Designation: E 1823 – 96$^{\epsilon 1}$

Standard Terminology Relating to Fatigue and Fracture Testing[1]

This standard is issued under the fixed designation E 1823; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ϵ^1 NOTE—This standard was updated editorially in February 1997.

1. Scope

1.1 This terminology contains definitions, definitions of terms specific to certain standards, symbols, and abbreviations approved for use in standards on fatigue and fracture testing. The definitions are preceded by two lists. The first is an alphabetical listing of symbols used. (Greek symbols are listed in accordance with their spelling in English.) The second is an alphabetical listing of relevant abbreviations.

1.2 This terminology includes Annex A1 on Units and Annex A2 on Designation Codes for Specimen Configuration, Applied Loading, and Crack or Notch Orientation.

2. Referenced Documents

2.1 *ASTM Standards:*

E 6 Terminology Relating to Methods of Mechanical Testing[2]
E 338 Test Method for Sharp-Notch Tension Testing of High-Strength Sheet Materials[2]
E 399 Test Method for Plane-Strain Fracture Toughness of Metallic Materials[2]
E 436 Test Method for Drop-Weight Tear Tests of Ferritic Steels[2]
E 466 Practice for Conducting Force-Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials[2]
E 467 Practice for Verification of Constant Amplitude Dynamic Loads on Displacements in an Axial Load Fatigue Testing System[2]
E 468 Practice for Presentation of Constant Amplitude Fatigue Test Results for Metallic Materials[2]
E 561 Practice for *R*-Curve Determination[2]
E 602 Test Method for Sharp-Notch Tension Testing with Cylindrical Specimens[2]
E 604 Test Method for Dynamic Tear Testing of Metallic Materials[2]
E 606 Practice for Strain-Controlled Fatigue Testing[2]
E 647 Test Method for Measurement of Fatigue Crack Growth Rates[2]
E 739 Practice for Statistical Analysis of Linear or Linearized Stress-Life (S-N) and Strain-Life (ε-N) Fatigue Data[2]
E 740 Practice for Fracture Testing with Surface-Crack Tension Specimens[2]
E 812 Test Method for Crack Strength of Slow-Bend Precracked Charpy Specimens of High-Strength Metallic Materials[2]
E 813 Test Method for J_{Ic}, A Measure of Fracture Toughness[2]
E 992 Practice for Determination of Fracture Toughness of Steels Using Equivalent Energy Methodology[2]
E 1049 Practices for Cycle Counting in Fatigue Analysis[2]
E 1152 Test Method for Determining *J-R* Curves[2]
E 1221 Test Method for Determining Plane-Strain Crack-Arrest Fracture Toughness, K_{Ia}, of Ferritic Steels[2]
E 1290 Test Method for Crack-Tip Opening Displacement (CTOD) Fracture Toughness Measurement[2]
E 1304 Test Method for Plane-Strain (Chevron-Notch) Fracture Toughness of Metallic Materials[2]
E 1457 Test Method for Measurement of Creep Crack Growth Rates in Metals[2]
E 1681 Test Method for Determining a Threshold Stress Intensity Factor for Environment-Assisted Cracking of Metallic Materials Under Constant Load[2]
E 1737 Test Method for *J*-Integral Characterization of Fracture Toughness[2]
E 1820 Test Method for Measurement of Fracture Toughness[2]
G 15 Terminology Relating to Corrosion and Corrosion Testing[3]

3. Terminology

3.1 *Symbols: Alphabetical Listing of Principal Symbols Used in This Terminology:*

Symbol	Term
a	crack depth, crack length, crack size, estimated crack size
a_e	effective crack size
a_n	notch length
a_o	original crack size
a_p	physical crack size
a/W	normalized crack size
A	load ratio (P_a/P_m)

[1] This terminology is under the jurisdiction of ASTM Committee E-8 on Fatigue and Fracture and is the direct responsibility of Subcommittee E08.02 on Standards and Terminology.

Current edition approved June 10, 1996. Published August 1996.

[2] *Annual Book of ASTM Standards*, Vol 03.01.

[3] *Annual Book of ASTM Standards*, Vol 03.02.

Symbol	Term
A_N	net-section area
b	remaining ligament
b_o	original uncracked ligament
B	specimen thickness
B_e	effective thickness
B_N	net thickness
$2c$	surface-crack length
C	normalized *K*-gradient
D	cycle ratio (n/N_f)
C*(t)	C*(t) − Integral
da/dN	fatigue-crack-growth rate
δ	crack-tip opening displacement (*CTOD*)
δd	speciment gage length
Δa	crack extension, estimated crack extension
ΔK	stress-intensity-factor range
ΔK_{th}	fatigue-crack-growth threshold
ΔP	load range
ϵ_a	strain amplitude
ϵ_{in}	inelastic strain
ϵ_m	mean load
G	crack-extension force
G_R	crack-extension resistance
H*	specimen center of pin hole distance
Γ	the path of the *J*-integral
J	*J*-integral
J_{Ic}	plane-strain fracture toughness
J_R	crack-extension resistance
k_f	fatigue notch factor
k_t	theoretical stress concentration factor (sometimes abbreviated stress concentration factor)
K, K_1, K_2, K_3, K_I, K_{II}, K_{III}	stress-intensity factor (see mode)
K_a	crack-arrest fracture toughness
K_c	plane-stress fracture toughness
K_{EAC}	stress intensity factor threshold for environment-assisted cracking
K_{Ia}	plane-strain crack-arrest fracture toughness
K_{IEAC}	stress intensity factor threshold for plane strain environment-assisted cracking
K_{Ic}	plane-strain fracture toughness
K_{IvM}, K_{Iv}, K_{Ivj}	plane-strain (chevron-notch) fracture toughness
K_{max}	maximum stress-intensity factor
K_{min}	minimum stress-intensity factor
K_o	stress-intensity factor at crack initiation
K_R	crack-extension resistance
n	cycles endured
N_f	fatigue life
P	load
P_a	load amplitude
P_m	mean load
P_M	precrack load
P_{max}	maximum load
P_{min}	minimum load
q	fatigue notch sensitivity
r	effective unloading slope ratio
r_c	critical slope ratio
r_y	plastic-zone adjustment
R	load ratio (P_{min}/P_{max})
s	sample standard deviation
s^2	sample variance
S	specimen span
S_a	load amplitude
S_f	fatigue limit
S_m	mean load
S_N	fatigue strength at *N* cycles
σ_c	crack strength
σ_N	nominal (net-section) stress
σ_r	residual strength
σ_s	sharp-notch strength
σ_{TS}	tensile strength
σ_x, σ_y, σ_z	normal stresses (refer to)
σ_Y	effective yield strength
σ_{YS}	yield strength
T	specimen temperature
t_T	transition time
τ_t	total cycle period
τ_{xy}, τ_{yz}, τ_{zx}	shear stresses (refer to Fig. 1)
u	displacement in *x* direction
v	displacement in *y* direction
$2v_m$	crack-mouth opening displacement
V_c	load-line displacement due to creep
w	displacement in *z* direction
W	specimen width
Y^*	stress-intensity factor coefficient
Y^*_m	minimum stress-intensity factor coefficient

3.2 *Alphabetical Listing of Abbreviations Used:*

CMOD	crack-mouth opening displacement
COD	see *CTOD*
CTOD	crack-tip opening displacement
DT	dynamic tear
DWTT	drop-weight tear test
EAC	environment-assisted cracking
K-EE	equivalent-energy fracture toughness
NTS	notch tensile strength
PS	part-through surface
SCC	stress corrosion cracking
SZW	stretch zone width

3.3 *Definitions*—Each definition is followed by the designation(s) of the standard(s) of origin. The listing of definitions is alphabetical.

alternating load—See **loading amplitude**.

block—*in fatigue loading*, a specified number of constant amplitude loading cycles applied consecutively, or a spectrum loading sequence of finite length that is repeated identically. **E 1823**

blunting line—*in fracture testing*, a line that approximates apparent crack advance due to crack-tip blunting in the absence of slow stable crack tearing. The line is defined based on the assumption that the crack advance is equal to one half of the crack-tip opening displacement. This estimate of pseudo-crack advance, Δa_B , is based on the effective yield strength of the material tested. **E 813**

$$\Delta a_B = J/2\,\sigma_Y \quad (1)$$

circulation rate [$L^3\ T^{-1}$]—*in fatigue testing*, the volume rate of change of the environment chamber volume. **E 1823**

clipping—*in fatigue spectrum loading*, the process of decreasing or increasing the magnitude of all loads (strains) that are, respectively, above or below a specified level, referred to as clipping level; the loads (strains) are decreased or increased to the clipping level (see Fig. 2). **E 1823**

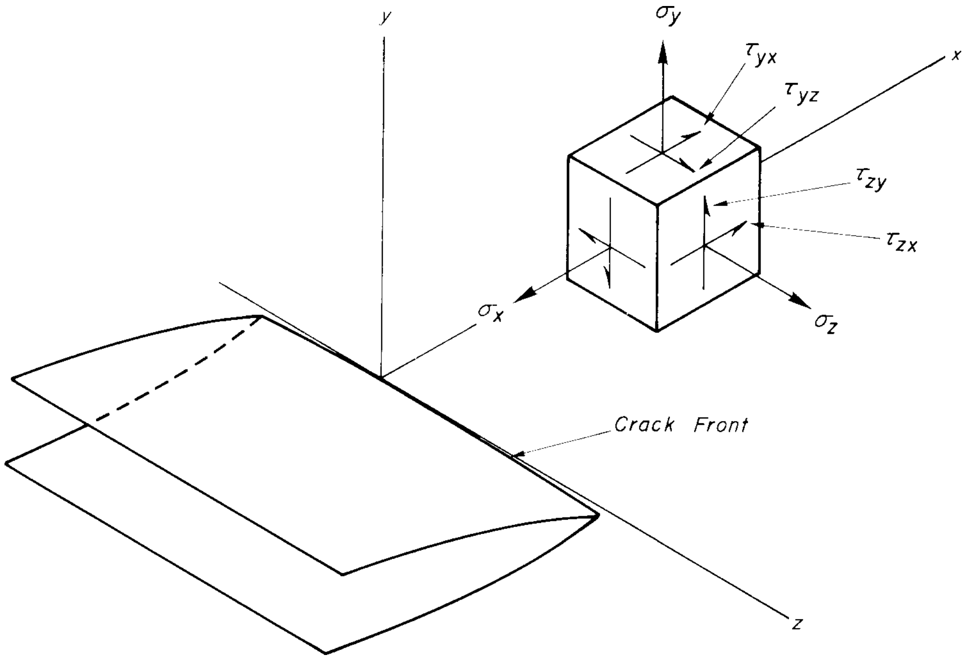
compliance (LF^{-1}], *n*— the ratio of displacement increment to load increment. **E 1820**

confidence interval—an interval estimate of a population parameter computed so that the statement ″the population parameter included in this interval" will be true, on the average, in a stated proportion of the times such computations are made based on different samples from the population. **E 1823**

confidence level (or coefficient)—the stated proportion of the times the confidence interval is expected to include the population parameter. **E 1823**

confidence limits—the two statistics that define a confidence interval. **E 1823**

constant amplitude loading— *in fatigue loading*, a loading (straining) in which all of the peak loads (strains) are equal and all of the valley loads (strains) are equal. **E 1049**



NOTE 1—See definition of mode.

FIG. 1 Customary Coordinate System and Stress on a Small Volume Element Located on the *x* Axis Just Ahead of the Crack Front

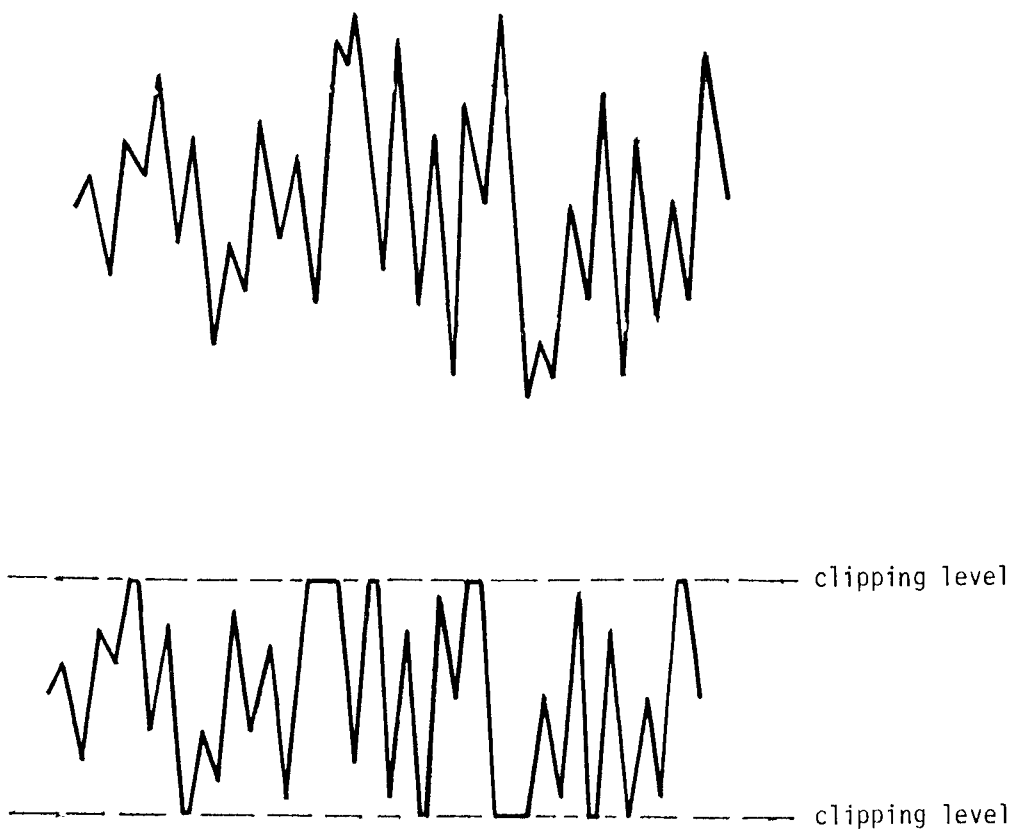


FIG. 2 Clipping of Fatigue Spectrum Loading

constant life diagram— *in fatigue*, a plot (usually on rectangular coordinates) of a family of curves each of which is for a single fatigue life, *N*, relating stress amplitude, S_a, to mean stress, S_m, or maximum stress, S_{max}, or both, to minimum stress, S_{min}. The constant life fatigue diagram is usually derived from a family of *S-N* curves each of which represents a different stress ratio (*A* or *R*) for a 50 % probability of survival. **E 1823**

corrosion fatigue—the process by which fracture occurs prematurely under conditions of simultaneous corrosion and repeated cyclic loading at lower stress levels or fewer cycles than would be required in the absence of the corrosive environment. **G 15**

counting method—*in fatigue spectrum loading*, a method of counting the occurrences and defining the magnitude of various loading parameters from a load-time history; (some of the counting methods are: level crossing count, peak count, mean crossing peak count, range count, range-pair count, rain-flow count, racetrack count). **E 1049**

crack displacement [L]—the load-induced separation vector between two points (on the facing surfaces of a crack) that were initially coincident.

DISCUSSION—In Practice E 561, displacement is the distance that a chosen measurement point on the specimen displaces normal to the crack plane. Measurement points on the C(W) and C(T) specimen configurations are identified as locations V0, V1, and V2. **E 561**

crack extension, Δa [L]—an increase in crack size.

DISCUSSION—For example, in Practice E 561, Δa_p or Δa_e is the difference between the crack size, either a_p (physical crack size) or a_e (effective crack size), and a_o (original crack size). **E 561**

crack-extension force, *G* [FL^{-1} or FLL^{-2}]—the elastic energy per unit of new separation area that is made available at the front of an ideal crack in an elastic solid during a virtual increment of forward crack extension.

DISCUSSION—This force concept implies an analytical model for which the stress-strain relations are regarded as elastic. The preceding definition of *G* applies to either static cracks or running cracks. From past usage, *G* is commonly associated with linear-elastic methods of analysis, although the *J* (see ***J*-integral**) also may be used for such analyses. **E 1823**

crack-extension resistance, K_R [$FL^{-3/2}$], G_R [FL^{-1}] or J_R [FL^{-1}]—a measure of the resistance of a material to crack extension expressed in terms of the stress-intensity factor, *K*; crack-extension force, *G*; or values of *J* derived using the *J*-integral concept.

DISCUSSION—See definition of *R*-curve. **E 561**

crack length, *a* [L]—See crack size and surface crack length. Also see crack length in the *Description of Terms*. For example, in the C(T) specimen, *a* is measured from the line connecting the bearing points of load application; in the M(T) specimen, *a* is measured from the perpendicular bisector of the central crack. **E 647**

crack-mouth opening displacement (*CMOD*), $2v_m$ [L]—the Mode 1 (also called opening-mode) component of crack displacement resulting from the total deformation (elastic plus plastic), measured under load at the location on a crack surface that has the greatest elastic displacement per unit load.

DISCUSSION—In part-through surface-crack (PS) specimens, *CMOD* is measured on the specimen surface at the midpoint of the crack length. **E 740**

crack-plane orientation—an identification of the plane and direction of a fracture in relation to product configuration. This identification is designated by a hyphenated code with the first letter(s) representing the direction normal to the crack plane and the second letter(s) designating the expected direction of crack propagation.

DISCUSSION—See also Annex A2, (A2.4 on crack or notch orientation). **E 399**

crack size, *a* [L]—a lineal measure of a principal planar dimension of a crack. This measure is commonly used in the calculation of quantities descriptive of the stress and displacement fields and is often also termed crack length or depth.

DISCUSSION—In practice, the value of *a* is obtained from procedures for measurement of physical crack size, a_p, original crack size, a_o, and effective crack size, a_e, as appropriate to the situation being considered. **E 647**

cumulative frequency spectrum—See **exceedances spectrum**.

cumulative occurrences spectrum—See **exceedances spectrum**.

crack strength, σ_c [FL^{-2}]—the maximum value of the nominal stress that a cracked structure is capable of sustaining.

DISCUSSION—1 Crack strength is calculated on the basis of the maximum load and the original minimum cross-sectional area (net cross section or ligament). Thus, it takes into account the original size of the crack but ignores any crack extension that may occur during the test.

DISCUSSION—2 Crack strength is analogous to the ultimate tensile strength, as it is based on the ratio of the maximum load to the minimum cross-sectional area at the start of the test. **E 338, E 602**

crack-tip opening displacement (*CTOD*), δ, [L]—the crack displacement resulting from the total deformation (elastic plus plastic) at variously defined locations near the original (prior to load application) crack tip.

DISCUSSION—In common practice, δ is estimated for Mode 1 by inference from observations of crack displacement nearby or away, or both, from the crack tip. **E 1290**

crack-tip plane strain—a stress-strain field (near the crack tip) that approaches plane strain to the degree required by an empirical criterion.

DISCUSSION—For example, in Mode 1, the criterion for crack-tip plane strain given by Test Method E 399 requires that plate thickness, *B*, must be equal to or greater than 2.5 $(K/\sigma_{YS})^2$. **E 399**

crack-tip plane stress—a stress-strain field (near the crack tip) that is not in plane strain.

DISCUSSION—In such situations, a significant degree of plane strain may be present. **E 1823**

criterion of failure—complete separation, or the presence of a crack of specified length visible at a specified magnification. Other criteria may be used but should be clearly defined. **E 468**

crystallographic cleavage—the separation of a crystal along a plane of fixed orientation relative to the three-dimensional crystal structure within which the separation process occurs, with the separation process causing the newly formed surfaces to move away from one another in directions containing major components of motion perpendicular to the fixed plane. **E 1823**

cycle—*in fatigue*, one complete sequence of values of load (strain) that is repeated under constant amplitude loading (straining). (See Fig. 3.) The symbol *N* (see definition of **fatigue life**) is used to indicate the number of cycles.

DISCUSSION—In *spectrum loading*, definition of cycle varies with the counting method. **E 1823**

cycles endured, *n*—*in fatigue*, the number of cycles of specified character (that produce fluctuating load) which a specimen has endured at any time in its load history. **E 1823**

cycle ratio, *D*— the ratio of cycles endured, *n*, to the estimated fatigue life, N_f, obtained from the stress versus fatigue life (*S-N*) or the strain versus fatigue life (ε-*N*) diagram for cycles of the same character, that is, $D = n/N_f$. **E 1823**

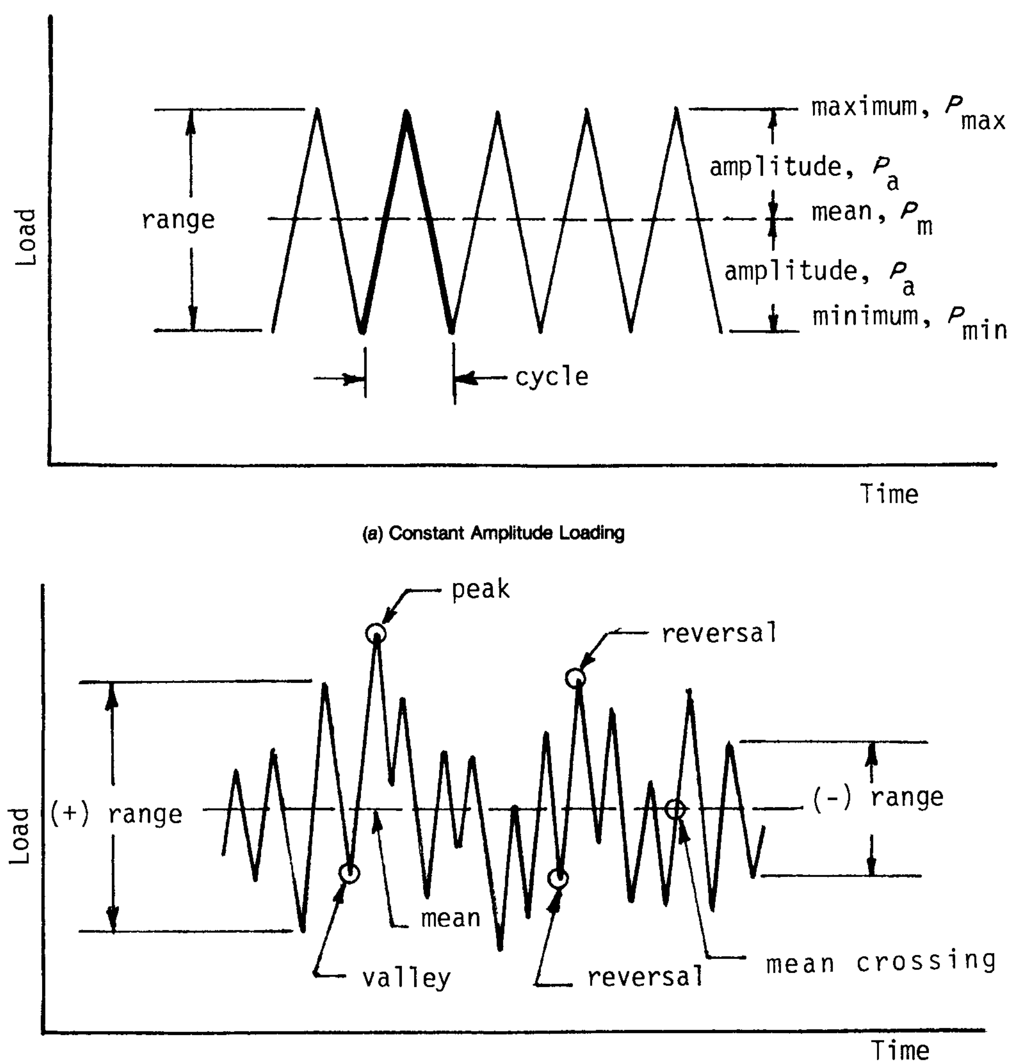
cyclic loading—See **fatigue loading.**

deaeration—*in environmentally affected fatigue testing*, the process of removal of air from the liquid environment before and during a test. **E 1823**

dynamometer—an elastic calibration device used to verify the indicated loads applied by a fatigue testing system. It shall consist of an instrumented member having mass, stiffness, and end displacements such that the inertial effects of the specimen and its attachments to the testing machine for which the verification of loads is desired are duplicated within 5 %. The instrumentation shall permit an accurate determination of the magnitude of the average strain in a region of the uniform transverse cross section when the dynamometer is subjected to a tensile or compressive force along its longitudinal axis, within 1 % of the true strains. A strain gaged specimen is often used as a dynamometer. **E 467**

dynamometer dynamic loads [F]—the maximum and minimum loads (or the mean load and the load amplitude) that correspond to the readings obtained from the dynamometer output according to an existing static calibration. Such loads are considered true specimen dynamic loads for the purpose of this terminology. **E 467**

dynamometer range [F]—the range of loads for which the dynamometer may be used for verification purposes. A dynamometer for use in tension and in compression will



(*a*) Constant Amplitude Loading

(*b*) Spectrum Loading

FIG. 3 Fatigue Loading Basic Terms

have two dynamometer ranges, one in tension and one in compression. **E 467**

effective crack size, a_e [L]—the physical crack size augmented to account for crack-tip plastic deformation.

DISCUSSION—Sometimes the effective crack size, a_e, is calculated from a measured value of a physical crack size, a_p, plus a calculated value of a plastic-zone adjustment, r_Y. Another method for calculation of a_e involves comparing the compliance from the secant of a load-deflection trace with the elastic compliance from a calibration for the given specimen design. **E 561**

effective thickness B_e [L]—for compliance-based extension measurements: **E 813**

$$B_e = B - (B - B_N)^2/B \quad (2)$$

effective yield strength, σ_Y [FL^{-2}]—an assumed value of uniaxial yield strength, that represents the influences of plastic yielding upon fracture test parameters.

DISCUSSION—1 It is calculated as the average of the 0.2 % offset yield strength, σ_{YS}, and the ultimate tensile strength, σ_{TS}, for example:

$$\sigma_Y = (\sigma_{YS} + \sigma_{TS})/2 \quad (3)$$

DISCUSSION—2 In estimating σ_Y, influences of testing conditions, such as loading rate and temperature, should be considered. **E 1823**

environment—*in fatigue testing*, the aggregate of chemical species and energy that surrounds a test specimen. **E 1823**

environment chamber— *in fatigue testing*, the container of the bulk volume surrounding a test specimen. **E 1823**

environment chamber volume [L^3]—*in fatigue testing*, that bulk volume surrounding a test specimen. **E 1823**

environment composition [ML^{-3}]—*in corrosion fatigue testing*, the concentration of the chemical components in the fluid environment surrounding a test specimen. **E 1823**

environment hydrogen content [ML^{-3}]—*in corrosion fatigue testing*, the hydrogen gas concentration of the fluid environment surrounding a test specimen. **E 1823**

environment monitoring— *in fatigue testing*, the periodic or continuous measurement of fluid concentrations of the environment. **E 1823**

environment oxygen content [ML^{-3}]—*in corrosion fatigue testing*, the oxygen concentration of the fluid environment surrounding a test specimen. **E 1823**

environment pressure [FL^{-2}]—*in fatigue testing*, the pressure of the bulk volume surrounding a test specimen. **E 1823**

environment temperature— *in fatigue testing*, the temperature of the bulk volume surrounding a test specimen. **E 1823**

environment volume [L^3]—*in fatigue testing*, the total volume immediately surrounding a test specimen plus that contained in a circulating reservoir if applicable. **E 1823**

estimate—*in statistical analysis*, the particular value or values of a parameter computed by an estimation procedure for a given sample. **E 1823**

estimated crack extension, Δa[L]—an increase in estimated crack size ($\Delta a = a - a_{oq}$). **E 1737**

estimated crack size a[L]—the distance from a reference plane to the observed crack front developed from measurements of elastic compliance or other methods. The reference plane depends on the specimen form, and it is normally taken to be either the boundary, or a plane containing either the load line or the centerline of a specimen or plate. The reference plane is defined prior to specimen deformation. **E 1737**

estimation—*in statistical analysis*, a procedure for making a statistical inference about the numerical values of one or more unknown population parameters from the observed values in a sample. **E 1823**

exceedances spectrum— *in fatigue loading*, representation of spectrum loading contents by the number of times specified values of a particular loading parameter (peak, range, and so forth) are equaled or exceeded (also known as *cumulative occurrences* or *cumulative frequency spectrum*). **E 1823**

fatigue—the process of progressive localized permanent structural change occurring in a material subjected to conditions that produce fluctuating stresses and strains at some point or points and that may culminate in cracks or complete fracture after a sufficient number of fluctuations.

DISCUSSION—1 In ceramic technology, static tests of considerable duration are called "static fatigue" tests, a type of test referred to as stress-rupture in metal testing.

DISCUSSION—2 Fluctuations may occur both in load and with time (frequency) as in the case of "random vibration." **E 1823**

fatigue-crack-growth rate, *da/dN* , [L]—the rate of crack extension under fatigue loading, expressed in terms of crack extension per cycle of fatigue. **E 1823**

fatigue cycle—See **cycle**.

fatigue life, N_f—the number of cycles of a specified character that a given specimen sustains before failure of a specified nature occurs. Fatigue life, or the logarithm of fatigue life, is a dependent variable. **E 1823**

fatigue life for *p* %survival—an estimate of the fatigue life that *p* % of the population would attain or exceed under a given loading. The observed value of the median fatigue life estimates the fatigue life for 50 % survival. Fatigue life for *p* % survival values, where *p* is any number, such as, 95, 90, and so forth, also may be estimated from the individual fatigue life values. **E 1823**

fatigue limit, S_f [FL^{-2}]—the limiting value of the median fatigue strength as the fatigue life, N_f, becomes very large.

DISCUSSION—Certain materials and environments preclude the attainment of a fatigue limit. Values tabulated as "fatigue limits" in the literature are frequently (but not always) values of S_N for which 50 % of the specimens survive a predetermined number of cycles. These specimens are frequently tested at a mean stress of zero. **E 1823**

fatigue limit for *p* %survival [FL^{-2}]—the limiting value of fatigue strength for *p* % survival as *N* becomes very large; *p* may be any number, such as 95, 90, and so forth. **E 1823**

fatigue loading—periodic, or not periodic, fluctuating loading applied to a test specimen or experienced by a structure in service. (Also known as *cyclic loading*.) **E 1823**

fatigue notch factor, k_f—the ratio of the fatigue strength of a specimen with no stress concentration to a specimen with a stress concentration for the same percent survival at *N* cycles and for the same conditions.

DISCUSSION—1 In specifying k_f, it is necessary to specify the geometry and the values of S_a, S_m, and *N* for which it is computed.

DISCUSSION—2 k_f was originally termed the fatigue limit (endurance limit) reduction factor. Early data pertained almost exclusively to mild steels, namely, to $S_a - N$ curves with knees. Later the term was generalized to fatigue strength reduction factor; but, nevertheless, the k_f values tabulated in the literature still pertain almost exclusively to very long ("infinite") fatigue lives where the notched and unnotched $S_a - N$ curves were almost parallel and almost horizontal. Otherwise, the k_f data are not consistent and are markedly dependent on the type of notch, the fatigue life of interest, and the value of the mean stress.

DISCUSSION—3 Virtually no k_f data exist for percentiles other than (approximately) 50 %. Nevertheless, k_f is highly dependent on the percentile of interest. **E 1823**

fatigue notch sensitivity, *q*—a measure of the degree of agreement between fatigue notch factor, k_f, and theoretical stress concentration factor, k_t.

DISCUSSION—1 The definition of fatigue notch sensitivity is $q = (k_f - 1)/(k_t - 1)$.

DISCUSSION—2 q was originally termed the fatigue notch sensitivity index.

DISCUSSION—3 Virtually all q data and q curves found in the literature pertain to very long ("infinite") fatigue lives where the notched and unnotched $S_a - N$ curves are almost parallel and almost horizontal, as well as to tests in which $S_m = 0$. Thus, these values should not be extrapolated to $S_m \neq 0$ or "finite" life situations.

DISCUSSION—4 Fatigue notch sensitivity is not considered to be a material property. **E 1823**

fatigue strength at *N* cycles, S_N [FL^{-2}]—a value of stress for failure at exactly N cycles as determined from an $S - N$ diagram. The value of S_N thus determined is subject to the same conditions as those which apply to the $S - N$ diagram.

DISCUSSION—The value of S_N that is commonly found in the literature is the value of S_{max} or S_a at which 50 % of the specimens of a given sample could survive N stress cycles in which $S_m = 0$. This is also known as the median fatigue strength for N cycles. **E 1823**

fatigue strength for *p* % survival at *N* cycles [FL^{-2}]—an estimate of the stress level at which p % of the population would survive N cycles; p may be any percent, such as 95, 90, and so forth.

DISCUSSION—ASTM STP 588[4] and STP 744[5] include estimation methods for these values. **E 1823**

fatigue testing system—a device for applying repeated load cycles to a specimen or component. **E 467**

fracture toughness—a generic term for measures of resistance to extension of a crack.

DISCUSSION—The term is sometimes restricted to results of fracture mechanics tests, which are directly applicable in fracture control. However, the term commonly includes results from tests of notched or precracked specimens which do not involve fracture mechanics analysis. Results from tests of the latter type are often useful for fracture control, based upon either service experience or empirical correlations with tests analyzed using fracture mechanics. **E 740**

frequency distribution—the way in which the frequencies of occurrence of members of a population, or a sample, are distributed in accordance with the values of the variable under consideration. **E 1823**

group—*in fatigue*, specimens of the same type tested at a specific time, or consecutively, at one stress level. A group may comprise one or more specimens. **E 1823**

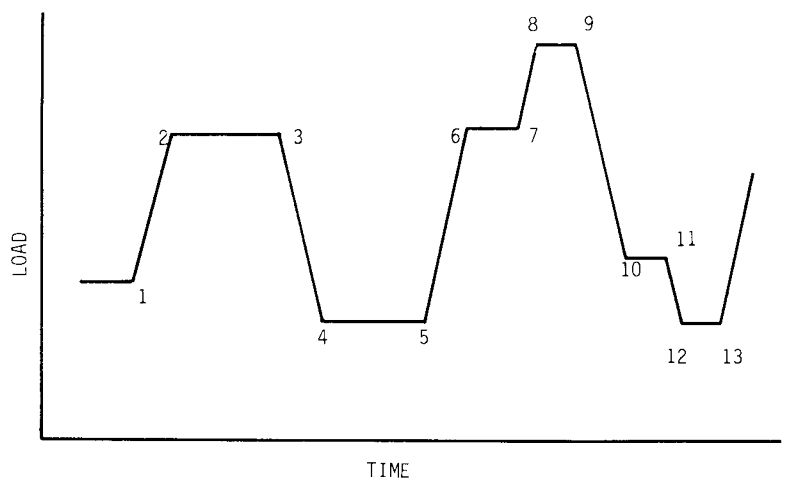
hold time [T]—*in fatigue testing*, the amount of time in the cycle where the controlled test variable (for example, load, strain, displacement) remains constant with time. (See Fig. 4.) **E 606**

hysteresis diagram—*in fatigue*, the stress-strain path during a cycle. **E 1823**

ideal crack—a simplified model of a crack. In a stress-free body, the crack has two smooth surfaces that are coincident and join within the body along a smooth curve called the crack front; in two-dimensional representations the crack front is called the crack tip. **E 1823**

ideal-crack-tip stress field—the singular stress field, infinitesimally close to the crack front, that results from loading

[4] *Manual on Statistical Planning and Analysis, ASTM STP 588*, ASTM, 1975.
[5] *Statistical Analysis of Fatigue Data, ASTM STP 744*, ASTM, 1979.



Examples of Definitions
Hold Times: 2–3, 4–5, 6–7, 8–9, 10–11, 12–13
Peaks: 2–3, 8–9
Valleys: 4–5, 12–13
Reversals: 3, 5, 9, 13

FIG. 4 Definitions of Terms for Load-Histories with Hold Times

an ideal crack. In a linear-elastic homogeneous body, the significant stress components vary inversely as the square root of the distance from the crack tip.

DISCUSSION—In a linear-elastic body, the crack-tip stress field can be regarded as the superposition of three component stress fields called modes. **E 1823**

independent variable—the selected and controlled variable (namely, stress or strain). It is denoted *X* when plotted on appropriate coordinates. **E 739**

inelastic strain, ϵ_{in} — the strain that is not elastic.

DISCUSSION—For isothermal conditions, ϵ_{in} is calculated by subtracting the elastic strain from the total strain. **E 606**

indicated dynamic loads [F]—the maximum and minimum loads (or the mean load and the load amplitude) that correspond to the readings obtained from the load cell associated with the fatigue testing system, according to an existing static calibration. The load cell calibration may have been furnished by the machine manufacturer or may have been developed by the user. **E 467**

interval estimate—the estimate of a parameter given by two statistics, defining the end points of an interval. **E 1823**

irregularity factor— *in fatigue loading*, the ratio of the number of zero crossings with positive slope (or mean crossings) to the number of peaks or valleys in a given, load-time history. **E 1823**

irregular loading— See **spectrum loading**.

***J*-integral, *J* [FL^{-1}]**—a mathematical expression, a line or surface integral that encloses the crack front from one crack surface to the other, used to characterize the local stress-strain field around the crack front.

DISCUSSION—1 The *J*-integral expression for a two-dimensional crack, in the *x-z* plane with the crack front parallel to the *z* axis, is the line integral,

$$J = \int_{\Gamma} \left(W dy - T \frac{\partial u}{\partial x} \, ds \right) \quad (4)$$

where:

W	=	loading work per unit volume or, for elastic bodies, strain energy density,
Γ	=	path of the integral, that encloses (that is, contains) the crack tip (see Fig. 5),
ds	=	increment of the contour path,
T	=	outward traction vector on ds,
u	=	displacement vector at ds,
x, y, z	=	rectangular coordinates (see Fig. 1), and
$T \frac{\partial u}{\partial x}$ ds	=	rate of work input from the stress field into the area enclosed by Γ.

DISCUSSION—2 The value of *J* obtained from the preceding equation is taken to be path independent for commonly used specimen designs. However, in service components (and perhaps in test specimens), caution is needed to adequately consider loading interior to Γ such as from motion of the crack and from residual and thermal stress.

DISCUSSION—3 In elastic (linear or nonlinear) solids, the *J*-integral equals the crack-extension force, *G*. (See definition of *G*.)

DISCUSSION—4 In Test Method E 813, in elastic (linear and nonlinear) solids for which the mathematical expression is path independent, the *J*-integral is equal to the value obtained from two identical bodies with infinitesimally differing crack areas each subject to stress. The parameter *J* is the difference in work per unit difference in crack area at a fixed value of displacement or, where appropriate, at a fixed value of load.[6] **E 813, E 1152**

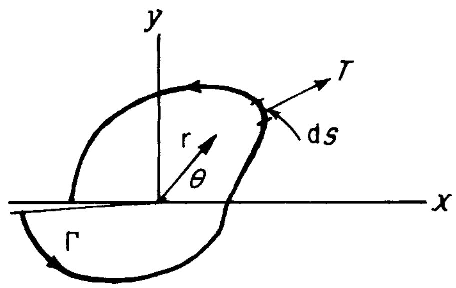


FIG. 5 J-Integral Contour and Symbolism

***J-R* curve**—a plot of resistance to stable crack extension, Δa_p.

DISCUSSION—In Test Method E 813, the *J-R* curve is a plot of the *J*-integral against physical crack extension Δa_p. **E 813**

level crossings—*in fatigue loading*, the number of times that the load-time (strain-time) history crosses a given load (strain) level with a positive slope or a negative slope, or both, as specified during a given period. **E 1823**

load, *P* [F]—the force applied to a test specimen or to a component. **E 1823**

load cell—a device which indicates the applied force by means of an electrical voltage. Usually the electrical voltage increases linearly with applied load. **E 467**

load cycle—See **cycle**.

load (strain) amplitude, P_a (S_a or ϵ_a) [F or FL^{-2}]—*in fatigue loading*, one half of the range of a cycle (see Fig. 3) (also known as *alternating load*). **E 1823**

loading (unloading) rate [F T^{-1}]—the time rate of change in the monotonic increasing (decreasing) portion of the load-time function. **E 1823**

load range, ΔP [FL^{-2}]—*in fatigue loading*, the algebraic difference between successive valley and peak loads (positive range or increasing load range) or between successive peak and valley loads (negative range or decreasing load range). (See Fig. 3.) In constant amplitude loading, the range is given as follows:

$$\Delta P = P_{max} - P_{min} \quad (5)$$

DISCUSSION—In cycle counting by various methods, it is common to employ ranges between valley and peak loads, or between peak and valley loads, which are not necessarily successive events. The word "range" is used in this broader sense when dealing with cycle counting. **E 1823**

load ratio (also stress ratio), *R, A*—*in fatigue*, the algebraic ratio of the two loading parameters of a cycle. The most widely used ratios are as follows

$$R = \frac{\text{minimum load}}{\text{maximum load}} = \frac{P_{min}}{P_{max}} = \frac{S_{min}}{S_{max}}, \text{ and} \quad (6)$$

[6] For further discussion, see Rice, J. R., *Journal of Applied Mechanics*, Vol 35, 1968, p. 379.

$$A = \frac{\text{loading amplitude}}{\text{mean load}} = \frac{P_a}{P_m} = \frac{S_a}{S_m} \quad (7)$$

E 647

log-normal distribution—the distribution of *N* when log (*N*) is normally distributed. (Accordingly, it is convenient to analyze log (*N*) using methods based on the normal distribution.) **E 739**

maximum load, P_{max} [F]—*in fatigue*, the highest algebraic value of applied load in a cycle. By convention, tensile loads are positive and compressive loads are negative. **E 647**

maximum stress-intensity factor, K_{max} [FL$^{-3/2}$]—*in fatigue*, the maximum value of the stress-intensity factor in a cycle. This value corresponds to P_{max}. **E 647**

mean crossings—*in fatigue loading*, the number of times that the load-time history crosses the mean load level with a positive slope or a negative slope, or both, as specified during a given period. (See Fig. 3.) **E 1049**

mean load, P_m (or S_m or ϵ_m) [F or FL^2]— *in fatigue loading*, the algebraic average of the maximum and minimum loads in constant amplitude loading, or of individual cycles in spectrum loading,

$$P_m = \frac{P_{max} + P_{min}}{2} \quad (8)$$

or the integral average of the instantaneous load values of a spectrum loading history. **E 1049**

median fatigue life—the middle value of the observed fatigue lives, arranged in order of magnitude, of the individual specimens in a group tested under essentially identical conditions. If the sample size is even, it is the average of the two middlemost values.

Discussion—1 The use of the median instead of the arithmetic mean (that is, the average) is usually preferred.

Discussion—2 In the literature, the abbreviated term "fatigue life" usually has meant the median fatigue life of the group. However, when applied to a collection of data without further qualification, the term" fatigue life" is ambiguous. **E 1823**

median fatigue strength at *N* cycles [FL^{-2}]—an estimate of the stress level at which 50 % of the population would survive *N* cycles.

Discussion—1 The estimate of the median fatigue strength is derived from a particular point of the fatigue life distribution, since there is no test procedure by which a frequency distribution of fatigue strengths at *n* cycles can be directly observed.

Discussion—2 This is a special case of the more general definition of fatigue strength for *p* % survival at *N* cycles. **E 1823**

minimum load, P_{min} [F]—*in fatigue*, the lowest algebraic value of applied load in a cycle. By convention, tensile loads are positive and compressive loads are negative. **E 647**

minimum stress-intensity factor, K_{min} [FL$^{-3/2}$]—*in fatigue*, the minimum value of the stress-intensity factor in a cycle. This value corresponds to P_{min} when $R > 0$ and is taken to be zero when $R \leq 0$. **E 647**

mode—one of the three classes of crack (surface) displacements adjacent to the crack tip. These displacement modes are associated with the stress-strain fields around the crack tip and are designated one, two, and three. Arabic numerals 1, 2, and 3 are used for the general case, and they represent opening, sliding, and tearing displacements, respectively. (See Fig. 6.) Roman numerals are used to specialize the mode to plane strain (I and II) or to antiplane-strain (III).

Discussion—For isotropic materials, these three modes can be represented by the crack (surface) displacements presented in Table 1 and Fig. 6. For anisotropic materials, displacements can be more complex. Using the coordinates shown in Fig. 1 and assuming a homogeneous, isotropic elastic body, the singular stresses on an infinitesimal element just ahead of the crack front for Modes I, II, and III are zero or non-zero as indicated in Table 1. For linear-elastic bodies, the three stress-strain fields can be added to describe any crack-tip stress-strain field. **E 1823**

net-section area, A_N [L^2]—area of the net remaining ligament.

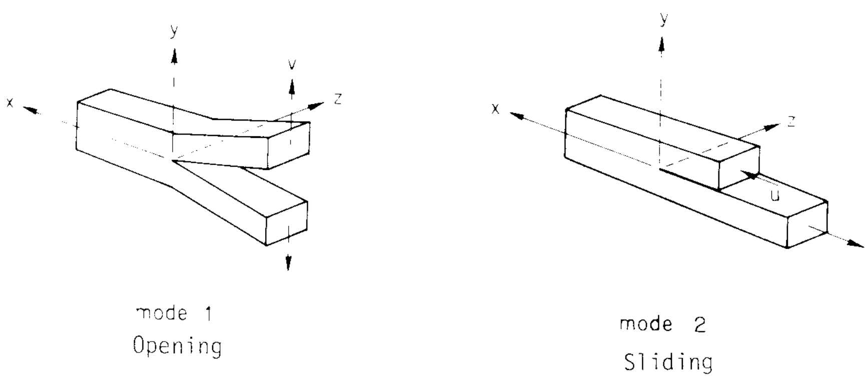
net thickness, B_N [L]—distance between the roots of the side grooves in side-grooved specimens. **E 813, E 1152**

neutral solution—a fluid environment containing an equal amount of hydrogen and hydroxyl ions, that is, pH = 7.

nominal (net-section) stress, σ_N [FL^{-2}]—*in fracture testing*, a measure of the stress on the net cross section calculated in a simplified manner and without taking into account stress gradients produced by geometric discontinuities such as holes, grooves, fillets, and so forth.

Discussion—1 In tension specimens (tension only), the average stress is used:

$$\sigma_N = P/A_N \quad (9)$$



Note 1—See definition of mode.

FIG. 6 Basic Modes of Crack (Surface) Displacements for Isotropic Materials

TABLE 1 Stress and Displacement Components[A] for Plane-Strain and Anti-Plane-Strain Modes (see Definition of Mode). See Fig. 6.

NOTE 1—It is recommended that the arabic subscript 1 be omitted except where needed for clarity.

	Mode I	Mode II	Mode III
Crack (surface) displacements[B] just behind the crack front:			
u	0	*	0
v	*	0	0
w	0	0	*
Stresses on the $x - z$ plane just ahead of the crack front (see Fig. 1):			
σ_x	*	0	0
σ_y	*	0	0
σ_z	*	0	0
τ_{xy}	0	*	0
τ_{yz}	0	0	*
τ_{zx}	0	0	0

[A] * means non-zero. 0 means zero.
[B] Not applicable generally to anisotropic materials.

where:
A_N = B(W − a) for rectangular sections, and
A_N = $(\pi\ d^2)/4$ for circular sections.

DISCUSSION—2 In bend specimens (bending only), a fiber stress is used:

$$\sigma_N = \frac{6M}{B(W-a)^2} \tag{10}$$

DISCUSSION—3 In compact specimens (tension and bending),

$$\sigma_N = \frac{2P(2W+a)}{B(W-a)^2} \tag{11}$$

DISCUSSION—4 In arc-shaped specimens (tension and bending),

$$\sigma_N = \frac{2P(3X+2W+a)}{B(W-a)^2} \tag{12}$$

DISCUSSION—5 In Notes 1 to 4:

d = diameter of notched section of a circumferentially notched specimen, m (in.),
P = load, N (lbf),
B = specimen thickness, m (in.),
W = specimen width, m (in.),
a = crack size (length of notch or notch plus precrack), m (in.),
X = loading hole offset, m (in.), and
M = bending moment, Nm (in.-lb).

The result, σ_N, is given in Pa (psi). See Test Method E 399 for further explanations on symbols. **E 399, E 602**

notch tensile strength (*NTS*) [FL^{-2}]—the maximum nominal (net-section) stress that a notched tensile specimen is capable of sustaining.

DISCUSSION—1 See definitions of nominal (net-section) stress and sharp-notch strength.
DISCUSSION—2 Values of notch tensile strength may depend upon section size, notch sharpness, and the eccentricity of the notch. See **sharp-notch strength**. **E 1823**

occurrences spectrum— *in fatigue loading*, representation of spectrum loading contents by the number of times a particular loading parameter (peak, range, and so forth) occurs within each specified loading interval between lower and upper bound values. **E 1823**

original crack size, a_o, [L]—the physical crack size at the start of testing. **E 561, E 740, E 813, E 1152**

original uncracked ligament, b_o [L]—distance from the original crack front to the back edge of the specimen, that is:

$$b_o = W - a_o \tag{13}$$

parameter—*in statistics*, a constant (usually to be estimated) defining some property of the population frequency distribution, such as the population median or the population standard deviation. **E 1823**

peak—*in fatigue loading*, the point where the first derivative of the load-time history changes from positive to negative sign; the point of maximum load in constant amplitude loading (see Fig. 3). For load histories with hold times see Fig. 4. **E 1049**

physical crack extension, Δa_p [L]—an increase in physical crack size.

$$\Delta ap = ap - a_o \tag{14}$$

E 813, E 1152

physical crack size, a_p [L]—the distance from a reference plane to the observed crack front. This distance may represent an average of several measurements along the crack front. The reference plane depends on the specimen form, and normally is taken to be either the boundary, or a plane containing either the load line or the centerline of a specimen or plate. The reference plane is defined prior to specimen deformation. **E 561, E 813, E 1152**

plane-strain fracture toughness, K_{Ic} [FL$^{-3/2}$], J_{Ic} [FL^{-1}]—the crack-extension resistance under conditions of crack-tip plane strain.

DISCUSSION—1 For example, in Mode I for slow rates of loading and negligible plastic-zone adjustment, plane-strain fracture toughness is the value of the stress-intensity factor designated K_{Ic} as measured using the operational procedure (and satisfying all of the validity requirements) specified in Test Method E 399, that provides for the measurement of crack-extension resistance at the start of crack extension and provides operational definitions of crack-tip sharpness, start of crack-extension, and crack-tip plane strain.
DISCUSSION—2 For example, in Mode I with slow rates of loading and substantial plastic deformation, plane-strain fracture toughness is the value of the *J*-integral designated J_{Ic} [FL^{-1}] as measured using the operational procedure (and satisfying all of the validity requirements) specified in Test Method E 813, that provides for the measurement of crack-extension resistance near the onset of stable crack extension.
DISCUSSION— See also **crack-extension resistance, crack-tip plane strain**, and **mode**. **E 399**

plastic-zone adjustment, r_Y [L]—an addition to the physical crack size to account for plastic crack-tip deformation enclosed by a linear-elastic stress field.

DISCUSSION—1 Commonly the plastic-zone adjustment is given as follows:

$$\text{Plane-Stress Mode 1: } r_Y = \frac{K^2}{2\pi\sigma_Y{}^2} \tag{15}$$

$$\text{Plane-Strain Mode } I\text{: } r_Y = \frac{\alpha K^2}{2\pi\sigma_Y{}^2} \tag{16}$$

where:
α = < *frax*;1;3 > to ¼ , and
σ_Y = effective yield strength.

DISCUSSION—2 See also **crack size**. **E 561**

point estimate—the estimate of a parameter given by a single statistic, for example, sample average (see **sample average**) (**arithmetic average**). **E 1823**

pop-in—a discontinuity in the load against clip gage displacement record. This discontinuity is characterized by a sudden increase in displacement and, generally, a decrease in load. Subsequently, the displacement and load increase to above their respective values at pop-in. **E 1290**

population (or universe)— *in fatigue testing*, the totality of the set of test specimens, real or conceptual, that could be prepared in the specified way from the material under consideration. **E 1823**

power spectral density—the limiting mean-square value (for example, of acceleration, velocity, displacement, stress, or other random variable) per unit bandwidth of frequency, that is the limit of the mean-square value of a given rectangular bandwidth divided by the bandwidth, as the bandwidth approaches zero. **E 1823**

precision—the closeness of agreement between randomly selected individual measurements or test results for a given set of experimental variables.

DISCUSSION—1 The standard deviation of the error of measurement may be used as a measure of "imprecision."

DISCUSSION—2 The estimate of precision usually contains two components of variance. One component is due to the variability of the test material. The other component is due to variability in the test method application. Special test setups may permit the separation of these two components of variance. **E 1823**

precrack load, P_M [F]—the allowable precrack load. **E 1737**

***R*-curve**—a plot of crack-extension resistance as a function of stable crack extension, Δa_p or Δa_e.

DISCUSSION—For specimens discussed in Practice E 561, the influence of in-plane geometry appears to be negligible, but *R*-curves normally depend upon specimen thickness and, for some materials, upon temperature and strain rate. **E 561, E 1152**

random loading—*in fatigue loading*, a spectrum loading (straining) where the peak and valley loads (strains) and their sequence result from a random process; the loading (straining) is usually described in terms of its statistical properties, such as the probability density function, the mean, the root mean square, the irregularity factor, and others as appropriate. **E 1823**

random-ordered loading— *in fatigue loading*, a spectrum loading that is generated from a distinct set of peak and valley loads into a loading sequence by using a specific random sequencing process; a sequence of finite length is usually repeated identically. **E 1823**

reference electrode—the electrode (for example, hydrogen electrode, normal calomel electrode, or saturated calomel electrode) against which the electrical potential of a specimen is measured. **E 1823**

remaining ligament, *b* [L]—distance from the physical crack front to the back edge of the specimen, that is

$$b = W - a_p \quad (17)$$

replicate (repeat) tests—nominally identical tests on different randomly selected test specimens conducted at the same nominal value of the independent variable *X*.

DISCUSSION—Such replicate or repeat tests should be conducted independently; for example, each replicate test should involve a separate set of the test machine and its settings. **E 739**

residual strength, σ_r [FL^{-2}]—the maximum value of the gross stress, neglecting the area of the crack, that a cracked specimen is capable of sustaining.

DISCUSSION—In part-through surface crack (PS) specimens, gross stress is the ratio of the maximum load (P_{max}) to the product of test section width (*W*) times thickness (*B*), P_{max} /(*BW*). It represents the stress at fracture normal to and remote from the plane of the crack. **E 740**

response curve for *N* cycles—a curve fitted to observed values of percentage survival at *N* cycles for several stress levels, where *N* is the preassigned number such as 10^6, 10^7, and so forth. It is an estimate of the relationship between applied stress and the percentage of the population that would survive *N* cycles.

DISCUSSION—1 Values of the median fatigue strength at *N* cycles and the fatigue strength for *p* % survival at *N* cycles may be derived from the response curve for *N* cycles if *p* falls within the range of the percent survival values actually observed.

DISCUSSION—2 Caution should be used in drawing conclusions from extrapolated portions of the response curves. In general, the curves should not be extrapolated to other values of *p*. **E 1823**

reversal (slope reversal)— *in fatigue loading*, the occurrence where the first derivative of the load-time (strain-time) history changes sign, (see Fig. 3). For load (strain) histories with hold times, see Fig. 4.

DISCUSSION—The number of reversals in constant amplitude loading (straining), is equal to twice the number of cycles. **E 1049**

run-out—no fatigue failure at a specified number of load cycles. **E 468, E 739**

sample—the specimens from the population selected for test purposes.

DISCUSSION—The method of selecting the sample fixes the statistical inferences or generalizations that may be made about the population. **E 1823**

sample average (arithmetic average)—the sum of all the observed values in a sample divided by the sample size. It is a point estimate of the population mean. **E 1823**

sample median—the (*1*) middle value when all observed values in a sample are arranged in order of magnitude if an odd number of items (units) are tested or (*2*) the average of the two middle-most values if an even number of items (units) are tested. It is a point estimate of the population median, or 50 % value. **E 1823**

sample percentage—the percentage of observed values between two stated values of the variable under consideration. It is a point estimate of the percentage of the population between the same two stated values. (One stated value may be ′′minus infinity" or ′′plus infinity.") **E 1823**

sample standard deviation, *s*—the square root of the sample variance. It is a point estimate of the population standard deviation, a measure of the ′′spread" of the frequency distribution of a population.

DISCUSSION—This value of *s* provides a statistic that is used in computing interval estimates and several test statistics. For small sample sizes, *s* underestimates the population standard deviation. (See a statistics text for an unbiased estimate of the standard deviation of a normal population.) **E 1823**

sample variance, s^2 —the sum of the squares of the differences between each observed value and the sample average divided by the sample size minus one. It is a point estimate of the population variance.

DISCUSSION—This value of s^2 provides both an unbiased point estimate of the population variance and a statistic that is used in computing the interval estimates and several test-statistics. Some texts define s^2 as "the sum of the squares of the differences between each observed value and the sample average divided by the sample size," but such a mean square statistic is not as useful. **E 1823**

sharp-notch strength, σ_s [FL^{-2}]—the maximum nominal (net-section) stress that a sharply notched specimen is capable of sustaining.

DISCUSSION—1 Values of sharp-notch strength may depend on notch and specimen configuration as these affect the net cross section and the elastic stress concentration.

DISCUSSION—2 The tension specimens used in Test Methods E 338 and E 602 have notch root radii that approach current machining limits. The radius in such specimens is believed to be small enough that any smaller radius would result in notch strength essentially unchanged from an engineering viewpoint. **E 338, E 602**

significant—statistically significant. An effect or difference between populations is said to be present if the value of a test statistic is significant, that is, lies outside of selected limits.

DISCUSSION—An effect that is statistically significant may or may not have engineering significance. **E 1823**

significance level—the stated probability (risk) that a given test of significance will reject the null hypothesis (that a specified effect is absent) when the hypothesis is true. **E 1823**

slow stable crack extension [L]—a displacement controlled crack extension beyond the stretch zone width. The extension stops when the applied displacement is held constant. **E 1290**

***S-N* curve for 50 % survival**—a curve fitted to the median values of fatigue life at each of several stress levels. It is an estimate of the relationship between applied stress and the number of cycles-to-failure that 50 % of the population would survive.

DISCUSSION—1 This is a special case of the more general definition of *S-N* curve for *p* % survival.

DISCUSSION—2 In the literature, the abbreviated term "*S-N* curve" usually has meant either the *S-N* curve drawn through the mean (averages) or the medians (50 % values) for the fatigue life values. Since the term " *S-N* curve" is ambiguous, its use in technical papers should be accompanied by an adequate description. **E 1823**

***S-N* curve for *p* %survival**—a curve fitted to the fatigue life for *p* % survival values at each of several stress levels. It is an estimate of the relationship between applied stress and the number of cycles-to-failure that *p* % of the population would survive where *p* may be any percent, such as 95, 90, and so forth.

DISCUSSION—Caution should be used in drawing conclusions from any extrapolated portion of an *S-N* curve. In general, *S-N* curves should not be extrapolated beyond observed life values. **E 1823**

***S-N* curve**—a plot of stress against the number of cycles to failure. The stress can be maximum stress, S_{max} ; minimum stress, S_{min} ; stress range, ΔS or S_r ; or alternating stress, S_a. The curve indicates the *S-N* relationship for a specified value of S_m, *A*, or *R* and a specified probability of survival. For *N*, a log scale is commonly used. For *S*, either a logarithmic or a linear scale is used. **E 1823**

specimen center of pin hole distance, H* [L], *n*—the distance between the center of the pin holes on a pin-loaded specimen. **E 1820**

specimen gage length, δd [L], *n*— the distince between the points of displacment measure (for example, clip gage, gage length). **E 1820**

specimen span, *S* [L]—distance between specimen supports. **E 813, E 1152**

specimen temperature, *T* [θ]—*in fatigue testing*, the average temperature in the specimen test section during isothermal testing, or the temperature in the specimen test section at any instant of time during cyclic-temperature testing. **E 1823**

specimen thickness, *B* [L]—the distance between the parallel sides of a test specimen (see Fig. A2.1). **E 813, E 1152**

specimen width, *W* [L]—the distance from a reference position (for example, the front edge of a bend specimen or the load line of a compact specimen) to the rear surface of the specimen. **E 813, E 1152**

spectrum loading—*in fatigue loading*, a load-time program consisting of some (or all) unequal peak and valley loads. (Also known as *variable amplitude loading* or *irregular loading*.) **E 1049**

stable crack extension [L], *n*—a displacement-controlled crack extension beyond the stretch-zone width. The extension stops when the applied displacement is held constant. **E 1820**

statistic—a summary value calculated from the observed values in a sample. **E 1823**

stress, [FL^{-2}]—force acting over a unit area. Traditionally, the symbol for stress is either *S* or σ , as a matter of choice. **E 1823**

stress concentration factor—See **theoretical stress concentration factor (or stress concentration factor) k_t** .

stress-corrosion cracking, SCC—a cracking process that requires the simultaneous action of a corrodent and sustained tensile stress. **E 1681**

stress cycle—See **cycle**.

stress-intensity-factor calibration, K calibration—See **applied- *K* curve** in3.4.

stress-intensity factor, K, K_1, K_2, K_3, K_I, K_{II}, K_{III} [FL$^{-3/2}$]—the magnitude of the mathematically ideal, crack-tip stress field (stress-field singularity) for a particular mode in a homogeneous, linear-elastic body.

DISCUSSION—Values of *K* for the modes 1, 2, and 3 are given by the following equations:

$$K_1 = \lim_{r \to 0} \sigma_y (2\pi r)^{1/2} \quad (18)$$

$$K_2 = \lim_{r \to 0} \tau_{xy} (2\pi r)^{1/2}, \text{ and} \quad (19)$$

$$K_3 = \lim_{r \to 0} \tau_{yz} (2\pi r)^{1/2} \quad (20)$$

where:
r = distance (in a cylindrical coordinate system) from the crack tip to a location where the stress is calculated. (See Fig. 6 for the description of modes.) **E 399, E 561, E 647, E 1304**

stress-intensity factor range, ΔK [$FL^{-3/2}$]—*in fatigue*, the variation in the stress-intensity factor in a cycle, that is

$$\Delta K = K_{max} - K_{min} \quad (21)$$

DISCUSSION—1 The loading variables R, ΔK, and K_{max} are related such that specifying any two uniquely defines the third in accordance with the following relationships:

$$\Delta K = (1 - R)K_{max} \text{ for } R \geq 0, \text{ and} \quad (22)$$

$$\Delta K = K_{max} \text{ for } R < 0. \quad (23)$$

DISCUSSION—2 These preceding stress-intensity-factor range definitions do not include local crack-tip effects; for example, crack closure, residual stress, and blunting.

DISCUSSION—3 While the operational definition of ΔK states that ΔK does not change for a constant value of K_{max} when $R < 0$, increases in fatigue crack growth rates can be observed when R becomes more negative. Excluding compressive loads in the calculation of ΔK does not influence the material's response (da/dN) which is independent of the operational definition of ΔK. For predicting crack-growth lives generated under various R conditions, the life prediction methodology must be consistent with the data reporting methodology. **E 647**

stress intensity factor threshold for environment assisted cracking, K_{EAC} [$FL^{-3/2}$]—the highest value of the stress intensity factor (K) at which crack growth is not observed for a specified combination of material and environment and where the measured value may depend on specimen thickness. **E 1681**

stress intensity factor threshold for plane strain environment-assisted cracking, K_{IEAC} [$FL^{-3/2}$]— the highest value of the stress intensity factor (K) at which crack growth is not observed for a specified combination of material and environment and where the specimen size is sufficient to meet requirements for plane strain as described in Test Method E 399. **E 1681**

stretch zone width (*SZW*) [L]—the length of crack extension that occurs during crack-tip blunting, for example, prior to the onset of unstable brittle crack extension, pop-in, or slow stable crack extension. The *SZW* is co-planar with the original (unloaded) fatigue precrack and refers to an extension of the original crack. **E 1290**

tensile strength, σ_{TS} [FL^{-2}]—the maximum tensile stress that a material is capable of sustaining. Tensile strength is calculated from the maximum load during a tension test carried to rupture and the original cross-sectional area of the specimen. **E 6, E 28**

test of significance—a statistical test that, by use of a specified test statistic, purports to provide a test of a null hypothesis (under certain assumptions); for example, that an imposed treatment in the experiment is without effect.

DISCUSSION—Recognizing the possibility of false rejection, the rejection of the hypothesis being tested usually indicates that an effect is present. **E 1823**

test statistic—a function of the observed values in a sample that is used in a test of significance. **E 1823**

theoretical elastic stress concentration factor (or stress concentration factor) k_t —the ratio of the greatest stress in the region of a notch or other stress concentrator as determined by the theory of elasticity (or by experimental procedures that give equivalent values) to the corresponding nominal stress.

DISCUSSION—The theory of plasticity should not be used to determine k_t. **E 1823**

tolerance interval—an interval computed so that it will include at least a stated percentage of the population with a stated probability. **E 1823**

tolerance level—the stated probability that the tolerance interval includes at least the stated percentage of the population. It is not the same as a confidence level but the term confidence level is frequently associated with tolerance intervals. **E 1823**

tolerance limits—the two statistics that define a tolerance interval. (One value may be "minus infinity" or "plus infinity.") **E 1823**

total cycle period, τ_t [T]— the time for the completion of one cycle. The parameter τ_t can be separated into hold and non-hold (that is, steady and dynamic) components:

$$\tau_t = \Sigma\tau_h + \Sigma\tau_{nh} \quad (24)$$

where:
$\Sigma\tau_h$ = sum of all the hold portions of the cycle and,
$\Sigma\tau_{nh}$ = sum of all the non-hold portions of the cycle.

τ_t also is equal to the reciprocal of the overall frequency when the frequency is held constant. **E 606**

trough—See **valley**.

truncation—*in fatigue loading*, the exclusion of cycles with values above or below a specified level (referred to as truncation level) of a loading parameter (peak, valley, range, and so forth). **E 1823**

unstable brittle crack extension [L]—an abrupt crack extension occurring with or without prior stable crack extension in a standard fracture test specimen under crosshead or clip gage displacement control. **E 1290**

valley—*in fatigue loading*, the occurrence where the first derivative of the load-time history changes from negative to positive sign; (also known as *trough*); the point of minimum load in constant amplitude loading (see Fig. 3). For load histories with hold times see Fig. 4. **E 1049**

variable amplitude loading— See **spectrum loading**.

wave form—the shape of the peak-to-peak variation of a controlled mechanical test variable (for example, load, strain, displacement) as a function of time. **E 1823**

yield strength, σ_{YS} [FL^{-2}]—the stress at which a material exhibits a specific limiting deviation from the proportionality of stress to strain. This deviation is expressed in terms of strain.

DISCUSSION—1 It is customary to determine yield strength by either (1) Offset Method (usually a strain of 0.2 % is specified) or (2) Total-Extension-Under-Load Method (usually a strain of 0.5 % is specified although other values of strain may be used.)

DISCUSSION—2 Whenever yield strength is specified, the method of test must be stated along with the percent offset or total strain under load. The values obtained by the two methods may differ. **E 6, E 28**

zero crossings—*in fatigue loading*, the number of times that the load-time history crosses zero load level with a positive slope or negative slope, or both, as specified, during a given period. **E 1823**

3.4 *Definitions of Terms (Specific to the Indicated Standards)*—Each term is followed by the designation(s) of the standard(s) of origin. The listing of terms is alphabetical. Some Definitions of Terms are quite similar to the Definitions. The Definitions of Terms herein apply to specific standards.

applied-K curve—a curve (a fixed-load or fixed-displacement crack-extension-force curve) obtained from a fracture mechanics analysis for a specific configuration. The curve relates the stress-intensity factor to crack size and either applied load or displacement.

DISCUSSION—The resulting analytical expression is sometimes called a *K* calibration and is frequently available in handbooks for stress-intensity factors. **E 647**

C*(t)—Integral, C*(t) [$FL^{-1}T^{-1}$]—a mathematical expression, a line or surface integral that encloses the crack front from one crack surface to the other, used to characterize the local stress-strain rate fields at any instant around the crack front in a body subjected to extensive creep conditions.

DISCUSSION—1 The C*(t) expression for a two-dimensional crack, in the *x-z* plane with the crack front parallel to the *z*-axis, is the line integral as follows:

(25) $C^*(t) = \Gamma\ W^*[t]dy - T \cdot \partial u \partial x\ \ ds$

where:

$W^*(t)$	=	instantaneous stress−power or energy rate per unit volume,
Γ	=	path of the integral, that encloses (that is,contains) the crack tip (see Fig. 5),
ds	=	increment in the contour path,
T	=	outward traction vector on ds,
$[|]M)$	=	displacement rate vector at ds,
x, y, z	=	rectangular coordinate system, and
	=	

$$T \cdot \frac{\partial u}{\partial x}\ ds$$

rate of stress-power input into the area enclosed by Γ.

The value of C*(t) from the preceding equation is path-independent for materials that deform according to a constitutive law that is separable into single-value time and stress functions as in the following form:

$\epsilon = f_1(t) f_2(\sigma)$

where:

f_1 and f_2 represent functions of elapsed time, *t*, and applied stress, σ, respectively;

ϵ is the strain rate. (26)

DISCUSSION—2 The equation for C* is path independent for materials obeying power-law creep constitutive relations. For such materials, the C*(t) integral is equal to the value obtained from two, stressed, identical bodies with infinitesimally differing crack areas. This value is the difference in the stress-power per unit difference in crack area at a fixed value of time and displacement rate or at a fixed value of time and load.

DISCUSSION—3 The value of C*(t) corresponding to the steady-state conditions is called C^*_s ; steady-state is said to have been achieved when a fully developed creep stress distribution has been produced around the crack tip. **E 1457**

crack-arrest fracture toughness, K_a [$FL^{-3/2}$]—the value of the stress-intensity factor shortly after crack arrest.

DISCUSSION—1 The in-plane specimen dimensions must be large enough for adequate enclosure of the crack-tip plastic zone by a linear-elastic stress field.

DISCUSSION—2 In Test Method E 1221, side-grooved specimens are used. The calculation of K_a is based upon measurements of both the arrested crack length and of the crack-mouth opening displacements prior to initiation of a fast-running crack and shortly after crack arrest. **E 1221**

crack depth, *a* [L]—*in part-through surface-crack specimens (PS)*, the distance from, and normal to, the cracked plate surface to the point of maximum penetration of the crack front into the material. Crack depth is less than the specimen thickness.

DISCUSSION—In Practice E 740, crack depth is the original depth a_o and the subscript $_o$ is everywhere implied. **E 740**

crack jump behavior— *in chevron-notch specimen tests*, that type of sporadic crack growth which is characterized primarily by periods during which the crack front is nearly stationary until a critical load is reached, whereupon the crack becomes unstable and suddenly advances at high speed to the next arrest point, where it remains nearly stationary until the load again reaches a critical value, and so forth. (see Fig. 7).

DISCUSSION—A chevron-notch specimen is said to have a crack jump behavior when crack jumps account for more than one half of the change in unloading slope ratio as the unloading slope ratio passes through the range from $0.8r_c$ to $1.2r_c$. Only those sudden crack advances that result in more than a 5 % decrease in load during the advance are counted as crack jumps (Fig. 7). The parameter r_c is the unloading slope ratio at the critical crack length. **E 1304**

crack length, *a* [L]—in Test Method E 1457, the physical crack size is represented as a_p . The subscript *p* is everywhere implied. **E 1457**

creep crack growth behavior—a plot of the time rate of crack growth, da/dt, as a function of C*(t). **E 1457**

creep zone boundary—the locus of points ahead of the crack front where the equivalent strain caused by the creep deformation equals the equivalent strain caused by the elastic deformation.

DISCUSSION—Under small-scale creep conditions, the creep zone expansion with time occurs in a self-similar manner, thus, the creep zone size can be defined as the distance to the creep zone boundary from the crack tip at a fixed angle, θ, with respect to the crack plane.

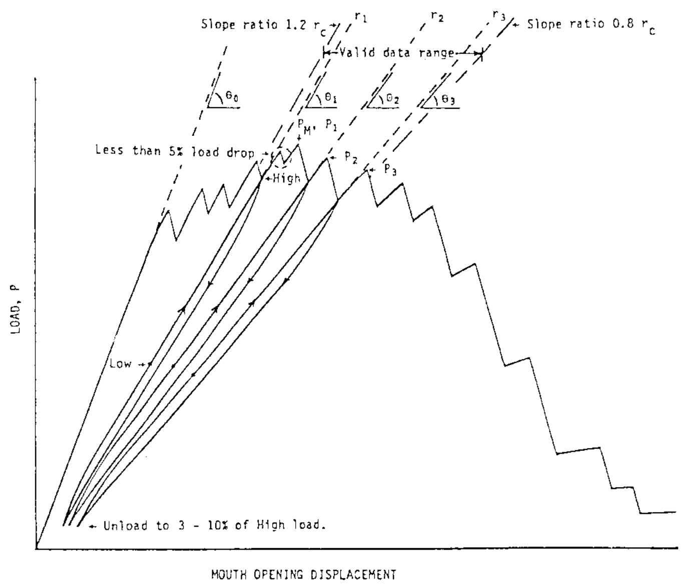


FIG. 7 Schematic of a Load-Displacement Test Record for Crack Jump Behavior, with Unloading/Reloading Cycles, Data Reduction Constructions, and Definitions of Terms

In Test Method E 1457, the fixed angle is 90°. **E 1457**

critical crack length [L]—the crack length in a chevron-notch specimen at which the specimen's stress-intensity factor coefficient, *Y**, is a minimum, or equivalently, the crack length at which the maximum load would occur in a purely linear elastic fracture mechanics test. At the critical crack length, the width of the crack front is approximately one third the dimension B. **E 1304**

critical slope ratio, r_c—the unloading slope ratio at the critical crack length. **E 1304**

drop-weight tear test (DWTT)—a test of plain-carbon or low-alloy pipe steels over the temperature range where the fracture changes from a brittle to a ductile mode. The mode can be determined from the appearance of propagating fractures. **E 436**

dynamic tear (DT) energy [J]—the total energy required to fracture standard DT specimens tested in accordance with the provisions of Test Method E 604.

Discussion—1 With pendulum-type machines, the DT energy value recorded is the difference between the initial and the final potential energies of the pendulum or pendulums.

Discussion—2 With drop-weight machines, the DT energy value recorded is the difference between the initial potential energy of the hammer and the final energy of the hammer, as determined by a calibrated energy absorption system. **E 604**

effective unloading slope ratio, *r*—the ratio of an effective unloading slope to that of the initial elastic loading slope on a test record of load versus specimen mouth opening displacement.

Discussion—1 This unloading slope ratio provides a method of determining the crack length at various points on the test record thus allowing evaluation of the stress intensity factor coefficient *Y**. The effective unloading slope ratio is measured by performing unloading-reloading cycles during the test as indicated schematically in Fig. 7 and Fig. 8. For each unloading-reloading trace, the effective unloading slope ratio, *r*, is defined in terms of the tangents of two angles:

$$r = \tan\theta / \tan\theta_o \quad (27)$$

where:

$\tan\theta_o$ = slope of the initial elastic line, and
$\tan\theta$ = slope of an effective unloading line.

The effective unloading line is designated as having an origin at the high point where the displacement reverses direction on unloading (slot mouth begins to close) and joining the low point on the reloading line where the load is one half that at the high point.

Discussion—2 For a brittle material with linear elastic behavior, the unloading-reloading lines of an unloading-reloading cycle would be linear and coincident. For many engineering materials, deviations from linear elastic behavior and hysteresis are commonly observed to varying degrees.

Discussion—3 Although *r* is measured only at those crack positions associated with unloading-reloading cycles, *r* nevertheless is defined at all points during a chevron-notch specimen test. For any particular point, *r* is the value that would be measured if an unloading-reloading cycle were performed at that point. **E 1304**

environment-assisted cracking, EAC—a cracking process in which the environment promotes crack growth or higher crack growth rates than would occur without the presence of the environment. **E 1681**

equivalent-energy fracture toughness (*K-EE*) [$FL^{-3/2}$]—the crack extension resistance determined by the procedure specified in Practice E 992.

Discussion—The thickness, *B*, of the standard specimen from which the result is obtained should be identified in quoting the result. For specimens thicker than the standard specimens, both *B* and *W* should be specified. **E 992**

fatigue-crack-growth threshold, ΔK_{th} [$FL^{-3/2}$]—that asymptotic value of ΔK at which da/dN is essentially zero. For most materials an operational, though arbitrary, definition of ΔK_{th} is given as that ΔK which corresponds to a fatigue crack growth rate of 10^{-10} m/cycle.

Discussion—The intent of this Definition of Terms is not to define a

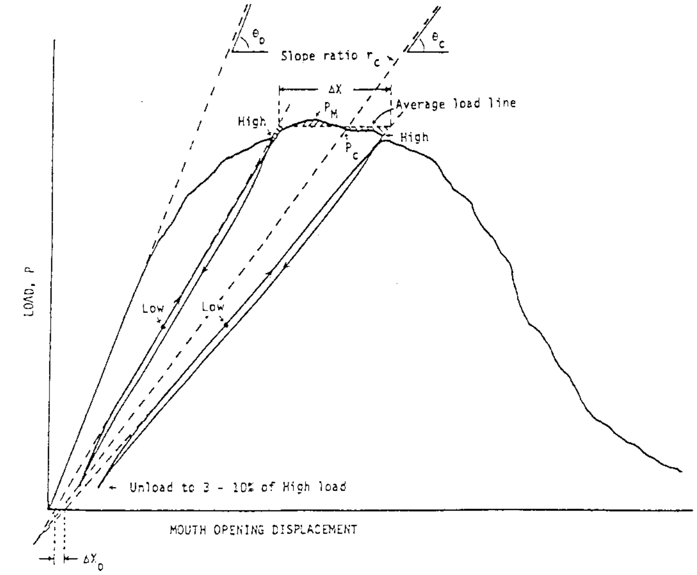


FIG. 8 Schematic of a Load-Displacement Test Record for Smooth Crack Growth Behavior, with Unloading/Reloading Cycles, Data Reduction Constructions, and Definitions of Terms

true threshold, but rather to provide a practical means of characterizing a material's fatigue crack growth resistance in the near-threshold regime. Caution is required in extending this concept to design. **E 647**

fixed-load or fixed-displacement applied *K* curves—curves obtained from a fracture mechanics analysis of a specific specimen configuration. **E 561**

high point, High—the point on a load-displacement plot, at the start of an unloading-reloading cycle, at which the displacement reverses direction, that is, the point at which the specimen mouth begins closing due to unloading (see points labeled High in Fig. 7 and Fig. 8). **E 1304**

***K*-decreasing test**—a test in which the normalized *K*-gradient is nominally negative. In Test Method E 647, *K*-decreasing tests involve load shedding as the crack grows either continuously or by a series of decremental steps. **E 647**

***K*-increasing test**—a test in which the normalized *K*-gradient is nominally positive. For the standard specimens in Test Method E 647, the constant-load-amplitude test will result in a *K*-increasing test where the normalized *K*-gradient increases but is always positive. **E 647**

load [F]—used in Practices E 1049 to denote force, stress, strain, torque, acceleration, deflection, or other parameters of interest. **E 1049**

load-line displacement resulting from creep, V_c [L]— displacement at the loading pins from cracking associated with creep strain accumulation.

Discussion—In creep-crack growth, the total load-point displacement, V, attributed to the crack can be partitioned into an instantaneous part, V_i , and a time-dependent creep part, V_c ;

$$V = V_i + V_c \tag{28}$$

low point, Low—the point on the reloading portion of an unloading-reloading cycle where the load is one half the high point load (see points labeled Low in Fig. 7 and Fig. 8). **E 1304**

minimum stress-intensity factor coefficient, Y^*_m — the minimum value of the stress intensity factor coefficient, Y^*. **E 1304**

normalized crack size, a/W—the ratio of crack size, a, to specimen width, W. **E 813**

normalized *K*-gradient, $C = (1/K) \cdot dK/da [L^{-1}]$—the fractional rate of change of K with increasing crack length.

Discussion—When C is held constant, the percentage change in K is constant for equal increments of crack length. The following identity is true for the normalized K-gradient in a constant load-ratio test:

$$\frac{1}{K}\cdot\frac{dK}{da} = \frac{1}{K_{max}}\cdot\frac{dK_{max}}{da} = \frac{1}{K_{min}}\cdot\frac{dK_{min}}{da} = \frac{1}{\Delta K}\cdot\frac{d\Delta K}{da} \tag{29}$$

notch length, a_n (L)—the distance from a reference plane to the front of the machined notch. The reference plane depends on the specimen form, and normally is taken to be either the boundary, or a plane containing either the loadline or the centerline of a specimen or plate. The reference plane is defined prior to specimen deformation.

plane-strain (chevron-notch) fracture toughness, K_{Iv} or K_{Ivj} $[FL^{-3/2}]$—under conditions of crack-tip plane strain in a chevron-notched specimen: K_{Iv} relates to extension resistance with respect to a slowly advancing steady-state crack. K_{Ivj} relates to crack extension resistance with respect to a sporadically advancing crack.

Discussion—For slow loading rates the measured fracture toughness, K_{Iv} or K_{Ivj} , is the value of stress-intensity factor obtained using the operational procedure, and satisfying all of the validity requirements, specified in Test Method E 1304. **E 1304**

plane-strain (chevron-notch) fracture toughness, K_{IvM} $[FL^{-3/2}]$—determined similarly to K_{Iv} or K_{Ivj} using the same specimen, or specimen geometries, but using a simpler analysis based on the maximum test load. Unloading-reloading cycles are not required in a test to determine K_{IvM} . **E 1304**

plane-strain crack-arrest fracture toughness, K_{Ia} $[FL^{-3/2}]$—the value of crack-arrest fracture toughness, K_a , for a crack that arrests under conditions of crack-front plane-strain.

DISCUSSION—The requirements for attaining conditions of crack-front plane-strain are specified in the procedures of Test Method E 1221. **E 1221**

plane-stress fracture toughness, K_c [FL$^{-3/2}$]—crack-extension resistance under conditions that do not approach crack-tip plane strain to the degree required by an empirical criterion.

DISCUSSION—In Practice E 561, plane-stress fracture toughness is represented by an *R*-curve. When plane-stress fracture toughness is used to define conditions for crack instability, it is designated K_c , a quantity dependent on specimen configuration by Practice E 561. The value of *K* at the tangency between the *R*-curve and the configuration-dependent applied *K* curve is K_c . The effective crack size concept may be used to compute plasticity-adjusted values of stress-intensity factor, *K*, if the crack-tip plastic zone is surrounded by an elastic stress field. **E 561**

reference load [F]—*for spectrum loading*, used in Practices E 1049 to denote the loading level that represents a steady-state condition upon which load variations are superimposed. The reference load may be identical to the mean load of the history, but this is not required. **E 1049**

regression line slope—the slope of a linear regression fit of acceptable *J* and Δ *a* values. **E 813**

smooth crack growth behavior—generally, crack extension in chevron-notch specimens which is characterized by slow, continuously advancing crack growth, and a relatively smooth load displacement record (Fig. 8). However, any test behavior is automatically characterized as smooth crack-growth behavior unless it satisfies the conditions shown in Fig. 7 for crack-jump behavior. **E 1304**

steady-state crack—a crack that has advanced slowly until the crack-tip plastic zone size and crack-tip sharpness remain constant with further crack extension. Although crack-tip conditions can be a function of crack velocity, the steady-state crack-tip conditions for metals have appeared to be independent of the crack velocity within the range attained by the loading rates specified in Test Method E 1304. **E 1304**

stress-intensity factor at crack initiation, K_o [FL$^{-3/2}$]—the value of *K* at the onset of rapid fracturing.

DISCUSSION—In Test Method E 1221, only a nominal estimate of the initial driving force is needed. For this reason, K_o is calculated on the basis of the original crack or notch length and the crack-mouth opening displacement at the initiation of a fast-running crack. **E 1221**

stress-intensity factor coefficient, *Y**—a dimensionless parameter that relates the applied load and specimen geometry to the resulting crack-tip stress-intensity factor in a chevron-notch specimen test. **E 1304**

surface-crack length, 2*c* [L]—in part-through surface crack (PS) specimens, a distance measured on the specimen surface between the two points at which the crack front intersects the specimen surface. Crack length is less than the specimen width.

DISCUSSION—In Practice E 740, crack length is the original surface length, $2c_o$, and the subscript o is everywhere implied. **E 740**

transition time, t_T [T]—time required for extensive creep conditions to develop in a cracked body. For specimens, this is the time required for the creep deformation zone to spread through a substantial portion of the uncracked ligament. **E 1457**

ANNEXES

(Mandatory Information)

A1. UNITS

A1.1 For stress intensity factor, *K*, and any measure of fracture toughness expressed in terms of *K*, the recommended unit is MPa (m)^{½}. The corresponding customary unit is ksi (in.) ½.

A1.2 For the crack-extension force, *G*, and for the elastic energy release rate, which in plane measurement problems is equal to *J*, and any measure of fracture toughness expressed in terms of *G* or *J*, the recommended unit is kJ/m ^{2}. The corresponding customary unit is in.-lb/in.^{2}

A1.3 For crack tip opening displacement, δ, and any measure of fracture toughness expressed in terms of δ, the recommended unit is metre. The corresponding customary unit is mil.

A2. DESIGNATION CODES FOR SPECIMEN CONFIGURATION, APPLIED LOADING, AND CRACK OR NOTCH ORIENTATION

A2.1 A consistent, uniform, systematic specimen code is described herein.[7] It has the following basic format:

1	2	3
Specimen Configuration	(Applied Loading)	(Crack or Notch Orientation)

These three elements of the designation code are presented in this annex as follows: A2.2 on Specimen Configuration, A2.3 on Applied Loading, and A2.4 on Crack or Notch Orientation.

[7] Wilhem, D. P., "Standard Designation Code for Fracture Specimens, Loading and Orientation," *Standardization News*, Vol 10, No. 5, May 1982.

A2.2 *Designation Code for Specimen Configuration:*

A2.2.1 Most specimens can be analyzed and illustrated in a plan view that is normal to the front of the notch or crack. From this plan view, the term edge (which is normally used to represent a line) represents a line boundary of the specimen. In test specimens, the two surfaces parallel to this plan view are termed side surfaces, and the four surfaces normal to this plan view (the boundaries in the plan view) are termed edge surfaces. Fig. A2.1 illustrates two edge surfaces and one side surface of a specimen that contains a mathematically ideal crack.

A2.2.1.1 The following specimen designations treat the specimen configurations that are used at present. As new specimens develop, they will be added to this listing. The symbol code of abbreviations for specimen configuration has one, two, or three capital letters.

M	Middle
DE	Double Edge
SE	Single Edge (0.6 < H/W)
C	Compact version of SE with H/W = 0.6
MC	Modified Compact (0.3 < H/W < 0.6)
DC	Disk-Shaped Compact (formerly called round compact specimen)
A	Arc
DB	Double Beam (H/W < 0.3)
RDB	Round Double Beam (formerly called short rod)
R-BAR	Round Bar
PS	Part-Through Surface (formerly designated SCT and PTC)

Examples are given in Fig. A2.2.

A2.2.1.2 Note that the words "cracked" and" notched" are not part of the code. For example, a standard compact that is notched (non-pre-cracked) is designated "notched C," and a precracked standard compact (specimen used in Method E 399) is a" pre-cracked C." Likewise, the terms "chevron" and" contoured" are not part of the code and they are spelled out when needed, as in the chevron RDB specimen.

A2.3 *Designation Code for Applied Loading:*

A2.3.1 The applied loading code consists of a one-letter abbreviation that is enclosed in parentheses and immediately follows the specimen code. The following list contains examples of applied loading. Examples are given in Fig. A2.2.

(T)	Tension
(B)	Bending
(M_x)	Torsion with a moment about the *x*-axis of the specimen (formerly called double torsion loading)
(M_z)	Moment about the *z*-axis of the specimen
(W)	Wedge loading
(W_b)	Wedge loading with a bolt

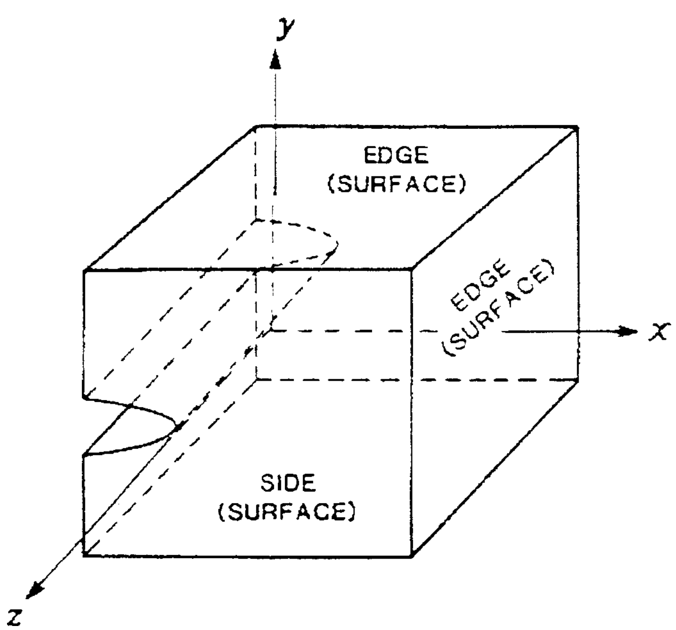


FIG. A2.1 Three-Dimensional View of Ideal Crack

A2.4 *Designation Code for Crack or Notch Orientation:*

A2.4.1 Crack-, notch-, or fracture-plane orientation is designated by a hyphenated code with the first letter(s) representing the direction normal to the crack plane and the second letter(s) designating the expected direction of crack propagation. It is presented in parentheses and follows the designations for the specimen configuration and applied loading.

A2.4.2 The fracture toughness of a material usually depends on the orientation and direction of propagation of the crack in relation to the anisotropy of the material, which depends, in turn, on the principal directions of mechanical working or grain flow. The orientation of the crack plane should be identified wherever possible in accordance with the following systems.[8] In addition, the product form should be identified (for example, straight rolled plate, cross rolled plate, pancake forging, and so forth).

A2.4.3 For rectangular sections, the reference directions are identified as in the examples for a rolled plate, Fig. A2.3 and Fig. A2.4. The same system would be suitable for sheet, extrusions, and forgings with nonsymmetrical grain flow.

L = direction of principal deformation (maximum grain flow),
T = direction of least deformation, and
S = third orthogonal direction.

A2.4.3.1 Using a two-letter code, the first letter designates the direction normal to the crack plane, and the second letter the expected direction of crack propagation. For example, in Fig. A2.3, the T-L specimen has a fracture plane whose normal is in the width direction of a plate and an expected direction of crack propagation coincident with the direction of maximum grain flow or longitudinal direction.

A2.4.3.2 For specimens that are tilted with respect to two of the reference axes, Fig. A2.4, the orientation is identified by a three-letter code. The code L-TS, for example, means that the crack-plane is perpendicular to the direction of principal deformation (L direction), and the expected fracture direction is intermediate between T and S. The code TS-L means that the crack-plane is perpendicular to a direction intermediate between T and S and the expected fracture is in the L direction.

A2.4.4 For certain cylindrical sections where the direction of principal deformation is parallel to the longitudinal axis of the cylinder, the reference directions are identified as in Fig. A2.5 which gives examples for a drawn bar. The same system would be useful for extrusions or forged parts having a circular cross section.

[8] Goode, R. J., "Identification of Fracture Plane Orientation," Materials Research and Standards (MIRSA), ASTM, Vol 12, No. 9, September 1972.

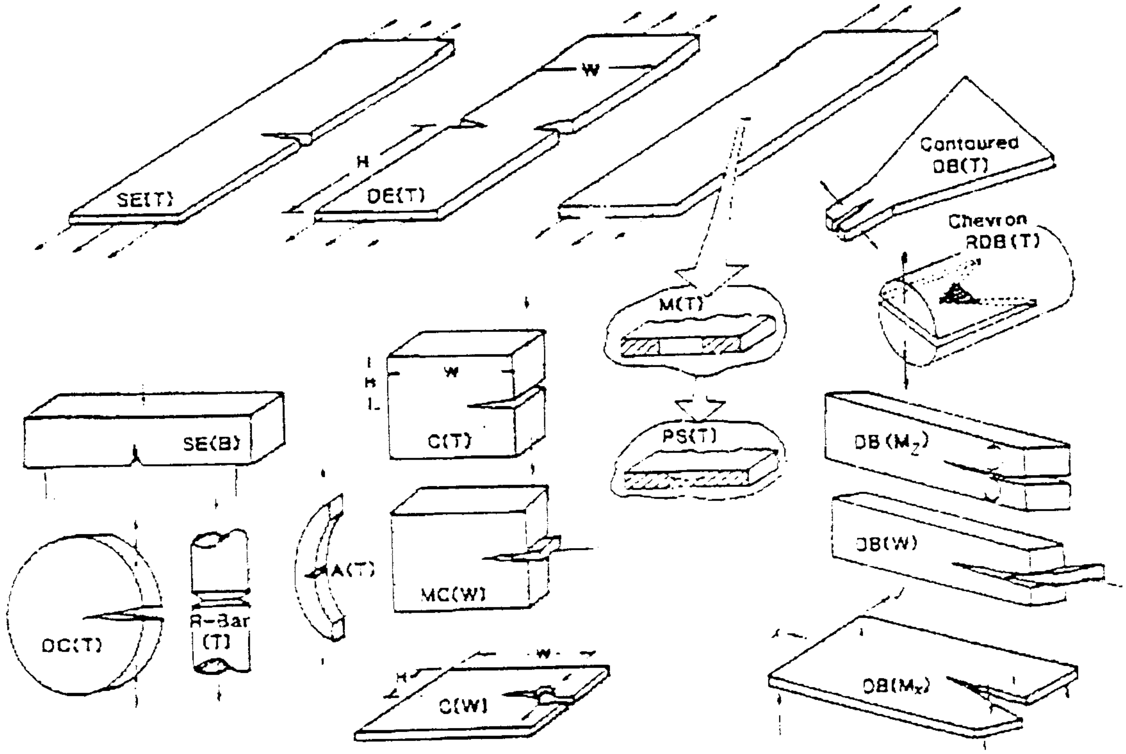


FIG. A2.2 Examples of Designation Codes for Specimen Configuration and Applied Loading

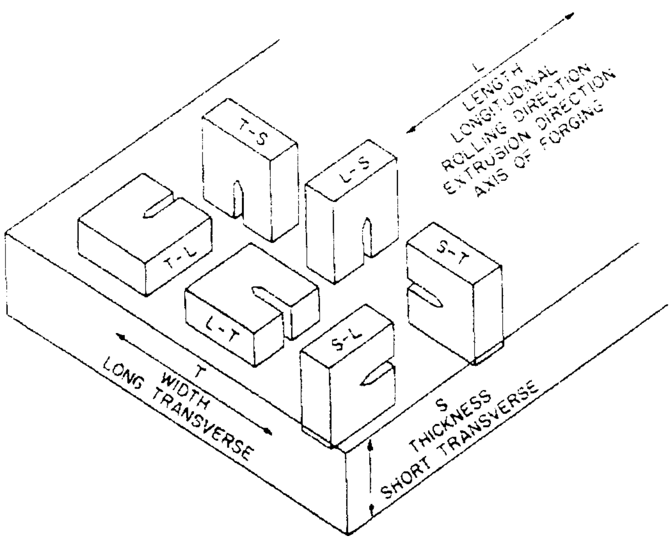


FIG. A2.3 Crack Plane Orientation Code for Rectangular Sections

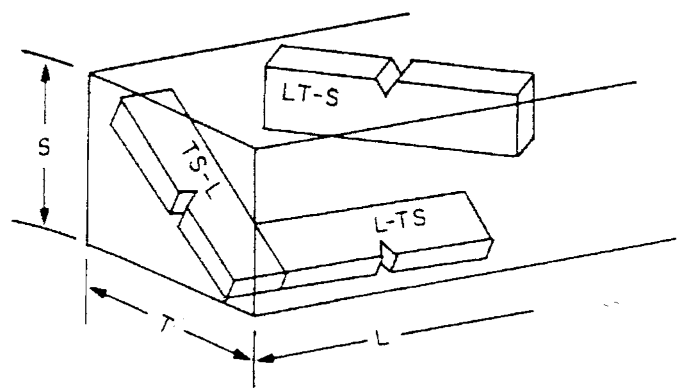


FIG. A2.4 Crack Plane Orientation Code for Rectangular Sections Where Specimens Are Tilted with Respect to the Reference Directions

L = direction of maximum grain flow,
R = radial direction, and
C = circumferential or tangential direction.

A2.4.5 The arc-shaped specimen is intended to measure the fracture toughness so that the plane normal to the crack is in the circumferential or tangential direction. This is designated the C-R orientation. For other orientations, a bend or compact specimen should be used.

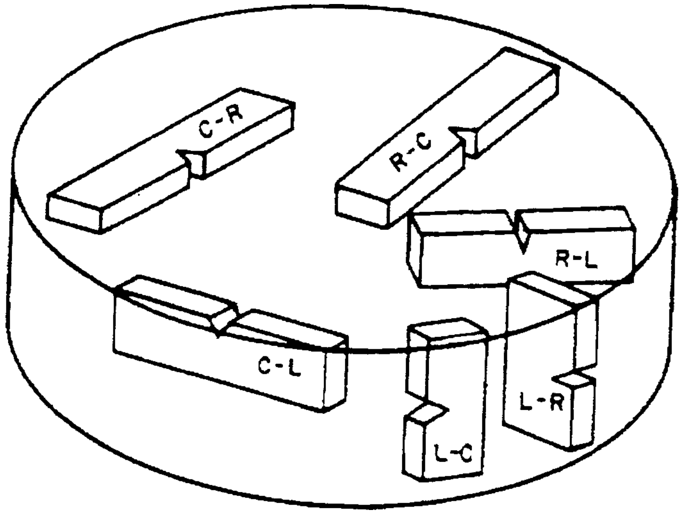


FIG. A2.5 Crack Plane Orientation Code for Bar and Hollow Cylinder

APPENDIX

(Nonmandatory Information)

X1. ABBREVIATED METRIC PRACTICE GUIDE FOR FATIGUE AND FRACTURE TESTING

X1.1 For additional information see "Metric Practice Guide E 380." In Vol 03.01 of the *Annual Book of ASTM Standards*, see also "Excerpts from Standard for Metric Practice," under the heading Related Material in the gray pages.

X1.2 *Selected SI Units and Symbols:*

Quantity [dimension symbol]	Unit (SI symbol)	Formula
length [L]	metre (m)	
mass [M]	kilogram (kg)	
time [T]	second (s)	
thermodynamic temperature [θ]	kelvin (K)	
energy, work, torque [FL]	joule (J)	N·m
force [F]	newton (N)	kg·m/s^2
frequency [T^{-1}]	hertz (Hz)	(cycle)/s
pressure, stress [FL^{-2}]	pascal (Pa)	N/m^2

X1.3 *SI Prefixes:*

Multiplication Factor	Prefix	SI Symbol
1 000 000 = 10^6	mega	M
1000 = 10^3	kilo	k
0.001 = 10^{-3}	milli	m
0.000001 = 10^{-6}	micro	µ

X1.4 *Selected Conversion Factors:*

To Convert From	To	Multiply By
dyne·cm	N·m	1.000 000* E-07
erg	joule (J)	1.000 000* E-07
erg/cm^2	J/m^2	1.000 000* E-03
ft (foot)	metre (m)	3.048 000* E-01
ft·lbf (foot-pound)	joule (J)	1.355 818 E + 00
in. (inch)	metre (m)	2.540 000* E-02
in.	mm	2.540 000* E + 01
in.·lbf	joule (J)	1.129 848 E-01
in.·lbf/in.^{2}	J/m^2	1.751 268 E + 02
in.·lbf/in.^{2}	kJ/m^2	1.751 268 E-01
kgf (kilogram-force)	newton (N)	9.806 650* E + 00
kgf/mm^2	pascal (Pa)	9.806 650* E + 06
kgf/mm^2	MPa	9.806 650* E + 00
kgf/mm$^{3/2}$	MP $\sqrt{m}$	3.101 135 E-01
kilocalorie	joule (J)	4.186 800* E + 03
kip (1000 lbf)	newton (N)	4.448 222 E + 03
kip/in.^{2}(ksi)	pascal (Pa)	6.894 757 E + 06
ksi (kip/in.^{2})	pascal (Pa)	6.894 757 E + 06
ksi	MPa	6.894 757 E + 00
ksi $\sqrt{in.}$	Pa $\sqrt{m}$	1.098 843 E + 06
ksi $\sqrt{in.}$	MPa $\sqrt{m}$	1.098 843 E + 00
lbf (pound-force, poundal)^A	newton (N)	4.448 222 E + 00
lbf/in.	N/m	1.751 268 E + 02
lbf/in.^{2}(psi)	pascal (Pa)	6.894 757 E + 03
lbm (pound-mass)^B	kilogram (kg)	4.535 924 E-01
mil	metre (m)	2.540 000* E-05
N/mm^2	MPa	1.000 000* E + 00
N/mm$^{3/2}$	MPa $\sqrt{m}$	$10^{-3/2}$*
psi (lbf/in.^{2})	pascal (Pa)	6.894 757 E + 03
psi	kPa	6.894 757 E + 00
psi $\sqrt{in.}$	Pa $\sqrt{m}$	1.098 843 E + 03
ton (long, 2240 lbm)	kilogram (kg)	1.016 047 E + 03
ton (metric)	kilogram (kg)	1.000 000* E + 03
ton (short, 2000 lbm)	kilogram (kg)	9.071 847 E + 02
ton-force (2000 lbf)	newton (N)	8.896 444 E + 03
ton-force/in.^{2}	pascal (Pa)	1.378 952 E + 07^{A,B}

^{A} The exact conversion factor is 4.448 221 615 260 5* E + 00.

^{B} The exact conversion factor is 4.535 923 7* E-01.

NOTE X1.1—Factors with an asterisk (*) are exact.