

Contents

Author Profiles	xxiii
Foreword	xxix
Preface.....	xxxii
Acknowledgment	xxxv

SECTION I INTRODUCTION TO HUMAN FACTORS WITHIN THE CHEMICAL AND PROCESS INDUSTRIES

CHAPTER 1 What is human factors?..... 3

J. Edmonds

List of Abbreviations	3
The Work System	4
Humans within the Work System	5
Scientific Background	9
Scientific Approach	10
Summary: What is Human Factors?.....	11
Key Points	11
Further Reading.....	11

CHAPTER 2 What part does human factors play within chemical and process industries? 13

J. Edmonds and J. Wilkinson

List of Abbreviations	13
Work Systems in the Chemical and Process Industries.....	13
Typical Human Factors Issues.....	14
Work Tasks.....	15
Work Tools and Work Equipment.....	16
Workspace and Work Area.....	18
Environmental Context	19
Organizational Context	20
Maturity of Human Factors	22
Summary: What Part Does Human Factors Play Within the Chemical and Process Industries?	22
Key Points	23
References	23
Further Reading.....	24

CHAPTER 3 Review of common human vulnerabilities and contributions to past accidents25

J. Edmonds

List of Abbreviations	25
Current Safety Management Practices	26
The Plateau in Safety Performance	27
Learning from Human Failures in Major Accidents	28
Summary of Key Human Factors Themes within Major Accidents	31
Final Remarks Regarding Human Performance.....	34
Personal Injury	34
Musculoskeletal Disorders.....	34
Psychological Related Ill Health	36
Other Types of Injury	36
Summary: Review of Common Human Vulnerabilities and Contributions to Past Accidents	37
Key Points	37
Reference.....	37
Further Reading.....	37

CHAPTER 4 Current regulatory and government focus on human factors39

J. Wilkinson

List of Abbreviations	39
The UK and Seveso Directives.....	41
Onshore.....	41
Offshore	41
Factoring the Human into Seveso	42
Safety Cases and Safety Reports	42
Implementing HOF in the UK and EU	43
HOF Regulation in the EU: Some Varieties	44
Inspection or Auditing: What is the Difference?	44
Conclusions on the UK and Seveso Picture.....	46
Australia	46
Conclusions for Australia	47
North America	47
Canada	48
The US	48
Standards.....	50
A Safety Case Regime for the US?.....	50

Developments Following the West Fertilizer Company	
Explosion	52
Conclusions for North America	53
What Does “Good” Look Like for Regulation?	53
Summary: Current Regulatory and Government Focus on	
Human Factors	55
Key Points	55
References	56

CHAPTER 5 Management frameworks for human factors.....59

J. Edmonds

List of Abbreviations	59
Basic Premise of a Human Factors Management Framework	60
Goals	61
Structure.....	61
Measurement, Action, and Review	61
Current Models for Human Factors Management Frameworks.....	62
Topic-Based Approaches	62
Risk-Based Approach	64
Human Factors Maturity® Model	65
Management Framework for Human Factors in Design.....	66
Practical Advice for Implementing a Management Framework.....	69
Organizational Position of Human Factors.....	69
Roles and Responsibilities for Human Factors.....	69
Summary: Management Frameworks for Human Factors	69
Key Points	70
References	70
Further Reading	70

SECTION II MANAGING HUMAN FAILURE

CHAPTER 6 Human factors in risk management.....73

R. Scaife

List of Abbreviations	73
Human Reliability Analysis	76
Qualitative Approaches	77
Identification of Safety-Critical Tasks	78
Safety-Critical Task Screening	78
Task Analysis	79
Workshop-based Analysis.....	80

Contents

Quantitative Approaches	82
Comparing Qualitative and Quantitative Approaches	84
Synergies with Safety Engineering	85
Hazard and Operability Studies	85
Failure Modes and Effects Analysis	86
Bow Ties	87
Other Forms of Risk Management	88
Summary: Human Factors in Risk Management	89
Key Points	89
References	90
 CHAPTER 7 Reducing human failure	93
<i>R. Scaife</i>	
List of Abbreviations	93
Overview of Human Error	94
Overview of Violations and Noncompliance	95
Key Points	97
 CHAPTER 7.1 Human error	98
<i>J. Mitchell and R. Scaife</i>	
Models of Human Error	98
The Skills, Rules, Knowledge Framework	98
Slips, Lapses, and Mistakes	100
Human Information Processing Model	101
Model of Situational Awareness	103
Human Errors in the Context of a Flawed System	104
Prevalence of Human Error	105
Performance Shaping Factors	107
Human Limits and Susceptibility to Bias	109
Potential Solutions for Managing Human Error	110
Summary: Human Error	115
Key Points	115
References	116
 CHAPTER 7.2 Intentional noncompliance	118
<i>R. Scaife and J. Mitchell</i>	
Recognizing Intentional Noncompliance	118
Tools and Methods for Analyzing Noncompliant Behaviors	120
Work Compatibility Model	120

ABC Model	122
Theory of Planned Behavior.....	122
The Links Between Noncompliance and Safety Culture	125
Risk Homeostasis and Safety Noncompliance.....	125
Actions to Reduce Intentional Noncompliances	126
Summary: Intentional Noncompliance.....	129
Key Points	129
References	129
References	130

CHAPTER 8 Human factors in incident investigation..... 131

E. Novatsis and J. Wilkinson

List of Abbreviations	131
The Investigation Process.....	131
Key Stages of an Investigation	132
Investigation Methods	132
Advantages of Mainstream Methods	134
Disadvantages of Mainstream Methods.....	135
Choice of Method	136
Including Human Factors Within Existing Investigation	
Methods	136
Human Factors Considerations for Investigators	138
Key Qualities of Investigators.....	140
Interviewing Skills.....	141
Cognitive Bias in the Investigation Process.....	143
Managing Investigation Capability	145
Proactive Application of Human Factors Analysis.....	148
Summary: Human Factors in Incident Investigation.....	148
Key Points	149
References	149

SECTION III HUMAN FACTORS WITHIN DESIGN AND ENGINEERING

CHAPTER 9 Overview of human factors engineering..... 153

J. Edmonds

List of Abbreviations	153
Definitions and Boundaries	155
Understanding Human Interactions.....	155

Contents

Human-Centered Design Approach.....	158
Context of Use	160
HFE Requirements.....	163
HFE in Support of Design	164
Evaluate Design	164
Practical Application	165
Summary: Overview of Human Factors Engineering	166
Key Points	166
References	166

CHAPTER 10 Human factors integration within design/engineering programs..... 169

J. Edmonds

List of Abbreviations	169
Cost-Benefits of HFI.....	170
Organization of HFI.....	172
HFI within the Project Life Cycle	174
Management of HFI	176
Typical HFI Management Activities by Life Cycle Stage	176
Scoping and Structuring of the HFI Program	177
Human Factors Integration Plan	177
Progress Updates and Coordination within Projects.....	179
Human Factors Issues Register	179
Technical Work Programs.....	179
Engineering Design.....	181
Health and Safety	182
Operations	182
Assurance Activities	183
Summary: HFI within Design Engineering Programs.....	184
Key Points.....	184
References	185

CHAPTER 11 Building and control room design..... 187

E.J. Skilling, C. Munro and K. Smith

List of Abbreviations	187
Human Factors Approach to Control Center Design.....	189
Step 1—Development of the Initial Design.....	189
Step 2—Development of Concept Design	193
Step 3—Development of Detailed Design.....	194
Step 4—Post-Commissioning	194
Control Building Layout.....	194

Space Design.....	197
Functional Layout.....	197
Console Orientation	199
Environmental Design	200
Thermal Comfort	201
Lighting.....	201
Noise	201
Vibration	201
Aesthetics.....	201
Summary: Building and Control Room Design	201
Key Points.....	202
Acknowledgment.....	202
References	202

CHAPTER 12 Workstation, work area, and console design205

E.J. Skilling

List of Abbreviations	205
Workstation Dimensions.....	206
Clearance.....	207
Reach.....	207
Posture.....	207
Work Area Space Requirements	208
Workspace Arrangement—Workstations and Consoles	209
Working Posture	210
Seated Workstations.....	211
Recommended Dimensions for Seated Workstations	211
Seating Design	212
Adjustability.....	212
Seat Height.....	213
Backrest.....	213
Seat Pan Depth and Width	213
Armrests	214
Mobility.....	214
Upholstery	215
Standing Workstations	215
Dimensions for Standing Workstations.....	215
Visual Requirements.....	217
Additional Information Relevant to Console Design	217
Vehicle Workstations	219
Plant Side Work Areas	220
Key Points.....	220
Acknowledgment.....	221

CHAPTER 13 Control system interface design 223

R. Scaife

List of Abbreviations 223

An Interdisciplinary Effort 224

Components of an HMI 224

Information Display 225

 Information Requirements 225

 Layout of Displayed Information 226

 Alarm Management 229

Controls 232

 Compatibility with the Task 232

 Compatibility with Displays 232

 Consistency 233

Management of Interaction 235

 Management of Change 236

 Error Trapping 236

 Data Security 237

 Modes of Operation 237

The Interface as a Control Room Component 238

Summary: Control System Interface Design 238

Key Points 238

References 239

CHAPTER 14 Plant and equipment design 241

C. Munro and J. Edmonds

List of Abbreviations 241

Plant Side Roles and Activities 242

Instrumentation Design 244

 Design of Displays 244

 Design of Controls 245

 Considerations for Control Panel Design 246

Valve Design 246

 Valve Positioning 247

 Size, Type, Orientation, and Torque of Valve Handles 248

 Valve and Pipework Access 249

Design for Maintenance 249

 Equipment Access 249

 Equipment Labeling 250

 Equipment Design 250

 Maintenance Tools 250

Equipment Handling	250
Equipment Safety Features	251
Workspace Access and Clearance.....	251
Equipment Positioning and Layout	252
Internal Plant Side Work Areas	252
External Plant Areas.....	253
Signage and Labeling.....	253
Key Points.....	255
References	255
CHAPTER 15 Human factors in materials handling.....	257
<i>E.J. Skilling and C. Munro</i>	
List of Abbreviations	257
Handling Injuries	258
Planning and Assessment of Materials Handling	258
Assessment of the Load	259
Mechanical Handling.....	261
Material Handling Study.....	261
Equipment Selection	262
Facility Layout	264
Environment.....	265
Maintenance of Equipment	265
Reducing the Risk of Manual Handling	265
Assessment of the Task	265
Assessment of the Work Area	266
Environmental Factors	267
Operator Factors.....	267
Manual Handling Analysis Tools.....	268
Summary: Human Factors in Materials Handling.....	268
Key Points.....	269
References	269
CHAPTER 16 Environmental ergonomics	271
<i>E.J. Skilling and C. Munro</i>	
List of Abbreviations	271
Measuring Environmental Factors.....	272
Thermal Comfort.....	272
Air Temperature	273
Radiant Temperature	274
Humidity	274
Air Velocity	274

Contents

Metabolic Rate	274
Clothing.....	274
Psychological and Physical Effects of Thermal Comfort	274
Assessment of Thermal Comfort	275
Thermal Indices	275
PMV and PPD.....	276
Comfort Surveys	276
Control Measures	276
Lighting	279
Lighting of Work Areas.....	279
Effects of Inappropriate Lighting.....	281
Lighting Maintenance	283
Emergency Lighting.....	283
Noise.....	283
Assessing Noise Exposure	283
Short-Term Noise Exposure Effects	284
Long-Term Noise Exposure Effects.....	284
Noise Exposure Requirements.....	284
Noise Distraction	285
Noise Controls	285
Vibration	286
Measuring Vibration Levels	287
Controlling the Risks of Vibration	288
Summary: Environmental Ergonomics.....	289
Key Points.....	289
References	289
CHAPTER 17 Human factors in the design of procedures.....	291
<i>E. Novatsis and E.J. Skilling</i>	
List of Abbreviations	291
Defining Procedures	292
Lessons from Past Incidents	294
Why Procedures Fail	294
Procedure Development Process	296
Understand the Task.....	297
Determine the Format	298
Prepare a Draft	298
Validate/Quality Assurance.....	299
Approval for Release	299
Review and Update	299

Presentation of Procedures	299
Format	300
Precautions	301
Task Steps	301
Layout	301
Grammar and Language	302
Terminology	302
Font	303
Visual Aids	303
Practical Tips for Implementing Procedure Improvement	
Programs	304
Gap Analysis	304
Evaluation Criteria	304
Selection and Training of Procedure Writers	304
Piloting the Approach	305
Coaching and Support to Procedure Writers (Post-training) ...	305
Summary: Human Factors in the Design of Procedures	305
Key Points	306
References	306
Further Reading	307

SECTION IV UNDERSTANDING AND IMPROVING ORGANIZATIONAL PERFORMANCE

CHAPTER 18 Safety culture and behavior 311

E. Novatsis

List of Abbreviations	311
Defining Safety Culture	312
Narrative Descriptions	313
Use of Organizational Culture Models	313
Factors Measured in Safety Climate Perception Scales	314
High Reliability Organizations	315
Cultural Progression Models	316
Behavior Standards for Health and Safety	317
An Organizational Culture Focused on Safety	318
Different Types of Safety	319
Summary	319
Assessing Safety Culture	320
Rationale for Assessing Safety Culture	320
Assessment Prerequisites	321

Assessment Methods..... 322

Triangulation..... 326

Summary 328

Developing and Sustaining Safety Culture..... 328

 Practical Examples of Tools to Develop Specific

 Behaviors 329

 Practical Examples of Organization-Wide Reinforcement

 Efforts..... 330

Summary: Safety Culture and Behavior..... 331

Key Points..... 331

References 332

CHAPTER 19 Managing organizational change..... 335

K. Gray and J. Wilkinson

List of Abbreviations 335

What is Organizational Change? 336

 Drivers for Change..... 337

Managing the Risks of Organizational Change..... 337

 How can Organizational Change Impact Safety? 338

 Communicating the Rationale for Change and

 Engaging Staff..... 339

 The Process of Managing Organizational Change..... 340

 Risk Assessment for Change..... 342

Managing Psychological Adjustment..... 343

 Understanding the Psychology of Change..... 343

 Understanding Individual Reactions to Change..... 346

 Understanding Group Reactions to Change: Considering

 Cultural Factors..... 347

 Understanding Barriers to Change..... 348

Preventative Measures: Planning for Change 348

The Role of Communication 352

Summary of Change Leader Support Actions 354

Summary: Managing Organizational Change 354

Key Points..... 354

References 355

CHAPTER 20 Staffing the operation 357

J. Edmonds

List of Abbreviations 357

CHAPTER 20.1 Staffing and workload360

J. Edmonds and C. Munro

Human Capabilities and Limitations	361
Tools for Assessing Workload and Staffing Arrangements.....	364
Time-based Assessment Methods	364
Tools for Workload Measurement and Prediction.....	366
Assessing Staffing Arrangements.....	370
Tools for Physical Workload Measurement	372
Metabolic Rate and Energy Consumption	372
Oxygen Uptake	373
Thermal Measurement	373
Heart Rate	373
Possible Solutions to Workload and Staffing Issues.....	374
Allocation of Functions.....	374
Work Equipment	375
Work Area	375
Work Environment.....	375
Job/Task Design	376
Resource Allocation	377
Skill, Knowledge, and Experience	377
Recruitment and Selection	377
Summary: Staffing and Workload.....	377
Key Points.....	377
References	378

CHAPTER 20.2 Training and competence379

J. Edmonds

Competence Management Systems.....	382
Phase 1—Establish the Requirement.....	382
Phase 2—Design the CMS.....	385
Phase 3—Implement the CMS.....	386
Phase 4—Maintain Competence.....	386
Phase 5—Audit and Review the CMS	387
Techniques for Defining Competencies.....	387
Structured Approach to Training Needs Analysis	388
Scoping Document.....	389
Operational Task Analysis	389
Training Gap Analysis	390
Training Options Analysis	391
Training Plan.....	391

Types of Learning	393
Summary: Training and Competence	394
Key Points.....	394
References	394

CHAPTER 20.3 Effective supervision 396

E. Novatsis and J. Mitchell

The Supervisory Role	396
The Importance of Supervision.....	396
Technical Competence and Non-technical Competencies	397
Technical Competence	398
Non-technical Competencies	398
Leadership Style.....	401
Challenges Faced by Supervisors	402
Selecting Effective Supervisors	404
Selection Methods.....	404
Developing Effective Supervisors	406
Designing Development Programs	406
Specific Skills Training	407
Practical “On-the-Job” Programs.....	409
Supervisor Development Center	410
Assessing Supervisor Safety Performance	411
The Role of Managers in Supporting Supervisors	412
Summary: Effective Supervision	413
Key Points.....	413
References	414
Further Reading	415

CHAPTER 21 Safety critical communication 417

J. Mitchell

List of Abbreviations	417
What are Safety Critical Communications?	417
A Model of Communication.....	418
Barriers to Communication	420
System Failures.....	420
Message Failures—Sender Errors	421
Deciding to Communicate	421
The Formulation of Goals	421
Choose When and Who to Communicate To	422

Choose the Appropriate Communication Medium for the Task.....	422
Formulate the Content of the Message	425
Select Appropriate Style of Communication	425
Produce Communication Signal	426
Reception Failures—Receiver Errors	428
Availability to Receive Message and Perceiving the Signal	428
Decode Signal, Establish Meaning of the Signal, and Evaluate Understanding of the Message.....	428
Potential Solutions for Managing Safety Critical Communications....	429
Developing Safety Communication Skills.....	429
Prejob and Postjob Briefs.....	431
Shift Handover	431
Summary: Safety Critical Communications.....	432
Key Points.....	433
References	433

CHAPTER 22 Managing fatigue 435

K. McCulloch

List of Abbreviations	435
Technical Terms.....	435
Managing Fatigue	437
Fatigue “Risk” Management	438
Fatigue Likelihood Analysis	440
Managing Sleep Opportunity—Planned Work Hours.....	440
Managing Sleep Opportunity—Actual Work Hours.....	441
Defining Individual Sleep Expectations.....	442
Consideration of Sleep Disorders	443
Identifying Fatigue-Related Symptoms	443
Fatigue Proofing	444
Monitoring and Review	445
Education and Awareness	446
Summary: Managing Fatigue	447
Key Points.....	447
References	448

CHAPTER 23 Managing performance under pressure 451

C. Amati, K. Gray and J. Foley

List of Abbreviations	451
Technical Terms.....	451
The Body under Duress	452

Acute Stress: The Experience “in the Moment”	452
The Impact of Acute Stress: Immediate and Longer-Term.....	453
The Causes of Acute Stress.....	456
Managing Acute Stress: Managers and Individuals.....	456
Summary: Acute Stress	458
Managing Pressure at Work: A Comprehensive Approach.....	458
Chronic Stress: Dealing with Pressure over Time	458
The Impact of Chronic Stress	459
The Causes of Chronic Stress	460
Managing Chronic Stress: The Organization’s Role.....	462
Summary: Chronic Stress	465
From Managing Stress to Promoting Resilience	465
Resilience: Recovery from Setbacks.....	465
Resilience: The “New” Answer for Managing Pressure at Work.....	466
Managing Stress and Building Resilience: The Manager’s Role	466
Summary: Managing Stress and Promoting Resilience.....	468
Stress, Resilience, and the Individual.....	468
Individual Differences: Stress and Resilience.....	468
Building Resilience and Managing Stress: The Individual’s Role	469
Summary: Stress and Resilience and the Individual.....	469
Summary: Managing Performance Under Pressure	469
Key Points.....	470
References	470
Further Reading	471
Index	473