Practical Reliability Engineering

With emphasis on practical aspects of engineering, this bestseller has gained worldwide recognition through progressive editions as the essential reliability textbook. This fifth edition retains the unique balanced mixture of reliability theory and applications, thoroughly updated with the latest industry best practices. Practical Reliability Engineering fulfills the requirements of the Certified Reliability Engineer curriculum of the American Society for Quality (ASQ). Each chapter is supported by practice questions, and a solutions manual is available to course tutors via the companion website.

Enhanced coverage of mathematics of reliability, physics of failure, graphical and software methods of failure data analysis, reliability prediction and modeling, design for reliability and safety as well as management and economics of reliability programmes ensures continued relevance to all quality assurance and reliability courses.

Notable additions include:

• New chapters on applications of Monte Carlo simulation methods and reliability demonstration methods.
• Software applications of statistical methods, including probability plotting and a wider use of common software tools.
• More detailed descriptions of reliability prediction methods.
• Comprehensive treatment of accelerated test data analysis and warranty data analysis.
• Revised and expanded end-of-chapter tutorial sections to advance students' practical knowledge.

The fifth edition will appeal to a wide range of readers from college students to seasoned engineering professionals involved in the design, development, manufacture and maintenance of reliable engineering products and systems.

www.wiley.com/go/oconnor_reliability5
Practical Reliability Engineering
‘The concept of chance enters into the very first steps of scientific activity, by virtue of the fact that no observation is absolutely correct. I think chance is a more fundamental concept than causality, for whether in a concrete case a cause–effect relationship exists can only be judged by applying the laws of chance to the observations.’

Max Born,  
*Natural Philosophy of Cause and Chance*

‘A statistical relationship, however strong and however suggestive, can never establish a causal connection. Our ideas on causation must come from outside statistics, ultimately from some theory.’

Kendall & Stuart,  
*The Advanced Theory of Statistics*

‘Reliability is, after all, engineering in its most practical form.’

James R. Schlesinger  
*Former US Secretary of State for Defense*
Practical Reliability Engineering

Fifth Edition

PATRICK D. T. O’CONNOR

and

ANDRE KLEYNER

WILEY

A John Wiley & Sons, Ltd., Publication
To my wife Lois,
for encouragement and support,
and to the memory of Ina
Patrick O’Connor

To my wife and best friend Faina,
for her patience and unwavering support
Andre Kleyner
Contents

Preface to the First Edition xv
Preface to the Second Edition xvii
Preface to the Third Edition xix
Preface to the Third Edition Revised xxi
Preface to the Fourth Edition xxiii
Preface to the Fifth Edition xxv
Acknowledgements xxvii

1 Introduction to Reliability Engineering 1
  1.1 What is Reliability Engineering? 1
  1.2 Why Teach Reliability Engineering? 2
  1.3 Why Do Engineering Products Fail? 4
  1.4 Probabilistic Reliability 6
  1.5 Repairable and Non-Repairable Items 7
  1.6 The Pattern of Failures with Time (Non-Repairable Items) 8
  1.7 The Pattern of Failures with Time (Repairable Items) 9
  1.8 The Development of Reliability Engineering 9
  1.9 Courses, Conferences and Literature 11
  1.10 Organizations Involved in Reliability Work 12
  1.11 Reliability as an Effectiveness Parameter 12
  1.12 Reliability Programme Activities 13
  1.13 Reliability Economics and Management 14
  Questions 17
  Bibliography 18

2 Reliability Mathematics 19
  2.1 Introduction 19
  2.2 Variation 19
  2.3 Probability Concepts 21
  2.4 Rules of Probability 22
  2.5 Continuous Variation 28
  2.6 Continuous Distribution Functions 33
  2.7 Summary of Continuous Statistical Distributions 41
  2.8 Variation in Engineering 41
  2.9 Conclusions 47
Contents

2.10 Discrete Variation 48
2.11 Statistical Confidence 51
2.12 Statistical Hypothesis Testing 53
2.13 Non-Parametric Inferential Methods 57
2.14 Goodness of Fit 59
2.15 Series of Events (Point Processes) 61
2.16 Computer Software for Statistics 64
2.17 Practical Conclusions 64
  Questions 66
  Bibliography 68

3 Life Data Analysis and Probability Plotting 70
  3.1 Introduction 70
  3.2 Life Data Classification 71
  3.3 Ranking of Data 75
  3.4 Weibull Distribution 78
  3.5 Computerized Data Analysis and Probability Plotting 85
  3.6 Confidence Bounds for Life Data Analysis 89
  3.7 Choosing the Best Distribution and Assessing the Results 95
  3.8 Conclusions 102
    Questions 103
    Bibliography 107

4 Monte Carlo Simulation 108
  4.1 Introduction 108
  4.2 Monte Carlo Simulation Basics 108
  4.3 Additional Statistical Distributions 108
  4.4 Sampling a Statistical Distribution 110
  4.5 Basic Steps for Performing a Monte Carlo Simulation 113
  4.6 Monte Carlo Method Summary 115
    Questions 118
    Bibliography 119

5 Load–Strength Interference 120
  5.1 Introduction 120
  5.2 Distributed Load and Strength 120
  5.3 Analysis of Load–Strength Interference 123
  5.4 Effect of Safety Margin and Loading Roughness on Reliability (Multiple Load Applications) 124
  5.5 Practical Aspects 131
    Questions 132
    Bibliography 133

6 Reliability Prediction and Modelling 134
  6.1 Introduction 134
  6.2 Fundamental Limitations of Reliability Prediction 135
  6.3 Standards Based Reliability Prediction 136
6.4 Other Methods for Reliability Predictions 141
6.5 Practical Aspects 143
6.6 Systems Reliability Models 143
6.7 Availability of Repairable Systems 147
6.8 Modular Design 151
6.9 Block Diagram Analysis 152
6.10 Fault Tree Analysis (FTA) 157
6.11 State-Space Analysis (Markov Analysis) 158
6.12 Petri Nets 165
6.13 Reliability Apportionment 169
6.14 Conclusions 170
  Questions 170
  Bibliography 175

7 Design for Reliability 177
  7.1 Introduction 177
  7.2 Design for Reliability Process 178
  7.3 Identify 179
  7.4 Design 183
  7.5 Analyse 196
  7.6 Verify 197
  7.7 Validate 198
  7.8 Control 198
  7.9 Assessing the DfR Capability of an Organization 201
  7.10 Summary 201
  Questions 202
  Bibliography 203

8 Reliability of Mechanical Components and Systems 205
  8.1 Introduction 205
  8.2 Mechanical Stress, Strength and Fracture 206
  8.3 Fatigue 208
  8.4 Creep 214
  8.5 Wear 214
  8.6 Corrosion 216
  8.7 Vibration and Shock 216
  8.8 Temperature Effects 218
  8.9 Materials 220
  8.10 Components 220
  8.11 Processes 221
  Questions 222
  Bibliography 223

9 Electronic Systems Reliability 225
  9.1 Introduction 225
  9.2 Reliability of Electronic Components 226
  9.3 Component Types and Failure Mechanisms 229
## Contents

9.4 Summary of Device Failure Modes 243
9.5 Circuit and System Aspects 244
9.6 Reliability in Electronic System Design 245
9.7 Parameter Variation and Tolerances 254
9.8 Design for Production, Test and Maintenance Questions 258
Bibliography 260

10 Software Reliability 262
10.1 Introduction 262
10.2 Software in Engineering Systems 263
10.3 Software Errors 265
10.4 Preventing Errors 267
10.5 Software Structure and Modularity 268
10.6 Programming Style 269
10.7 Fault Tolerance 269
10.8 Redundancy/Diversity 270
10.9 Languages 270
10.10 Data Reliability 272
10.11 Software Checking 272
10.12 Software Testing 274
10.13 Error Reporting 275
10.14 Software Reliability Prediction and Measurement 276
10.15 Hardware/Software Interfaces 281
10.16 Conclusions Questions 283
Bibliography 283

11 Design of Experiments and Analysis of Variance 284
11.1 Introduction 284
11.2 Statistical Design of Experiments and Analysis of Variance 284
11.3 Randomizing the Data 296
11.4 Engineering Interpretation of Results 297
11.5 The Taguchi Method 297
11.6 Conclusions Questions 301
Bibliography 305

12 Reliability Testing 306
12.1 Introduction 306
12.2 Planning Reliability Testing 307
12.3 Test Environments 309
12.4 Testing for Reliability and Durability: Accelerated Test 313
12.5 Test Planning 322
12.6 Failure Reporting, Analysis and Corrective Action Systems (FRACAS) Questions 323
Bibliography 325
Contents

13 Analysing Reliability Data 327
13.1 Introduction 327
13.2 Pareto Analysis 327
13.3 Accelerated Test Data Analysis 328
13.4 Acceleration Factor 329
13.5 Acceleration Models 330
13.6 Field-Test Relationship 335
13.7 Statistical Analysis of Accelerated Test Data 336
13.8 Reliability Analysis of Repairable Systems 339
13.9 CUSUM Charts 343
13.10 Exploratory Data Analysis and Proportional Hazards Modelling 346
13.11 Field and Warranty Data Analysis Questions 348
Bibliography 351

14 Reliability Demonstration and Growth 357
14.1 Introduction 357
14.2 Reliability Metrics 357
14.3 Test to Success (Success Run Method) 358
14.4 Test to Failure Method 359
14.5 Extended Life Test 360
14.6 Continuous Testing 361
14.7 Degradation Analysis 362
14.8 Combining Results Using Bayesian Statistics 365
14.9 Non-Parametric Methods 365
14.10 Reliability Demonstration Software 366
14.11 Practical Aspects of Reliability Demonstration 366
14.12 Standard Methods for Repairable Equipment 367
14.13 Reliability Growth Monitoring 373
14.14 Making Reliability Grow Questions 382
Bibliography 385

15 Reliability in Manufacture 386
15.1 Introduction 386
15.2 Control of Production Variability 386
15.3 Control of Human Variation 390
15.4 Acceptance Sampling 391
15.5 Improving the Process 395
15.6 Quality Control in Electronics Production 399
15.7 Stress Screening 402
15.8 Production Failure Reporting Analysis and Corrective Action System (FRACAS) 404
15.9 Conclusions Questions 405
Bibliography 406
Contents

16 Maintainability, Maintenance and Availability 408
  16.1 Introduction 408
  16.2 Availability Measures 409
  16.3 Maintenance Time Distributions 410
  16.4 Preventive Maintenance Strategy 411
  16.5 FMECA and FTA in Maintenance Planning 415
  16.6 Maintenance Schedules 415
  16.7 Technology Aspects 415
  16.8 Calibration 417
  16.9 Maintainability Prediction 417
  16.10 Maintainability Demonstration 418
  16.11 Design for Maintainability 418
  16.12 Integrated Logistic Support 418
    Questions 419
    Bibliography 420

17 Reliability Management 421
  17.1 Corporate Policy for Reliability 421
  17.2 Integrated Reliability Programmes 421
  17.3 Reliability and Costs 424
  17.4 Safety and Product Liability 428
  17.5 Standards for Reliability, Quality and Safety 428
  17.6 Specifying Reliability 431
  17.7 Contracting for Reliability Achievement 432
  17.8 Managing Lower-Level Suppliers 434
  17.9 The Reliability Manual 435
  17.10 The Project Reliability Plan 436
  17.11 Use of External Services 436
  17.12 Customer Management of Reliability 437
  17.13 Selecting and Training for Reliability 439
  17.14 Organization for Reliability 440
  17.15 Reliability Capability and Maturity of an Organization 442
  17.16 Managing Production Quality 444
  17.17 Quality Management Approaches 446
  17.18 Choosing the Methods: Strategy and Tactics 447
  17.19 Conclusions 448
    Questions 449
    Bibliography 450

Appendix 1 The Standard Cumulative Normal Distribution Function 451

Appendix 2 $\chi^2(\alpha, \nu)$ Distribution Values 453

Appendix 3 Kolmogorov–Smirnov Tables 455

Appendix 4 Rank Tables (5 %, 95 %) 457
Preface to the First Edition

This book is designed to provide an introduction to reliability engineering and management, both for students and for practising engineers and managers. The emphasis throughout is on practical applications, and the mathematical concepts described are accordingly limited to those necessary for solution of the types of problems covered. Practical approaches to problem-solving, such as the use of probability plotting techniques and computer programs, are stressed throughout. More advanced texts are cited for further reading on the mathematical and statistical aspects. The references given in the Bibliographies are limited to those considered to provide a direct continuation of the chapter material, with the emphasis on practical applications. Tables and charts are provided to complement the analytical methods described, and numerous worked examples are included.

The book describes and comments on the usage of the major national and government standards and specifications covering reliability engineering and management in the USA and the UK. It is considered that this is an important aspect of the practical approach, since so much engineering development work is now governed by such documents. The effects of current engineering, commercial and legislative developments, such as microelectronics, software-based systems, consumerism and product liability, are covered in some detail.

The requirements of the examination syllabi of the American Society for Quality Control, and the Institute of Quality Assurance (UK) in reliability engineering are covered, so the book will be suitable for use in courses leading to these qualifications. The emphasis on practical approaches to engineering and management, the comprehensive coverage of standards and specifications, and the overall layout of the book should make it equally as suitable as a general up to date reference for use in industry and in government agencies.

Patrick O’Connor
1981
Preface to the Second Edition

I have received much helpful criticism of the first edition of my book since it appeared in 1981. Whilst the reviews have generally not been unfavourable, critics have pointed out that, despite the title, the book was not quite practical enough in some areas. I have also come to realize this through my own work, particularly on the application of mathematical modelling and statistics to reliability problems. Consequently, much of the revision for the second edition has been to add to what I consider to be the practical aspects of management and engineering for reliability.

I have added to the sections on reliability prediction, demonstration and measurement, to explain and to stress the fundamental and considerable uncertainty associated with attempts to quantify and forecast a property of engineered products which is inherently non-deterministic. I believe that when people involved in reliability work manage to unshackle themselves from the tyranny of the ‘numbers game’ the way is cleared for the practical engineering and management approaches that are the only ways to achieve the highly reliable products demanded by the markets of today. I have not removed the descriptions of the methods for quantifying reliability, since I believe that, when these are applied with commonsense and understanding of their inherent limitations, they can help us to solve reliability problems and to design and make better products.

I have added three new chapters, all related to the practical aspects.

The first edition described how to analyse test data, but included little on how to test. I have therefore written a new chapter on reliability testing, covering environmental and stress testing and the integration of reliability and other development testing. I am indebted to Wayne Tustin for suggesting this and for his help and advice on this subject.

The quality of manufacture is obviously fundamental to achieving high reliability. This point was made in the first edition, but was not developed. I have added a complete chapter on quality assurance (QA), as well as new material on integrated management of reliability and QA programmes.

Maintenance also affects reliability, so I have added a new chapter on maintenance and maintainability, with the emphasis on how they affect reliability, how reliability affects maintenance planning and how both affect availability.

I have also added new material on the important topic of reliability analysis for repairable systems. Harry Ascher, of the US Naval Research Laboratory, has pointed out that the reliability literature, including the first edition of my book, has almost totally ignored this aspect, leading to confusion and analytical errors. How many reliability engineers and teachers know that Weibull analysis of repairable system reliability data can be quite misleading except under special, unrealistic conditions? Thanks to Harry Ascher, I know now, and I have tried to explain this in the new edition.

I have also brought other parts of the book up to date, particularly the sections on electronic and software reliability.

The third reprint of the first edition included many corrections, and more corrections are made in this edition.

I am extremely grateful to all those who have pointed out errors and have helped me to correct them. Paul Baird of Hewlett Packard, Palo Alto, was particularly generous. Colleagues at British Aerospace, particularly...
Preface to the Second Edition

Brian Collett, Norman Harris, Chris Gilders and Gene Morgan, as well as many others, also provided help, advice and inspiration.

Finally, my thanks go to my wife Ina for much patience, support and typing.

Patrick O’Connor

1985
Preface to the Third Edition

The new industrial revolution has been driven mainly by the continuing improvements in quality and productivity in nearly all industrial sectors. The key to success in every case has been the complete integration of the processes that influence quality and reliability, in product specification, design, test, manufacture, and support. The other essential has been the understanding and control of variation, in the many ways in which it can affect product performance, cost and reliability. Teachers such as W. E. Deming and G. Taguchi have continued to grow in stature and following as these imperatives become increasingly the survival kit of modern industry.

I tried to stress these factors in the second edition, but I have now given them greater prominence. I have emphasized the use of statistical experimentation for preventing problems, not just for solving them, and the topic is now described as a design and development activity. I have added to the chapter on production quality assurance, to include process improvement methods and more information on process control techniques. These chapters, and the chapter on management, have all been enlarged to emphasize the integration of engineering effort to identify, minimize and reduce variation and its effects. The important work of Taguchi and Shainin is described, for the first time in this book. Chris Gray gave me much valuable help in describing the Taguchi method.

I have updated several chapters, particularly those on electronic systems reliability. I have also added a new chapter on reliability of mechanical components and systems. I would like to thank Professor Dennis Carter for his advice on this chapter.

I have taken the opportunity to restructure the book, to reflect better the main sequence of engineering development, whilst stressing the importance of an integrated, iterative approach.

I have once more been helped by many people who have contributed kind criticisms of the earlier edition, and I have tried to take these into account. I also would like to record with thanks my continuing debt to Norman Harris for his contributions to bridging the gap between engineering and statistics, and for helping me to express his ideas.

Finally, my heartfelt thanks go to my wife and boys for their forebearance, patience, and support. Having an author at home must place severe demands on love and tolerance.

PATRICK O’CONNOR
1990
Preface to the Third Edition Revised

This revised edition has been produced in response to numerous suggestions that the book would be of greater value to students and teachers if it included exercise questions. David Newton and Richard Bromley have therefore teamed up with me to produce exercises appropriate to each chapter of the book.

The exercises cover nearly all of the types of questions that occur in the reliability examinations set by the UK Institute of Quality Assurance (IQA) and by the American Society for Quality Control (ASQC). The ASQC examination questions are of the multiple-choice type, which is not the format used here, but this should make no difference to the value of the exercises in preparing for the ASQC examination.

A solutions manual is available to teachers, free of charge, by writing to John Wiley and Sons Ltd in Chichester.

I would like to thank David Newton and Richard Bromley for their enthusiastic support in preparing this revised edition.

Patrick O’Connor
1995
Preface to the Fourth Edition

It is over ten years since the last major revision and update to my book. Inevitably in that time there have been developments in engineering technology and in reliability methods. In this new edition I have tried to include all of the important changes that affect reliability engineering and management today. In keeping with the original aims of the book, I have emphasised those with practical implications.

The main changes and additions include:

– Updated and more detailed descriptions of how engineering products fail (Chapters 1, 8 and 9).
– More detailed description of the nature of variation in engineering (Chapter 2).
– Descriptions of the Petri net and M(t) methods (Chapters 6 and 12).
– More detailed description of the particular aspects of software in engineering systems, and updated descriptions of design, analysis and test methods (Chapter 10).
– Expanded descriptions of accelerated test methods for development and manufacturing (Chapters 11 and 13).
– Updated and expanded descriptions of test methods for electronics and acceptance sampling (Chapter 13).
– More detailed descriptions of management aspects, including standards, “six sigma”, and supplier management (Chapter 15).
– Updated references to standards, and updated and expanded bibliographies.

Some of the new material is adapted from my book “Test Engineering”, with permission from the publisher.

The questions and the answers manual (available separately from the publisher) have been augmented to cover the new material.

An Internet homepage has been created for the book, at www.pat-oconnor.co.uk/practicalreliability.htm. The homepage includes listings of suppliers of reliability engineering related services and software.

I would like to express my gratitude to Prof. S.K. Yang for his kind assistance with the description of the Petri net method, Dr. Gregg Hobbs for his teaching and help on HALT/HASS testing, Prof. Jörgen Möltoft for helping with the description of the M(t) method, and Jim McLinn for providing additional material, questions and answers on aspects of accelerated testing and data analysis. I also thank all who have provided suggestions and pointed out errors. Last but certainly not least I thank my wife, Ina, again.

Patrick O’Connor
2001
Preface to the Fifth Edition

Another ten years have elapsed since publication of the fourth edition. In that interval there have been further significant developments in reliability engineering methods, mainly related to the use of software to perform analysis of designs and of reliability data. Of course there have also been developments in engineering that affect reliability. The internet has added a new dimension to the availability of information and tools.

In order to describe many of these developments, Andre Kleyner has taken on the role of joint author and the two of us have worked together to create this new edition. Andre has contributed most of the new material. In particular, he has provided the software-based solutions to many of the examples, supplementing or replacing manual and graphical methods. He has also updated some of the technology aspects and contributed new sections on data analysis and other topics.

The main changes and additions include:
– Software implementation of statistical methods, including probability plotting and a wider use of common software tools such as Microsoft Excel®.
– Expanded description and applications of Monte Carlo simulation methods, in a new chapter.
– More detailed descriptions of reliability prediction methods.
– Expanded treatment of accelerated test data analysis.
– Analysis of warranty data.
– Expanded description of reliability demonstration methods, in a new chapter.
– Course instructors who adapted this book can request the Solutions Manual at: www.wiley.com/go/oconnor_reliability5.
– General updating of references, including published papers and internet links.
– The Questions sections, originally developed with major contributions from David Newton and Richard Bromley, have been revised and expanded.

A solutions manual for the end-of-chapter questions and instructor’s PowerPoint slides are available as a free download, to course tutors only at: www.wiley.com/go/oconnor_reliability5.

We hope that the new edition will maintain the value of Practical Reliability Engineering to engineers, managers, teachers and students.

Patrick O’Connor
2011
Acknowledgements

We remain deeply indebted to the people who provided valuable help and advice on the first edition. Their generous efforts still enhance the book. In particular Dr. Ralph Evans, Kenneth Blemel and Norman Harris provided insights and assistance. Professor Dennis Carter was the originator of the load-strength concepts described in Chapter 5. Professor Bev Littlewood helped with the software reliability modelling descriptions in Chapter 10.

The authors would also like to express their gratitude to the people who have contributed to the present edition or helped to review the draft manuscript: Pantelis Vassiliou, Peter Sandborn, Mike Silverman, Vasilyi Krivtsov, Vitali Volovoi, Yizhak Bot, Michael Varnau, Steve McMullen, Andy Foote, Fred Schenkelberg, David Dylis, Craig Hillman, Cheryl Tulkoff, Walt Tomczykowski, Eric Juliet, Joe Boyle and Marina Shapiro.

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