

# Contents

<b>Foreword</b>	<b>xiii</b>
<b>Preface</b>	<b>xiv</b>
<b>Introduction</b>	<b>xvi</b>
<b>Case 1 Steam Turbine Performance Degradation</b>	<b>1</b>
1.1 Steam Turbine Types	2
1.1.1 Steam Turbine Components	5
1.1.2 Startup and Operation	7
1.1.3 Performance Monitoring and Analysis	10
1.1.4 Analyzing Performance Data – Corrected Pressures	10
1.1.5 Analyzing Performance Data – Flow Function	12
1.2 Refresher	14
1.2.1 Steam Turbine Efficiency	14
1.2.2 Example	14
1.3 Case Study Details	15
1.3.1 Performance Trend	15
1.3.2 IP Turbine Enthalpy Drop	16
1.4 Case Study Findings	17
1.5 Decision Making and Actions	18
1.5.1 Value	18
1.5.2 Decision Making and Actions – Alternatives	19
1.5.3 Decision Making and Actions – Making a Plan	20
1.6 Closure	20
1.7 Symbols and Abbreviations	21
1.8 Answer Key	21
References	24
<b>Case 2 Risk/Reward Evaluation</b>	<b>26</b>
2.1 Case Study	28
2.2 Background	29
2.2.1 Types of Gas Turbine Generating Plants	29

2.3	Gas Turbine Operating Risks	33
2.3.1	<i>Gas Turbine Major Maintenance</i>	35
2.3.2	<i>Equivalent Fired Hours</i>	36
2.3.3	<i>Failure Costs</i>	37
2.3.4	<i>Reading Assignment</i>	37
2.4	Case Study Evaluations	38
2.4.1	<i>Review</i>	38
2.4.2	<i>Presenting Results</i>	39
2.4.3	<i>Judgment Calls</i>	40
2.4.4	<i>Exercise</i>	40
2.4.5	<i>Sensitivities</i>	41
2.4.6	<i>Exercise – Sensitivities</i>	41
2.4.7	<i>Presentation of Results</i>	41
2.5	Case Study Results	42
2.6	Closure	42
2.7	Answer Key	43
	Reference	45
<b>Case 3</b>	<b>Gas Turbine Compressor Fouling</b>	<b>46</b>
3.1	Background	47
3.1.1	<i>Gas Turbine Types</i>	47
3.1.2	<i>Gas Compressor Fouling and Cleaning</i>	49
3.1.3	<i>Exercise 1</i>	50
3.1.4	<i>Inlet Filtration</i>	50
3.1.5	<i>Gas Turbine Performance Measurement</i>	52
3.2	Case Study Details	53
3.2.1	<i>Derivative of the Cost Function</i>	54
3.2.2	<i>Exercise 2</i>	55
3.2.3	<i>Linear Programming</i>	56
3.2.4	<i>New Methods – New Thinking</i>	56
3.2.5	<i>Exercise 3: Gas Turbine Inlet Filtration Upgrade</i>	57
3.2.6	<i>Presenting Results</i>	57
3.3	Case Study Results/Closure	58
3.4	Symbols and Abbreviations	60
3.5	Answer Key	60
	References	63
<b>Case 4</b>	<b>Flow Instrument Degradation, Use and Placement</b>	<b>64</b>
4.1	Background	65
4.1.1	<i>Nuclear Steam Power Cycles</i>	65
4.1.2	<i>Core Power-Level Measurement</i>	67
4.1.3	<i>Differential Pressure Flow Measurement Devices</i>	67
4.1.4	<i>Two-Phase Piping Pressure Drop</i>	71
4.1.5	<i>Uncertainty</i>	71
4.2	Case Study Details	72
4.3	Exercises	73
4.3.1	<i>Uncertainty</i>	74
4.3.2	<i>Conclusions</i>	76

---

4.4	Closure	76
4.5	Symbols and Abbreviations	76
4.6	Answer Key	77
4.7	Further Reading	79
	References	79
<b>Case 5</b>	<b>Two-Phase Hydraulics</b>	<b>80</b>
5.1	Background	81
	5.1.1 <i>Reading Assignment</i>	83
	5.1.2 <i>Müller-Steinhagen and Heck</i>	83
	5.1.3 <i>Void Fraction</i>	84
	5.1.4 <i>Pumping Net Positive Suction Head Required</i>	86
	5.1.5 <i>Projects</i>	86
5.2	Case Study Details	89
5.3	Exercises	90
	5.3.1 <i>Liquid Flow to Reboiler</i>	90
	5.3.2 <i>Two-Phase Flow from Reboiler</i>	90
	5.3.3 <i>Pump Suction</i>	91
	5.3.4 <i>Discuss</i>	92
5.4	Closure	92
5.5	Symbols and Abbreviations	92
5.6	Answer Key	93
	References	94
<b>Case 6</b>	<b>Reliability and Availability</b>	<b>95</b>
6.1	Background	96
	6.1.1 <i>Models</i>	97
	6.1.2 <i>Availability: Planned and Unplanned Outages – Parallel Systems</i>	100
	6.1.3 <i>Series and Parallel Processes</i>	102
	6.1.4 <i>Stochastic Models</i>	103
	6.1.5 <i>Reading</i>	104
	6.1.6 <i>Applicability</i>	104
6.2	Case Study Details	105
	6.2.1 <i>Initial Block Flow Diagram</i>	105
	6.2.2 <i>Business Structure</i>	106
	6.2.3 <i>Modified Block Flow Diagram</i>	108
	6.2.4 <i>Other Considerations</i>	108
	6.2.5 <i>Exercises</i>	109
6.3	Closure	110
6.4	Symbols and Abbreviations	110
6.5	Answer Key	111
	Reference	113
<b>Case 7</b>	<b>Efficiency and Air Emissions</b>	<b>114</b>
7.1	Background	115
	7.1.1 <i>Cogeneration or CHP</i>	115
	7.1.2 <i>Environmental Considerations</i>	116
	7.1.3 <i>Efficiency</i>	118

7.2	Case Study Details	119
7.2.1	<i>General</i>	119
7.2.2	<i>Proposed CHP Plant</i>	120
7.2.3	<i>Steam Boilers</i>	121
7.2.4	<i>Fuel</i>	121
7.2.5	<i>Gas Turbine</i>	121
7.2.6	<i>Air</i>	123
7.3	Refresher	123
7.3.1	<i>Gas Mixture Molecular Weight</i>	123
7.3.2	<i>Gas Mixture Heating Value</i>	123
7.3.3	<i>Species Weight Fraction</i>	123
7.3.4	<i>Ultimate Analysis</i>	124
7.4	Objective	124
7.5	Exercises	125
7.5.1	<i>Outside Reading</i>	125
7.5.2	<i>Boiler Operation</i>	125
7.5.3	<i>Cogeneration Plant</i>	126
7.5.4	<i>Conclusion</i>	126
7.6	Closure	126
7.7	Symbols and Abbreviations	127
7.8	Answer Key	127
	References	130
<b>Case 8</b>	<b>Low-Carbon Power Production</b>	<b>131</b>
8.1	Background	132
8.1.1	<i>Dispatch and Renewable Power Resources</i>	133
8.1.2	<i>Capacity Factor and Availability Factor</i>	134
8.1.3	<i>Fuel Costs (FC in Equation (8.1))</i>	134
8.1.4	<i>Capital Cost Recovery (CR in Equation (8.1))</i>	135
8.1.5	<i>Nonfuel Operations and Maintenance (M in Equation (8.1))</i>	135
8.1.6	<i>Regulation and Government Support</i>	135
8.2	Refresher	136
8.2.1	<i>Short-Run Marginal Cost</i>	136
8.2.2	<i>CO<sub>2</sub> Emissions</i>	136
8.2.3	<i>Long-Run Marginal Cost</i>	136
8.3	Case Study Details	136
8.3.1	<i>Reading Assignment</i>	137
8.3.2	<i>Transmission Costs</i>	138
8.3.3	<i>Economic Models</i>	139
8.3.4	<i>Carbon Emissions</i>	139
8.3.5	<i>Understanding the Findings</i>	140
8.3.6	<i>Explaining the Results</i>	141
8.4	Closure	141
8.5	Answer Key	142
	References	144

<b>Case 9 Heat Exchangers and Drain Line Sizing</b>	<b>146</b>
9.1 Background	147
9.1.1 <i>Steam Surface Condensers</i>	147
9.1.2 <i>Feedwater Heaters</i>	151
9.1.3 <i>Overall Heat Transfer Coefficient</i>	152
9.1.4 <i>Condensing Heat Transfer</i>	153
9.1.5 <i>Forced Convection Inside Tubes</i>	153
9.1.6 <i>Conduction Heat Transfer</i>	153
9.1.7 <i>Off-Design Exchanger Performance</i>	154
9.1.8 <i>Drain Line Sizing</i>	155
9.2 Reading	155
9.3 Case Study Details	156
9.3.1 <i>Flow Diagram and Equipment</i>	156
9.3.2 <i>Design Cases</i>	157
9.3.3 <i>Exercises</i>	159
9.4 Closure	160
9.5 Symbols and Abbreviations	161
9.6 Answer Key	162
9.7 Further Reading	164
References	164
<b>Case 10 Optimized Maintenance</b>	<b>165</b>
10.1 Background	166
10.1.1 <i>Maintenance Practices</i>	166
10.1.2 <i>Economic Model for Maintenance</i>	167
10.1.3 <i>Operating Costs other than Maintenance</i>	168
10.2 Refresher	169
10.2.1 <i>Cost to Generate Power</i>	169
10.2.2 <i>Fixed and Variable Operations and Maintenance (O&amp;M)</i>	169
10.2.3 <i>Cost of Fuel</i>	169
10.2.4 <i>Short-Run Gross Margin</i>	169
10.3 Presentation Techniques	169
10.3.1 <i>Waterfall Chart</i>	169
10.3.2 <i>Line and Scatter Plots</i>	171
10.4 Reading	171
10.4.1 <i>Questions</i>	171
10.5 Case Study Details	172
10.5.1 <i>Data</i>	172
10.5.2 <i>Exercises</i>	174
10.6 Closure	176
10.7 Symbols and Abbreviations	176
10.8 Answer Key	177
10.9 Further Reading	184
References	185

<b>Case 11 Project Engineering</b>	<b>186</b>
11.1 Opening	186
11.2 Background	187
11.2.1 <i>Mustard</i>	187
11.2.2 <i>Working with Warfare Agents</i>	188
11.2.3 <i>Alternative Technology for HD Decontamination</i>	189
11.3 Project Planning and Definition	189
11.3.1 <i>Project Management</i>	192
11.3.2 <i>Client Requirements</i>	192
11.3.3 <i>Work Breakdown Structure</i>	194
11.3.4 <i>Growing the Team</i>	195
11.3.5 <i>Process Basis of Design</i>	196
11.4 Executing the Project	197
11.4.1 <i>The Process</i>	198
11.4.2 <i>Stakeholder Communication</i>	198
11.4.3 <i>Ton Container Cleanout</i>	199
11.4.4 <i>Demonstration Tests</i>	199
11.4.5 <i>Materials of Construction</i>	200
11.4.6 <i>Unexpected Events</i>	201
11.5 Closure	201
11.6 Answer Key	202
Reference	208
<b>Case 12 In the Woodshop</b>	<b>209</b>
12.1 Background	211
12.1.1 <i>Band Saw</i>	211
12.1.2 <i>Table Saws</i>	211
12.1.3 <i>The Router</i>	213
12.1.4 <i>Safety</i>	214
12.1.5 <i>Measurements</i>	214
12.2 Case Study Details	214
12.2.1 <i>Exercise</i>	215
12.2.2 <i>The Cove</i>	215
12.2.3 <i>Extra Credit</i>	217
12.3 Closure	217
12.4 Glossary	219
12.5 Solutions	219
12.6 Further Reading	220
References	221
<b>Appendix</b>	<b>222</b>
<b>Glossary</b>	<b>225</b>
<b>Index</b>	<b>235</b>