
Contents

Preface to the Second Edition.....	xiii
Preface to the First Edition	xv
Author	xvii

Chapter 1 Introduction and Environmental Issues.....	1
1.1 Production Chemistry Overview.....	1
1.2 Factors That Affect the Choice of Production Chemicals.....	4
1.2.1 Chemical Injection, Where to Inject, and Other Methods of Chemical Deployment	6
1.2.1.1 What Is the Best Place to Inject the Chemical to Maximize the Efficacy of the Treatment?	7
1.2.1.2 Will the Chemical Have Enough Residence Time in the Line to Do Its Job Properly?.....	8
1.2.1.3 Is the Chemical Compatible with the Temperature at the Injection Site?.....	8
1.2.1.4 Is the Chemical Compatible with the Fluids into Which It Is Injected?.....	8
1.2.1.5 Will the Chemical Cause Unwanted Side Effects in the Injection, Production, or Processing Equipment?.....	8
1.2.1.6 Will the Chemical Affect the Efficacy of Other Production Chemicals?	8
1.2.1.7 Viscosity and Pumping Problems in the Injection Line	9
1.3 Environmental and Ecotoxicological Regulations	9
1.3.1 OSPAR Environmental Regulations for Oilfield Chemicals	10
1.3.2 European REACH Regulations.....	11
1.3.3 United States Environmental Regulations	12
1.3.4 Environmental Regulations Elsewhere	12
1.4 Designing Greener Chemicals.....	13
1.4.1 Bioaccumulation.....	13
1.4.2 Reducing Toxicity.....	13
1.4.3 Achieving Biodegradability	14
1.5 Mercury and Arsenic Production	17
References	18

Chapter 2 Water and Gas Control.....	23
2.1 Introduction	23
2.2 Resins and Elastomers.....	24
2.3 Inorganic Gels	24
2.4 Cross-Linked Organic Polymer Gels for Permanent Shut-Off	26
2.4.1 Polymer Injection	26
2.4.1.1 Metal Ion Cross-Linking of Carboxylate-Containing Acrylamides and Biopolymers	27
2.4.1.2 Gels Using Natural Polymers	28
2.4.1.3 Organic Cross-Linking.....	29

	2.4.1.4	Polyvinyl Alcohol or Polyvinylamine Gels	31
	2.4.1.5	Problems Associated with Polymer Gel Water Shut-Off Treatments	31
	2.4.1.6	Other Improvements for Cross-Linked Polymer Gels	32
	2.4.2	<i>In Situ</i> Monomer Polymerization	32
2.5		Viscoelastic Surfactant Gels.....	33
2.6		Disproportionate Permeability Reducer or Relative Permeability Modifier	33
	2.6.1	Emulsified Gels as DPRs.....	34
	2.6.2	Hydrophilic Polymers as RPMs	34
	2.6.2.1	Types of Polymer RPM.....	35
	2.6.2.2	Hydrophobically Modified Synthetic Polymers as RPMs	36
	2.6.2.3	Cross-Linked Polymer RPMs.....	38
	2.6.2.4	Viscoelastic RPMs.....	39
2.7		Water Control Using Microparticles	39
2.8		Thermally Sensitive Water-Soluble Polymers	40
2.9		Water-Swellable Polymers.....	40
2.10		Gas Shut-Off.....	41
		References	41
Chapter 3		Scale Control	51
	3.1	Introduction	51
	3.2	Types of Scale.....	51
	3.2.1	Calcium Carbonate Scale.....	52
	3.2.2	Sulfate Scales	53
	3.2.3	Sulfide Scales	54
	3.2.4	Sodium Chloride (Halite) Scale	54
	3.2.5	Mixed Scales	55
	3.3	Nonchemical Scale Control	55
	3.4	Scale Inhibition of Group II Carbonates and Sulfates	56
	3.4.1	Polyphosphates.....	58
	3.4.2	Phosphate Esters.....	58
	3.4.3	Nonpolymeric Phosphonates and Aminophosphonates	59
	3.4.4	Polyphosphonates	62
	3.4.5	Phosphino Polymers and Polyphosphinates	63
	3.4.6	Polycarboxylates.....	65
	3.4.6.1	Biodegradable Polycarboxylates.....	66
	3.4.7	Polysulfonates.....	68
	3.5	Sulfide Scale Inhibition	69
	3.6	Halite Scale Inhibition.....	70
	3.7	Methods of Deploying Scale Inhibitors.....	71
	3.7.1	Continuous Injection	72
	3.7.2	Scale Inhibitor Squeeze Treatments.....	72
	3.7.2.1	Scale Inhibitor Squeeze Treatments Combined with Other Well Treatments.....	77
	3.7.3	Nonaqueous or Solid Scale Inhibitors for Squeeze Treatments	78
	3.7.3.1	Oil-Miscible Scale Inhibitors.....	78
	3.7.3.2	Totally Water-Free Scale Inhibitors in Organic Solvent Bends	78
	3.7.3.3	Emulsified Scale Inhibitors.....	79

	3.7.3.4 Solid Scale Inhibitors (for Squeezing and Otherwise).....	79
	3.7.4 Placement of Scale Inhibitor in a Squeeze Treatment.....	80
3.8	Performance Testing of Scale Inhibitors	81
3.9	Chemical Scale Removal.....	83
	3.9.1 Carbonate Scale Removal	83
	3.9.2 Sulfate Scale Removal.....	85
	3.9.3 Sulfide Scale Removal.....	87
	3.9.4 Lead Scale Removal.....	88
	References	88
Chapter 4	Asphaltene Control.....	111
	4.1 Introduction	111
	4.2 Asphaltene Dispersants and Inhibitors.....	114
	4.3 Low Molecular Weight, Nonpolymeric Asphaltene Dispersants	116
	4.3.1 Low-Polarity Nonpolymeric Aromatic Amphiphiles.....	117
	4.3.2 Sulfonic Acid–Base Nonpolymeric Surfactant ADs.....	118
	4.3.3 Other Nonpolymeric Surfactant ADs with Acidic Head Groups.....	119
	4.3.4 Amide and Imide Nonpolymeric Surfactant ADs	121
	4.3.5 Alkylphenols and Related ADs	123
	4.3.6 Ion-Pair Surfactant ADs.....	124
	4.3.7 Miscellaneous Nonpolymeric ADs	125
	4.4 Oligomeric (Resinous) and Polymeric AIs.....	126
	4.4.1 Alkylphenol–Aldehyde Resin Oligomers.....	126
	4.4.2 Polyester and Polyamide/Imide AIs.....	128
	4.4.3 Other Polymeric Asphaltene Inhibitors.....	132
	4.5 Summary of ADs and AIs.....	133
	4.6 Asphaltene Dissolvers	134
	References	136
Chapter 5	Acid Stimulation.....	145
	5.1 Introduction	145
	5.2 Fracture Acidizing of Carbonate Formations.....	145
	5.3 Matrix Acidizing	146
	5.4 Acids Used in Acidizing.....	146
	5.4.1 Acids for Carbonate Formations	146
	5.4.2 Acids for Sandstone Formations	147
	5.5 Potential Formation Damage from Acidizing	148
	5.6 Acidizing Additives	148
	5.6.1 Corrosion Inhibitors for Acidizing.....	149
	5.6.1.1 General Discussion	149
	5.6.1.2 Nitrogen-Based Corrosion Inhibitors	149
	5.6.1.3 Oxygen-Containing Corrosion Inhibitors Including Those with Unsaturated Linkages.....	151
	5.6.1.4 Corrosion Inhibitors Containing Sulfur	154
	5.6.2 Iron Control Agents.....	155
	5.6.3 Water-Wetting Agents	156
	5.6.4 Other Optional Chemicals in Acidizing Treatments.....	156
	5.7 Axial Placement of Acid Treatments.....	157
	5.7.1 Solid Particle Diverters	158

5.7.2	Polymer Gel Diverters.....	158
5.7.3	Foam Diverters.....	160
5.7.4	Viscoelastic Surfactants.....	161
5.8	Radial Placement of Acidizing Treatments.....	165
5.8.1	Oil-Wetting Surfactants.....	165
5.8.2	Weak Organic Acids.....	166
5.8.3	Weak Sandstone-Acidizing Fluorinated Agents.....	166
5.8.4	Buffered Acids.....	166
5.8.5	Gelled or Viscous Acids.....	166
5.8.6	Foamed Acids.....	167
5.8.7	Temperature-Sensitive Acid-Generating Chemicals and Enzymes.....	167
5.8.8	Emulsified Acids.....	167
	References.....	168
Chapter 6	Sand Control.....	179
6.1	Introduction.....	179
6.2	Chemical Sand Control.....	179
6.2.1	Consolidation with Resins.....	179
6.2.2	Consolidation with Organosilanes.....	180
6.2.3	Other Chemical Consolidation Methods.....	181
	References.....	182
Chapter 7	Control of Naphthenate and Other Carboxylate Fouling.....	185
7.1	Introduction.....	185
7.2	Naphthenate Deposition Control Using Acids.....	186
7.3	Low-Dosage Naphthenate Inhibitors.....	186
	References.....	189
Chapter 8	Corrosion Control during Production.....	191
8.1	Introduction.....	191
8.2	Methods of Corrosion Control.....	193
8.3	Corrosion Inhibitors.....	194
8.4	Film-Forming Corrosion Inhibitors.....	195
8.4.1	How FFCIs Work.....	196
8.4.2	Testing Corrosion Inhibitors.....	197
8.4.3	Efforts to Develop More Environment-Friendly FFCIs.....	198
8.4.4	Classes of FFCIs.....	198
8.4.4.1	Phosphate Esters.....	199
8.4.4.2	Amine Salts of (Poly)carboxylic Acids.....	200
8.4.4.3	Quaternary Ammonium and Iminium Salts and Zwitterionics.....	200
8.4.4.4	Amidoamines and Imidazolines.....	203
8.4.4.5	Amides.....	207
8.4.4.6	Polyhydroxy and Ethoxylated Amines/Amides.....	207
8.4.4.7	Other Nitrogen Heterocyclics.....	208
8.4.4.8	Sulfur Compounds.....	208
8.4.4.9	Polyamino Acids and Other Polymeric Water-Soluble Corrosion Inhibitors.....	211
	References.....	212

Chapter 9	Gas Hydrate Control.....	219
9.1	Introduction	219
9.2	Chemical Prevention of Hydrate Plugging	221
9.2.1	Thermodynamic Hydrate Inhibitors.....	221
9.2.1.1	Operational Issues with THIs	224
9.2.2	Kinetic Hydrate Inhibitors	224
9.2.2.1	Introduction to KHIs and KHI Mechanisms	224
9.2.2.2	Vinylactam KHI Polymers	227
9.2.2.3	Hyperbranched Polyesteramide KHIs	230
9.2.2.4	Compatibility of KHIs with other Production Chemicals	231
9.2.2.5	Pyroglutamate KHI Polymers	231
9.2.2.6	Poly(di)alkyl(meth)acrylamide KHIs	232
9.2.2.7	Other Classes of KHIs	233
9.2.2.8	Performance Testing of KHIs.....	235
9.2.2.9	Recycling or Disposal of KHIs.....	237
9.2.3	Anti-Agglomerants.....	237
9.2.3.1	Emulsion Pipeline AAs	238
9.2.3.2	Hydrate-Philic Pipeline AAs	238
9.2.3.3	Performance Testing of Pipeline AAs	242
9.2.3.4	Natural Surfactants and Nonplugging Oils	243
9.2.3.5	Gas-Well AAs	243
9.3	Gas Hydrate Plug Removal.....	244
9.3.1	Use of THIs	244
9.3.2	Heat-Generating Chemicals	245
	References	245
Chapter 10	Wax (Paraffin Wax) Control.....	259
10.1	Introduction	259
10.1.1	Wax Deposition	260
10.1.2	Increased Viscosity and Wax Gelling	261
10.2	Wax Control Strategies.....	261
10.3	Chemical Wax Removal	263
10.3.1	Hot Oiling and Related Techniques	263
10.3.2	Wax Solvents	264
10.3.3	Thermochemical Packages.....	264
10.4	Chemical Wax Prevention	266
10.4.1	Test Methods	266
10.4.2	Wax Inhibitors and PPDs	267
10.4.3	Ethylene Polymers and Copolymers.....	269
10.4.4	Comb Polymers	270
10.4.4.1	(Meth)acrylate Ester Polymers	270
10.4.4.2	Maleic Copolymers.....	272
10.4.5	Miscellaneous Polymers.....	274
10.4.6	Wax Dispersants.....	276
10.4.7	Polar Crude Fractions as Flow Improvers.....	277
10.4.8	Deployment Techniques for Wax Inhibitors and PPDs.....	278
	References	278

Chapter 11	Demulsifiers	287
11.1	Introduction	287
11.2	Methods of Demulsification	288
11.3	Water-in-Oil Demulsifiers	289
11.3.1	Theory and Practice	289
11.3.2	Test Methods and Parameters for Demulsifier Selection	290
11.3.3	Classes of Water-in-Oil Demulsifier	291
11.3.3.1	Polyalkoxylate Block Copolymers and Ester Derivatives...	293
11.3.3.2	Alkylphenol–Aldehyde Resin Alkoxylates.....	293
11.3.3.3	Polyalkoxylates of Polyols or Glycidyl Ethers	295
11.3.3.4	Polyamine Polyalkoxylates and Related Cationic Polymers	296
11.3.3.5	Polyurethanes (Carbamates) and Polyalkoxylate Derivatives	296
11.3.3.6	Hyperbranched Polymers.....	297
11.3.3.7	Vinyl Polymers	297
11.3.3.8	Polysilicones	298
11.3.3.9	Demulsifiers with Improved Biodegradability	298
11.3.3.10	Dual-Purpose Demulsifiers	301
	References	302
Chapter 12	Foam Control.....	307
12.1	Introduction	307
12.2	Defoamers and Antifoams.....	307
12.2.1	Silicones and Fluorosilicones.....	308
12.2.2	Polyglycols.....	309
	References	310
Chapter 13	Flocculants	313
13.1	Introduction	313
13.2	Theory of Flocculation	314
13.3	Flocculants.....	314
13.3.1	Performance Testing of Flocculants.....	316
13.3.2	Cationic Polymers	316
13.3.2.1	Diallyldimethylammonium Chloride Polymers.....	317
13.3.2.2	Acrylamide or Acrylate-Based Cationic Polymers.....	317
13.3.2.3	Other Cationic Polymers.....	319
13.3.2.4	Environment-Friendly Cationic Polymeric Flocculants ..	320
13.3.2.5	Dithiocarbamates; Pseudocationic Polymeric Flocculants with Good Environmental Properties	321
13.3.3	Anionic Polymers	322
13.3.4	Amphoteric Polymers.....	323
	References	323
Chapter 14	Biocides	327
14.1	Introduction	327
14.2	Chemicals for Control of Bacteria.....	328
14.3	Biocides	330

14.3.1	Oxidizing Biocides	330
14.3.2	Nonoxidizing Organic Biocides	332
14.3.2.1	Aldehydes	333
14.3.2.2	Quaternary Phosphonium Compounds.....	334
14.3.2.3	Quaternary Ammonium Compounds	336
14.3.2.4	Cationic Polymers.....	337
14.3.2.5	Organic Bromides.....	337
14.3.2.6	Metronidazole	338
14.3.2.7	Isothiazolones (or Isothiazolinones) and Thiones	338
14.3.2.8	Organic Thiocyanates.....	339
14.3.2.9	Phenolics	339
14.3.2.10	Alkylamines, Diamines, and Triamines.....	339
14.3.2.11	Dithiocarbamates.....	340
14.3.2.12	2-(Decylthio)ethanamine and Its Hydrochloride.....	340
14.3.2.13	Triazine Derivatives.....	340
14.3.2.14	Oxazolidines	341
14.3.2.15	Specific Surfactant Classes.....	341
14.4	Biostats (Control “Biocides” or Metabolic Inhibitors)	341
14.4.1	Anthraquinone as Control Biocide.....	342
14.4.2	Nitrate and Nitrite Treatment	342
14.4.3	Other Biostats	343
14.5	Summary	344
	References	344
Chapter 15	Hydrogen Sulfide Scavengers	353
15.1	Introduction	353
15.2	Nonregenerative H ₂ S Scavengers	355
15.2.1	Solid Scavengers.....	356
15.2.2	Oxidizing Chemicals.....	356
15.2.3	Aldehydes	357
15.2.4	Reaction Products of Aldehydes and Amines, Especially Triazines....	359
15.2.5	Metal Carboxylates and Chelates	362
15.2.6	Other Amine-Based Products	362
15.3	Summary	364
	References	364
Chapter 16	Oxygen Scavengers.....	369
16.1	Introduction	369
16.2	Classes of Oxygen Scavengers	369
16.2.1	Dithionite Salts.....	370
16.2.2	Hydrazine and Guanidine Salts.....	370
16.2.3	Hydroxylamines and Oximes	370
16.2.4	Activated Aldehydes and Polyhydroxyl Compounds	371
16.2.5	Catalytic Hydrogenation.....	371
16.2.6	Enzymes	372
16.2.7	Sulfided Iron Reagents	372
16.2.8	Bisulfite, Metabisulfite, and Sulfite Salts	372
	References	373

Chapter 17	Drag-Reducing Agents	375
17.1	Introduction	375
17.2	Drag-Reducing Agent Mechanisms.....	376
17.3	Oil-Soluble DRAs.....	378
17.3.1	Background	378
17.3.2	Oil-Soluble Polymeric DRAs	378
17.3.2.1	Polyalkene (Polyolefin) DRAs	378
17.3.2.2	Poly(meth)acrylate Ester DRAs.....	380
17.3.2.3	Other Oil-Soluble DRA Polymers	381
17.3.2.4	Overcoming Handling, Pumping, and Injection Difficulties with UHMW DRA Polymers	381
17.3.2.5	Oil-Soluble Polymeric DRAs in Multiphase Flow	382
17.3.3	Oil-Soluble Surfactant DRAs.....	382
17.4	Water-Soluble DRAs	383
17.4.1	Water-Soluble Polymer DRAs.....	383
17.4.1.1	Polysaccharides and Derivatives	384
17.4.1.2	Polyethylene Oxide Drag-Reducing Agents	384
17.4.1.3	Acrylamide-Based DRAs	385
17.4.2	Water-Soluble Surfactant DRAs.....	387
17.4.3	Drag Reduction and Corrosion Inhibition.....	389
	References	389
Chapter 18	Chemicals for Hydrotesting	397
18.1	Introduction	397
18.2	Hydrotesting Formulations.....	398
18.2.1	Biocides	399
18.2.2	Oxygen Scavengers.....	399
18.2.3	Corrosion Inhibitor.....	400
18.2.4	Dyes.....	400
18.2.5	Other Hydrotesting Chemicals.....	400
18.2.6	Environmental-Friendly Developments	400
	References	401
Chapter 19	Foamers for Gas Well Deliquification	403
19.1	Introduction	403
19.2	Properties and Classes of Foamers.....	403
	References	404
Appendix 1:	OSPAR Environmental Regulations for Oilfield Chemicals	407
A.1	United Kingdom and the Netherlands North Sea Ecotoxicological Regulations	409
A.2	Norwegian Offshore Ecotoxicological Regulations	410
	References	411
Index		413