

A Guide for Fatigue Testing and the Statistical Analysis of Fatigue Data

**(Supplement to Manual on Fatigue
Testing, STP No. 91)**

ASTM Special Technical Publication No. 91-A (Second Edition)



**American Society for Testing and Materials
1916 Race Street, Philadelphia 3, Pa.**

PROPERTY OF

*The
University of
Michigan
Libraries*

1817



ARTES SCIENTIA VERITAS

A GUIDE FOR FATIGUE TESTING AND THE STATISTICAL ANALYSIS OF FATIGUE DATA

Prepared by
COMMITTEE E-9 ON FATIGUE
AMERICAN SOCIETY FOR TESTING AND MATERIALS
1963



Reg. U. S. Pat. Off.

ASTM Special Technical Publication No. 91-A (Second Edition)

Price: \$5.00; to Members: \$4.00

Published by the
AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race Street, Philadelphia 3, Pa.

©BY AMERICAN SOCIETY FOR TESTING AND MATERIALS 1963
Library of Congress Catalog Card Number: 63-16331

FOREWORD

The First Edition of this Guide was the composite work of many people who contributed a great deal of time to the discussion and writing of the text under the guidance of Task Group Leader, F. B. Stulen. A major portion of the statistical section was written by Miss Mary N. Torrey. George R. Gohn not only contributed to the discussion and planning, but also edited and arranged for the printing of the advance copies of the text. The coordination of contributions and discussions was done by H. N. Cummings. Appreciable contributions to the statistical parts of the Guide were also made by D. H. Shaffer. In addition to the above, R. E. Peterson, H. F. Dodge, D. P. Gaver, R. Hooke, W. T. Lankford, R. B. Murphy, W. C. Schulte, P. R. Toolin, and M. B. Wilk contributed to the discussions at various conferences.

The original Task Group was organized under the leadership of J. T. Ransom, and a first rough draft was prepared in 1954 and revised in 1955. Other contributors to these drafts were E. W. Ellis, W. T. Lankford, F. A. McClintock, R. E. Peterson, E. H. Schuette, F. B. Stulen, and E. J. Ward. In 1956, F. B. Stulen became Leader of the Task Group and the Guide was completed under his direction.

Upon the formation of Subcommittee VI on the Statistical Aspects of Fatigue, this subcommittee was asked to review the First Edition and to make any revisions necessary to bring the Guide up to date. As a result of this study, extensive revisions have been made in various sections as printed in this Second Edition. They include: (1) revisions in the definitions (Section II) and their separate publication as ASTM Tentative Definitions E 206,¹ (2) an expansion of Section IV on the number of test specimens, (3) changes in Section V on tests of significance, and (4) the preparation of a new section, Appendix IV, on the use of the Weibull distribution function for fatigue life.

This work was carried out by four Task Groups headed by S. M. Marco, H. E. Frankel, Miss M. N. Torrey, and C. A. Moyer, respectively. Others who assisted in the preparation of the Second Edition were W. N. Findley, R. A. Heller, J. H. K. Kao, H. N. Cummings, W. S. Hyler, B. Ruley, and G. R. Gohn, Chairman of Subcommittee VI.

¹ Definitions of Terms Relating to Fatigue Testing and the Statistical Analysis of Fatigue Data (E 206), 1962 Supplement to Book of ASTM Standards, Part 3.

NOTE.—The Society is not responsible, as a body, for the statements
and opinions advanced in this publication.

CONTENTS

	PAGE
I. Purposes of Fatigue Testing	1
II. Definitions, Symbols, and Abbreviations	2
III. Test Procedures	8
IV. Minimum Number of Test Specimens and Their Selection	16
V. Analysis of Fatigue Data	22
Appendices	
Miscellaneous Reference Tables	55
Additional Technique for Distribution Shape Not Assumed	68
Analysis of Correlation Between Two Variables	69
The Weibull Distribution Function for Fatigue Life	71
References	78
Index	81

LIST OF TABLES

TABLE	PAGE
1.—Allocation of Test Specimens for "Probit" Method of Test	11
2.—Minimum Number of Specimens Needed for Determining 95 Per Cent Confidence Intervals of Stated Width for a Population Mean, μ	19
3.—Minimum Number of Specimens Needed for Determining 95 Per Cent Confidence Intervals of Stated Width for a Population Standard Deviation, σ	19
4.—Minimum Number of Specimens Needed to Detect if the Standard Deviation of a Population Is a Stated Percentage of a Fixed Value	20
5.—Minimum Number of Specimens Needed in Each Sample to Detect if a Standard Deviation of One Population Is a Stated Multiple of the Standard Deviation of Another Population	20
6.—Minimum Number of Specimens Needed to Detect a Stated Difference Between a Mean and a Fixed Value	21
7.—Minimum Number of Specimens Needed to Detect a Stated Difference Between the Means of Two Populations	21
8.—Median Percentage of Survivors for the Population	24
9.—Confidence Intervals for the Median	26
10.—Approximate Confidence Intervals for the Mean	27
11.—Confidence Intervals for Percentages	28
12.—Fatigue Test Data	29
13.—Fatigue Test Data	31
14.—Percentages Surviving 10^8 Cycles	32
15.—"Probit" Test Data	33
16.—Computations for Fitting a Response Curve by Method of Least Squares	35
17.—Computation of Standard Deviation, s	36
18.—Method of Computing 95 Per Cent Confidence Limits for Per Cent Survival Values	37
19.—Method of Computing 95 Per Cent Confidence Limits for Fatigue Strength Values	38
20.—Computations for Significance Tests	46
21.—R. R. Moore Rotating Beam; Step Tests of 42 Specimens	50
22.—Analysis of Data in Table 21	51
23.—Prot Test Computations	52

TABLE	PAGE
24.—Prot Test Computations.....	53
25.—Minimum Per Cent of Population Exceeding Median of Low Ranking Points..	56
26.—Unpaired Rank Test.....	58
27.—Percentiles of the χ^2 Distribution.....	60
28.—Areas of the "Normal" Curve.....	61
29.—Values of t	62
30.—Percentiles of the χ^2 /d.f. Distribution.....	63
31.— $u_{0.25}$ and $u_{0.975}$ for Runs Among Elements in Samples of Sizes N_1 and N_2	64
32.— F Distribution.....	65
33.— k Factors for $S-N$ Curves (Normal Distribution Assumed).....	67
34.—Working Significance Levels for Quadrant Sum.....	69
35.—Ordinate Locations Corresponding to Per Cent Failed Values.....	72
36.—Mean-Rank Estimates of the Per Cent Population Failed Corresponding to Failure Order in Sample.....	74
37.—Typical Fatigue Test Data.....	75
38.—Typical Fatigue Test Data, Without Runouts.....	75
39.—Typical Fatigue Test Data, with Runouts.....	77

LIST OF FIGURES

FIGURE	
1.—Probability-Stress-Cycle ($P-S-N$) Curve for Phosphor-Bronze Strip.....	10
2.—Response or Survival Tests.....	11
3.—Illustration of Staircase Method.....	12
4.—Representation of "Step" Testing of Single Specimen.....	14
5.—Graphical Illustration of Prot Data.....	15
6.—"Normal" or Gaussian Distribution Curve.....	22
7.—Response Curves for a Particular Type of Steel.....	34
8.—Per Cent of Specimens Having at Least the Indicated Fatigue Strength at 10^7 Cycles.....	51
9.—Prot Test: Stress as Linear Function of Stress Cycles.....	53
10.—Log-Log Plot of Prot Data.....	54
11.—Scatter Diagram.....	70
12.—Typical Weibull Distribution Curves.....	72
13.—Construction of Weibull Probability Paper from Log-Log Paper.....	73
14.—Estimation of Weibull Distribution Function Parameters for Data in Table 38.....	75
15.—Per Cent Failed at Weibull Mean.....	76
16.—Estimation of Weibull Distribution Function Parameters for Data in Table 39.....	77

RELATED ASTM PUBLICATIONS

Abstracts of Articles on Fatigue (STP 9)
 Fatigue Manual (STP 91) (1949)
 Statistical Aspects of Fatigue (STP 121) (1951)
 Fatigue, with Emphasis on Statistical Approach (STP 137) (1952)
 Papers on Metals (STP 196) (1956)
 Fatigue of Aircraft Structures (STP 203) (1956)
 Large Fatigue Testing Machines and Their Results (STP 216) (1957)
 Basic Mechanisms of Fatigue (STP 237) (1958)
 Fatigue of Aircraft Structures (STP 274) (1959)
 Acoustical Fatigue (STP 284) (1960)
 Fatigue of Aircraft Structures (STP 338) (1963)

THIS PUBLICATION is one of many issued by the American Society for Testing and Materials in connection with its work of promoting knowledge of the properties of materials and developing standard specifications and tests for materials. Much of the data result from the voluntary contributions of many of the country's leading technical authorities from industry, scientific agencies, and government.

Over the years the Society has published many technical symposiums, reports, and special books. These may consist of a series of technical papers, reports by the ASTM technical committees, or compilations of data developed in special Society groups with many organizations cooperating. A list of ASTM publications and information on the work of the Society will be furnished on request.

