

---

# *Contents*

---

Preface.....	xiii
Author.....	xvii
<b>1. Introduction.....</b>	<b>1</b>
1.1 Background .....	1
1.2 Oil and Gas Industry Safety and Reliability-Related Facts, Figures, and Examples .....	1
1.3 Terms and Definitions .....	3
1.4 Useful Sources for Obtaining Information on Safety and Reliability in the Oil and Gas Industry .....	4
1.4.1 Journals .....	4
1.4.2 Conference Proceedings .....	5
1.4.3 Books.....	6
1.4.4 Data Sources .....	6
1.4.5 Standards .....	7
1.4.6 Organizations.....	7
1.5 Scope of This Book.....	8
Problems.....	9
References .....	9
<b>2. Basic Mathematical Concepts .....</b>	<b>13</b>
2.1 Introduction .....	13
2.2 Boolean Algebra Laws.....	14
2.3 Probability Definition and Properties.....	15
2.4 Useful Mathematical Definitions.....	16
2.4.1 Cumulative Distribution Function.....	16
2.4.2 Probability Density Function.....	18
2.4.3 Expected Value.....	18
2.4.4 Laplace Transform Definition .....	19
2.4.5 Laplace Transform: Final-Value Theorem .....	20
2.5 Probability Distributions .....	21
2.5.1 Binomial Distribution .....	21
2.5.2 Exponential Distribution .....	22
2.5.3 Rayleigh Distribution .....	23
2.5.4 Weibull Distribution.....	24
2.5.5 Bathtub Hazard Rate Curve Distribution .....	24
2.6 Solving First-Order Linear Differential Equations Using Laplace Transforms.....	25
Problems.....	27
References .....	27

<b>3. Safety and Reliability Basics .....</b>	31
3.1    Introduction .....	31
3.2    Need for Safety and Safety and Engineers .....	31
3.3    Safety Management Principles.....	33
3.4    Product Hazard Classifications and Product Safety Organization Tasks.....	33
3.5    Common Causes of Work Injuries and Mechanical Injuries.....	36
3.6    Accident Causation Theories.....	37
3.6.1    Human Factors Accident Causation Theory.....	37
3.6.2    Domino Accident Causation Theory .....	38
3.7    Occupational Stressors and Human Error Occurrence Reasons ..	40
3.8    Consequences of Human Error and Human Error Classifications .....	40
3.9    Bathtub Hazard Rate Curve .....	42
3.10    General Reliability-Related Formulas .....	43
3.10.1    Probability (or Failure) Density Function.....	43
3.10.2    Time-Dependent Failure Rate (or Hazard Rate) Function.....	44
3.10.3    General Reliability Function .....	45
3.10.4    Mean Time to Failure .....	46
3.11    Reliability Networks.....	47
3.11.1    Series Network .....	48
3.11.2    Parallel Network .....	50
3.11.3 $n$ -out-of- $k$ Network.....	53
3.11.4    Standby System .....	55
Problems.....	56
References .....	57
<b>4. Methods for Performing Safety and Reliability Analyses in the Oil and Gas Industry .....</b>	59
4.1    Introduction .....	59
4.2    Root Cause Analysis.....	59
4.3    Hazards and Operability Analysis.....	60
4.4    Technique of Operations Review.....	62
4.5    Interface Safety Analysis .....	63
4.5.1    Physical Relationships.....	63
4.5.2    Flow Relationships .....	64
4.5.3    Functional Relationships .....	64
4.6    Job Safety Analysis .....	64
4.7    Preliminary Hazard Analysis.....	65
4.8    Failure Modes and Effect Analysis.....	65
4.8.1    Failure Mode Effects and Criticality Analysis .....	67
4.9    Fault Tree Analysis .....	67
4.9.1    Probability Evaluation of Fault Trees.....	69
4.9.2    Fault Tree Analysis: Advantages and Disadvantages .....	71

4.10	Markov Method.....	72
Problems.....		76
References .....		76
<b>5.</b>	<b>Safety in Offshore Oil and Gas Industry.....</b>	<b>79</b>
5.1	Introduction .....	79
5.2	Offshore Industrial Sector Risk Picture .....	79
5.3	Offshore Worker Situation Awareness Concept, Studies, and Their Results .....	80
5.3.1	Offshore Worker Situation Awareness-Related Studies and Their Results.....	81
5.3.1.1	Study I.....	81
5.3.1.2	Study II.....	83
5.4	Offshore Industry Accident Reporting Approach and Offshore Accident-Related Causes .....	84
5.4.1	Offshore Accident-Related Causes .....	85
5.5	Offshore Industry Accidents' Case Studies .....	86
5.5.1	Mumbai High North Platform Accident .....	86
5.5.2	Piper Alpha Accident .....	87
5.5.3	Bohai 2 Oil Rig Accident.....	88
5.5.4	Alexander L. Kielland Accident .....	88
5.5.5	Enchova Central Platform Accident.....	89
5.5.6	Ocean Ranger Accident.....	89
5.5.7	Glomar Java Sea Drillship Accident.....	89
5.5.8	Baker Drilling Barge Accident .....	90
5.5.9	Seacrest Drillship Accident .....	90
Problems.....		90
References .....		91
<b>6.</b>	<b>Case Studies of Oil Tanker Spill-Related Accidents and Oil Tanker Spill Analysis .....</b>	<b>93</b>
6.1	Introduction .....	93
6.2	Case Studies of Oil Tanker Spill-Related Accidents .....	93
6.2.1	Independenta Accident .....	93
6.2.2	Sea Star Accident.....	94
6.2.3	Haven Accident .....	94
6.2.4	ABT Summer Accident.....	94
6.2.5	Jakob Maersk Accident.....	95
6.2.6	Hawaiian Patriot Accident.....	95
6.2.7	Torrey Canyon Accident .....	95
6.2.8	Exxon Valdez Accident.....	96
6.2.9	Irenes Serenade Accident.....	96
6.2.10	Urquiola Accident .....	96
6.2.11	Hebei Spirit Accident.....	97
6.2.12	Atlantic Empress Accident .....	97

6.2.13	Castillo de Bellver Accident .....	97
6.2.14	Amoco Cadiz Accident .....	98
6.2.15	Odyssey Accident .....	98
6.2.16	Braer Accident .....	98
6.2.17	Katina P Accident .....	99
6.2.18	Prestige Accident .....	99
6.2.19	Sea Empress Accident .....	99
6.2.20	Aegean Sea Accident .....	100
6.2.21	Nova Accident .....	100
6.2.22	Khark 5 Accident.....	100
6.3	Tanker Oil Spills Number Analysis .....	101
6.4	Quantities of Oil Spilt.....	102
6.5	Oil Spill Causes .....	103
	Problems.....	105
	References .....	106
<b>7.</b>	<b>Human Factors Contribution to Accidents in the Oil and Gas Industry and Fatalities in the Industry.....</b>	<b>109</b>
7.1	Introduction .....	109
7.2	Human Factors That Affect Safety in General.....	109
7.2.1	Organizational Factors.....	110
7.2.2	Group Factors .....	111
7.2.3	Individual Factors .....	111
7.3	Categorization of Accident-Related Human Factors in the Industrial Sector .....	112
7.4	Categories of Human Factors Accident Causation in the Oil Industry .....	113
7.5	Oilfield Fatality Analysis .....	115
7.6	Recommendations to Reduce Fatal Oil and Gas Industry Incidents .....	117
	Problems.....	119
	References .....	120
<b>8.</b>	<b>Case Studies of Maintenance Influence on Major Accidents in Oil and Gas Industry and Safety Instrumented Systems and Their Spurious Activation in Oil and Gas Industry .....</b>	<b>121</b>
8.1	Introduction .....	121
8.2	Maintenance Influence on Major Accidents in the Oil and Gas Industry: Case Studies.....	121
8.2.1	Piper Alpha Accident .....	122
8.2.2	Sodegaura Refinery Accident.....	122
8.2.3	Texas City Refinery Accident .....	123
8.2.4	Flixborough Accident.....	123
8.2.5	Bhopal Gas Accident.....	124
8.3	Safety Instrumented Systems.....	124

8.4	Spurious Activation of Safety Instrumented Systems .....	125
8.4.1	Spurious Operation Causes.....	126
8.4.2	Spurious Trip Causes .....	127
8.4.3	Spurious Shutdown Causes.....	127
8.5	International Electrotechnical Commission and Its Standards: IEC 61511 and IEC 61508 .....	127
8.5.1	IEC 61511: Functional Safety—Safety Instrumented Systems for the Process Industry Sector.....	128
8.5.2	IEC 61508: Functional Safety of Electrical/ Electronic/Programmable Electronic Safety-Related Systems.....	129
	Problems.....	130
	References .....	130
<b>9.</b>	<b>Oil and Gas Industry Accident Data and Accident Data Analysis.....</b>	<b>133</b>
9.1	Introduction .....	133
9.2	Offshore Oil and Gas Industry Accident Databases and Accident Data Collection Sources.....	133
9.2.1	Worldwide Offshore Accident Databank .....	134
9.2.2	Well Control Incident Database .....	134
9.2.3	Collision Database .....	135
9.2.4	Hydrocarbon Release Database .....	135
9.2.5	Danish Energy Agency .....	135
9.2.6	Performance Measurement Project .....	136
9.2.7	International Association of Oil & Gas Producers (IOGP) .....	136
9.3	Onshore and Offshore Oil and Gas Industry Accident Data and Analysis.....	137
9.3.1	Category I: Fatalities .....	137
9.3.2	Category II: Lost Time Injuries .....	138
9.3.3	Category III: Fatal Accident Rate .....	138
9.4	Offshore Oil and Gas Rigs Accident Analysis.....	139
9.4.1	Distribution of Accidents per Type of Human-Related Causes .....	140
9.4.2	Distribution of Accidents per Type of Equipment-Related Causes .....	141
9.5	Failures and Lessons Learned from Landmark Offshore Oil and Gas Accidents and Corrective Measures.....	142
9.5.1	Classification I: Prevention .....	142
9.5.2	Classification II: Mitigation .....	143
9.5.3	Classification III: Emergency .....	144
9.5.4	Classification IV: Safety Management .....	145
9.5.5	Classification V: Preparedness and Planning .....	145
9.5.6	Classification VI: Aftermath/Restoration .....	146

9.5.7	Classification VII: Early Warning .....	146
9.5.8	Classification VIII: Lesson Learning .....	146
Problems.....		147
References .....		147
<b>10. Oil and Gas Industry Equipment Reliability .....</b>		<b>149</b>
10.1	Introduction .....	149
10.2	Mechanical Seals' Failures.....	149
10.2.1	Mechanical Seals' Typical Failure Modes and Their Causes .....	150
10.3	Optical Connector Failures.....	151
10.4	Corrosion-Related Failures .....	152
10.4.1	Types of Corrosion or Degradation That Can Cause Failure .....	153
10.4.2	Corrosion/Condition Monitoring Methods.....	154
10.5	Oil and Gas Pipeline Fault Tree Analysis.....	154
10.6	Common Cause Failures Defense Approach for Oil and Gas Industry Safety Instrumented Systems .....	158
10.6.1	Common Cause Failures Defense Approach.....	159
10.7	Fatigue Damage Initiation in Oil and Gas Steel Pipes Assessment.....	162
Problems.....		163
References .....		164
<b>11. Mathematical Models for Performing Safety and Reliability Analyses in Oil and Gas Industry .....</b>		<b>167</b>
11.1	Introduction .....	167
11.2	Model I.....	167
11.3	Model II .....	170
11.4	Model III .....	174
11.5	Model IV.....	177
11.6	Model V .....	178
11.7	Model VI.....	181
11.8	Model VII.....	186
Problems.....		189
References .....		190
<b>Bibliography: Literature on Safety and Reliability in the Oil and Gas Industry .....</b>		<b>191</b>
<b>Index .....</b>		<b>205</b>