

**Recommended Guidelines for Fatigue Testing of
Elastomeric Materials and Components**

Foreword—These guidelines describe:

- a. A set of definitions and terminology to allow interchange of information on a common basis. (Section 3)
- b. The manner in which elastomeric materials and components undergo changes due to stresses and/or strains in a fatigue environment that ultimately culminate in failure. (Sections 4 and 5)
- c. Factors to be considered in selecting from available test methods or in developing a test method to meet specific requirements. (Sections 6 through 10)
- d. Important considerations in the evaluation and reporting of test information. (Section 11)

1. Scope—The purpose of this SAE Recommended Practice is to review factors that influence the behavior of elastomers under conditions of dynamic stress and to provide guidance concerning laboratory procedures for determining the fatigue characteristics of elastomeric materials and fabricated elastomeric components.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1085—Test for Dynamic Properties of Elastomeric Isolators
SAE J1883—Elastomeric Bushing “TRAC” Application Code
SAE Fatigue Design Handbook, Third Edition, 1997

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 429-81—Test Methods for Rubber Property—Adhesion to Rigid Substrates
ASTM D 430-95—Test Methods for Rubber Deterioration—Dynamic Fatigue
ASTM D 623-93—Test Methods for Rubber Property—Heat Generation and Flexing Fatigue in Compression
ASTM D 813-95—Test Method for Rubber Deterioration—Crack Growth
ASTM D 1052-85—Test Method for Measuring Rubber Deterioration—Cut Growth Using Ross Flexing Apparatus
ASTM D 1149-91—Test Method for Rubber Deterioration—Surface Ozone Cracking in a Chamber

SAE Technical Standards Board Rules provide that: “This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user.”

SAE reviews each technical report at least every five years at which time it may be reaffirmed, revised, or cancelled. SAE invites your written comments and suggestions.

TO PLACE A DOCUMENT ORDER; (724) 776-4970 FAX: (724) 776-0790
SAE WEB ADDRESS <http://www.sae.org>

2.1.3 OTHER PUBLICATIONS

1. P. W. Allen, P. B. Lindley, and A. R. Payne, "Use of Rubber in Engineering," London: Maclaren and Sons, Ltd., 1967, pp. 60-71.
2. Anonymous, "Fatigue Failure and Its Reduction in Natural Rubber." Akron: Monsanto Technical Bulletin O/RC-7.
3. Anonymous, "Fatigue to Failure Tester." Akron: Monsanto Literature with attachments.
4. A. B. Davey and A. R. Payne, "Rubber in Engineering Practice." New York: Palmerton Publishers, 1964.
5. McPherson and Klemin, "Engineering Uses of Rubber." New York: Rheinhold, 1956. pp. 132-134, 139, 165-167, 170.
6. A. R. Payne and J. R. Scott, "Engineering Design with Rubber," New York Interscience Publishers, Inc., 1960, pp. 104-106.
7. J. R. Scott, "Physical Testing of Rubber," New York: Palmerton Publishing Co. 1965 pp. 129-113.
8. SAE Fatigue Design Handbook, Vol. 4, 1968.
9. Charles R. Hicks, "Fundamental Concepts in the Design of Experiments," New York: Holt, Rinehart and Winston, 1964.
10. Bernard Ostle, "Statistics in Research," Iowa State University Press, 1964.
11. United States Department of Commerce, "Experimental Statistics," Washington, D.C.: U.S. Government Printing Office (1963).
12. "ASTM Rubber Products, Industrial Specifications and Related Test Methods; Carbon Black; Gaskets; Tires." Annual Book of ASTM Standards, Part 37, 1976.
13. "Webster's New Collegiate Dictionary," Springfield: G & C Merriam Co.
14. "Handbook of Molded and Extruded Rubber," Akron: The Goodyear Tire and Rubber Co., Third Edition, 1969.
15. "Properties and Selection of Metals," ASM Metals Handbook, Volume 1.

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J200—Classification System for Rubber Materials
SAE TRACK CODE

2.2.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 1349—Standard Test Temperature for Rubber and Rubberlike Materials
ASTM D 1566—Terms Relating to Rubber and Rubberlike Materials
ASTM F 4—Standard Method of Verification of Testing Machines
ASTM E 74—Standard Methods of Verification of Calibration Devices for Verifying Testing Machines
"ASTM General Test Methods," Annual Book of ASTM Standards, Part 41, 1976.

2.2.3 ASME PUBLICATION—Available from ASME, 345 East 47 Street, New York, NY 10017-2330.

Yost, "Fatigue Characteristics of Rubber," ASME Transactions, Vol. 65, pp. 881-888.

2.2.4 OTHER PUBLICATIONS

T. A. Knurek and R. P. Salisbury, "Carbon Black Effect on Engine Mount Compounds." Rubber World (August 1964), pp. 45-57.
G. J. Lake, "Corrosive Aspects of Fatigue," Rubber Age (August 1972). pp. 30-42.

- 3. Definitions**—The following terms and definitions are applicable to this document:
- 3.1 Aging**—The irreversible change of material properties after exposure to an environment for an interval of time. (See 2.1.3 [12].)
- 3.2 Ambient Temperature**—The temperature of the environment surrounding the test specimen. (SAE J1085)
- 3.3 Bushing**—A cylindrical bearing or guide. (See 2.1.3 [15].)
- 3.4 Compound**—An intimate admixture of a polymer with all the materials necessary for the finished article. (See 2.1.3 [12].)
- 3.5 Compression**—Reduction of dimension from an external force.
- 3.6 Creep**—The time-dependent part of a strain resulting from stress. (See 2.1.3 [12].)
- 3.7 Damping**—Decreasing the amplitude of vibrations in the motion of a body subject to influences which cause vibration.
- 3.8 Elastomer**—Macromolecular material that returns rapidly to approximately the initial dimensions and shape after substantial deformation by a weak stress and release of the stress. (See 2.1.3 [12].)
- 3.9 Elongation**—Extension produced by a tensile stress. (See 2.1.3 [12].)
- 3.10 Equilibrium Temperature**—Stable temperature at which heat loss equals heat input.
- 3.11 Failure**—When a material or component ceases to fulfill the design specified responses essential to the successful operation as a sub unit of a system. A rubber part may fail from tearing, cracking, rupture, hardening, softening, heat or chemical degradation, creep, set, or a combination thereof.
- 3.12 Fatigue**—The process of progressive localized permanent structural changes occurring in a material or component subject to conditions which produce fluctuating stresses and strains at some point or points and which may culminate in loss of load bearing ability, cracks or complete fracture after a sufficient number of fluctuations. (See 2.1.1 SAE Fatigue Design Handbook.)
- 3.13 Fatigue Life**—The number of cycles of stress or strain of a specified character that a given specimen sustains before failure of a specified nature occurs. (See 2.1.1 SAE Fatigue Design Handbook.)
- 3.14 Frequency**—The number of complete cycles, whole periods, of forced vibrations per unit of time caused and maintained by a periodic excitation, usually sinusoidal. (SAE J1085)
- 3.15 Friction**—The resistance to relative motion between two bodies in contact. (See 2.1.3 [13].)
- 3.16 Hysteresis**—The percent energy lost per deformation cycle. (See 2.1.3 [14].)
- 3.17 Maximum Stress - S_{max}** —The stress having the highest algebraic value in the stress cycle, tensile stress being considered positive, and compressive stress negative. In this definition, the nominal stress is used most commonly. (See 2.1.1 SAE Fatigue Design Handbook.)
- 3.18 Mean Stress (or Steady Component of Stress) - S_m** —The algebraic average of the maximum and minimum stresses in one cycle, that is, $(S_{max} + S_{min})/2$.
- 3.19 Minimum Stress - S_{min}** —The stress having the lowest algebraic value in the cycle, tensile stress being considered positive and compressive stress negative. (See 2.1.1 SAE Fatigue Design Handbook.)

- 3.20 Modulus of Elasticity**—Ratio of stress to the strain produced by that stress $E = \text{Stress}/\text{Strain}$ property of material. (See 2.1.3 [14].)
- 3.21 Nominal Stress - S**—The stress at a point calculated on the net cross-section by simple elastic theory, without taking into account the effect on the stress produced by geometric discontinuities such as holes, grooves, fillets, etc. (See 2.1.1 SAE Fatigue Design Handbook.)
- 3.22 Ozone - O₃**—An allotropic form of oxygen. It is a gas with a characteristic odor and is a powerful oxidizing agent.
- 3.23 Permanent Set**—The residual deformation of a specimen or component after removal of the external load.
- 3.24 Pinching**—A phenomena where a fold is formed by deflection of the elastomeric component which causes a high stress concentrated at the surface of the elastomer, causing the elastomer to tear. Reshaping the section to eliminate the pinch condition will typically yield significant gains in fatigue life.
- 3.25 Polymer**—A macromolecular material formed by the chemical combination of monomers having either the same or different chemical composition. (See 2.1.3 [12].)
- 3.26 Preload**—An external static load producing a strain in a test specimen. Preload is imposed prior to forced vibration testing. Preload is usually expressed in force units instead of deflection units. (SAE J1085)
- 3.27 Resilience**—The ratio of energy output to energy input in a rapid (or instantaneous) full recovery of a deformed specimen. (See 2.1.3 [12].)
- 3.28 Resonant Frequency**—The frequency at which maximum amplitude occurs for a given input force in a forced vibration system.
- 3.29 S-N_f Diagram**—A plot of stress against the number of cycles to failure. The stress can be S_{\max} , S_{\min} or S_a . The diagram indicates the S-N_f relationship and a specified probability of survival. For N_f a log scale is almost always used. For S_a a log scale is used most often but a linear scale is sometimes used. (See 2.1.1 SAE Fatigue Design Handbook.)
- 3.30 Shear**—Force which causes two contiguous parts of the same body to slide relative to each other in a direction parallel to their plane of contact. (See 2.1.3 [13].)
- 3.31 Silentbloc**—A type of bushing consisting of a thin wall, elastomeric cylinder compressed between concentric metal sleeves.
- 3.32 Specimen Temperature**—The temperature obtained by placing or locating a temperature sensing device in or on the specimen. In most cases, temperature gradients that develop within flexing rubber specimens make it necessary to define the precise points and techniques used to measure temperature.
- 3.33 Spring Rate**—Ratio of force to the deflection produced by that force. Spring rate = Force/Deflection property of the particular elastic body under consideration. (See 2.1.3 [14].)
- 3.34 Strain**—Change (in length) per unit length in a linear dimension of a part or specimen. (See 2.1.3 [15].)
- 3.35 Stress (Uniaxial)**—Load on a specimen divided by the area through which it acts.
- 3.36 Stress Amplitude (or Variable Component of Stress) - S_a**—One-half the range of stress, that is $S_a = S/2 = 1/2(S_{\max} - S_{\min})$.
- 3.37 Stress Relaxation**—The decrease in stress after a given time at a constant strain.

3.38 Tension—Increase in dimension from an external force.

3.39 Torsion—A twisting action resulting in shear stresses and strains.

4. Elastomeric Characteristics—An elastomer is a material that exhibits both viscoelastic and temperature dependent behavior. Viscoelastic materials exhibit both displacement (elastic) and time (viscous) dependencies. The elastic property of the material relates stress versus strain behavior. Because of the viscoelastic characteristics exhibited by elastomers, the dynamic response and mechanical behavior are dependent upon stress or strain history, rate of loading, frequency, and amplitude of strain.

The viscous property of the material causes internal energy loss, or hysteresis (damping). The lost energy is converted into heat and since elastomers are poor heat conductors, this can result in a considerable temperature rise, which affects the previously discussed material properties. In liquid-filled rubber components (e.g., hydraulic engine mounts) heat is generated due to the fluid pumping action as well.

In addition to being viscoelastic and temperature dependent, elastomers have a lower elastic modulus and lower strength than most metals and plastics. Although softer and weaker than structural metals and plastics, elastomers are like these materials from an energy per unit volume standpoint. For elastomers, metals, and plastics, loaded in tension, a power form of a fatigue correlation exists:

$$N_f W^b = C \quad (\text{Eq. 1})$$

where:

- N_f = cycles to failure
- W = energy input (~ 1/2 stress x strain)
- b and C = constants for specific materials

The application of this fatigue law to elastomers is discussed in Appendix A. Normally, however, conventional design practice avoids loading rubber components in tension. Also, the above relationship is valid only if the frequency of applied loading does not create significant heat in the material, which could generate an elevated temperature condition and result in adversely affecting the fatigue constant of the material. References 2.1.3 [1], [4], [5], [6], and [7] listed in Section 2.1.3 of this document, provide comprehensive information on general elastomeric behavior.

5. Failure Criteria—Since elastomeric components often exhibit more than one failure mode, failure should be defined in such a manner that it can be accurately detected in order to precisely determine the time of its occurrence.

5.1 Commonly Used Failure Criteria:

- a. Complete rupture of the specimen, i.e., total separation in tensile specimens, bond failure, or metal-to-metal contact between opposing mounting surfaces in bushings or compression specimens.
- b. Time or cycles until appearance of visible cracks of a specified size, or growth of a crack or partial rupture to a specified point. For cracks which initiate from internal stress concentrations, the part is sectioned to reveal crack formation prior to propagation to the surface.
- c. A specified level of change in physical properties such as hardness, (Shore Durometer A, International Rubber Hardness degrees (IRHD), etc.), static spring rate (K_s), dynamic spring rate (K_d), or damping (C_d , Loss Angle, etc.)
- d. A specified change in static deflection due to creep, set, or abrasive wear.
- e. Failure to function as intended.
- f. Fluid leakage from a fluid-filled component.
- g. Component noise changes.
- h. Change of state (embrittlement or reversion).

5.2 Since different failure criteria will rank various elastomers differently, it is important that the definition of failure be relevant to the type of failure that occurs in the intended application.

6. Test Parameters—To achieve accurate and consistent results, test procedures should precisely define the test parameters discussed in this section.

6.1 Specimen History—Mechanical preflexing and temperature history must be the same for all samples for consistency of test results.

6.1.1 MECHANICAL PREFLEXING—Elastomers undergoing load deflection tests will progressively change (as much as 25%) for up to the first 1000 cycles until a steady-state condition is reached. The stiffness on the first cycle will usually recover if a period of approximately 8 h or more elapses between load deflection tests. Consequently, if some specific change in spring rate of the specimen is the failure definition, preflexing influences must be considered to establish the initial stiffness. For shock type applications, the first cycle data might be the basis. For steady-state vibration applications, the third (or more) cycle data might be required. For preflexing to be effective, the load and/or deflection must be at least that at which the stiffness is to be determined.

6.1.2 TEMPERATURE EFFECTS—Because elastomers are viscoelastic materials, it is necessary to know the temperature of the specimen and its temperature history prior to testing.

A specimen stored in a very cold or hot environment influences the amount of preflexing required to achieve a steady state condition.

6.1.3 CONDITIONING OF OIL ASSEMBLED COMPONENTS—Oil assembled components such as silentblocs require approximately one week for the elastomer to absorb the assembly oil to yield more consistent results. Oven conditioning for 3 h at 70 °C is sometimes used as a substitute for natural conditioning.

6.2 Test Specification Selection

6.2.1 MECHANICAL SPECIFICATIONS

6.2.1.1 Direction of Loading—Refer to SAE J1883 for terminology to be used in defining the direction of applied loads.

6.2.1.2 Types of Fatigue Loads—The method of applying and maintaining test loads must be specified. In addition to the dynamic fatigue load, the test specimen may also be subjected to a constant static load, which is applied simultaneously with the dynamic load. Loads may be applied (and specified) through a single axis or through multiple axes. The following load profiles may be specified.

- a. Apply a specified dynamic fatigue load.
- b. Apply a specified dynamic displacement.
- c. Apply and maintain a specified static load and apply a dynamic fatigue load about the static load point.
- d. Apply and maintain a specified static load and apply a dynamic displacement about the static load point.
- e. Apply and maintain a specified deflection and apply a dynamic displacement about the initial deflection.

6.2.1.3 Magnitude of Load or Displacement—The magnitude of load and displacement specified should reflect the operational environment of the component. This is especially important for fixed displacement testing to assure fatigue results are consistent with in-service performance. Higher load and displacement conditions can be used to accelerate testing, refer to 6.2.4.1.

- 6.2.1.4 *Frequency of Dynamic Excitation*—Fluid-filled mounts, for example, tend to be designed to have high damping at specific frequencies. At these peak frequencies, the fluid absorbs a large percentage of the damping energy; while at other frequencies, damping energy is absorbed by the elastomer. Thus the life of the component's elastomeric material can be highly frequency dependent as well as load dependent.
- 6.2.1.5 *Waveform of Dynamic Excitation*—The type of waveform excitation, i.e., sinusoidal, random, continuous or intermittent, should be specified. Alternatively, real-time dynamic loads may also be specified if road load data has been measured and test equipment is available to reproduce the measured loads.
- 6.2.2 PART TEMPERATURE—Elastomers are functional over a rather narrow temperature range compared to other materials such as metals. Further, each component of a given elastomer has its own temperature range where it is functional. Within that functional range will lie a band of temperatures at which maximum fatigue life is obtained. It is not unusual for fatigue life to change by a factor of two or more over a 20 °C change in temperature near the boundaries of that band. Therefore, the temperature specified should be representative of service conditions, and part temperature should be controlled throughout the test.
- 6.2.2.1 *Definition of Part Temperature*—Since rubber is a poor heat conductor, thick parts will usually have large temperature gradients. Measurements should, therefore, be made by placing the temperature sensing element as close to the area of heat generation as possible. The location chosen and the type of temperature measurement should be carefully defined and consistently adhered to.
- 6.2.2.2 *Part Temperature Control*—Part temperature is a function of ambient temperature, hysteresis of the specimen, energy input, external friction, and heat dissipation off the surface of the part.

Ambient temperature control is necessary. First, it is recommended that the part and associated fixturing be allowed to reach equilibrium with the environment before starting the test. Guidelines for achieving this are given in the Appendix to SAE J1085 for elevated temperature testing. For elevated temperature testing, it is suggested that the part be enclosed in an air circulating heat chamber. At moderate temperatures, circulation of air over the specimen is commonly used to control part temperature. It should be recognized, however, that in some situations this may lower specimen surface temperature but have a relatively small effect on temperature within the specimen. Air cooling magnifies the ability of any fixturing in contact with the specimen to conduct heat out of the specimen (i.e., to behave as a heat sink) so care must be taken to ensure consistency in fixture contact area, shape, and mass. In cases where correlation between test facilities is necessary, air cooling may be undesirable as another source of variability.

Internal heat generation due to the combination of hysteresis and energy input should not cause the part to exceed the desired test temperature. Hysteresis in elastomers will cause an increase in component temperature which will be proportional to frequency and/or amplitude test conditions. This sometimes makes it necessary to adjust test conditions when elastomers of different hysteresis levels are tested. In most cases, it is desirable to design the test in such a way that a significant portion of the testing takes place after the part temperature has stabilized.

Sometimes elastomer hysteresis is falsely blamed for high specimen temperature when the source heat is actually friction due to slip between elastomer and metal components and/or test fixtures. When this is the case, and the elastomer has low hysteresis, reducing the test amplitude and/or load and increasing frequency will sometimes reduce temperature without adding significantly to test time.

6.2.3 OTHER PARAMETERS

- 6.2.3.1 *Ozone Concentration*—Some elastomers are inherently ozone resistant so that ozone has little effect on their fatigue life. Other elastomers are not ozone resistant and must be chemically protected to prevent ozone cracking in stressed areas. Ozone cracking results in shortened flex life, particularly so for specimens with a high ratio of exposure surface to mass. Ozone crack rate increases with stress level and temperature.

It is desirable to avoid uncontrolled and excessive ozone concentrations as can be found in close proximity to electrical discharges or some motors. In critical situations, ozone concentration should be measured and reported in test conditions. ASTM D 1149 (see 2.1.3 [12]) describes ozone concentration measurement.

The antiozonants used in many elastomer compositions must migrate to the surface of the specimen before they become fully effective. Testing of recently molded specimens should not be conducted before protective agents have migrated to the surface. Usually, 24 h is the minimum time for migration.

6.2.3.2 *Oxidation*—The reaction of oxygen (oxidation) with many elastomers can initiate crack formation as well as result in hardening or softening. At temperatures higher than room temperature, the effect of oxygen is accelerated. Test specimens should not be stored for long time periods at elevated temperatures unless this is a necessary and controlled part of the test requirement.

6.2.3.3 *Deleterious Fluids and Gases*—No elastomer is resistant to all fluids and gases. Oils, oil vapor, and solvents can seriously degrade non-resistant elastomers. Water, steam, coolants, acids, and alkalis in fluid or vapor form can reduce specimen fatigue life. The atmosphere surrounding the test specimen should be free of deleterious fluids and gases unless they are a necessary and controlled part of the test requirement.

6.2.4 ACCELERATION METHODS—Table 1 describes examples of acceleration methods and possible affects they may have on the test and/or specimen.
An elevated temperature presoak may be used to condition the component. This serves to accelerate testing.

A cut may be used to initiate the crack before the start of the test.

TABLE 1—ACCELERATION METHODS

Method of Acceleration	Possible Effects on Test and Specimen
Increase static load or displacement	Increase or decrease in cycles to failure (depending upon the load applied and the load deflection characteristics of the part). Failure by splitting and tearing (tensile failure) rather than by abrasive wear or fatigue cracking. Failure due to pinching (see definitions). Increased bulge area (compression). Decreased cross-sectional area (tension). Increased creep. Slip between specimen and fixturing. More data scatter (hardness sensitivity).
Increase dynamic load or displacement	Decrease in cycles to failure. Increase in temperature due to hysteresis. Increase in temperature due to slip between specimen and fixturing. Decrease in modulus. Tensile failure rather than abrasive wear or fatigue cracking. Increased bulge area (compression). Decreased cross-sectional area (tension). More data scatter (hardness sensitivity).
Increase frequency of dynamic load or displacement	Increased heat generation per unit time. Change from mechanical to chemical failure. Change in load or displacement waveform. Change in dynamic response of specimen. Increase or decrease in cycles to failure.
Increase ambient temperature (Presoak)	Increased specimen temperature. Decrease in modulus. Change in cycles to failure. Change in dynamic response of specimen. Change in mode of failure.

6.2.4.1 *Effects of Acceleration*—Acceleration can introduce obvious or subtle factors that affect the test by changing the point of failure initiation, final location failure, propagation, and major cause of failure. This can be misleading when materials for end use are chosen based on results of such a test.

7. *Proper Test Procedures*

7.1 **Application of Parameters**—Methods of applying static and dynamic deformation must be studied carefully to ensure that only the intended parameter is applied to the specimen. Most methods have inherent characteristics resulting from mass, friction, geometry, compliance, misalignment, and nonlinearity which may affect the parameter being applied. Through design, many of these undesirable effects can be reduced to an acceptable level.

7.2 **Property Measurement**—Since the properties of different elastomeric specimens in a fatigue environment change differently, it is desirable to measure as many of these changes as possible. The instrumentation required will depend on the nature and purpose of the test, i.e., a material evaluation would call for more detailed data than a quality control test. In all cases, however, the instrumentation must be adequate to observe both:

- a. Changes corresponding to those that adversely affect performance in the intended application and which, therefore, qualify as criteria for failure.
- b. Changes which can affect the severity of the test, obscure the point of failure, or affect the mode of failure, thereby giving misleading results. Stress relaxation, set, and excessive heat buildup due to accelerated test conditions are examples of such changes.

7.2.1 Temperature influences all of the failure definitions previously mentioned. One common situation concerns periodic evaluation of some physical property during fatigue testing. The specimen will heat up during testing due to internal heat generation. Consequently, when the periodic test is run, the specimen must be allowed to cool down or the initial property must be run at this elevated temperature. This is especially important when running low ambient temperature tests.

Tables 2a and 2b show changes that can be anticipated and examples of the types of instrumentation that can be used to detect them.

7.3 **Instrumentation**—Proper instrumentation is a good aid to accuracy in that error can be seen in the parameter measurement and, if recognized as such, and the source of error identified, be corrected. In measuring displacement, direct specimen deflection measurement is recommended rather than that of a test machine component attached to the specimen. In measuring loads, a load measuring device located in series between the specimen and the loading mechanism is recommended.

TABLE 2A—INSTRUMENTATION TO DETECT PHYSICAL CHANGES IN TEST SPECIMEN

Change in Specimen	Method of Observation	Notes
Abrasive wear	Weight change	May be dry or tacky depending on polymer type and formulation.
Amplitude of vibration under fixed force input	LVDT ⁽¹⁾ , velocity transducer (integrated), accelerometer (integrated twice), leaf spring with strain gauge, optical methods, or micro-switches.	If not fixed or controlled, amplitude usually increases during test due to the combined effect of temperature rise, chemical degradation, tearing, abrasion, etc. In some configurations, amplitude can decrease due to overall movement relative to constraints.
Bond failure (to metal or fabric)	Visual.	Type and percentage of failure may be indicated using terminology of ASTM D 429.
Cracks or tearing—Initiation and rate of growth	Visual or optical. May also be inferred from changes in deflection, damping, or elastic rate.	Possibility of internal failure must be considered with thick specimens, in which case sectioning is required.
Deflection (midpoint) or drift	LVDT ⁽¹⁾ leaf spring with strain gauge or micrometer head (if member maintaining fixed load is different than member applying oscillating load) optical methods, micro-switches.	If constant force is maintained by a dead weight or servo system, deflection usually increases due to changes in the material, tearing, abrasion, etc. Temperature rise may result in decreased or increased deflection.
Distortion	Visual	Buckling, banding, etc., can lead to typical failure modes.
Dynamic properties—Elastic rate and viscous damping	Analysis of force and amplitude signals (magnitude and phase angle).	Increases or decreases in either property can occur due to chemical changes or changes in physical dimensions due to set.
Force—Static and dynamic in displacement controlled test equipment	Load cell—Strain gauge or piezoelectric type	Load cell must be placed so as to avoid the effects of the weight of surrounding machine elements and extraneous inertial forces.

1. Linear variable differential transformer.

TABLE 2B—INSTRUMENTATION TO DETECT PROPERTY CHANGES IN TEST SPECIMEN

Property Undergoing Change	Instrumentation	Notes
Permanent set	Direct measurement after a specified period of recovery.	Method of measurement must be carefully defined. Usually not applicable to badly cracked or degraded specimens.
Porosity (internal)	Visual examination of sectioned specimen comparison with standard specimens.	Indicative of chemical degradation due to internal heat build-up.
Temperature	Thermocouple, thermistor in, on, or adjacent to test specimen. Infrared pyrometer for surface temperature.	Sample temperature is normally non-uniform throughout the part due to the internal viscosity and poor heat transfer characteristics of elastomers.

7.4 Machine Geometry and Test Fixtures

- 7.4.1 Instrumentation alone is not assurance of equivalent data between machines of different design used to run the same test. Machine geometry can affect specimen restraint, and if significantly different, can dramatically influence test results even though the measured parameters are identical.
- 7.4.2 In many tests, the specimen will roll, shift, bulge, or otherwise react when the major parameters are applied. These reactions are often of high force magnitude. Improper attempts to completely restrict motions of this type often cause bending and friction in machine components which may adversely affect test repeatability.
- 7.4.3 It is recommended that the influencing machine geometry that affords the best compromise of the following be chosen:
- Restrains specimen similar to the intended application
 - Has no inherent adverse effect on test repeatability
 - Has minimum effect on data as a result of wear, changes in friction, minor misadjustment, or other slight loss of precision
- 7.4.4 Test fixtures, poorly designed or improperly specified, may constitute a test variable. The following should be considered in the specifying of test fixtures:
- Fixture stiffness
 - Cleanliness and finish of surfaces in contact with specimen
 - Heat sink effects

8. Test Apparatus—This document is intended to apply to all elastomer and elastomeric component fatigue testing apparatus. Typical commercially available testers are:

8.1 Mechanical Testers

- Chrysler "Diving Board"
- De Mattia Flexing Machine (ASTM D 430 and D 813 (2.1.3 [12]))
- E. I. duPont Flexing Machine (ASTM D 430 (2.1.3 [12]))
- Firestone Flexometer (ASTM D 623 (2.1.3 [12]))
- Goodrich Flexometer (ASTM D 623 (2.1.3 [12]))
- Monsanto Flex to Failure Tester (2.1.3 [2]), (2.1.3 [3])
- Roelig Machine
- Ross Flexing Machine (ASTM D 1052 (2.1.3 [12]))
- St. Joe Flexometer
- Sonntag Low Frequency Fatigue Testing Machine

8.2 Servo-controlled Devices

- Hydro-dynamic machines (such as marketed by MTS and Schenck)
- Electrodynamic machines (such as marketed by Unholtz-Dickey and Bruel & Kjaer)

Other applicable test machines may be proprietary or especially constructed to evaluate a specific component.

- 9. Degree of Test Acceleration**—Elastomeric material and component fatigue tests are accelerated to various degrees depending on the type and/or purpose of the test. Most tests fall into one of the following categories:
- 9.1 Engineering Evaluation Tests**—The purpose of evaluation testing is to rank and/or optimize material or component design performance under test conditions simulating the intended application as closely as practical.
- 9.2 Quality Test**—The purpose of quality testing is to measure the fatigue life of a specimen against a standard that is based on tests run on known quality specimens. The test conditions used may or may not simulate the type or direction of deformation found in the intended application, and are usually highly accelerated.
- 9.3 Comparison Tests**—This type of test is performed to compare fatigue performance of materials or components. The initial comparison testing or screening may be performed under accelerated quality test conditions and final evaluation under conditions simulating the intended application.
- 10. Experimental Design**—A designed experiment can obtain more information for less material and process cost than can be obtained by traditional methods. References 2.1.3 [9], 2.1.3 [10], and 2.1.3 [11] listed in Section 2 of this document, cover experiment design in detail.
- 11. Reporting Data**—Reporting test results in a clear, concise manner is every bit as important as assuring that the test conducted was valid and accurate. Also, hardware is often disassembled after a test is completed; the test report is needed to assure that the information of interest is not lost.

Following is a suggested outline of the minimum information that should be presented in a fatigue test report.

- 11.1 Summary**—Present only the important findings with some background information so that the report's contents can be rapidly digested and analyzed.
- 11.2 Material Specification and Properties**—The minimum information presented should include the designation and/or specification, form of product, condition, chemical composition, and note of any special treatment applied.
- Also, to be included, is a presentation of the mechanical properties of the material in the test component, designation of the test method used to procure those properties, and identification of the location from which the samples were taken.
- 11.3 Component Dimensions**—Present a drawing(s) or sketch(es) showing test section details, grip section, orientation with respect to force application and geometry of any induced notches.
- 11.4 Specimen Preparation**—Report any observed deterioration of the specimen during storage, such as changes in shape, dimensions, or mechanical properties. Also desirable would be the reporting of any environmental factors in which the specimens were stored and any protection applied to the samples.
- 11.5 Information on Test Procedures**—Included should be information on the test machine, its functional characteristics (electrohydraulic, pneumatic, etc.), frequency of load application, forcing function, method of calibration, and load monitoring procedures. Further information would encompass the direction of loading (Refer to SAE J1883), failure criteria, number of cycles to run out, and the statistical techniques used to design the test program and accommodate expected or unexpected deviations. Also desirable would be the procedure for mounting the specimen in the machine, fixture details, and precautions taken to ensure that unknown stresses induced by vibration, friction, and eccentricity are negligible. Ambient conditions including temperature and humidity average values and ranges together with controls applied should be reported. Special items of interest such as ozone level, deleterious substance presence, and so on, should also appear.