

## ACKNOWLEDGMENTS

The following material has been used in this book with the kind permission of the copyright owners.

On pages 12, 17, 20, and 21, the control chart factors and formulas.

Taken by permission from the *ASTM Manual on Quality Control of Materials*, STP 15-C, copyright 1951, American Society for Testing Materials, Philadelphia, Pa. Some of this material was originally published in *British Standards 600: 1935*, (E. S. Pearson, "The Application of Statistical Methods to Industrial Standardization and Quality Control") and in *British Standards 600R: 1942* (B. P. Dudding and W. J. Jennett, "Quality Control Charts"), British Standards Institute, London, England.

On page 115, the table of random numbers.

Taken by permission from Table XIX "Random Sampling Numbers" from the book, *Statistical Tables and Formulas*, by A. Hald. John Wiley & Sons, Inc., New York, 1952.

On pages 133, 135 and 136 probabilities for the normal law and the second approximation to the normal law.

Taken by permission from *Biometrika Tables for Statisticians*, by E. S. Pearson and H. O. Hartley, Cambridge University Press, 1954.

On page 145, diagram for calculating a line of regression.

From *Facts from Figures* by M. J. Moroney, 95¢, a Pelican Book published by Penguin Books Inc., 3300 Clipper Mill Road, Baltimore 11, Md.

On page 147, form for calculating the coefficient of correlation.

Reprinted by permission from Hawthorne Club Evening School Manual AM-8, *Statistical Methods Applied to Manufacturing Problems*, Western Electric Co., Inc., 1945.

On page 241, curves for calculating the probability of acceptance.

Reprinted by permission from *Sampling Inspection Tables*, by H. F. Dodge and H. G. Romig. John Wiley & Sons, Inc., New York, 1944.

On pages 247-248, excerpts from the Mil. Std. Tables 105A.

Reprinted by permission from Military Standard *Sampling Procedures and Tables for Inspection by Attributes*, United States Government Printing Office, September 1950.

On pages 250 and 253, examples of AOQL and LTPD sampling tables.

Reprinted by permission from *Sampling Inspection Tables*, by H. F. Dodge and H. G. Romig. John Wiley & Sons, Inc., New York, 1944.

On page 252, table of values of  $x$  and  $y$  for given values of  $c$ . Used in calculating AOQL.

Reprinted by permission from *Sampling Inspection Tables*, by H. F. Dodge and H. G. Romig. John Wiley & Sons, Inc., New York, 1944.

On page 258, sampling plans for continuous production.

Reprinted by permission from "A Sampling Inspection Plan for Continuous Production," by H. F. Dodge, Bell Telephone Laboratories, Inc. Published in *Transactions of the American Society of Mechanical Engineers*, Volume 66, No. 2, pages 127 to 133, February 1944.

## REFERENCES

- (1) Abruzzi, Adam, "Work Measurement," Columbia University Press, 1952.
- (2) American Society for Testing Materials, "Quality Control of Materials," ASTM STP 15-C 1951.
- (3) American National Standards Institute, "Control Chart Method of Controlling Quality During Production," ANSI Z1.3 - 1942.
- (4) Bowker, A. H., and Goode, H. P., "Sampling Inspection by Variables," McGraw-Hill Book Co., Inc., 1952.
- (5) Brownlee, K. A., "Industrial Experimentation," Chemical Publishing Co., Inc., 1947.
- (6) Burr, I. W., "Engineering Statistics and Quality Control," McGraw-Hill Book Co., Inc., 1953.
- (7) Burr, I. W., and Weaver, W. R., "Stratification Control Charts," *Industrial Quality Control Magazine*, March 1949.
- (8) Dodge, H. F., "Sampling Plans for Continuous Production," *Industrial Quality Control Magazine*, November 1947.
- (9) Dodge, H. F., "Skip-Lot Sampling Plans," *Industrial Quality Control Magazine*, February 1955.
- (10) Dodge, H. F., "Chain Sampling," *Industrial Quality Control Magazine*, January 1955.
- (11) Dodge, H. F., and Romig, H. G., "Sampling Inspection Tables—Single and Double Sampling," John Wiley & Sons, Inc., 1944.
- (12) Dodge, H. F., and Torrey, M. N., "Continuous Sampling Inspection Plans," *Annals of Mathematical Statistics*, 1943.
- (13) Duncan, A. J., "Quality Control and Industrial Statistics," R. D. Irwin, Inc., 1953.
- (14) Ferrell, E. B., "Control Charts Using Midranges and Medians," *Industrial Quality Control Magazine*, March 1953.
- (15) Fisher, R. A., "The Design of Experiments," Oliver and Boyd, Edinburgh, 1935.
- (16) Fisher, R. A., "Statistical Methods for Research Workers," Oliver and Boyd, Edinburgh, 1938.
- (17) Fisher and Yates, "Statistical Tables," Hafner Publishing Co., 1953.
- (18) Freeman, H. A., "Industrial Statistics," John Wiley & Sons, 1946.
- (19) Fry, T. C., "Probability and Its Engineering Uses," D. Van Nostrand Co., New York, 1928.
- (20) Grant, E. L., "Statistical Quality Control," McGraw-Hill Book Co., Inc., 1952.
- (21) Hald, A., "Statistical Theory with Engineering Applications," John Wiley & Sons, 1952.
- (22) Heiland, R. E., and Richardson, W. J., "Work Sampling," McGraw-Hill, 1957.
- (23) Hoel, P. G., "Introduction to Mathematical Statistics," John Wiley & Sons, Inc., 1947.
- (24) Ireson, W. Grant, and Grant, Eugene L., "Handbook of Industrial Engineering and Management," Prentice-Hall, Inc., 1955.
- (25) Juran, J. M., "Quality Control Handbook," McGraw-Hill Book Co., Inc., 1951.
- (26) Kenney, J. F., and Keeping, E. S., "Mathematics of Statistics," D. Van Nostrand Co., Inc., New York, 1951.
- (27) Miscellaneous Articles in *Industrial Quality Control Magazine*.
- (28) Molina, E. C., "Poisson's Exponential Binomial Limit," D. Van Nostrand Co., New York, 1947.
- (29) Moroney, J. M., "Facts from Figures," Penguin Books, Inc., 1954.

- (30) Munitions Board Standards Agency, Department of Defense. Military Standard: "Sampling Procedures and Tables for Inspection by Attributes (Mil. Std. 105A)," United States Government Printing Office, 1950.
- (31) Olmstead, P. S., "How to Detect the Type of an Assignable Cause," *Industrial Quality Control Magazine*, November 1952 and January 1953.
- (32) Ott, E. R., "Analysis of Machine vs. Shift Performance Data," *Industrial Quality Control Magazine*, January 1952.
- (33) Ott, E. R., "Variables Control Chart in Production Research," *Industrial Quality Control Magazine*, November 1949.
- (34) Ott, E. R., and Mundel, A. B., "Narrow Limit Gauging," *Industrial Quality Control Magazine* Volume X, No. 5, March 1954.
- (35) Pearson, E. S., "The Probability Integral of the Range in Samples of  $n$  Observations from a Normal Population," *Biometrika*, Volume 32, 1942.
- \* (36) Quality Assurance General Procedures Handbooks, Western Electric Co., Inc.
- (37) Quality Assurance "An Introduction to the Quality Measurement Plan," Western Electric Co., Inc., 1980.
- (38) Shewhart, W. A., "Economic Control of Quality of Manufactured Product," D. Van Nostrand Co., New York, 1931.
- (39) Shewhart, W. A., "Statistical Method from the Viewpoint of Quality Control," United States Department of Agriculture, 1939.
- (40) Simon, L. E., "An Engineer's Manual of Statistical Methods," John Wiley & Sons, 1945.
- (41) Small, Bonnie B., "Control Chart Analysis of Engineering Experiments," Transactions of the Ninth Annual Convention, American Society for Quality Control, 1955.
- (42) Snedecor, G. W., "Statistical Methods," Iowa State College Press, 1946.
- (43) Statistical Research Group, Columbia University, "Sequential Analysis of Statistical Data: Applications," Columbia University Press, 1945.
- (44) Stevens, W. L., "Control by Gauging," *Royal Statistical Society Journal*, Series B, Volume 10, 1948.
- (45) "Tables of the Binomial Probability Distribution," Applied Mathematics Series No. 6 Government Printing Office, Washington, D. C., 1952.
- (46) United States Department of Navy, "An Introduction to Statistical Quality Control," Government Printing Office, Washington, D. C., 1949.
- \* (47) Western Electric Company Training Manual No. 62 (Allentown Works) on "Sampling Plans for Final Inspection Adjusted to be Compatible with Demerit Quality Stds." OUT OF PRINT.
- (48) Westman, A. E., and Lloyd, B. H., "Quality Control Charts Adjusted for Within Sub-Group Pattern," *Industrial Quality Control Magazine*, March 1949.
- (49) Wilks, S. S., "Elementary Statistical Analysis," Princeton University Press, 1951.
- (50) Yule, G. U., "An Introduction to the Theory of Statistics," Charles Griffin and Co., Ltd., London, 1919.
- (51) Yule and Kendall, "An Introduction to the Theory of Statistics," Hafner Publishing Co., 1950.

\* These references contain proprietary information and are therefore available for use only in connection with Company work.

### Special References

Among the topics not covered in this book are the following:

Chi-Square Test. See References Nos. 5 and 13.

Confidence Intervals (or Confidence Limits). See References Nos. 3, 13 and 26.

Contingency Tables. See References Nos. 13 and 26.

Estimating from a Sample. See References Nos. 3 and 26.

Various Tests of Significance. See Reference No. 26.

# INDEX

## A

- A*<sub>2</sub> factor, 12, 13, 14, 195, 196  
Abbreviations used by clerks, 229  
Abnormal  
  causes, 6, 9, 150  
  data, 52-53, 116-117  
  measurements, 141, 160  
  sources of variation, 6, 10, 35, 37, 52, 149-151  
Abnormalities, 154, 156, 163  
Abrupt changes  
  in a curve, 164  
  in a process, 11, 164, 178  
Abruzzi, A., 50, 277  
Absences, 11, 21  
Absolute value of residual, 98, 107  
Acceptance  
  and rejection, 4, 38-39, 188, 233, 237-239, 254, 260-261, 268-269  
  by control charts, 188, 246, 262-263, 265, 274  
  on outside limit basis, 254, 269  
  probability of (*See* Probability of acceptance)  
  sampling (*See* Statistical sampling inspection)  
  sampling by variables (*See* Variables sampling plans)  
Acceptance number, 39, 237, 238, 240, 259, 265, 267  
  in Dodge-Romig tables, 249-253, 255, 270  
  in double or multiple sampling, 238, 259-260, 261  
  in Mil. Std. tables, 247-248  
  in single sampling, 259-260  
Accidental  
  damage, 163, 180  
  loss of unit, 116  
  shipment, 165  
Accidents, 21  
  (*See* Damage)  
Accounting  
  problems, 3  
  records, 6, 21, 50, 189, 191, 197, 226  
  standards, 35, 46, 54  
Accumulation of product, 167, 246, 260-262  
Accuracy  
  of control limits, 52, 153  
  of measurements, 49, 89, 90-91  
Action  
  criteria for, 208-209, 237  
  in inspection, 263, 269, 270  
  in process capability studies, 61-63, 63-65, 67-70  
  not taken as required, 217, 219, 227  
  on an  $\bar{X}$  and *R* chart, 66-72  
  on an  $\bar{X}$  chart, 66-67, 69-70, 228  
  on control chart audits, 227  
  on designed experiments, 77, 83, 87, 101, 112  
  on shop charts, 25 (footnote), 63, 65, 194-195, 208-209, 217-221, 227  
Activation, 91, 92, 93, 100, 101  
Active causes, 217  
Addition  
  of distributions, 122-123  
  of requirements, 61-63, 165, 175, 178  
  of variables in an experiment, 101-103  
Adjusting operation, 46, 49, 61, 188  
Adjustment  
  between process and OC curve, 244, 246, 255, 264-265  
  of a machine, 16, 30, 37, 67, 153, 166, 188, 202, 203-204, 212  
  of a meter, 67  
  of a process, 16, 30, 37, 67, 153, 188, 202, 203-204, 265  
  (*See* Overadjustment)  
Administration  
  of inspection, 234, 236, 260, 267-271  
  of process control, 201-216, 217-222, 227  
  of the quality control program, vii, 4, 33-41, 187-199, 201-216, 221-222, 223-229, 234  
  (*See* Process control; Quality control program; Quality control engineering)  
Administrative uses of control charts, 3, 4, 10, 21, 22, 23, 46, 225-226  
Advantages  
  of control chart analysis, 83-84, 91, 97  
  of control charts in general, 9, 10  
  of designed experiments, 75-76, 77, 91-93, 101, 187  
  of joint cost reduction cases, 226  
  of process capability studies, 10, 34-36, 45-47, 61-63, 71, 112, 187  
  of quality control, 10, 33-38, 225-226, 233, 236, 246, 273-274  
  of sampling inspection, 4, 38-39, 187, 233-236  
  of shop charts, 4, 10, 15-16, 19-20, 36, 37-38, 62, 187, 201-204, 216, 219-220, 221, 224, 225-226, 235, 246, 265, 274  
  of unnatural variation, 35, 54, 151, 221  
Adverse effect on quality, 72, 121, 246  
Advice given by quality control engineer, 40, 113, 192, 228, 236  
Age  
  as a variable, 153, 178  
  of a fixture or machine, 168  
  of a person, 7  
Aging of product, 153, 178  
Aims  
  of a cost reduction case, 226  
  of a quality control program (*See* Objectives)  
Aircraft, 21  
Algebraic  
  differences, 21, 22, 102-106  
  value of residual, 98  
Alignment, 5, 8, 19, 69, 155, 167, 175, 180  
Allowances  
  engineering, 35, 46, 54, 122, 125  
  establishment of, 46, 54, 235, 265  
  to be based on a natural pattern, 54, 59-60  
  work sampling data for, 50  
Alloying, 102, 104  
Alternate pairs of samples, 108, 109  
American Society for Testing & Materials (*See* ASTM)  
American National Standards Institute (ANSI), 277  
Amount  
  of inspection, 39, 46, 225, 226, 233, 236, 262, 273-274  
  of production, 71, 226 (*See* Efficiency; Schedules)  
  of product rejected by Inspection, 226, 246, 255  
  of product requiring detailing, 226, 235, 263, 265  
  of record keeping, by inspection, 260, 268-269  
  of sorting, 46, 226, 235, 265  
Amount of data  
  for statistical conclusions, 28, 62, 112, 146  
  required for a control chart, 9  
  required for chart of individual measurements, 50-51, 160

- Amount of data, *continued*  
 required for designed experiments, 28, 77, 78-79, 90, 92-93, 110, 111, 112, 113  
 required for engineering studies, 50-51, 62  
 required for experiments not formally designed, 77, 92  
 required for process capability studies, 28, 47, 50-51, 61, 62, 63-64, 66-72  
 required for studying correlation, 146  
 required for studying skewness, 56  
 (See Data)
- Ampere turns, 66-71
- Analysis  
 of a *c*-chart, 72-73  
 of a designed experiment, 77-84, 84-91, 91-101, 107-111, 111-112  
 of an  $\bar{X}$  and *R* chart, 15-16, 66-72  
 of a *p*-chart, 19-20, 31, 59, 73, 157-159  
 of a process capability study, 47, 51-63, 66-73  
 of complex unnatural patterns, 54-56, 60, 66-71, 72-73  
 of control charts, 152-180  
 of control charts in an experiment, 100-101, 111-112  
 of data in general, 3, 9  
 of engineering data, 46  
 of patterns, 53-56, 66-71, 72-73, 161-180  
 of shop charts, 190, 199, 203-204, 217-219  
 (See Formal analysis; Informal analysis)
- Analysis of factorial design  
 control chart method, 93, 97-101, 101-106, 107-111, 111-112  
 sum of squares method, 93-97, 101
- Analysis of variance  
 by control charts, 93, 97-101, 101-107, 107-111  
 by sums of squares, 78, 80, 81, 82, 91, 93-97, 101  
 explanation of, 78, 80, 93  
 for comparing averages, 80-81  
 for determining components of variance, 91, 95, 96, 98
- Anchoring of fixture, 55
- Annual  
 reports, 225-226  
 savings, 226
- Answers  
 to questions asked by engineers, 4, 34, 36, 46-47, 75  
 to questions asked by operators, 201-202
- to questions asked of machine setters, 202, 217
- AOQ, 251
- AOQL  
 calculation of, 251-252  
 choice of, 254-255, 264, 265, 273  
 compared with target value for shop, 254-255  
 derived from quality rates, 264, 273  
 equation for, 251  
 ignored in case of Minimum Inspection, 273, 274  
 may hold product to tighter level than planned, 251, 252  
 meaning of, 249  
 misuse of, 254  
 selection of values of, 263-265, 273  
 used in conjunction with LTPD sampling plans, 250, 253
- AOQL sampling plans, 249-251, 252-255, 256, 263-265, 273
- Apparatus, 3, 189
- Apparent  
 complexity, 37-38, 70, 166-167  
 correlation, 56, 146, 156, 176-177  
 effects in data, 9, 10, 46, 75-76, 99, 103, 161  
 freaks, 52-53, 58, 117, 162, 164  
 savings, 246, 262  
 skewness, 58, 163  
 spread, 61, 123, 141  
 stratification, 173-174  
 trends, 160, 178, 179  
 trouble with specification, 122, 204, 206  
 worsening of pattern, 67, 68
- Appearance  
 as a variable, 12  
 of chart mountings used in shop, 192  
 of control charts, 192, 216, 221
- Applications  
 in the shop, vii, 4, 5-6, 10, 15-16, 19-20, 22-23, 33-41, 45-47, 50, 62-65, 72, 74, 75, 125, 183, 187-229  
 leading to cost reduction, 226  
 of control charts, in general, 33  
 of designed experiments, 34, 75-117  
 of process capability studies, 34, 45-47  
 of quality control, 3-4, 33, 34
- Approach to capability, 36, 47, 63, 64, 71, 73, 74, 83
- Approval of shop charts, 189, 192, 199, 228
- AQL, 119, 247, 265
- AQL sampling plans, 246-248, 265
- Areas  
 for applying statistical quality control, 3-4, 33, 34, 46-47, 66, 187-189
- for inspection, 260  
 of squares, 57  
 storage, 246, 260
- Arithmetic mean, 129 (See Averages)
- Armature, 213
- Arrangement  
 of points on a control chart, 149, 160  
 of points in a natural pattern, 24, 162, 170, 175, 176
- Arrangement of data  
 for calculating standard deviation, 130  
 for control charts, 14, 18, 22, 72-73, 82, 86, 98, 109, 149, 151  
 for correlation, 143-144, 145, 147  
 for designed experiments, 76, 78, 82, 84, 86, 92, 94, 99, 102, 109, 117  
 for frequency distribution, 139  
 for obtaining median, 129  
 for process capability studies, 51-52, 55-56, 72-73, 75
- Arrows, in margin, 13-14, 16, 30-31, 65, 190, 205, 206, 212
- "a's," writing of, 7
- Assemblies  
 complex, 3, 55, 122, 189  
 methods for, 3, 46, 71, 175, 226  
 parts needed for, 246, 254  
 positioning of, 69, 167, 176  
 problems in, 48, 61, 188, 189  
 selective, 123, 127, 188
- Assembly tolerances, 124-127
- Assignable causes  
 effect of, in setting standards, 59-60, 122, 145  
 good or bad? 35-36, 54, 62, 149-151  
 in a complex pattern, 66  
 in a designed experiment, 79, 82-83, 87, 88, 99-101, 101-106, 106-107, 109, 111, 112, 113-114, 116-117  
 in an error of measurement study, 87, 88, 89, 90, 91  
 in data for an experiment, 111  
 information from, 35-36, 54-56, 151, 221  
 in general, 6, 145, 149-151, 217  
 in process capability studies, 25 (footnote), 34, 35-36, 45, 46, 47, 51, 53, 55-56, 59-61, 66-73, 122, 150-151, 161-180  
 meaning of, 9, 10, 37-38, 47, 149-151  
 on a *p*-chart, 19-20, 48, 59, 157-159, 189  
 on shop charts, 25 (footnote), 189, 212-213, 217, 218-219

- patterns associated with, 11, 54-56, 60, 66-71, 72-73, 99-100, 161-180
- tests for, 25 (footnote), 25-30, 180-183
- tests for, within boxes in a designed experiment, 111
- treatment of, 35-36, 54, 62, 122, 150-151
- Assistance  
in writing layouts, 192, 236  
to Quality Control Team, 40, 228-229, 236
- Assortment of product, 166
- Assumptions  
about average, 153, 154  
of constancy, 78, 79, 80, 82, 114, 218  
of equivalent variances, 78-80, 82  
of normality, 78-79, 80, 82, 132, 134, 154
- Assurance, in inspection, 274  
(See Quality assurance)
- Asterisk  
used for marking control charts, 99, 100, 107, 109  
used for marking effects in sum of squares analysis, 97
- ASTM Manual on Quality Control of Materials, 139, 275, 277
- Atmospheric conditions, 6
- Attendance, 6  
(See Absences)
- Attitudes, 4, 158  
(See Motivation)
- Attributes control charts, 7-8, 11, 17-21, 48-49, 113, 144, 157-160, 188-189, 191, 196-197, 198, 204, 218, 227  
examples of, 19, 72-73, 194  
other than *p*-charts, 11, 20-21, 72-73, 160, 189, 191, 198  
where to use, 48-49, 54, 59, 72-73, 113, 188-189, 191, 196-197, 218  
(See *p*-Charts; *np*-Charts; *c*-Charts; *u*-Charts)
- Attributes data  
for control charts in general, 11, 17, 18, 31, 38, 47, 48-49, 50, 157-160  
used in designed experiments, 113  
used in process capability studies, 48-49, 50, 53, 54, 56, 59, 66, 72-73, 74, 144  
used on shop charts, 188-189, 191, 194, 196-197, 198, 206, 210, 225, 227-228
- Attributes inspection, 237-265, 267-271
- Attributes measurements, 5, 6, 17, 18, 20-21, 47, 144  
(See Attributes data)
- Audit inspection  
(See Minimum inspection; Quality rating)
- Audits  
of finished product, 270  
of inspection, 227  
of process controls, 38, 41, 198-199, 219, 223, 227, 233, 274  
of various areas of management interest, 34  
performed by Inspection, 233-234, 268, 274
- Authorization  
of questionable practices, 45, 61  
of data collection, by the Quality Control Team, 41, 192, 223, 228
- Automatic controls, 10, 70, 156, 171, 180, 235
- Automatic timer, 70, 235
- Automatic welder, 5, 19
- Automation, 47
- Average amount of inspection, 46, 260
- Average range, 12, 56, 58, 131
- Averages, 11, 137, 138  
addition of, 123-124  
affected by change in proportion, 153, 154  
calculation of, 12, 129, 210, 213  
change in, 153, 179  
conclusions based on, 111  
distribution of, 137-138  
limits for, 16, 138  
meaning of, 154  
of a distribution, 63, 129, 171  
of a series of samples, 137  
of two related points, 109  
process (See Process average)  
should not be used for estimates, 60, 61  
substitutes for, 129, 197  
unreliable, 60, 61, 83  
use of, in a designed experiment, 78, 80-81, 111  
use of, in analysis, 78  
various forms of, 129  
(See  $\bar{X}$  and *R* Charts)
- Average value of electrical characteristic, 71, 83, 91, 101
- Axiom, 217
- B**
- Backing for shop charts, 192, 228
- Back schedules, reduction of, 37, 46, 226
- Bake-out, 102, 104
- Balance  
around a centerline, 24, 187, 208  
between costs and savings, 10, 34, 36, 38, 45, 47, 61-63, 64, 71, 75, 121, 171, 217, 223-226, 246, 262, 263, 265  
between cost and quality, 33, 38, 41, 45, 62, 64, 120-122, 193, 264-265  
between two types of error, 25 (footnote)  
in a factorial experiment, 92-93, 101  
statistical, 59, 76, 93, 150, 157, 159, 170-171 (See Stability; Statistical control)
- Ballast lamps, 224, 225
- "Band" of acceptable levels, on a control chart, 63, 64, 65, 120, 193-194, 195-196
- Barrel plating, 156
- Bartlett's test, 78, 79-80, 83
- Batches of material, 61, 62, 151, 196, 218
- Batch-type operations  
(See Intermittent operations)
- Beaker, 218
- Bearing, 15, 126, 219
- Bell System, 270
- Benches, 192, 218
- Benefits  
of control charts (See Advantages)  
to shop, 36, 63, 64, 71, 219
- Bent springs, 270
- "Between sample" causes, 150
- Bias  
in a sample, 113, 116, 207, 214, 267-268  
in a technique, 30, 114, 116, 204  
Bias between measurements in a designed experiment, 111
- Bifurcated springs, 53
- Bimodal distributions  
causes of, 136  
examples of, 153, 154, 162, 163, 165, 169, 172, 174, 176, 179  
(See Non-normal distributions)
- Binding, 70, 71
- Binomial distribution, 239, 242, 252 (footnote), 278
- Bins, 167, 171
- Blank charts and data sheets, 207, 210-211, 228, 271
- Blindfolded driver, 216
- Block design, 92
- Blueprint limits, 16, 30-31, 119, 189, 205  
(See Specifications)
- Board for control charts, 209, 217, 218
- "Boats" in an oven, 114
- Bolts, 156
- Bonding (of contact to wire), 209
- Bottlenecks, 33, 77, 187, 202, 246  
(See Delays)
- Bowker, A. H., 242, 262, 277
- Boxes  
assignment of variables to, in an experiment, 92, 98, 102-103  
identification of, in an experiment, 98

Boxes, *continued*  
 number of measurements in, 93, 111, 113  
 of product, 157, 173  
 shaded, 97, 106, 107, 110, 111  
 Breakdown  
 by operations, 166  
 dielectric, 20, 162  
 of data, 36, 54-55, 166, 199, 218  
 (See Production paths)  
 of facilities, 163, 180  
 of pattern, 55, 66-68, 72, 166  
 of  $p$ -chart, 48, 59, 159  
 of process controls, 233, 273-274  
 of quality safeguards, 273, 274  
 voltage, 20  
 "Bright dip" finish, 102  
 Broken bolts, 146  
 Brownlee, K. A., 79, 80, 81, 96, 97, 101, 116, 148, 278  
 Budge, 54  
 Bulk of shop records, 228-229  
 "Bunching" of measurements, 11, 31, 54, 68, 160, 161, 165-166, 179  
 Burr, I. W., 101, 132, 135, 277  
 Burrs  
 as a variable, 156, 162, 270  
 example of data on, 49-50, 113  
 Business  
 at quality control meetings, 40, 41, 223-224, 226, 236  
 unfinished, 47, 63, 122, 235-236  
 By-products  
 of process capability studies, 34, 36  
 of shop charts, 36, 38, 233, 262

## C

$\bar{c}$ , 21  
 Cable, 3  
 Calculation of control limits  
 as a variable, 153-154, 156, 173, 219  
 for a moving range chart, 8, 22, 173-174, 191, 196, 197, 222  
 for an  $\bar{X}$  and  $R$  chart, 12-14, 82-83, 153-154, 191, 194-195  
 for an  $\bar{X}$  chart, 138  
 for attributes charts, 7-8, 17-18, 20, 21, 191, 196-197  
 for designed experiments, 97, 98, 107-108, 111  
 for miscellaneous control charts, 74, 197-198, 221-222  
 for process capability studies, 51-52, 53  
 Calculations  
 authorized by Quality Control Team, 228  
 correctness of, 4, 145, 162, 173, 215, 227

in an experiment, 82, 86, 94-97, 98, 107-109, 110  
 made by process checker, 192, 208, 213, 214-215, 227  
 made by statistical clerk, 228-229  
 mistakes in, 4, 162, 163, 173, 180, 215, 227  
 of average, 12, 71, 129, 137, 197, 213  
 of effects in data, 94-95, 98, 103  
 of measurement error, 88, 89  
 of percentage, 18, 19, 20, 213, 215  
 of percentage outside of limits, 30-31, 54, 58-59, 71, 127, 132-136  
 of probabilities, 180-183, 239-242  
 of process capability, 53-54, 56, 58-59, 71  
 of  $p$  values, 17, 18, 20, 162, 215  
 of range, 12, 131, 213, 214-215  
 of  $\bar{R}$ , in a designed experiment, 98, 107-108  
 of residual, 96-97, 97-98, 106, 107, 110, 111  
 of  $R$  points, 12, 14, 82, 86, 109, 162  
 of sigma, 56, 58, 71, 88, 89, 123, 124, 127, 130, 131, 147-148  
 of sigma for a line of regression, 145  
 of skewness, 56, 59, 122, 131, 134-136, 196  
 of spread, 30-31, 56, 58-59, 71, 122, 123-124, 127, 130-131, 195  
 of tests for unnatural patterns, 25, 109, 180-183  
 of  $\bar{X}$  points, 12, 14, 82, 86, 109, 162  
 optional, in an experiment, 98  
 shortcut methods for, 97-98, 110, 130-131  
 Calibration, 53, 113, 153, 159, 165, 175  
 Capability  
 approach to, 36, 47, 63, 71, 73, 74  
 as a percentage, 45, 56, 59  
 as a percentage of defects, 235, 244, 245, 250, 253, 265, 273, 274  
 compared with performance, 45, 61, 74, 187-188, 265  
 determination of, 53, 54, 56  
 of a machine, 33, 35, 46, 170, 172, 175, 202, 204, 207, 224, 235  
 of an operator, 35, 46, 57, 73, 170, 202, 204  
 of a process (See Process capability)  
 of a tool, 35, 46  
 of designs, 35, 46, 47, 224  
 of material, 35, 46, 224  
 of methods, 35, 46, 224  
 overall, 46, 48

Capacitance, 102  
 Capacitors, 4  
 Capacity, 38, 46, 224, 226  
 Car, 216  
 Care shown by operators, 33, 164, 178, 203  
 Carelessness, 55, 155, 156, 167, 175, 180, 235  
 Carrier tubes, 224, 225  
 Cases, cost reduction, 38, 47, 54, 62, 71, 224, 225, 226  
 Casual checks, 190, 224  
 Categories  
 for data, 55, 92, 101-102, 210, 271 (See Production paths)  
 for operations, 224-225  
 Cause and effect relationships as shown by a control chart, 10, 11, 27, 35-38, 53, 66-73, 149-180, 187, 190, 218-220  
 as shown by correlation, 29, 56, 143-144, 146, 176-177  
 as shown by process capability studies, 34-36, 46-47, 49, 54-56  
 as studied in designed experiments 4, 75-76, 99-101, 111-112  
 revealed through unnatural patterns, 6, 9, 11, 34, 35, 36, 54-56  
 verification of, 56, 177  
 (See Correlation; Causes)  
 Causes  
 abnormal, 6  
 affecting a  $p$ -chart, 17, 48, 158-159, 192  
 as related to correlation, 146, 176-177  
 assignable (See Assignable causes)  
 associated with patterns, 6, 9, 11, 35-36, 54-56, 66-71, 99-101, 149-161, 161-180, 212, 215, 217-219  
 associated with unstable patterns, 55, 66-70, 166-167, 179-180  
 "between sample," 150  
 combinations of, 37-38, 67, 68, 70, 166 (See Interactions)  
 detectable through unnatural patterns, 6, 9, 11, 35-36, 37-38, 54-56, 161-180, 197, 221  
 elimination of, 153  
 erratic, 68, 166  
 extraneous, 91, 149, 166  
 found by Shop, 71, 190, 208, 212-213, 215, 217-219, 227  
 hidden (See Hidden variables)  
 identification of, 56, 166  
 known to Operating, 48, 188, 218  
 large, 6, 55, 66-67, 70  
 not applicable, 69  
 of a natural pattern, 170-171

- of bunching, 165-166
- of complex patterns, 55, 66-73, 166, 167-169, 179-180 (*See also* Mixtures; Stratification)
- of cycles, 69-70, 161-162
- of defects, 46, 66-71, 72-73, 233, 235, 246, 265
- of disturbances on chart of individual measurements, 31, 160-161
- of disturbances on various attributes charts, 157-160
- of disturbances on  $p$ -chart, 31, 157-159
- of disturbances on  $R$  chart, 30, 66-68, 154-156, 168
- of disturbances on  $\bar{X}$  chart, 30, 152-154
- of freaks, 163-164
- of gradual change in level, 164-165
- of grouping, 165-166
- of instability, 55, 166-167
- of interaction, 167-169
- of mixtures, 169-170, 171, 179-180
- of natural variation, 6, 150, 171
- of patterns, 149-180
- of repairs, 46, 64, 188, 189
- of rework, 37, 46, 188, 202
- of scrap, 37, 46, 188, 202, 217
- of skewness, 56-58, 70
- of stratification, 53, 173-174
- of sudden shift in level, 174-175
- of systematic variation, 175-176
- of tendency of one chart to follow another, 176-177
- of trends, 10, 53, 164, 177-179
- of trouble, 10, 11, 35, 36-37, 46, 187, 188, 189-190, 202, 217
- of unnatural variation, 6, 35-36, 149-151 (*See* Causes detectable through unnatural patterns)
- on shop charts, 71, 208, 212-213, 215, 217-219, 227
- operating in combination, 37, 66-68, 70, 166, 167-168
- outstanding, 70
- simple, 38, 54, 72, 166, 217
- single, 4, 37, 45, 68, 70, 166
- susceptible to analysis, 54, 55, 67, 70
- tracing of, in inspection, 261
- ultimate, 166, 171
- unknown, 4, 10, 34, 38, 46, 54, 66, 75-76, 188, 190, 218-219, 223
- "within sample," 150
- Cause system, data representative of, 50-51, 66, 76  
(*See* Systems of causes)
- Caution
  - in interpreting control charts, 66, 72, 154, 159, 160, 161, 197
  - in using designed experiments, 76, 112
- Cavity, 152
- $c$ -Charts, 20-21, 48-49, 66, 72-73, 137, 189, 191, 196-197, 204
- Cells
  - midpoint of, 130, 131, 140
  - used in calculating standard deviation, 130-131
  - used in making a frequency distribution, 138-140
- Center
  - allowable shift in (of a process), 64, 65, 122, 193-194, 195-196
  - estimated from a process capability study, 56, 61, 62, 119
  - methods of adjusting, 30, 120-121, 202, 203-204
  - of a distribution, 30, 53, 56, 71, 121, 129, 138, 139-140, 152, 160, 188
  - of a distribution (as an inspection requirement), 119, 122, 265
  - of a process, 53, 56, 193-194, 195-196, 212
  - of the sampling distribution of averages, 138
  - shown by an  $\bar{X}$  chart, 16, 30, 48, 53, 56, 62, 67, 152
  - (*See* Central tendency; Centerlines)
- Centering
  - between specifications, 64, 65, 120-121, 160, 193, 220
  - of a distribution, 120, 121, 188, 226
  - of a machine, 30, 188
  - of a process, 30, 62, 64-65, 120-121, 167, 170, 188, 202, 220
  - of parts etc. (*See* Alignment.)
- Centerlines
  - definition of, 152, 193-194
  - double, 64, 65, 193, 195-197
  - economic, 62, 64-65, 192, 193-194, 195-197
  - for shop control charts, 63, 64-65, 190, 192, 193-196, 228
  - on an  $R$  chart, 12, 14, 71, 87-89, 98, 100, 107-108, 131, 154-155
  - on an  $\bar{X}$  chart, 12, 90-91, 228
  - on experimental control charts, 98, 100, 107-109
- Central tendency
  - estimated from a process capability study, 56, 59-60, 61-62, 119
  - measures of, 30, 56, 129
  - on an  $\bar{X}$  chart, 152, 154
- Certainty
  - degree of, in conclusions from a control chart, 9, 10, 25 (footnote), 52, 180-183
  - degree of, in conclusions from an experiment, 97, 99, 100, 107, 109, 112  
(*See* Risk)
- Chain sampling, 262
- Chamfer, 156, 235
- Chance
  - effects due to, 24, 103, 150, 171
  - of accepting poor product, 245
  - of rejecting good product, 244-245, 255, 273
  - of wrong decisions, 25 (footnote), 83-84, 100, 107, 112, 237-238, 278
  - laws of, 6, 24, 116
  - second, for an inspection lot, 260  
(*See* Chance causes; Certainty; Risk)
- Chance causes, 24, 25 (footnote), 152
  - effect of, on a control chart, 9, 24, 150, 170-171
- Changes
  - abrupt, 11, 164, 178
  - based on control charts, 10, 16, 37, 67, 72, 166-167, 188, 199, 202-204, 217
  - detected by control charts, 8-9, 25, 35-36, 37, 51-52, 83, 218, 220
  - effect of, on product, 46, 72, 202
  - engineering, 46, 62, 63-64, 69, 70, 72, 224
  - gradual, 11, 161, 164-165, 177-179
  - in a cause system, 6, 8-10, 19-20, 25, 27, 37-38, 53-54, 61, 62, 66-71, 83, 141
  - in a fixture, 53, 69, 83, 164, 175, 213, 215, 219, 235
  - in a process, 6, 8-10, 19, 37, 46-47, 49, 53, 54, 61-63, 64, 66-72, 120-122, 141, 187-190, 192, 198-199, 202, 203, 206, 208, 212-213, 215, 218-220, 224, 226
  - in assortment of product, 166
  - in average, 153, 170
  - in calibration, 53, 113, 153, 159, 175
  - in design, 46, 51, 198, 224
  - in design of tool, 46, 212, 219
  - in distribution, 37, 57-58, 122, 141, 152-158, 164, 166, 174, 178, 179-180
  - in efficiency, 71, 158
  - in equipment, 47, 53, 70, 113, 174, 215
  - information on, in a process, 35, 37, 54, 72, 208, 215, 217, 218



## Changes, *continued*

in gaging, 72  
in inspection levels, 246, 273-274  
in layouts, 40, 192, 198-199, 219, 223-224  
in master control chart, 65, 228  
in material, 30, 62, 63, 174, 176  
in method of test, 165, 180, 218, 219  
in methods, 30, 46-47, 62, 63, 68-70, 121, 174, 219, 226  
in methods of assembly, 46, 70, 175, 226  
in motion patterns, 158, 219  
in operations, 187, 202  
in pattern (on a chart), 55, 67, 73, 153, 155, 164-165, 166, 168, 174-175, 177-179, 203, 206, 218  
in personnel, 227 (*See* New operators)  
in product characteristics, 164  
in proportions, 153, 157, 178, 179  
in requirements, 198  
in schedules, 155, 166, 178, 198, 224  
in setup, 16, 30, 71, 174, 188, 202, 203-204  
in shape of distribution, 57-58, 160  
in shop charts, 38, 41, 65, 189-190, 198-199, 219, 223, 227-229  
in specifications, 10, 34, 35, 36, 38, 46, 47, 48, 57, 61-65, 120-122, 187, 188, 198, 203-206, 219, 220, 224, 226  
in spread, 71, 120, 121, 154-156, 179  
in standards, 31, 158, 159, 165, 175, 178  
in suppliers, 207  
in test sets, 47, 165, 167, 175, 180, 218  
in the design of process control charts, 189-190, 198-199, 219, 223, 224  
in work habits, 158, 167, 219  
of water in tank, 50  
visual impressions of, 160, 178 (*See* Intuitive impressions)

## Characteristics

associated with trouble, 64, 66, 121, 188  
combined on a *p*-chart, 17, 48, 59, 157-159, 189, 190  
effect of, on other characteristics, 46, 64, 187, 202, 218, 223 (*See* Interactions)  
for inspection, 263, 265, 268, 270 (*See* Inspection items)  
of a distribution, 6, 129  
of a product, 48, 66, 91, 101, 180, 202, 270

## of the letter "a," 7

plotted on a control chart, 66, 188-189  
quality, 3, 132, 188, 265  
to be checked, 201, 202, 209, 265, 270  
to be plotted, 66, 99, 106, 108, 113, 188, 189

## Charge on an electron, 6

Chart holders, 192, 228

## Charts

maintained by Inspection, 39, 225, 246, 262-263, 265, 274  
plotted by engineers, 53, 82, 86-88, 107-109  
plotted by the Shop, 213-216 (*See* Control charts; Process control charts; Shop charts)

## Charts for individual measurements

amount of data required for (in engineering studies), 50-51  
apparent stratification on, 173-174

calculations for, 21-22

causes affecting, 162, 163, 165, 166, 167, 171, 175, 176, 179, 180

centerlines for, in the shop, 193-194, 196

construction of, 21-22

control limits for, 8, 11-12, 21-22  
control limits for, in the shop, 194, 196

examples of, 5, 8, 22, 23

general use of, 11, 12

importance of, 12

interpretation of (*See* Interpretation)

samples for, in the shop, 191

sensitivity of, 11, 12, 160, 161

substitutes for, 198

symbols for, 21

used for correlation, 144

uses in the shop, 188, 189

where to use, in general, 11-12, 21, 22, 23, 50, 144, 160-161, 189, 196, 221-222

## Checking

as a variable, 4, 31, 159, 167, 171, 180, 215-216

devices, 192, 209, 270

frequency of, 41, 192, 199, 209, 219, 227

intervals, 41, 190-192, 199-207, 214, 219, 227, 233, 262, 274

of freaks, 52, 70, 117, 163, 218

of gages, 219

of machine setter's notes, 67

of machine setting, 30, 202, 203-204, 217, 219

of possible causes, 55, 69, 161, 166, 217-218

of process controls, 41, 187, 189-190, 198, 219, 227, 233-234, 273-274

of samples, 192, 207-209, 213-216, 227, 268-269

Chemical operations, 4, 11, 21, 23, 35, 48, 114, 189, 224, 225

Chi-square test, 78, 79, 80, 82, 133, 140, 278

Chronic troubles, 188

Chronological history, 192, 228-229

Chucks, 55, 69, 176, 180, 213, 219

Circled effects, in an experiment, 95, 98

Circled *x*'s, on a control chart, 28-30

Circuit, 68

## Clarity

of patterns, 54-55, 67-68, 166

of specifications, 61-63

shown by *x*'s, 67

Classical methods (other than control charts), 78-81, 83-84, 91, 93-97, 144-148, 278

## Classification

basis of, for *p*-chart, 158, 159

in inspection, 268, 270

of data, 55, 56, 166

of defects, 198, 263, 270

Cleaning operations, 35, 50, 91, 93, 100, 101, 114

Clearances, 126-127, 188

(*See* Assembly tolerances)

## Clearing

in continuous sampling, 256, 257, 269

interval, 256, 270, 271

sample, 256, 257, 267

Clerical work, 3, 34, 50, 228-229

Clerks, statistical, 216, 228-229

Clinching operation, 270

Clogging of fixtures, 178

## Closing

of a cost reduction case, 226

of items in control chart audit, 227

Cloth, 20, 191

Clues obtained from pattern, 55, 66, 67, 68, 166

Clustering of measurements, 160, 165-166

## Code numbers

referring to notes on a control chart, 208, 212

referring to product, 167, 171, 196  
referring to semi-variables data, 49-50 (*See* Semi-variables)

Codes of product, 160, 167, 171, 196

Cold weld, 212

## Collection of data

for shop charts, 38, 41, 63-64, 65, 77, 190-192, 201, 205-210, 213-216, 219, 223, 227, 228, 229

- in a process capability study, 36, 41, 47, 49-51, 55, 62, 63-64, 66, 67, 74, 223, 228
- Comb (on a relay), 19
- "Combination" residual, 96-97, 110
- Combinations
  - of causes, 68, 70, 166, 167
  - of characteristics on a  $p$ -chart, 17, 48, 59, 157, 159, 189, 190
  - of distributions, 68, 121, 122-124, 126-127, 160, 166 (See Mixtures)
  - of variables in an experiment, 91, 92, 93, 97, 100-101, 105-106, 108, 116, 117 (See Interactions)
- Comments on control charts, 53, 66-67, 188, 208-209, 212-213, 215, 221
- Comparator, 209, 213
- Comparisons
  - basis for, on a  $p$ -chart, 51, 159
  - between process and specification, 30-31, 58-59, 61-63, 64-65, 71, 119-122, 170, 204-206, 224 (See Process)
  - between shop chart and process capability study, 63
  - of assembly techniques, 46
  - of control charts with other methods, 75, 79, 82-84, 91, 93, 97, 98, 106, 110, 112, 141, 167, 203-204
  - of designs, 46
  - of distributions, 71, 139-141
  - of engineering responsibility vs. shop responsibility, 46, 204, 224
  - of instruments, 84, 89
  - of machines, 36, 46, 49, 54, 90, 159, 170, 171, 172-173, 175, 202, 215, 224
  - of methods, 35, 46, 53, 55, 63, 72, 90, 92, 175, 202, 218, 220, 224
  - of operators, 36, 49, 55, 159, 170, 171, 175, 204, 215, 218
  - of suppliers, 36, 39, 55, 162, 207
  - of tools, 46, 55, 224
  - of two  $R$  charts, 67-68
  - of variability, 78-80, 83, 87-89, 154-156
  - of variables in an experiment, 4, 91-101, 101-106, 112, 114
  - to be based on natural patterns, 53-54, 58, 59, 61, 122, 170, 204-206
- Compatibility
  - of process with specification, 119-122
  - of specifications with each other, 64, 121
- Compensation for process variables, 37, 64, 220
- Competence
  - of inspector, 155, 218, 236
  - of operator, 155, 164, 167, 175, 178, 180
  - of process checker, 171, 213, 215-216, 218
- Complaints, 38, 62, 226, 246, 264
- Complete
  - inspection of samples, 227, 260, 261, 268
  - job studies, 224-225
- Completion of studies made by engineer, 38, 45, 47, 61, 62, 63-65, 71, 74, 75, 221
- Complexity
  - causes of, 35, 36, 37-38, 54-56, 66, 67, 68, 69, 75 (See Instability; Mixtures; Freaks)
  - in experimental designs, 76, 77, 114
  - of apparatus, equipment etc., 3-4, 20, 21, 38, 55, 122-124, 166, 189
  - of cause systems, 3, 4, 38, 45, 75, 171
- Complex patterns
  - assignable causes in, 66
  - examples of, 66-67, 72
  - importance of, 35, 54
  - importance of  $R$  chart in analyzing, 55, 66-69, 153, 155, 168 (See  $R$  chart)
  - in a process capability study, 54-56, 66, 67-73
  - interpretation of, 54-56, 66-71, 72-73, 166
  - on a  $c$ -chart, 72-73
  - on an  $\bar{X}$  and  $R$  chart, 66-71
  - on a  $p$ -chart, 17, 48, 59, 157, 159, 162, 163, 167, 171, 173, 180, 196-197
  - list of, 11, 54, 161
  - simple causes for, 37-38, 54, 70, 166
- (See Unnatural patterns; Simplification)
- Complicated variables (in a process capability study), 55, 66
- Complications due to interactions, 76, 77, 91, 105-106, 167-169
- Component distributions, 68, 122, 124-125, 127, 153, 155, 160 (See Mixtures)
- Components
  - of assemblies, 4, 55, 122, 124-127
  - of distributions, 153
  - of mixture, 166, 169-170, 171
  - of variance, 75, 89, 93, 95-97, 98
  - on a  $p$ -chart, 48, 59, 157, 159
- Composition of chemical baths, 23, 114
- Concise reports, 224, 225, 226
- Conclusions
  - based on averages, 61, 78, 111, 153, 154
- from a control chart, 8-10, 15-16, 19-20, 30-32, 48, 53-56, 203-206
- from analysis of variance by control chart method, 100-101, 111-112
- from analysis of variance by sum of squares method, 81, 97
- from an experiment, 76, 77, 81, 82-83, 87-89, 92, 97, 100-101, 111-112, 220
- from a process capability study, 35, 36, 53-56, 58-60, 61-63, 71, 73, 75, 76, 112
- Condensed history, 229
- Conductive material, 165
- Conductivity, 21
- Conferences, 219, 246 (See Meetings)
- Confidence
  - in control charts, 10
  - in process controls, 273, 274
  - intervals, 278
- Conflict
  - between Operating and Inspection results, 274
  - between process and specification, 122 (See Comparisons; Specifications)
  - between quality and cost, 264-265
- Confusion
  - between control limits and specification limits, 16, 30-31, 151, 190
  - in speaking of natural tolerance, 61
- Connections in an assembly, 17, 191
- Consistency
  - associated with a natural pattern, 150
  - associated with an  $R$  chart, 30, 154
  - in judgment, 50
  - in shop practices, 223, 227
  - of results, 48, 71, 77, 88, 89, 101 (See Reproducibility)
- Consolidation of charts, 41, 199
- Constancy
  - artificial, 29, 172-174
  - associated with a natural pattern, 150, 170-171
  - assumption of, 78, 79, 82, 114, 218
  - hypothesis of, 82, 83
  - of inspection load, 260
  - tests for, 25-28, 78, 82
- Constant
  - quantity, for a  $c$ -chart, 20, 191
  - sample size, 18, 20, 191
  - system of causes, 6-7, 9, 10, 45, 53, 83, 150, 170-171
- Consumer's risk, 245, 246
- Contacts (on a relay), 19, 154, 209

- Containers, for product, 157, 173
- Contingency tables, 278
- Continuity in shop operations, 36, 46, 187, 202, 217, 219
- Continuous
- checks on control charts, 38, 41, 64, 190, 192, 201, 217-219, 221-222, 223-225, 227
  - disturbance in a process, 150
  - movement of a pattern, 9, 29-30, 160, 177
- Continuous sampling plans, 255-258
- Contraction (as a variable), 153
- Control
- automatic, 10, 70, 156, 171, 180, 235
  - by machine setters, 48, 188, 202, 203-204
  - by operators, 48, 188
  - economical, 36, 63, 220-221
  - importance of, 10, 35-38, 53-54, 59-61, 62, 75, 122, 124-127, 141, 150-151, 171, 187-190, 217, 220-221, 225-226, 233, 273-274
  - meaning of, 3, 5-7, 35-36, 37-38, 53-54, 150, 171, 220-221
  - of a process (See Process control)
  - of inspection piece rates, 260
  - of lots, 163, 164, 167, 171, 180, 260-262
  - of manufacture, 226
  - of shop processes, 35, 37, 63, 187, 190, 202, 217, 219, 220-222, 223-226
  - reasons for lack of, 190, 219, 221
  - results in savings, 10, 35, 36, 38, 46-47, 62, 187, 217, 225-226, 246, 265, 274
  - state of, 6-7, 9, 10, 36, 37-38, 41, 45, 53-54, 56, 59, 71, 119, 122, 126, 127, 149, 150, 170-171, 189, 204, 205, 206, 219, 220-221, 222, 244, 246, 265, 273-274
  - statistical (See Statistical control)
  - (See also "In control" and "Out of control")
- Control chart audits, 227
- Control chart forms, 192, 207, 210-211, 228-229
- Control chart formulas
- (See individual names of control charts)
- Control chart patterns, 4, 5-7, 11, 23-25, 66-71, 161-180, 219
- (See Patterns; Natural patterns; Unnatural patterns; Tests for unnatural patterns; Interpretation of patterns)
  - (See also the names of individual patterns)
- Control charts
- (See individual names of control charts: *p*-Charts, *np*-Charts, *c*-Charts, *u*-Charts,  $\bar{X}$ -charts, *R* charts, Charts for individual measurements, Demerit charts, "Dot" charts, Multi-vari charts, Summary control charts, "Sum and range" charts, "Total and range" charts, "X" charts *t*-Charts)
  - (See also Control charts in general, Control chart sampling plans, 39, 246, 262-263, 265, 268, 274)
- Control charts in general
- administrative uses for, 3, 4, 10, 21, 22, 23, 46, 225-226
  - advantages of, 9, 10, 36, 38, 83-84, 91, 97, 187, 202-203, 265
  - appearance of, 192, 216, 221, 228-229
  - as basis for correct interpretation of data, 9
  - as related to assignable causes, 149-151
  - as related to order of production, 151
  - as foundation of a quality control program, vii, 4, 33, 187
  - as source of assurance, 274
  - as the central concept in statistical quality control, 4
  - attributes, 5, 7-8, 11
  - audits, of, 227
  - based on sampling distributions, 23, 137, 151
  - basis for confidence in, 10
  - compared with other statistical methods, 78, 79, 82-84, 91, 93, 97, 98, 100-101, 106, 110, 131, 141, 143-144, 145
  - confidence in, 10, 274
  - consolidation of, 41, 199
  - construction of, 12-23, 107-111, 193-197
  - correlated, 121, 156, 176-177, 218, 223
  - correlation on, 11, 143-144, 145, 153, 156, 161, 176-177
  - durability of, 192
  - effect of, in the shop, 37-38, 155, 164, 177, 187, 202-203, 235, 265
  - experience in reading, 67
  - formation of patterns on, 4, 149
  - forms and routines for, 192, 207, 210-211, 213-215, 217-219, 227-229
  - formulas for (See Control chart formulas)
  - for solving problems, 31, 33, 34-36, 45-47, 63, 187, 202
  - holders for, 192, 228
  - improvement due to, 19-20, 164, 177, 202, 235, 265
  - in experimental work, 75-112, 220
  - interpretation of, 9, 10, 30-31, 53-56, 66-73, 152-180, 218-219
  - maintenance of, 192, 224, 227, 228-229
  - meaning of, 3, 5-10
  - mounting of, 192, 228
  - need for, vii, 9, 10, 15, 33-38, 45-47, 141, 158, 187-189, 190, 198-199, 202, 219, 265
  - non-random arrangement of samples on, 149, 160 (See Sequence)
  - plans for, in the shop (See Process control charts)
  - plotting of, 5-6, 12-15, 17-19, 20-21, 22, 51, 53, 65, 72-73, 143-144, 192, 213-216
  - plotting of, in an experiment, 82-83, 85, 98-99, 107-109, 111
  - properties of, 4, 10-12
  - random samples for, 51, 113, 114-116, 192, 207, 214
  - rational subgroups for, 151
  - reacting together, 156, 176-177, 218, 223
  - reading of, 67, 69 (See Interpretation)
  - reliability of, 10 (See Certainty; Risk)
  - removal of, 41, 189, 199, 219, 223, 227
  - results from, 10, 35-36, 38, 187, 225-226
  - reversion to, after sampling plan, 262, 263
  - right and wrong use of, in shop, 202
  - sequence of points on, 4, 6, 23, 29, 55-56, 72-73, 99, 109, 149, 151
  - simple introduction to, 5-10
  - simplicity of, 91, 97
  - statistical background of, 5-7, 23-25, 35-36, 37-38, 149
  - theory of, 5-7, 137-138, 149-161
  - types of, 10-12, 188
  - unnecessary, 219 (See Removal)
  - used as a basis for accepting product, 246, 262, 263, 274
  - used as sampling plan (See Control chart sampling plans)
  - used by inspectors, 39, 246, 262-263, 274
  - used by operators, 158, 164, 203, 235, 265
  - used in reports, 226
  - used to evaluate cost reduction savings, 224, 226
  - verification of, 10, 274
  - Who should plot? 216, 234

- (See Process control charts; Process capability studies; Designed experiments)  
(See also the individual names of control charts)
- Control chart tests  
(See Tests for unnatural patterns)
- Control limits  
based on  $R$  chart, 13, 14, 97, 111, 153, 156  
based on residual, 97-98, 107-108  
calculation of, 7-8, 12-23, 51-52, 64, 65, 74, 97, 98, 99, 107-108, 111, 191, 192, 194, 195-197, 198, 228, 229  
calculation of, as a variable, 173, 219  
calculation of, by statistical clerks, 229  
compared with drawing limits, 16, 30-31, 62, 151  
compared with spread of individuals, 13, 16, 30-31, 72-73, 137-138  
confused with specification limits, 16, 30-31, 151, 190  
economic, 64-65, 194, 195-197  
explanation of, 7-9, 51-52, 87-88, 99, 107, 194-195  
for a  $c$ -chart, 20, 72  
for a chart of individual measurements, 22, 161, 173-174, 191, 196  
for an  $np$ -chart, 20, 191, 229  
for an  $R$  chart, 12-13, 97-98, 99, 108, 154  
for an  $\bar{X}$  chart, 13, 87-89, 99, 108, 138, 153-154  
for a  $p$ -chart, 17-19, 191, 194, 196-197, 229  
for a  $u$ -chart, 21, 191  
for shop charts in general, 64, 192, 194-195, 196-197, 219, 229  
in a designed experiment, 82, 87-89, 97, 98, 99, 107-108, 109  
incorrect, 52, 153, 173-174, 219  
inner, 99, 100, 107-108, 109  
modified, 121, 195-197  
outer, 99, 100, 107-109 (See Three sigma control limits)  
precision of, 9, 52, 161  
sensitivity of, 8, 9, 150, 161  
special types of, 197-198  
theory of, on the  $\bar{X}$  chart, 138  
too narrow for pattern, 11, 24, 72-73, 150, 153-154, 166  
unsymmetrical, 18, 28, 182-183, 191  
width of, 13, 17, 22, 87, 153-154, 173  
width of, in a designed experiment, 109
- Conveyors, 176, 256
- Cooling, 69 (See Temperature)
- Cooperation  
between Operating and Engineering, 33, 38, 39-41, 45, 65, 74, 188, 190, 202, 219, 220, 223-226  
in a cost reduction case, 226  
through Quality Control Teams, 39-41, 45, 64, 66, 187-199, 201-202, 219, 220, 221, 223-229, 236
- Copies of shop charts, 192, 207, 228
- Core (for a relay), 64
- Core plate, 58
- Corrected main effects, 105, 106
- Correction factor  
in a sum of squares analysis, 81, 94, 96  
in  $F$ -test, 79
- Corrective  
action, based on control charts, 41, 189-190, 198-199, 217-219, 223, 227, 263 (See Action)  
sorting (See Sorting)
- Correctness  
of calculations, 162, 163, 173, 215, 227  
of conclusions in an experiment, 77, 83-84, 92, 101, 112, 117  
of conclusions in a process capability study, 54, 56, 61-63, 67, 72  
of control charts, 10, 189-190, 199  
of measurements (See Error)  
of plotting, 163, 214-215, 227  
of shop data, 49, 117, 214-216
- Correlation, vii, 143-148  
absence of, 56, 143, 146  
as related to cause and effect, 146, 176-177  
as represented by a line of best fit, 144-145  
as represented by a line of regression, 144-146  
between characteristics, 35, 46, 113, 121, 176-177, 187, 218, 223  
between control charts, 53, 69, 176-177, 218, 223  
between specifications, 64, 120-121  
between  $\bar{X}$  and  $R$  points, 69, 156, 176-177  
coefficient of, 145, 146-147  
curvilinear, 148  
degree of, 146, 147, 148, 177  
discovery of, 46, 218, 223  
level to level, 176-177  
multiple, 148  
negative, 143, 146, 156  
on control charts, 143-144, 145, 156, 176, 177, 202, 218, 223  
partial, 148  
point to point, 69, 156, 176-177  
positive, 143, 146, 156  
possible effect of, on specifications, 64, 121  
regression lines for, 144-145, 148  
scatter diagrams for, 143  
significance of, 56, 146, 147, 177  
slope of, 144-145  
trend arrangements for, 143-144  
used as a method of simplifying patterns, 56
- Cost reduction  
as one of the aims in a process capability study, 34, 35, 36, 46, 47, 54, 62, 63, 71, 223-226, 228, 235  
as one of the aims in a shop chart, 34, 36, 38, 187, 224, 226  
as one of the objectives in sampling inspection, 39, 187, 233-236, 274  
as one of the objects of a designed experiment, 34, 91, 101, 112, 226  
carried out by Quality Control Team, 33, 41, 71, 223-226  
closing of, 226  
cooperation of Shop in, 224, 225-226  
examples of, 38, 71, 226  
formal cases of (See Cases)  
from unnatural patterns, 35, 54, 171  
importance of, in a quality control program, 33-34, 226  
opportunities for, 34, 36, 54, 62, 71, 120, 171, 188, 225-226  
reports on, 224, 225-226  
through decreased inspection, 34, 38, 39, 71, 188, 225, 226, 233-236, 246, 273-274  
through process capability studies, 10, 34, 36, 54, 62, 66-71, 224, 226  
through process control charts, 10, 36, 38, 41, 62, 64, 72, 224-226, 265  
through process improvement, 34, 36, 38, 71, 224, 225-226, 233
- Costs  
affected by grouping of inspection items, 263  
affected by inspection, 233, 236, 244, 245-246, 254-255, 260, 273-274  
affected by quality rating, 273  
associated with producer's and consumer's risks, 245-246  
associated with unnatural variation, 35  
conflict of, with quality requirements, 265  
effect of, on inspection levels, 255, 265

- Costs, *continued***  
 information on, 40, 46  
 of obtaining data, 17, 47-48, 77, 92, 116, 188, 189  
 of inspection, 33, 34, 35, 36, 39, 46, 71, 187, 233-236, 246, 260, 263, 273-274  
 of maintenance, 4  
 of manufacture, 10, 33-34, 35, 36, 38, 46-47, 54, 62, 64, 187, 193, 217, 226, 236, 244-246, 255, 262-263, 265  
 of process control charts, 38, 189, 190-192, 199, 223, 225-226  
 of selecting samples, 260  
 reduction of (*See* Cost reduction)  
 standard, 40, 46
- Counts, 11, 20-21, 137, 191**  
**Courses, vii, 23, 33, 97**  
**Coverage (with control charts), 34, 38, 41, 72, 189, 224-225, 226**  
**Cracked insulators, lugs etc., 270**  
**Cracks, 12, 113**  
**Criteria**  
 change in, 31, 159, 268  
 for action, 208-209, 237  
 for classifying units of product, 157, 159  
 for inspection, 227, 237, 268, 269  
 for process control, 208, 227  
**Criterion I (Shewhart's), 25 (foot-note)**  
**Critical**  
 defects, 198, 263  
 material, 262  
**Crossbar frames, 20**  
**Cross-classification, 36, 55, 72, 85, 92-93, 101-103, 167-169**  
**Cross-referencing of layouts, 205, 227, 267, 270**  
**Cubing, as a cause of skewness, 57**  
**Curing, 102, 104**  
**Current**  
 difficulties in the shop, 33, 187, 202, 224  
 electrical, 66, 68, 71, 152  
 level of business, 226  
 production, 225, 226  
 shop charts, 189, 199, 224-225, 227, 228-229  
**Curtailed inspection, in double or multiple sampling, 261**  
**Curve**  
 AOQ, 251  
 drawn by eye, 31, 59, 137, 144  
 fitted to a set of data (*See* Curve fitting)  
 operating characteristic (*See* OC curves)  
 representing a sampling plan, 238-239  
 slope of, 144-145, 164, 242
- Curve fitting, 139-141**  
**Customer's interests, 246, 254, 264, 270, 273**  
**Cutting tool, 207**  
**Cycles**  
 causes of, 69, 70, 161-162  
 examples of, 69, 162  
 in production, 66  
 in the sense of electrical frequencies, 48  
 of steps in a process capability study, 34-35, 36, 47, 63  
 on control charts, 11, 31, 53, 54, 69, 70, 160, 175  
 short, 160  
 tracing of, 69, 70
- D**
- $d_2$  factor, 56, 58, 71, 89, 98, 108, 131, 196**  
**Damage, 113, 156, 163, 180, 246**  
**Data**  
 action on, in a process capability study, 61, 62  
 amount of, for checking distribution shape, 56  
 amount of, for designed experiments, 77, 78-79, 90, 92, 110, 111, 112, 113  
 amount of, for detecting unnaturalness, 9, 28, 112, 146, 170  
 amount of, for engineering studies, 50-51, 55, 62, 63-64, 66-72  
 amount of, for shop charts, 63, 64, 191, 192, 207, 209, 223, 228-229  
 amount of, for testing normality, 78-79, 82, 133-134  
 amount of, in study of correlation, 146  
 amount of, in study of skewness, 56  
 analysis of (*See* Analysis; Analysis of factorial design; Analysis of variance)  
 attributes, 11, 17, 18, 31, 38, 47, 48-49, 50, 54, 56, 59, 72-73, 74, 113, 144, 157-160, 188-189, 191, 194, 196-197, 198, 206, 210, 225, 227-228, 237, 262, 269  
 classification of, 36, 55, 56, 72-73, 85, 92-93, 117, 218  
 collection of, in a process capability study (*See* Collection of data)  
 division of, 36, 55, 72, 166, 175, 176  
 engineering, 34, 46, 49, 63-64, 76, 117  
 for a designed experiment, 76-77, 78, 84, 86, 90, 92, 113, 115-117
- for a process capability study, 36, 41, 47-51, 66-67, 72-73, 223, 228  
 for a shop chart, 65, 190-192, 207-210, 214-216, 227, 228-229  
 for performance studies, 74, 228  
 freaks in, 52-53, 68, 70, 116-117, 162-164, 166, 179, 209, 214  
 identification of (*See* Identification)  
 identification of, in an experiment, 85, 92, 98, 117  
 inspection, 268-269, 271  
 modification of, in making estimates, 61  
 non-random patterns in, 116  
 obtaining of (*See* Obtaining)  
 percentage, 5, 7-8, 11, 17, 18, 19-20, 48-49, 74, 113, 144, 157-159, 189, 191, 194, 196-198, 206, 210, 213, 215, 221-222, 225-226, 227  
 plotted in an experiment, 82, 85-88, 99  
 rearrangements of, 36, 53, 55, 56, 72-73, 75-76, 85, 109, 117, 143-144  
 recording of, 207, 210, 227, 268-269, 271  
 reduced, in an experiment, 103, 106  
 reliability of, 41, 49, 62, 84-91, 111, 113, 117, 213-216  
 restrictions imposed on, 96, 106  
 semi-variables, 12, 49-50, 113  
 separation of, 36, 54-56, 75-76, 149, 166-167, 168, 179-180, 218-219  
 significant categories in, 55, 166  
 simple breakdown in, 36, 55, 75, 166  
 sources of, for simplification of patterns, 36, 54-55, 75, 160, 166, 168, 218-219  
 submitted by process checker, 229  
 suitability of, 10-12, 15, 41, 47, 49, 61, 72, 77, 84, 89-90, 113-114, 190  
 variables, in general, 6, 8, 9-10, 11, 12, 14, 21-23, 137-139, 152-156, 160-161  
 variables, in engineering studies, 15-16, 47-48, 49-50, 53-59, 66-72, 78, 82, 84, 86, 92, 107-111, 113, 119-127, 141, 144, 147  
 variables, in ship charts, 188, 189, 191, 194, 195-198, 203-206, 209, 210, 212, 215, 218, 225, 227-229  
 work sampling, 50, 277  
 (*See* Records)

- Data sheets, 208, 210, 271
- Date of samples, 207, 210, 271
- Days  
 between samples, 192, 207  
 of the week, 49, 114, 162
- Day shift, 72, 73, 161, 162  
 (See Shifts)
- Decibels, 12, 14, 138, 139, 140, 141
- Decimal point, as a variable, 173
- Decisions  
 about control charts, 187-199,  
 219, 223, 228-229  
 about the job, 40, 62, 64, 202, 216,  
 218-219, 220, 223-224  
 engineering, 33, 34-36, 46-47,  
 53-54, 56, 58, 61-64, 77, 83,  
 87, 89, 92, 99-101, 119-127,  
 141, 146, 192, 194, 196, 199,  
 212, 219-220, 224, 233-236,  
 263-265, 274
- Defective units  
 meaning of, 31, 159  
 distinguished from "defects," 20,  
 206, 239, 267  
 reduction of, 38, 46, 71, 233, 265
- Defects  
 causes of, 46, 72-73  
 classification of, in inspection,  
 263, 270  
 classification of, in quality rating,  
 263, 264  
 classification of, on demerit  
 charts, 198  
 combination of, on a *p*-chart, 17,  
 48, 59, 157, 159, 189, 196  
 definition of, 20, 31, 159, 206,  
 267  
 failure to look for, 159  
 level of, on a *p*-chart, 159  
 number of, 20-21, 46, 191, 206,  
 229, 233, 236, 239, 240, 265  
 plotted on a *c*-chart, 20, 72-73,  
 189  
 prevention of, 35, 36, 187-189,  
 201, 202, 217-219, 221, 225-  
 226, 233, 235, 265  
 reduction of, 10, 46, 71, 187, 189,  
 225, 233, 235-236, 265  
 vs. defectives, 20, 206, 239, 267
- Definitions  
 of technical terms associated with  
 control charts, 12, 17, 20, 21,  
 150, 151, 152, 197-198  
 of technical terms associated with  
 patterns, 24-25, 29, 160, 161-  
 180  
 of terms used in designed experi-  
 ments, 76, 77, 78-80, 85, 86,  
 89, 92-93, 96, 97, 98, 101, 103,  
 104, 105, 106-107, 109  
 of terms used in engineering  
 studies, 124, 143, 144, 145,  
 225  
 of terms used in inspection, 39,  
 233, 234-236, 237, 238, 244-  
 245, 247, 249, 251, 256, 259,  
 260, 262-263, 267-269, 270,  
 273, 274  
 of terms used in process capability  
 studies, 35, 36, 45-46, 47, 49,  
 56, 61, 74, 75  
 of terms used in quality control,  
 3, 4, 9, 11, 33, 40, 50, 74, 89,  
 90, 129-131, 134, 135, 137,  
 139, 154  
 of terms used in shop control, 36,  
 191, 194, 195, 205-207, 214,  
 220, 221  
 used by statistical clerks, 229
- Degreaser, 50, 178
- Degrees  
 associated with freaks, 162  
 of assurance, 274  
 of certainty (See Certainty)  
 of completion, in engineering  
 studies, 36, 47, 63, 64, 74  
 of confidence, 273-274, 278  
 of defectiveness, 159, 190  
 of freedom, 79-81, 95, 96, 106  
 of mixture, 179  
 of protection, 273-274  
 of significance, in an experiment,  
 96-97, 99, 107, 109  
 of skewness, 131, 156  
 of training for operators, 46, 164,  
 168, 204  
 measurement by, 49-50, 113
- Delays  
 cost of, 217, 246  
 in obtaining supplies, 246, 260  
 in production, 33, 77, 187, 202,  
 246  
 in taking action, 190, 217, 219  
 reduction of, in the shop, 33, 202,  
 246, 260-262  
 unnecessary, 246, 262
- Demarcation, line of, 159
- Demerits, 198, 263, 264, 270, 273,  
 278
- Demonstrations for operators, 202
- Dented units, 214
- Department of Defense  
 (See U. S. Dept. of Defense)
- Department of Navy  
 (See U. S. Dept. of Navy)
- Dependent variables  
 (See Variables)
- Depth of nicks and scratches, 113
- Derivation  
 of AOQL's for Final Inspection,  
 264, 273, 278  
 of plans for various inspection  
 levels, 273-274
- Design  
 and development, 4, 10, 34, 35, 36,  
 38, 46-47, 52, 54, 60-63, 75,  
 76, 77, 83, 89, 91, 101, 141,  
 119-122, 122-127, 140, 141,  
 143-144, 198, 205, 219, 220,  
 221, 224, 226  
 "balanced block," 92-93  
 capability of, 35, 46, 220, 224  
 changes in, 46, 51, 69, 91, 198,  
 212, 219  
 comparison of, 35, 46, 224  
 improvement in, 38  
 new, 46, 47, 52, 224  
 of a fixture, 62, 69, 164, 213, 219  
 of a machine, 34, 35, 46, 47, 69,  
 70, 83, 155, 171, 175, 213  
 of a tool, 34, 35, 46, 47, 62, 63,  
 121, 155, 169, 212, 219  
 of process control charts, 63-65,  
 189-192, 193-199, 211, 219,  
 223, 227-229  
 of product, 10, 34, 38, 40, 46, 47,  
 52, 60-61, 76, 91, 101, 119-  
 127, 140, 143-144, 193, 198,  
 205, 219, 220, 224, 226  
 of sampling plans, 263-265, 273  
 quality control in (See Design  
 problems)  
 statistical, 76-77, 85, 92-93, 101-  
 107
- Designations on control charts, 65,  
 207, 209, 228-229
- Designed experiments, vii, 4, 28, 34,  
 36, 41, 51, 55-56, 62, 75-117,  
 120, 121, 122, 183, 187, 219,  
 220, 224, 229  
 advantages of, 75-77, 84-85, 91-  
 93, 112, 187  
 analysis of, 78-83, 87-89, 93-97,  
 97-111  
 assignable causes in, 83, 87, 89,  
 111  
 boxes in, 92, 97, 98, 101-103  
 calculations for, 79-82, 86, 89,  
 94-97, 97-98, 107-111  
 combination of variables in, 89-  
 90, 91-93, 94-98, 99-101,  
 102-106, 114  
 conclusions from, 75, 76, 80, 81,  
 83, 87-89, 97, 100-101, 109,  
 111-112  
 control limits for, 83, 87, 89, 98,  
 99, 100, 108-109  
 diagrams for, 98, 109, 110-111  
 effects in, 94-95, 98, 101-106  
 error in, 103, 168  
 examples of, 77-78, 84-85, 92-93  
 factors in, 76, 77, 84, 90, 92-93,  
 98, 99, 101-103, 106, 108,  
 113-114  
 five factor, 90, 110  
 five percent level in, 100  
 four factor, 90, 91-109

- Designed experiments, *continued*  
 guides for, 98, 99, 109  
 higher order interactions in, 105-106  
 identification of data in, 85, 98, 99, 100, 109  
 inner control limits for, 99, 100, 107, 109  
 interactions in, 36, 76, 77, 93, 96-97, 98, 104-106, 107, 168  
 interpretation of charts in, 83, 84, 87-89, 100-101, 109, 111-112, 116-117  
 levels in, 93, 94, 97, 102-103, 107  
 limitations of, 76, 112  
 main effects in, 93, 96, 98, 101-103, 104, 105, 107  
 marking  $x$ 's in, 100, 107, 109  
 number of observations per box, 93, 107, 111, 113  
 numerical effects in, 98, 99  
 one factor, 76, 77-84  
 one percent level in, 99, 107, 109  
 plotting of, 82, 85, 87-88, 98-100, 107-109, 229  
 potential effects in, 95, 98  
 practical advice on, 112-117  
 range chart in, 97-98, 100, 109  
 related points in, 109  
 residual in, 81, 93, 94, 96, 97-98, 100, 101, 103, 105, 106, 107, 110-111, 113, 168  
 $R$  points in, 100, 109  
 shortcuts in, 97-98, 106, 110  
 significance in, 80, 81, 83, 87, 89, 97, 100, 107-109  
 significant points in, 87, 89, 97, 99, 100, 109  
 simplification of data in, 102-103, 105, 106  
 square root values in, 98  
 symbols used in, 98, 99, 109  
 tests for unnatural patterns in, 83, 100, 109  
 three factor, 89, 90, 110  
 three sigma control limits for, 82, 87, 88, 99, 100, 107-108, 109  
 two factor, 84-91  
 use of asterisks in, 97, 99-100, 107, 109  
 use of question marks in, 99-100, 107, 109  
 using attributes data, 113  
 using variables data, 77-112  
 variables in, 4, 76, 77, 83, 84, 88, 89-90, 92-93, 100, 101-103, 112, 113-114  
 $\bar{x}$  points in, 100, 109  
 (See Design of experiment)
- Design engineer, 4, 10, 40, 46-47, 52, 60-61, 76, 91-92, 101, 119-127, 198, 219, 220, 224  
 (See Design problems)
- Design of experiment  
 as related to process capability studies, 4, 34, 36, 41, 55-56, 63, 75, 76, 77, 83, 90, 91, 112, 114, 120, 121, 168, 218, 220-221, 224  
 in general, 4, 34, 36, 55, 56, 75-77  
 meaning of "design," 76, 84-85, 86, 89-90, 92-93, 101-103  
 references on, 101, 277-278  
 (See Designed experiments)
- Design problems, 4, 10, 46, 52-53, 119-122, 122-127, 167, 205, 224, 225-226  
 (See Design; Design engineer)
- Desired average, as basis for shop control chart, 64, 193
- Destructive testing, 113, 188, 197, 254
- Detail inspection (also called 100% inspection), 46, 188, 190, 226, 233-236, 249-251, 254, 256, 263, 265
- Details (for a tool), 213
- Deterioration of quality, 233, 273
- Development  
 expense, 226  
 of a product (See Design and development)  
 of a quality control program, vii, 10, 33-34, 41, 224-226  
 of manufacturing methods, 34, 47, 226  
 of new processes, 4, 36, 46, 47, 167, 180, 224, 226  
 quality control during (See Design problems)
- Deviations from authorized procedures, 45, 61, 158, 220
- Diagnosis of production troubles, 11, 36, 188, 202, 217
- Diagrams  
 for calculating residual, 97, 110, 111  
 for identifying data in an experiment, 92, 98, 101-102  
 for plotting control charts in an experiment, 99, 108, 109
- Diameter, as a variable, 6, 8, 10, 12, 47
- Die, 162
- Dielectric breakdown, 162
- Differences  
 as potential assignable causes, 6, 66, 151, 156, 162, 163, 167, 171, 180, 190, 215, 218-219  
 between shop charts and process capability studies, 63  
 due to natural variation, 6, 7, 62, 150  
 in calibration, 53, 113, 153, 159, 165, 175  
 in inspection levels, 246, 247, 264, 273  
 in training of operators, 204
- in treatment of product, 155  
 related to systematic variation, 175, 176  
 significant, 6, 16, 25-28, 35, 36, 46, 61, 75, 78, 79-81, 82, 87-88, 96-97, 99, 103, 107, 109, 112, 145, 146, 150, 218-219  
 (See Changes)
- Difficulties in the shop, 15-16, 19, 36, 37-38, 159, 165, 188, 189-190, 202, 246, 254-255, 260-263
- Digits, 116
- Dimensions, 6, 8, 10, 12, 15, 46, 152, 177, 190
- Directions  
 for making control charts (See names of individual charts)  
 for plotting, in an experiment, 82-83, 84-85, 98-99, 107-109
- Dirt, 178, 212
- Discriminating power  
 of a measuring instrument, 87, 88-89  
 of a sampling plan, 242
- Discs (used in manufacture), 162, 165
- Dispersion, 129-131  
 (See Spread; Standard deviation)
- Disposal of product, 262
- Distortion, 90
- Distributions, 6, 46, 129-141  
 addition of, 122-124, 124-127  
 advantages of working with, 119, 202  
 as an inspection requirement, 46, 119, 122, 265  
 as related to fluctuations, 6, 23, 24  
 associated with freaks, 163  
 as statistical laws, 6-7  
 center of, 30, 53, 56, 71, 120, 121, 129, 138, 139-140, 152, 160, 188  
 center of, as an inspection requirement, 119, 122, 265  
 changes in, 174, 180 (See Changes)  
 characteristics of, 56, 63, 129  
 combinations of (See Mixtures)  
 compared with specifications, 30-31, 58-59, 71, 119-122  
 component, 68, 122, 124-125, 127, 153, 155, 160  
 double (See Bimodal)  
 estimates of percentages in, 30-31, 56-59, 71, 127, 132-133, 135-136  
 examples of, 15, 37, 57-59, 78, 137-138, 139-141, 152-179  
 fitted to observed data, 139-141  
 from a constant system of causes, 6, 45, 170-171  
 in nature, 6  
 interpretation of, 16, 61, 78, 140-141

- location of, 62, 64, 65, 120-121, 171, 174, 179, 188, 193-196, 226
- may look alike on a  $p$ -chart, 158
- misuse of, 61, 78, 141
- mixtures of, 58, 68, 160, 166
- non-linear combinations of, 123 (footnote)
- non-normal, 31, 56-58, 59, 69-70, 122, 134-136, 160-161, 182-183, 196
- normal, 30-31, 56, 58-59, 78-79, 80, 82, 83, 127, 131-134, 138, 139-140, 154, 170, 180-182, 195-196
- of ranges, 137, 181, 182
- peaks in, 136, 158, 162, 166, 175
- plotted from data in  $\bar{X}$  and  $R$  chart, 16, 53, 138-139
- plotting of, 15, 30, 78, 138-141
- probabilities associated with, 132-136, 181-183
- profile of, 131, 160 (See Shape)
- proportions of, 153
- requirements, 46, 119, 265
- sampling, 23, 137-138, 151, 180-183
- separation of, 68, 155, 165, 166, 169, 173, 179
- shape of (See Shape)
- shift in, 166, 174
- should not be used for estimates, 61, 141
- spread of, 9 (footnote), 30-31, 45, 56, 58-59, 62, 71, 83, 89, 119-122, 124-127, 129-132, 137-139, 154-156, 195-196
- spread of, as an inspection requirement, 119, 122, 265
- steep part of, 159
- theory of, 6, 7, 23, 137-138, 151
- truncated, 57
- uses of, 15, 16, 53, 61, 78, 139-141 (See Frequency distribution)
- Dividing line, in classification, 159
- Dodge, H. F., 256, 262, 275, 277
- Dodge-Romig sampling tables, 241, 242, 245 (footnote), 249, 250-251, 253, 254, 255, 256
- Door of welder, 213
- "Dot" charts, 198
- Double centerlines (on shop control charts), 64, 65, 193-196
- Double sampling, 238, 242, 259, 260, 261
- Doubling of AOQL's, 273
- Downtime on machines, 38, 226
- Drawings, 16, 30, 119, 151, 153, 205 (See Blueprints; Specifications)
- Drift
- as a source of error in measurement, 90
- of a process, 67, 90, 153, 175
- of a test set, 46, 113, 153, 178, 218
- Driver on a highway, 216
- Drop (in a level or curve), 159, 164, 174
- Dropouts
- charts on, 38, 48, 189, 225, 227
- minimized by process control charts, 38
- records of, 224-225, 227, 264
- reduction of, 225
- Drying time (as a variable), 91, 92, 93, 100, 101
- Dullness of a tool, 178
- Duncan, A. J., 79, 133, 134, 148, 277, 278
- Duplicate
- conclusions, in an experiment, 111, 112
- measurements, 6, 84-86, 90, 93, 111, 113
- Durability of charts, 192
- Duties
- of engineers, 34-36, 39-41, 45-74, 75-77, 119-127, 187-192, 198-199, 201, 202, 212, 219, 220, 223-227, 236, 244-246, 254-255, 263-265, 273-274
- of inspectors, 39, 216, 218, 219, 227, 234, 235, 236, 237, 267-271
- of management, vii, 33-34, 41, 226
- of process checkers, 41, 159, 192, 205-212, 213-216, 217, 227
- of product engineers (See Duties of engineers)
- of quality control engineers, 33, 39-41, 45-74, 75-77, 112-117, 120-121, 183, 187-199, 201-202, 213, 216, 218-222, 223-229, 233-236, 254-255, 263-265, 273-274
- of statistical clerks, 216, 228-229
- of supervisors, 39-41, 190-192, 201-216, 217-222, 223-227, 236
- of suppliers, 39, 224 (See Piece parts)
- of the Quality Control Team, vii, 33, 39-41, 45, 64, 66, 187, 189-192, 198-199, 201-202, 213, 219, 220, 223-229, 236 (See Responsibilities)
- E**
- $E_2$  factor, 196
- Early operations
- effect of, 167, 171, 180, 189, 202, 218
- importance of, 37-38, 46, 48, 51, 63, 64, 114, 187, 188
- Earnings, 11, 22, 203
- Eccentricity, 57, 162, 198
- Economical state of control (See Control)
- Economic centerlines, 64-65, 192, 193-194, 195-196
- Economic considerations
- in choice of sampling plan, 239, 245-246, 254-255, 263-265
- in inspection, 39, 187, 233-236, 246, 260-262, 263, 264, 265, 273-274
- in process capability studies, 34-36, 46, 54, 61-65, 71
- in setting up shop control charts, 37, 38, 64-65, 188, 189-190, 199, 227
- in specifications, 34, 36, 64-65, 71, 122
- in the quality control program, 4, 10, 33-34, 34-46, 38, 41, 46-47, 187, 224-226, 233, 273
- on  $p$ -charts (in the shop), 196-197
- on  $\bar{X}$  and  $R$  charts (in the shop), 63, 64-65, 193-196
- related to OC curves, 242-246, 255, 265 (See Costs; Cost reduction)
- Economic control limits, 64-65, 194, 195-197
- Economic decisions, 36, 62, 64-65, 188, 190, 192, 193-194, 199, 220, 223
- Economic gains, 10, 33-34, 36, 38, 54, 61-63, 71-72, 101, 187, 199, 202, 217, 219, 220, 225-226
- Economic stopping point, 33-34, 35, 36, 45, 47, 55, 61-63, 166, 194
- Effectiveness
- of maintenance, 155, 162, 164, 167-169, 175, 178, 180, 204, 206, 219, 227
- of process controls, 16, 19, 34, 37-38, 62, 64, 155, 164, 167, 177, 178, 187, 226, 233, 235, 265
- Effects (in an experiment)
- calculation of, 93-97, 98, 102-103
- removal of, 103, 105, 106
- Efficiency
- in the shop, 10, 21, 33, 37, 38, 71, 158, 202-203, 224, 226 (See Output)
- in tracing causes, 261 (See Active causes)
- Electric current, 68 (See Current)
- Electrical characteristics, 6, 8, 9, 10, 66, 71, 77, 90
- Electrical properties (See Electrical characteristics)
- Electrical signals, 14, 67
- Electrodes, 10, 37, 212
- Electrons, 6
- Electron tubes, 3, 4, 224, 225



- Elements**  
 in a process, 35, 36, 53, 54-56, 155, 158, 164, 166, 176, 218-219  
 of a machine, 3, 151, 161, 207
- Elimination**  
 of an adjustment, 67  
 of assignable causes, 9, 35-36, 37, 53, 54-56, 61-63, 66-72, 122, 150-151, 153, 217  
 of gaging, 71, 72  
 of interference in a circuit, 67  
 of lines of identification (in an experiment), 108  
 of a major variable, 55, 67  
 of noise, 67  
 of 100% inspection, 234-236  
 of operations, 34, 47  
 of possible causes, 69, 153, 218  
 of unnatural variations, 34, 35-36, 37, 75  
 of unstable mixtures, 68-69, 166  
 of variables in an experiment, 76, 114  
 of variables in a process capability study, 34, 55, 66-68, 166, 171
- Emergencies**  
 in shop and engineering, 40, 187, 202  
 inspection plans for, 233, 246, 263, 273-274
- Emphasis**  
 in a quality control program, vii, 33, 34, 41, 226  
 on control charts, vii, 4, 9, 10, 33, 38, 75, 84, 187-190, 201-203, 217, 223  
 on cost reduction, 33, 34, 36, 38, 224, 225, 226  
 on demerits, 198  
 on designed experiments, 4, 34, 76, 77  
 on Engineering, vii, 10, 34-36, 38, 39-41, 45-47, 53-56, 61, 63-65, 69, 70, 75, 77, 122, 188, 192, 219, 220, 223-226, 233, 236, 245-246, 260-265  
 on Inspection, vii, 39, 233-236  
 on Operating, vii, 10, 33-34, 38, 39-41, 45, 63-65, 67, 72-73, 114, 120-121, 187, 190, 201-204, 216-219, 220, 223-224, 233, 236, 246, 255, 260-262, 263, 265, 274  
 on process capabilities, vii, 33-34, 36, 62, 64, 75-76, 112, 124, 125, 127, 187, 235  
 on Quality Control Teams, vii, 39-41, 187, 223
- End**  
 of parts, 90  
 of process capability studies, 36, 45, 47, 61, 62, 63, 71, 74, 75, 221  
 of month or week, 189  
 of rods or strips of stock, 156, 163  
 End product, 46, 48, 51, 171, 233, 264-265, 270, 273
- Engineering**  
 comments on a control chart, 53, 212  
 cooperation with shop, vii, 33-34, 38, 39-41, 45, 49, 63-65, 66-72, 74, 114, 117, 120-121, 124-125, 127, 187-199, 204, 209, 212, 213, 214, 219, 220, 223-229  
 courses (See Engineering training)  
 data, analysis of, 46 (See Process capability studies; Designed experiments)  
 decisions, 33, 34, 36, 46-47, 53-54, 61-63, 64, 99, 192, 194, 196, 199, 212, 265  
 effort, 63-64, 77, 246  
 for inspection, 46, 224, 226, 233-236, 242-246, 254-255, 260-265, 267-271, 273-274  
 for process control, 33-38, 39-41, 45-46, 61-65, 66-72, 74, 76, 83, 101, 112, 119-127, 187-199, 201-202, 205-211, 212, 219, 220-229  
 for quality control program (See Development of a quality control program)  
 information, 34, 35, 46-47, 54, 75-77, 177, 219, 220  
 judgment (See Engineering decisions)  
 knowledge, 35, 40, 46, 54, 75, 77, 114, 159, 177, 219  
 layouts, 25, 192, 199, 205-209, 213, 214, 217, 218, 224, 227, 236, 262, 263, 265, 267-271  
 problems, 3, 4, 10, 33-34, 35-36, 46-47, 61-63, 66-72, 75-77, 84, 91, 112-113, 119-127, 187, 188, 204, 219, 220, 223-224, 225-226, 233-236, 242-246, 254-255, 262, 263-265, 273, 274  
 questions, 4, 34, 46-47, 75, 220  
 responsibility, 46, 204  
 studies, 4, 10, 55, 63-64, 188, 190, 191, 212, 226 (See Process capability studies)  
 studies in the shop, 34, 36, 38, 39-41, 51, 63-64, 66-72, 75, 77, 162, 167, 188, 220, 226  
 time, 63-64, 77, 92, 246  
 training, vii, 23, 33, 97
- Engineering experiments**  
 conducted in the shop, 77, 117, 220  
 effect of, on patterns, 167, 180  
 examples of, 77-78, 84, 91-93  
 importance of, 36, 62, 75-77, 120-121, 219, 220  
 interpretation of, 46, 76-77, 78-117  
 made inconclusive by unnatural variation, 35, 38, 75, 220  
 results of, 46, 112, 224  
 used for cost reduction, 226 (See Designed experiments)
- Engineers**  
 (See Design engineers; Product engineers; Wage incentive engineers; Quality control engineers)
- Equipment**  
 as a process variable, 3, 35, 38, 46, 51, 53, 67, 70, 89, 90-91, 158, 159, 164, 167, 180, 203, 204, 206, 215, 216, 217, 219, 235  
 changes in, 47, 53, 70, 113, 174, 215  
 complex, 3-4, 21, 189, 191  
 held up unnecessarily, 246  
 unreliable, 180  
 Equipment engineering (See Wired equipment)  
 Equivalence of variances  
 assumption of, 78, 80, 82  
 hypothesis of, 82
- Erratic**  
 causes, 150, 155, 166  
 controls, 167  
 fluctuations, 53, 68, 72, 166, 167, 174  
 performance of a machine, 15-16, 166  
 variables, 37, 69, 166-167, 179-180
- Erratic patterns**, 31, 53, 54, 166, 167, 174, 179, 204  
 estimating from, 59-60  
 meaning of (See examples on pages 60, 67 and 72. See also the names of specific patterns such as Instability, Mixtures)  
 simplification of, 54-56, 66-72, 72-73, 166
- Error**  
 experimental, 103 (See Residual)  
 in calculating, 162, 163, 180, 214-215  
 in plotting, 163, 166, 180, 215  
 in subtraction, 163  
 normal distribution of, 88  
 of estimate (in correlation), 145  
 of first kind, 25 (footnote), 99-100, 107  
 of second kind, 25 (footnote)  
 (See Error of measurement; Trial and error methods)
- Error of measurement**, 46, 49, 50, 53, 61, 62, 75, 76, 84-91, 111, 113, 163, 215, 219  
 (See Precision of measurement; Accuracy of measurement)

- Establishment of standards, 46, 54
- Estimates
- based on  $R$  chart, 156
  - from a pattern out of control, 54-56, 59-60, 60-61
  - from a sample, 50, 278
  - of costs, 34, 35, 38, 46-47, 62, 233, 236, 245-246, 260, 263, 273-274
  - of current production, 226
  - of expenditures for cost reduction, 226
  - of operator capability, 35, 46, 73, 170
  - of percentage outside of limits, 30-31, 58-59, 119, 120, 127, 132-133, 135-136
  - of process capability, 45, 56, 58-59, 71, 73, 127, 235
  - of process spread, 56 (*See Spread*)
  - of random variation, 103
  - of residual, 95-96, 97-98, 103, 105, 106, 107, 110
  - of savings, 224, 226
  - of skewness, 53, 56-58, 61, 122, 196
  - of standards and allowances, 34, 35, 36, 46, 53-54, 61, 122, 125, 235, 265
  - of ultimate number of charts, 38, 189, 225
  - to be based on a natural pattern, 35, 53-54, 61
  - wrong, 60-61, 141
- Etching solution, 178, 218
- Evenness of plating, 156
- Evidence
- obtained from control charts, 9, 10, 83, 100, 218
  - of an effect, in an experiment, 103
  - of the Law of Large Numbers, 6
  - on an  $R$  chart, 66, 67, 68, 154-156, 168, 194 (*See R chart*)
  - statistical, 8, 9, 10, 45, 75, 103
- Examination of units, 163, 218
- Examples
- of calculations, 14, 18, 22, 58-59, 71, 78, 79-82, 86, 89, 94-97, 98, 103-106, 107-109, 124-127, 130, 147-148, 180-183, 196, 229, 240, 242, 251-252
  - of  $c$ -charts, 72-73
  - of chart for individual measurements, 22, 23
  - of designed experiments, 82, 87, 88, 92, 99, 100
  - of marking of charts, 212-213
  - of patterns, 5, 8, 15, 16, 19, 23, 24-30, 52, 60, 67-71, 72-73, 74, 82, 85, 87-88, 99, 120-121, 144, 146, 153-154, 161-180, 203-206, 212, 221
  - of pattern simplification, 66-72, 72-73
- of  $p$ -charts, 8, 19, 74, 144, 194
  - of process capability studies, 66-73
  - of shop charts, 65, 203-206, 211, 212-213
  - of  $\bar{X}$  and  $R$  charts, 15, 16, 31, 65, 67-71, 82, 85, 87-88, 99, 120-122, 144, 203-206
- Exhaustion of degreaser, 178
- Existing processes, 34, 226
- Expansion
- as a variable, 153
  - of plotting scales, 190
- Expense
- of certain operations, 34, 47, 122
  - of development, 226
  - of obtaining data, 48, 77, 92, 116, 188
  - of sorting, 122, 226, 234, 236, 263, 265
- Experience
- as a means of interpreting control charts (*See Job knowledge*)
  - as a variable, 38, 55, 72-73, 158, 167, 204
  - gives evidence of the Law of Large Numbers, 6, 10
  - in using control charts, 10, 40, 66-67, 201-206, 219
  - of operators, 6, 30, 73, 158, 167, 204
  - results in conflict with, 77, 218, 219
- Experiment, steps in, 47, 75-77 (*See Designed experiments*)
- Experimental
- error, 103
  - units, 92, 163, 180
  - work, 167, 180
- Experimental control charts
- headings on, 84, 99, 108-109
  - identification on, 99, 108-109
  - interpretation of, 83, 87-88, 89, 99-101, 111-112
  - plotting of, 82, 84-85, 87-88, 97, 98-99, 107-109, 116
  - used in the shop, 38, 63-64, 74, 188, 220, 228
- Experiments
- affected by state of control in the shop, 10, 38, 67, 75, 112, 188, 220
  - compared with process capability studies, 4, 34, 36, 47, 75-76, 112
  - complicated designs for, 77
  - conduct of, 112-117
  - containing more than one measurement per box, 93, 111, 113
  - importance of, 34, 36, 41, 55-56, 62, 75-77, 120, 121, 219, 220, 224
- interpretation of, 77, 78-84, 87-89, 92, 93-101, 107, 109, 111-112
  - involving a number of variables, 77, 89-90, 91-111
  - meaning of terms in, 76, 103, 104, 106-107
  - on a going process, 76-77, 191, 220, 224, 228
  - planning of, 41, 84-85, 92-93, 112-117
  - types of, 76-77
  - using attributes data, 113
  - using variables data, 77-111
  - without statistical design, 77, 84, 91-92, 220
- (*See Designed Experiments.*)
- Exponential scale, 163
- Extraneous causes, 6, 9, 10, 45, 53, 150, 166, 171

## F

### Facilities

- as a variable, 158, 175
- breakdown of, 163
- for handling product, 5, 40, 246, 260
- for testing (*See Test sets*)
- inspection of, 227
- maintenance of (*See Maintenance*)
- need for productive work, 246
- reduction of, 38
- (*See Equipment*)

### Factorial design, 75, 92-93, 101-107

### Factorial experiment

(*See Factorial design*)

### Factors

- for calculating control limits on an  $\bar{X}$  and  $R$  chart, 12, 275, 277
- for estimating  $\sigma'$ , 131, 275, 277
- for limits on experimental control charts, 107-108
- in an experiment, 4, 36, 76-77, 84, 89-90, 92-93, 97, 98-99, 101-103, 106, 110-111, 113-114
- to be plotted in an experiment, 108, 109

### Factual reports, 226

### Failure

- to look for defects, 159
- to meet requirements, 15, 19, 20, 66, 121, 189, 204, 205, 206, 234

### Fatigue, 161, 162, 178, 180, 219, 236

### Feeding of parts, 19, 83

### Feeler gage, 270

### Ferrell, E. B., 198, 277

### Files of charts and layouts, 192, 207, 227, 228-229

### Filter, 67

- Final inspection  
 AOQL's for, 264, 273  
 made compatible with quality rating, 263, 264, 270, 273  
 reduction of, 10, 38, 39, 46, 71, 120, 187, 188, 234, 236, 246, 260-263, 273-274  
 relations with shop, 37, 202, 224, 226, 227, 236, 254-255, 262, 263, 265, 269, 274, 278  
 sampling plans for, 39, 255-263, 264, 265, 273-274  
 use of results of, 39, 234, 269, 270
- Final tests of product, 48, 51, 167, 217, 233, 234, 260-262, 264, 270, 273
- Finish, 102
- First order interactions, 93, 94, 98, 105, 106
- First shift, 72, 73, 161, 162  
 (See Shifts)
- Fisher, R. A. 101, 277
- Fit of parts  
 (See Clearances)
- Five factor experiment, 75, 90, 110-111
- Five percent limits, 97, 99, 100, 107, 109
- Five week month, 191
- Fixtures  
 as a variable, 3, 10, 35, 53, 55, 69, 156, 158, 162, 168, 176, 203, 207, 212, 219  
 changes in, 53, 69, 83, 164, 175, 212, 213, 215, 219, 235  
 clogging of, 178  
 design of, 62, 69, 164, 213, 219  
 for holding charts, 192  
 play in, 55, 68, 155, 162, 167, 180, 219, 235  
 re-design of, 62, 69  
 used by Operating as essential equipment, 216
- Flatness of spring, 270
- Flattening of reeds, 213
- Flaws, 20
- Flexibility of control chart method, 83, 91, 97, 106
- Flow of product, 260
- Fluctuating patterns, 5, 6, 9, 24, 66, 72, 160, 175, 176, 178, 190, 219, 237-238
- Fluctuations  
 abnormally large, 11, 24, 66, 68, 166-167  
 abnormally small, 11, 24, 29, 172-174  
 as related to distributions, 6  
 causes of, 6, 150, 152-180, 217-219  
 effect of, on a shop chart, 190  
 erratic, 53, 60, 68, 72, 166, 167, 174  
 evidence of, in the world around us, 5-7  
 in a pattern, 5-6, 7, 9, 24-25  
 in a process, 8-9, 30, 35, 37, 56, 60, 61, 62, 64, 65, 67, 122, 193, 195, 196, 203, 220  
 in voltage, 10, 162  
 limits of, 7-9 (See Control limits)  
 magnitude of, 6, 11, 24, 29, 68, 160, 166, 172-174, 190  
 natural, 6, 24, 150  
 normal to a process, 203  
 on an  $R$  chart, 67, 69, 154-156, 168  
 on an  $\bar{X}$  chart, 67-68, 69, 152-154, 166, 168  
 on a  $p$ -chart, 173, 196-197  
 random, 8-9, 24, 46, 103, 149, 150, 156, 161, 172, 173, 175, 176-177, 203, 237-238  
 sampling, 5-6, 7-8, 24-25, 46, 103, 112, 145, 146, 203, 237, 238  
 statistical, 5-9, 46, 173, 203  
 unnatural, 6, 9, 24-25  
 (See Patterns)
- Follow (of a control chart)  
 (See Tendency to follow)
- Forecasts, 278  
 to be based on a natural pattern, 35, 46-47, 53-54, 59-60  
 (See Predictions)
- Foreign particles, 20, 270
- Formal  
 control chart audits, 227  
 cost reduction cases, 34, 36, 224, 226  
 inspection audit, 227  
 study of interactions, 4, 36, 75, 94-97, 167-168
- Formal analysis (other than control chart)  
 analysis of variance by the sum of squares method, 78, 81, 82, 83, 93-97  
 Bartlett's test, 78, 79, 80, 82, 83  
 Chi-square test, 78, 82, 133, 140, 278  
 comparison of averages, 78, 80-81, 83  
 correlation, 143-148  
 $F$ -test, 78, 79, 81, 82, 83, 96-97  
 other tests of significance, 134, 278  
 regression, 144-145  
 test for significance of correlation coefficient, 146  
 tests for constancy of cause system, 78, 79  
 tests for equivalence of variances, 79-80  
 tests for normality, 78-79, 133-134  
 $t$ -test, 78, 80, 82, 83
- Formation  
 of patterns on a control chart, 4, 149  
 of samples in an experiment, 82, 85, 108, 109
- Forms for recording and charting, 41, 192, 227  
 (See Control chart forms; Inspection forms)
- Formulas  
 for addition of distributions, 123  
 for AOQ, 251  
 for AOQL, 251  
 for arithmetic mean, 12, 129  
 for calculating control chart tests, 180-183  
 for  $c$ -charts, 20  
 for charts of individual measurements, 8, 21-22  
 for correlation coefficient, 146  
 for error of measurement, 88, 89  
 for estimating percentage outside of limits, 31, 58-59, 133, 135, 136  
 for estimating sigma, 56, 58, 130, 131  
 for estimating sigma from a sample, 131  
 for estimating the spread of a normal distribution, 56, 61, 122, 132, 195  
 for estimating the spread of a skewed distribution, 56, 61, 122, 196  
 for line of regression, 145  
 for modified control limits on shop charts, 195-196  
 for  $np$ -charts, 20  
 for  $p$ -charts, 7-8, 17  
 for range, 11, 12, 131  
 for removing the effects of a variable, 102-103  
 for residual, 97, 106, 110  
 for sigma of averages compared to sigma of parent, 138  
 for standard deviation, 130  
 for standard error of estimate, 145  
 for  $u$ -charts, 21  
 for variance, 130  
 for  $\bar{X}$  and  $R$  charts, 12, 14  
 to be used in designed experiments, 98, 104-106, 107-108, 110
- Four factor experiment, 75, 90, 91-109
- Four week month, 191
- Fraction defective, 17, 20, 191  
 (See Percent defective)
- Freaks  
 apparent, 52-53, 58, 116-117, 162, 164  
 as a pattern, 11, 161, 179  
 in designed experiments, 83, 111, 116-117  
 in process capability studies, 52-53, 54, 58, 68  
 in shop data, 192, 209, 214, 215  
 interpretation of, 155-156, 160, 162-164, 179

on a chart for individual measurements, 160, 163  
 on  $p$ -chart, 11, 163  
 on  $R$  chart, 68, 70, 153, 155-156, 163, 166  
 on  $\bar{X}$  chart, 11, 70, 153, 163  
 treatment of, 52, 53, 117, 192, 209, 214, 269  
 Freedom, degrees of, 95, 96, 97, 106  
 Freeman, H. A., 277  
 Frequency  
 electrical, 48, 90, 164  
 known, used as a standard, 90  
 of checking, 41, 192, 209, 214, 227  
 of defects (on a  $p$ -chart), 159  
 of re-grinding, 203  
 of re-setting, 16, 67, 166, 188, 203-204  
 of sampling, 219, 262  
 of trouble associated with certain characteristics, 188  
 Frequency distributions  
 addition of, 68, 122-123  
 affected by error of measurement, 89  
 comparison of, with specification, 30-31, 119-122  
 for comparing machines, 15  
 for comparing methods, 78  
 specified as a requirement, 119, 265  
 study of, in engineering, 45, 46, 53-54, 56, 61, 68, 70, 83, 152-180, 220  
 study of, in the shop, 16, 30-31, 37, 188, 195-196, 202, 220  
 theory of, 23  
 (See Distributions)  
 Fresh copies of shop control charts, 192, 207, 228  
 Front insulator, 270  
 Fry, T. C., 134, 277  
 $F$ -test, 78, 79, 81, 82, 83, 96-97  
 Fully reduced data, 106  
 Furnace, as a variable, 21, 51, 114, 189

## G

Gages  
 as a process variable, 3, 10, 46, 49, 113, 158, 162, 167, 168, 171, 203, 218, 219, 224  
 checking of, 153  
 correct use of, 216, 227  
 insertion of, 155, 216  
 inspection of, 219, 227  
 master, 91  
 provision of, 192, 270  
 specification of, 227, 270  
 wear of, 178  
 Gaging, elimination of, 71, 72  
 Gain in db., 14

Gas composition, 21  
 General instruction  
 for inspection, 267-271  
 for process control, 205-211, 213, 215  
 Generalization (to be based on a natural pattern), 35, 53-54, 59, 61, 62  
 General purpose tubes, 224, 225  
 Glass, 224, 225  
 Glow lamps, 224, 225  
 "Going through the mill," 164  
 Gold plating, 156  
 Goode, H. P., 242, 262, 277  
 Good or bad? 35, 54, 57, 62, 63, 150-151, 189  
 Good will of customer, 246  
 Good work done by operators, 202, 203, 223, 226  
 Government inspection, 119, 247-248  
 Government Printing Office  
 (See U. S. Government Printing Office)  
 Gradual  
 breakdown in process controls, 273  
 changes in a process, 11, 53, 54, 161, 164-165, 177-179  
 extension of maintenance program, 164  
 shift in level, 11, 53, 54, 161, 164-165 (See Trends)  
 Grand average, 12, 21, 107, 129  
 Grant, E. L., 182, 239, 242, 277  
 Graph paper, 13, 17, 22, 79, 133, 211, 215  
 Grease on a control chart, 216  
 Grids, 224, 225  
 Grinding, 57, 203  
 Groove, 119  
 Group leaders, 202, 213, 217  
 Grouping of inspection items, 263, 265, 270, 271, 274  
 Grouping or "bunching" of measurements, 11, 54, 68, 160, 161, 165-166, 179  
 Growth of program, 33-34, 41, 224-226  
 Guidance by management, 33, 41, 224-227  
 Guided missiles, 4  
 Guides for plotting, in an experiment, 99, 108, 109  
 Guiding mechanism, 19

## H

Habits of operators  
 (See Work habits)  
 Hald, A., 116, 275, 277  
 Handbook  
 history of, iv, v

purpose of, v, vii  
 treatment of topics in, vii, 4, 9, 23, 25 (footnote), 33, 34, 36, 38, 45, 49, 75, 77, 78, 84, 110, 148, 149, 151, 153, 187, 201, 216, 233, 239, 264, 270  
 Handling of product, 38, 156, 163, 246, 260-261, 263, 265  
 Handwriting, 7  
 Haphazard arrangement of data, 116  
 Hardness of stock, 153  
 Hartley, H. O., 275, 277  
 Hawthorne Club Evening School, Western Electric Co., 147-148, 275  
 Headings  
 on control charts used in experiments, 99, 108  
 on shop charts, 65, 228  
 Heads (on a machine), 55, 66, 71, 72, 151, 161, 202, 207  
 Heat treating, 35, 47, 50, 114  
 (See Chemical operations)  
 Heiland, R. E., 50, 277  
 Helps for operators, 4, 37, 188, 201, 202, 203, 204, 217  
 Hidden  
 pattern, 67-68, 75, 218  
 variables, 36, 48, 66-68, 75, 76, 77, 219  
 Higher order interactions, 93, 94, 98, 105-106  
 High points on a control chart, 70  
 Highway, 216  
 Histogram, 15, 139, 140, 141  
 (See Frequency distributions)  
 History of a job, 188, 192, 228, 229  
 (See Progress reports)  
 Hit and miss  
 data, 116  
 experimentation, 76, 220  
 Hoel, P.G., 277  
 Holders  
 for control charts, 192, 228  
 for product, 156, 167, 178, 180  
 Holding devices, 69, 175, 235  
 Holes, 162, 176, 178  
 Homogeneity, 150, 151, 178, 262  
 (See Consistency;  $R$  chart)  
 Hook for control charts, 217  
 Hours  
 between samples, 192, 207, 209  
 required for making product, 71, 203  
 Housekeeping, 10, 50, 178  
 Human variables, 3, 4, 6, 30, 35, 40, 45, 62, 63, 72, 114, 116, 158, 162, 166, 178, 202, 219, 227  
 Humidity, 21, 153, 162, 178  
 Humps (in a distribution), 162  
 (See Peaks)  
 Hypergeometric equation, 239, 242  
 Hypothesis  
 in a process capability study, 47

## Hypothesis, *continued*

- of constancy, 47, 82
- of equivalent variances, 82
- of normality, 82, 132
- rejected by a control chart, 82, 83

## I

### *I*<sub>1</sub>, 229

- Ideas for interpreting charts, 55, 75, 161, 218

### Identification

- of boxes in an experiment, 98
- of causes, 11, 56, 111, 146, 166, 176
- of causes of trouble, 217-219
- of duplicate measurements in an experiment, 85, 111
- of product, 209, 218, 261, 270
- of unnatural disturbances, 9, 36, 54-56, 217-219
- of variables, 36, 37-38, 55, 75-76, 168, 218-219
- of variables in an experiment, 93, 99, 100, 103, 108, 109, 111

### Identification of data

- in a designed experiment, 76, 84-85, 92, 98, 109, 117
- in a process capability study, 49, 51, 52, 53, 54-56, 72-73, 76
- in inspection, 261, 269, 270
- on a chart for individual measurements, 160
- on a data sheet, 210, 271
- on a layout, 209, 269-270
- on shop charts, 207, 208, 212-213, 215, 218-219, 227, 229

### Importance

- of AOQL's, 274
- of dimensions, etc., 46, 48, 51, 187, 202
- of fluctuations, 190
- of patterns, 4, 6, 9, 11, 35, 36, 39, 45, 47, 53-56, 60, 61, 66-71, 72-73, 74, 83, 87-89, 91, 97, 99-101, 144, 145, 149-180, 203-206, 215, 218, 219, 221, 223
- of process control, 33, 34, 36-38, 41, 62, 63-64, 77, 122, 187, 201-202, 217, 219, 220, 226, 233, 274
- of *R* chart, 11, 15-16, 55-56, 66-69, 89, 91, 125, 127, 144, 153-154, 154-156, 168, 171, 195, 196, 204
- of simplicity, 91, 97, 189-190
- of specifications, 36, 62-63, 65, 119, 122, 187, 188, 224
- of taking action, 61-63, 190, 217, 219, 221
- of variables in an experiment, 4, 91-101, 103, 112, 114

- of variables in a process capability study, 35, 36, 51, 53, 54-56, 62, 66-73, 76, 112
- of *x*'s, 23, 25, 27, 52, 168, 195, 218
- Impregnating operations, 64
- Impressions, visual, 10, 46, 67, 78, 99, 103, 160, 161, 164, 173-174, 178, 179, 190 (*See* Apparent)

### Improvement

- due to control charts, 37-38, 62, 64, 155, 164, 167, 177, 178, 187, 226, 233, 235, 265
  - in alignment, 69
  - in design, 34, 38, 46-47, 69, 187, 212, 224
  - in equipment, 47, 70, 174, 175
  - in maintenance, 178, 204, 206
  - in methods, 34, 46-47, 175, 178, 187, 224, 226
  - in piece parts, 219 (*See* Piece part quality)
  - in positioning, 69
  - in process average, 265
  - in quality ratings, 226
  - in reliability, 72
  - in specifications, 10, 35, 36, 38, 46, 48, 61-63, 65, 122, 125, 188, 219, 224, 226
  - of existing processes, 34, 46, 226
  - of operators, 4, 167, 188 (*See* Training)
  - of process, 10, 11, 19, 33-34, 35, 36, 38, 41, 46-47, 54, 61-63, 64, 67-71, 74, 76, 83, 101, 112, 120-121, 122, 164, 187, 188, 190, 198-199, 202, 206, 219, 220, 221, 222, 223-226, 228, 229, 234, 236, 246, 265
  - of products, 16, 19, 72, 83, 101, 112, 121, 187, 220, 233, 265
  - of quality, 10, 19, 33-34, 35, 36, 46, 54, 63, 72, 83, 187, 225, 226, 233, 234-236, 246, 265
  - on paper, 187
  - opportunities for, 35-36, 54-56, 66-71, 76, 120-121, 220, 226
  - real, 36, 187, 225-226
  - reflected on charts, 74, 199, 228, 229
  - shown by *R* chart, 71, 168, 195
- ### Inattention, 235
- (*See* Carelessness)
- ### Incomplete operation, 163, 180, 270
- ### Inconclusive
- pattern, 28, 62, 64, 112, 146
  - results in an experiment, 62, 77, 81, 91-92, 97, 112, 117
- ### Inconsistency
- as one of the meanings of assignable causes, 150
  - as shown by *R* chart, 30, 154
- ### "In control"
- good or bad? 35, 54, 150-151, 171, 189-190, 221

- importance of, 36, 38, 45, 47, 53-54, 56, 58, 59, 61, 87, 91, 119-122, 127, 131, 141, 187, 188, 189, 190, 195, 196, 204, 219, 233, 246, 265, 273-274
- meaning of, 9, 16, 19, 24, 30, 71, 74, 149, 150, 159, 170-171, 172, 204, 205, 220-221, 262-263

(*See also* "Out of control")

### Incorrect

- calculations, 162, 163, 173, 214-215, 219
- control limits, 52, 153-154, 173-174, 219
- frequency of check, 219, 227
- measurements, 49, 113, 215-216, 219, 227 (*See* Error of measurement)
- plotting, 163, 166, 215, 219

### Increase

- in cost reduction effort, 226
- in emphasis on engineering, 34, 41
- in number of charts, 189, 224-225
- in production, 71, 178 (*See* Schedules; Efficiency)

### Independent variables

(*See* Variables)

### Indexing of a machine, 155

### Indicators

- of capability, 45, 63, 71, 74
- of progress, 225-226 (*See* Progress reports)

### Individual

- errors, in measurement, 88, 89
- heads, positions etc., 66, 70, 72, 151, 172, 176
- machines, 3, 10, 15-16, 19, 46-47, 48, 49, 54, 55, 66-69, 70, 114, 221
- motors, 70
- points on a control chart, 7, 24, 70, 149, 156, 176, 177

### Individual layouts

- for inspection, 236, 262, 263, 267, 269-270
- for process control, 199, 201, 207, 209, 213, 214, 217, 219

### Individual numbers or measurements

- as used in control charts, 6, 8, 11-12, 50-51, 188, 189
- control limits for, 8, 12, 21-22, 196
- distribution of, 6, 16, 31, 137, 138, 139, 140-141, 195
- interpretation of, 9, 10, 31, 160-161
- plot of, 6, 8, 12, 16, 22-23, 137, 144, 198
- relation of, to average, 16, 30-31, 137, 138
- spread of, 16, 30-31, 53, 56, 58, 62, 88, 89, 122, 131, 137-138, 151-152, 160, 195, 196

- use of, in checking calculations, 215  
(See Charts for individual measurements)
- Individual operators
  - benefits for, from quality control, 201, 202, 203
  - charts for, 4, 5, 8, 16, 17, 38, 48, 49, 72-73, 188, 204, 218, 221
  - training of (See Operators)
- Individuals, in the sense of individual measurements  
(See Individual numbers)
- Individuals, in the sense of individual people  
(See Human variables; Individual operators)
- Individual samples
  - estimates from, 50, 278
  - in correlation, 146
  - in inspection, 39, 237
  - in the shop, 16, 167, 190, 203-204
  - on a  $p$ -chart, 197
- Individual units, 6, 115-117, 119, 153, 156, 163, 165, 172, 173, 175, 218  
(See Freaks)
- Industrial Quality Control Magazine, 277
- Inflation
  - due to hidden variables, 66-68
  - due to interactions, 66-68, 105, 168
  - in control limits, 173-174
  - in estimate of  $\sigma$ , 131
  - on an  $R$  chart, 66-68, 168
  - reduction of, 66-68, 168-169, 195
  - removal of, 55, 67
- Informal cost reduction, 226
- Informal analysis
  - by frequency distribution, 56, 78, 140-141
  - by observation of data, 78
  - of interactions, 167-169
- Information
  - for management, 224, 225, 226, 227 (See Progress reports)
  - from a  $p$ -chart, 159
  - from out-of-control patterns, 35-36, 37, 54-56, 66-72, 72-73, 159, 161-180, 218-219, 221, 223
  - from patterns in general, 53-54, 97, 159, 171, 189
  - from process capability studies, 34-36, 46, 53-61, 66-73, 75, 76, 112, 187
  - given to shop, 65, 158, 192 (See Layouts)
  - needed for control, 190
  - obtained from control charts, 9, 10, 34-36, 37, 46-47, 72, 83, 84-89, 101, 202, 203-206, 218-219, 223-224
  - on Head No. 6: 66, 72
  - on process variables, 4, 11, 33, 35, 46, 54, 66-72, 75-77, 114, 159, 202, 215, 218-219, 223-224
  - reliability of, 46, 61, 75-76, 112, 141 (See Apparent)
  - to be plotted, 209, 215, 270
  - to be recorded, 209, 270
  - which may be needed in the future, 192, 228
- Ingenuity in separating data, 55
- Initial capability of a process, 34-35, 45, 47, 75-76
- Initials on a shop chart, 70, 212, 217, 218
- Initial variation in a process, 35, 75
- Initiation of action, 208-209, 217-218
- Injury, personal, 234
- Inner control limits, 99, 100, 107, 109
- Inner third of a control chart, 25, 27, 181, 182, 183, 208
- Insertion of gage, 155
- Inspection
  - amount of, 4, 23, 35, 39, 46, 188, 225, 226, 233-236, 254, 260, 262, 273-274
  - areas, 260
  - as an auditing operation (See Minimum inspection; Quality rating)
  - as a process variable, 46, 49, 159, 218, 236
  - as related to process control, 10, 37, 38, 39, 187, 202, 233-236, 273-274
  - audit of, 227
  - characteristics covered in, 265 (See Inspection items)
  - charts for, 39, 225, 246, 262-263, 265, 274
  - cost of (See Costs)
  - definition of, 233
  - detail (also known as 100%), 46, 188, 226, 233-236, 249-251, 254, 256, 257, 263, 265
  - economy of, 10, 39, 46, 71, 187, 233-236, 273-274
  - emergency (See Emergencies)
  - fatigue in, 236
  - forms used in, 270-271
  - general instruction for, 267-271
  - included in control chart audit, 227
  - lots, 196, 227, 259, 260-262, 267
  - layouts, 227, 236, 260, 261, 262, 263, 267-270, 274
  - load, 260
  - methods, 227, 267-271
  - need for, 38-39, 233-234
  - normal amount of, 46, 235-236, 273-274
  - of final product, 264, 273
  - of gages, test sets etc., 227
  - of piece parts, 264
  - of purchased supplies, 39, 158, 254, 264
  - of raw materials, 39, 158, 264
  - of sub-assemblies, 264
  - one hundred percent (See Detail inspection)
  - piece rates, 260, 263
  - planning, 39, 233, 236, 242-246, 254-255, 260-262, 263-265, 267-270, 273-274
  - principles, 38-39, 233-236, 273, 274
  - problems, 3, 4, 39, 46, 202, 216, 217, 218, 224, 227, 233-236, 273-274
  - product rejected by, 37, 46, 203, 217, 226, 246, 254, 261, 265, 269, 270, 273
  - protection in hands of, 273
  - quality levels for, 263-265, 273
  - records kept by, 39, 226, 227, 260, 261, 263, 268-269, 271
  - reduction of, 4, 10, 23, 33, 34, 35, 36, 38, 39, 46, 71, 120, 188, 225, 226, 233-236, 246, 252, 254, 260, 273-274
  - relations with shop, 37, 201, 202, 203, 216, 217, 219, 224, 233, 234-236, 263, 265, 273-274
  - requirements, 265, 273 (See Inspection standards)
  - responsibilities, 233-234, 235, 236 (See Responsibilities; Duties)
  - results, 39, 269, 270
  - standards, 264, 265, 268, 270, 273, 274
  - treatment of, in Handbook, vii, 233
  - types of, 264  
(See Final inspection)
- Inspection items
  - grouping of, 263, 265, 270, 274
  - selection of, 265, 270, 271
- Inspection levels
  - explanation of, 273-274
  - in Mil. Std. tables, 247
  - need for, 246, 264, 273
  - shifting of, 273-274, 278  
(See Normal inspection; Reduced inspection; Minimum inspection; Tight inspection)
- Inspection plans, 34, 187, 224, 227, 246-263, 265, 273-274
- Inspection supervisors, vii, 23, 33, 236, 267-271
- Inspectors
  - advice given by, 40, 216, 219, 234, 236
  - affected by fatigue, 155, 236
  - as a variable, 30, 152, 155, 168, 174, 215, 218
  - charts plotted by, 39, 216, 225, 234, 262-263, 247

- Inspectors, *continued*  
 duties of (*See* Duties)  
 gages used by, 162  
 instructions for, 267-271  
 number of, 23, 38, 226  
 results reported by, 173, 269, 271  
 sampling plans used by, 4, 237, 238, 242, 246-263
- Instability  
 causes of, 27, 68-69, 150, 166-167, 179-180  
 of product, 46, 67, 90, 175  
 on a  $p$ -chart, 19, 159, 167, 180, 194  
 on an  $R$  chart, 16, 67, 69, 155, 156, 166, 167, 179, 180, 204, 206, 212  
 on an  $\bar{X}$  chart, 15, 16, 66, 67, 153-154, 166, 167, 179, 180, 203, 204, 206, 212  
 patterns of, 11, 25, 54, 68-69, 72, 83, 87-89, 161, 166-167, 179-180  
 recognition of, 66, 67, 68, 72  
 statistical, 25, 155, 156  
 tests for, 25-28, 180-183
- Installation  
 of a quality control program, 33-34, 41  
 of control charts, 39-41, 72, 187-199, 201-202, 223, 224-225, 234, 265  
 of timer, etc., 70, 235
- Instantaneous samples, 192
- Instructions  
 for inspection, 267-271  
 for machine setters, 66, 67, 203-204, 217, 218  
 for making control charts (*See* Directions)  
 for plotting designed experiments, 82, 85-86, 99-100, 107-109  
 for process checkers, 41, 205-211, 213-216, 227  
 for process control, 205-213  
 for statistical clerks, 228-229  
 given to operator, 158, 212 (*See* Training)
- Instruments  
 calibration of, 165  
 comparison of, 84-91  
 use of, 84, 87, 89, 227
- Insulation resistance, 163
- Insulators, 17, 270
- Insurance companies, 7
- Intangible human elements (*See* Human variables)
- Intangible results (*See* Results; Savings)
- Integration of quality control techniques, 33-34, 39-41, 75-76, 187, 233, 265, 274
- Interactions  
 as a source of variability, 168  
 calculation of, 94-95, 98, 104-106
- capable of affecting the main effects in an experiment, 95, 96, 105, 106  
 explanation of, 11, 77, 93, 104-106, 167-169  
 first order, 93, 94-95, 98, 104-105, 106  
 higher order, 105-106  
 in a designed experiment, 36, 75, 76, 77, 81, 91, 93, 94-96, 98, 101, 104-107  
 in a process capability study, 53, 54, 161, 167-169  
 introduction of, in an experiment, 104-105  
 meaning of, 11, 93, 104, 107, 167  
 on the  $R$  chart, 11, 68, 155, 156, 168-169, 179  
 on the  $\bar{X}$  chart, 11, 167, 168  
 removal of, 105, 106  
 second order, 94-96, 98, 105-106, 110  
 third order, 105-106  
 used as a guide in plotting control charts, 98-99
- Interest  
 shown by management, 33, 34, 41, 225, 226, 227  
 shown by Quality Control Team, 190, 199, 219, 223-229
- Interference  
 due to assignable causes, 47, 149  
 fits, 126, 188  
 in an electrical circuit, 67  
 with productive work (*See* Interruptions)
- Intermittent behavior  
 of a process, 46, 60, 187, 194  
 of relay, timer etc., 154
- Intermittent operations, 3, 37, 46, 51, 160, 175, 189, 192, 221-222
- Interpretation  
 in analysis of variance, 81, 82, 83, 97  
 of a control chart in a designed experiment, 97, 100-101, 109, 111  
 of a distribution, 15, 16, 56-58, 59, 61, 78, 137, 141  
 of an AOQL, 254-255  
 of an  $F$ -test, 79, 82, 83, 96-97  
 of an OC curve, 238-239, 242-244  
 of a scatter diagram, 143  
 of a specification, 119  
 of assignable causes, 149-151  
 of asterisks in an experiment, 97, 100, 107, 109  
 of averages, 61, 78, 83, 153-154  
 of Bartlett's test, 79, 82, 83  
 of capability studies, 34-36, 45-46, 52-53, 53-56, 56-63, 66-73, 189
- of  $c$ -charts, 21, 30, 72-73, 160, 191 (*See* Interpretation of  $p$ -charts)  
 of charts for individual measurements, 9, 10, 12, 22-23, 31, 160-161, 191 (*See also* appropriate portions of pages 161-180)  
 of coefficient of correlation, 146, 148  
 of complex patterns, 54-56, 66-73, 166-167, 179-180, 218-219  
 of control charts (*See* Interpretation of patterns; Control charts)  
 of control limits, 7-9, 16, 24-25, 30-31, 51-52, 72-73, 87-89, 100, 107, 109, 137-138, 151, 153, 161, 173-174, 189-190, 194-195  
 of demerit charts, 198  
 of designed experiments, 76-77, 78-84, 87-91, 92, 97, 100-103, 109, 111-112, 115-117  
 of error of measurement charts, 84, 87-88, 89  
 of freaks, 52-53, 54, 117, 162-164  
 of inspection results, 39, 274  
 of  $np$ -charts, 20, 31, 160, 191 (*See* Interpretation of  $p$ -charts)  
 of  $p$ -charts, 9, 10, 11, 17, 19-20, 31, 48-49, 53-56, 59-60, 61-62, 73, 157-159, 183, 188-189, 190, 191, 194, 196-197, 198, 215, 217-219, 221, 223 (*See also* appropriate portions of pages 161-180)  
 of question marks in an experiment, 100, 107, 109  
 of  $R$  charts, 11, 15-16, 30, 48, 53-59, 61-63, 66-72, 83-84, 87, 88, 89, 90-91, 100, 153-156, 182-183, 191, 195, 204, 212 (*See also* appropriate portions of pages 161-180)  
 of regression lines, 145  
 of shop charts, 37-38, 40, 41, 63, 65, 171, 189-190, 194, 199, 202-206, 208-209, 212-219, 221, 223-224, 227  
 of  $t$ -charts, 197  
 of trend charts, 144, 177-179  
 of  $t$ -test, 80, 82, 83  
 of  $u$ -charts, 21, 31, 160, 191 (*See* Interpretation of  $c$ -charts)  
 of verification points on a control chart, 274  
 of  $\bar{X}$  and  $R$  charts, 15-16, 30-31, 66-72, 152-156, 170, 176, 177 (*See* separate entries under  $\bar{X}$  and  $R$ )

of  $\bar{X}$  charts, 11, 16, 30-31, 47-48, 53-59, 61-63, 66-72, 82-84, 87-91, 100, 109, 152-154, 156, 180-182, 212 (See also appropriate portions of pages 161-180)

of  $\bar{x}$ 's in an experiment, 83, 87-89, 100, 107, 109, 111

Interpretation of patterns

by a Quality Control Team, 219, 223-224

by machine setters etc., 202-206, 212-213, 217

by process checkers, 208-209, 215, 217, 227

in designed experiments, 83-84, 87-89, 100-101, 107, 109, 111-112, 116-117

in general, 6, 9, 10, 11, 23-31, 149, 152-180, 180-183

in process capability studies, 35-36, 52-56, 59-60, 62, 66-73, 171

in the shop, 37-38, 63, 65, 171, 189-190, 192, 194, 195, 217-219, 221

(See also the names of individual patterns and charts)

Interruptions

in the shop, 33, 77, 187, 202, 220, 225

of a pattern, 60, 194

of production, 33, 37, 38, 246, 254-255, 263, 265

Intervals

between cycles, 162

between samples, 41, 192, 199, 227, 233, 274

confidence, 100, 107, 109, 278

in a frequency distribution, 138

required for processing, 218, 223

(See Checking intervals; Checking frequency)

Introduction

of a quality control program, vii, 33-34, 39-41, 233-234

of control charts in the shop, 39-41, 62, 63-65, 72, 187-192, 201-216, 223

of sampling plans in the shop, 224, 236, 254, 263

to control chart theory, 4, 5-10, 11, 23-25, 149-151

to designed experiments, 75-77, 101-107

to statistical quality control, 3-4

Intuitive impressions from data, 10, 46, 61, 78, 123, 160, 161, 178-179, 190

(See Apparent)

Invalid methods of estimating, 60-61, 122, 141

Inverted image, 156

Investigations

based on  $R$  chart, 15-16, 48, 55, 66-70, 83, 87, 88-89, 153, 154-156, 163, 167, 168, 171, 173, 179, 195

cost of, 77, 246

in a process capability study, 34, 35-36, 45-47, 54-56, 59, 61, 62-63, 66-73, 74, 75-76, 120-121, 122

of assignable causes, 6, 9, 10, 11, 15-16, 19-20, 27, 30-31, 34-36, 38, 45-46, 48, 52-53, 54-56, 61-63, 63-64, 66-73, 83, 87, 89, 91, 113, 116-117, 122, 141

of proper conduct of process controls, 227

of shop control charts, 9-10, 37-38, 41, 64, 74, 217-219, 221, 227

of shop troubles, 34, 202, 217-219, 223-224, 235

to verify control chart, 10

when chart goes out of control, 158, 190, 192, 217-219, 221

Ireson, W. G., 277

Irregular shape of distribution, 131, 138, 166

Isolated points (on an  $R$  chart), 156

## J

Jamming of locating device, 83

Jigs, 212, 216, 235

Job knowledge

for interpreting a  $p$ -chart, 11, 19, 31, 48, 59, 72-73, 158-159, 218

for interpreting engineering data, 53, 54-55, 61, 75, 77

for interpreting shop charts, 40, 71, 201, 202, 212, 219

importance of, in a process capability study, 34-36, 40, 49, 52, 54-55, 56, 61, 62-63, 64-65, 67-70, 75

importance of, in the shop, 10, 11, 37, 40, 63-64, 219, 236

supported by control charts, 38, 91, 101, 219

(See Shop experience)

Jo-blocks, 90

Jobs

chronological record of, 192, 228

covered by process control, 202, 226

decisions about, 40, 223, 224

effect of charts on, 202-203

history of, 192

knowledge of (See Job knowledge)

made interesting, 203

on sampling inspection, 226

time on, 73

training for, 204

Job setters

(See Machine setters; Layout operators)

Job shop (See Intermittent operations)

Joint

action, 39-41, 62, 187, 189, 199, 201, 218, 219, 223-224, 236

(See Cooperation; Quality Control Teams)

cost reduction cases, 224, 226

interpretation of  $\bar{X}$  and  $R$  charts, 16, 156, 176-177

reaction of charts, 64, 121, 176, 177, 218, 223

Jumps in a test set etc., 171

Junking of product, 254

Juran, J. M., 277

## K

"k," 134

Keeping, E. S., 148, 277

Kendall, M. G., 277

Kenney, J. F., 148, 277

Key found in  $R$  chart, 67

Knowledge

about process variables, 11, 16, 19-20, 33, 34, 35, 49, 54, 55, 59, 157, 189, 202, 212-213, 215, 218-219, 221, 224-225

affording protection, 273

gained by process capability studies, 4, 34, 35, 36, 46-47, 53-73, 75-77, 112, 187, 223, 224, 228, 235

gained through unnatural patterns, 35, 36-37, 54-56, 66-71, 72-73, 159, 161-180, 221

needed by inspectors, 273

needed by shop, 71, 202, 217-219

needed by Team in a process capability study, 38, 40, 66, 67, 75, 112, 220

needed to interpret patterns, 31, 38, 40, 55, 66-68, 71, 218-219

not available to people on job, 10, 68 (See Unsuspected; Unknown)

of control charts, 31, 40, 55, 67, 218-219

of job, 38, 61, 219 (See Job knowledge)

of people, 40, 201-202, 203 (See Human variables)

of process controls, 233, 273

reflected in shop charts, 199, 212-213, 219, 223, 228 (See Notes)

results in conflict with, 77

shop, 38, 40, 71, 114, 217-219

technical, 40, 54, 75, 114, 177, 218, 219, 223-224



Known frequency, used as a standard, 90  
Known sources of complexity, 36, 55, 69, 75, 114, 166, 218.  
(See Production paths)  
Kurtosis, measure of, 134

## L

Labor, 57

(See Shortcuts)

Laboratories, 10, 91, 93, 100, 101

Lack of alignment, 69, 155, 167, 180

Lag in chart reaction, 218, 223

Lapping, 167, 168

Large samples, for inspection, 242, 260, 273

Later operations

(See Subsequent operations)

Law of Large Numbers, 5-7, 170, 171

Laws

of chance, 24, 116

of nature, 6

statistical, 6-7, 23-25, 123-124, 214

(See Randomness)

Layout operators, 202, 213, 217

Layouts

as a process variable, 158, 224

changes in, 40, 192, 199, 219

for inspection, 227, 236, 260, 261, 262, 263, 267-270, 274

for process control, 25 (footnote), 192, 199, 201, 205-209, 223, 227

manufacturing, 205, 227, 262, 267

Lead wire, 209

Least squares, method of, 145

Leeway (in running a process), 64, 65, 122, 193-197

Length

as a variable, 12, 119

of life, 7 (See Life test)

of lines in a pattern, 160, 169

of process capability study, 36, 45, 47, 50-51, 63, 72, 76

of service, 72, 73

standard of, 90

Leptokurtic distribution

(See Symmetrical non-normal distributions)

Lettering on shop charts, 65, 228

"Level Four" inspection (minimum), 263, 264, 273, 274

"Level One" inspection (tight), 264, 273, 274

Levels

for inspection (See Inspection levels; Quality levels)

in a designed experiment, 92-93, 94, 96-97, 102-103, 105, 107, 110, 112

in terms of percent defective, 265

of a process, 62, 120, 121, 194, 220 (See Centering)

of a variable, 168

of quality, 265 (See Quality Levels)

of significance, 97, 100, 107, 109, 180-183

on a control chart, 11, 51-52, 60, 61, 62, 64, 71, 152, 154-155, 156, 159, 164-165, 168, 174-175, 176, 177, 194

on an *R* chart, 71, 168, 175

on a *p*-chart, 159, 194

optimum, for a process, 64, 193

simple shifts in, 55, 72, 152, 174-175

"Level Three" inspection (reduced), 264, 273

Level-to-level correspondence on a control chart, 156, 176, 177

"Level Two" inspection (normal), 264, 273

Life

of a person, 7

of a tool, 23 (See Toolwear)

Life test, 113, 197

Limits

confidence, 278

control (See Control limits)

maximum or minimum, 57, 58-59, 64, 66, 71, 119, 125, 126, 127, 132, 133, 135, 136, 193, 195-196, 202, 204, 205, 206 (See Arrows)

narrowed, for inspection, 262

natural, 5-9, 16, 53-54, 61, 122, 151-152, 170

percentage outside of, 30-31, 53-54, 56, 58-59, 61, 64, 71, 119, 127, 132-133, 135-136, 189, 194, 225, 235

product outside of, 66, 71, 120-121, 160, 189, 195, 204, 254

specified, 13, 15, 16, 30-31, 54, 58-59, 61, 62-63, 64-65, 119-122, 124-127, 132, 151, 160, 224 (See Specifications; Specification limits)

statistical, 5-9 (See Control limits)

Line

of best fit, 144-145

of demarcation, 159

of regression, 144-146, 147, 148

of standard length or width, 90

Liquid, 189

Liquor, 146

List of variables, 91, 113

Lloyd, B. H., 101, 277

Loading, 246

Locating devices, 19, 83, 176

Location

in the sense of manufacturing plant (See Western Electric)

of distributions, 62, 64, 65, 120-121, 171, 174, 179, 188, 193-196, 226, 228

of jobs, 51

of parts, 55, 68, 69, 83, 167, 176, 180, 235

of trouble, 51, 188, 190, 202, 217-219

(See Early Operations.)

Locator (for a relay), 19

Locking device, 10, 68, 162

Logarithmic scale, 163

Long drying, 91, 92, 100, 101

Long-term capability, 34-35, 36, 45-46, 61-63, 64, 122

Loose connections, 20, 191

Looseness

of a mechanical device, 19, 69, 155, 178, 180, 219

of inspection plans, 273

of spoolheads, 5, 7, 8, 64

Losses

affected by inspection practices, 246, 254-255, 261, 263

charts on, 4, 21, 23, 38, 48, 188, 225, 227

minimized by process control charts, 36, 38

normal amount of, 46

reduction of, 4, 10, 16, 19-20, 33, 34, 35-36, 38, 46-47, 61-63, 71, 120-121, 122, 187-188, 217, 226, 265

Loss of data, unit etc., in an experiment, 116, 117

Lot-by-lot sampling plans, 255, 259-261, 262, 265, 268, 269, 270

Lots

as a process variable, 55, 156, 163, 164, 167, 175, 178

definition of, in inspection, 229, 259, 267

disposition of, 227, 254, 269

given a "second chance," 260

in continuous sampling, 255, 256 may be used as "samples," 17, 191

rejection of, 227, 249-250, 254-255, 265, 269, 273

sampling from, in inspection, 227, 255, 256, 260, 261, 265, 267, 269, 270

Lot size

affected by process control, 262

disregarded, 262, 263

in calculating AOQ, 251

in Dodge-Romig tables, 250, 253

in lot-by-lot inspection, 227, 247, 250, 251, 253, 259, 260-262, 265, 267, 270

in Mil. Std. tables, 247

L-shaped distribution, 163

LTPD, 249, 250, 253

LTPD sampling plans, 249, 250, 264, 265  
Lubricating oil, 23  
Lugs, 270  
Lunch periods, 70, 162

## M

Machine operations, 15-16, 66-72, 203-204  
Machines  
  adjustment of, 16, 30, 37, 67, 153, 166, 188, 202, 203-204, 212 (See Overadjustment)  
  age of, 168  
  as a variable, 3, 36, 45, 114, 158, 169, 174, 215, 217, 218-219, 224  
  capability of, 33, 35, 46, 170, 172, 175, 202, 204, 207, 224, 235  
  centering of, 30, 188  
  comparison of, 36, 46, 49, 54, 90, 159, 171, 172-173, 175, 202, 215, 224  
  construction of, 66, 151, 161  
  design of, 34, 35, 36, 46, 47, 69, 70, 83, 155, 171, 175, 213  
  downtime on, 38, 226  
  improvement of, 69, 70, 83  
  maintenance of, 10, 15-16, 19, 30, 35, 48, 167, 168, 175  
  needing repair, 10, 16, 30, 48, 69, 155, 167, 180  
  number of (for identification), 49, 207  
  overhauling of, 16, 219  
  purchase of, 47, 121  
  sampling from, 66, 151, 214  
  setup of, 150, 151, 174, 188, 202 (See Machine setting)  
  trouble with, 15-16, 19-20, 48, 66, 202  
Machine setters, 201, 202, 223, 226  
  adjustments by, 6, 16, 67, 150, 152, 166, 174, 190, 202, 203-204, 219, 220  
  as a variable, 10, 180  
  control exerted by, 48, 66, 67, 188, 202, 203-204  
  instructions to, 16, 66, 67, 217, 218  
  investigations by, 209, 212, 213, 217-218  
  notes by, 66, 67, 212, 213  
Machine setting, 6, 16, 30, 48, 50, 62, 150, 151, 152, 163, 202, 203, 204, 219  
Magnet, 125, 235  
Magnetic alignment, 69  
Main effects  
  corrected, 105, 106

  in a designed experiment, 75, 92-93, 94-97, 98, 99, 103, 104-105, 106, 107  
  meaning of, 104, 107  
  removed from an experiment, 102-103, 106  
Maintenance  
  amount of, 168, 175  
  considered as a process variable  
    53, 113, 167, 168, 175, 178, 180  
  cost of, 4  
  improvement in, 164, 204, 219  
  of a quality control program, 4, 33-34, 39-41, 223-229, 236  
  of fixtures, 35, 219  
  of machines, 10, 15-16, 19, 30, 35, 48, 167, 168, 175  
  of shop charts, 36, 38, 41, 65, 199, 205-209, 213-216, 219, 223-229  
  of soldering tips, 219  
  of test sets or gages, 159, 178, 219, 227  
  organization, 16, 202, 219  
  problems, 15-16, 19, 38, 206, 219, 227  
  program for, 46, 155, 162, 164, 180  
Major  
  components, 55  
  defects, 196, 263  
  variables, 55, 66-68, 113-114, 187-188  
"Make operations," 216, 235  
Management  
  courses, vii, 23, 33  
  guidance of program, 33-34, 41  
  interest in results, 10, 33-38, 41, 225-227  
  problems, 3, 4, 10, 22, 23, 33-41, 46-47, 77, 187, 233-236, 273-274  
  reports, 33, 225, 226, 227, 229  
Manual operations, 3, 4, 5, 8, 9, 10, 30, 38, 45, 48-49, 55, 57, 61, 62, 70, 72-73, 158, 162, 164, 167, 169, 170, 172, 175, 188, 203-204, 218, 219, 221, 235, 265  
Manuals  
  for Final inspection sampling plans, 264, 273, 278  
  for statistical clerks, 229  
  for training (See Training)  
Manual skill, 168  
Manufacturing  
  costs, 34, 35, 36, 236 (See Costs)  
  engineers (See Product engineers)  
  layouts (See Layouts)  
  problems, 3, 4, 46, 47, 75-77, 187-189  
Margin, arrows in, 13-14, 16, 30-31, 65, 67-71, 120-121, 190, 205-206, 212  
Markings (on control charts)

  designed experiments, 82-83, 87-88, 99, 100, 107, 109, 111  
  engineering charts, 52, 53, 66-71, 72-73, 188, 212  
  shop charts, 25(footnote), 192, 194-195, 208-209, 212-213, 215, 217, 218, 221, 227, 229  
Marking  $x$ 's  
  importance of, in general, 13, 18, 19, 20-21, 22, 23, 25 (footnote), 25-29  
  on engineering charts, 23, 52, 53, 83, 99, 100, 107, 109, 111, 168, 170  
  on shop charts, 23, 65, 192, 194-195, 202, 208, 209, 213, 215, 216, 217, 218, 221, 227, 229  
Masking  
  of a pattern, 66-67  
  of cycles, 69  
  of parts during spraying, 165  
  of variables, 55, 66, 67, 69, 168  
Master charts in the shop, 65, 228  
Master gage, 91  
Materials  
  as a variable, 3, 5, 6, 30, 45, 55, 69, 152, 155, 158, 164, 167, 168, 169, 171, 174, 175, 176, 178, 179, 180, 218  
  capability of, 35, 46, 224  
  changes in, 30, 62, 63, 174, 176  
  critical, 262  
  for assembly, 10, 37, 61, 64, 219, 254  
  for progress reports, 225-226  
  physical limits of, 57  
Mavericks, 156  
Maximum  
  limit, in specifications, 13, 15-16, 30-31, 57, 58-59, 61-65, 66, 71, 119-122, 124-127, 132-133, 135-136, 193, 195-196, 205, 206, 212, 220  
  values plotted on control chart, 197  
Mean  
  as an average (See Averages)  
  squares, 81, 91, 95, 96, 98, 130  
Mean deviation, 198  
Meaning  
  of "individual," "month," etc., 191  
  of "same essential conditions," 85, 90  
  (See Definitions)  
Measurements  
  accuracy of, 49, 89, 90-91  
  at end or sides of part, 90  
  attributes, 5, 6, 17, 18, 20-21, 47 (See Attributes data)  
  considered as a process variable, 49, 53, 62, 87, 89, 111, 113, 116-117, 165, 166, 215-216, 219, 227

- Measurements, *continued*  
 error of, 46, 49, 50, 53, 61, 62, 75, 76, 84-91, 111, 113, 163, 215, 219 (*See Accuracy; Precision*)  
 identification of, 49, 51, 52, 53, 54-56, 72-73, 84-85, 92, 98, 99, 100, 109, 111, 117, 208-209, 212-213, 215, 218-219, 227  
 incorrect, 215-216, 219 (*See Error*) in inspection, 270  
 may occur in non-random clusters, 160, 164-165 (*See Grouping*)  
 may reflect either process or product, 47  
 number of, 6, 50, 66, 90, 92, 93, 110, 111, 113 (*See Amount*)  
 of things which "cannot be measured," 12, 49-50, 113  
 randomized, in an experiment, 93, 113, 114-116  
 scale of, 138, 139, 216  
 scatter of, 129-131, 138, 143 (*See Spread*)  
 semi-variables, 12, 49, 50, 113  
 suitability of, 49-50, 51, 62, 84-85, 89-90, 113, 114, 116-117, 146, 190-192, 214, 215-216, 219  
 taken by process checker, 41, 49, 192, 201, 207, 209, 210, 213, 214, 215-216, 223, 228, 229  
 treated as separate factor in an experiment, 111  
 variables, 6, 8, 12, 14, 21-22, 47, 78, 84, 92, 139, 147 (*See Variables data*)
- Measuring instrument, 84-91, 165  
 Mechanical devices, 69  
 Medians  
 chart of, 197  
 meaning of, 129, 132  
 used in life testing, 197  
 used with midranges, 198, 277  
 Medical data, 6, 21  
 Meetings  
 of the Quality Control Team (*See Quality control meetings*)  
 with machine setters, 201-202, 218, 223, 226  
 with operators, 201-202, 223, 226  
 Members of the Team, 39, 40, 201-202, 223, 226, 234, 236  
 Mental activity, as a system of causes, 4  
 (*See Human variables*)  
 Mental arithmetic, 4, 215  
 Merchandise losses, 4, 23, 34, 46, 50 (*See Losses*)  
 Mercury switch, 209  
 Metallurgists, 40  
 Meter, 67, 71  
 Methods  
 as a variable, 3, 4, 45, 158, 164, 167, 217, 219, 227  
 capability of, 35, 46, 224  
 changes in, 30, 46-47, 62, 63, 68-70, 121, 165, 174, 175, 218, 219, 226  
 comparison of, 35, 46, 53, 55, 63, 72, 75, 76, 77-84, 90, 91-92, 93, 100-101, 112, 141, 175, 202, 218, 220, 224  
 development of, 34, 47, 226  
 of analysis, 36, 53, 54-56, 75-76, 77-84, 91-92, 93, 101, 141, 143-148, 149-183, 217-219, 220  
 of calculating residual, 94-95, 97, 103, 106, 107, 110-111  
 of changing inspection levels, 273-274, 278  
 of randomizing data, 93, 114-116  
 of selecting samples, 15, 49, 51, 82, 84, 113, 116, 149, 151, 190-192, 207, 209, 213, 214, 219, 227, 237, 239, 257, 259, 260-262, 267-268  
 of testing (*See Testing; Test sets*)  
 unreliable, 180  
 variability in, 83
- Methods of measurement  
 changes in, 165, 180, 218, 219  
 errors in, 49, 53, 62, 84-91, 113, 215-216, 219  
 for engineers, 49, 53, 62, 113  
 for inspectors, 268, 270  
 for process checkers, 192, 209, 214-216  
 (*See Error of measurement*)
- Methods of processing  
 general, 47, 48, 54, 114, 158, 218, 226  
 units for an experiment, 93, 113, 114-116, 117
- Micrometer, 91  
 Middle  
 of a pattern, 24-25, 29, 160, 169, 171, 172-174  
 third of a control chart, 25, 27, 181, 182, 183, 208
- Midpoint of cell, 130, 131, 154  
 Midranges and medians, 198, 277  
 Milling (on a welder), 213  
 Millivolts, 119  
 Mil. Std. sampling tables, 242, 247, 248, 278  
 Miniature tubes, 224, 225  
 Minimum  
 limit, in specifications (*See Maximum*)  
 values plotted on control chart, 197
- Minimum inspection  
 as an inspection level, 246, 247, 262-263, 264, 273-274  
 provision for, in Dodge-Romig tables, 254
- Minor defects, 198, 263  
 Minutes  
 between samples, 192, 207  
 of quality control meetings, 224, 226  
 spent on repairs, 225
- Mishandling  
 of data, 16, 49, 52-53, 61, 66-67, 76, 78-81, 84-85, 112, 117, 125, 131, 141, 145, 146, 153-154, 159, 163, 172, 173-174, 175, 178, 190, 194, 214-216, 219, 227, 254  
 of product (*See Damage*)
- Misinterpretation  
 of AOQL, 254-255  
 of chart for individual measurements, 160, 161, 173-174, 179  
 of control limits, 16, 151, 173-174, 190  
 of data (*See Mishandling; Wrong conclusions; Apparent*)  
 of instructions, 213  
 of  $p$ -chart, 59, 157, 159  
 of  $R$  chart, 67  
 of scale, 163, 190, 215  
 of  $\bar{X}$  chart, 153, 154
- Missile systems, 4  
 Mistakes  
 associated with specification limits, 16, 151, 190  
 in calculation, 162, 173, 215 (*See Calculations*)  
 in estimating 60-61 (*See Wrong conclusions*)
- Misunderstanding  
 of drawing, 153  
 of procedures, 67, 213, 227  
 of process controls, 227
- Mixed product, 36, 54-55, 150, 155, 156, 164, 166, 167, 171, 172-173, 179-180, 218-219
- Mixtures  
 as a pattern on a control chart, 11, 29, 53, 54, 67-68, 83, 111, 161, 166-167, 169-170, 171-174, 175-176, 179-180, 219  
 of distributions, 57-58, 68, 136, 156, 158, 163, 165, 166, 169-170, 171, 173, 176, 179  
 of product (*See Mixed product*)  
 on a chart for individual measurements, 160, 167, 171, 176, 180  
 on an  $R$  chart, 11, 66-68, 154-156, 161, 167, 168, 171, 172-173, 176, 178, 179-180  
 on an  $\bar{X}$  chart, 11, 153-154, 161, 167, 171, 173, 175, 179-180  
 on a  $p$ -chart or  $c$ -chart, 11, 72, 73, 157, 158, 159, 161, 167, 171, 173, 176, 180, 190
- Mode, 129, 131, 132  
 Moderate degree of defectiveness, 190

## Modification

- of a machine, 68-70, 83, 212, 213
- of a requirement, 38, 48, 61-63, 65, 122, 153, 187-188, 198, 219, 224, 226
- of data, 61, 141
- of layouts, 192, 199
- of process control charts, 38, 41, 65, 189-190, 198-199, 219, 223, 227-229
- of specifications, 61-63, 65, 122, 198, 219
- of statistical conclusions, 61, 83, 101, 141, 145
- of test sets, 174, 218, 224
- of tools, 62, 63, 121, 155, 158, 169, 179, 203, 212, 213, 219, 224

## Modified control limits

- for *c*-charts, 196-197
- for charts of individual measurements, 196
- for *p*-charts, 196-197
- for  $\bar{X}$  and *R* charts, 64, 65, 120, 195-196

## Moisture, 153

## Mold, 152

## Molina, E. C., 239-242, 277

## Money saved in experiments, 77, 92

## Monthly samples, 191, 192

## Moroney, M. J., 145, 275, 277

## Motion patterns, 61, 158

(See Work habits)

## Motivation of operators, 158, 174, 188, 201-203, 223, 226, 235, 265

## Motives, 4

(See Human variables)

## Motors, 70-71

## Mounting of charts in the shop, 192, 209, 217, 218, 228

## Movements

- of a machine, 151, 161
- of a pattern, 9, 29, 160, 177, 178, 179

## Moving range charts, 21-23

(See Charts for individual measurements)

## Moving range limits

- for individual plotted points (See Charts for individual measurements)
- for *p*-charts or *c*-charts, 196-197
- for summary control charts, 222

## Multifactor experiments, 75, 77, 97, 110-111

## Multi-modal distributions, 136, 166, 173 (See Non-normal distributions; Bimodal distributions)

## Multiple spindles, positions, heads etc., 66, 72, 151, 161, 172, 176, 219

## Multiple sampling, 238, 242, 259-261 (See Sequential sampling)

## Multiple tests

- for interpreting control chart patterns, 25 (footnote), 25-30, 53, 100, 107, 109, 180-183, 208, 218-219
- probabilities associated with, 25 (footnote), 180-183
- "Multi-vari" charts, 198
- Mundel, A. B., 262, 278
- Munitions Board, 278 (See U. S. Dept. of Defense)
- Mysterious troubles, 4, 35, 38, 51, 54-56, 66-67, 75, 76, 77, 91-92, 155, 157, 159, 166, 187, 188, 202, 206, 217, 218, 219, 220 (See Unknown causes of trouble)

## N

## Narrowed limit sampling plans, 262, 278

## Narrowness

- of control limits, 72, 73, 150, 166
- of process, 62, 120, 121
- of specified limits (See Tightness)

## Natural

- behavior of a process, 34, 36, 45, 150, 171
- limits, 46, 61, 64, 122, 124-127, 151-152
- tolerances, 61, 152 (See Natural spread of a process; Natural variation)

## Natural pattern

- amount of data required for, 9, 150, 170, 171
- causes of, 6, 9, 24, 53, 150, 171
- characteristics of, 8, 9, 24, 161, 170, 175
- conclusions from, in a process capability study, 35, 36, 53-54, 56, 58, 59, 61-63, 71, 119-122, 127
- explanation of, 6-7, 9, 24-25, 149, 150, 170-171
- importance of, 34-35, 36, 45, 47, 53-54, 56, 61, 71-72, 87, 119, 122, 125, 127, 141, 145, 189-190, 217, 219
- not necessarily desirable, 35, 54-56, 61, 112, 171, 189, 205
- Natural spread of a process, 9, 16, 30-31, 45, 56, 58-59, 61, 62, 71, 83, 89, 119-122, 124, 131, 151-152, 156, 170, 195, 196, 205

## Natural variation

- importance of, 35, 36, 53-54
- meaning of, 6, 9, 24, 35, 53, 149, 150, 170-171 (See Variability; Variation; Natural pattern)

## Neatness of shop charts, 216

## Negative correlation

(See Correlation)

## Negative skewness

(See Skewness)

## Neglect

- of charts, 217, 221, 227
- of process controls, 227

## New

- capability studies, 40, 62, 228
- characteristics created by assembly, 122
- designs, 34, 46, 47, 52, 188
- jobs in the shop, 188
- operator or inspector, 49, 73, 152, 155, 167, 174, 175, 180, 202, 204, 218
- performance studies, 74, 227
- plant expense, 226
- process checker, 41, 192, 212, 213, 218, 223
- processes, 34, 38, 47, 52, 76, 220, 226
- products, 47, 188
- supervisor, 51, 169, 178

## Nicks, 113

## Night shift, 72, 73, 161, 162

(See Shifts)

## Noise, 10, 12, 68, 138-141

## "Nominal" dimension

- moved to another place, 63, 121
- working on one side of, 64, 167, 204, 220

## Non-assignable causes, 6, 150, 152, 171

## "Nonconforming" material, 269

## Non-homogeneous product

(See Mixed product; Homogeneity)

## Non-linear

- behavior of a variable, 164
- combinations of distributions, 123 (footnote)
- correlation, 148
- scale, 163

## Non-normal distributions, 131, 134-136, 138

- causes for, 56-58, 83, 136
- compared with specification, 56, 122
- detected on a control chart, 69-70, 83, 156
- estimating shape of, 30-31, 56, 59, 141
- estimating spread of, 31, 56, 59, 61, 122, 134-136
- "modified" limits for, 196
- not properly allowed for, 125, 153, 160
- percentage outside of limits in, 31, 59, 122, 134, 135, 136
- probabilities associated with, 56, 134-136, 182-183, 239, 242
- related to chart of individual measurements, 160-161, 170