

Contents

Preface to the Second Edition	xv
Preface to the First Edition	xvii
Authors	xxi
1. Introduction to Quality	1
1.1 An Historical Overview	1
1.1.1 A Note about “Quality Engineering”	7
1.2 Defining Quality	9
1.2.1 Product Quality vs. Service Quality	11
1.3 The Total Quality System.....	11
1.4 Total Quality Management.....	13
1.5 Economics of Quality	15
1.6 Quality, Productivity, and Competitive Position.....	16
1.7 Quality Costs	17
1.7.1 Categories of Quality Costs.....	18
1.7.1.1 Prevention Cost	18
1.7.1.2 Appraisal Cost	20
1.7.1.3 Internal Failure Cost	20
1.7.1.4 External Failure Cost	21
1.7.2 Steps in Making a Quality Cost Study	21
1.7.3 Projects Arising from a Quality Cost Study	26
1.7.4 Quality Cost Scoreboard.....	27
1.7.5 Quality Costs Not Included in the TQC.....	29
1.7.6 Relationship among Quality Cost Categories	31
1.7.7 Summary of Quality Costs.....	32
1.7.8 A Case Study in Quality Costs	32
1.8 Success Stories	39
1.9 Exercise.....	39
1.9.1 Practice Problems.....	39
1.9.2 Mini-Projects	43
References	46
2. Statistics for Quality	49
2.1 Variability in Populations	49
2.2 Some Definitions	50
2.2.1 The Population and a Sample	50
2.2.2 Two Types of Data.....	51
2.3 Quality vs. Variability	52

2.4	Empirical Methods for Describing Populations	53
2.4.1	The Frequency Distribution	53
2.4.1.1	The Histogram.....	53
2.4.1.2	The Cumulative Frequency Distribution.....	54
2.4.2	Numerical Methods for Describing Populations	59
2.4.2.1	Calculating the Average and Standard Deviation	61
2.4.3	Other Graphical Methods.....	61
2.4.3.1	Stem-and-Leaf Diagram	61
2.4.3.2	Box-and-Whisker Plot	63
2.4.4	Other Numerical Measures.....	64
2.4.4.1	Measures of Location.....	64
2.4.4.2	Measures of Dispersion.....	65
2.4.5	Exercise in Empirical Methods	65
2.5	Mathematical Models for Describing Populations.....	67
2.5.1	Probability.....	67
2.5.1.1	Definition of Probability.....	68
2.5.1.2	Computing the Probability of an Event	69
2.5.1.3	Theorems on Probability.....	72
2.5.1.4	Counting the Sample Points in a Sample Space	80
2.5.2	Exercise in Probability	85
2.5.3	Probability Distributions.....	87
2.5.3.1	Random Variable.....	87
2.5.3.2	Probability Mass Function.....	89
2.5.3.3	Probability Density Function	91
2.5.3.4	The Cumulative Distribution Function.....	92
2.5.3.5	The Mean and Variance of a Distribution	93
2.5.4	Some Important Probability Distributions	96
2.5.4.1	The Binomial Distribution	96
2.5.4.2	The Poisson Distribution.....	99
2.5.4.3	The Normal Distribution	101
2.5.4.4	Distribution of the Sample Average $\bar{X}$	109
2.5.4.5	The Central Limit Theorem	110
2.5.5	Exercise in Probability Distributions.....	111
2.6	Inference of Population Quality from a Sample.....	113
2.6.1	Definitions.....	114
2.6.2	Confidence Intervals.....	115
2.6.2.1	CI for the μ of a Normal Population When σ Is Known	115
2.6.2.2	Interpretation of CI	116
2.6.2.3	CI for μ When σ Is Not Known	117
2.6.2.4	CI for σ^2 of a Normal Population	118
2.6.3	Hypothesis Testing	120
2.6.3.1	Test Concerning the Mean μ of a Normal Population When σ Is Known.....	121

2.6.3.2	Why Place the Claim Made about a Parameter in H_1 ?	123
2.6.3.3	The Three Possible Alternate Hypotheses	124
2.6.3.4	Test Concerning the Mean μ of a Normal Population When σ Is Not Known	125
2.6.3.5	Test for Difference of Two Means When σ s Are Known	127
2.6.4	Tests for Normality	129
2.6.4.1	Use of the Normal Probability Plot	129
2.6.4.2	Normal Probability Plot on the Computer	130
2.6.4.3	A Goodness-of-Fit Test	133
2.6.5	The P -Value	134
2.6.6	Exercise in Inference Methods	135
2.6.6.1	Confidence Intervals	135
2.6.6.2	Hypothesis Testing	136
2.6.6.3	Goodness-of-Fit Test	137
2.7	Mini-Projects	137
	References	142
3.	Quality in Design	143
3.1	Planning for Quality	143
3.1.1	The Product Creation Cycle	143
3.2	Product Planning	144
3.2.1	Finding Customer Needs	145
3.2.1.1	Customer Survey	146
3.2.2	Quality Function Deployment	150
3.2.2.1	Customer Requirements and Design Features	152
3.2.2.2	Prioritizing Design Features	153
3.2.2.3	Choosing a Competitor as Benchmark	154
3.2.2.4	Targets	154
3.2.3	Reliability Fundamentals	155
3.2.3.1	Definition of Reliability	156
3.2.3.2	Hazard Function	156
3.2.3.3	The Bathtub Curve	158
3.2.3.4	Distribution of Product Life	161
3.2.3.5	The Exponential Distribution	161
3.2.3.6	Mean Time to Failure	162
3.2.3.7	Reliability Engineering	165
3.3	Product Design	166
3.3.1	Parameter Design	166
3.3.2	Design of Experiments	167
3.3.2.1	2^2 Factorial Design	168
3.3.2.2	Randomization	170
3.3.2.3	Experimental Results	171
3.3.2.4	Calculating the Factor Effects	172

3.3.2.5	Main Effects	173
3.3.2.6	Interaction Effects.....	174
3.3.2.7	A Shortcut for Calculating Effects	175
3.3.2.8	Determining the Significance of Effects	175
3.3.2.9	The 2 ³ Design	178
3.3.2.10	Interpretation of the Results	182
3.3.2.11	Model Building	183
3.3.2.12	Taguchi Designs	184
3.3.3	Tolerance Design.....	185
3.3.3.1	Traditional Approaches	185
3.3.3.2	Tolerancing According to Dr. Taguchi	186
3.3.3.3	Assembly Tolerances.....	187
3.3.3.4	The RSS Formula	188
3.3.3.5	Natural Tolerance Limits.....	191
3.3.4	Failure Mode and Effects Analysis	191
3.3.5	Concurrent Engineering	195
3.3.5.1	Design for Manufacturability/Assembly	196
3.3.5.2	Design Reviews	197
3.4	Process Design.....	197
3.4.1	The Process Flow Chart	198
3.4.2	Process Parameter Selection: Experiments	200
3.4.3	Floor Plan Layout.....	204
3.4.4	Process FMEA	205
3.4.5	Process Control Plan.....	205
3.4.6	Other Process Plans	205
3.4.6.1	Process Instructions.....	205
3.4.6.2	Packaging Standards	207
3.4.6.3	Preliminary Process Capabilities.....	207
3.4.6.4	Product and Process Validation	207
3.4.6.5	Process Capability Results	208
3.4.6.6	Measurement System Analysis	208
3.4.6.7	Product/Process Approval	208
3.4.6.8	Feedback, Assessment, and Corrective Action.....	208
3.5	Exercise	209
3.5.1	Practice Problems.....	209
3.5.2	Mini-Projects	212
	References	214
4.	Quality in Production—Process Control I	217
4.1	Process Control.....	217
4.2	The Control Charts	218
4.2.1	A Typical Control Chart.....	219
4.2.2	Two Types of Data.....	221
4.3	Measurement Control Charts.....	221
4.3.1	$\bar{X}$ - and R -Charts	222

4.3.2	A Few Notes about the $\bar{X}$ - and R-Charts	228
4.3.2.1	The Many Uses of the Charts	228
4.3.2.2	Selecting the Variable for Charting	229
4.3.2.3	Preparing Instruments	230
4.3.2.4	Preparing Check Sheets	230
4.3.2.5	False Alarm in the $\bar{X}$ -Chart	231
4.3.2.6	Determining Sample Size	231
4.3.2.7	Why 3-Sigma Limits?	232
4.3.2.8	Frequency of Sampling	233
4.3.2.9	Rational Subgrouping	233
4.3.2.10	When the Sample Size Changes for $\bar{X}$ - and R-Charts	235
4.3.2.11	Improving the Sensitivity of the $\bar{X}$ -Chart	236
4.3.2.12	Increasing the Sample Size	236
4.3.2.13	Use of Warning Limits	238
4.3.2.14	Use of Runs	238
4.3.2.15	Patterns in Control Charts	240
4.3.2.16	Control vs. Capability	240
4.3.3	X and S-Charts	242
4.4	Attribute Control Charts	245
4.4.1	The P-Chart	245
4.4.2	The C-Chart	248
4.4.3	Some Special Attribute Control Charts	251
4.4.3.1	The P-Chart with Varying Sample Sizes	251
4.4.3.2	The nP -Chart	254
4.4.3.3	The Percent Defectives Chart (100P-Chart)	255
4.4.3.4	The U-Chart	255
4.4.4	A Few Notes about the Attribute Control Charts	258
4.4.4.1	Meaning of the LCL on the P- or C-Chart	258
4.4.4.2	P-Chart for Many Characteristics	259
4.4.4.3	Use of Runs	259
4.4.4.4	Rational Subgrouping	259
4.5	Summary on Control Charts	262
4.5.1	Implementing SPC on Processes	263
4.6	Process Capability	268
4.6.1	Capability of a Process with Measurable Output	268
4.6.2	Capability Indices C_p and C_{pk}	269
4.6.3	Capability of a Process with Attribute Output	274
4.7	Measurement System Analysis	275
4.7.1	Properties of Instruments	275
4.7.2	Measurement Standards	277
4.7.3	Evaluating an Instrument	279
4.7.3.1	Properties of a Good Instrument	279
4.7.3.2	Evaluation Methods	279
4.7.3.3	Resolution	280

	4.7.3.4	Bias	283
	4.7.3.5	Variability (Precision)	284
	4.7.3.6	A Quick Check of Instrument Adequacy	287
4.8	Exercise		289
	4.8.1	Practice Problems	289
	4.8.2	Mini-Projects	293
	References		296
5.	Quality in Production—Process Control II		297
5.1	Derivation of Limits		298
	5.1.1	Limits for the $\bar{X}$ -Chart	298
	5.1.2	Limits for the R -Chart	301
	5.1.3	Limits for the P -Chart	302
	5.1.4	Limits for the C -Chart	303
5.2	Operating Characteristics of Control Charts		304
	5.2.1	Operating Characteristics of an $\bar{X}$ -Chart	304
		5.2.1.1 Computing the OC Curve of an $\bar{X}$ -Chart	305
	5.2.2	OC Curve of an R -Chart	307
	5.2.3	Average Run Length	309
	5.2.4	OC Curve of a P -Chart	312
	5.2.5	OC Curve of a C -Chart	313
5.3	Measurement Control Charts for Special Situations		315
	5.3.1	$\bar{X}$ - and R -Charts When Standards for μ and/or σ are Given	315
		5.3.1.1 Case I: μ Given, σ Not Given	316
		5.3.1.2 Case II: μ and σ Given	316
	5.3.2	Control Charts for Slow Processes	319
		5.3.2.1 Control Chart for Individuals ($\bar{X}$ -Chart)	320
		5.3.2.2 Moving Average and MR Charts	322
		5.3.2.3 Notes on Moving Average and Moving Range Charts	324
	5.3.3	The Exponentially Weighted Moving Average Chart	326
		5.3.3.1 Limits for the EWMA Chart	331
	5.3.4	Control Charts for Short Runs	333
		5.3.4.1 The DNOM Chart	333
		5.3.4.2 The Standardized DNOM Chart	335
5.4	Topics in Process Capability		339
	5.4.1	The C_{pm} Index	340
	5.4.2	Comparison of C_p , C_{pk} , and C_{pm}	341
	5.4.3	Confidence Interval for Capability Indices	342
	5.4.4	Motorola's 6σ Capability	344
5.5	Topics in the Design of Experiments		349
	5.5.1	Analysis of Variance	349
	5.5.2	The General 2^k Design	355
	5.5.3	The 2^4 Design	356

5.5.4	2 ^k Designs with Single Trial	357
5.5.5	Fractional Factorials: One-Half Fractions.....	359
5.5.5.1	Generating the One-Half Fraction	361
5.5.5.2	Calculating the Effects.....	361
5.5.6	Resolution of a Design	362
5.6	Exercise.....	369
5.6.1	Practice Problems.....	369
5.6.2	Mini-Projects	372
	References	373
6.	Managing for Quality.....	375
6.1	Managing Human Resources.....	375
6.1.1	Importance of Human Resources.....	375
6.1.2	Organizations.....	376
6.1.2.1	Organization Structures.....	376
6.1.2.2	Organizational Culture	378
6.1.3	Quality Leadership.....	380
6.1.3.1	Characteristics of a Good Leader.....	380
6.1.4	Customer Focus.....	381
6.1.5	Open Communications.....	383
6.1.6	Empowerment	385
6.1.7	Education and Training	387
6.1.7.1	Need for Training.....	387
6.1.7.2	Benefits from Training.....	388
6.1.7.3	Planning for Training.....	388
6.1.7.4	Training Methodology.....	390
6.1.7.5	Finding Resources.....	391
6.1.7.6	Evaluating Training Effectiveness	392
6.1.8	Teamwork.....	392
6.1.8.1	Team Building.....	393
6.1.8.2	Selecting Team Members	393
6.1.8.3	Defining the Team Mission.....	393
6.1.8.4	Taking Stock of the Team's Strength	394
6.1.8.5	Building the Team	394
6.1.8.6	Basic Training for Quality Teams	395
6.1.8.7	Desirable Characteristics among Team Members	396
6.1.8.8	Why a Team?	397
6.1.8.9	Ground Rules for Running a Team Meeting	397
6.1.8.10	Making the Teams Work	398
6.1.8.11	Different Types of Teams	399
6.1.8.12	Quality Circles.....	400
6.1.9	Motivation Methods	401
6.1.10	Principles of Management.....	402
6.2	Strategic Planning for Quality	402
6.2.1	History of Planning	402

6.2.2	Making the Strategic Plan	404
6.2.3	Strategic Plan Deployment	405
6.3	Exercise	407
6.3.1	Practice Problems	407
6.3.2	Mini-Project	408
	References	408
7.	Quality in Procurement	409
7.1	Importance of Quality in Supplies	409
7.2	Establishing a Good Supplier Relationship	410
7.2.1	Essentials of a Good Supplier Relationship	410
7.3	Choosing and Certifying Suppliers	411
7.3.1	Single vs. Multiple Suppliers	411
7.3.2	Choosing a Supplier	412
7.3.3	Certifying a Supplier	413
7.4	Specifying the Supplies Completely	414
7.5	Auditing the Supplier	415
7.6	Supply Chain Optimization	416
7.6.1	The Trilogy of Supplier Relationship	417
7.6.2	Planning	417
7.6.3	Control	418
7.6.4	Improvement	419
7.7	Using Statistical Sampling for Acceptance	420
7.7.1	The Need for Sampling Inspection	420
7.7.2	Single Sampling Plans for Attributes	422
7.7.2.1	The Operating Characteristic Curve	422
7.7.2.2	Calculating the OC Curve of a Single Sampling Plan	423
7.7.2.3	Designing an SSP	426
7.7.2.4	Choosing a Suitable OC Curve	426
7.7.2.5	Choosing a Single Sampling Plan	428
7.7.3	Double Sampling Plans for Attributes	431
7.7.3.1	Why Use a DSP?	432
7.7.3.2	The OC Curve of a DSP	432
7.7.4	The Average Sample Number of a Sampling Plan	434
7.7.5	MIL-STD-105E (ANSI Z1.5)	436
7.7.5.1	Selecting a Sampling Plan from MIL-STD-105E ..	438
7.7.6	Average Outgoing Quality Limit	447
7.7.7	Some Notes about Sampling Plans	451
7.7.7.1	What Is a Good AQL?	451
7.7.7.2	Available Choices for AQL Values in the MIL-STD-105E	451
7.7.7.3	A Common Misconception about Sampling Plans	452

7.7.7.4	Sampling Plans vs. Control Charts.....	452
7.7.7.5	Variable Sampling Plans	452
7.8	Exercise.....	453
	References	454
8.	Continuous Improvement of Quality.....	457
8.1	The Need for Continuous Improvement	457
8.2	The Problem-Solving Methodology	458
8.2.1	Deming's PDCA Cycle	458
8.2.2	Juran's Breakthrough Sequence	459
8.2.3	The Generic Problem-Solving Methodology	461
8.3	Quality Improvement Tools.....	464
8.3.1	Cause-and-Effect Diagram	465
8.3.2	Brainstorming.....	466
8.3.3	Benchmarking	467
8.3.4	Pareto Analysis	471
8.3.5	Histogram	472
8.3.6	Control Charts	474
8.3.7	Scatter Plots.....	476
8.3.8	Regression Analysis	479
8.3.8.1	Simple Linear Regression.....	479
8.3.8.2	Model Adequacy	481
8.3.8.3	Test of Significance.....	482
8.3.8.4	Multiple Linear Regression.....	487
8.3.8.5	Nonlinear Regression	489
8.3.9	Correlation Analysis.....	490
8.3.9.1	Significance in Correlation.....	491
8.4	Lean Manufacturing.....	493
8.4.1	Quality Control	496
8.4.2	Quantity Control.....	497
8.4.3	Waste and Cost Control	498
8.4.4	Total Productive Maintenance	499
8.4.5	Stable, Standardized Processes.....	500
8.4.6	Visual Management.....	500
8.4.7	Leveling and Balancing	502
8.4.8	The Lean Culture	504
8.5	Exercise.....	504
8.5.1	Practice Problems.....	504
8.5.2	Term Project 8.1	506
	References	507
9.	A System for Quality	509
9.1	The Systems Approach.....	509
9.2	Dr. Deming's System	510
9.2.1	Long-Term Planning.....	511
9.2.2	Cultural Change.....	512

9.2.3	Prevention Orientation.....	512
9.2.4	Quality in Procurement.....	513
9.2.5	Continuous Improvement.....	513
9.2.6	Training, Education, Empowerment, and Teamwork.....	514
9.3	Dr. Juran's System	518
9.3.1	Quality Planning	519
9.3.2	Quality Control	522
9.3.3	Quality Improvement.....	523
9.4	Dr. Feigenbaum's System	527
9.5	Baldrige Award Criteria.....	530
9.5.1	Criterion 1: Leadership.....	533
9.5.2	Criterion 2: Strategic Planning.....	534
9.5.3	Criterion 3: Customer Focus.....	535
9.5.4	Criterion 4: Measurement, Analysis, and Knowledge Management.....	537
9.5.5	Criterion 5: Workforce Focus.....	538
9.5.6	Criterion 6: Process Management.....	540
9.5.7	Criterion 7: Results.....	541
9.6	ISO 9000 Quality Management Systems	543
9.6.1	The ISO 9000 Standards.....	543
9.6.2	The Eight Quality Management Principles.....	544
9.6.3	Documentation in ISO 9000	545
9.7	ISO 9001:2008 Requirements	546
9.7.1	Quality Management System (4).....	547
9.7.2	Management Responsibility (5)	548
9.7.3	Resource Management (6).....	551
9.7.4	Product Realization (7).....	552
9.7.5	Measurement, Analysis, and Improvement (8)	558
9.8	Six Sigma System	561
9.8.1	Six Themes of Six Sigma	562
9.8.2	The 6 σ Measure.....	563
9.8.3	The Three Strategies	565
9.8.4	The Two Improvement Processes	566
9.8.5	The Five-Step Road Map.....	566
9.8.6	The Organization for the Six Sigma System	569
9.9	Summary of Quality Management Systems	569
9.10	Exercise.....	571
9.10.1	Practice Problem.....	571
9.10.2	Mini-Projects	573
	References	573
	Appendix 1	575
	Appendix 2	587
	Index	595