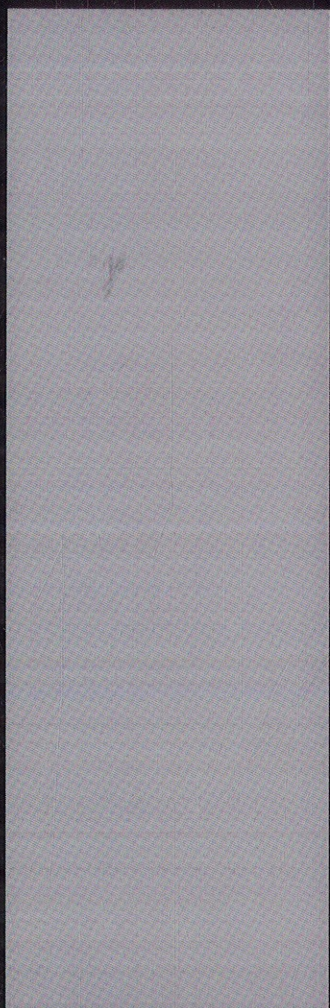


# Guidelines for Safe Process Operations and Maintenance



**CCPS**



# Contents

<i>Preface</i>	<i>xi</i>
<i>Acknowledgments</i>	<i>xiii</i>
<i>List of Tables</i>	<i>xv</i>
<i>List of Figures</i>	<i>xvii</i>
<i>Glossary</i>	<i>xxiii</i>

<b>1. INTRODUCTION</b>	<b>1</b>
1.1. Process Safety Management Activities of the Center for Chemical Process Safety (CCPS)	1
1.2. Process Safety Activities of Governmental Agencies and Trade Organizations	2
1.3. Target Audience and Objective of This Document	5
1.4. Use of This Document	8
1.5. References	9
<b>2. ROLE OF OPERATIONS AND MAINTENANCE IN PROCESS SAFETY MANAGEMENT</b>	<b>11</b>
2.1. Accountability	12
2.2. Process Knowledge and Documentation	13
2.3. Capital Project Review and Design Procedures	13
2.4. Process Risk Management	14
2.5. Process and Equipment Integrity	14
2.6. Human Factors	16
2.7. Training and Performance	18
2.8. Incident Investigation	20
2.9. Standards, Codes, and Regulations	20
2.10. Audits and Corrective Action	20
2.11. Enhancement of Process Safety Knowledge	21

2.12. Management of Change	22
2.12.1. Importance of Changes	22
2.12.2. Examples of Lessons To Be Learned from the Failure to Manage Change	23
2.12.3. What Constitutes a Change?	24
2.12.4. Process Change Authorization	26
2.13. Summary	30
2.14. References	31
<b>3. PLANT DESIGN</b>	<b>33</b>
3.1. Operations and Maintenance Departments' Roles	34
3.2. Documentation	37
3.3. Process Hazard Reviews	39
3.4. Designing for Inherent Process Safety	44
3.4.1. Process Fluids	45
3.4.2. Inventory Minimization	45
3.4.3. Operating and Storage Conditions	45
3.5. Controlling of Hazards to Reduce Risks	46
3.6. Plant Layout	47
3.6.1. Site Planning	48
3.6.2. Process Area Layout	50
3.7. Plant Standards and Practices	52
3.8. Human Factors in Plant Design	54
3.9. Maintenance Considerations	55
3.10. Management of Change	56
3.11. References	57
<b>4. PLANT CONSTRUCTION</b>	<b>59</b>
4.1. Roles of the Operations and Maintenance Department	59
4.1.1. Communication and Coordination with Project Team	60
4.1.2. Control of Specific Construction-Related Activities	62
4.1.3. Inspection of Equipment Installation	62
4.2. Materials of Construction	66
4.3. Custom Equipment Fabrication and Inspection	67
4.4. Field Installation	68
4.4.1. Piping Installation	68
4.4.2. Pressure-Relief/Vent Collection	70
4.4.3. Other Safety Systems	72
4.5. Equipment Recordkeeping	72
4.6. Summary	74



4.7. References	74
<b>5. PRE-STARTUP AND COMMISSIONING</b>	<b>75</b>
5.1. Organization and Roles	76
5.1.1. Startup Team	76
5.1.2. Role of Operations and Maintenance Departments	78
5.2. Planning	79
5.3. Preparation for Startup	84
5.3.1. Staffing Operations and Maintenance Departments	85
5.3.2. Training	87
5.3.3. Maintenance Activities during Pre-Startup	93
5.3.4. Development of Operating Procedures	96
5.4. Pre-startup Safety Review	103
5.5. Commissioning	104
5.5.1. Commissioning Utilities	105
5.5.2. Commissioning Equipment	105
5.5.3. Instruments, Computer, and Control	106
5.6. Final Preparations for Startup	107
5.7. References	110
<b>6. STARTUP</b>	<b>113</b>
6.1. Roles and Responsibilities	114
6.2. Initial Startup	115
6.2.1. Final Preparation	124
6.2.2. Introduction of Process Chemicals and Materials	125
6.2.3. Process and Process Equipment Monitoring	126
6.2.4. Baseline Data	130
6.2.5. Updating Startup Procedures	131
6.3. Restart	131
6.4. Startup after Turnaround	132
6.5. Startup after Extended Outage	134
6.6. Resources	135
6.7. Summary	137
6.8. References	138
<b>7. OPERATION</b>	<b>139</b>
7.1. Roles and Responsibilities	139
7.2. Routine Operations	140
7.2.1. Operating within Process and Equipment Limits	141

7.2.2. Written Procedures	143
7.2.3. Communication	147
7.2.4. Communication During Shift Changes	149
7.2.5. Special Safety Considerations of Batch Processes	152
7.2.6. Process Control Software	161
7.3. Nonroutine Operations	164
7.3.1. Abnormal Operations	165
7.3.2. Standby Operations	167
7.4. Emergency Operations	169
7.5. Management of Change	170
7.6. Safety Protective Systems	173
7.6.1. Safety Shutdown Systems	175
7.6.2. Pressure Relief Equipment	177
7.7. Operator Training	178
7.7.1. Refresher Training	179
7.7.2. Playing "What-If" Games	180
7.8. Incident Investigation	184
7.8.1. Recognizing and Reporting Incidents	185
7.8.2. the Investigation	188
7.8.3. Investigation Results and Followup	189
7.9. Human Factors	192
7.9.1. Human-Process Interfaces	192
7.9.2. Behavioral Issues	194
7.9.3. Spontaneous Response	195
7.10. Audits, Inspections, Compliance Reviews	198
7.11. Summary	201
7.12. References	202

## **8. MAINTENANCE** **203**

8.1. Roles and Responsibilities	203
8.2. Routine Maintenance	205
8.2.1. Preventive Maintenance	205
8.2.2. Predictive Maintenance	207
8.2.3. Communication between the Maintenance and Operations Departments	208
8.2.4. Communication at Shift Change	209
8.3. Nonroutine Maintenance	212
8.3.1. Breakdown Maintenance	212
8.3.2. Troubleshooting Maintenance	213
8.4. Management of Change	214
8.5. Aging Equipment	214

8.5.1. Corrosion, Erosion, and Fatigue	217
8.5.2. Wear, Intermittent Operation, and Fouling	218
8.6. Critical Instrumentation and Safety Interlocks	219
8.6.1. Proof Testing	221
8.6.2. Critical Instrumentation and Interlock Classification	223
8.7. Maintenance Training	224
8.7.1. Upgrade and Refresher Training	225
8.7.2. Loss of Plant-Specific Maintenance Knowledge	226
8.8. Work Permits	226
8.9. Maintenance Management Information Systems	232
8.9.1. Work Order Tracking	232
8.9.2. Process Equipment Files	233
8.9.3. Process and Equipment Drawings	234
8.10. Quality Control	236
8.10.1. Replacement Parts	236
8.10.2. Inspection	237
8.10.3. Certified Equipment	238
8.10.4. Continuous Improvement	238
8.11. Contractor Safety	239
8.12. Incident Investigation	240
8.13. Summary	241
8.14. References	242
Additional References	243

## **9. SHUTDOWN** **245**

9.1. Normal Shutdown	247
9.1.1. Pre-shutdown Planning	248
9.1.2. Shutdown Sequence Steps	254
9.1.3. Testing Safety Protective Systems	257
9.1.4. Shutdown Period Maintenance Activities	259
9.1.5. Unit Restart after Maintenance	259
9.1.6. Formal Review of Shutdown	259
9.2. Extended or Mothball Shutdown	261
9.3. Sudden or Emergency Shutdown	262
9.3.1. Preplanning for Sudden Shutdown	263
9.3.2. Shutdown Sequences	265
9.3.3. Safety Interlock Failures	266
9.3.4. Investigation of Sudden Shutdowns	267
9.4. Emergency Response	268
9.5. Summary	268
9.6. References	268

<b>10. DECOMMISSIONING AND DEMOLITION</b>	<b>271</b>
10.1. Decommissioning/Demolition Plan	272
10.2. Operation and Maintenance Roles	274
10.3. Decommissioning Procedures	276
10.4. Maintenance of Decommissioned Status	280
10.5. Demolition Concerns	281
10.6. Summary	282
10.7. References	283
 <b>Appendix A. Summary of the Process Safety Management Rule Promulgated by the Occupational Safety and Health Administration, United States Department of Labor</b>	 <b>285</b>
 <b>Appendix B. Example Management Guidelines for the Safe Dismantling and Demolition of Process Plants</b>	 <b>293</b>
 <b>Appendix C. Example of Site-Specific Demolition Checklist/Questionnaire</b>	 <b>305</b>
 <b>Index</b>	 <b>311</b>