Contents to Volume 1

Preface XVII

List of Contributors XIX

Part I Engineering Management for Loss Prevention Engineering 1

1 Management Systems – Loss Prevention Engineering Programs and Policy 3

Shakirudeen Shakioye

1.1 Introduction – Understanding the Need for Management Systems 3

1.2 Management Systems – Definitions 6

1.3 Loss Prevention Engineering – Considerations 7

1.4 Management Systems – Loss Prevention Engineering 9

1.4.1 Leadership Commitment 10

1.4.2 Vision and Objectives 10

1.4.3 Resources / Policy / Processes / Procedure / Regulations 11

1.4.3.1 Resources 12

1.4.3.2 Policy 14

1.4.3.3 Regulatory Consideration 14

1.4.3.4 Processes 15

1.4.3.5 HES Processes Approach and Structure 15

1.4.4 Business Planning (HES) 18

1.4.5 Implementation 20

1.4.6 Evaluation of Management System for Improvement 21

1.4.7 Periodic Corporation Audit 21

1.4.8 Enterprise Audit Plan 21

1.4.9 Audits Levels and Continuous Improvement 22

Appendix 1.A: BCN – NSHE Sample Drug and Alcohol Policy 24

Appendix 1.B: Behavior-Based Safety Supporting Tool 26

Appendix 1.C: Sample Internal Simple Inspection Checklist 27

References 28
## Contents

### 2 Resource Allocation and Effectiveness Measures for Loss Prevention 31

*Samuel A. Oyewole*

- 2.1 Introduction 31
- 2.2 What Is Loss Prevention/Safety and Health Intervention? 32
- 2.3 Historical Perspective of Resource Allocation for Loss Prevention 33
- 2.4 Loss Prevention/Safety and Health Intervention Effectiveness Evaluation 36
- 2.5 Importance of Multiple Factors in Loss Prevention 37
- 2.6 Research Methodology in Resource Allocation for Loss Prevention 38
- 2.7 Experimental Method 39
- 2.8 Analysis and Results 39
- 2.9 Conclusion 48

References 50

### 3 Engineering Systems and Engineering Economics of Loss Prevention 53

*Joel M. Haight*

- 3.1 Introduction 53
- 3.2 Cost of Injuries 55
- 3.3 Return on Investment Versus Cost Savings Versus Productivity Savings 56
- 3.4 Engineering Economics 57
- 3.5 Engineering Economic Decision-Making 59
- 3.6 Net Present Value Comparison (Equipment Replacement) 59
- 3.6.1 Final Result and Decision 64
- 3.6.2 Accept or Reject Decision for a Simple Investment Based on Rate of Return 64
- 3.7 Payback Period Comparison 65
- 3.8 Financial Considerations of a Loss Prevention Engineering Project 66
- 3.8.1 Project Budget 66
- 3.9 Conclusion 69

References 69

### 4 Safety Management and Culture 71

*Brian W. Tink and Brian A. Tink*

- 4.1 What Is Organizational Culture? 71
- 4.2 How Does Culture Form? 74
- 4.3 Why Is It Good Business to Improve Your Company’s Culture? 77
- 4.4 Measuring Culture 79
- 4.5 How to Bring About Changes in Culture 82

References 86
5 Leadership and Loss Prevention Engineering: Creating Conditions to Get Beyond Compliance to High Performance 89
Michele Lindsay
5.1 Introduction 89
5.2 Management Theories 92
5.2.1 Scientific Management Theory 92
5.2.2 The Link Between Motivation in Individuals and Management Theories 93
5.2.3 Motivation Theories Integrated into Management Theories 94
5.2.3.1 Autonomy for the Individual 96
5.2.3.2 Competence for the Individual 97
5.2.3.3 Relatedness for Individual 98
5.3 Moving Beyond Mechanistic Management 99
5.4 Humanistic Organizations 99
5.4.1 Autonomy in Organizations 101
5.4.2 Competence in Organizations 102
5.4.3 Relatedness in Organizations 105
5.5 Case Studies of Humanistic Management 107
References 110

Part II Design and Analysis of Protective Systems – General Loss Prevention Engineering 113

6 General Loss Prevention Engineering Programs – Including Fire Loss Control 115
Jeffery Robinson
6.1 Background 115
6.2 Introduction 116
6.3 Elements of a Fire Loss Control Program 116
6.3.1 Policy Statement 116
6.3.2 Roles and Responsibilities 116
6.4 Fire Prevention Controls 118
6.4.1 Design Considerations – Selection of Materials for Construction 118
6.4.2 Fire Prevention Controls 121
6.4.3 Preventing Losses – Safe Hot Work Practices 122
6.4.4 Identifying Electrical Hazards 126
6.4.5 Controlling Losses 127
6.4.6 Fire Impairment Management 128
6.4.6.1 Planned Impairments 129
6.4.6.2 Unplanned Impairments 131
6.4.6.3 Restoration of Impaired Systems 131
6.4.7 Plant Emergency Organization (PEO) 131
6.4.7.1 Firefighting Team Selection 132
6.4.7.2 Salvage and Restoration 133
7 Permits-to-Work Systems 141
John W. Mroszczyk

7.1 Introduction 141
7.2 The Permit-to-Work Process 141
7.3 Regulations and Standards 145
7.4 Hot Work 145
7.5 Confined Space 149
7.6 Live Line Electrical Work 151
References 156
Recommended Reading 156

8 Excavation and Trenching 159
Michael W. Hayslip

8.1 Introduction 159
8.2 Hazard Identification and Federal OSHA Regulation 162
8.3 Soil Types 166
8.3.1 Loess 168
8.3.2 Expansive Soils 169
8.3.3 Organic Soils and Peat 170
8.3.4 Colluvium and Talus 170
8.3.5 Shales and Degradable Materials 171
8.3.6 Caliche and Cemented Sands 171
8.3.7 Sensitive Clays and Sands 172
8.4 Basic Soil Mechanics Theory 172
8.5 Testing and Soil Classification Systems 176
8.5.1 Standard Penetration Test (SPT) 181
8.5.1.1 Procedures Which May Affect the Measured N Values 182
8.5.2 Cone Penetrometer 183
8.5.3 Other Types of Shear Tests (Laboratory) 183
8.6 Protective Systems 185
8.6.1 Slope Configurations (OSHA 29 CFR 1926) 186
8.6.1.1 Excavations Made in Type A Soil 186
8.6.1.2 Excavations Made in Type B Soil (OSHA 29 CFR 1926) 189
8.6.1.3 Excavations Made in Type C Soil (OSHA 29 CFR 1926) 190
8.6.2 Timber Shoring – Appendix C to OSHA 29 CFR 1926.652 191
8.6.3 Aluminum Hydraulic Shoring – Appendix D to OSHA 29 CFR 1926.652 191
8.6.4 Alternatives to Timber Shoring – Appendix E of OSHA 29 CFR 1926.652 192
Glossary (Taken in Part from Standard Handbook for Civil Engineers (Ricketts, Loftin, and Merritt, 2003) and OSHA 29 CFR 1926 (OSHA, 2012b)) 192
References 199

9 Machine Safeguarding 201
John W. Mroszczyk
9.1 Introduction 201
9.2 Regulations and Standards 202
9.3 Machine Motion Hazards 203
9.4 Human Factor Aspects of Machine Guarding 206
9.5 Machine Safeguarding Methodology 207
9.6 Basic Machine Guarding Principles 212
9.7 Types of Machine Safeguarding 213
9.8 Machine Controls 220
9.9 Responsibilities of the Machine Builder 223
9.10 Mechanical Power Presses 224
9.11 Power Press Brakes 224
9.12 Conveyors 225
9.13 Roll-Forming and Roll-Bending Machines 225
9.14 Shearing Machines 225
9.15 Laser Machining 226
9.16 Robots 227
9.17 Conclusion 228
References 228
Further Reading 229

10 Boilers and Pressure Vessels: a Brief Look at General Safeguards 231
Patrick Fortune
10.1 Water 231
10.2 Safeguards 234
10.3 Codes, Regulations, and Training 235
10.4 Types of Boilers 238
10.5 Operating Considerations 240
10.6 Boiler Feed Water 244
10.7 Chemical Handling 247
10.8 Steam 251
10.9 Special Considerations for Pressure Vessels 255
10.10 Fire Detection and Control 256
10.11 Incident Investigation 257
10.12 Closing Thoughts 258
References 259
11 Welding and Cutting 261
Jeffery S. Haight
11.1 Introduction 261
11.2 Basic Equipment for Welding Comfortably and Safely 264
11.2.1 Eye Protection 264
11.2.2 Hand Protection 265
11.2.3 Body Protection 266
11.2.4 Respiratory Protection 266
11.3 The Welding Process 267
11.3.1 Gas Metal Arc Welding (MIG) 268
11.3.2 Tungsten Inert Gas Welding (TIG) 270
11.4 Cutting 272
11.4.1 Safety 273
11.4.2 Plasma Cutting 274
11.5 Conclusion 276
References 276

12 Power Tools 277
Warren K. Brown
12.1 Introduction 277
12.2 Guards 281
12.3 Safety Switches 282
12.4 Electric Tools 282
12.5 Powered Abrasive Wheel Tools 283
12.6 Liquid Fuel Tools 283
12.7 Pneumatic Tools 284
12.8 Hydraulic Power Tools 284
12.8.1 Portable Hand-Held Circular Saw 285
12.8.2 Portable Angle Grinder 287
12.8.3 Portable Drill/Driver 289
12.8.4 Portable Sanders 291
12.8.5 Reciprocating Saws 292
12.8.6 Impact Wrench – Air and Electric 294
12.8.7 Jigsaw/Saber Saw 295
12.8.8 Multifunction Power Tool 296
12.8.9 Heat Gun 297
12.8.10 Portable Air Compressor 298
12.8.11 Shop Vacuum 300
12.9 Conclusion 301
References 301

13 Personal Protective Equipment 303
Christopher M. Stroz
13.1 Introduction 303
13.2 General Selection 304
13.3 Types 304
13.3.1 Head Protection 304
13.3.2 Hand Protection 306
13.3.3 General Hand Protection 307
13.3.4 Chemical Hand Protection 307
13.3.5 Hand Protection from Cuts and Punctures 310
13.3.6 Thermal and Flame Hand Protection 311
13.3.7 Eye and Face Protection 312
13.3.8 General Eye and Face Protection 312
13.3.9 Eye and Face Protection for Welding, Burning, and Brazing Activities 315
13.3.10 Eye Protection for Lasers 316
13.3.11 Foot 317
13.3.12 Ear 319
13.3.13 Heat, Flame, and Electric Arc 322
13.4 Conclusion 323
References 323

14 Powered Industrial Trucks 327
Thaddeus M. Pajak and Mary Hoerster
14.1 Introduction 327
14.2 Lift Truck Accident Prevention: An Integrated Approach 329
14.3 Fork Truck Safety Observations 330
14.4 Making Safety Observations 331
14.4.1 Safe Speeds 331
14.4.2 Baseline Environment Status 333
14.4.3 Lighting 333
14.4.4 Housekeeping 334
14.4.5 Overhead Hazards 334
14.4.6 Other Safety Observations 335
14.5 Loading Dock Safety 335
14.6 Whole Body Vibration 338
14.7 Administrative Controls for Lift Truck Operator Strains and Sprain Prevention 340
14.8 Rack and Overhead Storage and Industrial Lift Truck Operations 341
14.9 Carbon Monoxide and Dilution Ventilation 344
14.10 MVR Program and Physical Requirements 345
14.11 Case Studies 346
14.11.1 Case Study 1 346
14.11.1.1 The Events 346
14.11.1.2 Preventive Measures 347
14.11.2 Case Study 2 347
14.11.2.1 The Events 347
14.11.2.2 Preventive Measures 347
14.11.3 Case Study 3 347
14.11.3.1 The Events 347
14.11.3.2 Preventive Measures 348
14.12 Using Acceptable Safety Tolerances in Defining Preventive Maintenance 348
14.13 Industrial Lift Truck Accident Costs 349
14.13.1 Example 350
14.14 Conclusions and Establishing Safe Behavior Observation Management Programs 350
References 352

Part III Ergonomics and Human Factors Engineering 355

15 Biomechanics and Physical Ergonomics 357
Kyung-Sun Lee and Myung-Chul Jung
15.1 Introduction 357
15.2 Biomechanics 357
15.2.1 Trunk Biomechanics 358
15.2.1.1 Trunk Anatomy 358
15.2.1.2 Trunk Range of Motion 358
15.2.1.3 Trunk Biomechanics Model 359
15.2.1.4 Trunk Electromyography 360
15.2.2 Wrist Biomechanics 360
15.2.2.1 Wrist Anatomy 360
15.2.2.2 Wrist Range of Motion 361
15.2.2.3 Wrist Biomechanics Model 361
15.2.2.4 Wrist Electromyography 362
15.2.3 Hand Biomechanics 363
15.2.3.1 Hand Anatomy 363
15.2.3.2 Hand Range of Motion 365
15.2.3.3 Hand Biomechanics Model 365
15.2.3.4 Hand Electromyography 365
15.3 Applications of Biomechanics in Ergonomics 366
15.3.1 Application of Trunk Biomechanics 366
15.3.2 Application of Hand and Wrist Biomechanics 368
15.4 Conclusion 369
References 370

16 Human Factors and Cognitive Engineering 373
Anand Tharanathan and Ling Rothrock
16.1 Introduction 373
16.2 Models of Human Cognition 374
16.2.1 SRK Framework in Process Operations 376
16.2.2 Cognitive Task Analysis 377
16.2.3 Situation Awareness 378
16.3 Applications to Process Engineering and Surface Transportation 379
19.4 Graphical Methods of Technical Hazards Assessment in Underground Mechanical Systems 449
19.4.1 Introduction to the CAD/CADD Systems and Graphical Methods of Technical Hazards Assessment 449
19.4.2 Detection of Collisions During Transport Operation 451
19.5 Virtual Prototyping of FOPS 454
19.6 Application of Computational Fluid Dynamics (CFD) Analyses in Virtual Prototyping of Mining Machines 457
19.7 Conclusion 460
References 460

Contents to Volume 2

List of Contributors XXIII

Part IV Process Safety Management and System Safety Engineering 463

20 Process Safety Regulations Around the World 465
Remigio Agraz-Boeneker

Paul Baybutt

22 Safety Instrumented Systems 555
Geoffrey S. Barnard

Paul Baybutt

24 Chemical Reaction Safety 637
John C. Wincek

25 Application of Systems Engineering to Safety and Risk Management: a Human–Systems Integration Perspective 681
Tareq Ahram and Waldemar Karwowski

26 Management of Change 701
Tracey Zarn and Aaron Hade
The Importance of Fostering a Strong Industrial Safety Culture and Change Management 725
Jeffery M. Kramer

Contractor Safety Management 747
Michael Farris

Emergency Preparedness and Response 773
Leo J. DeBobes

Security and Terrorism 785
Mohammed Nasir Mohammed Ismail

Part V  Occupational Health and Environmental Engineering 795

Control of Chemical Hazards 797
Marjory E. Anderson

Control of Physical Hazards 821
Marjory E. Anderson

Control of Air Pollution 855
Tyler Nguyen

Hazardous Waste Management and Engineering 897
Darryl C. Hill

Part VI  Incident Investigation and Root Cause Analysis Methodology and Management 913

How to Conduct Effective Incident Investigations 915
Kevin McManus

Incident Investigations – Lessons Learned – Development and Communications 937
David Janney

Managing Records, Investigation and Recommendation Management and Closure 947
David Janney

Part VII  Fire Protection Engineering 959

Fire Dynamics 961
Christopher C. Venn
Contents

39  Fire Prevention and Protection  999
    Craig Arthur Brown

40  The Science and Engineering of Explosions  1041
    David G. Lilley

Index  1083