

| | |
|--|----------|
| Preface | 1 |
| Chapter 1 — Risk Management | 1 |
| Introduction | 1 |
| Technical, Process and Occupational Safety | 3 |
| Historical Development | 4 |
| 1. Safety as a Value..... | 5 |
| 2. Codes and Standards..... | 6 |
| 3. Workers’ Compensation | 6 |
| 4. Occupational Safety..... | 6 |
| 5. Systems Analysis | 6 |
| 6. Regulations | 7 |
| 7. Management Systems | 7 |
| 8. Behavior-Based Safety..... | 10 |
| 9. Safety Culture | 10 |
| Major Events | 10 |
| Health, Safety & Environmental Programs..... | 11 |
| Environmental / Sustainability..... | 12 |
| Health..... | 12 |
| Safety | 13 |
| Prescriptive / Non-Prescriptive | 13 |
| Safety Management Programs | 14 |
| Regulations | 15 |
| The Regulator’s Dilemma..... | 16 |
| Process Safety Management | 16 |
| Definition of Process Safety Management..... | 18 |
| Safe Limits..... | 19 |
| Set Point Values..... | 22 |
| Operating, Safe and Emergency Limits | 24 |
| Measurement Strategies | 28 |
| Involvement | 31 |
| Thoroughness..... | 31 |
| Holistic..... | 31 |
| Environment..... | 32 |
| Quality Management..... | 32 |
| Statistical Process Control | 32 |
| ISO 9000 / 14001 | 32 |
| Six Sigma..... | 33 |
| Risk | 33 |
| Components of Risk..... | 34 |
| Hazards | 35 |
| Consequence | 35 |
| Predicted Frequency | 36 |
| Safeguards..... | 37 |
| Presence of Persons | 37 |
| Single Contingency Events | 38 |
| Economies of Scale..... | 39 |
| Common Cause Events | 39 |
| Fukushima-Daiichi..... | 39 |
| Examples..... | 40 |

| | |
|---|----|
| Utility Failure..... | 40 |
| Instruments on Manual | 40 |
| Instrument Pluggage | 40 |
| Vibration | 40 |
| External Events | 40 |
| Maintenance Availability..... | 41 |
| Human Error / Untrained Personnel..... | 41 |
| Subjective Nature of Risk | 41 |
| Degree of Control | 42 |
| Familiarity with the Hazard | 42 |
| Direct Benefit..... | 42 |
| Personal Impact..... | 43 |
| Natural vs. Man-Made Risks | 43 |
| Recency of Events | 43 |
| Perception of the Consequence Term | 43 |
| Comprehension Time..... | 44 |
| Randomness | 45 |
| Regression to the Mean..... | 45 |
| Bias toward Positive Evidence / Prior Beliefs | 45 |
| Availability | 45 |
| Quantification of Risk..... | 46 |
| Mathematical Terms | 46 |
| Frequency..... | 46 |
| Predicted Frequency..... | 46 |
| Probability..... | 47 |
| Likelihood and Failure Rate..... | 47 |
| Error / Statistical Significance Confidence | 47 |
| Failure / Fault..... | 47 |
| Independence and Randomness | 48 |
| FN Curves | 48 |
| Limitations | 50 |
| Acceptable Risk | 50 |
| The Third Law | 51 |
| Perfection as a Slogan..... | 52 |
| As Low as Reasonably Practical — ALARP..... | 52 |
| De Minimis Risk..... | 54 |
| Citations / ‘Case Law’ | 54 |
| RAGAGEP..... | 54 |
| Indexing Methods | 55 |
| Risk Matrices | 55 |
| Consequence Matrix | 55 |
| Worker Safety | 56 |
| Public Safety and Health..... | 56 |
| Environmental Impact..... | 57 |
| Economic Loss..... | 57 |
| Frequency Matrix..... | 58 |
| Risk Matrix | 58 |
| A — (Red) Very High..... | 59 |
| B — (Orange) High | 59 |
| C — (Yellow) Moderate | 59 |
| D — (Green) Low | 59 |

| | |
|---|-----------|
| Other Categories | 60 |
| Limitations of Risk Matrices | 60 |
| Low-Hanging Fruit | 61 |
| Prepare for the Worst Case | 61 |
| Expensive Good Ideas..... | 61 |
| Black Swan Events..... | 62 |
| Different Industries | 62 |
| Oil Refineries..... | 63 |
| Offshore Oil and Gas | 64 |
| Lack of Escape Routes..... | 65 |
| Persons on Board (POB)..... | 65 |
| Cyclones / Hurricanes | 66 |
| Downers and Leaners..... | 66 |
| Blowouts | 67 |
| Hydrogen Sulfide | 67 |
| Dropped Objects | 68 |
| Helicopters | 68 |
| Ship Collision / Mooring Failure | 68 |
| Spill Response..... | 68 |
| Pipelines..... | 69 |
| Examples..... | 69 |
| Example 1 — Facility Design..... | 70 |
| Example 2 — Process Flow | 70 |
| Example 3 — Heat Exchanger..... | 71 |
| Example 4 — Risk Management Workflow..... | 72 |
| External Standard..... | 72 |
| Guidance | 73 |
| Risk Analysis Plan and Implement | 73 |
| Audit / Deltas | 73 |
| Success / Continuous Improvement..... | 73 |
| Example 5: Significant Potential Incident | 73 |
| Chapter 2 — Compliance and Standards..... | 75 |
| Introduction..... | 75 |
| Regulations | 76 |
| Rule-Based Approach..... | 77 |
| Goal-Driven Approach | 78 |
| Process Safety Regulations | 78 |
| Codes and Standards | 80 |
| Development of a Standard..... | 81 |
| Standards Organizations | 82 |
| American Chemistry Council / Responsible Care® | 83 |
| American National Standards Institute (ANSI) | 85 |
| American Petroleum Institute (API) | 85 |
| American Society of Mechanical Engineers (ASME) | 86 |
| International Organization for Standardization (ISO)..... | 86 |
| National Fire Protection Association (NFPA) | 88 |
| Other Industry Sources | 88 |
| Center for Chemical Process Safety..... | 88 |
| Center for Offshore Safety | 88 |
| Chemical Safety and Hazard Investigation Board | 89 |
| Company Standards | 89 |

| | |
|---|-----|
| Industry Information | 90 |
| Regulatory Guidance | 90 |
| Open Literature | 90 |
| Commercial Information..... | 91 |
| Analysis..... | 91 |
| United States Federal Regulations | 91 |
| The Regulatory Process | 91 |
| Code of Federal Regulations..... | 92 |
| General Duty Clauses | 93 |
| The Tenth Amendment to the United States Constitution | 93 |
| The Environmental Protection Agency (EPA)..... | 93 |
| The Occupational Safety & Health Administration (OSHA)..... | 94 |
| OSHA Inspections | 95 |
| Variances..... | 96 |
| Enforcement..... | 97 |
| The Entry Process | 97 |
| Fatality / Catastrophe | 98 |
| Programmed Inspections..... | 98 |
| Complaints | 98 |
| Citations | 98 |
| Willful..... | 99 |
| Serious | 100 |
| Other-than-Serious..... | 100 |
| Repeat and Failure-to-Abate | 101 |
| OSHA Standards..... | 101 |
| Part 29 | 101 |
| Subparts of Part 29..... | 103 |
| Sections of Subparts..... | 103 |
| Interpretations and Guidance | 104 |
| The OSHA PSM Standard | 105 |
| Covered Processes | 105 |
| Other Standards..... | 106 |
| Audit Guidelines | 107 |
| National Emphasis Programs | 109 |
| Proposed Update | 109 |
| 1. Atmospheric Storage Tanks | 110 |
| 2. Oil- and Gas-Well Drilling and Servicing..... | 110 |
| 3. Oil- and Gas-Production Facilities..... | 111 |
| 4. Reactivity Hazards | 111 |
| 5. Highly Hazardous Chemicals..... | 112 |
| 6. Management System Elements | 112 |
| 7. RAGAGEP | 112 |
| 8. Definition of RAGAGEP | 112 |
| 9. Safety-Critical Equipment..... | 113 |
| 10. Organizational Changes | 113 |
| 11. Emergency Planning | 113 |
| 12. Third-Party Compliance Audits | 113 |
| 13. Explosives, Blasting Agents and Pyrotechnics | 113 |
| 14. Flammable Liquids and Spray Finishing | 113 |
| 15. Ammonium Nitrate | 114 |
| 16. Retail Facilities | 114 |

| | |
|--|-----|
| 17. Concentrations of Highly Hazardous Chemicals | 114 |
| The Environmental Protection Agency (EPA)..... | 114 |
| The EPA Risk Management Program — 40 CFR 68 | 115 |
| Tiering / Program Levels | 115 |
| Covered Chemicals | 115 |
| Formal Management System | 115 |
| Worst Case Release | 116 |
| Emergency Plan | 116 |
| Five-Year Accident History | 116 |
| BSEE..... | 116 |
| State Regulations..... | 118 |
| New Jersey Toxic Catastrophe Prevention Act..... | 118 |
| Delaware/Nevada..... | 118 |
| The Safety Case Regime | 118 |
| Elements of a Safety Case..... | 119 |
| Duty-Holder Responsibility | 119 |
| Responsibility of the Auditor / Assessor..... | 119 |
| Risk Management System..... | 120 |
| Management Systems | 120 |
| Living Document | 120 |
| Structure of a Safety Case..... | 120 |
| 1. Facility Description..... | 120 |
| 2. Safety Management System..... | 121 |
| 3. Formal Safety Assessment..... | 122 |
| Preparation and Implementation | 122 |
| Assessment..... | 123 |
| Performance Measurement | 124 |
| International Agencies | 124 |
| Elements of PSM | 124 |
| 1. Employee Participation..... | 125 |
| Written Plan of Action | 126 |
| Consultation | 126 |
| Access to Information | 127 |
| 2. Process Safety Information | 127 |
| 3. Process Hazards Analysis | 130 |
| Initial Hazard Analysis | 133 |
| Methodology | 133 |
| Issues to Address..... | 133 |
| Team | 133 |
| Revalidation | 134 |
| 4. Operating Procedures..... | 134 |
| Written Down..... | 136 |
| Initial Start-Up | 136 |
| Temporary and Emergency Operations | 137 |
| Certification | 137 |
| 5. Training..... | 137 |
| 6. Contractors..... | 140 |
| Application..... | 142 |
| Employer Responsibilities | 143 |
| 7. Prestartup Safety Review (PSSR)..... | 143 |
| Process Safety Information | 144 |

| | |
|--|------------|
| Construction and Equipment..... | 144 |
| Procedures..... | 145 |
| New / Modified Facilities | 145 |
| 8. Mechanical Integrity | 145 |
| Application..... | 148 |
| Written Procedures..... | 148 |
| Training..... | 148 |
| Inspection and Testing | 148 |
| Deficiencies..... | 148 |
| Quality Assurance | 149 |
| 9. Hot Work | 149 |
| 10. Management of Change | 150 |
| Employer Responsibility..... | 151 |
| Written Down..... | 152 |
| Replacement In-Kind | 152 |
| Factors that Affect Change | 152 |
| Training and Participation / Accountability..... | 152 |
| Information Base..... | 153 |
| Operating Procedures..... | 153 |
| Making the Change | 153 |
| Training / PSI / Operating Procedures | 153 |
| 11. Incident Investigation..... | 153 |
| Investigation..... | 155 |
| Timing..... | 155 |
| Team | 155 |
| Report..... | 155 |
| Follow Up | 155 |
| Participation | 156 |
| 12. Emergency Planning and Response | 156 |
| 13. Compliance Audits | 158 |
| Certification | 160 |
| Technical Qualifications | 161 |
| Report..... | 161 |
| Response | 161 |
| Retention of Reports | 161 |
| Chapter 3 — Culture and Participation | 162 |
| Introduction..... | 162 |
| Regulations and Standards | 163 |
| BSEE Standard for Culture..... | 163 |
| HSE and Culture | 165 |
| National Energy Board | 166 |
| Survey | 166 |
| Warning Flags over Your Organization..... | 166 |
| Flag One — Unrealistic Stretch Goals..... | 167 |
| Production Creep | 167 |
| Production Records..... | 168 |
| Initiative Overload | 168 |
| Flag Two — Excessive Cost Reduction | 169 |
| Reduction of “Non-Essentials” | 171 |
| Reductions in Work Force | 171 |
| The “Big Crew Change” | 172 |

| | |
|--|-----|
| Flattened Organizations | 172 |
| Aging Infrastructure..... | 173 |
| Out-Sourcing..... | 173 |
| Not Enough Time for Detailed Work | 173 |
| Project Cutbacks | 174 |
| Organizational Spread..... | 174 |
| Flag Three — Belief That “It Cannot Happen Here” | 174 |
| Lack of Direct Experience | 174 |
| Good Occupational Safety Performance..... | 175 |
| Failure to Learn from Near-Misses..... | 175 |
| Failure to Draw on Experience Elsewhere..... | 175 |
| Flag Four — Over-Confidence in Rule Compliance | 176 |
| Flag Five — Departmentalized Information Flow..... | 176 |
| Critical Safety Information Is Buried, Lost or Diluted | 176 |
| Team Player Culture | 177 |
| Fear of Litigation | 177 |
| Mergers, Acquisitions and Divestitures | 178 |
| Flag Six — Ineffective Audit Process | 178 |
| Softened News to Senior Managers | 178 |
| Failure to Identify Root Causes | 179 |
| Inadequate Follow Up..... | 179 |
| Thinking Backwards | 179 |
| Imagination | 180 |
| Culture Matrices..... | 180 |
| Elements of Culture | 181 |
| On-Going and Consistent..... | 182 |
| Actions and Words..... | 182 |
| External Evaluation..... | 182 |
| Learning from Incidents..... | 183 |
| Attention to Basics / Housekeeping | 183 |
| Mergers and Acquisitions | 183 |
| Generational Differences | 184 |
| Measurement..... | 185 |
| Key Performance Indicators..... | 186 |
| Lagging and Leading Indicators..... | 186 |
| Lagging Indicators | 186 |
| OSHA Recordable Rate | 188 |
| Process Safety | 188 |
| Leading Indicators | 189 |
| Near Misses..... | 190 |
| Unplanned Maintenance | 190 |
| Process Safety Incident | 190 |
| KPI Limitations..... | 191 |
| Activity and Quality..... | 191 |
| Quality of Reporting | 191 |
| Management Elements..... | 192 |
| API RP 754 | 192 |
| Tiers | 194 |
| Tier 1 — Process Safety Event | 195 |
| Tier 2 — Process Safety Event | 195 |
| Tier 3 — Challenge to Safety Systems | 195 |

| | |
|---|------------|
| Tier 4 — Operating Discipline and Management System Performance | 196 |
| Data Submission | 196 |
| Selection of KPIs | 196 |
| Surveys..... | 197 |
| Creating a Strong Culture | 197 |
| Mission Statement..... | 198 |
| Guiding Tenets..... | 199 |
| Detailed Program | 199 |
| Behavior Based Safety | 199 |
| Observed Hazard Card..... | 200 |
| Five by Five Policy | 202 |
| Off-the-Job Safety..... | 202 |
| Pointless Activities | 202 |
| Employee Participation | 203 |
| Developing Employee Participation | 204 |
| Safety Committees | 204 |
| Involvement in PSM Elements | 204 |
| Difficulties with Workforce Involvement..... | 204 |
| Inefficiencies..... | 205 |
| Unwillingness to Accept Change..... | 205 |
| Labor / Management Relations..... | 205 |
| Stakeholder Outreach..... | 205 |
| Chapter 4 — Technical Information | 207 |
| Introduction..... | 207 |
| Table of Contents..... | 208 |
| Process Description..... | 210 |
| Flowsheets..... | 211 |
| Block Flow Diagrams | 211 |
| Process Flow Diagrams | 212 |
| Piping & Instrument Diagrams | 213 |
| Design Phases | 214 |
| Equipment and Line Designations | 214 |
| Instrument Designations | 215 |
| Updating P&IDs..... | 215 |
| Editing Engineering Information | 215 |
| Materials of Construction Table | 216 |
| Material Safety Data Sheet or Safety Data Sheet..... | 216 |
| Global Harmonization System | 219 |
| The Safety Diamond | 220 |
| Chapter 5 — Hazard Identification | 222 |
| Introduction..... | 222 |
| Hazards Management Process | 224 |
| Step 1. Identify the Hazards..... | 226 |
| Creative / Imaginative Techniques | 227 |
| Experience-Based | 228 |
| Logical / Rational..... | 228 |
| Step 2. Risk Rank..... | 229 |
| Step 3. Eliminate or Substitute the Hazard | 229 |
| Step 4. Remove the People | 229 |
| Step 5. Reduce the Consequence | 229 |
| Step 6. Reduce the Likelihood..... | 229 |

| | |
|---|-----|
| Step 7. Install Safeguards..... | 230 |
| Organization of a Hazards Analysis..... | 230 |
| Charge / Scope Letter | 231 |
| Objective | 231 |
| Physical Scope | 232 |
| Method(s) to be Used..... | 232 |
| Assigned Personnel..... | 232 |
| Risk Management Guidance | 232 |
| Schedule and Reporting | 232 |
| Abandoned Equipment | 232 |
| Preparations | 232 |
| Logistics..... | 233 |
| Meeting Protocol..... | 233 |
| Location of the Meeting..... | 233 |
| Projection of Notes | 234 |
| Documentation Requirements..... | 234 |
| Security of the Information | 235 |
| Time Required | 235 |
| Kick-Off and Close-Out Meetings..... | 236 |
| HAZID / Major Hazards Screening | 236 |
| The Team | 237 |
| Leader / Facilitator..... | 238 |
| Process Knowledge..... | 239 |
| Stimulate Thinking..... | 239 |
| Creative Thinking | 240 |
| Casual Remarks | 240 |
| “If we had unlimited money” | 241 |
| Generalizations | 241 |
| Team Management..... | 241 |
| Knowledge of Actual Incidents..... | 242 |
| Lawyer-Like Behavior | 243 |
| Persona..... | 243 |
| Personal Preparation | 243 |
| Engineering Standards | 243 |
| The Scribe | 244 |
| Operations / Maintenance Expert..... | 244 |
| Process and Instrument Experts | 244 |
| Specialists | 245 |
| Use of Sophisticated Language..... | 245 |
| The One-Minute Engineering Department | 245 |
| Results of the Analysis..... | 246 |
| Findings | 246 |
| Recommendations..... | 246 |
| Action Items..... | 247 |
| Risk Register..... | 248 |
| Finding Number and Date..... | 249 |
| Hazard..... | 249 |
| Source | 249 |
| Consequence(s) / Likelihood / Risk | 249 |
| Follow-Up | 250 |
| The Hazards Analysis Report | 250 |

| | |
|--|-----|
| Completeness of the Notes..... | 251 |
| Cross-Reference..... | 252 |
| Anonymity | 252 |
| Findings Terminology..... | 252 |
| Completeness | 253 |
| ‘Non-Findings’..... | 253 |
| Appearance | 253 |
| Pictures..... | 253 |
| Report Distribution | 254 |
| Communication with the Public..... | 254 |
| Table of Contents..... | 254 |
| 1. Disclaimer..... | 254 |
| 2. Executive Summary | 255 |
| 3. Objectives of the Analysis | 255 |
| 4. Summary of Findings..... | 256 |
| 5. Method Used..... | 256 |
| 6. Risk Ranking..... | 257 |
| 7. The Team | 257 |
| 8. Regulations and Standards | 257 |
| 9. Attachments | 258 |
| 10. Meeting Notes..... | 258 |
| Development of the Report..... | 258 |
| Step 1. Notes Clean-Up..... | 258 |
| Step 2. Team Review | 259 |
| Step 3. Draft Report | 260 |
| Step 4. Client Review | 261 |
| Step 5. Final Report | 262 |
| Step 6. Risk Register..... | 263 |
| Legal Issues..... | 263 |
| Need to Act on Findings | 265 |
| Informal Notes | 265 |
| Internal Communication | 265 |
| PHA Leadership..... | 266 |
| Special Types of Hazards Analysis..... | 267 |
| Temporary and Transient Operations | 267 |
| Non-Process Applications..... | 267 |
| Decommissioning / Demolition | 268 |
| Revalidation Hazards Analyses | 268 |
| Benefits and Limitations of Hazard Analyses..... | 270 |
| Strengths | 270 |
| Providing Time to Think..... | 270 |
| Challenging Conventional Thinking | 270 |
| Cross-Discipline Communication | 270 |
| Education | 271 |
| Development of Technical Information | 271 |
| Economic Payoff..... | 271 |
| Limitations and Concerns | 271 |
| Imprecision in Defining Terms | 272 |
| Multiple Contingencies..... | 272 |
| Complexities and Subtle Interactions | 273 |
| Dynamic Conditions | 274 |

| | |
|---|------------|
| Knowledge of Safe Operating Limits | 274 |
| Lack of Quantification | 274 |
| Team Quality | 274 |
| Personal Experience..... | 275 |
| Boredom..... | 275 |
| TRIZ 275 | |
| Confusion with Design Reviews..... | 276 |
| False Confidence..... | 276 |
| Equipment Orientation..... | 277 |
| Interfaces..... | 277 |
| Human Error | 278 |
| The Hazard and Operability Method (HAZOP)..... | 279 |
| Step 1. Node Selection and Purpose | 280 |
| Selection of Nodes | 281 |
| Pressure/Spec Breaks | 282 |
| Step 2. Process Guideword / Safe Limits..... | 283 |
| Step 3. Identification of Hazards and their Causes | 283 |
| Step 4. ‘Announcement’ of the Hazard..... | 287 |
| Step 5. Consequences | 287 |
| Step 6. Identification of Safeguards..... | 288 |
| Step 7. Predicted Frequency of Occurrence of the Hazard | 288 |
| Step 8. Risk Rank..... | 289 |
| Step 9. Findings | 290 |
| Step 10. Next Process Guideword / Node..... | 290 |
| Effectiveness of HAZOPs..... | 290 |
| Checklists..... | 291 |
| Checklist Categories and Guidewords | 291 |
| Structure of a Checklist..... | 294 |
| The What-If Method | 296 |
| Node / Functional Area Review..... | 297 |
| Equipment and Function Review..... | 298 |
| Ignition Source Controls..... | 298 |
| Instrumentation and Control Systems | 299 |
| Human Factors..... | 299 |
| Process Upsets | 299 |
| Siting..... | 299 |
| Structured What-If | 299 |
| Utility Systems..... | 300 |
| Batch Processes..... | 300 |
| Operating Procedures..... | 301 |
| Layout Reviews | 301 |
| What-If / Checklist Method | 302 |
| Failure Modes & Effects Analysis | 302 |
| Bow Tie Analysis..... | 308 |
| Indexing Methods | 310 |
| Interface Hazards Analysis | 310 |
| Chapter 6 — Operating Procedures..... | 313 |
| Introduction..... | 313 |
| Definition of Operating Procedures | 317 |
| Operations..... | 317 |
| Written Instructions | 318 |

| | |
|---|-----|
| Design or Operating Intent..... | 318 |
| Definition of Maintenance Procedures..... | 319 |
| Terminology..... | 319 |
| Engineering the Solution..... | 322 |
| Quick Assessment of Operating Procedures..... | 324 |
| The Users..... | 327 |
| Experienced Technicians..... | 327 |
| Less Experienced Technicians..... | 327 |
| Engineering / Management..... | 327 |
| DCS / SCADA Programmers..... | 327 |
| Auditors, Regulators and Inspectors..... | 328 |
| Translators..... | 328 |
| Elements of Operational Integrity Management..... | 328 |
| Workforce Involvement..... | 328 |
| Knowledge Management..... | 329 |
| Hazard Identification and Risk Management..... | 330 |
| Management of Change..... | 331 |
| Operational Readiness..... | 331 |
| Emergency Management..... | 331 |
| Technical Information..... | 331 |
| Types of Operating Procedure..... | 331 |
| Steady-State Operating Procedures..... | 331 |
| Types of Steady-State Procedure..... | 332 |
| Shift Change..... | 332 |
| Start-Up Procedures..... | 334 |
| Shutdown Procedures..... | 334 |
| Levels of Shutdown..... | 335 |
| Stand-By..... | 335 |
| Unit Shutdown..... | 335 |
| Facility Shutdown..... | 336 |
| Emergency Shutdown..... | 336 |
| Turnaround..... | 336 |
| Trouble Shooting Procedures..... | 336 |
| Elements of Troubleshooting Procedures..... | 338 |
| Structure of Troubleshooting Procedures..... | 338 |
| Temporary Operating Procedures..... | 338 |
| Batch Procedures..... | 340 |
| Standard Operating Procedures..... | 340 |
| Maintenance Procedures..... | 344 |
| Job Safe Practices..... | 345 |
| Software Analogy..... | 347 |
| Modular Design..... | 347 |
| Connecting the Modules..... | 348 |
| If / Then / Else Instructions..... | 349 |
| Modular Operating Manual..... | 350 |
| Data Base Structure..... | 353 |
| Top-Down Development..... | 354 |
| Prototyping..... | 356 |
| Limitations of Modularity..... | 357 |
| Design of an Operating Manual..... | 357 |
| Adding and Removing Modules..... | 361 |

| | |
|---|-----|
| Numbering the Modules | 361 |
| Module Design | 362 |
| The Title Block | 363 |
| Procedure Name | 364 |
| Module Number | 365 |
| Purpose of the Procedure | 365 |
| Revision Number | 365 |
| Date of Revision | 365 |
| Covered Persons | 366 |
| Company / Facility | 366 |
| Safe Upper and Lower Limits | 366 |
| Special Safety Items | 366 |
| Equipment Information | 366 |
| Training | 367 |
| The Operating Task Instructions | 367 |
| Step Number Column | 368 |
| Person | 368 |
| Action | 368 |
| Discussion / Illustration | 368 |
| The Authorization Block | 369 |
| Written By | 370 |
| Approval — Superintendent | 370 |
| Approval — Manager | 370 |
| Authorization Sheet | 370 |
| Overall Module | 371 |
| Links to Other Procedures and Manuals | 374 |
| Links to Technical Information | 374 |
| Training | 374 |
| Two-Page Modules | 374 |
| Content Development | 376 |
| Level of Detail | 376 |
| Level 1 — Overview / Checklists | 376 |
| Level 2 — Equipment Description | 377 |
| Level 3 — Valve Detail | 377 |
| Sources of Information | 378 |
| Existing Procedures | 378 |
| Technician Interviews | 378 |
| Engineering Information | 379 |
| Vendor Manuals | 379 |
| Process Hazards Analyses | 379 |
| The Procedures-Writing Team | 379 |
| Writing and Publishing | 379 |
| Project Organization | 380 |
| 1. Define the Scope of Work | 380 |
| Physical Area / Equipment Covered | 381 |
| Users | 381 |
| Types of Procedure | 381 |
| Job Task Analysis | 381 |
| Design of the Manual | 382 |
| Regulations / Standards | 382 |
| Writer's Guide | 382 |

| | |
|--|-----|
| 2. Create the Team | 382 |
| Steering Committee | 382 |
| Project Manager | 383 |
| Project Lead | 383 |
| Technicians | 383 |
| Technology Expert | 384 |
| Interviewer-Writers | 384 |
| Publisher / Webmaster | 384 |
| 3. Develop a Detailed Plan | 384 |
| Schedule and Progress Metric | 385 |
| Budget | 386 |
| Prepare the SOPs | 387 |
| 4. Collect Information | 387 |
| Operator Interviews | 387 |
| Existing Procedures / Vendor Manuals | 387 |
| Logbooks | 388 |
| 5. Write the Procedures | 388 |
| Draft Releases | 388 |
| Plan to Throw One Away — You Will Anyway | 389 |
| 6. Review and Sign | 389 |
| 7. Publish | 389 |
| Potential Difficulties | 390 |
| Poorly Defined Goals | 390 |
| Too Many People | 390 |
| Extended Review Cycle | 391 |
| Lack of Signatures | 391 |
| Maintaining the Procedures | 392 |
| Procedures Modification Process | 393 |
| Organization | 394 |
| Writing Guidelines | 394 |
| Vigorous Writing | 395 |
| Minimalist Writing | 396 |
| Short, Pithy Instructions | 396 |
| Avoid Repetition of Instructions | 397 |
| Omit Needless Words | 397 |
| Omit Adverbs | 397 |
| Short and Old Words | 398 |
| Avoid Wordy Phrases and Padded Syllables | 398 |
| Writing Style | 399 |
| Imperative Tense | 399 |
| Active Voice | 400 |
| Reading Grade Level | 400 |
| List Instructions Singly | 401 |
| Implied Instructions | 402 |
| Bulleted Lists | 402 |
| Conditional Instructions | 402 |
| Positive / Negative Instructions | 403 |
| Vocabulary | 404 |
| Identification of Equipment | 404 |
| Consistency | 404 |
| Should / Would / Could | 404 |

| | |
|---|------------|
| The Word ‘You’..... | 405 |
| The Word ‘This’ | 405 |
| Arabic Numerals | 406 |
| Adverbs and Adjectives | 406 |
| Articles..... | 406 |
| Humor | 406 |
| Spelling..... | 407 |
| Latin Abbreviations..... | 408 |
| Apostrophes | 409 |
| Ambiguous Words | 409 |
| Repetition of Messages | 409 |
| Danger, Warning, Caution, Note | 410 |
| Proofreader Marks | 410 |
| Illustrations | 411 |
| Photographs | 412 |
| P&IDs | 412 |
| Iconic Flow Diagrams / Schematics | 412 |
| Maps / Plot Plans | 414 |
| Publishing | 414 |
| Color | 414 |
| White Space | 415 |
| Fonts | 415 |
| Paragraph Formatting | 416 |
| Emphasis Techniques | 416 |
| Heading..... | 417 |
| Page Numbering | 417 |
| Single-Sided versus Double-Sided Printing..... | 417 |
| Indexing | 417 |
| Glossary | 417 |
| The Binder | 418 |
| Multiple Languages..... | 418 |
| Chapter 7 — Training and Competence..... | 419 |
| Introduction..... | 419 |
| Levels of Competence..... | 419 |
| Level 1 — Basic Skills | 419 |
| Level 2 — Certification | 420 |
| Level 3 — Master Technician..... | 420 |
| Elements of a Training Program | 420 |
| Orientation | 420 |
| Initial / Basic Training | 421 |
| Site Training | 422 |
| Abnormal Situation Management | 422 |
| Refresher Training | 423 |
| SEMS (BSEE)..... | 423 |
| PSM (OSHA) | 430 |
| Procedures and Training | 431 |
| Management of a Training Program | 433 |
| Training Matrix..... | 433 |
| Budget Allocation | 436 |
| Measuring Progress..... | 436 |
| Economics of Training..... | 437 |

| | |
|--|------------|
| Process Simulators and Emulators..... | 438 |
| Features..... | 438 |
| Benefits..... | 438 |
| Simulator Design..... | 438 |
| Testing and Certification..... | 440 |
| Safe Gulf..... | 441 |
| Pipeline Operator Training..... | 442 |
| Chapter 8 — Prestartup Reviews..... | 444 |
| Introduction..... | 444 |
| What the Review Is Not..... | 445 |
| Regulations..... | 445 |
| OSHA’s PSM..... | 445 |
| (i) Construction and Equipment..... | 447 |
| (ii) Procedures..... | 447 |
| (iii) New / Modified Facilities..... | 447 |
| SEMS..... | 447 |
| Types of Review..... | 448 |
| Review Not Required..... | 448 |
| Small Projects / Engineering Changes..... | 448 |
| Medium Size..... | 449 |
| Large Projects..... | 449 |
| Restart Reviews..... | 449 |
| Organizational Responsibility..... | 450 |
| Time Required..... | 450 |
| Team Structure..... | 450 |
| Using the Elements of Process Safety Management..... | 451 |
| Knowledge Management..... | 452 |
| Operating Procedures..... | 452 |
| Asset Integrity / Reliability..... | 452 |
| Training / Performance..... | 452 |
| Chapter 9 — Asset Integrity..... | 453 |
| Introduction..... | 453 |
| Engineering Standards..... | 453 |
| Inherent Safety..... | 453 |
| Eliminate..... | 454 |
| Remove Equipment..... | 454 |
| Remove People..... | 455 |
| Minimize..... | 456 |
| Substitute..... | 456 |
| Moderate..... | 456 |
| Equipment Modification..... | 457 |
| Spacing..... | 457 |
| Underground Location..... | 457 |
| Simplify..... | 457 |
| Applying Inherent Safety..... | 458 |
| Law of Unintended Consequences..... | 460 |
| Serendipity..... | 460 |
| Undesirable Outcome..... | 460 |
| Original Situation Worse..... | 461 |
| Passive Safety Systems..... | 461 |
| Active Safety Systems..... | 462 |

| | |
|--|------------|
| Administrative Safety Systems | 462 |
| Safety Critical Items | 462 |
| Priority 1 | 462 |
| Priority 2 | 462 |
| Priority 3 | 463 |
| RAGAGEP | 463 |
| Chapter 10 — Management of Change..... | 464 |
| Introduction..... | 464 |
| Benefits of Management of Change..... | 464 |
| Increased Production, Productivity and Quality | 464 |
| Maintenance Expense and Safety | 465 |
| Environmental Performance | 465 |
| Personal Reputation | 465 |
| Definition of MOC..... | 465 |
| Deviation beyond Limits | 466 |
| Impact on other Process Safety Elements..... | 467 |
| Critical Changes..... | 467 |
| In-Kind / Not-In-Kind Change..... | 467 |
| Same Specification | 468 |
| Same Service and Materials of Construction..... | 468 |
| Same Storage and Handling Process..... | 468 |
| Procedural Replacement | 469 |
| Process Chemistry..... | 469 |
| Instrumentation and Control Systems | 469 |
| Types of Change | 469 |
| Initiated Equipment Change | 469 |
| Large and Small Changes | 470 |
| Turnarounds | 470 |
| Field Change | 470 |
| Non-Initiated Equipment Change | 471 |
| Overt Change | 471 |
| Covert Change | 471 |
| Temporary Changes | 472 |
| Emergency Changes | 474 |
| Administrative and Organizational Change..... | 475 |
| Reorganization | 476 |
| Management by Contractors | 476 |
| Informal Aspects of MOC..... | 476 |
| The Management of Change Process..... | 477 |
| Section A — Initiator Request | 478 |
| Initiator..... | 478 |
| Personal Recognition | 479 |
| Company Loyalty..... | 479 |
| Safety | 479 |
| Sponsor | 480 |
| Request Process | 480 |
| Step 1 — Problem / Opportunity Identified..... | 481 |
| Step 2 — Need For Change | 481 |
| Step 3 — Corrective Action..... | 481 |
| Step 4 — System Change | 482 |
| Management of Change Form — Section A..... | 482 |

| | |
|---|------------|
| Name of the Sponsor / Initiator(s) / Date | 483 |
| Description of Problem and Its Consequences | 483 |
| Proposed Change | 484 |
| Justification..... | 484 |
| Emergency Change/ Temporary Change | 484 |
| Previous Actions Taken | 484 |
| Section B — First Review | 485 |
| In-Kind / Not-In-Kind Change..... | 486 |
| Selecting the First Reviewers..... | 486 |
| Management of Change Form — Section B..... | 487 |
| Name / Date | 488 |
| Discussion..... | 488 |
| Suggested Modifications..... | 488 |
| Section C — Detailed Evaluation | 488 |
| Review Process | 489 |
| MOC Coordinator | 490 |
| Review Team | 491 |
| Process Manager | 491 |
| Engineering Manager..... | 491 |
| Operations Manager..... | 491 |
| Builders..... | 492 |
| Project Team..... | 492 |
| Software | 492 |
| Reviewers..... | 493 |
| 1. Confirm the Problem..... | 493 |
| 2. Problem Analysis..... | 493 |
| 3. Identify Possible Solutions | 493 |
| Qualifications..... | 493 |
| Experience..... | 493 |
| Technical Knowledge | 494 |
| Feasibility..... | 494 |
| “Out-of-the-Box” Thinking | 495 |
| Recommendations..... | 495 |
| Management of Change Form — Section C..... | 495 |
| Section D — Formal Approval | 496 |
| Management of Change Committee | 497 |
| Operations..... | 497 |
| Maintenance..... | 497 |
| Technical..... | 498 |
| Engineering/Construction | 498 |
| Process Hazards Analysis | 498 |
| Variance Procedures | 498 |
| Section E — New Limits / Process Safety Update | 499 |
| Section F — Notification | 499 |
| Section G — Implementation | 500 |
| Section H — Follow-Up | 501 |
| Chapter 11 — Incident Investigation and Root Cause Analysis..... | 503 |
| Introduction..... | 503 |
| Management Level..... | 504 |
| Line Supervision | 504 |
| Facility Management | 504 |

| | |
|--|-----|
| Executive Management..... | 505 |
| Industry Regulations and Standards..... | 505 |
| Incident Investigation and Analysis Philosophy | 505 |
| Trust and Candor | 506 |
| Listen to the Facts | 507 |
| Technical Expertise..... | 507 |
| Root Cause Analysis..... | 508 |
| Difficulties with “Root Cause” | 508 |
| Ockham’s Razor..... | 510 |
| Project Management | 510 |
| Attorney-Client Privilege..... | 510 |
| Blame and Fault-Finding | 510 |
| Management Trust | 511 |
| Early Reporting of Bad News | 512 |
| Management Pressure | 512 |
| Safety as a Cause of Incidents | 512 |
| Communications | 512 |
| Technicians | 513 |
| Mid-Level Managers..... | 513 |
| Senior Managers | 513 |
| Definitions..... | 513 |
| Incident | 514 |
| Accident..... | 514 |
| Near Miss / Hit..... | 514 |
| Potential Incident | 515 |
| High Potential Incident..... | 515 |
| Incident Investigation Steps | 515 |
| Step 1 — Initial Investigation..... | 516 |
| Step 2 — Evaluation and Team Formation..... | 516 |
| Step 3 — Information Gathering | 518 |
| Step 4 — Timeline Development | 518 |
| Step 5 — Root Cause Analysis..... | 518 |
| Step 6 — Report and Recommendations | 518 |
| Step 1. Initial Investigation | 519 |
| The ‘Go Team’..... | 519 |
| Immediate Actions | 519 |
| Team Preparation | 520 |
| Drug and Alcohol Testing..... | 521 |
| Incident Report Form..... | 521 |
| Incident Number | 522 |
| Title | 522 |
| Location, Date and Time of Event | 522 |
| Duration of Event..... | 523 |
| Date and Time of Report..... | 523 |
| How Observed | 523 |
| Person(s) Reporting | 523 |
| Preliminary Ranking..... | 523 |
| Incident Type | 523 |
| Incident Flags..... | 523 |
| First Description of Event..... | 523 |
| Immediate Corrective Actions Taken | 524 |

| | |
|--|-----|
| Witnesses | 524 |
| Contractor Involvement | 524 |
| Detailed Location..... | 524 |
| Consequences..... | 524 |
| Emergency Response | 525 |
| Security Issues | 525 |
| System Alert..... | 525 |
| Incident Owner / Department..... | 525 |
| Notes and Attachments | 525 |
| First Management Report | 525 |
| Step 2. Evaluation and Team Formation..... | 526 |
| Evaluation | 526 |
| Team Formation..... | 527 |
| Outside Investigators | 527 |
| Corporate Support..... | 528 |
| Team Members | 528 |
| Sponsor | 528 |
| Incident Owner..... | 528 |
| Facility Manager | 529 |
| Lead Investigator | 529 |
| Administrator | 530 |
| Area Supervisor | 530 |
| HSE Representative | 530 |
| Process Safety Management Coordinator | 530 |
| Employee Representative..... | 530 |
| Process / Facilities Engineer | 530 |
| Maintenance Technicians..... | 530 |
| Subject Matter Experts..... | 531 |
| Contractors / Vendors | 531 |
| Emergency Response Specialists | 531 |
| Attorneys..... | 531 |
| Charter / Terms of Reference..... | 531 |
| Team Member Qualifications | 532 |
| Objectivity..... | 532 |
| Common Sense | 532 |
| Jumping to Conclusions..... | 533 |
| Haughtiness and Empathy..... | 533 |
| Understand Incident Investigation Methodology..... | 534 |
| You Do Know What You Don't Know | 534 |
| Understand Process Systems..... | 534 |
| Logical Thinking / Painstaking | 534 |
| Step 3. Information Gathering | 535 |
| Interviews..... | 536 |
| Interview Guidelines..... | 537 |
| Regulatory / Legal Interviews..... | 539 |
| Witness Interviews..... | 540 |
| Interviewer Attributes | 541 |
| Rapport and Trust | 541 |
| Technical Skills..... | 542 |
| Critical Factors Recognition | 542 |
| Objective..... | 542 |

| | |
|---|-----|
| Effective Note Taking..... | 543 |
| Management Interviews..... | 543 |
| Documentation..... | 543 |
| Engineering Information..... | 543 |
| Operating Information | 543 |
| Instrument Records | 544 |
| Log Books, Maintenance Records and JSAs | 544 |
| Hazards Analysis Reports | 544 |
| Management of Change Records | 544 |
| Operating Manuals / Procedures | 544 |
| Incident Investigations and Audits..... | 544 |
| Vendor Data..... | 544 |
| Field Information | 544 |
| Damage Assessment | 545 |
| Photographs and DVDs | 545 |
| Closed Circuit Television | 546 |
| Instrument Records | 546 |
| Testing / Lab Analysis | 546 |
| Step 4. Timeline Development..... | 546 |
| Timeline Steps | 547 |
| Section 1 — Events Prior to the Incident..... | 547 |
| Section 2 — The Incident | 547 |
| Section 3 — Post-Incident Response | 547 |
| Timeline Construction | 548 |
| Conditions..... | 549 |
| Multiple Timelines..... | 549 |
| Timeline Table..... | 552 |
| Background Information..... | 553 |
| Step 5. Root Cause Analysis..... | 554 |
| Levels of Root Cause..... | 555 |
| Single Incidents..... | 555 |
| Multiple Incidents | 555 |
| Types of Root Cause Analysis..... | 556 |
| Argument by Analogy: Story Telling | 557 |
| False Extrapolation | 557 |
| Linearity..... | 558 |
| World Views | 558 |
| Safeguards..... | 558 |
| Management Action..... | 559 |
| Categorization..... | 559 |
| Equipment Failure..... | 560 |
| Human Error as a Root Cause..... | 561 |
| Process Systems Failure..... | 561 |
| System Analysis..... | 561 |
| Why Trees..... | 562 |
| Single Chain of Events..... | 562 |
| Wrong Chain..... | 562 |
| Fault Tree Analysis..... | 563 |
| Linkage of Fault Trees to the Timeline..... | 567 |
| Common Cause Events..... | 568 |
| 6. Report and Recommendations | 568 |

| | |
|---|------------|
| Levels of Recommendation | 569 |
| Short Term Recommendations..... | 570 |
| Intermediate Recommendations..... | 570 |
| Long Term Recommendations..... | 570 |
| Industry Guidance..... | 570 |
| Report Structure..... | 571 |
| Executive Summary..... | 571 |
| What Happened?..... | 572 |
| What Could Have Happened?..... | 572 |
| What Was the Cause?..... | 572 |
| What Actions Should Be Taken?..... | 572 |
| Recognition..... | 572 |
| Terms of Reference..... | 573 |
| Reason for Selection..... | 573 |
| Sequence of Events..... | 573 |
| Consequences..... | 573 |
| Root Causes..... | 573 |
| Other Hazards..... | 573 |
| Recommendations..... | 574 |
| Attachments..... | 574 |
| Attachment A — Regulations and Standards..... | 574 |
| Attachment B — Root Cause Analysis..... | 574 |
| Attachment C — Organization Chart..... | 574 |
| Attachment D — Review of Similar Events..... | 574 |
| Attachment E — Investigation Team..... | 574 |
| Attachment F — Review of Modern Designs..... | 575 |
| Attachment G — Index to Pictures and Documents..... | 575 |
| Attachment H — Detailed Timeline..... | 575 |
| Issuing the Report..... | 575 |
| Writing the Report..... | 575 |
| Presenting the Report..... | 575 |
| Follow Up and Recommendations Tracking..... | 576 |
| Legal Issues..... | 576 |
| Information Security and Chain of Custody..... | 577 |
| Record Retention..... | 579 |
| Removing Evidence..... | 579 |
| File Systems..... | 580 |
| Incident / Risk Register..... | 580 |
| Feedback..... | 582 |
| Incident Data Bases..... | 584 |
| National Response Center (NRC)..... | 584 |
| Accidental Release Information Program (ARIP) Database..... | 584 |
| CFOI (Census of Fatal Occupational Injuries)..... | 585 |
| Major Accident Reporting System (MARS)..... | 585 |
| Marsh & McLennan Reviews..... | 585 |
| Annual Loss Prevention Symposia..... | 586 |
| Process Safety Beacon..... | 586 |
| Government Agencies..... | 586 |
| Chapter 12 — Emergency Management..... | 587 |
| Introduction..... | 587 |
| Abnormal Situation Management..... | 589 |

| | |
|---|------------|
| Human Response..... | 589 |
| Human Error Rate | 589 |
| Fixation | 590 |
| Heroism and Buddy Loyalty | 590 |
| Trouble Shooting..... | 591 |
| Levels of Emergency | 591 |
| Cause of Emergency | 593 |
| Emergency Operations..... | 594 |
| Local Emergency Response..... | 595 |
| General Emergency Response | 595 |
| Recovery Operations..... | 595 |
| Investigation and Follow Up..... | 596 |
| Emergency Planning | 596 |
| Organization and Personnel | 596 |
| Emergency Response Manual..... | 596 |
| Emergency Procedures | 598 |
| Emergency Response Training | 599 |
| Communications | 600 |
| Emergency Shutdown | 600 |
| ESD Hierarchy | 600 |
| Shutdown Zones | 602 |
| System Reset..... | 602 |
| Fire and Gas Detection..... | 602 |
| Fire Detection | 603 |
| Fire Eyes / Flame Detectors..... | 604 |
| Smoke Detectors | 605 |
| Heat Detectors..... | 605 |
| Fusible Links..... | 605 |
| Low Oxygen Detectors | 606 |
| Combustible Gas Detectors..... | 606 |
| Manual Call Points..... | 606 |
| Toxic Gas Releases | 606 |
| Escape Routes | 607 |
| Fire Fighting..... | 607 |
| Single Fire Concept | 607 |
| Deluge Systems..... | 607 |
| Fire Zones | 608 |
| Chapter 13 — Audits and Assessments..... | 610 |
| Introduction..... | 610 |
| Formal Audits | 611 |
| Reasons for Audits..... | 612 |
| Accident Follow-Up..... | 613 |
| Regulatory / Standards Compliance..... | 613 |
| Stakeholder Outreach..... | 613 |
| Voluntary Check | 613 |
| Insurance and Business Security | 614 |
| Audit Standards..... | 614 |
| Regulations | 614 |
| Reporting Requirements | 614 |
| Industry Standards | 614 |
| Internal Standards | 615 |

| | |
|--|-----|
| Audit Frequency | 615 |
| Audit Personnel..... | 615 |
| Outside Auditors | 615 |
| Internal Auditors | 616 |
| Team Composition..... | 617 |
| Auditor Attributes | 617 |
| Audit Service Providers | 617 |
| Interview Skills | 618 |
| Technical Knowledge | 618 |
| Writing Skills..... | 619 |
| Demeanor | 619 |
| The Host Company | 619 |
| First Impressions..... | 620 |
| Employees..... | 620 |
| Planning the Audit | 620 |
| Goals 621 | |
| Determine the Audit Standard..... | 621 |
| Scope 621 | |
| Budget..... | 622 |
| Schedule..... | 623 |
| One-Point Contact..... | 623 |
| Pre-Audit Activities | 624 |
| Audit Forms | 624 |
| Conducting the Audit..... | 626 |
| Auditor Preparation..... | 626 |
| Kick Off Meeting..... | 627 |
| Plant Tour | 627 |
| Information Collection..... | 627 |
| Role of Personnel..... | 628 |
| Interviews..... | 628 |
| On-Site Inspection | 629 |
| Close-Out Meeting..... | 629 |
| Report | 629 |
| Draft Report | 630 |
| Generalities | 630 |
| Report Distribution | 631 |
| Letter of Certification | 631 |
| Audit Verification | 632 |
| Positive Findings..... | 632 |
| Report Retention | 632 |
| Findings | 633 |
| Follow Up | 633 |
| Unannounced Audits..... | 633 |
| The SEMS Audit Rule | 634 |
| SEMS II | 647 |
| Audit Requirements | 648 |
| Independent Third Party Auditors (I3Ps)..... | 651 |
| I3P Qualifications | 651 |
| National Emphasis Program (NEP) | 652 |
| Reviews and Expert Assessments | 652 |
| Review Issues | 653 |

| | |
|--|------------|
| Management Systems Effectiveness | 653 |
| Workforce Involvement | 654 |
| Real World Usefulness | 654 |
| “Learned to Live with It” Problems | 654 |
| Lessons Learned..... | 654 |
| Reviewer Attributes | 654 |
| Management Elements Assessment | 655 |
| Level 1 — Risk Management | 656 |
| Level 2 — Management Element Spreadsheet | 658 |
| Level 3 — Detailed Questions | 659 |
| Scoring Template..... | 661 |
| Guidance | 661 |
| Benefits of the Elements Assessment Approach..... | 662 |
| Independent of Events..... | 662 |
| Handling Abstraction | 662 |
| Smoothing of Results..... | 663 |
| Objectivity..... | 663 |
| Chapter 14 — Consequence Analysis..... | 664 |
| Introduction..... | 664 |
| Range of Consequences | 664 |
| Safety | 666 |
| Health..... | 667 |
| Environmental..... | 667 |
| Economic | 667 |
| Effect of a Release | 667 |
| Hole Size..... | 668 |
| Fires..... | 668 |
| Flammable Range | 668 |
| Ignition Temperature / Energy | 669 |
| Spontaneous Combustion | 670 |
| Ignition Sources | 671 |
| Vacuum Trucks | 671 |
| Radiant Heat..... | 671 |
| Static Electricity | 672 |
| Lightning..... | 673 |
| Pyrophorics / Iron Sulfide..... | 673 |
| Flammability Hazard Ranking..... | 673 |
| Passive Fire Protection / Fireproofing | 674 |
| Explosions..... | 675 |
| Physical Explosions | 675 |
| Vapor Cloud Explosions..... | 675 |
| Deflagrations and Detonations..... | 676 |
| Blast Effects..... | 677 |
| BLEVEs..... | 677 |
| Dust Explosions | 677 |
| Toxic Gas Releases | 677 |
| Gas Release Modeling | 678 |
| Effect of Toxic Gases | 679 |
| Probit Equations..... | 681 |
| Short-Term Exposure Limits | 681 |
| Emergency Response Planning Guidelines (ERPGs) | 682 |

| | |
|---|------------|
| Immediately Dangerous to Life and Health..... | 683 |
| Permissible Exposure Limits (PEL)..... | 684 |
| Threshold Limit Values (TLV)..... | 684 |
| Short Term Exposure Limit (STEL)..... | 685 |
| Levels of Concern (EPA)..... | 685 |
| Acutely Toxic Concentration / Levels (New Jersey / Delaware)..... | 685 |
| Substance Hazards Index..... | 685 |
| Location of Monitors..... | 686 |
| Chapter 15 — Frequency Analysis..... | 687 |
| Introduction..... | 687 |
| The Pareto Principle..... | 687 |
| Importance Ranking..... | 688 |
| Fault Tree Analysis..... | 689 |
| Gates..... | 691 |
| OR Gate..... | 691 |
| AND Gate..... | 693 |
| VOTING Gate..... | 696 |
| Events..... | 698 |
| Top Event..... | 698 |
| Intermediate Events..... | 699 |
| Base Events..... | 699 |
| House Event..... | 700 |
| Top-Down Development of a Fault Tree..... | 700 |
| 1. Define the Top Event..... | 701 |
| 2. Build the Tree..... | 701 |
| 3. Identify the Cut Sets..... | 708 |
| 4. Eliminate Repeat Sets..... | 709 |
| 5. Eliminate Repeat Events in a Set..... | 710 |
| 6. Eliminate Redundant Events..... | 711 |
| 7. Quantify the Risk..... | 713 |
| Mathematics of an OR Gate..... | 713 |
| Mathematics of an AND Gate..... | 714 |
| Mathematics of a Voting Gate..... | 715 |
| Cut Set Quantification..... | 715 |
| 8. Risk Rank..... | 716 |
| Event Contribution..... | 716 |
| Important Few..... | 718 |
| Unimportant Many..... | 718 |
| Power of the AND Gate..... | 718 |
| Importance Equalization..... | 718 |
| Cost-Benefit Analysis..... | 718 |
| Importance Ranking Using Cut Sets..... | 719 |
| Birnbaum Factor Method..... | 719 |
| Fussell-Vesely Method..... | 719 |
| Perturbation Method..... | 719 |
| Common Cause Events..... | 720 |
| Fukushima-Daiichi..... | 723 |
| Generic Fault Trees..... | 724 |
| Generic Safety Fault Tree..... | 724 |
| Generic Reliability Fault Tree..... | 726 |
| Discussion of the Fault Tree Method..... | 727 |

| | |
|--|-----|
| Qualitative Fault Tree Analysis | 727 |
| Event Tree Analysis | 728 |
| Quantification of an Event Tree | 730 |
| Scope of Event | 732 |
| Combining Event Trees and Fault Trees | 732 |
| Short Sequence of Events | 734 |
| Many Events | 734 |
| Partial Success | 734 |
| Discrete Event Analysis | 734 |
| Non-Linearities and Complexities | 734 |
| Conveying Statistical Uncertainty | 735 |
| Monte Carlo Simulation | 735 |
| Random Number Generators | 735 |
| Seed Numbers | 736 |
| Speeding the Simulation | 736 |
| Markov Models | 737 |
| Top-Down / Bottom-Up Approach | 740 |
| Top-Down | 740 |
| Bottom-Up | 740 |
| Qualitative Insights | 740 |
| Limitations to Quantification | 741 |
| Mathematical Understanding | 741 |
| Value-Laden Assumptions | 741 |
| Lack of Exhaustivity | 742 |
| Human Behavior | 742 |
| Data Quality | 742 |
| Safeguards | 743 |
| Safeguard Level 1: Normal Operations | 744 |
| Safeguard Level 2: Procedural Safeguards | 745 |
| Safeguard Level 3: Safety Instrumented Systems | 745 |
| Safeguard Level 4: Mechanical Safeguards | 746 |
| Safeguard Level 5: Passive Safeguards | 746 |
| Safeguard Level 6: Emergency Response | 746 |
| Layer of Protection Analysis | 746 |
| The LOPA Process | 747 |
| Single Scenarios | 748 |
| IPLs | 748 |
| Specific | 749 |
| Independent | 749 |
| Dependable | 750 |
| Auditable | 750 |
| Human Response | 750 |
| Implementing LOPA | 750 |
| Team Makeup | 750 |
| Timing | 750 |
| Tools | 751 |
| Procedures and Inspections | 751 |
| Risk Criteria | 751 |
| Failure Rate Data | 751 |
| Conditional Probability / Bayes' Theorem | 752 |
| Evaluation of Tests | 752 |

| | |
|--|------------|
| Sequential Observations | 753 |
| Combining Data Sources | 753 |
| Chapter 16 — Reliability, Availability and Maintainability..... | 759 |
| Introduction..... | 759 |
| Benefits of a RAM Program | 761 |
| Increased Production and Profitability..... | 761 |
| Increased Productivity | 762 |
| Reduced Investment..... | 762 |
| Lower Maintenance Costs..... | 762 |
| Lower Inventories | 762 |
| Enhanced Customer Satisfaction | 762 |
| Personal Recognition | 762 |
| Personal Life | 763 |
| Improved Public Perception..... | 763 |
| Reliability and Safety | 763 |
| Hazardous Operations..... | 763 |
| Unsafe Process Conditions | 763 |
| Safety Bypasses | 763 |
| Transient Stresses | 763 |
| Reduced Chance of Catastrophic Losses | 764 |
| Increased Safety May Reduce Reliability..... | 764 |
| Loss of Experience..... | 764 |
| Engineering Practices | 764 |
| Daily Operations | 764 |
| Definitions..... | 764 |
| Reliability..... | 765 |
| Availability | 765 |
| Effectiveness..... | 767 |
| Maintainability..... | 767 |
| Failure Modes | 768 |
| Equipment Description | 768 |
| Primary, Secondary and Command Failures..... | 768 |
| Catastrophic, Degraded and Incipient Failures | 768 |
| Real Failures / Necessary Replacements | 768 |
| Failure Rates | 769 |
| Constant / Exponential Distribution..... | 770 |
| Lognormal Distribution | 771 |
| Bathtub Curve..... | 771 |
| Early Failures..... | 772 |
| Constant Failure Rate..... | 772 |
| Wear-Out Failures..... | 772 |
| Reliability Block Diagrams..... | 773 |
| Active / Standby Redundancy..... | 776 |
| Quantification of Block Diagrams | 777 |
| Human Reliability | 778 |
| Types of Human Error | 779 |
| Errors of Intent..... | 779 |
| Mistakes | 779 |
| Slips | 779 |
| Fixation | 780 |
| Error in an Emergency | 780 |

| | |
|---|------------|
| Incorrect Response..... | 780 |
| Human Reliability Analysis..... | 780 |
| THERP..... | 781 |
| Chapter 17 — Managing a Risk Program | 782 |
| Introduction..... | 782 |
| Clients / Customers | 782 |
| Senior Management | 782 |
| Facility Managers | 782 |
| Project Managers and Design Engineers | 782 |
| Regulators / Auditors | 783 |
| Program Organization | 783 |
| Step 1 — Determine the Objectives..... | 783 |
| Step 2 — Set Up an Organization..... | 783 |
| Management..... | 784 |
| Steering Committee | 784 |
| Coordinator | 785 |
| Sub-Committees..... | 785 |
| Operating Binders | 786 |
| Step 3 — Create the Metrics and Baseline | 787 |
| Step 4 — Develop a Plan..... | 789 |
| Goals | 790 |
| Resources Needed..... | 790 |
| Develop a Schedule..... | 790 |
| Reviews and Signatures | 791 |
| Step 5 — Implement the Plan | 792 |
| Step 6 — Audit / Improve..... | 792 |
| Risk Management on Projects..... | 792 |
| Phase I — Concept Selection..... | 795 |
| Phase II — Preliminary Engineering | 795 |
| Philosophies | 795 |
| Hazards Analysis | 796 |
| Phase III — Detailed Engineering | 797 |
| Phase IV — Fabrication and Construction | 797 |
| Phase V — Commissioning and Start-Up | 797 |
| Chapter 18 — Project Management..... | 798 |
| Introduction..... | 798 |
| Phase / Gate System..... | 798 |
| Hazards Analysis on Projects..... | 799 |
| Phase I — Concept Selection..... | 801 |
| Documents | 802 |
| Hazards Analysis | 802 |
| Phase II — Preliminary Design (FEED)..... | 803 |
| Documents | 803 |
| Hazards Analysis | 804 |
| Phase III — Detailed Engineering | 805 |
| Documents | 805 |
| Hazards Analysis | 805 |
| Phase IV — Fabrication and Construction..... | 805 |
| Precommissioning..... | 806 |
| Punchlists | 806 |
| Transfer of Care, Custody and Control..... | 807 |

| | |
|---|------------|
| Documents | 807 |
| Turnover Packages..... | 807 |
| Procedures..... | 810 |
| Hazards Analysis | 810 |
| Phase V — Commissioning and Start-Up..... | 811 |
| Commissioning..... | 811 |
| Operational Readiness Review | 811 |
| Startup and Line Out..... | 812 |
| Documents | 812 |
| Start-Up Procedures..... | 812 |
| Acceptance Test..... | 813 |
| Warranty | 813 |
| Hazards Analysis | 813 |
| Project Organization | 813 |
| Chapter 19 — Contractors..... | 815 |
| Introduction..... | 815 |
| Regulations and Standards | 817 |
| OSHA PSM Standard | 817 |
| OSHA PSM Guidance | 819 |
| Application..... | 819 |
| Employer Responsibilities | 819 |
| BSEE SEMS | 820 |
| API RP 76..... | 821 |
| Types of Contractor | 821 |
| Contract Companies..... | 823 |
| Selecting a Contract Company..... | 823 |
| Contractor HSE Program | 824 |
| Design Companies | 825 |
| Subcontractors | 825 |
| Contract Workers..... | 825 |
| Maintenance Contractors | 826 |
| Visitor / Consultant..... | 826 |
| Bridging Documents | 826 |
| Operator/Contractor Bridging Document | 827 |
| Bridging through a Regulation..... | 827 |
| Contractor Management..... | 828 |
| Contractor Selection | 828 |
| Record Keeping | 829 |
| Contractor Training..... | 829 |
| Safety Meetings | 829 |
| Equipment..... | 830 |
| Infractions | 830 |
| Contractor Training..... | 830 |
| Safety Meetings | 831 |
| Contractor Evaluation..... | 831 |
| Chapter 20 — The Risk Management Professional..... | 833 |
| Introduction..... | 833 |
| Attributes..... | 833 |
| Education and Certification | 833 |
| Technical Knowledge | 833 |
| Holistic..... | 833 |

| | |
|---|-----|
| Numerate..... | 834 |
| Communication Skills..... | 834 |
| Industrial Experience | 834 |
| Knowledge of Past Events | 834 |
| Professional Involvement..... | 835 |
| Network | 835 |
| The Resumé / CV | 835 |
| Level of Detail | 836 |
| Publications..... | 836 |
| Gaps / Negative Facts | 836 |
| Multiple Resumés | 836 |
| Declining Experience..... | 836 |
| Professional Engineer | 837 |
| Consultants..... | 837 |
| True Expertise..... | 837 |
| The Consultant as Outsider..... | 838 |
| Consultants — Not Contractors..... | 838 |
| Cuts Gordian Knots | 839 |
| Quick Study | 839 |
| Role of the Client..... | 840 |
| Response to Criticism | 840 |
| Marketing..... | 840 |
| Communicating with Management/Clients..... | 840 |
| Presentations | 841 |
| Meetings..... | 841 |
| Report Writing | 842 |
| Draft Report | 842 |
| Language of the Report..... | 843 |
| Completeness / Thoroughness | 843 |
| Personal Information..... | 843 |
| Writing Style..... | 844 |
| Non-Emotional Language | 844 |
| Minimalist Writing — Make Every Word Tell | 844 |
| Omit Needless Words / Tautologies | 845 |
| Short, Simple Words..... | 845 |
| Minimize ‘Soft’ Materials..... | 846 |
| Eschew Obfuscation..... | 846 |
| Develop a Theme | 847 |
| Modifiers..... | 847 |
| No Typos..... | 847 |
| Date Format | 847 |
| Active/Passive Voice | 848 |
| He / She..... | 848 |
| You / I..... | 848 |
| Choice of Words | 849 |
| Use of Humor..... | 849 |
| Copyright | 849 |
| Responsible Document Creation..... | 850 |
| Anecdotes / Story-Telling | 851 |
| Stories | 852 |
| Elements of a Story..... | 852 |

| | |
|---|------------|
| Characters | 852 |
| Setting | 853 |
| Plot 853 | |
| Conflict | 853 |
| Resolution | 853 |
| Sensitivity | 853 |
| Communicating with the Public..... | 853 |
| The Community | 854 |
| Other Businesses..... | 855 |
| The Media..... | 855 |
| Regulators / Non-Governmental Organizations (NGOs)..... | 855 |
| Types of Public Communication | 856 |
| Developing a Risk Communication Program | 856 |
| Communicating New Paradigms | 856 |
| Trade Secrets (OSHA) | 857 |
| Litigation Support | 861 |
| Use of Legal Services | 862 |
| Types of Litigation..... | 862 |
| The Participants | 863 |
| Timeline / Story Line..... | 863 |
| Documentation..... | 863 |
| The Discovery Process..... | 864 |
| Depositions | 864 |
| Witnesses to Fact | 865 |
| The Expert Witness..... | 865 |
| Acceptance by the Court..... | 866 |
| Daubert and Frye Rules | 867 |
| Prior Testimony | 867 |
| Timeline / Story Line..... | 867 |
| The Report | 868 |
| Attributes of an Expert Witness..... | 868 |
| To Thine Own Self Be True..... | 868 |
| Be Prepared..... | 868 |
| Be a True Expert | 868 |
| Be a Teacher | 869 |
| “Reasonable”Risk | 869 |
| Privilege..... | 869 |
| Citations..... | 871 |