



Fouling in Refineries

James G. Speight, PhD, DSc



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By

James G. Speight PhD, DSc



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Fouling in Refineries

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
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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

Preface	xiii
Biography	xv

1. The Concept of Fouling	
1.1 Introduction	1
1.2 Fouling	4
1.2.1 Fouling on Surfaces	4
1.3 Parameters Affecting Fouling	5
1.3.1 Fluid Flow Velocity	5
1.3.2 Surface Temperature	6
1.3.3 Surface Material	7
1.3.4 Surface Roughness	7
1.3.5 Fluid Properties	7
1.4 Fouling Mechanisms	8
1.4.1 Particles in the Feedstock	8
1.4.2 Particle Formation	10
1.4.3 Corrosion Fouling	10
1.4.4 Aggregation and Flocculation	12
1.4.5 Phase Separation	13
1.4.6 Particle Deposition	15
1.4.7 Deposit Growth and Deposit Deterioration	15
1.5 Rate of Fouling and Fouling Factor	16
1.5.1 Rate of Fouling	16
1.5.2 Fouling Factor	18
1.6 Determination of Fouling Potential	18
1.6.1 Definitions and Terminology	19
1.6.2 General Chemistry	20
1.6.3 Test Methods	21
1.6.4 Determination of Fouling Potential	21
1.7 The Future	24
References	25
2. Refinery Feedstocks	
2.1 Introduction	31
2.2 Feedstock Character	35
2.2.1 Conventional Petroleum	37
2.2.2 High-acid Crudes	41

2.2.3	Opportunity Crudes	44
2.2.4	Oil from Tight Shale	45
2.2.5	Foamy Oil	47
2.2.6	Heavy Oil	48
2.2.7	Extra Heavy Oil	48
2.2.8	Tar Sand Bitumen	48
2.2.9	Biomass	49
2.3	Composition	51
2.3.1	Elemental Composition	51
2.3.2	Chemical Composition	52
2.3.3	Fractional Composition	53
2.3.4	Biomass	58
2.4	Petroleum Products	58
	References	61
3.	Refining Chemistry and Fouling Potential	
3.1	Introduction	65
3.2	Cracking	66
3.2.1	Thermal Cracking	67
3.2.2	Catalytic Cracking	73
3.3	Hydroprocesses	76
3.3.1	Hydrotreating	76
3.3.2	Hydrocracking	79
3.4	Other Reactions	81
3.4.1	Dehydrogenation	81
3.4.2	Dehydrocyclization	82
3.4.3	Isomerization	82
3.4.4	Alkylation	83
3.4.5	Polymerization	84
	References	84
4.	The Stability of Petroleum	
4.1	Introduction	87
4.2	The Petroleum System	89
4.3	Stability/Instability of the Petroleum System	90
4.4	Effects on Recovery and Refining	96
4.4.1	Recovery Operations	97
4.4.2	Refining Operations	100
4.5	Epilog	103
	References	104
5.	Analytical Methods	
5.1	Introduction	109
5.2	Standard Test Methods	111
5.2.1	Elemental Analysis	112
5.2.2	Density	113
5.2.3	Volatility	113

5.2.4	Viscosity	114
5.2.5	Asphaltene Content	114
5.2.6	Pour Point	116
5.2.7	Acidity	116
5.2.8	Metals (Ash) Content	117
5.2.9	Water Content, Salt Content, and Bottom Sediment/Water (BS&W)	118
5.3	Methods for Determining Fouling Potential	118
5.3.1	Feedstock Analysis	120
5.3.2	Foulant Analysis	122
	References	124
6.	Asphaltene Deposition and Fouling	
6.1	Introduction	129
6.2	Separation	131
6.3	Composition	134
6.4	Molecular Weight	137
6.5	Reactions	138
6.5.1	Thermal Reactions	138
6.5.2	Oxidation	140
6.5.3	Other Reactions	140
6.6	Solubility Parameter	141
6.7	Deposition and Fouling	144
6.7.1	Fouling During Production	144
6.7.2	Fouling During Refining	146
	References	150
7.	Wax Deposition and Fouling	
7.1	Introduction	155
7.2	Composition	157
7.3	Solids Deposition	159
7.3.1	Wax Crystallization	160
7.3.2	Wax Deposition	160
7.3.3	Factors Leading to Wax Deposition	161
7.3.4	Measurement of the Wax Appearance Temperature	164
7.3.5	Phase Behavior	165
7.3.6	Wax Analysis	167
7.4	Fouling	167
7.4.1	Mechanism	168
7.4.2	Management and Mitigation	169
	References	170
8.	Fouling During Predistillation and Distillation	
8.1	Introduction	175
8.2	Fouling During Production	176
8.2.1	Wax Deposition	177
8.2.2	Asphaltene Deposition	178

8.3	Refinery Configurations	179
8.4	Dewatering and Desalting	180
8.5	Distillation	185
8.5.1	Distillation at Atmospheric Pressure	186
8.5.2	Distillation Under Reduced Pressure	190
8.6	Fouling and Corrosion	191
8.6.1	Dewatering and Desalting	195
8.6.2	Heat Exchangers	197
8.6.3	The Distillation Towers	200
	References	203
9.	Fouling During Deasphalting and Dewaxing	
9.1	Introduction	209
9.2	Deasphalting Processes	210
9.2.1	The Deasphalting Process	210
9.2.2	Process Options for Heavy Feedstocks	218
9.3	Dewaxing Processes	223
9.3.1	Cold Press Process	224
9.3.2	Solvent Dewaxing Process	224
9.3.3	Urea Dewaxing Process	227
9.3.4	Centrifuge Dewaxing Process	228
9.3.5	Catalytic Dewaxing Process	228
9.4	Fouling	230
9.4.1	Deasphalting	230
9.4.2	Dewaxing	233
	References	234
10.	Fouling During Thermal Processes	
10.1	Introduction	237
10.2	Processes	242
10.2.1	Thermal Cracking	244
10.2.2	Visbreaking	246
10.2.3	Coking	251
10.3	Fouling	260
10.3.1	Fouling During Visbreaking	261
10.3.2	Impact of Foulants	262
10.3.3	Fouling During Coking	264
10.3.4	Impact of Foulants	266
	References	267
11.	Fouling During Catalytic Cracking	
11.1	Introduction	271
11.2	Commercial Processes	275
11.2.1	Fixed-Bed Processes	277
11.2.2	Fluid-Bed Processes	277
11.2.3	Moving-Bed Processes	280
11.2.4	Process Variables	281

11.3 Catalysts	287
11.3.1 Catalyst Properties	288
11.3.2 Catalyst Variables	289
11.3.3 Catalyst Treatment	290
11.4 Options for Heavy Feedstocks	290
11.4.1 Asphalt Residual Treating (ART) Process	291
11.4.2 Residue Fluid Catalytic Cracking Process	292
11.4.3 Heavy Oil Treating Process	293
11.4.4 R2R Process	293
11.4.5 Reduced Crude Oil Conversion Process	294
11.4.6 Shell FCC Process	294
11.4.7 S&W Fluid Catalytic Cracking Process	295
11.5 Fouling	295
11.5.1 Catalyst Fouling	296
11.5.2 Fractionator Fouling	297
11.5.3 Heat-Exchanger Fouling	299
References	301
 12. Fouling During Hydrotreating	
12.1 Introduction	303
12.2 Commercial Processes	306
12.2.1 General Aspects	306
12.2.2 Process Parameters	311
12.2.3 Reactors	313
12.2.4 Commercial Processes	316
12.3 Options for Heavy Feedstocks	317
12.3.1 Residuum Desulfurization and Vacuum Residuum Desulfurization Process	318
12.3.2 Residfining Process	319
12.4 Catalysts	320
12.5 Fouling	325
12.5.1 Catalyst Bed Fouling	326
12.5.2 Heat Exchanger Fouling	327
References	328
 13. Fouling During Hydrocracking	
13.1 Introduction	329
13.2 Process Parameters	330
13.2.1 Process Design	332
13.2.2 Single-Stage and Two-Stage Options	332
13.2.3 Process Variants	334
13.3 Options for Heavy Feedstocks	336
13.3.1 H-Oil Process	336
13.3.2 LC-Fining Process	338
13.3.3 Residfining Process	339
13.3.4 Uniflex Process	340
13.4 Catalysts	341

13.5	Fouling	344
13.5.1	General Aspects	344
13.5.2	Catalyst Fouling	345
13.5.3	Fractionator Fouling	347
	References	348
14.	Fouling During Gas Cleaning	
14.1	Introduction	351
14.2	Gas Streams	351
14.2.1	Natural Gas	352
14.2.2	Process Gas	353
14.3	Gas Cleaning	356
14.4	Acid Gas Removal	361
14.5	Fouling	364
14.5.1	Olamine Fouling	365
14.5.2	Absorber Fouling	370
14.5.3	Heat Exchanger Fouling	371
14.5.4	Regenerator Fouling	371
14.5.5	Filter Fouling	371
14.5.6	Mitigation	372
	References	372
15.	Fouling During Product Improvement Processes	
15.1	Introduction	375
15.2	Reforming	375
15.2.1	General Aspects	375
15.2.2	Fouling	378
15.3	Isomerization	379
15.3.1	General Aspects	379
15.3.2	Fouling	380
15.4	Alkylation	381
15.4.1	General Aspects	381
15.4.2	Fouling	382
15.5	Polymerization	385
15.5.1	General Aspects	385
15.5.2	Fouling	386
15.6	Product Blending	386
	References	388
16.	Fouling in Petroleum Products	
16.1	Introduction	391
16.2	Fuels	394
16.2.1	Manufacture	394
16.2.2	Fouling	394

16.3 Fuel Oil	399
16.3.1 Manufacture	399
16.3.2 Fouling	400
16.4 Lubricating Oil	402
16.4.1 Manufacture	402
16.4.2 Fouling	403
16.5 Wax	405
16.5.1 Manufacture	405
16.5.2 Fouling	406
16.6 Asphalt	406
16.6.1 Manufacture	407
16.6.2 Fouling	408
References	411
 17. Fouling as a Result of Corrosion	
17.1 Introduction	413
17.2 Types of Corrosion	414
17.2.1 Acidic Corrosion	414
17.2.2 Sulfidic Corrosion	416
17.2.3 Oxidative Corrosion	417
17.2.4 Carburization	418
17.2.5 Sour Water Corrosion	418
17.2.6 Biocorrosion	418
17.3 Effect of Temperature	419
17.4 Corrosion in Refinery Systems	420
17.4.1 Heat Exchangers	423
17.4.2 Pipelines	424
17.4.3 Storage Tanks	427
17.4.4 Refinery Processes	427
17.4.5 Distillation	431
17.4.6 Coking	434
17.4.7 Catalytic Cracking	435
17.4.8 Hydroprocesses	436
17.4.9 Product Improvement Processes	437
17.5 Corrosion in Gas Processing Plants	443
17.5.1 Hydrogen Sulfide Corrosion	443
17.5.2 Carbon Dioxide Corrosion	447
17.5.3 Other Corrosive Agents	448
References	448
 18. Fouling Treatment and Control	
18.1 Introduction	453
18.2 Monitoring	455
18.2.1 Sampling	456
18.2.2 Feedstock Analysis	457
18.2.3 Foulant Analysis	458

18.3 Treatment and Mitigation	461
18.3.1 Treatment	462
18.3.2 Mitigation	465
References	470
 Conversion Factors	475
Glossary	477
Index	517

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, slugging, 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 is often used to generally describe the blockage of tubes and pipes while, on the other hand microfouling is generally used 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

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,