INTERNATIONAL STANDARD

ISO 1099

Second edition
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Metallic materials — Fatigue testing — Axial force-controlled method

Matériaux métalliques — Essais de fatigue — Méthode par force axiale contrôlée

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 1099 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 5, *Fatigue testing*.

This second edition cancels and replaces the first edition (ISO 1099:1975), which has been technically revised.

Introduction

This International Standard is intended to provide guidance for conducting axial, constant-amplitude, force-controlled cyclic fatigue tests on specimens of a metal for the sake of generating fatigue-life data (i.e. stress vs. cycles to failure).

Nominally identical specimens are mounted on an axial force-type fatigue testing machine and subjected to the required loading conditions that introduce any one of the types of cyclic stress illustrated in Figure 1. The test waveform shall be of constant amplitude, and sinusoidal unless otherwise specified.

The force being applied to the specimen is along the longitudinal axis passing through the centroid of each cross-section.

The test is continued until the specimen fails or until a predetermined number of stress cycles has been exceeded. (See Clauses 4 and 13.)

The test is typically conducted at ambient temperature (ideally between 10 °C and 35 °C).

NOTE The results of a fatigue test may be affected by atmospheric conditions, and where controlled conditions are required, subclause 2.1 of ISO 554:1976 applies.

Metallic materials — Fatigue testing — Axial force-controlled method

1 Scope

This International Standard specifies the conditions for carrying out axial, constant-amplitude, force-controlled fatigue tests at ambient temperature on metallic specimens, without deliberately introduced stress concentrations. The object of testing is to provide fatigue information, such as the relation between applied stress and number of cycles to failure for given materials at various stress ratios.

While the form, preparation and testing of specimens of circular and rectangular cross-section are described, component testing and other specialized forms of testing are not included in this International Standard.

NOTE Fatigue tests on notched specimens are not covered by this International Standard since the shape and size of notched test pieces have not been standardized. However, fatigue-test procedures described in this standard may be applied to fatigue tests on notched specimens.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 554:1976, *Standard atmospheres for conditioning and/or testing — Specifications*

ISO 4287:1997, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

ISO 4288:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture*

ISO 4965:1979, *Axial load fatigue testing machines — Dynamic force calibration – Strain gauge technique*

ISO 7500-1:2004, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines – Verification and calibration of the force-measuring system*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
test diameter
d
diametral distance or width of the specimen or test piece where the stress is a maximum

See Figures 3 and 4

3.2
thickness of test section
a
thickness of a rectangular cross-section specimen or test piece

3.3
width of test section
b
width of a rectangular cross-section specimen or test piece

3.4
parallel length
L_c
length in the gauge test section of a specimen or test piece that has equal test diameter or test width and is parallel

See Figures 3 and 4.

3.5
radius
r
curvature at the ends of the test section that starts the transition from the test diameter, d, or test width, b, to the diameter or width of the gripped ends; or the continuous radius between the gripped ends of the specimen or test piece

NOTE The curve need not be a true arc of a circle over the whole of the distance between the end of the test section and the start of the enlarged end for the types shown in Figures 3a) and 4a).

3.6
maximum stress
σ_{max}, S_{max}
highest algebraic value of stress in a stress cycle

See Figure 2.

3.7
mean stress
σ_m, S_m
one-half the algebraic sum of the maximum stress and the minimum stress in a stress cycle

See Figure 2.

3.8
minimum stress
σ_{min}, S_{min}
lowest algebraic value of stress in a stress cycle

See Figure 2.

3.9
stress amplitude
σ_a, S_a
one-half the algebraic difference between the maximum stress and the minimum stress in a stress cycle

See Figure 2.

3.10
stress range
$\Delta\sigma$, ΔS
arithmetic difference between the maximum and minimum stress

$\Delta\sigma = \sigma_{max} - \sigma_{min}$ or $\Delta S = S_{max} - S_{min}$

See Figure 2.

3.11
stress ratio
R_s
ratio of minimum to maximum stress during any single cycle of fatigue operation

$R_s = \sigma_{min}/\sigma_{max}$

See Figure 2.

3.12
stress cycle
variation of stress with time, repeated periodically and identically

See Figure 2.

3.13
number of cycles
N
number of smallest segments of the force-time, stress-time, strain-time, etc., function that is repeated periodically

3.14
fatigue life
endurance
N_f
number of applied cycles to achieve a defined failure criterion

3.15
fatigue strength at N cycles
σ_N
value of the stress amplitude at a stated stress ratio under which the specimen would have a life of N cycles

4 Test plan

4.1 General outline

Before commencing testing, the following shall be agreed by the parties concerned, unless specified otherwise in the relevant product standard:

a) The form of specimen to be used (see 5.1).

b) The stress ratio(s) to be used.

c) The objective of the tests, i.e., which of the following is to be determined:

— the fatigue life at a specified stress amplitude;

— the fatigue strength at a specified "endurance";

— a full Wöhler or S-N curve.

d) The number of specimens to be tested and the testing sequence.

e) The number of cycles at which a test on an unfailed specimen shall be terminated.

f) The testing temperature if different from the requirements given in 5.2.

Commonly employed "endurances" are, for example, 10^7 cycles for structural steels and 10^8 cycles for other steels and non-ferrous alloys. In the light of recent research, however, it is of importance to note that metals generally do not exhibit an "endurance limit" or "fatigue limit" per se, that is, a stress below which the metal will endure an "infinite number of cycles". Typically, the "plateau(s)" in stress-life are referred to as the conventional "fatigue limit(s)" or "endurance limit(s)", but failures below these levels have been reported and do occur. See, for example, References [1] to [3] in the Bibliography.

4.2 Presentation of fatigue results

The design of the investigation, and the use to be made of the results, govern the choice of the most suitable method of presenting the results from the many available, graphically and otherwise. The results of fatigue tests are usually presented graphically. In reporting fatigue data, the test conditions should be clearly defined. In addition to graphical presentations, tabulated numerical data are desirable where the presentation format permits.

4.2.1 Wöhler or S-N curve

The most general method of presenting the results graphically is to plot the number of cycles to failure, N, as abscissa and the values of stress amplitude or, depending on the type of stress cycle, those of any other stress, as ordinate. The curve drawn smoothly as an approximate middle line through the experimental points is called a Wöhler or S-N curve. A logarithmic scale is used for the number of cycles and the choice of whether a linear or logarithmic scale is used for the stress axis lies with the experimenter. Individual curves are plotted for each set of tests for each R-ratio. Experimental results are usually plotted on the same figure. An example of these graphical representations is shown in Figure 5, where a linear stress scale is used.

4.2.2 Mean stress diagrams

The fatigue strengths derived from the Wöhler or S-N curve are plotted in fatigue strength diagrams. The results can be represented by a graph giving directly, for particular "endurances", the stress amplitude against the mean stress, as shown in Figure 6 (Haigh diagram); or by plotting the maximum and minimum stresses against the mean stress, as shown in Figure 7 (Smith diagram); or by plotting the maximum stress against the minimum stress, as shown in Figure 8 (Ros diagram). Experimental results may be plotted on the same figure.

4.2.3 Alignment

The alignment check shall be carried out using a standard calibration specimen. The alignment specimen illustrated in Figure 9 should be of a geometry similar to the specimens being tested. It is suggested that the alignment specimen be made from a hardened heat-treated steel or similar material capable of totally elastic strains up to at least 0,4 % or the force corresponding to the maximum strain imposed on the specimen used in the test series.

In order to check the misalignment due to angular offset, lateral offset and/or load-train offset, the alignment specimen should have resistance strain gauges secured at the locations A, B and C illustrated in Figure 9. With the top **or** bottom (not both) of the strain-gauged specimen secured in the gripping arrangement, the temperature should be allowed to equilibrate and the zero reference adjustments to the bridge amplifiers accomplished. At this time, the alignment specimen should then be gripped in both the upper and lower grip.

The gauged specimen should then be loaded in **tension** to a maximum strain of 0,4 % or the force corresponding to the maximum strain to be imposed on the specimens in the test series, if this value does not exceed 0,4 % strain on the gauge specimen. The force shall be applied to the gauged specimen four (4) times, corresponding to the specimen positions of 0, 90, 180, 270 degrees. The percent bending is calculated for each of the four specimen positions according to the scheme in Figure 9. If the percent bending exceeds 5 % on one or more of the three instrumented planes for any of the four specimen positions, adjustments should be made in the test frame actuator or fixtures and/or force transducer, followed by repeating the procedure until the less than 5 % limit on percent bending is achieved.

The procedure should be repeated in **compression** to ascertain that the alignment is within that specified (i.e. $\leqslant$ 5 %).

If the check is not satisfactory:

— The reproducibility of the measurements shall be verified by carrying out the process several times.

— It shall be established that the results are attributable to the test assembly and not to the specimen.

— The elements making up the gripping train (instruments, cell, machine) shall be checked for their geometric accuracy.

5 Shape and size of specimen

5.1 Form of specimens

Generally, a specimen having a fully machined test section of one of the types shown in Figures 3 and 4 shall be used.

The specimens may be of the following:

— circular cross-section, with tangentially blending fillets between the test section and the ends [Figure 3 a)], or with a continuous radius between the ends [Figure 3 b)];

— rectangular cross-section of uniform thickness over the test section with tangentially blending fillets between the test section and the gripped ends [Figure 4 a)], or with a continuous radius between the ends [Figure 4 b)].

It is important to mention that, for specimens of rectangular cross-section, it may be necessary to reduce the test section in both width and thickness. If this is necessary, then blending fillets will be required in both the width and thickness directions. Also, for a rectangular-section specimen, where it is desired to take account of the surface condition in which the metal will be used in actual application, then at least one surface of the test section of the test piece should remain unmachined. It is often the case, for fatigue tests conducted using a rectangular-section piece, that the results are not always comparable to those determined on cylindrical specimens, because of the difficulty in obtaining an adequate surface finish or because fatigue cracks initiate preferentially at the corner(s) of the rectangular test piece.

For either form of specimen where the test section is formed by a continuous radius, this radius shall be at least $3d$ (or $3b$) and the elastic stress concentration factor shall be included in the test report.

5.2 Specimen temperature measurement

The test is typically conducted at ambient temperature (ideally between 10 °C and 35 C). In a high or low temperature test, the specimen temperature may be measured using thermocouples in contact with the specimen surface, or other appropriate devices accurate to within ± 2 °C. The specimen temperature, T, must be documented if it is considered "high" (H), that is, greater than or equal to 0,3 × homologous temperature of the metal [i.e. $\geqslant 0{,}3T_{\mathrm{H}} = T_{\mathrm{test}}\,(K) / T_{\mathrm{melt}}\,(K)$].

6 Specimens

6.1 Geometry

6.1.1 Products (bars, flat sheets over 5 mm thick)

The gauge portion of the specimen represents a volume element of the material under study, which implies that the geometry of the specimen shall not affect the use of the results.

The geometric dimensions in Table 1 (see Figure 3) are recommended.

Table 1

Parameter	Dimension
Diameter of cylindrical gauge length	$d \geqslant 3$ mm
Transition radius (from parallel section to grip end)	$r \geqslant 2d$
External diameter (grip end)	$D \geqslant 2d$
Length of reduced section	$L_C \leqslant 8d$

Other geometric cross-sections and gauge lengths may be used. It is important that general tolerances of the specimens respect the three following properties:

— Parallelism // $\leqslant 0{,}005d$

— Concentricity ⊚ $\leqslant 0{,}005d$

— Perpendicularity ⊥ $\leqslant 0{,}005d$

(These values are expressed in relation to the axis or reference plane.)

6.1.2 Flat products with thickness of 5 mm or less

In general, the considerations discussed in the 6.1.1 also apply to tests on the above products.

Because low loads are generally applied, more sensitive force transducers than usual may be required.

In general, the width of the specimen is reduced in the gauge length to avoid failures in the grips. In some applications, it might be necessary to add end-tabs to increase the grip and thickness, as well as to avoid failure in the grips (Figure 10).

The correct alignment of the specimen shall be carefully checked with a trial specimen for

— parallelism and alignment of grips, and

— alignment of the specimen with the loading axis.

This verification shall be carried out using a specimen with geometry as similar as possible to that of the test specimen, instrumented with strain gauges on the two faces. In some instances, the use of anti-buckling restraints may be required on the faces of the specimen. An example of an anti-buckling restraint is shown in Figure 11. However, the use of anti-buckling restraints is generally discouraged.

6.2 Preparation of specimens

In any fatigue-test program designed to characterize the intrinsic properties of a material, it is important to observe the following recommendations in the preparation of specimens. A deviation from these recommendations is possible if the test program aims to determine the influence of a specific factor (surface treatment, oxidation, etc.) that is incompatible with these recommendations. In all cases, these deviations shall be noted in the test report.

6.2.1 Machining procedure

6.2.1.1 General

The machining procedure selected may produce residual stresses on the specimen surface that are likely to affect the test results. These stresses may be induced by heat gradients at the machining stage, stresses associated with deformation of the material or microstructural alterations. Their influence is less when tested at elevated temperatures because they are partially or totally relaxed at high temperatures. However, they are to be reduced by using an appropriate final machining procedure, especially prior to a final polishing stage.

For harder materials, grinding rather than tool operation (turning or milling) may be preferred. This is followed by polishing.

— Grinding: from 0,1 mm of the final diameter at a rate of no more than 0,005 mm/pass.

— Polishing: remove the final 0,025 mm with papers of decreasing grit size. It is recommended that the final direction of the polishing be along the specimen axis.

6.2.1.2 Alteration in the microstructure of the material

This phenomenon may be caused by the increase in temperature and by the strain-hardening induced by machining. It may be a matter of a change in phase or, more frequently, of surface recrystallization. The immediate effect of this is to make the test invalid, as the material tested is no longer the initial material. Every precaution should therefore be taken to avoid this risk.

6.2.1.3 Introduction of contaminants

The mechanical properties of certain materials deteriorate when in the presence of certain elements or compounds. An example of this is the effect of chlorine on steels and titanium alloys. These elements shall therefore be avoided in the products used (cutting fluids, etc.). Rinsing and degreasing of specimens prior to storage is also recommended.

6.2.2 Sampling and marking

The sampling of test materials from a semi-finished product or a component may have a major influence on the results obtained during the test. It is therefore necessary for this sampling to be carried out with full knowledge of the situation. A sampling drawing, attached to the test report, should indicate clearly:

— the position of each of the specimens,

— the characteristic directions in which the semi-finished product has been worked (direction of rolling, extrusion, etc., as appropriate), and

— the marking/identifying of each of the specimens.

The specimens shall carry a mark/identification during each different stage of their preparation. Such a mark/identification may be applied using any reliable method in an area not likely to disappear during machining or likely to adversely affect the quality of the test.

6.2.3 Surface condition of the specimen

The surface conditions of the specimens have an effect on the test results. This effect is generally associated with one or more of the following factors:

— the specimen surface roughness;

— the presence of residual stresses;

— alteration in the microstructure of the material;

— introduction of contaminants.

The recommendations below allow the influence of these factors to be reduced to a minimum.

The surface condition is commonly quantified by the mean roughness or equivalent (e.g. ten-point roughness or maximum height of irregularities). The influence of this variable on the results obtained depends largely on the test conditions, and its influence is reduced by surface corrosion of the specimen or plastic deformation. It is preferable, whatever the test conditions, to specify a mean surface roughness of less than 0,2 µm R_a (or equivalent). See ISO 4287 and ISO 4288.

Another important parameter not covered by mean roughness is the presence of localized machining scratches. Finishing operations on round specimens should eliminate all circumferential scratches produced during turning. Final grinding followed by longitudinal mechanical polishing is particularly recommended. A low magnification check (approximately ×20) shall not show any circumferential scratches within the gauge length.

If heat treatment is to be carried out after rough finishing of the specimen, it is preferable to carry out the final polishing after the heat treatment. If this is not possible, the heat treatment should be carried out in a vacuum or in inert gas to prevent oxidation of the specimen. This treatment shall not alter the microstructural characteristics of the material under study. The specifics of the heat treatment and machining procedure shall be reported with the test results.

6.2.4 Dimensional checks

The dimensions should be measured on completion of the final machining stage using a method of metrology that does not alter the surface condition.

6.2.5 Storage and handling

After preparation, the specimens should be stored so as to prevent any risk of damage (scratching by contact, oxidation, etc.). The use of individual boxes or tubes with end caps is recommended. In certain cases, storage in a vacuum or in a desiccator filled with silica gel is necessary.

Handling should be reduced to the minimum necessary. Particular attention shall be given to marking the specimens. Identification shall be applied to each end of the specimen before testing.

7 Apparatus

7.1 Testing machine

The tests shall be carried out on a tension-compression machine, designed for a smooth start-up with no backlash when passing through zero. The machine shall have lateral rigidity and accurate alignment.

The complete machine-loading system (including force transducer, grips, and specimen) shall have lateral rigidity and be capable of controlling and measuring force when applying the recommended wave cycle.

7.1.1 Force transducer

The force transducer shall have axial and lateral rigidity. Its capacity shall be suitable for the forces applied during the test. It shall be fatigue rated and suitable for the forces applied during the test. The indicated force as recorded at the output from the computer in an automated system, or from the final output recording device in any non-automated system, shall be within the specified permissible variation from the actual force. The load cell capacity shall be sufficient to cover the range of loads measured during a test to an accuracy of better than 1 % of the reading. The load cell shall be temperature compensated and not have zero drift or sensitivity variation greater than 0,002 % of full scale per 1 °C.

7.1.2 Gripping of specimen

The gripping device shall transmit the cyclic forces to the specimen without backlash along its longitudinal axis. The distance between the grips shall be as small as possible to avoid the tendency of the specimen to buckle. The geometric qualities of the device shall ensure correct alignment in order to meet the requirements specified in 7.1.3; it is therefore necessary to limit the number of components of which these gripping devices are composed, and to reduce the number of mechanical interfaces to a minimum.

The gripping device shall ensure that the assembly of the specimen is reproducible. It shall have surfaces ensuring the alignment of the specimen and surfaces, allowing transmission of tensile and compressive forces without backlash throughout the duration of the test.

7.1.3 Alignment check

Bending due to misalignment in rigid-grip systems is generally caused by

a) an angular offset of the test piece grips,

b) a lateral offset of the loading bars (or test piece grips) in an ideally rigid system,

c) an offset in the force-train assembly with respect to a non-rigid system, or

d) in the case of servo-hydraulic machines, an actuator rod with side-play in the bearings.

The alignment shall be checked before each series of tests or any time a change is made to the force train. The percent bending due to machine misalignment shall be ⩽ 5 % of the axial strain or ± 50 microstrain, whichever is greater. Figure 9 represents a recommended example of a strain-gauged alignment specimen. There are other techniques for measuring alignment that are adequate for this purpose.

7.2 Instrumentation for test monitoring

7.2.1 Recording systems

The following systems shall be considered as a minimum requirement for recording of data:

A device for measuring peak force against time. For example, an oscilloscope or digital storage device capable of reproducing the recorded signal either in photographic or analog form. These devices are necessary when the rate of recorded signals is too high with respect to the maximum rate of the recorder. They, therefore, allow permanent records to be reproduced subsequently at a lower rate. The systems described above may be replaced with a computerized system capable of carrying out the task of collecting and processing data digitally.

7.2.2 Cycle counter

A cycle counter is essential for recording the number of cycles.

7.3 Checking and verification

The testing machine and its control and measurement systems should be checked regularly.

Specifically, each transducer and associated electronics shall always be checked as a unit.

— The force shall be calibrated in accordance with ISO 7500-1 and, according to this standard, shall be traceable to a national standard.

— The temperature measuring system(s) shall be verified according to the relevant ISO or national standard.

8 Testing machine

The testing machine force-measuring system shall be verified statically in accordance with ISO 7500-1:2004, Class 1. It shall be ensured that incremental dynamic force-measurement errors do not exceed ± 1 % of the demanded force range.

NOTE 1 It is very important to recognize the importance of dynamic (inertia force) errors introduced by the mass between the load cell and the test specimen. Inertia force error = the grip mass multiplied by its local acceleration. Inertia force errors, expressed as a percentage of force range, can be expected to vary with the square of the frequency and are strongly influenced by specimen compliance. The testing machine (rigid body) resonance on its mountings can be a dominant error source.

The testing machine with the specific load cell, grips and couplings used for dynamic testing and a strain-gauged specimen or dynamometer, of similar compliance to the test specimens, should be verified for dynamic force measurement over the frequency range of interest.

NOTE 2 To avoid dynamic errors > ± 1 % of force range, it may be necessary to create an error table to correct the dynamic force range of the testing machine.

The machine shall be equipped with a cycle-counting system accurate to 1 % and with error trips to shut down the machine when the specimen fails.

When reversed force is involved in the test series, the load-train shall be free from backlash.

NOTE 3 ISO 4965, which covers dynamic verification, addresses these issues in more detail.

9 Mounting of specimen

Care should be taken to ensure that each test piece is located in the top and bottom grips so that the force is applied axially, and that the intended stress pattern is imposed. With rectangular test pieces, it may be important to ensure that the force is evenly distributed over the test piece cross-section. Although not recommended, where test pieces of circular cross-section are screwed at the ends, the grip design shall ensure that no (or minimal) torsional stress is imparted to the test piece due to tightening of the locking nuts. In instances where threaded-end specimens are used, some forced mating of flats and of a concentric surface may be employed along the threads to minimize tightening torques.

10 Speed of testing

The frequency of the force cycle will depend upon the type of testing machine employed and, in many cases, upon the stiffness of the test piece.

The frequency chosen shall be that which is most suitable for the particular combination of material, test piece and testing machine. If the frequencies are determined from the dynamic characteristics of the test piece and testing machine combination, it may be necessary to measure the stiffness of the test piece before testing is started.

NOTE 1 The frequency range of axial force controlled fatigue-testing machines in common use is approximately 5 to 300 Hz.

At high frequencies, substantial heating of the specimen can occur, that could affect the test result of fatigue life and strength. If heating occurs, it is advisable to decrease the test frequency. If the specimen temperature exceeds 35 °C, the temperature shall be recorded.

NOTE 2 If the influence of the environment is significant, the test result is likely to be frequency dependent.

11 Application of force

The general procedure for attaining full-force running conditions shall be the same for each test piece. The mean force and force range shall be maintained to within ± 1 % of the force range, over and above the static errors specified in ISO 7500-1. See Clause 8.

12 Recording of temperature and humidity

The maximum and minimum air temperature and humidity shall be recorded daily for the duration of the test.

13 Criterion of failure and test termination

13.1 Criterion of failure

Unless agreed otherwise, the criterion of failure shall be test piece separation.

NOTE In particular applications, other criteria, for example, occurrence of a visible fatigue crack, plastic deformation of the test piece or rate of crack propagation, may be adopted.

13.2 Test termination

The test is terminated when either the specimen fails or a predetermined number of cycles has been applied, as agreed upon by the concerned parties.

14 Test report

The test report shall include the following information for the test series, if available:

a) a reference to this International Standard;

b) material tested, its metallurgical characteristics, mechanical properties, and any heat treatment given to the test piece(s);

c) location of the test piece(s) in the parent material;

d) form and nominal dimensions of the test piece(s);

e) surface condition of the test piece(s).

The test report shall include the following information for each individual test piece:

1) cross-sectional dimensions;

2) minimum and maximum peak force applied;

3) applied stress conditions;

4) frequency and fatigue life;

5) description of testing machine used: type, serial number, load cell and serial number, number and load train description;

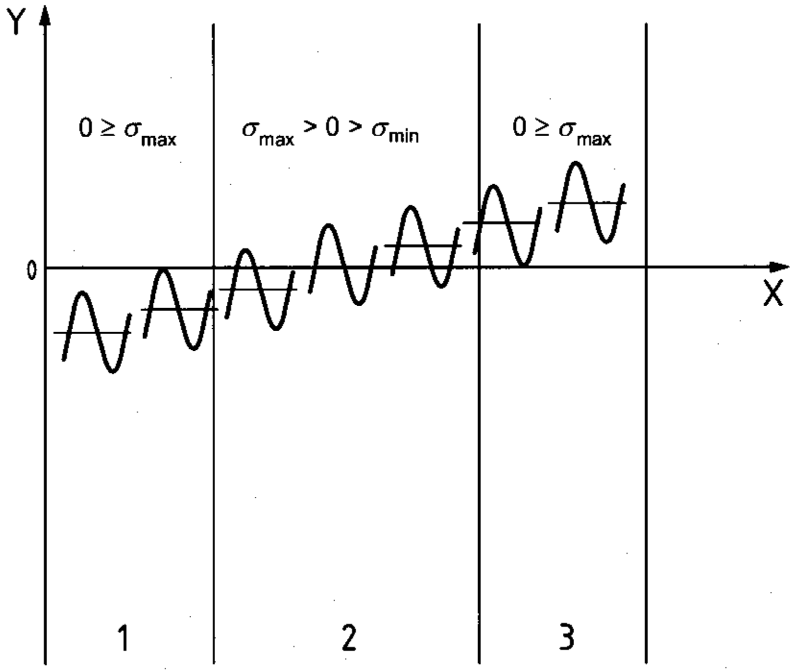
6) temperature of the test piece if heating occurs (i.e., greater than 35°C);

7) maximum and minimum air temperature and relative humidity;

8) criterion of the end of the test; i.e., its duration (for example, 10^7 cycles), or complete failure of the test piece, or any other criterion;

9) any special observations or deviations from the required test conditions.

Additionally, the test results can be presented graphically.



Key

X Time

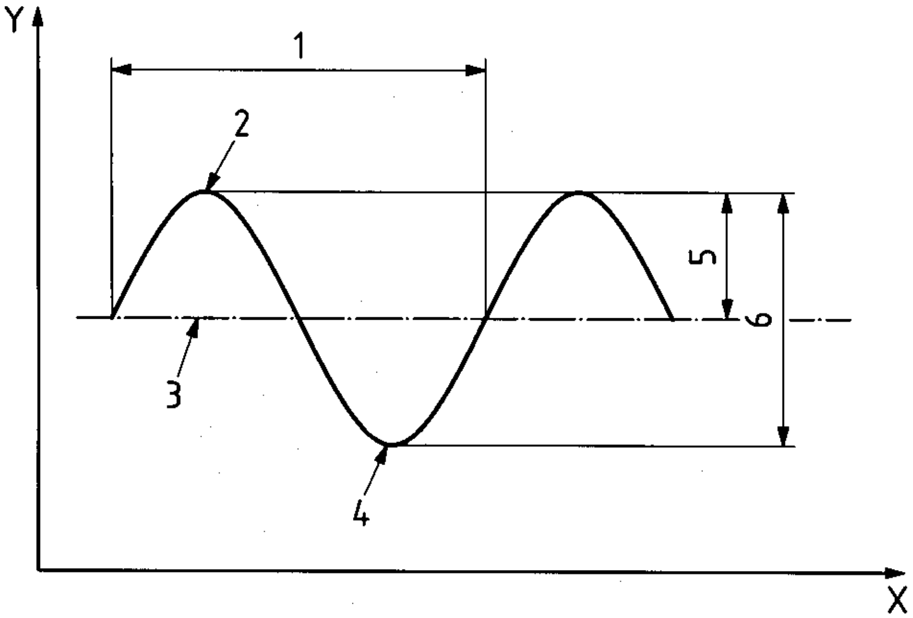
Y Stress

1 fluctuating compression

2 reversed

3 fluctuating tension

Figure 1 — Types of cyclic stress



Key

X Time

Y Stress

1 one stress cycle

2 maximum stress, σ_{max}

3 mean stress, σ_m

4 minimum stress, σ_{min}

5 range of stress, σ_a

6 stress amplitude, $\Delta\sigma_a$

Figure 2 — Fatigue stress cycle

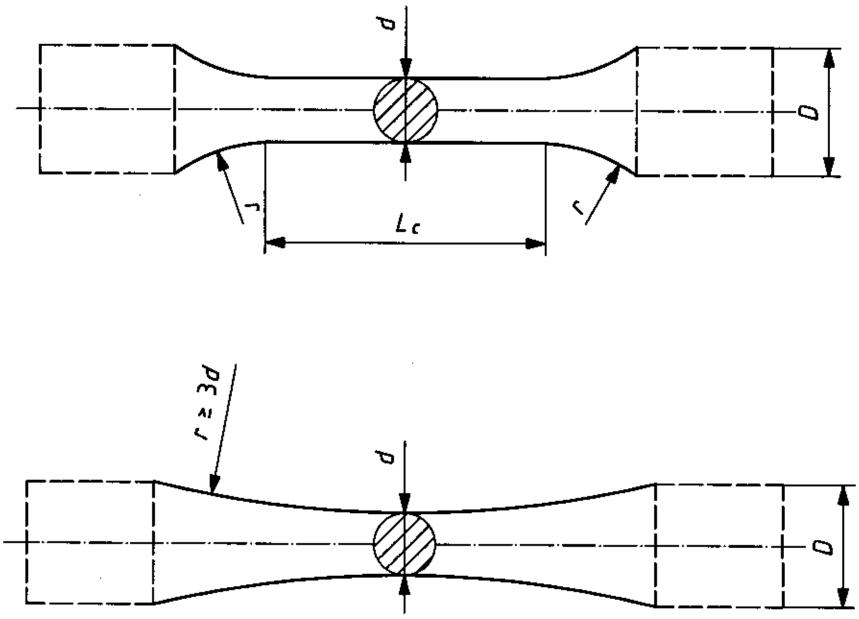


Figure 3 — Specimens of circular cross-section

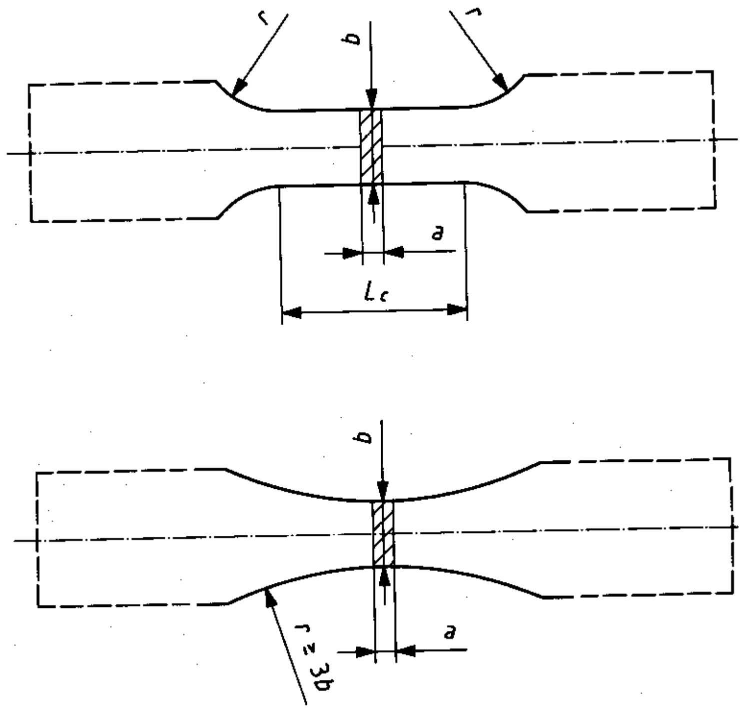
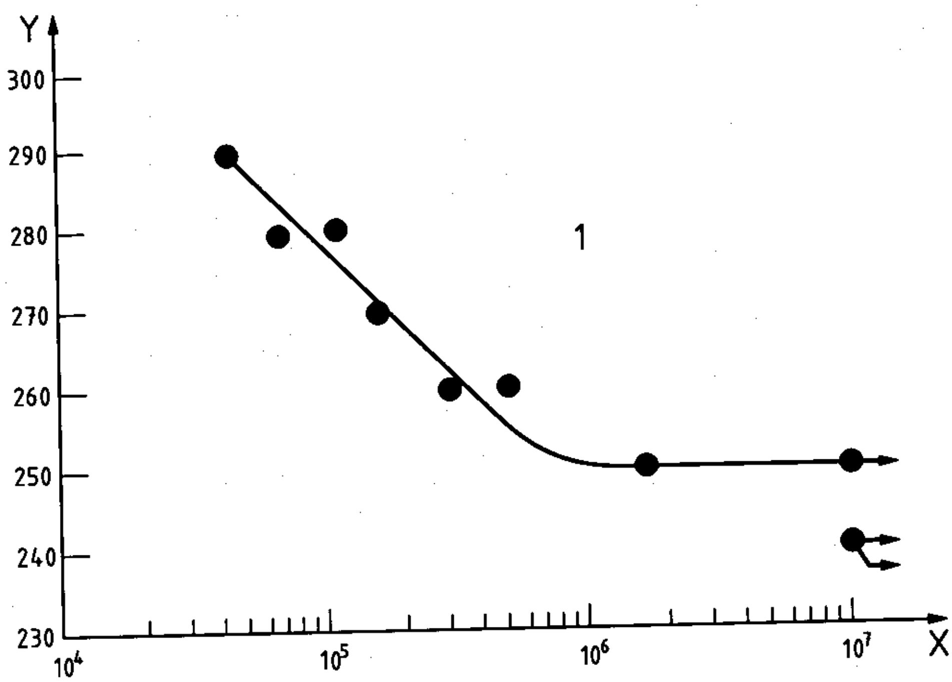


Figure 4 — Specimens of rectangular cross-section



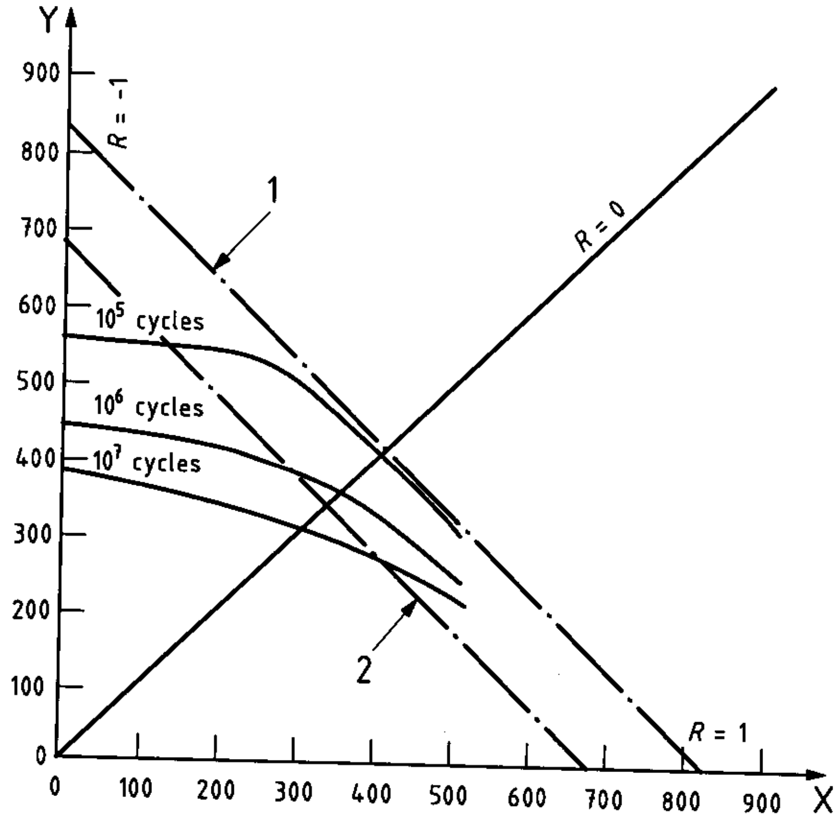
Key

X Number of cycles to failure, N

Y Stress amplitude, σ_a, N/mm²

1 $R = -1$
ambient temperature

Figure 5 — Wõher or S-N curve



Key

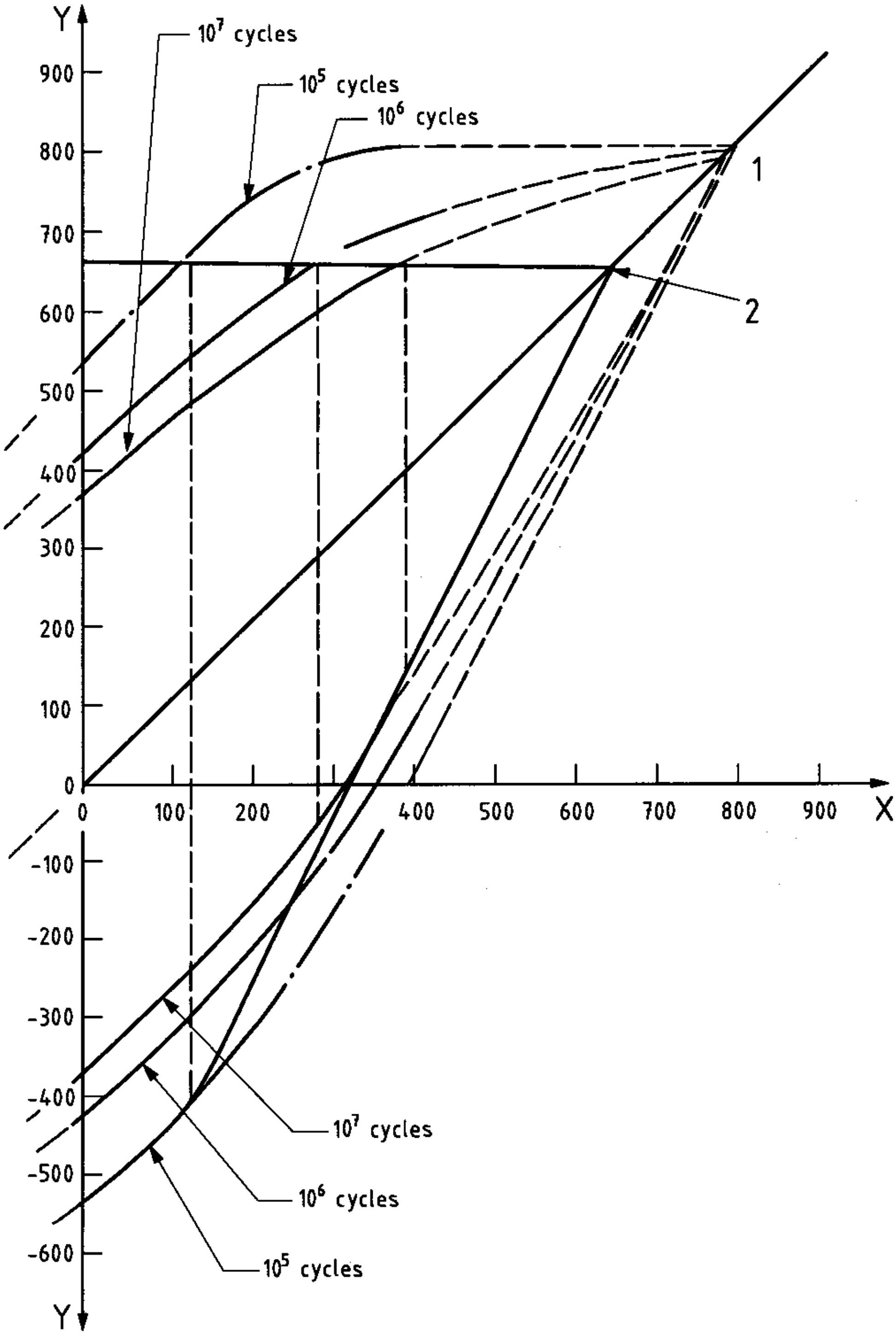
X Mean stress, σ_m, N/mm²

Y Stress amplitude, σ_a, N/mm²

1 tensile strength

2 0,2 % proof stress

Figure 6 — Stress amplitude (σ_a) against mean stress (σ_m), [Haigh diagram]



Key

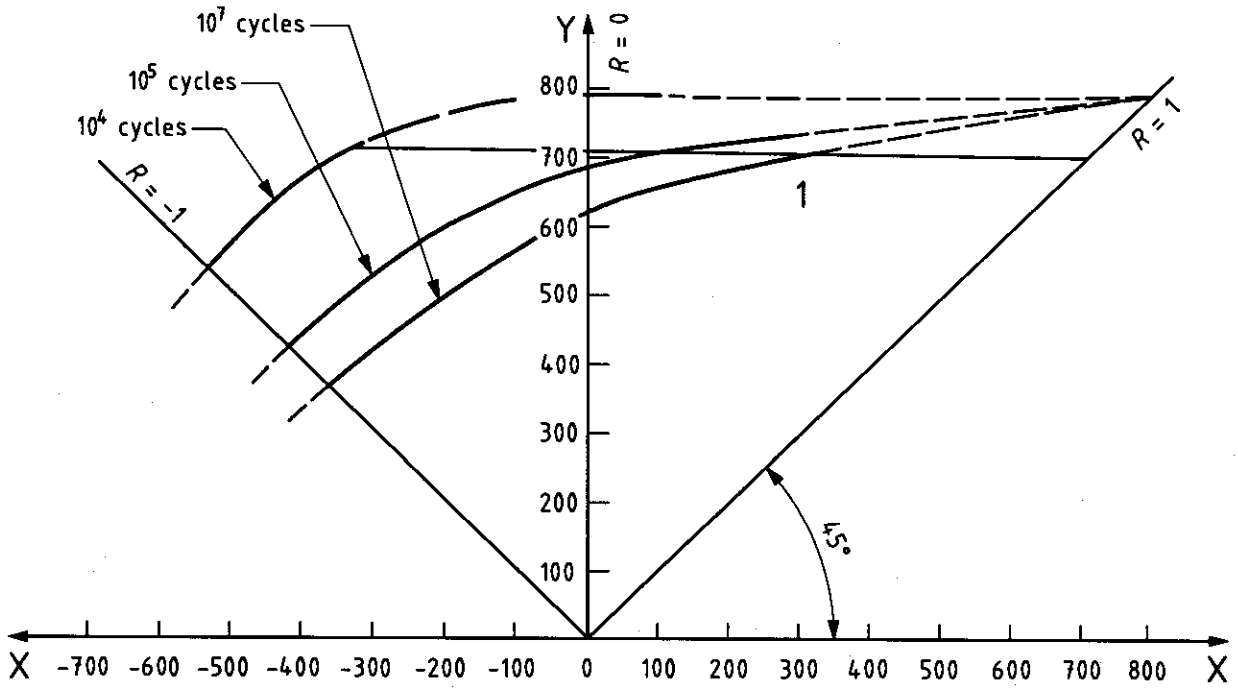
X Mean stress, σ_m, N/mm²

Y Maximum and minimum stress, σ_{max} and σ_{min}, N/mm²

1 tensile strength

2 0,2 % proof stress

Figure 7 — Maximum and minimum stresses (σ_{max} and σ_{min}) against mean stress (σ_m) [Smith diagram]



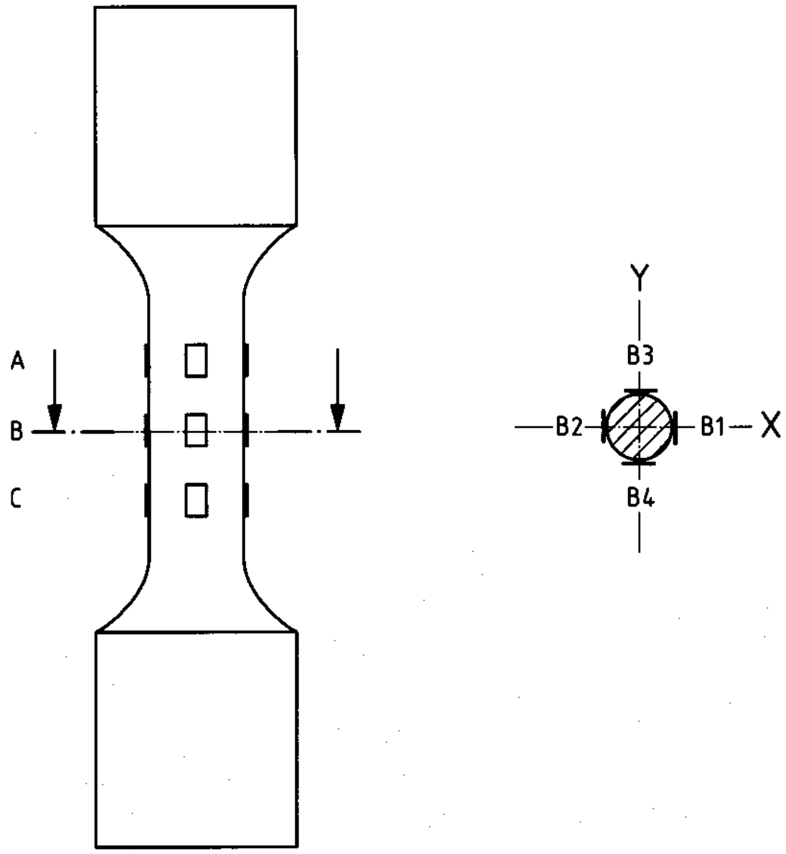
Key

X Minimum stress, σ_{min}, N/mm^2

Y Maximum stress, σ_{max}, N/mm^2

1 0,2 % proof stress

Figure 8 — Maximum stress (σ_{max}) against minimum stress (σ_{min}) [Ros diagram]



Bending X-X: $\frac{\varepsilon_{A2} - \varepsilon_{A1}}{\varepsilon_{A2} + \varepsilon_{A1}} \times 100 = \%\, A_{X-X}$

Bending Y-Y $\frac{\varepsilon_{A3} - \varepsilon_{A4}}{\varepsilon_{A3} + \varepsilon_{A4}} \times 100 = \%\, A_{Y-Y}$

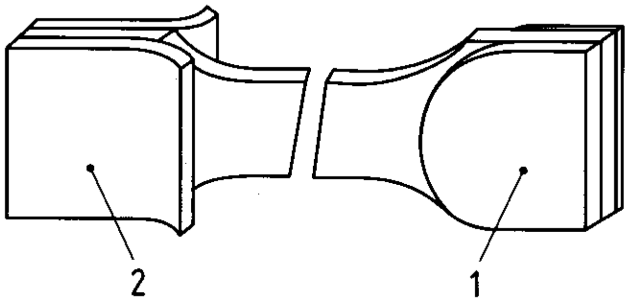
Bending on plane A $\sqrt{(\%A_{X-X})^2 + (\%A_{Y-Y})^2} < 5\,\%$

Must be repeated for four (4) positions on gauge 1; 0, 90, 180, 270 degrees
Must be repeated for plane C with plane B optional.
No plane is allowed to have bending greater than 5 %

Key

ε strain: the unit change, caused by force, in the size or shape of a body. Each of the subscripts refers to the position of the strain gage on the specimen shown.

Figure 9 — Alignment scheme

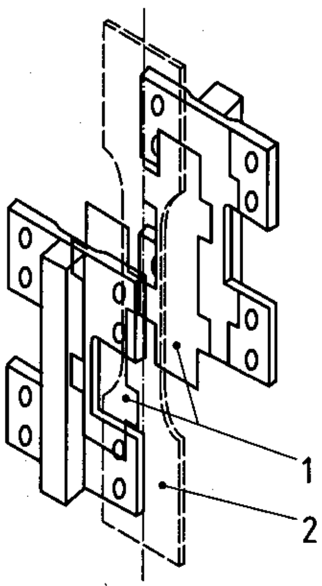


Key

1 rounded end tabs

2 bent end tabs to prevent grip indentation in gripping area. May be held in place by epoxy

Figure 10 — Schematic gripping for flat-sheet specimens



Key

1 polytetrafluoroethylene

2 specimen

Figure 11 — Anti-buckling restraints for flat-sheet specimens

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