



Human Reliability, Error, *and* Human Factors in Engineering Maintenance

*with Reference to Aviation
and Power Generation*

B.S. Dhillon

Contents

Preface	xiii
Author Biography.....	xv

Chapter 1

Introduction.....	1
1.1 Background.....	1
1.2 History	1
1.2.1 Human Factors.....	1
1.2.2 Human Reliability and Error	2
1.2.3 Engineering Maintenance.....	2
1.3 Human Reliability, Error, and Human Factors in Engineering Maintenance–Related Facts and Figures.....	2
1.4 Terms and Definitions.....	4
1.5 Useful Information on Human Reliability, Error, and Human Factors in Engineering Maintenance	5
1.5.1 Publications.....	5
1.5.1.1 Books	5
1.5.1.2 Technical Reports	6
1.5.1.3 Conference Proceedings	6
1.5.1.4 Journals	7
1.5.2 Data Sources	8
1.5.3 Organizations.....	8
1.6 Scope of the Book.....	9
1.7 Problems	10
References	10

Chapter 2

Basic Mathematical Concepts.....	13
2.1 Introduction	13
2.2 Boolean Algebra Laws and Probability Properties	13
2.3 Useful Definitions.....	16
2.3.1 Probability	16
2.3.2 Cumulative Distribution Function Type I.....	17
2.3.3 Probability Density Function Type I	17
2.3.4 Probability Density Function Type II.....	17
2.3.5 Cumulative Distribution Function Type II	17
2.3.6 Reliability Function	18
2.3.7 Hazard Rate Function.....	18
2.3.8 Expected Value Type I.....	18
2.3.9 Expected Value Type II	18

2.3.10	Laplace Transform.....	18
2.3.11	Laplace Transform: Final-Value Theorem.....	19
2.4	Probability Distributions	20
2.4.1	Poisson Distribution.....	20
2.4.2	Binomial Distribution.....	21
2.4.3	Geometric Distribution.....	21
2.4.4	Exponential Distribution.....	22
2.4.5	Normal Distribution.....	23
2.4.6	Gamma Distribution	23
2.4.7	Rayleigh Distribution.....	24
2.4.8	Weibull Distribution	24
2.5	Solving First-Order Differential Equations Using Laplace Transforms.....	25
2.6	Problems	26
	References.....	27

Chapter 3

	Introductory Human Factors, Reliability, and Error Concepts.....	29
3.1	Introduction	29
3.2	Human Factors Objectives and Man–Machine System Types and Comparisons	29
3.3	Human Sensory Capacities and Typical Human Behaviors and Their Corresponding Design Considerations	31
3.3.1	Touch.....	31
3.3.2	Sight.....	31
3.3.3	Vibration	32
3.3.4	Noise	32
3.4	Human Factors–Related Formulas	33
3.4.1	Formula for Estimating Inspector Performance.....	33
3.4.2	Formula for Estimating Rest Period.....	33
3.4.3	Formula for Estimating Character Height.....	33
3.4.4	Formula for Estimating Glare Constant	34
3.5	Useful Human Factors Guidelines and Data Collection Sources.....	34
3.6	Human Performance Effectiveness and Operator Stress Characteristics	35
3.7	Occupational Stressors and General Stress Factors	36
3.8	Human Performance Reliability and Correctability Functions.....	37
3.8.1	Human Performance Reliability Function.....	37
3.8.2	Human Performance Correctability Function.....	39
3.9	Human Error Occurrence Reasons, Consequences, Ways, and Classifications	39
3.10	Human Reliability and Error Data Collection Sources and Quantitative Data.....	40
3.11	Problems	41
	References.....	42

Chapter 4

Methods for Performing Human Reliability and Error Analysis in Engineering Maintenance.....	45
4.1 Introduction	45
4.2 Failure Modes and Effect Analysis (FMEA).....	45
4.3 Man–Machine Systems Analysis	47
4.4 Root Cause Analysis (RCA)	47
4.5 Error-Cause Removal Program (ECRP).....	49
4.6 Cause-and-Effect Diagram (CAED).....	49
4.7 Probability Tree Method.....	50
4.8 Fault Tree Analysis (FTA).....	53
4.8.1 Fault Tree Symbols	53
4.8.2 Steps for Performing FTA	54
4.8.3 Probability Evaluation of Fault Trees	54
4.9 Markov Method	57
4.10 Problems	60
References.....	60

Chapter 5

Human Error in Maintenance.....	63
5.1 Introduction	63
5.2 Facts, Figures, and Examples	63
5.3 Occurrence of Maintenance Error in Equipment Life Cycle and Elements of a Maintenance Person’s Time	64
5.4 Maintenance Environment and Causes for the Occurrence of Maintenance Errors	65
5.4.1 Noise	65
5.4.2 Poor Illumination.....	65
5.4.3 Temperature Variations	65
5.5 Types of Maintenance Errors and Typical Maintenance Errors	66
5.6 Common Maintainability Design Errors and Useful Design Improvement Guidelines to Reduce Equipment Maintenance Errors	67
5.7 Maintenance Work Instructions.....	68
5.8 Maintenance Error Analysis Methods.....	69
5.8.1 Probability Tree Method.....	69
5.8.2 Pontecorvo Method.....	71
5.8.3 Pareto Analysis	74
5.8.4 Markov Method	74
5.9 Problems	76
References.....	76

Chapter 6

Human Factors in Aviation Maintenance	79
6.1 Introduction	79

6.2	The Need for Human Factors in Aviation Maintenance and How Human Factors Impact Aircraft Engineering and Maintenance	79
6.3	Human Factors Challenges in Aviation Maintenance	80
6.4	Practical Human Factors Guide for the Aviation Maintenance Environment	80
6.5	Integrated Maintenance Human Factors Management System (IMMS)	83
6.6	Aviation Maintenance Human Factors Training Program and Human Factors Training Areas for Aviation Maintenance Personnel	84
6.7	Common Human Factors–Related Aviation Maintenance Problems	86
6.8	Problems	86
	References	87

Chapter 7

	Human Factors in Power Plant Maintenance.....	89
7.1	Introduction	89
7.2	Human Factors Engineering Maintenance–Related Deficiencies in Power Plant Systems.....	89
7.3	Desirable Human Factors Engineering Maintenance–Related Attributes of Well-Designed Systems in Power Generation.....	90
7.4	Power Generation Plant Performance Goals That Drive Decisions about Human Factors.....	91
7.5	Study of Human Factors in Power Plants	92
7.6	Human Factors Approaches for Assessing and Improving Power Plant Maintainability	93
	7.6.1 Task Analysis.....	93
	7.6.2 Maintainability Checklist.....	94
	7.6.3 Potential Accident/Damage Analyses	94
	7.6.4 Structured Interviews	94
	7.6.5 Critical Incident Technique	95
	7.6.6 Surveys.....	95
7.7	Benefits of Human Factors Engineering Applications in Power Generation	96
7.8	Problems	96
	References.....	97

Chapter 8

	Human Error in Aviation Maintenance	99
8.1	Introduction	99
8.2	Facts, Figures, and Examples	99
8.3	Causes of Human Error in Aviation Maintenance and Major Categories of Human Errors in Aviation Maintenance and Inspection Tasks.....	100
8.4	Types of Human Error in Aircraft Maintenance and Their Frequency.....	100
8.5	Common Human Errors in Aircraft Maintenance Activities.....	101
8.6	Aircraft Maintenance Error Analysis Methods.....	101

8.6.1	Cause-and-Effect Diagram.....	101
8.6.2	Error-Cause Removal Program (ECRP).....	102
8.6.3	Fault Tree Analysis.....	104
8.7	Maintenance Error Decision Aid (MEDA).....	106
8.8	Useful Guidelines for Reducing Human Error in Aircraft Maintenance Activities.....	107
8.9	Case Studies in Human Error in Aviation Maintenance.....	109
8.9.1	Continental Express Embraer 120 Accident.....	109
8.9.2	Air Midwest Raytheon (Beechcraft) 1900D Accident.....	109
8.9.3	British Airways BAC1-11 Accident.....	110
8.10	Problems.....	110
	References.....	110

Chapter 9

	Human Error in Power Plant Maintenance.....	113
9.1	Introduction.....	113
9.2	Facts and Figures.....	113
9.3	Causes of Human Error in Power Plant Maintenance.....	114
9.4	<i>Maintenance Tasks Most Susceptible to Human Error</i> in Power Generation.....	116
9.5	Methods for Performing Maintenance Error Analysis in Power Generation.....	116
9.5.1	Fault Tree Analysis.....	116
9.5.2	Markov Method.....	119
9.5.3	Maintenance Personnel Performance Simulation (MAPPS) Model.....	122
9.6	Steps for Improving Maintenance Procedures in Power Generation and Useful Guidelines for Human Error Reduction and Prevention in Power Generation Maintenance.....	122
9.7	Problems.....	123
	References.....	124

Chapter 10

	Safety in Engineering Maintenance.....	127
10.1	Introduction.....	127
10.2	Facts, Figures, and Examples.....	127
10.3	Causes of Maintenance Safety Problems and Factors Responsible for Dubious Safety Reputation in Maintenance Activity.....	128
10.4	Factors Influencing Safety Behavior and Safety Culture in Maintenance Personnel.....	129
10.5	Good Safety-Related Practices during Maintenance Work and Maintenance-Related Safety Measures concerning Machinery.....	129
10.6	Maintenance Safety-Related Questions for Engineering Equipment Manufacturers.....	131
10.7	Guidelines for Engineering Equipment Designers to Improve Safety in Maintenance.....	132

10.8	Mathematical Models	132
10.9	Problems	135
	References	136

Chapter 11

	Mathematical Models for Performing Human Reliability and Error Analysis in Engineering Maintenance	139
11.1	Introduction	139
11.2	Models for Predicting Maintenance Personnel Reliability in Normal and Fluctuating Environments	139
	11.2.1 Model I.....	140
	11.2.2 Model II	141
	11.2.3 Model III.....	145
11.3	Models for Performing Single Systems Maintenance Error Analysis.....	147
	11.3.1 Model I.....	148
	11.3.2 Model II	150
11.4	Models for Performing Redundant Systems Maintenance Error Analysis.....	153
	11.4.1 Model I.....	153
	11.4.2 Model II	156
11.5	Problems	158
	References.....	159
	Appendix.....	161
	Index	175