speight has been honored as the recipient of the following awards:

- Diploma of Honor, United States National Petroleum Engineering Society. *For Outstanding Contributions to the Petroleum Industry*. 1995.
- Gold Medal of the Russian Academy of Sciences. *For Outstanding Work in the Area of Petroleum Science*. 1996.
- Einstein Medal of the Russian Academy of Sciences. *In recognition of Outstanding Contributions and Service in the field of Geologic Sciences*. 2001.
- Gold Medal—Scientists without Frontiers, Russian Academy of Sciences. *In recognition of His Continuous Encouragement of Scientists to Work Together across International Borders*. 2005.
- Methanex Distinguished Professor, University of Trinidad and Tobago. *In Recognition of Excellence in Research*. 2006.
- Gold Medal—Giants of Science and Engineering, Russian Academy of Sciences. *In recognition of Continued Excellence in Science and Engineering*. 2006.

Contents

Chapter 1

The Concept of Fouling

1.1 INTRODUCTION

Fouling, as it pertains to petroleum refineries (Speight, 2000; Speight and Ozum, 2002; Parkash, 2003; Hsu and Robinson, 2006; Gary et al., 2007; Speight, 2014a–e), is deposit formation, encrustation, deposition, scaling, scale formation, slagging, and sludge formation which has an adverse effect on operations. It is the accumulation of unwanted material within a processing unit or on the on solid surfaces of the unit to the detriment of function. For example, when it does occur during refinery operations, the major effects include (1) loss of heat transfer as indicated by charge outlet temperature decrease and pressure drop increase, (2) blocked process pipes, (3) under-deposit corrosion and pollution, and (4) localized hot spots in reactors, all of which culminate in production losses and increased maintenance costs. In addition, the term macrofouling if often used to generally describe the blockage of tubes and pipes while, on the other hand microfouling is generally iced to describe scaling on the walls of the tubes and pipes. Again, the outcome is a loss of efficiency and output to the refinery.

Fouling during production or transportation or refining can occur in a variety of processes, either inadvertently when the separation is detrimental to the process or by intent (such as in the deasphalting process or in the dewaxing process). Thus, separation of solids occurs whenever the solvent characteristics of the liquid phase are no longer adequate to maintain polar and/or high molecular weight constituents in solution. Examples of such occurrences are: (1) separation of asphaltene constituents, which occurs when the paraffin nature of the liquid medium increases, (2) wax separation which occurs when there is a drop in temperature or the aromaticity of the liquid medium increases, and (3) sludge/sediment formation in a reactor which occurs when the solvent characteristics of the liquid medium change so that asphaltic or wax materials separate, coke formation which occurs at high temperatures and commences when the solvent power of the liquid phase is not sufficient to maintain the coke precursors in solution, and sludge/sediment formation in fuel products which occurs because of the interplay of several chemical and physical factors.

Typically, the fouling material consists of organic and/or inorganic materials deposited by the feedstock that is deposited by the occurrence of instability or

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incompatibility of the feedstock (one crude oil) with another during and shortly after a blending operation (Speight, 2014a).

Blending is one of the typical operations that a refinery must pursue not only to prepare a product to meet sales specifications, but also to blend the different crudes and heavy feedstocks to produce a refinery feedstocks (Speight, 2000; Speight and Ozum, 2002; Parkash, 2003; Hsu and Robinson, 2006; Gary et al., 2007; Speight, 2014a–e). Although simple in principle, the blending operation must be performed with care and diligence with the regular acceptance by refineries of heavy feedstocks as part of the refinery slate. Lack of attention to the properties of the individual feedstocks prior to the blending operations can lead to asphaltene precipitation or phase separation (fouling) due to incompatibility of the different components of the blend (Schermer et al., 2004; Speight, 2014a–e). This would result in the occurrence of fouling deposits in heat transfer equipment and reactors as a substantial energy cost to the refinery (Stark and Asomaning, 2003; Van den Berg et al., 2003). Therefore, it is advisable for the refiner to be able to predict the potential for incompatibility by determining not only the appropriate components for the blend, but also the ration of individual crude oils and heavy feedstocks in the blend.

The compatibility of crude oils is generally evaluated by colloidal stability based on bulk composition or asphaltene precipitation (Mushrush and Speight, 1995, 1998; Asomaning and Watkinson, 2000). Typically, the test methods are performed under used to evaluate oil stability at ambient conditions, but applying the data to the potential for fouling under the actual parameters used in heat transfer equipment must be done with caution. Fouling is dependent upon not only the conditions of asphaltene separation fluid and the stability of the crude oil/heavy feedstock system (Chapter 4), but also on flow conditions and other parameters (Asomaning and Watkinson, 2000; Saleh et al., 2005; Stark and Asomaning, 2003; Derakhshesh et al., 2013). Fouling is concerned with not only asphaltene precipitation (Srinivasan and Watkinson, 2003). In addition, fouling can also be a consequence of corrosion in a unit when deposits of inorganic solids become evident (Speight, 2014b). With the influx of opportunity crudes, high-acid crudes, heavier crude oils, extra heavy crude oils, and tar sand bitumen into refineries (Chapter 2) fouling phenomena are more common and diverse (Speight, 2005, 2008, 2009, 2013a–c, 2014a).

In the petroleum industry, the components that may be subject to fouling and the corresponding effects of fouling are (1) the production zone of crude oil reservoirs and oil wells, which is reflected by a decrease in production with time though the formation of plugs which can lead to complete cessation of flow, (2) pipes and flow channels which results in reduced flow, increased pressure drop, increased upstream pressure, slugging in two-phase flow, and flow blockage, (3) heat exchangers surfaces, which results in a reduction in thermal efficiency along with decreased heat flux, increased temperature on the hot side, decreased temperature on the cold side, and under-deposit corrosion,