

Table of Contents

CHAPTER 1: FUNCTIONS OF DRILLING FLUIDS	1
DRILLING FLUID DEFINITION AND GENERAL FUNCTION	1
COOL AND LUBRICATE THE BIT AND DRILL STRING.....	1
CLEAN THE BIT AND THE BOTTOM OF THE HOLE	1
SUSPEND SOLIDS AND TRANSPORT CUTTINGS AND SLOUGHINGS TO THE SURFACE	1
STABILIZE THE WELL BORE AND CONTROL SUBSURFACE PRESSURES	2
ASSIST WITH GATHERING SUBSURFACE GEOLOGICAL DATA AND FORMATION EVALUATION.....	2
CHAPTER 2: DRILLING FLUID PROPERTIES.....	5
INTRODUCTION.....	5
<i>Field Determined Properties.....</i>	5
Mud Weight.....	6
<i>Hydrostatic Head</i>	6
<i>Field Measurements of Mud Weight</i>	7
<i>Equivalent Circulating Density (ECD).....</i>	8
<i>Drilling Fluid Viscosity.....</i>	8
The Affect of Viscosity on Stokes Law	9
Newton’s Law of Viscous Behavior	9
Bingham Plastic Model.....	11
Measurement of Flow Properties	11
Controlling the Mud Viscosity.....	13
Plastic Viscosity ($PV = \theta_{600} - \theta_{300}$).....	13
Yield Value ($YV = \theta_{300} - PV$).....	13
Viscoelastic Fluids.....	16
Power Law Model.....	16
<i>Calculating n and K</i>	18
Herschel-Bulkley Rheological Model.....	19
Optimum Drilling Fluid Viscosity	21
Adjustment of Rheology	21
Gel Strengths	23
<i>Filtrate Loss.....</i>	24
<i>Factors Affecting Filtrate Loss</i>	25
Temperature.....	25
Particle Type and Size	26
Time.....	26
Pressure.....	26
Flow Profile	27
<i>Field Measurements of Filtrate Loss.....</i>	27
<i>API Standard Test</i>	28
<i>API HT-HP Test.....</i>	28
<i>Method of Obtaining Spurt Loss and Ultimate Loss</i>	30
<i>Filtrate Loss-Example Calculation.....</i>	30
<i>Controlling the Filtrate Loss.....</i>	32
<i>Solids Content.....</i>	34
<i>Field Measurements of Solids Concentration</i>	34
Sand Content.....	34
<i>Retort Analysis.....</i>	35
<i>Methylene Blue Test.....</i>	37
<i>Calculating the Type and Amount of Solids.....</i>	39
<i>Chemical Analysis of Drilling Muds.....</i>	40
<i>pH</i>	40
<i>Alkalinity (P_{nv}, P_f, M_f and P_1, P_2).....</i>	41
<i>Interpreting Test Results</i>	43
<i>Interpretation of P_f and M_f.....</i>	43
<i>Interpretation of P_1 and P_2.....</i>	44
<i>Chlorides.....</i>	44
<i>Total Hardness</i>	45
EVALUATING THE DAILY DRILLING FLUID REPORTS	49
SUGGESTED SUPERVISION AND MONITORING PRACTICES	49

CHAPTER 3: BASIC CHEMICAL CONCEPTS AND TERMINOLOGY.....	55
INTRODUCTION.....	55
THE CHEMIST'S CONCEPT OF DRILLING FLUID.....	55
THE FUNDAMENTAL UNITS OF SUBSTANCES.....	56
FORMING CHEMICAL COMPOUNDS.....	61
<i>Ionic Bonding.....</i>	<i>61</i>
<i>Covalent Bonding.....</i>	<i>62</i>
<i>Polar and Non-Polar Bonds.....</i>	<i>63</i>
<i>Organic and Inorganic Compounds.....</i>	<i>65</i>
<i>Mixtures.....</i>	<i>65</i>
<i>Suspensions.....</i>	<i>65</i>
<i>Solubility and Solutions.....</i>	<i>67</i>
<i>Stoichiometry and Calculations Based on Chemical Reactions.....</i>	<i>71</i>
<i>Acids and Bases.....</i>	<i>72</i>
<i>Acid-Base Neutralization and pH.....</i>	<i>73</i>
<i>pH.....</i>	<i>74</i>
<i>The Concept of Equilibrium.....</i>	<i>76</i>
<i>The Driving Force for Chemical Change.....</i>	<i>80</i>
<i>Chemical Calculations.....</i>	<i>81</i>
<i>Stoichiometry and Calculations Based on Chemical Reactions.....</i>	<i>81</i>
<i>Solution.....</i>	<i>81</i>
<i>Methods of Expressing Concentration.....</i>	<i>81</i>
Concentration of Solutions.....	82
Weight of Solute in a Volume of Solvent.....	82
Weight of Solute in a Volume of Solution (w/v).....	82
Weight of Solute Per Weight of Solvent.....	82
Weight of Solute Per Weight of Solution (w/w).....	82
Molarity (M).....	83
Molality (m).....	83
Normality (N).....	83
<i>Chemical Analysis of the Drilling Fluid.....</i>	<i>85</i>
CHAPTER 4: CLAY CHEMISTRY.....	87
INTRODUCTION.....	87
FUNDAMENTAL STRUCTURE OF CLAYS.....	88
CLAY MINERALS OF INTEREST.....	91
<i>Bentonite.....</i>	<i>91</i>
<i>Kaolinite.....</i>	<i>93</i>
<i>Illite.....</i>	<i>93</i>
<i>Mixed-Layer Clays.....</i>	<i>97</i>
Attapulgite.....	98
<i>Clay Behavior in Drilling Fluids.....</i>	<i>99</i>
<i>Aggregated Systems.....</i>	<i>100</i>
<i>Dispersed Systems.....</i>	<i>100</i>
<i>Flocculated Systems.....</i>	<i>100</i>
<i>Deflocculated Systems.....</i>	<i>101</i>
<i>Flocculating/Deflocculating Mechanisms.....</i>	<i>101</i>
SUMMARY OF PHYSICOCHEMICAL INTERACTIONS.....	105
<i>Molecular Weight.....</i>	<i>105</i>
<i>Adsorption onto the Clay.....</i>	<i>105</i>
CHAPTER 5: ENGINEERING AND MAINTENANCE CALCULATIONS.....	107
INTRODUCTION.....	107
HYDROSTATIC PRESSURE.....	107
<i>Examples Using the Hydrostatic Pressure Equation.....</i>	<i>108</i>
MATERIAL BALANCE EQUATIONS.....	108
Weight Up A Mud.....	110
Dilute A Mud With Water.....	111
Make An Exact Volume of Mud.....	112
Weight Up A Mud and Maintain The Same Volume.....	113
Dilute A Mud and Maintain The Same Volume.....	114
Determine the Average Specific Gravity of Solids.....	115
Determine Concentrations of High and Low Gravity Solids.....	116
Determine the Average Specific Gravity of Solids In A High Salinity Mud.....	117

Determine the Concentrations, in Pound/Barrel, of Low- and High-Gravity Solids for the Previous High Salinity Mud ..	118
Changing Oil/Water Ratio of An Oil Mud.....	121
Determine Requirements to Change O/W Ratio	123
Make An Exact Volume of Oil Mud	124
CALCULATIONS RELATED TO CIRCULATION, HOLE, AND EQUIPMENT VOLUMES.....	125
Calculation of Pump Output	125
Hole Volume and Annular Capacity Calculations	126
Drill Pipe Capacity and Displacement.....	126
Pit Volume Calculations	127
Circulating Time Calculations.....	127
Calculating Maintenance and Treatment Requirements for an Active Mud System.....	130
Barite Reclamation	138
Daily Maintenance of Polymer Systems	140
HYDRAULICS AND HYDRAULIC FORMULAS	141
Drilling Fluids Flow Rate	141
Bit Pressure Drop.....	141
Jet Velocity	142
Impact vs. Hydraulic Horse Power	142
Hydraulic Formulas.....	144
CHAPTER 6: WELL BORE STABILITY.....	147
ROCKS	148
Igneous Rocks	148
Metamorphic Rocks.....	148
Sedimentary Rocks	149
Mechanical Factors Affecting Bore Hole Stability	153
Overburden Gradient	153
Pore Pressure.....	155
Tectonic Movement	156
Rapid Deposition	157
Reservoir Structure.....	157
Clay Diagenesis.....	158
Salt Domes and Salt Deposition.....	160
Fracture Gradient.....	160
Circulating Pressures.....	163
Pipe Movement in the Hole.....	163
Formations Susceptible To Loss Circulation	163
Propagation Stress.....	164
Hole Instability Associated With Salt Formations	165
Drilling Fluid Effect on Well Bore Stability.....	166
Shale Dehydration Mechanisms	168
Shale Classification.....	170
Shale Classification Based on Descriptive Geological Tests	170
Shale Classification Based on Static and Dynamic Performance Tests	170
Shale Stabilization and Drilling Fluid Selection.....	173
Chemical Inhibition of Reactive Shales.....	174
Encapsulation of Shale	175
Mechanical Stabilization of Shale	175
CHAPTER 7: DRILLING FLUID COMPONENTS.....	177
Weight Materials or Densifiers.....	179
Viscosifiers.....	180
Filtration Control Materials.....	180
Rheology Control Materials.....	181
Alkalinity and pH Control Materials	181
Lost Circulation Control Materials.....	181
Surface Active Agents	182
Lubricating Materials.....	183
Flocculating Materials.....	183
Shale Stabilizing Materials	184
Protection from Toxic Agents and/or Corrosion	184
MISCELLANEOUS SPECIALTY FUNCTIONS	186
Biocides.....	186
Precipitants.....	186
Scale Inhibiting Materials.....	186

<i>Mineral Ores</i>	186
Barite	186
<i>Iron Minerals</i>	187
Iron Oxides	187
Iron Carbonate	188
Iron Titanate	188
<i>Other Minerals</i>	188
Calcium Carbonate	188
Strontium Sulfate	188
Lead Sulfide.....	188
Soluble Salts	189
<i>Clays</i>	189
Bentonite.....	189
Attapulgit	190
Sepiolite.....	191
Organophilic Clays	191
<i>Other Mineral Products</i>	192
Asbestos.....	192
Lignite.....	192
Organophilic Lignite (Humate).....	193
<i>Polymers</i>	194
<i>Fundamental Structure and Types of Polymers</i>	195
<i>Polymer Structure and Function in Drilling Fluids</i>	198
<i>Characterization of Some Organic Polymers Used in Drilling Fluids</i>	199
<i>Saccharides and Polysaccharides</i>	200
<i>Starches</i>	201
<i>Guar Gum</i>	203
<i>Microbial Polysaccharides – Xanthan Gum</i>	204
<i>Lignite and Lignosulfonates</i>	205
<i>Tannin</i>	207
<i>Modified Tannins</i>	207
<i>Cellulose Derivatives</i>	207
<i>Carboxymethylcellulose (CMC)</i>	208
<i>Polyanionic Cellulose</i>	208
<i>Hydroxyethyl Cellulose</i>	209
<i>Other Water-Soluble Cellulosic Polymers</i>	209
<i>Synthetic Polymers</i>	210
<i>Inorganic Polymers</i>	211
<i>Organic Phosphates</i>	211
<i>Common Inorganic Materials</i>	212
<i>Simple Commercial Materials</i>	214
LOST CIRCULATION MATERIALS	215
<i>Surface Active Agents</i>	216
<i>Drilling Mud Surfactant</i>	216
<i>Drilling Mud Emulsifier</i>	216
<i>Oil Wetting Agents</i>	217
<i>Biocides</i>	217
<i>Lubricants</i>	218
<i>Defoamers</i>	218
CHAPTER 8: DRILLING FLUID SYSTEMS	221
CLAY BASED DRILLING FLUID SYSTEMS	222
<i>Fresh Water Clay Based Systems</i>	222
<i>Brackish or Seawater Clay Based Fluids</i>	224
<i>Saturated Salt, Clay Based Fluids</i>	225
<i>Clay Based Inhibited Fluids</i>	226
<i>Clay Based Gyp Fluids</i>	226
<i>Clay Based Lime Fluids</i>	227
<i>Clay Based Potassium Fluids</i>	228
<i>Polymer Based Fluids</i>	229
<i>Single-Salt Brines</i>	229
<i>Potassium Chloride Brine</i>	229
<i>Sodium Chloride Brine</i>	229
<i>Calcium Chloride Brine</i>	230
<i>Oil Base Systems</i>	231

<i>Invert Emulsion Drilling Fluids</i>	231
<i>Relaxed Filtration Systems</i>	234
CHAPTER 9: TREND ANALYSIS	235
<i>Identifying Trends</i>	237
<i>Well bore Indicators</i>	238
<i>Materials That Affect Properties</i>	240
CHAPTER 10: CONTAMINANTS	245
CONTAMINANTS ENCOUNTERED WHILE DRILLING	246
CHEMICALLY TREATABLE CONTAMINANTS	246
<i>Drilled Solids</i>	247
<i>Solids Control Techniques</i>	249
<i>Settling</i>	249
<i>Dilution</i>	249
<i>Mechanical Separation</i>	249
<i>Chemical Treatment</i>	250
<i>Evaporite (Soluble) Salts</i>	251
<i>Sodium Chloride</i>	251
<i>Rock Salt Formations</i>	251
<i>Salt Water Flow</i>	251
<i>Salty Make-up Water</i>	252
<i>Evaporite Formations</i>	252
<i>Calcium Sulfate Formation</i>	252
<i>Contamination Due to Soluble Carbonate</i>	253
<i>Cement</i>	253
<i>Other Divalent Ions That Cause Contamination</i>	253
<i>Acid Gases</i>	253
<i>Contamination Due to Bacteria</i>	255
<i>Oils</i>	255
<i>Drilling Fluids Property Changes – Contaminants and Treatments</i>	256
<i>Solids Contamination (clay or shale)</i>	257
<i>Bicarbonate Contamination</i>	259
<i>Carbonate Contamination</i>	259
<i>Salt Contamination</i>	261
<i>Cement Contamination</i>	262
<i>Anhydrite Contamination</i>	263
<i>High Temperature Contamination</i>	264
<i>Bacterial Contamination</i>	265
<i>Oil Base Fluids Contaminants</i>	266
<i>Drilled Solids</i>	266
<i>Water</i>	267
<i>Acid Gases</i>	268
<i>Evaporite Salts</i>	269
<i>Other Contaminants</i>	270
CHAPTER 11: PLANNING A DRILLING FLUID PROGRAM	271
PREPARING A DRILLING FLUID PROGRAM	272
<i>Formation Pressures</i>	274
<i>Huber and Willis Method</i>	275
<i>Matthew and Kelly Method</i>	281
<i>Ben Eaton Method</i>	281
<i>Description of Test Procedures and Analysis of Core Samples</i>	282
<i>Visual Examination and Grouping of Core Samples</i>	282
<i>Description of Analytical Tests</i>	284
<i>Representative Test Results and Interpretation</i>	284
<i>Elemental Analysis</i>	291
<i>Temperature Considerations</i>	302
RECOMMENDED DRILLING FLUID PROGRAM	302
CHAPTER 12 SOLIDS CONTROL	305
INTRODUCTION	305
<i>Shale Shakers and Screens</i>	311
Application	311
Selection	311

<i>Capacity</i>	313
<i>Installation</i>	315
<i>Maintenance</i>	316
<i>Effect of Mud Properties on Removal Equipment Performance</i>	316
<i>Centrifuges</i>	321
<i>Operating Hints</i>	323
DEGASSERS	323
<i>Gas Busters(Poor Boy Degasser)</i>	323
<i>Degasser</i>	323
<i>Agitators</i>	326
<i>Centrifugal Pumps</i>	327
Head.....	328
Miscellaneous Operational Information and Guidelines.....	332
TABLE OF FIGURES	333
REFERENCES	338