

CONTENTS

1. Introduction to Quality Control Concepts	1
1.1 Introduction—Historical Sketch	1
1.2 The Japanese Quality Movement after World War II	3
1.3 Quality Assurance	7
1.4 Some Aspects of Quality and Quality Control	9
1.5 Leadership: Responsibility, Authority, and Knowledge	16
1.6 Quality Management Principles: Deming's 14 Points	19
1.7 The \bar{Q} -Statistics Paradigm in SPC	30
1.8 Summary	31
Problems	32
 2. Probability Distributions to Describe Variability in Data Sets	 34
2.1 The Variability Inherent in Measurements, Reference Distributions for Continuous Variables	34
2.2 Reference Distributions for Discrete Variables	36
2.3 Some Properties of Theoretical Reference Distributions	38
2.4 The Hypergeometric Distribution	41
2.5 The Binomial Distribution	44
2.6 The Poisson Distribution	49
2.7 The Negative Binomial or Waiting Time Distribution	55
2.8 The Normal Distribution	61
2.9 Normal Sampling Distributions: Chi-Squared, Student- t , and F Distributions	66
2.10 The Exponential Distribution	76
2.11 Summary	80
Problems	80
 3. Collecting and Studying Data Sets: Descriptive Statistics and Sampling Distributions	 93
3.1 Populations and Samples	93

3.2	Graphs of Data Sets: Dot Plots, Histograms, Pareto Diagrams, Stem-and-Leaf Diagrams	96
3.3	Cause-and-Effect or Ishikawa Diagrams	103
3.4	Studying Samples, Descriptive Statistics	104
3.5	Properties of Sampling Distributions of Sample Means, Variances, and Ranges	117
3.6	Concepts of Statistical Inference: Estimation, Prediction Problems	125 127
4.	Classical Shewhart Control Charts for Variables	135
4.1	Work Process Control and Quality Variables	135
4.2	Observed and Expected Mean Squares	141
4.3	Shewhart Control Charts for Variables—General Description	142
4.4	The \bar{X} -, R -, and S -Charts for both σ and μ “Known”	147
4.5	Runs Tests for 3-Sigma \bar{X} Control Chart Patterns, μ and σ Known	158
4.6	Assessing \bar{X} -Chart Performance: OC and Power Functions, Run Length Distributions, μ and σ both Known	163
4.7	The OC, Power, and ARL Functions for an S -Chart, σ Known	173
4.8	Estimating μ , σ , and the Control Limits	177
4.9	Examples of \bar{X} -, S -, and R -Charts; Stratification and Rational Subgroups	185
4.10	Charts for Individual Measurements	196
4.11	Estimating Shewhart Charts Control Limits from Past Data, Sample Size Considerations	203
4.12	Summary Problems	220 220
5.	Classical Shewhart Control Charts for Attributes	227
5.1	Introduction	227
5.2	The Classical 3-Sigma p -Chart for Fraction Nonconforming	228
5.3	c -Charts for Numbers of Nonconformities	241
5.4	u -Charts for the Average Number of Defects per Standard Inspection Unit	250
5.5	c - and u -Charts when Sample Sizes Vary—Standardized Charts	258

5.6	Summary Problems	260 260
6.	MA, EWMA, and CUSUM Charts for Classical Stable Processes	266
6.1	The Moving Average (MA) Control Chart	267
6.2	The Exponentially Weighted Moving Average (EWMA) Chart for a Classical Stable Process	273
6.3	Cumulative Sum (CUSUM) Charts	285
6.4	Summary Problems	298 299
7.	<i>Q</i>-Charts for Variables	302
7.1	Some Considerations in Using Classical Charts for Variables	302
7.2	Introduction to Normalized Statistics and <i>Q</i> -Charts	306
7.3	<i>Q</i> -Charts for a Normal Process, Subgrouped Data	307
7.4	<i>Q</i> -Charts Based on Individual Measurements	334
7.5	The EWMA <i>Q</i> -Chart	342
7.6	The CUSUM <i>Q</i> -Chart	349
7.7	Sensitivities of Transformations, Competing Tests, Implementation Issues	352
7.8	Some Examples	358
7.9	The Exponential <i>Q</i> -Chart	363
7.10	Summary	368
	Appendix 7A Minimum Variance Estimation of a Linear Function	369
	Appendix 7B Distributional Properties of <i>Q</i> -Statistics	370
	Appendix 7C On Optimality Properties of <i>Q</i> -Charts 1-of-1 Tests	373
	Problems	374
8.	<i>Q</i>-Charts for Attributes	378
8.1	Considerations in Using Classical Charts for Attributes	378
8.2	Binomial <i>Q</i> -Statistics and Shewhart <i>Q</i> -Charts	380
8.3	An Arcsin Transformation, Comparisons with <i>z</i> - and <i>Q</i> -Charts, Sample Size Issues	387
8.4	Binomial EWMA and CUSUM <i>Q</i> -Charts, Sample Sizes, Binomial <i>Q</i> -Charts Performance	390

8.5	Poisson Q -Charts	396
8.6	Comparisons Among Shewhart z -, Q -, and y -Charts, Sample Size Recommendations	403
8.7	The Geometric Q -Chart	411
8.8	Weighted Systems of Nonconformities (Weighted Poisson Charts)	430
8.9	Summary	437
	Problems	438
9.	Process Capability and Performance Analysis, Quadratic Loss Functions	444
9.1	Some Key Background Results	444
9.2	Basic Graphical Methods	446
9.3	Uniform Residuals Plots	447
9.4	Classical Probability Plots	453
9.5	Goodness-of-Fit Tests	455
9.6	Transforming Skewed Data to Normality	461
9.7	Specification Limits, Fallout, Yield, Natural Tolerance Limits, and Process Capability	464
9.8	The C_p Capability and C_{PK} Performance Indices	470
9.9	The Taguchi Quadratic Loss Function	480
9.10	Summary	503
	Appendix 9A	504
	Problems	505
10.	Measurement Assurance	509
10.1	Measurement System Stability, Accuracy, Precision	509
10.2	Sources of Error in a Gauging Process	510
10.3	An Analysis of Variance (ANOVA) for Gauges	527
10.4	Gauge Sensitivity or Measurement Resolution	539
10.5	Gauge Stability	551
10.6	Summary	558
	Problems	559
11.	Regression SPC Models	565
11.1	SPC for the Simple Linear Regression Model	565
11.2	The Tool-Wear Problem	570
11.3	SPC for the Multiple Linear Regression Models	574
11.4	SPC for Subgrouped Growth Data	579

11.5	Summary	588
	Problems	588
12.	Combining Statistical Process Control and Statistical Process Adjustment Methods	590
12.1	Process Stability and Process Adjustment for the Classical Constant Mean and Variance Model	590
12.2	Sample Mean Adjustment of a Constant Mean and Variance Process	591
12.3	SPC and Statistical Process Adjustment (SPA) of a Classical Stable Process	598
12.4	Statistical Process Adjustment for a Linear Tool-Wear Process with Independent Errors	605
12.5	Estimating σ^2 and β_1 from Process Data	615
12.6	Combining SPC and SPA for Simple Linear Regression Tool-Wear Processes	616
12.7	SPC and SPA for a Linear Tool-Wear Process with Independent Errors	619
12.8	Summary	623
	Appendix 12A	623
	Problems	625
13.	Some SPC Methods for Autocorrelated Processes	626
13.1	Studying the Independence Assumption	626
13.2	SPC for Stationary Processes Based on Autoregressive Models	634
13.3	Summary	646
	Problems	647
14.	<i>Q</i>-Charts for Two or More Quality Variables	649
14.1	The Multinormal Distribution	649
14.2	Parameter Estimation for the Multinormal Distribution	650
14.3	Multivariate Mean <i>Q</i> -Charts for Individual Measurements	651
14.4	Multivariate Mean <i>Q</i> -Charts for Subgrouped Measurements	653
14.5	Discussion of Multivariate Mean Charts	655
14.6	Some Examples with Generated Data	656
14.7	Control Charts for Correlation	658

14.8	The X^2 Control Chart, General Formulation of X^2 Charts	660
14.9	The X^2 Chart to Control a Set of Percentages	663
14.10	Summary	666
	Problems	667
Appendix		669
References		683
Index		690