AS 1391—2005

AS 1391—2005

Australian Standard™

Metallic materials—Tensile testing at ambient temperature

STANDARDS AUSTRALIA

This Australian Standard was prepared by Committee MT-006, Mechanical Testing of Metals. It was approved on behalf of the Council of Standards Australia on 30 May 2005. This Standard was published on 21 June 2005.

The following are represented on Committee MT-006:

Australian Railway Association
Bureau of Steel Manufacturers of Australia
CSIRO National Measurement Laboratory
CSIRO Telecommunications and Industrial Physics
Institute of Materials Engineering Australia
National Association of Testing Authorities Australia

Keeping Standards up-to-date

Standards are living documents which reflect progress in science, technology and systems. To maintain their currency, all Standards are periodically reviewed, and new editions are published. Between editions, amendments may be issued. Standards may also be withdrawn. It is important that readers assure themselves they are using a current Standard, which should include any amendments which may have been published since the Standard was purchased.

Detailed information about Standards can be found by visiting the Standards Web Shop at www.standards.com.au and looking up the relevant Standard in the on-line catalogue.

Alternatively, the printed Catalogue provides information current at 1 January each year, and the monthly magazine, *The Global Standard*, has a full listing of revisions and amendments published each month.

Australian Standards™ and other products and services developed by Standards Australia are published and distributed under contract by SAI Global, which operates the Standards Web Shop.

We also welcome suggestions for improvement in our Standards, and especially encourage readers to notify us immediately of any apparent inaccuracies or ambiguities. Contact us via email at mail@standards.org.au, or write to the Chief Executive, Standards Australia, GPO Box 5420, Sydney, NSW 2001.

This Standard was issued in draft form for comment as DR 05050.

AS 1391—2005

Australian Standard™

Metallic materials—Tensile testing at ambient temperature

Originated as AS A23—1928.
Previous edition AS 1391—1991.
Third edition 2005.

Published by Standards Australia, GPO Box 5420, Sydney, NSW 2001, Australia

ISBN 0 7337 6780 X

PREFACE

This Standard was prepared by Standards Australia Committee MT-006, Mechanical Testing of Metals to supersede AS 1391—1991, *Methods for tensile testing of metals*. The Committee decided to change the title of the Standard to indicate the testing temperature at the time of test. The title was changed to *Metallic materials—Tensile testing at ambient temperature*.

The objective of this edition is to align more closely with ISO 6892:1998, *Metallic materials—Tensile testing at ambient temperature*.

During the preparation of this Standard, cognisance was taken of the following Standards:

AS

1545 Methods for the calibration and grading of extensometers

ISO

377 Steel and steel products—Location and preparation of samples and test pieces for mechanical testing

3785 Steel—Designation of test piece axes

6892 Metallic materials—Tensile testing at ambient temperature

9513 Metallic materials—Calibration of extensometers used in uniaxial testing

This Standard is one of a series of Standards covering the range of tensile testing methods. The series comprises the following:

AS

1391 Metallic materials—Tensile testing at ambient temperature (this Standard)

1545 Methods for the calibration and grading of extensometers

1855 Methods for the determination of transverse tensile properties of round steel pipes

2291 Methods for tensile testing of metals at elevated temperatures

2403 Method for the measurement of the plastic strain 'r' of sheet and strip metals

2346 Methods for the determination of uniform elongation in sheet and strip metals

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

CONTENTS

Page

1 SCOPE 5
2 REFERENCED DOCUMENTS 5
3 DEFINITIONS 5
4 TEST CONDITIONS 8
5 SYMBOLS AND DESIGNATIONS 8
6 TEST PIECE 10
7 MARKING THE ORIGINAL GAUGE LENGTH (L_o) 11
8 ACCURACY OF TESTING APPARATUS 12
9 TESTING RATE 12
10 DETERMINATION OF THE PERCENTAGE PLASTIC EXTENSION AT MAXIMUM FORCE (A_g) 13
11 DETERMINATION OF PERCENTAGE ELONGATION AFTER FRACTURE (A) 13
12 DETERMINATION OF PERCENTAGE TOTAL ELONGATION AT MAXIMUM FORCE (A_{gt}) 15
13 DETERMINATION OF THE PERCENTAGE YIELD POINT EXTENSION (A_e) 15
14 DETERMINATION OF PROOF STRENGTH, PLASTIC EXTENSION (R_p) 15
15 DETERMINATION OF PROOF STRENGTH, TOTAL EXTENSION (R_t) 16
16 METHOD OF VERIFICATION OF PERMANENT SET STRENGTH ($\boldsymbol{R}_r$) 16
17 DETERMINATION OF PERCENTAGE REDUCTION OF AREA (Z) 16
18 ACCURACY OF THE RESULTS 16
19 RECORD OF RESULTS 17
20 TEST REPORT 17
21 FORCE-EXTENSION DIAGRAMS 18
22 TEST PIECE FORMS 24

APPENDICES
A TYPES OF TEST PIECE TO BE USED FOR THIN PRODUCTS: SHEETS, STRIPS AND FLATS BETWEEN 0.1 mm AND 3 mm THICK 27
B TYPES OF TEST PIECE TO BE USED FOR WIRE, BARS AND SECTIONS WITH A DIAMETER OR THICKNESS OF LESS THAN 4 mm 30
C TYPES OF TEST PIECE TO BE USED FOR SHEETS AND FLATS OF THICKNESS EQUAL TO OR GREATER THAN 3 mm AND WIRE, BARS AND SECTIONS OF DIAMETER OR THICKNESS EQUAL TO OR GREATER THAN 4 mm 31
D TYPES OF TEST PIECE TO BE USED FOR TUBES 34
E PRECAUTIONS TO BE TAKEN WHEN MEASURING THE PERCENTAGE ELONGATION AFTER FRACTURE IF THE SPECIFIED VALUE IS LESS THAN 5% 36
F MEASUREMENT OF PERCENTAGE ELONGATION AFTER FRACTURE BASED ON SUBDIVISION OF THE ORIGINAL GAUGE LENGTH 37

Page

G DETERMINATION OF THE PERCENTAGE PLASTIC ELONGATION WITHOUT NECKING (A_{wn}) FOR LONG PRODUCTS SUCH AS BARS, WIRE AND RODS 39
H AN 'ERROR BUDGET' APPROACH TO THE ESTIMATION OF THE UNCERTAINTY OF MEASUREMENT IN TENSILE TESTING 40
I DESIGNATION OF TEST PIECE AXES 45
J LOCATION AND PREPARATION OF SAMPLES AND TEST PIECES 49

STANDARDS AUSTRALIA

Australian Standard

Metallic materials—Tensile testing at ambient temperature

1 SCOPE

This Standard specifies methods by which a test piece of metal is strained in uni-axial tension at room temperature in order to determine one or more of its tensile properties. It defines the properties to be determined and the terms used in describing tests and test pieces. The Standard also specifies the dimensions of standard test pieces and methods for tensile testing a wide range of product forms.

Where material Standards (product Standards) specify the dimensions of the test piece, those dimensions take precedence over the dimensions which are specified in Appendices A and C.

2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS	
1545	Methods for the calibration and grading of extensometers
1654	ISO system of limits and fits
1654.2	Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts
2193	Calibration and classification of force-measuring systems
ISO	
2566	Steel—Conversion of elongation values
2566-1	Part 1: Carbon and low alloy steels
2566-2	Part 2: Austenitic steels
5725	Accuracy (trueness and precision) of measurement methods and results
5725-2	Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method

3 DEFINITIONS

For the purpose of this Standard, the following definitions apply.

3.1 Elongation

Increase in the original gauge length (L_o) at any moment during the test (see Figure 1).

3.2 Engineering stress

At any moment during the test, force divided by the original cross-sectional area (S_o) of the test piece.

3.3 Extensometer gauge length (L_e)

Length of the parallel portion of the test piece used for the measurement of extension by means of an extensometer.

NOTE: It is recommended that for measurement of yield and proof strength parameters L_e should span as much of the parallel length of the test piece as possible. Ideally, as a minimum, L_e should be greater than 0.50 L_o but less than 0.9 L_c. This should ensure that the extensometer detects all yielding events that occur in the test piece. It is further recommended that for measurement of parameters 'at' or 'after' maximum force, L_e is approximately equal to L_o.

3.4 Final gauge length (L_u)

Gauge length after rupture of the test piece.

3.5 Fracture

Phenomena that are deemed to occur when total separation of the test piece occurs or force decreases to become nominally zero.

3.6 Gauge length (L)

Length of the cylindrical or prismatic portion of the test piece on which elongation is measured.

3.7 Lower yield strength (R_{eL})

Lowest value of stress during plastic yielding, ignoring any initial transient effects (see Figure 2).

3.8 Maximum force (F_m)

The greatest force which the test piece withstands during the test once the yield point has been passed.

3.9 Original gauge length (L_o)

Gauge length before application of force.

3.10 Parallel length (L_c)

Parallel portion of the reduced section of test piece.

NOTE: The concept of parallel length is replaced by the concept of distance between grips for non-machined test pieces.

3.11 Percentage elongation

Elongation expressed as a percentage of the original gauge length (L_o).

3.12 Percentage elongation after fracture (A)

Permanent elongation of the gauge length after fracture ($L_u - L_o$), expressed as a percentage of the original gauge length (L_o).

NOTE: In case of proportional test pieces, only if the original gauge length is other than $5.65\sqrt{S_o}$ * where S_o is the original cross-sectional area of the parallel length, the symbol A should be supplemented by an index indicating the coefficient of proportionally used, for example:

$A_{11.3}$ = percentage elongation of a gauge length (L_o) of $11.3\sqrt{S_o}$.

In the case of non-proportional test pieces, the symbol A should be supplemented by an index indicating the original gauge length used, expressed in millimetres, for example:

$A_{80\ \text{mm}}$ = percentage elongation of a gauge length (L_o) of 80 mm.

3.13 Percentage permanent elongation

Increase in the original gauge length of a test piece after removal of a specified stress, expressed as a percentage of the original gauge length (L_o).

---

* $5.65\sqrt{S_o} = 5\sqrt{\frac{4S_o}{\pi}}$

3.14 Percentage plastic elongation at maximum force (A_g)

Permanent increase in the gauge length of the test piece at maximum force expressed as a percentage of the original length.

3.15 Percentage total elongation at fracture (A_t)

Total elongation (elastic elongation plus plastic elongation) of the gauge length at the moment of fracture expressed as a percentage of the original gauge length (L_o).

3.16 Percentage permanent extension

Increase in the extensometer gauge length, after removal of a specified stress from the test piece, expressed as a percentage of the extensometer gauge length (L_e).

3.17 Percentage plastic elongation without necking (A_{wn})

The plastic elongation measured at a minimum distance from the fracture expressed as a percentage of the gauge length specified in the product Standard.

3.18 Percentage reduction of area (Z)

Maximum change in cross-sectional area ($S_o - S_u$), which has occurred during the test expressed as a percentage of the original cross-sectional area (S_o).

3.19 Percentage total extension at maximum force (A_{gt})

Total extension (elastic plus plastic) at maximum force, expressed as a percentage of the extensometer gauge length (L_e).

3.20 Percentage yield point extension (A_e)

In discontinuous yielding materials, the extension between the start of discontinuous yielding and the start of uniform work hardening. It is expressed as a percentage of the extensometer gauge length (L_e).

3.21 Permanent set strength (R_r)

Stress at which, after removal of force, a specified permanent elongation or extension expressed respectively as a percentage of the original gauge length (L_o) or extensometer gauge length (L_e) has not been exceeded (see Figure 5).

The symbol used is followed by a suffix giving the specified percentage of the original gauge length (L_o) or of the extensometer gauge length (L_e), for example $R_{r0.2}$.

3.22 Proof strength, plastic extension (R_p)

Stress at which a plastic extension is equal to a specified percentage of the extensometer gauge length (L_e) (see Figure 3). The symbol used is followed by a suffix giving the prescribed percentage, for example $R_{p0.2}$.

3.23 Proof strength, total extension (R_t)

Stress at which total extension (elastic extension plus plastic extension) is equal to a specified percentage of the extensometer gauge length (L_e), (see Figure 4). The symbol used is followed by a suffix giving the prescribed percentage for example $R_{t0.5}$.

3.24 Reference condition

Condition of a sample specimen or test piece having undergone a heat treatment to represent the intended final condition of the product.

NOTE: In such cases the sample, specimen or test piece is called the reference sample, reference rough specimen or reference test piece.

3.25 Tensile strength (R_m)

Stress corresponding to the maximum force (F_m), excluding the upper yield force.

3.26 Test pieces

3.26.1 *Test piece*

A prepared piece for testing made from or comprising a test specimen.

3.26.2 *Longitudinal test piece*

A test piece in which the longitudinal axis is parallel to the principal direction of the final processing.

3.26.3 *Transverse test piece*

A test piece in which the longitudinal axis is at right angles to the principal direction of final processing.

3.27 Test sample

A portion of material, a product, or a group of items selected by a sampling procedure from a batch.

3.28 Test specimen

A portion of a single item taken from the test sample for the purpose of testing.

3.29 True stress

Force at any moment during the test divided by the instantaneous cross sectional area of the test piece.

3.30 Upper yield strength (R_{eH})

Value of stress at the moment when the first decrease in force is observed (see Figure 2).

3.31 Yield strength

When the metallic material exhibits a yield phenomenon, a point is reached during the test at which plastic deformation occurs without any increase in the force.

4 TEST CONDITIONS

The test shall be carried out at ambient temperature between 10°C and 35°C, unless otherwise specified. Tests carried out under controlled conditions shall be made at a temperature of 23°C ±5°C.

5 SYMBOLS AND DESIGNATIONS

Symbols and corresponding designations are given in Table 1.

TABLE 1
SYMBOLS AND DESIGNATIONS*

Symbol	Unit	Designation
a†	mm	Thickness of a flat test piece or wall thickness of a tube
b	mm	Width of the parallel length of a flat test piece or average width of a longitudinal strip from a tube or width of flat wire
d	mm	Diameter of the parallel length of a circular test piece, or diameter or round wire or internal diameter or a tube
D	mm	External diameter of a tube
L_o	mm	Original gauge length
L'_o	mm	Initial gauge length for determination of A_g
L_c	mm	Parallel length
L_e	mm	Extensometer gauge length
L_t	mm	Total length of test piece
L_u	mm	Final gauge length
L'_u	mm	Final gauge length after fracture for determination of A_g (see Appendix G)
S_o	mm^2	Original cross-sectional area of the parallel length
S_u	mm^2	Minimum cross-sectional area after fracture
Z	%	Percentage reduction of area: $\frac{S_o - S_u}{S_o} \times 100$
l	—	Gauge length interval
Elongation		
—	mm	Elongation after fracture $L_u - L_o$
A‡	%	Percentage elongation after fracture $\frac{L_u - L_o}{L_o} \times 100$
A_e	%	Percentage yield point extension
ΔL_m	mm	Extension at maximum force
A_g	%	Percentage plastic elongation at maximum force (F_m)
A_{gt}	%	Percentage total elongation at maximum force (F_m)
A_{wn}	%	Percentage plastic elongation without necking
A_t	%	Percentage total elongation at fracture
α	%	Specified percentage non-proportional extension
β	%	Percentage total extension
γ	%	Specified percentage permanent set extension or elongation
Force		
F_m	N	Maximum force

(*continued*)

TABLE 1 (*continued*)

Symbol	Unit	Designation
Yield strength—Proof strength—Tensile strength		
R_{eH}	MPa	Upper yield strength
R_{eL}	MPa	Lower yield strength
R_m	MPa	Tensile strength
R_p	MPa	Proof strength, non-proportional extension
R_r	MPa	Permanent set strength
R_t	MPa	Proof strength, total extension
E	MPa	Modulus of elasticity

* See Figures 1 to 11.

† The symbol T is also used in steel tube product Standards.

‡ See Clause 3.12.

NOTE: 1 MPa = 1 N/mm^2

6 TEST PIECE

6.1 Shape and dimensions

6.1.1 *General*

The shape and dimensions of the test piece depend on the shape and dimensions of the metallic product from which the test piece is taken, see Clause 22 and Appendix C, Paragraph C1.

The test piece is usually obtained by machining a sample from the product or a pressed blank or casting. However, products of constant cross-section (sections, bars, wires, etc.) and also as-cast test pieces (i.e. cast irons and non-ferrous alloys) may be tested without being machined.

The cross-section of the test pieces may be circular, square, rectangular, annular or, in special cases, some other shape.

Test pieces, the original gauge length of which is related to the original cross-sectional area by the equation $L_o = k\sqrt{S_o}$ are called proportional test pieces. The internationally adopted value for k is 5.65. The original gauge length shall not be less than 20 mm. When the cross-sectional area of the test piece is too small for this requirement to be met with the coefficient k value of 5.65, a higher value (preferably 11.3) or a non-proportional test piece may be used.

NOTE: For precautions when measuring elongation after fracture, see Appendix E and Appendix G.

In the case of non-proportional test pieces, the original gauge length (L_o) is taken independently of the original cross-sectional area (S_o).

The dimensional tolerances of the test pieces shall be in accordance with the appropriate Appendices (see Clause 6.2).

6.1.2 *Machined test pieces*

Machined test pieces shall incorporate a transition curve between the gripped ends and the parallel length if these have different dimensions. The dimensions of this transition radius may be important and it is recommended that they be defined in the material specification if they are not given, see Appendix A and Appendix C.

The gripped ends may be of any shape to suit the grips of the testing machine. The axis of the test piece shall coincide with or be parallel to the axis of application of the force.

6.1.3 *Non-machined test pieces*

If the test piece consists of an unmachined length of the product or of an unmachined test bar, the free length between the grips shall comply to Appendices A, B, C and D.

As-cast test pieces shall incorporate a transition radius between the gripped ends and the parallel length. The dimensions of this transition radius are important and it is recommended that they be defined in the product Standard. The gripped ends may be of any shape to suit the grips of the testing machine. The parallel length (L_c) shall always be greater than the original gauge length (L_o).

6.2 Types

The main types of test piece are defined in Appendices A, B, C and D according to the shape and type of product as shown in Table 2. Other types of test piece may be specified in product Standards.

TABLE 2

MAIN TYPES OF TEST PIECE

Type of product	Thickness (a) or Diameter (d) mm	Corresponding Appendix
Sheets—Flats	$0.1 \leqslant a < 3$	A
	$a \geqslant 3$	C
Wire—Bars—Sections	$d < 4$	B
	$d \geqslant 4$	C
Tubes	—	D

6.3 Preparation of test pieces

The test pieces shall be taken and prepared in accordance with this Standard for different products (see Appendix I and Appendix J).

NOTE: The mechanical working of a material may influence the test results.

7 MARKING THE ORIGINAL GAUGE LENGTH (L_o)

Each end of the original gauge length shall be marked by means which will survive the tests, fine marks or scribed lines, but not by notches which could result in premature fracture.

For proportional test pieces, the calculated value of the original gauge length may be rounded off to the nearest multiple of 5 mm, provided that the difference between the calculated and marked gauge length is less than 10% of L_o. The original gauge length shall be marked to an accuracy of ±1%.

If the parallel length (L_c) is much greater than the original length, as, for instance, with unmachined test pieces, a series of overlapping gauge lengths may be drawn.

NOTE: In some cases, it may be helpful to draw, on the surface of the piece, a line parallel to the longitudinal axis, along which the gauge lengths are drawn.

8 ACCURACY OF TESTING APPARATUS

8.1 General

Calibration of equipment shall relate to the specific equipment in use for the test, e.g. the ancillary equipment and ranges. When readings are taken from the chart paper, procedures shall be in place to overcome the possible effects of humidity and to demonstrate that the accuracy requirements are met at the time of testing. When computerized data acquisition or treatment is used, or when computerized or automatic machines control is used, it shall also be demonstrable that the system is accurate for the particular material under test.

8.2 Force measuring system

The relevant force-measurement system of the testing machine, including the ancillary recording equipment if this is used to measure force during the test, shall be calibrated in accordance with AS 2193 and shall be maintained in Grade A or better.

8.3 Extensometer

Extensometers, including ancillary electronic or autographic extension measuring equipment, proof stress indicators as other strain measuring equipment, shall be calibrated in accordance with AS 1545. The property to be measured shall comply with the following class requirements at the appropriate value of strain as specified in AS 1545.

When an extensometer is used it shall be Grade D or better for the determination of upper and lower yield strength and for proof strength (non-proportional extension). For other properties (with higher extension) a Grade D extensometer may be used, see AS 1545.

9 TESTING RATE

9.1 Speed of testing

Unless otherwise specified in the product Standard, the speed of testing shall conform to the requirements of this Clause depending on the nature of the material.

9.2 Yield and proof strengths

9.2.1 *Upper yield strength (R_{eH})*

Unless otherwise specified, any convenient speed of testing may be used up to one half the specified yield strength. The rate of separation of the crossheads of the machine above this point shall be kept as constant as possible and within the limits corresponding to the stress rates in Table 3.

TABLE 3

STRESS RATE

Modulus of elasticity of the material (E) MPa	Stress rate MPas^{-1}	
	Min.	Max.
<150 000	6	20
≥ 150 000	6	60

9.2.2 *Lower yield strength (R_{eL})*

If only the lower yield strength is being determined, the strain rate during yielding of the parallel length of the test piece shall be between 0.000 25 s^{-1} and 0.00 25 s^{-1}. The strain rate within the parallel length shall be kept as constant as possible. If this rate cannot be regulated directly, it shall be fixed by regulating the stress rate just before yield begins, the controls of the machine not being further adjusted until completion of yield.

In no case, shall the stress rate in the elastic range exceed the maximum rates given in Table 3.

9.2.3 *Upper and lower yield strength (R_{eH} and R_{eL})*

If the two yield strengths are determined during the same test, the conditions for determining the lower yield strength shall be complied with (Clause 9.2.2).

9.2.4 *Proof strength plastic extension (R_p) and proof strength total extension (R_t)*

Unless otherwise specified, any convenient speed of testing may be used to one half the specified proof strength. The rate of separation of the crossheads of the machine above this point shall be kept as constant as possible and within the limits corresponding to the stress rates in Table 3.

Within the plastic range and up to the proof strength (plastic extension or total extension) the strain rate shall not exceed 0.0025 s^{-1}.

9.2.5 *Rate of separation*

If the testing machine is not capable of measuring or controlling the strain rate, a cross head separation rate equivalent to the stress rate given in Table 3 shall be used until completion of yield.

9.2.6 *Tensile strength (R_m)*

After determination of the required yield/proof strength properties the test rate may be increased to a strain rate (or equivalent crosshead separation rate) no greater than 0.008 s^{-1}.

If only the tensile strength of the material is required to be measured, the test rate shall not exceed 0.008 s^{-1} throughout the test.

10 DETERMINATION OF THE PERCENTAGE PLASTIC EXTENSION AT MAXIMUM FORCE (A_g)

The method consists of determining the extension at maximum force (ΔL_m) on the force-extension diagram obtained with an extensometer and subtracting the elastic strain.

The percentage plastic extension at maximum force shall be calculated from the following equation:

$$A_g = \frac{\Delta L_m}{L_e} - \frac{R_m}{E} \times 100$$

NOTE: For materials which exhibit a plateau at maximum force, the percentage plastic extension at maximum force is taken at the mid-point of the plateau.

11 DETERMINATION OF PERCENTAGE ELONGATION AFTER FRACTURE (A)

11.1 Percentages elongation after fracture

To determine the percentage elongation after fracture the two broken ends of the test piece are carefully fitted back together so that their axes lie in a straight line.

The two following paragraphs (a) and (b) explain how proportional and non-proportional total elongations may be reported.

(a) In case of proportional test pieces, only if the original gauge length is other than $5.65\sqrt{S_o}$ * where S_o is the original cross-sectional area of the parallel length, the symbol A shall be supplemented by an index indicating the coefficient of proportionally used, for example:

$A_{11.3}$ = percentage elongation of a gauge length (L_o) of $11.3\sqrt{S_o}$.

(b) In the case of non-proportional test pieces, the symbol A shall be supplemented by an index indicating the original gauge length used, expressed in millimetres, for example:

$A_{80\text{ mm}}$ = percentage elongation of a gauge length (L_o) of 80 mm.

Special precautions shall be taken to ensure proper contact between the broken parts of the test piece when measuring the final gauge length. This is particularly important in the case of test pieces of small cross-section and test pieces having low elongation values.

Elongation after fracture ($L_u - L_o$) shall be determined with a device able to measure to the nearest 0.25 mm. The value of percentage elongation after fracture shall be rounded to the nearest 1.0 %. If the specified minimum percentage elongation is less than 5%, it is recommended that special precautions be taken when determining elongation (see Appendix E).

This measurement is, in principle, valid only if the distance between the fracture and the nearest gauge mark is no less than one third of the original gauge length (L_o). However, the measurement is valid, irrespective of the position of the fracture, if the percentage elongation after fracture is equal to or greater than the specified value.

11.2 Machines capable of measuring extension at fracture using an extensometer

For machines capable of measuring extension at fracture using an extensometer, it is not necessary to mark the gauge lengths. The elongation is measured as the total extension at fracture, and it is therefore necessary to deduct the elastic extension in order to obtain percentage elongation after fracture.

In principle, this measurement is only valid if fracture occurs within the extensometer gauge length (L_e). The measurement is valid regardless of the position of the fracture if the percentage elongation after fracture is equal to or greater than the specified value.

If the product Standard specifies the determination of percentage elongation after fracture for a given gauge length, the extensometer gauge length shall be equal to this length.

11.3 Elongation measured over a given fixed length

If elongation is measured over a given fixed gauge length, it can be converted to a proportional gauge length, using conversion formuli or tables. For ferritic steels see ISO 2566-1 and for austenitic steels see ISO 2566-2.

NOTE: Comparisons of percentage elongation are possible only when the gauge length or extensometer gauge length, the shape and area of the cross-section are the same or when the coefficient of proportionality (k) is the same.

11.4 Avoidance of reject test pieces

In order to avoid having to reject test pieces in which fracture may occur outside the limits specified in Clause 11.1, the method based on the subdivision of L_o into N equal parts may be used.

NOTE: This method is described in Appendix F.

---

* $5.65\sqrt{S_o} = 5\sqrt{\frac{4S_o}{\pi}}$

12 DETERMINATION OF PERCENTAGE TOTAL ELONGATION AT MAXIMUM FORCE (A_{gt})

The method consists of determining on the force-extension diagram obtained with an extensometer, the extension at maximum force (ΔL_m).

Some materials exhibit a flat plateau at maximum force. When this occurs, the percentage total elongation at maximum force is taken at the mid-point of the flat plateau (see Figure 1).

The extensometer gauge length shall be recorded in the test report.

The percentage total elongation at maximum force is calculated by the following formula:

$$A_{gt} = \frac{\Delta L_m}{L_e} \times 100$$

If the tensile test is carried out on a computer controlled testing machine having a data acquisition system, the elongation is directly determined at the maximum force.

13 DETERMINATION OF THE PERCENTAGE YIELD POINT EXTENSION (A_e)

For materials with discontinuous yielding, the percentage yield point extension is determined from the force-extension diagram by subtracting the extension at R_{eH} from the extension at the start of uniform work hardening. The extension at the start of uniform work hardening is defined by the intersection of a horizontal line through the last local minimum point, or a regression line through the range of yielding, prior to uniform work hardening and a line corresponding to the highest slope of the curve occurring at the start of uniform work hardening (see Figure 7). It is expressed as a percentage of the extensometer gauge length L_e.

14 DETERMINATION OF PROOF STRENGTH, PLASTIC EXTENSION (R_p)

The proof strength (plastic extension) is determined from the force-extension diagram by drawing a line parallel to the straight portion of the curve and at a distance from this equivalent to the prescribed plastic percentage extension, for example 0.2%. The point at which this line intersects the curve gives the force corresponding to the desired proof strength (plastic extension). The latter is obtained by dividing this force by the original cross-sectional area of the test piece (S_o) (see Figure 3).

Accurate drawing of the force-extension diagram is essential.

If the straight portion of the force-extension diagram is not clearly defined, thereby preventing drawing the parallel line with sufficient precision, the following procedure is recommended.

When the presumed proof strength has been exceeded, the force is reduced to a value equal to about 10% of the force obtained. The force is then increased again until it exceeds the value obtained originally. To determine the desired proof strength a line is drawn through the hysteresis loop. A line is then drawn parallel to this line, at a distance from the corrected origin of the curve, measured along the extension axis, equal to the prescribed plastic percentage extension. The intersection of this parallel line and the force-extension curve gives the force corresponding to the proof strength. The latter is obtained by dividing this force by the original cross-sectional area of the test piece (S_o) (see Figure 6).

NOTES:

1 The correction of the origin of the curve can be done by various methods. The following method is generally used: draw a line parallel to the line defined by the hysteresis loop which crosses the rising elastic part of the diagram, the slope of which is nearest to that of the loop. The point at which this line intersects the abscissa gives the corrected origin of the curve.

2 The property may be obtained without plotting the force-extension curve by using automatic devices (e.g. microprocessor).

15 DETERMINATION OF PROOF STRENGTH, TOTAL EXTENSION (R_t)

The proof strength (total extension) is determined on the force-extension diagram by drawing a line parallel to the force axis and at a distance from this equivalent to the prescribed total percentage extension. The point at which this line intersects the curve gives the force corresponding to the desired proof strength. The latter is obtained by dividing this force by the original cross-sectional area of the test piece (S_0) (see Figure 4).

NOTES:

1 The property may be obtained without plotting the force-extension diagram by using automatic devices.

2 Correction for initial non-linearity of the stress strain curve may be required.

16 METHOD OF VERIFICATION OF PERMANENT SET STRENGTH (R_r)

The test piece is subjected to a force for 10 s to 12 s corresponding to the specified stress and it is then confirmed, after removing the force, that the permanent set extension or elongation is not more than the percentage specified for the original gauge length.

17 DETERMINATION OF PERCENTAGE REDUCTION OF AREA (Z)

Percentage reduction of area shall be determined by ($S_o - S_u$).

NOTE: Refer to Clause 3.18.

The two broken pieces of the test piece are carefully fitted back together so that their axes lie in a straight line. The minimum cross-sectional area after fracture (S_u) shall be measured to an accuracy of ±3%. The difference between the area (S_u) and the original cross-sectional area (S_o) expressed as a percentage of the original area gives the percentage reduction of area. The percentage reduction of area shall be rounded to the nearest whole number.

18 ACCURACY OF THE RESULTS

The accuracy of results is dependent on various parameters which may be separated into two categories as follows:

(a) Metrological parameters such as class of machine and extensometer and the accuracy of specimen dimensional measurements.

(b) Material and testing parameters, such as nature of material, test piece geometry and preparation, testing rate, temperature, data acquisition and analysis technique.

In the absence of sufficient data on all types of materials it is not possible, at present, to fix values of accuracy for the different properties measured by the tensile test.

NOTE: Appendix H provides a guideline for the determination of uncertainty related to metrological parameters.

For the purpose of compliance assessment, properties determined in accordance with this Standard shall be considered absolute.

At the request of the purchaser measurement uncertainly factors may be applied to the properties measured when assessing compliance. In such cases, the uncertainty to be applied shall be nominated by the purchaser and shall be reported (see Clause 20(vii)).

19 RECORD OF RESULTS

A record of relevant details and results shall be made and shall be capable of providing the following information:

(a) Identification of the testing authority.

(b) Identification of the testing apparatus.

(c) The date of test.

(d) The product and sample identity.

(e) The presence of any surface coatings or layers on the test sample and whether these coatings or layers were removed or retained on the test piece. If the coating is retained, the record shall state whether the base thickness or the total thickness was used to calculate the cross-sectional area of the test piece.

(f) The test piece type and dimensions.

(g) The product Standard.

(h) The test piece direction.

(i) The original and extensometer gauge length.

(j) The indicated results.

(k) The calculated properties.

(l) Measurement uncertainty factors to be applied if applicable.

(m) Any other information required to support any report issued.

20 TEST REPORT

Any report issued shall include the following information:

(a) The report number and date.

(b) The product identity, including relevant product Standard where applicable.

(c) The sample identity.

(d) The presence and nature of any surface coatings or layers, whether removed or retained, and the method of removal, if applicable. If the coating is retained, the report shall state whether the base thickness or the total thickness was used to calculate the cross-sectional area of the test piece.

(e) The calculated values of the specified properties, including, where relevant, the value of any alternative yield or proof stress measurements, or, where relevant, both the measured and converted elongation values.

(f) Where relevant, a note concerning deformation or fracture position.

NOTE: See Appendix F.

(g) Reference to this Australian Standard, i.e. AS 1391.

If not specified in the product Standard or when a test condition varies from the product Standard, the report shall also include the following information, as appropriate:

(i) A statement that the minimum specified strain rate may not have been complied with.

(ii) The strain rate, if a special strain rate was employed.

(ii) The form, nominal dimensions, direction and location of test pieces.

(iv) The nominal gauge length.

(v) Where appropriate, the method used for any straightening, flattening or heat treatment of test pieces, and, if necessary, a note qualifying the results.

(vi) For product section test pieces from repetitively patterned products, the basis for the determination of the test piece cross-sectional area.

(vii) Uncertainty factors, if applied in compliance assessment.

(viii) Where appropriate if the material complies with product Standards.

21 FORCE-EXTENSION DIAGRAMS

Figures 1 to 11 are typical of the force-extension diagrams that may be obtained during a tensile test and illustrate variations in upper and lower yield stress behaviour and the absence of the yield phenomenon.

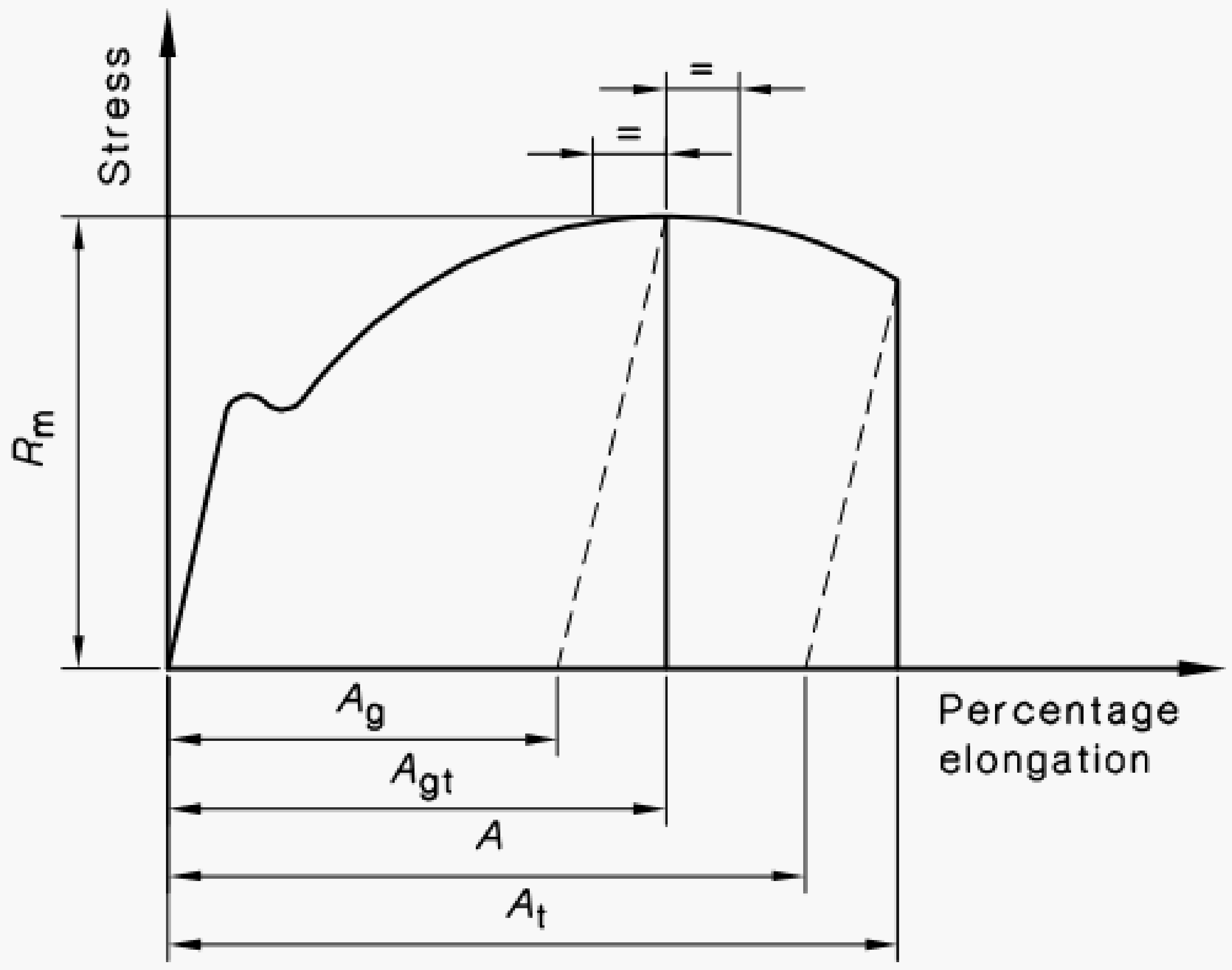
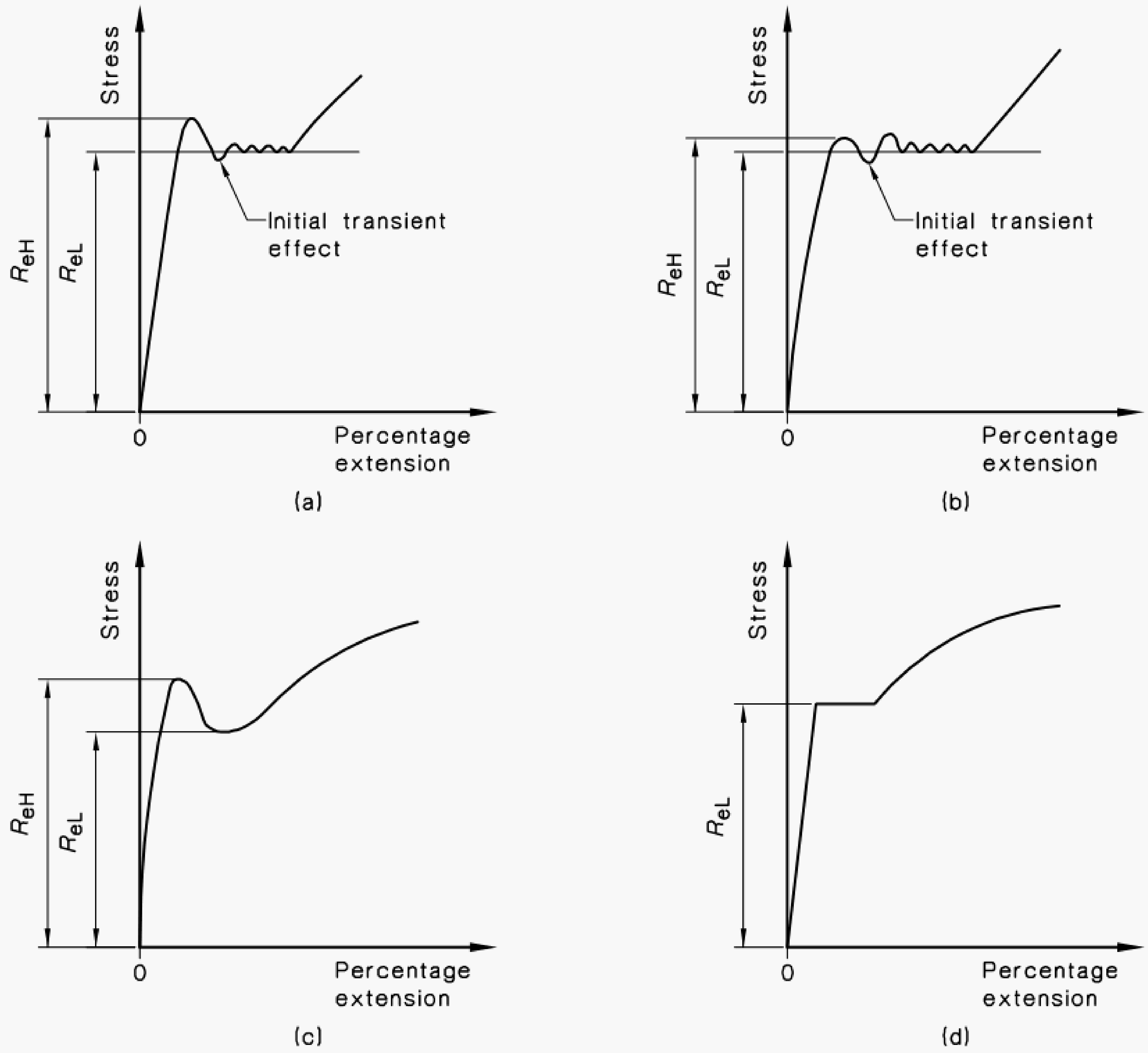


FIGURE 1 DEFINITIONS OF ELONGATION



NOTE: When the force drops after reaching the upper yield stress, there is a release of energy, which will result in a short sudden increase in strain on the test piece. The energy released is proportional to the decrease in force and the amount of elastic deflection of the testing system. This may be manifested as a temporary low stress such as the initial transient effect, see Figures 2(a) and 2(b). The transient effect should be ignored in the determination of the lower yield stress.

FIGURE 2 DEFINITIONS OF UPPER AND LOWER YIELD STRENGTHS FOR DIFFERENT TYPES OF CURVES

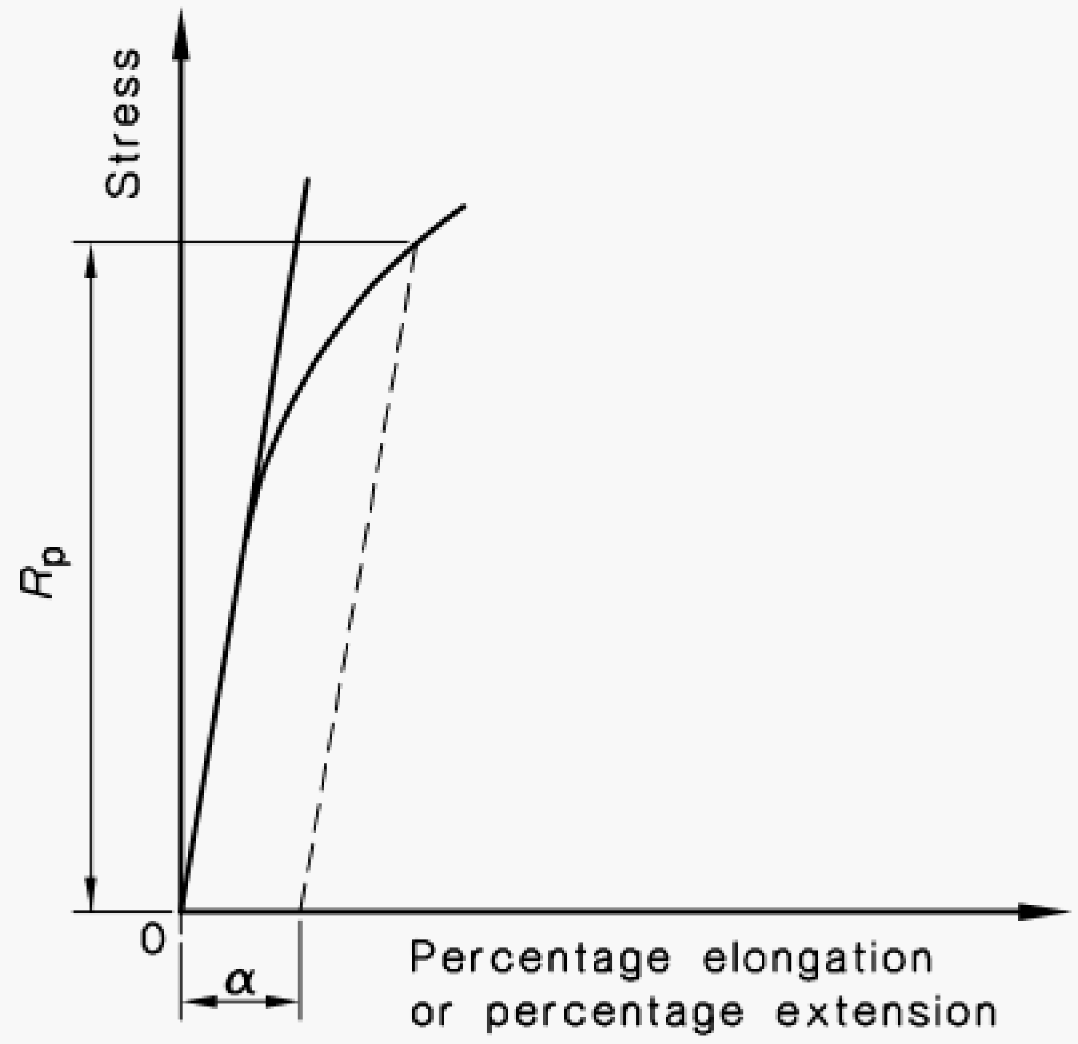


FIGURE 3 PROOF STRENGTH, PLASTIC EXTENSION (R_p)

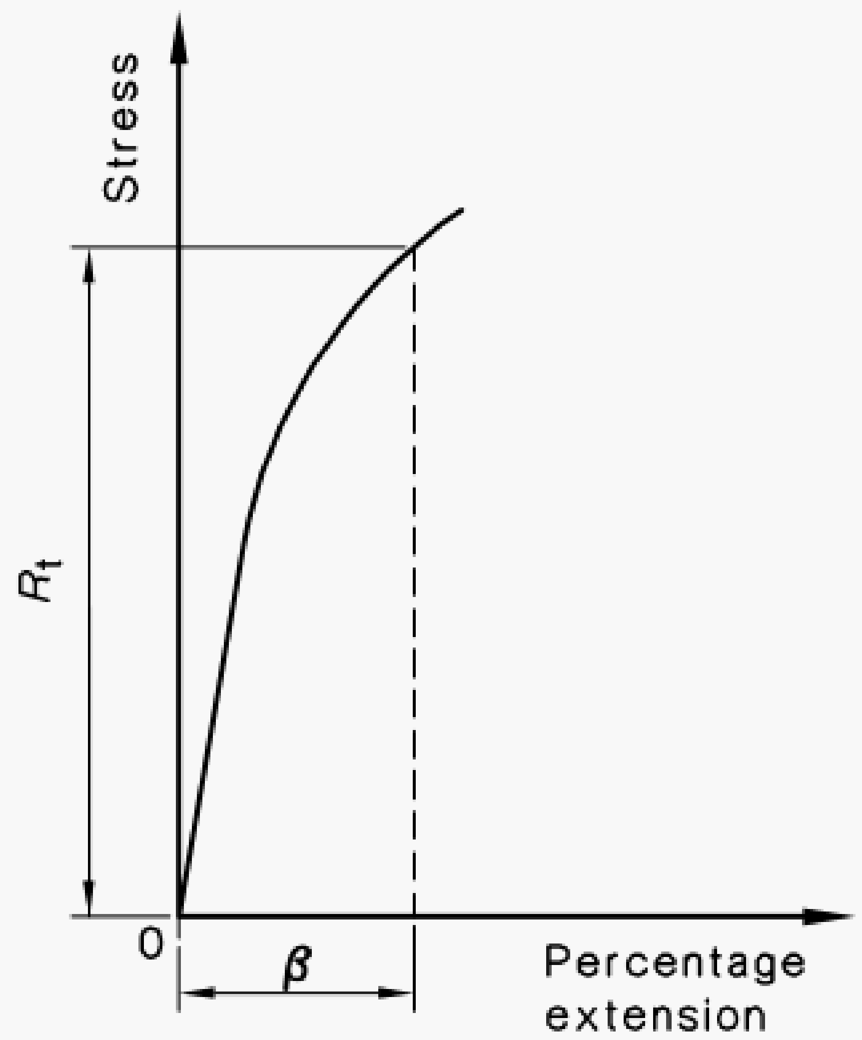


FIGURE 4 PROOF STRENGTH, TOTAL EXTENSION (R_t)

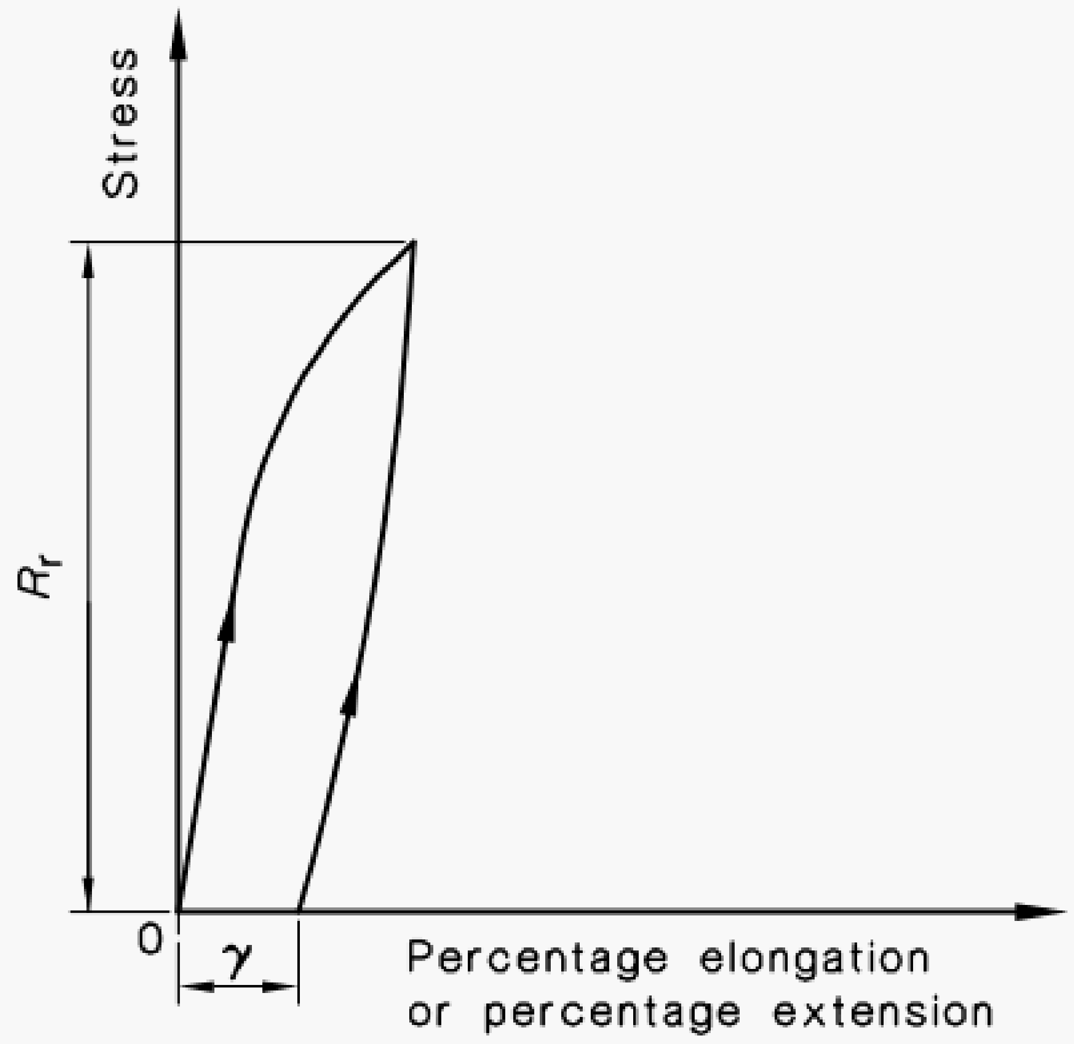
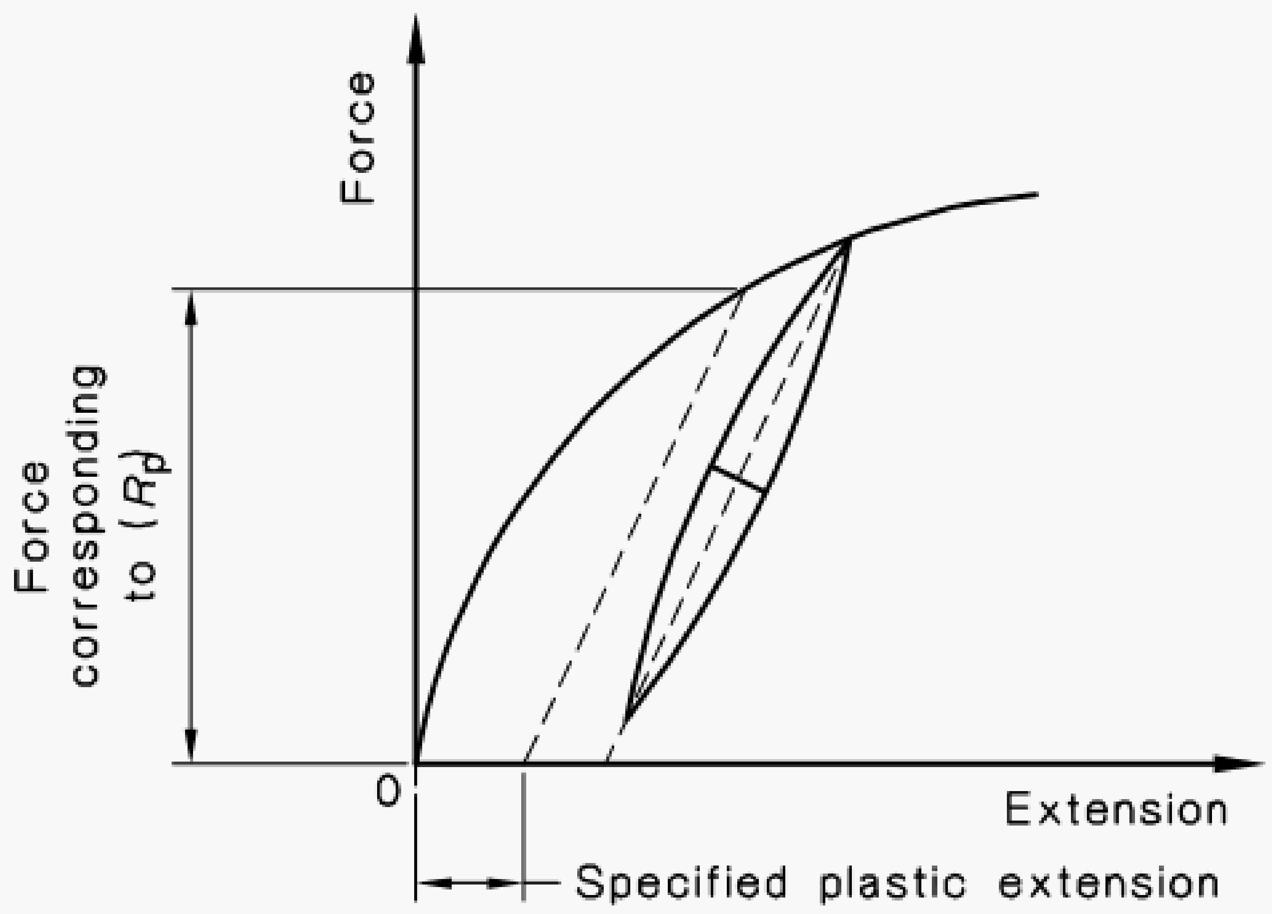
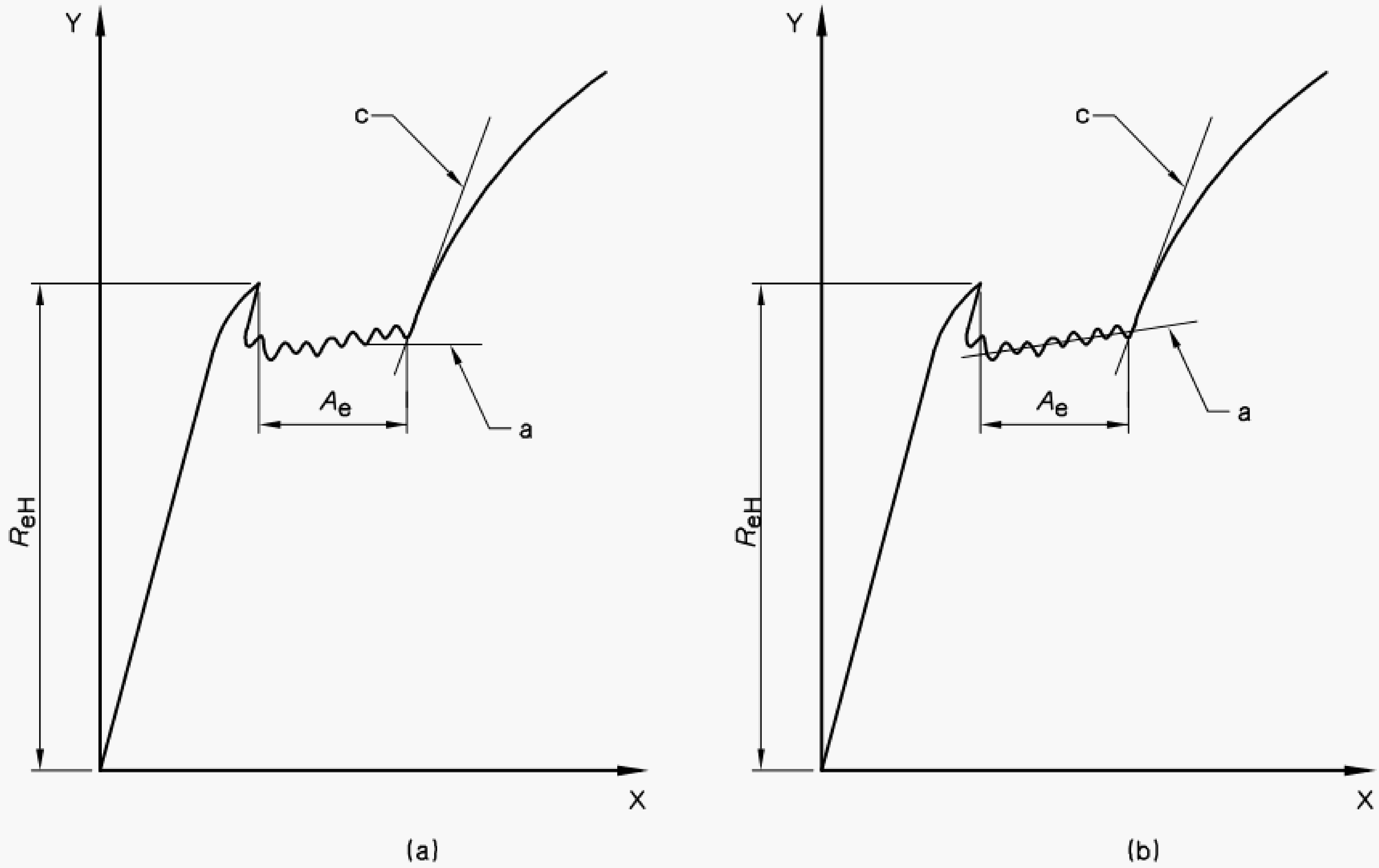


FIGURE 5 PERMANENT SET STRENGTH (R_r)



NOTE: See Clause 14, Note 1.

FIGURE 6 PROOF STRENGTH, PLASTIC EXTENSION (R_P)



LEGEND:

X = Percentage extension
Y = Stress
a = Horizontal line through the last local minimum point, prior to uniform work hardening
b = Regression line through the range of yeilding, prior to uniform work hardening
c = Line corresponding to the highest slope of the curve occuring at the start of uniform work hardening

FIGURE 7 PERCENTAGE YIELD POINT EXTENSION (A_e)

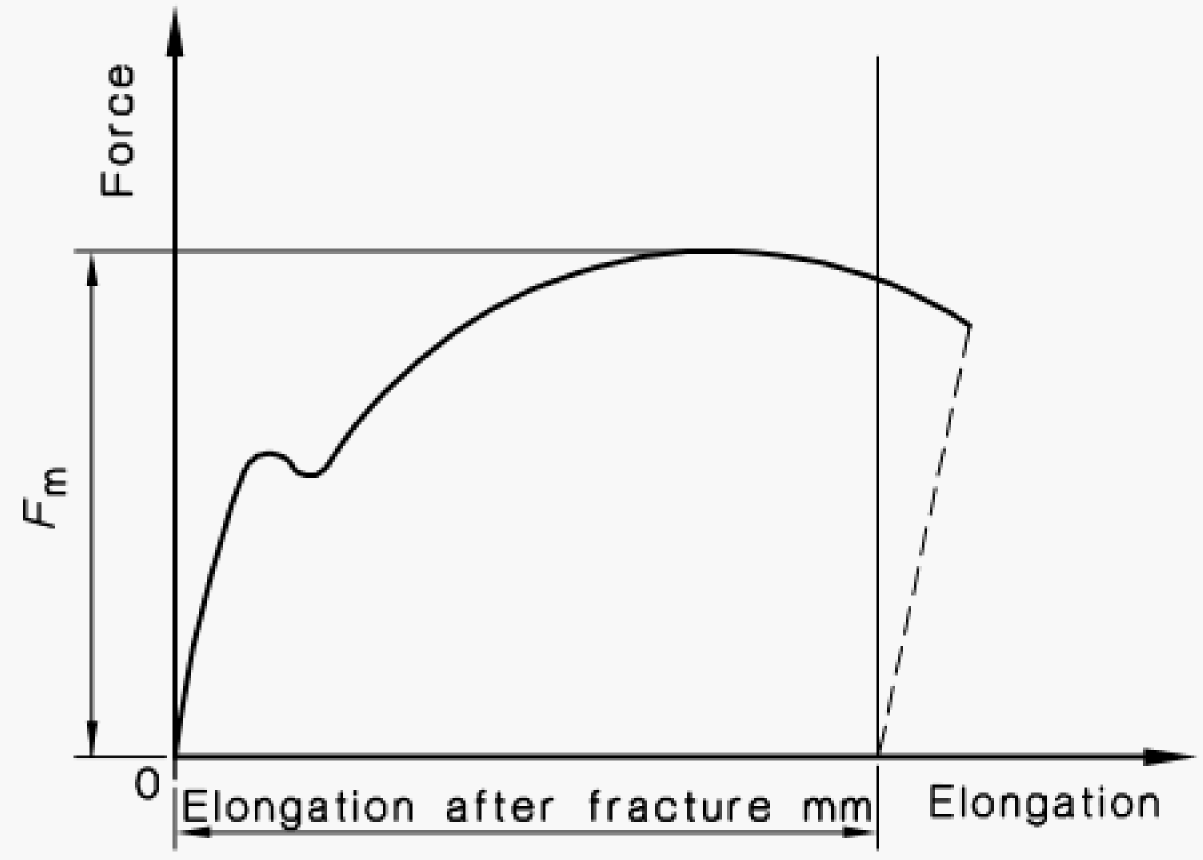


FIGURE 8 MAXIMUM FORCE

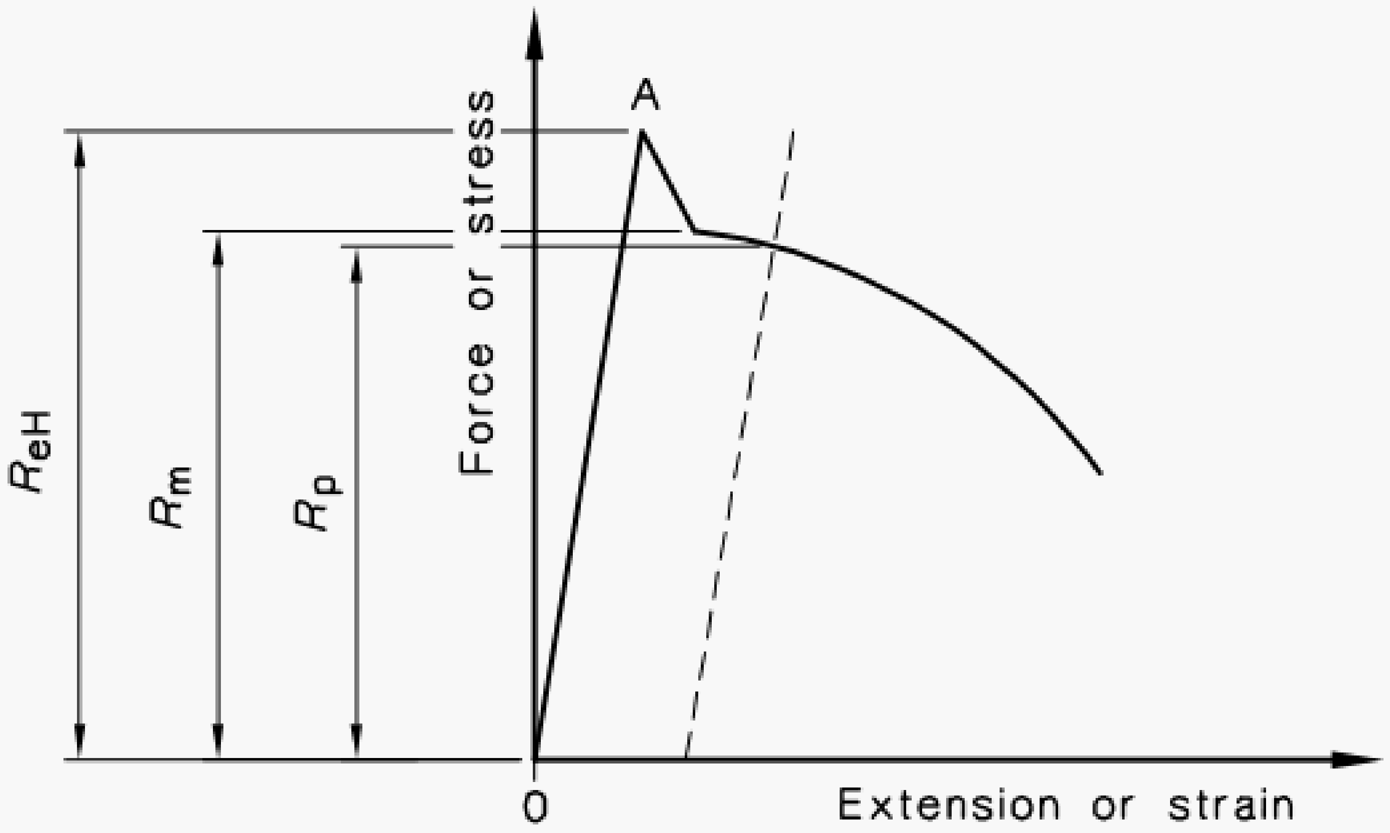


FIGURE 9 UPPER YIELD HIGHER THAN THE TENSILE STRENGTH (EXAMPLE 1)

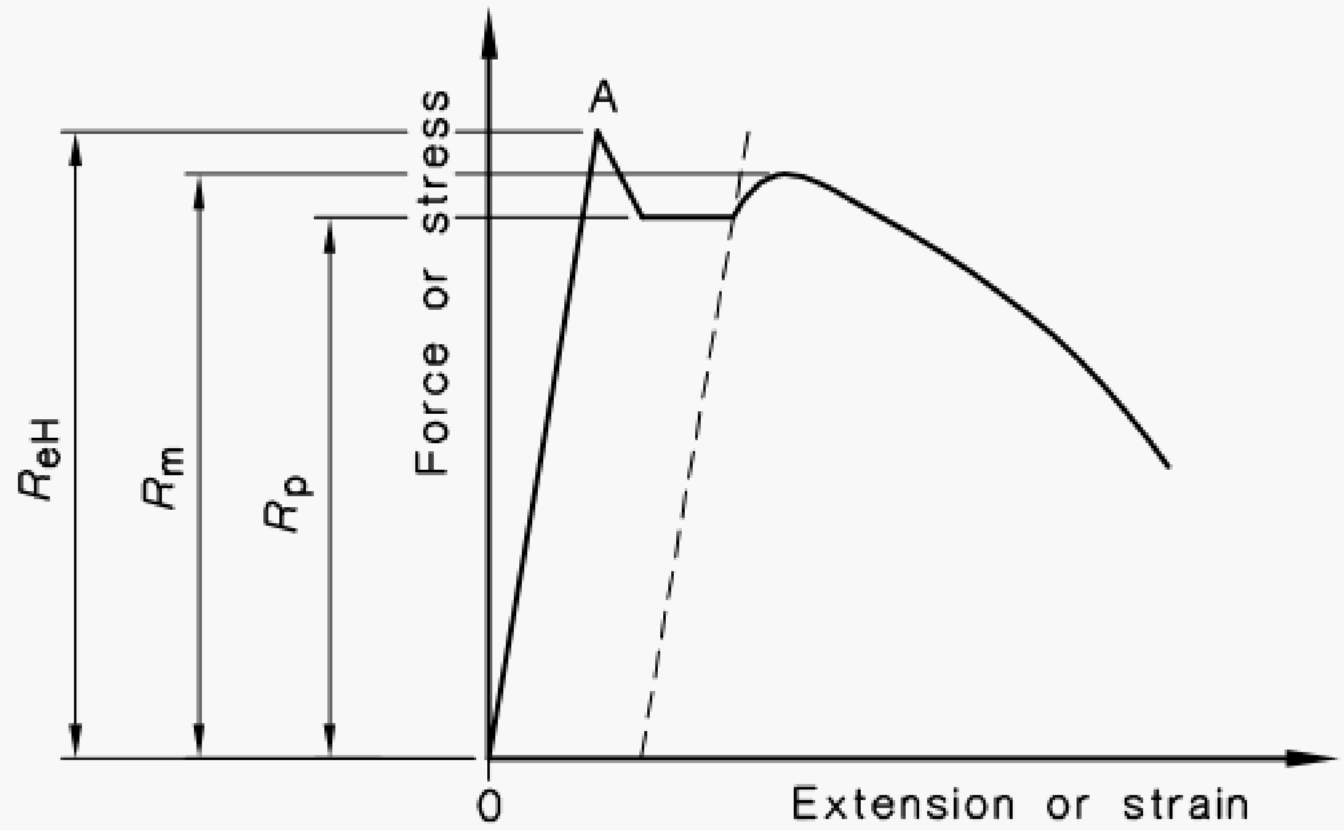


FIGURE 10 UPPER YIELD HIGHER THAN THE TENSILE STRENGTH (EXAMPLE 2)

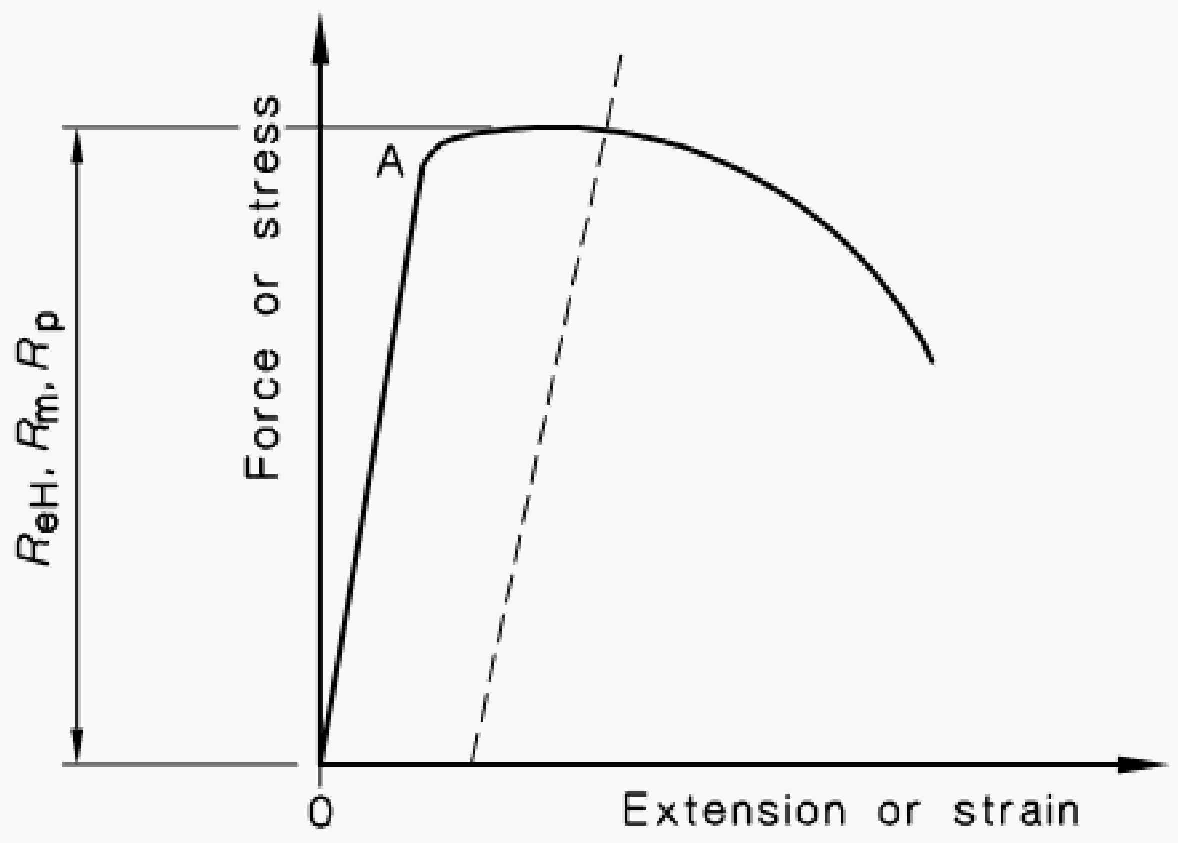


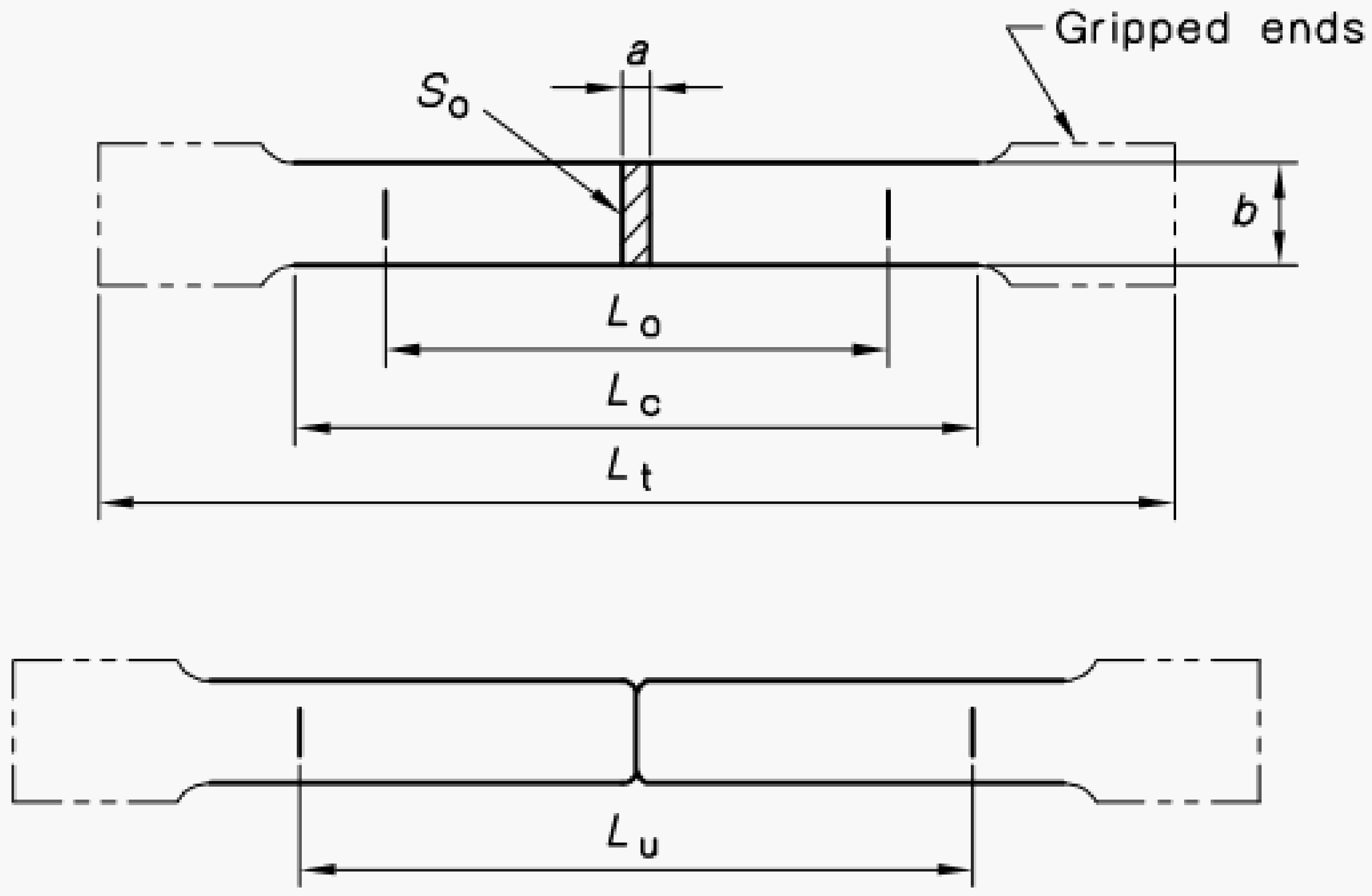
FIGURE 11 SUPPRESSED UPPER YIELD CORRESPONDING TO TENSILE STRENGTH

22 TEST PIECE FORMS

The shape and dimension of the test pieces are limited in many cases by the shape and dimensions of the metallic product or test specimen from which it is to be taken (see Clause 6). The test piece may be prepared by methods including cutting, machining, blanking or casting as follows:

(a) By manufacture to one of the forms shown in Figure 12 to 16 to dimensions specified in Clause 6.1.2.

(b) Without machining when products of constant cross-section, such as extruded sections, bars, wire, narrow strip, and cast-to-shape test bars, meet the requirements of Clause 6.1.3.



NOTE: The shape of the gripped ends is given only as a guide.

FIGURE 12 MACHINED TEST PIECES OF RECTANGULAR CROSS SECTION (SEE APPENDIX A)

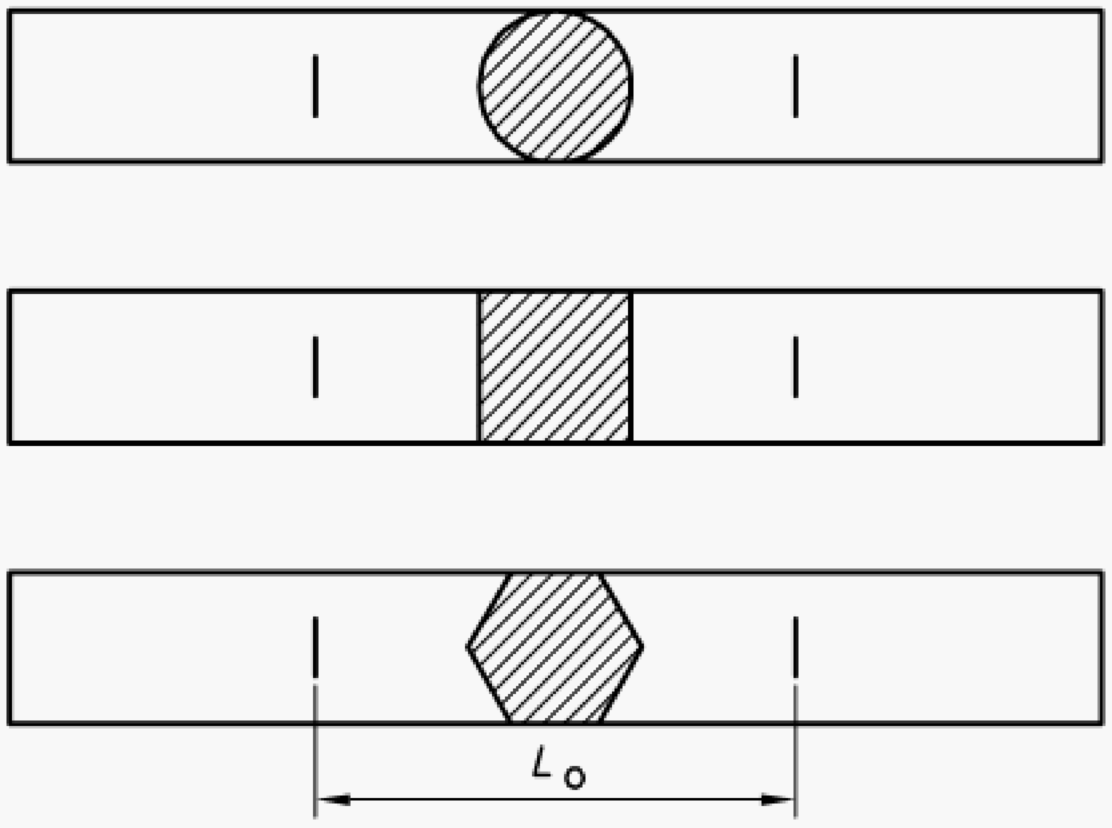
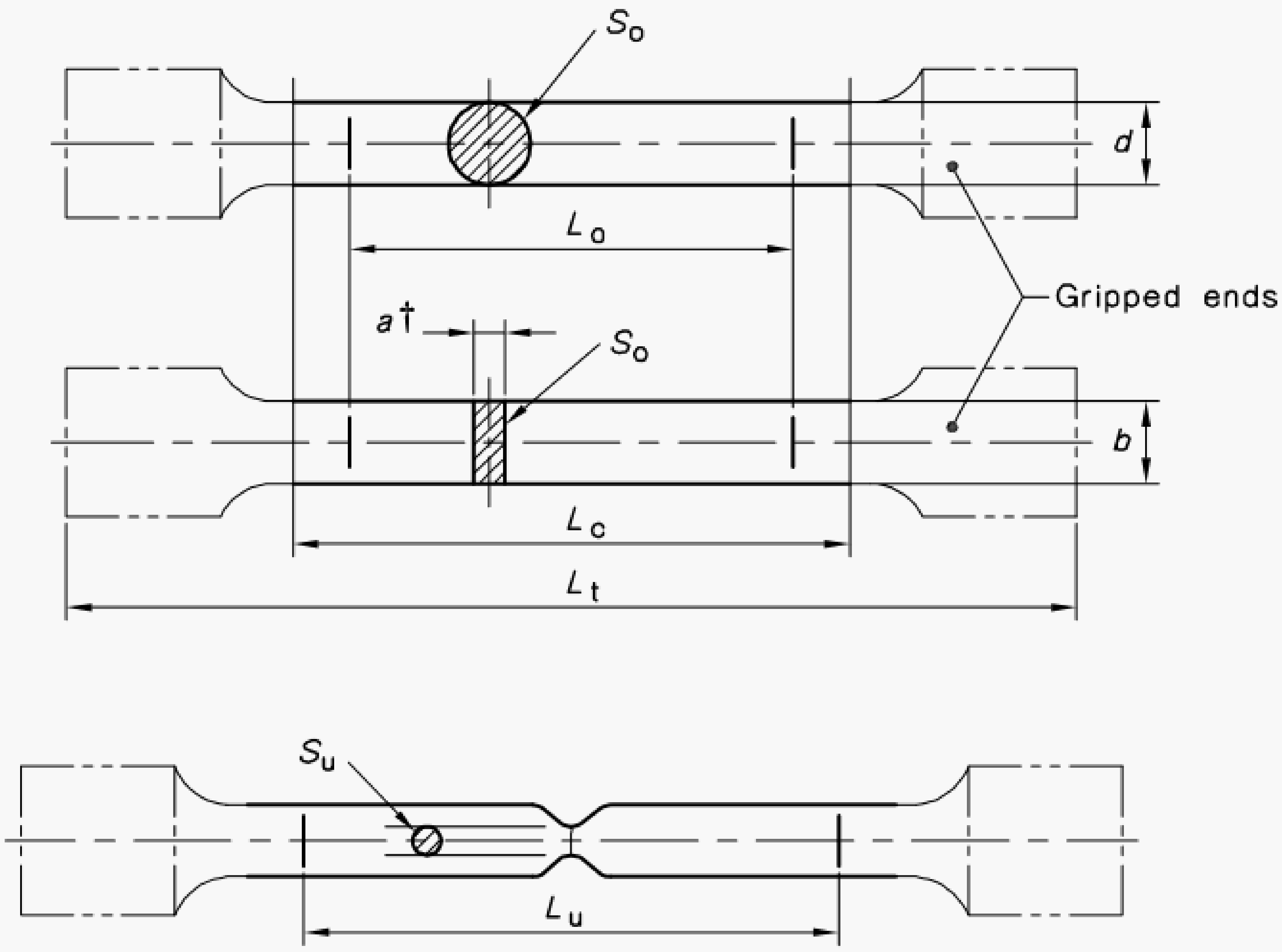


FIGURE 13 TEST PIECES COMPRISING A NON-MACHINED PORTION OF THE PRODUCT (SEE APPENDIX B)



NOTE: The shape of the gripped ends is given only as a guide.

FIGURE 14 PROPORTIONAL TEST PIECES (SEE APPENDIX C)

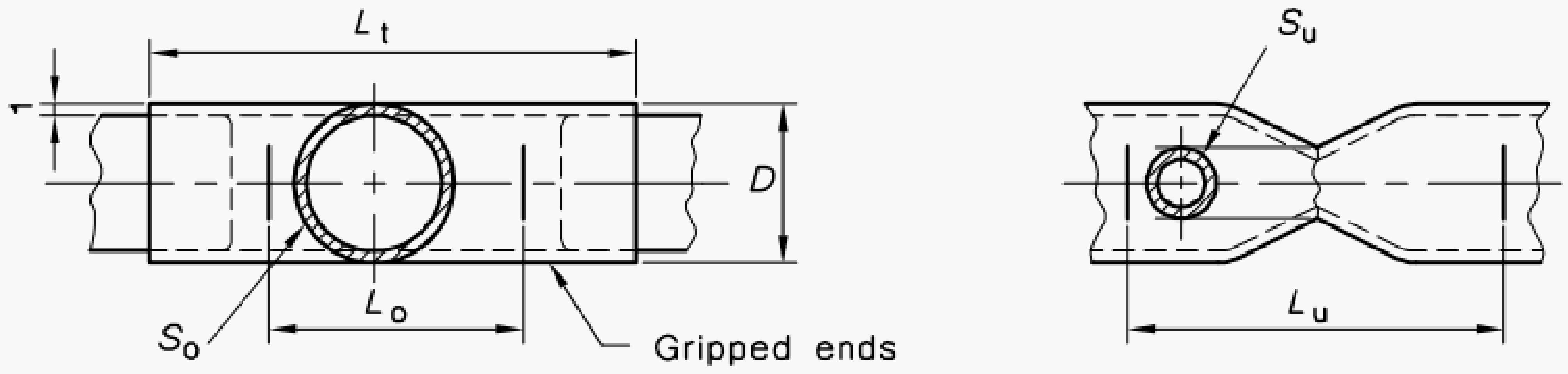
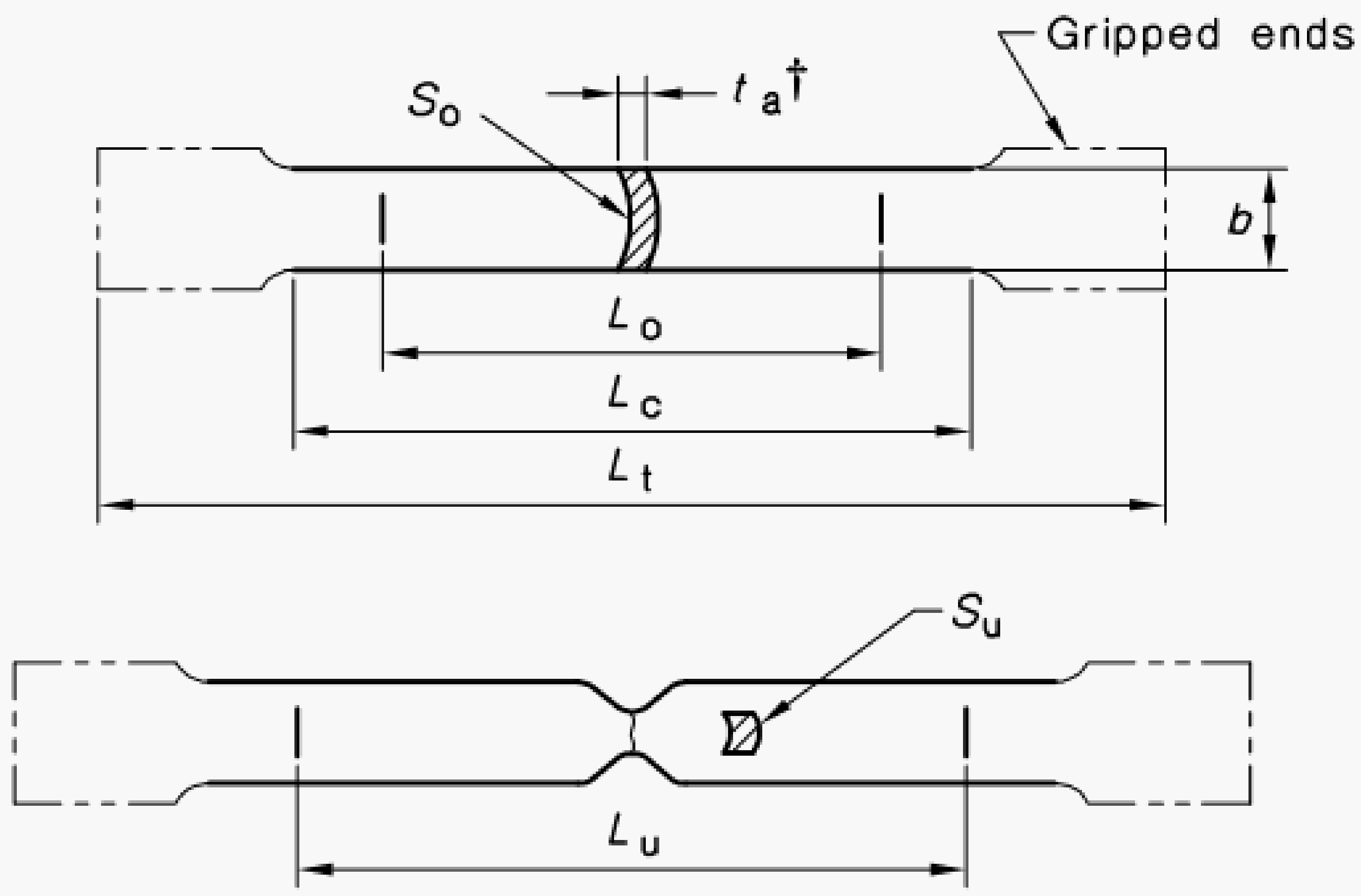


FIGURE 15 TEST PIECES COMPRISING A LENGTH OF TUBE (SEE APPENDIX D)



NOTE: The shape of the gripped ends is given only as a guide.

FIGURE 16 TEST PIECE CUT FROM A TUBE (SEE APPENDIX D)

APPENDIX A

TYPES OF TEST PIECE TO BE USED FOR THIN PRODUCTS: SHEETS, STRIPS AND FLATS BETWEEN 0.1 mm AND 3 mm THICK

(Normative)

A1 GENERAL

For products of less than 0.5 mm thickness, special precautions may be necessary.

A2 SHAPE OF THE TEST PIECE

Generally, the test piece has gripped ends which are wider than the parallel length. The parallel length (L_c) shall be connected to the ends by means of transition curves with a radius of not less than the width of the parallel length b.

The test piece may also consist of a strip with parallel sides. For products of width equal to or less than 20 mm, the width of the test piece may be the same as that of the product.

A3 DIMENSIONS OF THE TEST PIECE

The parallel length shall not be less than $L_o + \frac{b}{2}$.

In case of dispute, the length $L_o + 2b$ shall be used unless there is insufficient material.

In the case of parallel side test pieces less than 20 mm wide, and unless otherwise specified in the product Standard, the original gauge length (L_o) shall be equal to 50 mm. For this type of test piece, the free length between the grips shall be equal to $L_o + 3b$.

There are four types of non-proportional test pieces, with dimensions as given in Table A1.

When measuring the dimensions of each test piece, the tolerances on shape given in Table A2 shall apply.

In the case of test pieces where the width is the same as that of the product, the original cross-sectional area (S_o) shall be calculated on the basis of the measured dimensions of the test piece.

The nominal width of the test piece may be used, provided that the machining tolerances and tolerances on shape given in Table A2 have been complied with, to avoid measuring the width of the test piece at the time of the test.

The 3 mm and 6 mm wide pieces shall be used if the sample dimensions preclude the use of larger test pieces.

TABLE A1

DIMENSIONS OF MACHINED TEST PIECES

millimetres

Test piece type	Width b	Original gauge length L_o	Parallel length L_c	Free length between the grips for parallel sided test piece
1	3 ±0.2	12	18	21
2	6 ±0.3	24	36	42
3	12.5 ±1	50	75	87.5
4	20 ±1	80	120	140

TABLE A2

TOLERANCES ON WIDTH OF TEST PIECES

millimetres

Nominal width of test piece	Machine tolerance See Note 1	Tolerance on shape See Note 2
3	—	0.025
6	—	0.03
12.5	±0.09	0.043
20	±0.105	0.052

NOTES:

1 Tolerances js 12 in accordance with AS 1654.2. These tolerances are applicable if the nominal value of the original cross-section (S_o) is to be included in the calculations without having to measure it.

2 Tolerances IT9 (see AS 1654.2). Maximum deviation between the measurements of the width along the entire parallel length (L_c) of the test piece.

A4 PREPARATION OF TEST PIECES

A4.1 Preparation

The test pieces are prepared so as not to affect the properties of the metal. Any areas which have been hardened by shearing or pressing shall be removed by machining.

A4.2 Width tolerance

The value given in Table A2, for example ±0.09 mm for a nominal width of 12.5 mm, means that no test piece shall have a width outside the two values given below, if the nominal value of the original cross-sectional area (S_o) is to be included without having to measure it:

12.5 + 0.09 = 12.59 mm.

12.5 – 0.09 = 12.41 mm.

A5 DETERMINATION OF THE ORIGINAL CROSS-SECTIONAL AREA (S_0)

The original cross-sectional area shall be calculated from measurements of the dimensions of the test piece.

The error in determining the original cross-sectional area shall not exceed ±2%. As the greatest part of this error normally results from the measurement of the thickness of the test piece, the error in measurement of the width shall not exceed ±0.2%.

APPENDIX B

TYPES OF TEST PIECE TO BE USED FOR WIRE, BARS AND SECTIONS WITH A DIAMETER OR THICKNESS OF LESS THAN 4 mm

(Normative)

B1 SHAPE OF THE TEST PIECE

NOTE: The test piece generally consists of a length of the product but reduced section and parallel sided machined test pieces may be used.

B2 DIMENSIONS OF THE TEST PIECE

The original gauge length (L_o) shall be taken as 200 mm ±2 mm or 100 mm ±1 mm. The distance between the grips of the machine shall be equal to at least L_o + 50 mm, i.e. 250 mm and 150 mm respectively, except in the case of small diameter wires where this distance may be taken as equal to L_o.

NOTE: In cases where the percentage elongation after fracture is not to be determined, a distance between the grips of at least 50 mm may be used.

B3 PREPARATION OF TEST PIECES

Straightening or flattening the test specimen should be avoided but may be performed where specified in the product Standard, or in this Clause. No further deformation of any kind shall be given.

Where straightening is required, to produce an acceptable test piece but is not provided for in the product Standard, it may be carried out subject to the following constraints:

(a) It is performed at room temperature taking care to minimize stresses imposed, e.g. by the use of smooth lubricated dies.

(b) The possibility of any strain-ageing effects occurring in the test piece prior to testing is minimized by the use of appropriate storage conditions.

(c) All reported test results on test pieces so treated shall be qualified by a statement of the type:

 'This test was performed on a test piece which was cold straightened; the properties will differ from those of the product sampled'.

 NOTE: The effects of deformation and the possibility that strain-age embrittlement may be induced in many metals, will affect all tensile properties, however the effects may be especially significant on the values obtained for the yield, proof and permanent set stresses.

B4 DETERMINATION OF THE ORIGINAL CROSS-SECTIONAL AREA (S_o)

The original cross-sectional area (S_o) shall be determined to an accuracy of ±1%.

For products of circular cross-section, the original cross-sectional area may be calculated from the arithmetic mean of two measurements carried out in two perpendicular directions.

The original cross-sectional area may be determined from the mass of a known length and its density.

APPENDIX C

TYPES OF TEST PIECE TO BE USED FOR SHEETS AND FLATS OF THICKNESS EQUAL TO OR GREATER THAN 3 mm AND WIRE, BARS AND SECTIONS OF DIAMETER OR THICKNESS EQUAL TO OR GREATER THAN 4 mm

(Normative)

C1 SHAPE OF THE TEST PIECE

Sections and bars may be tested either machined or unmachined. If machined with a reduced section the parallel length shall be connected by means of transition curves to the gripped ends, which may be of any suitable shape for the grips of the test machine (see Figure 14). The minimum transition radius between the gripped ends and the parallel length shall be:

(a) 0.75*d* where *d* is the diameter of the parallel length for the cylindrical test pieces; and

(b) not less than the width of the parallel length *b* for other test pieces.

The cross-section of the test piece may be circular, square, rectangular or, in special cases, of another shape.

For test pieces with a rectangular cross-section it is recommended that the width to thickness ratio should not exceed 8:1.

The diameter of the parallel length of machined cylindrical test pieces shall be not less than 4 mm.

C2 DIMENSIONS OF THE TEST PIECE

C2.1 Parallel length of machined test piece (L_c)

The parallel length (L_c) shall be at least equal to—

(a) $L_o + \frac{d}{2}$ in the case of test pieces with circular cross-section; or

(b) $L_o + 1.5\sqrt{S_o}$ in the case of prismatic test pieces.

Depending on the type of test piece, the length $L_o + 2d$ or $L_o + 2\sqrt{S_o}$ shall be used in cases of dispute, unless there is insufficient material.

C2.2 Length of unmachined test pieces

The test piece shall be gripped in such a way that the free length between the nearest end of the gauge length, both original and extensometer, and the grip, is not less than 0.5*b* or 0.5*d*.

C2.3 Original gauge length (L_o)

C2.3.1 *Proportional test pieces*

As a general rule, proportional test pieces are used where the original gauge length (L_o) is related to the original cross-sectional area (S_o) by the equation:

$$L_o = k\sqrt{S_o}$$

Where *k* is equal to 5.65 or 11.3.

Test pieces of circular cross-section should preferably have the dimensions given in Table C1.

TABLE C1

CIRCULAR CROSS-SECTION TEST PIECES

k	Diameter d mm	Original cross-section area S_o mm^2	Original gauge length $L_o = k\sqrt{S_o}$ mm	Minimum parallel length L_c mm	Total length L_t
5.65	20 ±0.150	3.14	100 ±1.0	110	Depends on the method of fixing the test piece in the machine grips In principle: $L_t > L_c + 2d$ or $4d$
	10 ±0.075	78.2	50 ±0.5	55	
	5 ±0.040	19.6	25 ±0.25	28	

C2.3.2 *Non-proportional test pieces*

Non-proportional test pieces may be used if specified by the product Standard.

The parallel length (L_c) should not be less than $L_o + b/2$. In case of dispute, the parallel length $L_c = L_o + b/2$ shall be used there unless there is insufficient material.

Table C2 gives details of some typical test piece dimensions.

TABLE C2

TYPICAL TEST PIECE DIMENSIONS

Nominal width b mm	Original gauge length L_o mm	Parallel length (L_c) minimum mm	Approximate total length L_t mm
40	200	225	450
25	200	225	450
20	80	90	300

C3 PREPARATION OF TEST PIECES

The tolerances on the transverse dimensions of machined test pieces are given in Table C3.

An example of the application of these tolerances is given below:

(a) *Machining tolerances*

The value given in Table C3, for example ±0.075 mm for a nominal diameter of 10 mm, means that no test piece shall have a diameter outside the two values given below, if the nominal value of the original cross-sectional area (S_o) is to be included in the calculation without having to measure it:

10 + 0.075 = 10.075 mm

10 – 0.075 = 9.925 mm

(c) *Tolerances on shape*

The value given in Table C3 means that, for a test piece with a nominal diameter of 10 mm which satisfies the machining conditions given above, the deviation between the smallest and largest diameters measured shall not exceed 0.04 mm.

Consequently, if the minimum diameter of this test piece is 9.99 mm, its maximum diameter shall not exceed 9.99 + 0.04 = 10.03 mm

TABLE C3

TOLERANCES RELATING TO THE TRANSVERSE DIMENSIONS OF TEST PIECES

millimeters

Description	Nominal transverse dimension	Machining tolerance on the nominal dimension*	Tolerance on shape
Diameter of machine test pieces of circular cross-section	3	±0.05	0.025†
	> 3 ≤ 6	±0.06	0.03†
	> 6 ≤ 10	±0.075	0.04†
	> 10 ≤ 18	±0.09	0.04†
	> 18 ≤ 30	±0.105	0.05†
Transverse dimension of test pieces of rectangular cross-section machined on all four sides		Same tolerance as on the diameter of test pieces of circular cross-section	
Transverse dimensions of test pieces of rectangular cross-section machined on only two sides	3	—	0.14‡
	> 3 ≤ 6	—	0.18‡
	> 6 ≤ 10	—	0.22‡
	>10 ≤ 18	—	0.27‡
	> 18 ≤ 30	—	0.33‡
	> 30 ≤ 50	—	0.39‡

* Tolerances js 12 in accordance with AS 1654.2. These tolerances are applicable if nominal value of the original cross-sectional area (S_o) is to be included in the calculation without having to measure it.

† Tolerances IT9 — Maximum deviation between the measurement of a specified transverse dimension along the entire parallel length (L_c) of the test piece.

‡ Tolerances IT13 — Maximum deviation between the measurement of a specified transverse dimension along the entire parallel length (L_c) of the test piece.

C4 DETERMINATION OF THE CROSS-SECTIONAL AREA (S_O)

The nominal diameter may be used to calculate the original cross-sectional area of test pieces of circular cross-section which satisfy the tolerances given in Table C3. For all other shapes of test pieces, the original cross-sectional area shall be calculated from measurements of the appropriate dimensions, with an error not exceeding ±0.5% on each dimension.

APPENDIX D

TYPES OF TEST PIECE TO BE USED FOR TUBES

(Normative)

D1 SHAPE OF THE TEST PIECE

The test piece consists either of a length of tube or a longitudinal or transverse strip cut from the tube and having the full thickness of the wall tube (see Figures 15 and 16), or of a test piece of circular crosssection machined from the wall of the tube.

Machined transverse, longitudinal and circular cross-section test pieces are described in Appendix A for tube of wall thickness less than 3 mm and in Appendix C for thicknesses equal to or greater than 3 mm. The longitudinal strip is generally used for tubes with a wall thickness of more than 0.5 mm.

D2 DIMENSIONS OF THE TEST PIECE

D2.1 Length of tube

The length of tube may be plugged at both ends. The free length between each plug and the nearest gauge marks shall exceed $D/4$. In cases of dispute, the value D shall be used, as long as there is sufficient material.

The length of the plug projecting relative to the grips of the machine in the direction of the gauge marks shall not exceed D, and its shape shall be such that it does not interfere with the gauge length deformation.

D2.2 Longitudinal or transverse strip

The parallel length (L_c) of the longitudinal strips shall not be flattened but the gripped ends may be flattened for gripping in the testing machine.

Transverse or longitudinal test piece dimensions other than those given in Appendices A and C may be specified in the product Standard.

Special precautions shall be taken when straightening the transverse test pieces.

D2.3 Circular cross-section test piece machined in tube wall

The sampling of the test pieces if not specified in the product Standard shall be in accordance with Appendix J.

D3 DETERMINATION OF THE ORIGINAL CROSS-SECTIONAL AREA (S_O)

The original cross-sectional area of the test piece shall be determined to the nearest ±1 %.

The original cross-sectional area of the length of tube or longitudinal strip may be determined from the mass of the test piece, the length of which has been measured, and from its density.

The original cross-sectional area (S_o) of a test piece consisting of a longitudinal strip shall be calculated according to the following equation:

$$S_o = \frac{b}{4}\left(D^2 - b^2\right)^{1/2} + \frac{D^2}{4}\arcsin\frac{b}{D} - \frac{b}{4}\left[(D-2a)^2 - b^2\right]^{1/2} - \left(\frac{D-2a}{2}\right)^2 \arcsin\frac{b}{D-2a}$$

where

a = thickness of the tube wall, in millimetres

b = average width of the strips, in millimetres

D = external diameter, in millimetres

The following simplified equations can be used for longitudinal test pieces:

$$S_o = ab\left[1 + \frac{b^2}{6D(D-2a)}\right]$$

when $\frac{b}{D} < 0.25$;

$$S_o = ab \text{ when } \frac{b}{D} < 0.17$$

In the case of a length of tube, the original cross-sectional area (S_o) shall be calculated as follows:

$$S_o = \pi a(D - a)$$

APPENDIX E

PRECAUTIONS TO BE TAKEN WHEN MEASURING THE PERCENTAGE ELONGATION AFTER FRACTURE IF THE SPECIFIED VALUE IS LESS THAN 5%

(Informative)

A recommended method is as follows:

Prior to the test, a very small mark should be made near one of the ends of the parallel length. Using a pair of needle-pointed dividers set at the gauge length, an arc is scribed with the mark as the centre. After fracture, the broken test piece should be placed in a fixing clamp and axial compressive force applied, preferably by means of a screw, sufficient to hold the pieces firmly together during measurement. A second arc of the same radius should then be scribed from the original centre, and the distance between the two scratches measured by means of a measuring microscope or other suitable instrument. In order to render the fine scratches more easily visible, a suitable dye film may be applied to the test piece before testing.

APPENDIX F

MEASUREMENT OF PERCENTAGE ELONGATION AFTER FRACTURE BASED ON SUBDIVISION OF THE ORIGINAL GAUGE LENGTH

(Informative)

To avoid having to reject test pieces where the position of the fracture does not comply with the conditions of Clause 11.1, the following method may be used, by agreement:

(a) Before the test, sub-divide the original gauge length (L_o) into N equal parts.

(b) After the test, use the symbol X to denote the gauge mark on the shorter piece and the symbol Y to denote it on the longer piece, the subdivision of which is at the same distance from the fracture as mark X.

If n is the number of intervals between X and Y, the elongation after fracture is determined as follows:

(i) If $N - n$ is an even number [see Figure F1 (a)], measure the distance between X and Y and the distance from Y to the graduation mark Z located at

$\frac{N-n}{2}$ intervals beyond Y;

calculate the percentage elongation after fracture using the equation:

$$A = \frac{\text{XY} + 2\text{YZ} - L_o}{L_o} \times 100$$

(ii) If $N - n$ is an odd number [Figure G1(b)], measure the distance between X and Y and the distance from Y to the graduation marks Z' and Z" located respectively at

$\frac{N-n-1}{2}$ and $\frac{N-n+1}{2}$ intervals beyond Y;

calculate the percentage elongation after fracture using the equation:

$$A = \frac{\text{XY} + \text{YZ}' + \text{YZ}'' - L_o}{L_o} \times 100$$

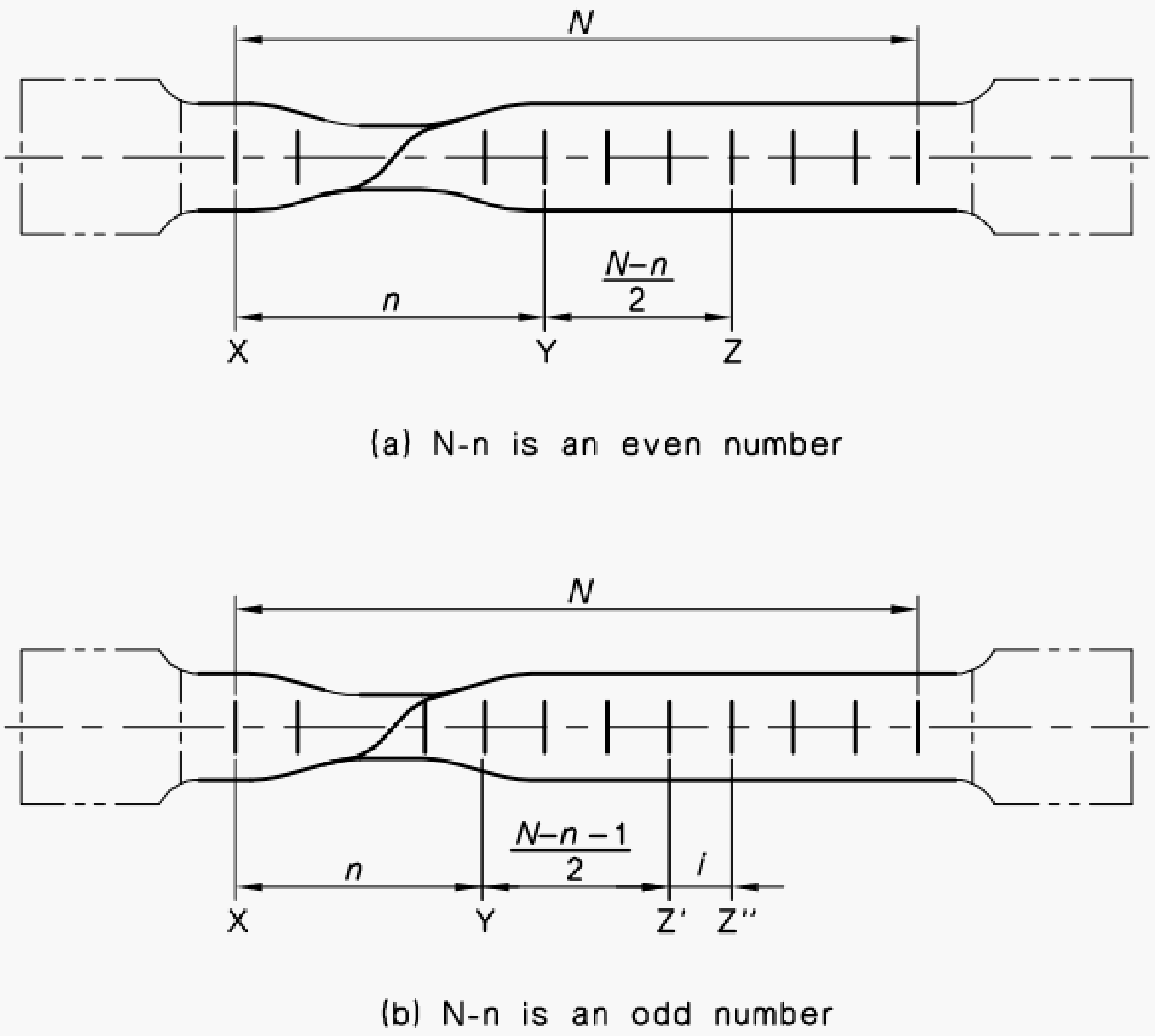


FIGURE F1 EXAMPLE OF MEASUREMENT OF PERCENTAGE ELONGATION AFTER FRACTURE

APPENDIX G

DETERMINATION OF THE PERCENTAGE PLASTIC ELONGATION WITHOUT NECKING (A_{wn}) FOR LONG PRODUCTS SUCH AS BARS, WIRE AND RODS

(Informative)

The method is to be performed on the longer part of a broken tensile test piece.

Before the test, equidistant marks are made on the gauge length, the distance between two successive marks being equal to a fraction of the initial gauge length (L'_o). The marking of the initial gauge length (L'_o) should be accurate to within ±0.5 mm. The measurement of the final gauge length after fracture (L'_u) is made on the longest broken part of the test piece and should be accurate to within 0.5 mm.

In order that the measurement is valid, the two following conditions should be met:

(a) The limits of the measuring zone should be located at least 2.5*d* from the fracture and at least 2.5*d* from the grip.

(b) The measuring gauge length should be at least equal to the value specified in the product standard.

The percentage plastic elongation without necking is calculated by the following formula:

$$A_{wn} = \frac{L'_u - L'_o}{L'_o} \times 100$$

NOTE: For many metallic materials the maximum force occurs in the range where necking starts. This means that the values for A_g and A_{wn} for these materials will be nearly equal. Large differences will be found in highly cold deformed material such as double reduced tin plate or irradiated structural steel or tests performed at elevated temperatures.

APPENDIX H

AN 'ERROR BUDGET' APPROACH TO THE ESTIMATION OF THE UNCERTAINTY OF MEASUREMENT IN TENSILE TESTING

(Informative)

H1 INTRODUCTION

An approach for estimating the uncertainty of measurements is outlined based upon the 'error budget' concept using the measurement tolerances specified in the testing and calibration standards. It should be noted that it is not possible to calculate a single value for the measurement uncertainty for all materials since different materials exhibit different response characteristics to some of the specified control parameters, e.g. straining rate or stressing rate. The error budget presented here could be regarded as an upper limit to the measurement uncertainty for a laboratory undertaking testing in compliance with this Standard (Grade A machine and Grade D extensometer).

It should be noted that when evaluating the total scatter in experimental results the uncertainty in measurement should be considered in addition to the inherent scatter due to material inhomogeneity.

H2 ESTIMATION OF UNCERTAINTY

H2.1 Material independent parameters

The manner in which errors from a variety of sources should be added together has been treated in considerable detail and more recently guidance has been given on assessing precision and uncertainty in ISO 5725-2.

In the following analysis the conventional least mean squares approach has been used.

The tolerances for the various testing parameters for tensile properties are given in Table H1 together with expected uncertainty. Because of the shape of the stress-strain curve, some of the tensile properties in principle can be determined with a higher degree of precision than others, e.g. the upper yield strength R_{eH} is only dependent on the tolerances for measurement of force and cross sectional area, whilst proof strength, R_p, is dependent on force, strain (displacement), gauge length and cross-sectional area. In the case of reduction in area, Z, the measurement tolerance for cross-sectional area both before and after fracture needs to be considered.

TABLE H1

SUMMARY OF MAXIMUM ADMISSIBLE MEASUREMENTS UNCERTAINTIES FOR DETERMINING TENSILE TEST DATA

Parameter	Tensile properties, % error					
	R_{eH}	R_{eL}	R_m	R_p	A	Z
Force	1	1	1	1	—	—
Strain* (displacement)	—	—	—	1	1	—
Gauge length, L_o*	—	—	—	1	1	—
S_o	1	1	1	1	—	1
S_u	—	—	—	—	—	2
Expected uncertainty	$\pm\sqrt{2}$	$\pm\sqrt{2}$	$\pm\sqrt{2}$	$\pm\sqrt{4}$	$\pm\sqrt{2}$	$\pm\sqrt{5}$

* Assuming a Grade D extensometer calibrated in accordance with AS 1545.

NOTE: Error summation using least-mean squares.

H2.2 Material dependent parameters

For room temperature tensile testing, the only tensile properties significantly dependent upon the materials response to the straining rate (or stressing rate) control parameters are R_{eH}, R_{eL} and R_p. Tensile strength, R_m, can also be strain rate dependent, however in practice it is usually determined at a much higher straining rate than R_p and is generally less sensitive to variations in strain rate.

In principle, it will be necessary to determine any material's strain rate response before the total error budget can be calculated. Some limited data are available and the following examples may be used to estimate uncertainty for some classes of materials.

Typical examples of data sets used to determine materials' response over the strain rate range specified in this Standard are shown in Tables H2 and H3 and a summary of materials' response for proof stress for a number of materials measured under strain rate control is given in Table H2.

TABLE H2

EXAMPLES OF VARIATION IN ROOM TEMPERATURE PROOF STRESS OVER THE STRAIN RATE RANGE PERMITTED IN THIS AUSTRALIAN STANDARD

Material	Nominal composition	$R_{p0,2}$ Mean value MPa	Proof stress strain rate response %	Equivalent tolerance %
Ferritic steel				
Pipe steel	Cr-Mo-V-Fe(bal)	680	0.1	±0.05
Plate steel	C-Mn-Fe(bal)	315	1.8	±0.9
Austenitic steel				
(X5 17Cr, 12Ni, 2Mo)	17Cr, 11Ni-Fe(bal)	235	6.8	±3.4
Nickel base alloys				
Ni Cr 20 Ti	18Cr, 5Fe, 2Co-Ni(bal)	325	2.8	±1.4
Ni Cr CoTi Al 25-2	24Cr, 20Co, 3Ti, 1,5Mo, 1, 5AI-Ni(bal)	790	1.9	±0.95

H2.3 Total measurement uncertainty

The material-dependent response of proof strength over the permitted strain rate range specified in Table H2 may be combined with the material independent parameters specified in Table H1 to give a total estimate of uncertainty for the various materials indicated, as shown in Table H3.

For the purpose of this analysis, the total value of the variation in proof strength over the strain rate range permitted in the standard has been halved and expressed as an equivalent tolerance, i.e. for X5 17Cr, 12Ni, 2Mo stainless steel, the proof strength can vary by 6.8% over the permitted strain rate range so it is equivalent to a tolerance of +3.4%. Therefore for X5 17Cr, 12Ni, 2Mo stainless steel, the total uncertainty is given by:

$$\sqrt{2^2 + 3.4^2}\,6 = \pm\sqrt{15.6} = \pm 3.9\%$$

TABLE H3

EXAMPLES OF TOTAL EXPECTED MEASUREMENT UNCERTAINTY FOR ROOM TEMPERATURE PROOF STRENGTH DETERMINED IN ACCORDANCE WITH THIS AUSTRALIAN STANDARD

Material	$R_{p0,2}$ Mean value MPa	Values from Table H1 %	Values from Table H2 %	Total expected measurement uncertainty %
Ferritic steel				
Pipe steel	680	±2	0.05	$\sqrt{4.0} = \pm 2.0$
Plate steel	315	±2	0.9	$\sqrt{4.8} = \pm 2.2$
Austenitic steel				
(X5 17Cr, 12Ni, 2Mo)	235	±2	3.4	$\sqrt{15.6} = \pm 3.9$
Nickel base alloys				
Ni Cr 20 Ti	325	±2	1.4	$\sqrt{6.0} = \pm 2.4$
Ni Cr CoTi Al 25-20	790	±2	0.95	$\sqrt{4.9} = \pm 2.2$

H3 CONCLUDING REMARKS

A method of calculating the measurement uncertainty for room temperature tensile testing using an 'Error Budget' concept has been outlined and examples given for a few materials where the material response to the testing parameters is known. In addition, there are other factors that can affect the measurement of tensile properties such as test piece bending, methods of gripping the test piece, or the testing machine control mode, i.e. extensometer control or load/crosshead control which may affect the measured tensile properties. However since there is insufficient quantitative data available it is not possible to include their effects in error budgets at present. It should also be recognized that this error budget approach only gives an estimate of the uncertainty due to the measurement technique and does not make an allowance for the inherent scatter in experimental results attributable to material inhomogeneity.

Finally, it should be appreciated that when suitable reference materials become available they will offer a useful means of measuring the total measurement uncertainty on any given testing machine including the influence of grips, bending, etc. which at present have not been quantified.

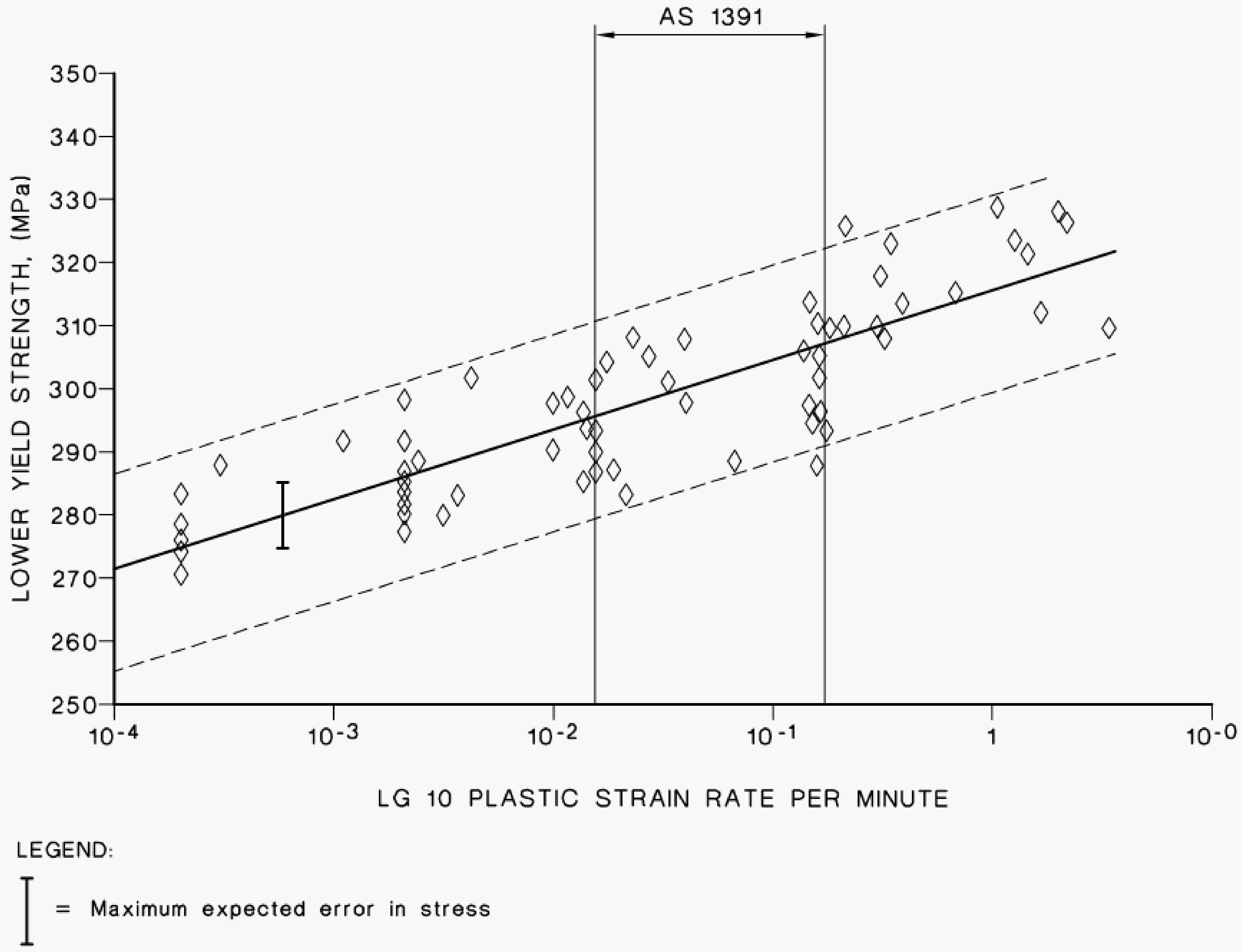


FIGURE H1 VARIATION OF LOWER YIELD STRENGTH (R_{eL}) AT ROOM TEMPERATURE AS A FUNCTION OF STRAIN RATE, FOR PLATE STEEL

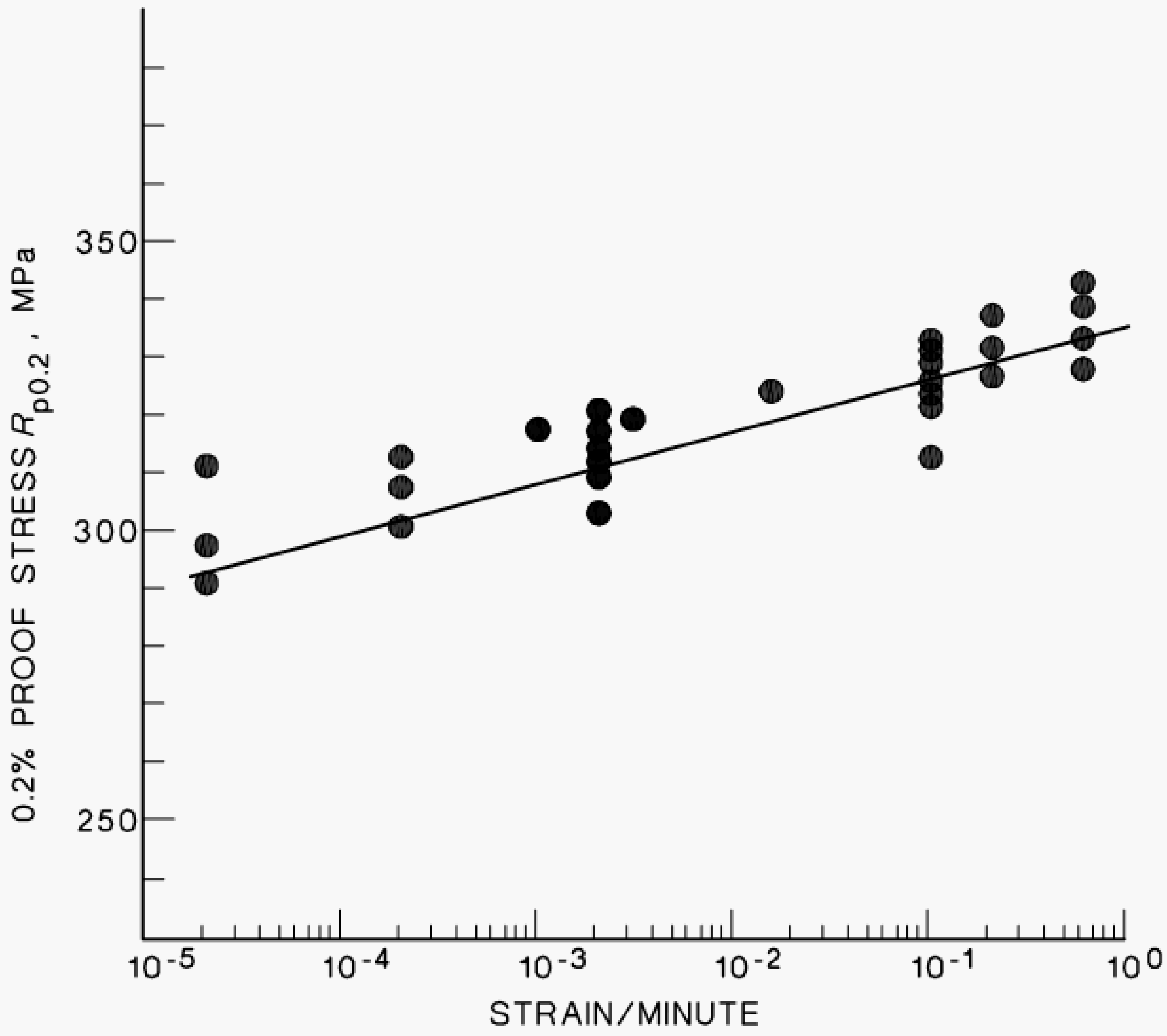


FIGURE H2 TENSILE TEST DATA AT 22°C FOR Ni, Cr, 20,Ti.

APPENDIX I

DESIGNATION OF TEST PIECE AXES

(Normative)

I1 SCOPE

This Appendix specifies a method for the identification of test piece axes in relation to the grain flow, by means of a system of co-ordinates.

The system presented is only intended to be applied in situations where a uniform grain flow can be unambiguously identified (see Paragraph I3.2).

NOTE: The mechanical properties of a metallic product, especially those characterizing its deformability and toughness, such as elongation after fracture, reduction of area, fracture toughness and impact resistance, are dependent on the position in the product of the test piece on which these properties are measured. This Standard provides a method for designating the position of the test piece in relation to product grain flow and its effect on these properties.

I2 DESIGNATORY SYSTEM

I2.1 Method of designation

The method of designation is based on the assumption that a system of co-ordinates is laid into a metallic product so that:

(a) The X-axis is coincident with the main direction of grain flow.

(b) The Z-axis is coincident with the direction of the main working force.

(c) The Y-axis is normal to the X-and Z-axis.

I2.2 Application of this system

When applying this system to actual products, the following additional conditions shall obtain:

(a) All test pieces normal to the grain flow of products whose grain flow has only one direction, so that in accordance with the above definition, Y and Z test pieces are equivalent, are called Z test pieces.

(b) In cylindrical sections with an axial grain flow, the radial direction is the Z-axis.

(c) All test pieces parallel to the surface of sheets processed with the same degree of deformation in two directions normal to each other so that, in accordance with the above definition, X and Y test pieces are equivalent are called Y test pieces.

I2.3 Position

This system offers the possibility of accurately designating all the positions of test pieces which may occur, and positions which do not coincide with any of the three axes of the system of co-ordinates can also be defined by a simple combination of the relative letters, see Figures I1 to I5.

Examples of this system are as follows:

(a) A test piece taken parallel to the grain flow of a bar (geometrically a longitudinal test piece) is an X test piece (or lies in the direction of X).

(b) A test piece taken normal to the grain flow (lamella) of a sheet so that its axis coincides with the broad side of the lamella (geometrically a transverse test piece) is a Y test piece (or lies in the direction of Y).

(c) A test piece whose axis lies through the thickness of a plate (short transverse test piece) is a Z test piece.

(d) Test pieces taken either longitudinally or transversely from a (thin-walled) tube with helical grain flow are X-Y test pieces.

NOTE: The examples given in I2.3 may be taken from Figures I1 to I5. It should, however, be noted that the scale of reproduction of these drawings is not the same in all cases and that the place where the test pieces are taken and the actual sampling do not always apply in practice. These drawings, and especially the positions of the test pieces, have been idealized so as to show as clearly as possible the various methods of designating the test piece position by the system of X-Y-Z co-ordinates.

I3 APPLICATION OF DESIGNATORY SYSTEM TO PROPERTIES LISTED IN MATERIAL SPECIFICATIONS

I3.1 Application

The position of the test piece in relation to the grain flow is only one of the characteristics required for ascertaining the properties which may be obtained. Moreover, the position of a test piece relative to the grain flow is only sufficiently defined in simple products whose production and processing are well known.

I3.2 Limits of application

The system described may be used to designate the position of test pieces relative to the direction of the grain flow whenever a uniform grain flow direction can be identified. In all other cases, the location of the test piece shall be related to component geometry and marked on a drawing of the same, together with a brief description of the method of production of the component (i.e. casting, upset forging, etc.).

The position of the test pieces in actual products shall be taken from the relevant material specifications.

The cases in which various products may be compared depend on the circumstances and may differ, to a varying extent, from one another. Thus definite numerical relations of the property values which have been obtained in this way for various classifications of the position of the test piece in relation to the grain flow apply to the particular case only and may not be generalized.

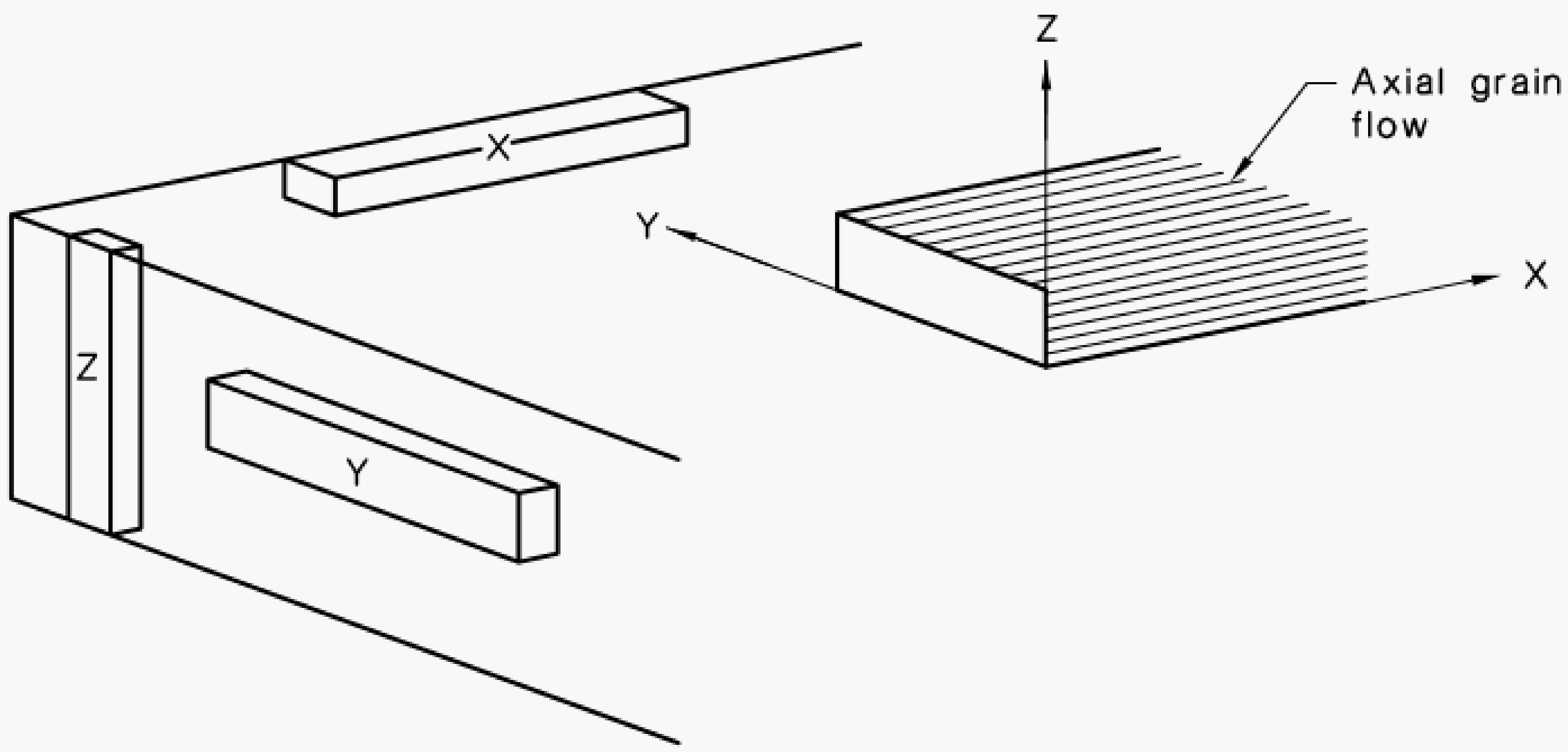


FIGURE I1 DESIGNATION OF TEST PIECES

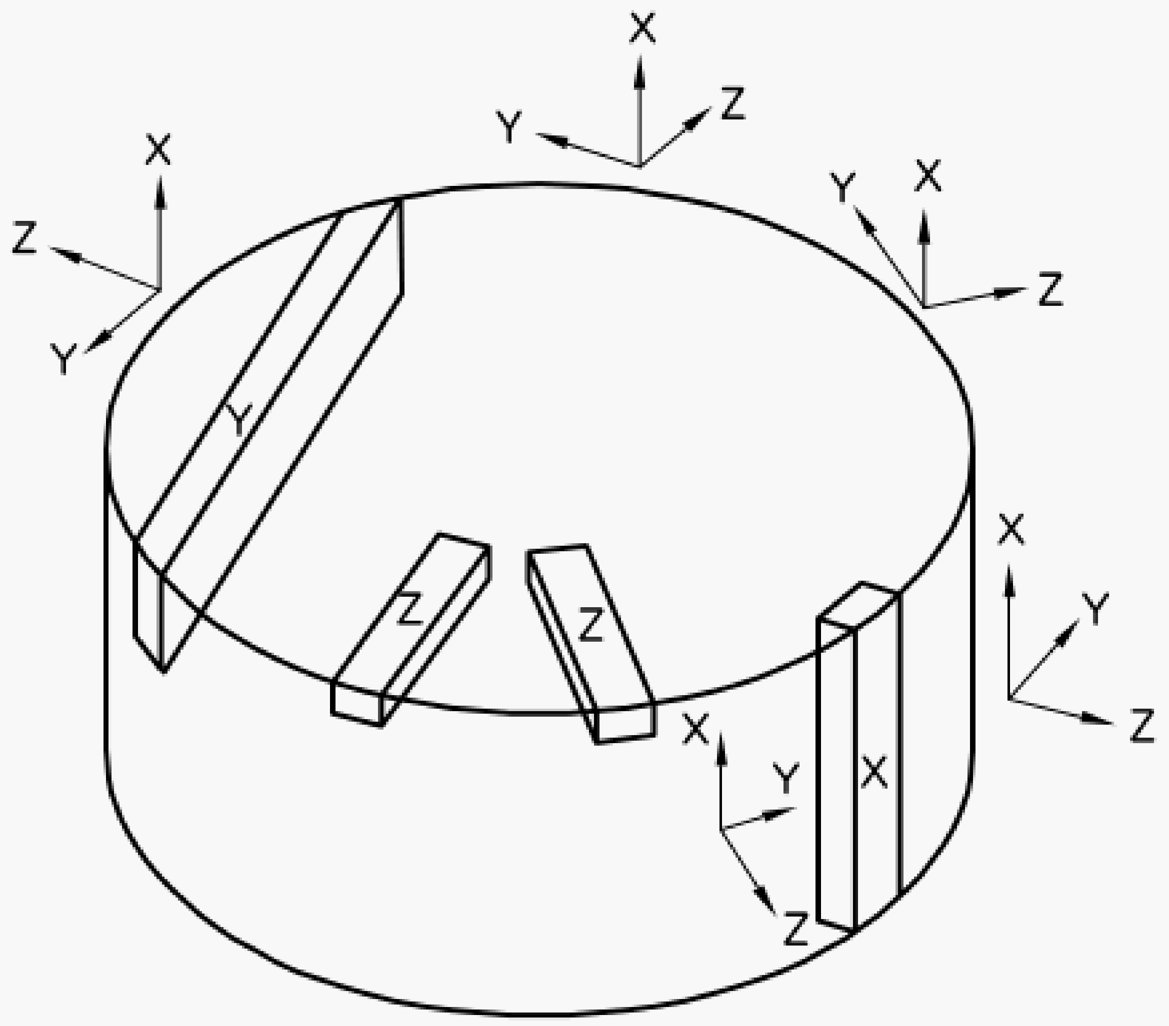


FIGURE I2 CYLINDRICAL SECTION (AXIAL GRAIN FLOW)

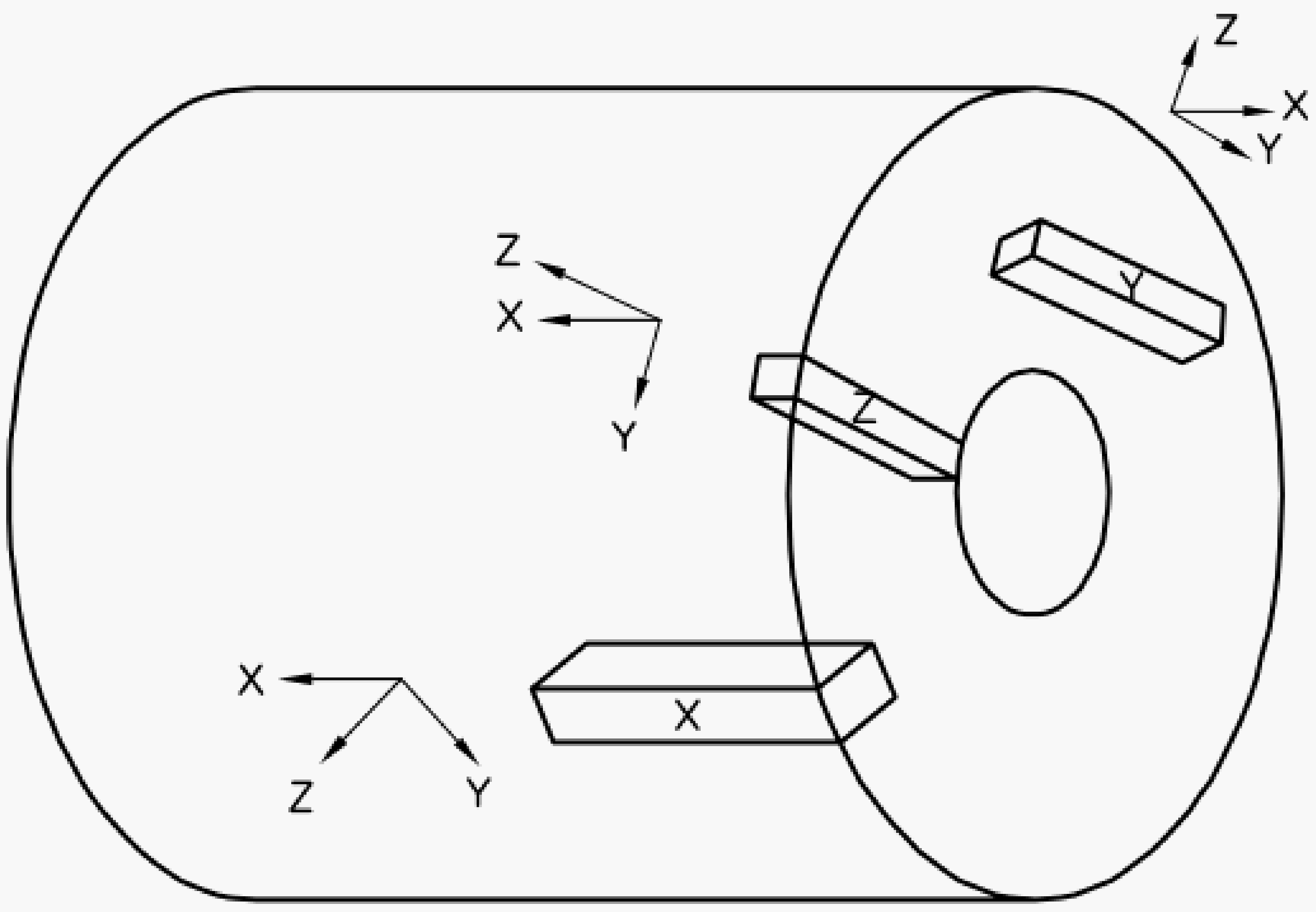


FIGURE I3 TUBE (AXIAL GRAIN FLOW)

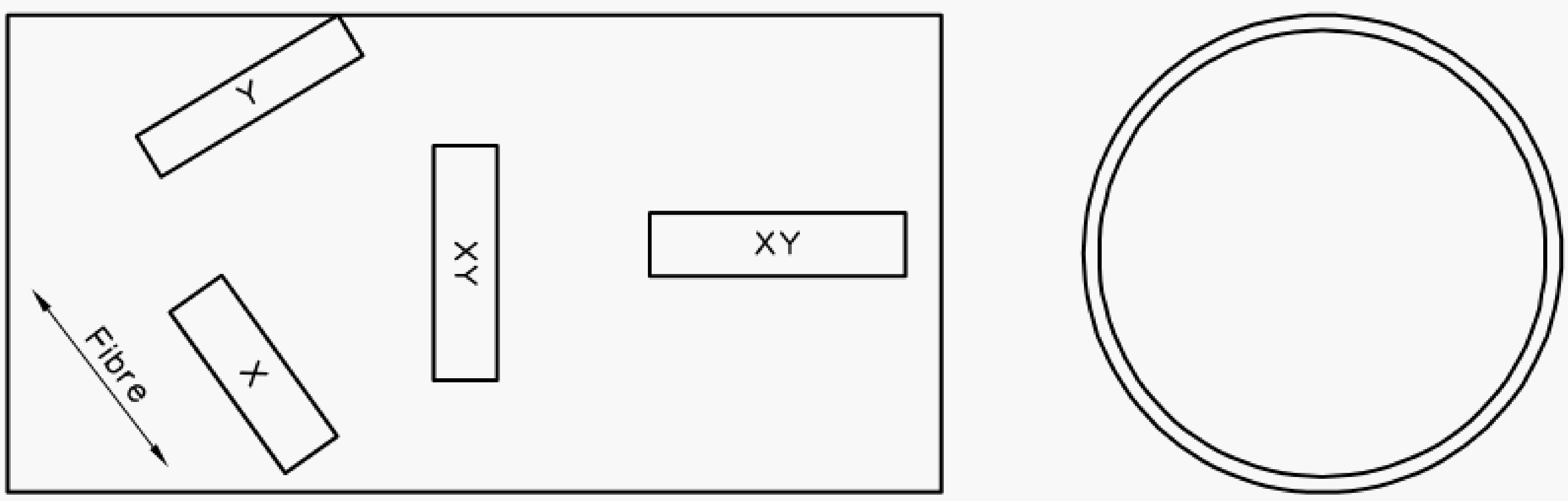


FIGURE I4 THIN-WALLED TUBE WITH HELICAL GRAIN FLOW

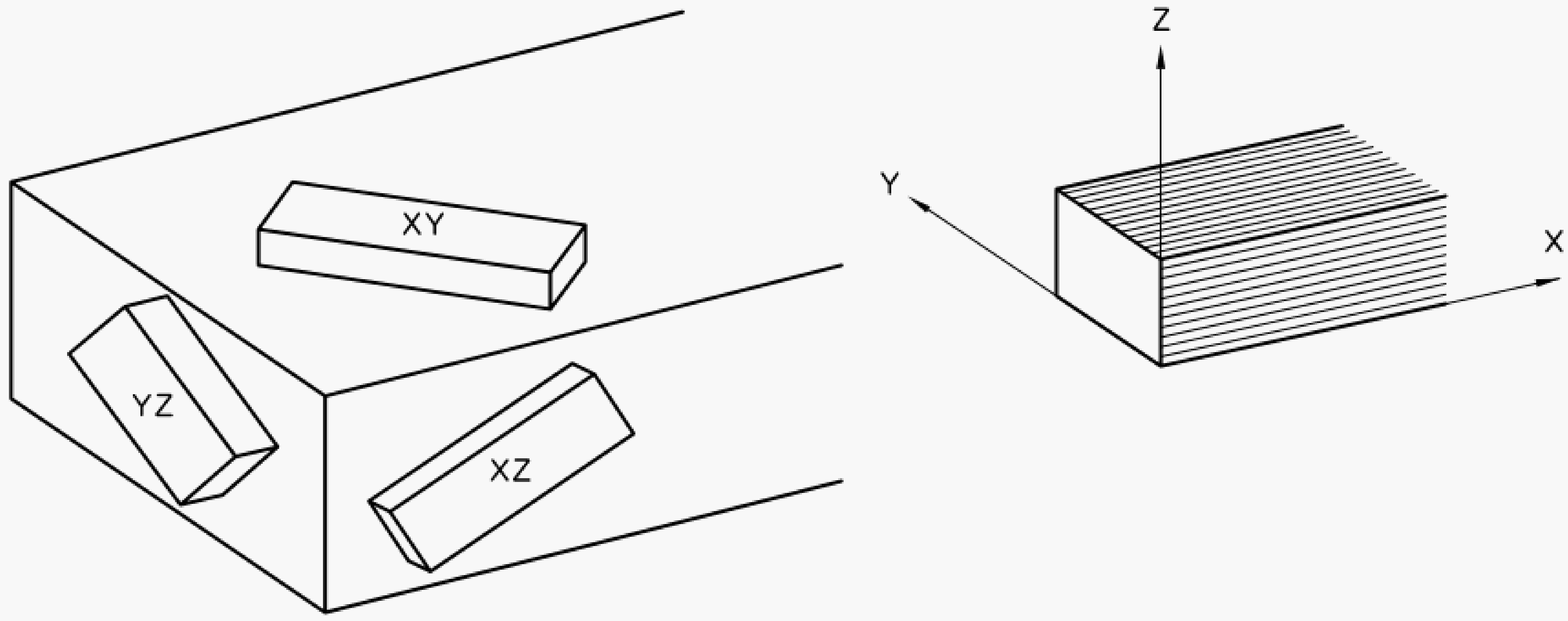


FIGURE I5 NON-BASIC FLAT PRODUCT

APPENDIX J

LOCATION AND PREPARATION OF SAMPLES AND TEST PIECES

(Normative)

J1 SCOPE

This Appendix specifies requirements for the identification, location and preparation of samples and test pieces intended for mechanical tests on steel sections, bars, rod, flat products and tubular products.

NOTES:

1 If agreed in the order this Standard may also apply to other metallic products.

2 It does not apply to non-destructive tests.

These samples and test pieces are for use in tests which are carried out in conformity with the methods specified in the product or material standard or, in the absence of this, in the test Standard.

Where the requirements of the order or product Standard differ from those given in this Appendix, then the requirements of the order or product Standard apply.

J2 GENERAL REQUIREMENTS

J2.1 Representative testing

Samples, rough specimens and test pieces selected in accordance with Paragraph J5, shall be considered to be representative of the product.

NOTE: As a result of their production sequence i.e. melting, casting, hot and/or cold forming, heat treatment etc., steel products are not homogeneous. The mechanical properties of samples taken from other locations may be different.

J2.2 Identification of sample products, samples, rough specimens and test pieces

Sample products, samples, rough specimens and test pieces shall be marked to ensure traceability to the original product and their location and orientation in that product. For this purpose, if, during the preparation of the sample, rough specimen and/or test pieces, removal of the marks cannot be avoided, transfer of these marks shall be carried out before the existing marks are removed or in the case of automatic preparation equipment before the test piece is removed from the equipment. In the case of specific inspection and testing and where requested by the purchaser the transfer of the marks shall be carried out in the presence of the purchaser's representative.

In the case of fully automatic in line preparation and testing systems, marking of samples, rough specimens and test pieces is not necessary if an adequate control system exists, which clearly defines the procedures to be followed in the event of system failure.

J3 PREPARATION OF SAMPLES AND SELECTION OF TEST PIECES

J3.1 Selection and dimensions of samples and location of test pieces

The sample shall be selected so that the test piece can be located as indicated in Paragraph J5. The sample shall have sufficient dimensions to allow sufficient test pieces required for carrying out specified tests, and for any retests which may be necessary.

J3.2 Direction of axis of test pieces

The direction of the test piece axis relative to the principle direction of working shall be as specified in the appropriate product Standard or order. The designation of the test piece axis shall be in accordance with Appendix I.

J3.3 Condition and separation of samples

J3.3.1 *General*

The material or product Standard shall specify whether the test is intended to determine the properties—

(a) in the as-delivered condition (see Paragraph J3.3.2); or

(b) in the reference condition (see Paragraph J3.3.3).

J3.3.2 *Testing in the as-delivered condition*

A sample intended for testing in the as-delivered condition shall be separated from the product either—

(a) after the forming and heat treatment processes have been completed; or

(b) before the heat treatment process, in which case the heat treatment of the separated sample shall be carried out under the same conditions as that of the product.

Separation of the sample shall be carried out in such a manner so as not to change the characteristics of that part of the sample used to provide the test pieces.

Where flattening or straightening of the sample is unavoidable in the preparation of the test piece, it shall be carried out cold unless otherwise specified in the product Standard.

J3.3.3 *Testing in the reference condition*

J3.3.3.1 *Sample*

A sample intended for testing in the reference condition shall be separated from the product at the stage of manufacture specified in the product standard or order.

Separation of the sample shall be carried out in such a manner so as not to change the characteristics of that part of the sample used to provide the test pieces after heat treatment.

NOTE: When flattening or strengthening is necessary it may be carried out either hot or cold before any heat treatment. When carried out hot it should be at a temperature below the final heat treatment temperature.

J3.3.3.2 *Rough specimen*

A rough specimen intended for testing in the reference condition shall be prepared as follows.

(a) *Mechanical treatment prior to heat treatment*

When the sample is to be made smaller for the process of heat treatment, the product standard shall specify the dimensions to which the rough specimen shall be reduced and the reduction process e.g. forging, rolling, machining.

(b) *Heat treatment*

The heat treatment of the rough specimen shall take place in an environment where the uniformity of the temperature is adequately assured and the temperature is measured by means of a calibrated instrument. The heat treatment shall be in accordance with the requirements of the product Standard or of the order.

J4 PREPARATION OF TEST PIECES

J4.1 Cutting and machining

Cutting and machining of samples and rough specimens for the preparation of test pieces shall be carried out taking such precautions as necessary to avoid superficial work hardening and heating of the material likely to change the mechanical characteristics. After machining, any marks left by the tool which might interfere with the results of the test shall be removed, either by grinding (with ample coolant supply) or by polishing, provided that the chosen method of finishing maintains the dimensions and shape of the test piece within the tolerances specified in the Standard for the appropriate test.

The tolerances on the dimensions of the test pieces shall be those specified in the appropriate test methods.

J4.2 Reference heat treatment

When the required reference heat treatment is to be carried out on the test piece the provisions for heat treatment shall be the same as for the rough specimen (see Paragraph J3.3.3.2(b)).

J5 LOCATION OF SAMPLES AND TEST PIECES

J5.1 General

This Appendix applies to the location of test pieces for the following product forms:

(a) Sections.

(b) Bars and rod.

(c) Flat products.

(d) Tubular products.

The location of test pieces for tensile tests are indicated in Figures J1 to J8.

Where more than one test piece is required they may be placed adjacent to each other in the location specified.

J5.2 Sections

J5.2.1 *Location of test pieces across the width of section*

The location of test pieces shall be in accordance with Figure J1.

NOTES:

1 For sections with tapered flanges; if agreed at the time of enquiry and ordering the sample may be taken from the web see Figure J1 (b) and (d) or the sample from the tapered flange may be machined.

2 For unequal leg angles, samples may be taken from either leg.

J5.2.2 *Location of test pieces in thickness of section*

The location of tensile test pieces shall be in accordance with Figure J2. Full thickness test pieces (see Figure J2(a)) shall be used whenever machining and test equipment allows.

J5.3 Rounds bars and rods

The location of tensile test pieces shall be selected in accordance with Figure J3. Full section test pieces (see Figure J3(a)) shall be used whenever machining and test equipment allows.

J5.4 Hexagonal bar

The location of tensile test pieces shall be selected in accordance with Figure J4.

Full section test pieces (see Figure J4(a)) shall be used wherever machining and test equipment allows.

J5.5 Rectangular bar

The location of tensile test pieces shall be in accordance with Figure J5.

Full section or rectangular test pieces see Figures J5(a), (b) or (c) shall be used whenever machining and test equipment allow.

J5.6 Flat products

The location of tensile test pieces shall be in accordance with Figure J6.

Full section test pieces (see Figure J6(a)) shall be used whenever machining and test equipment allow.

Where transverse tensile test pieces are specified and the width of flat product is not sufficient to take the test piece from the $W/4$ location, then the centre of the test piece shall be as near to $W/4$ as possible.

J5.7 Tubular products

The location of tensile test pieces shall be selected in accordance with Figure J7. Full section test pieces (Figure J7(a)) shall be used whenever machining and test equipment allow.

For welded tubes, when testing the weld using strip test pieces, the weld shall be at the centre of the test piece.

If not specified in the product Standard or in the order the sampling position is at the discretion of the manufacturer.

J5.8 Rectangular hollow sections

The location of tensile test pieces shall be in accordance with Figure J8. Full section test pieces (see Figure J8(a)) shall be used whenever machining and test equipment allow.

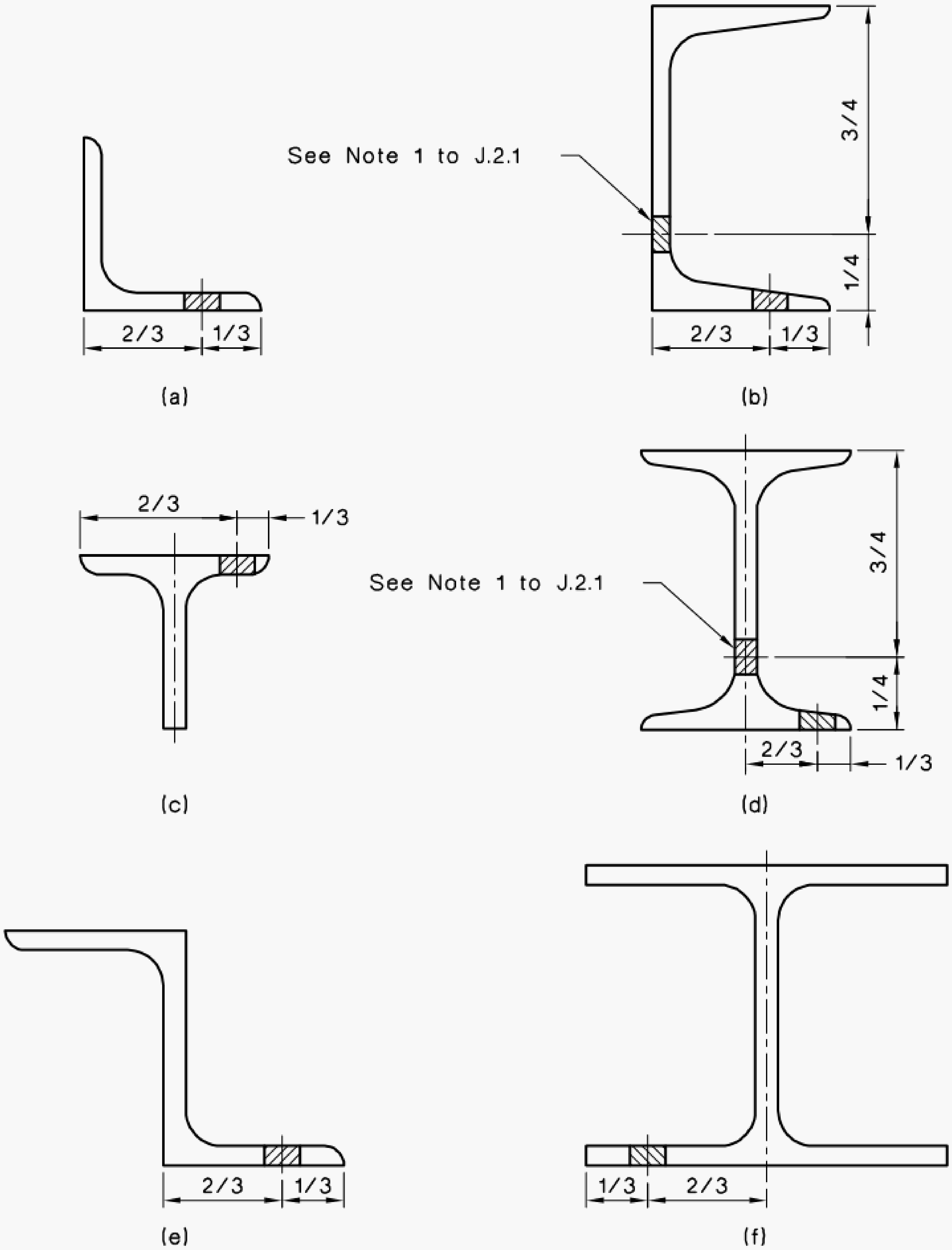
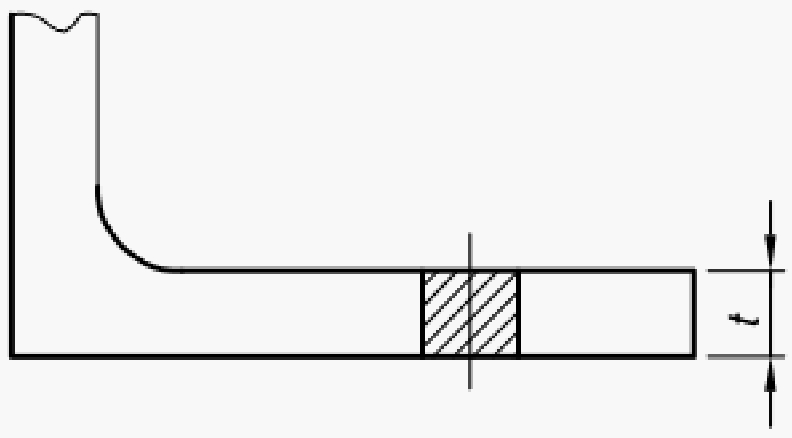
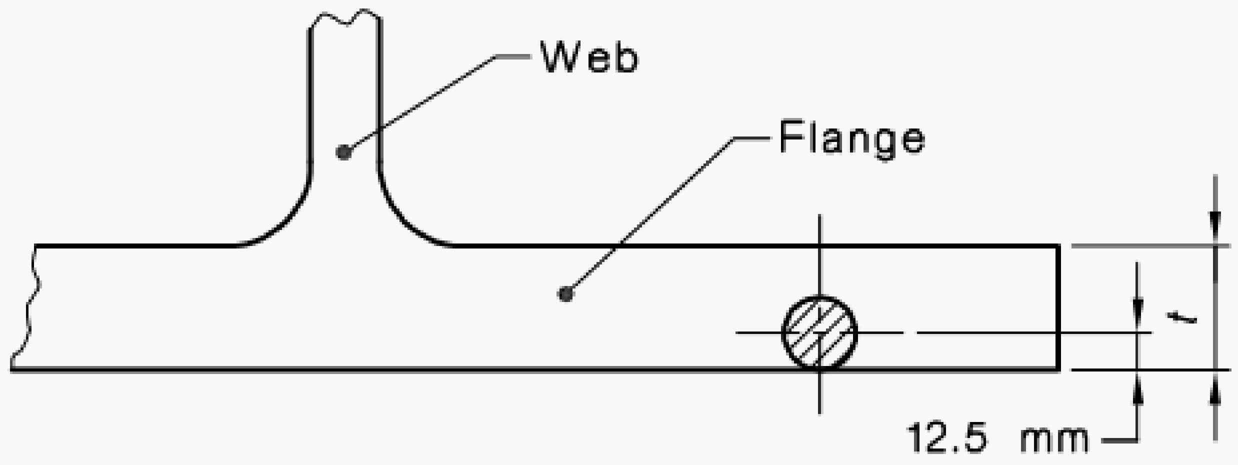


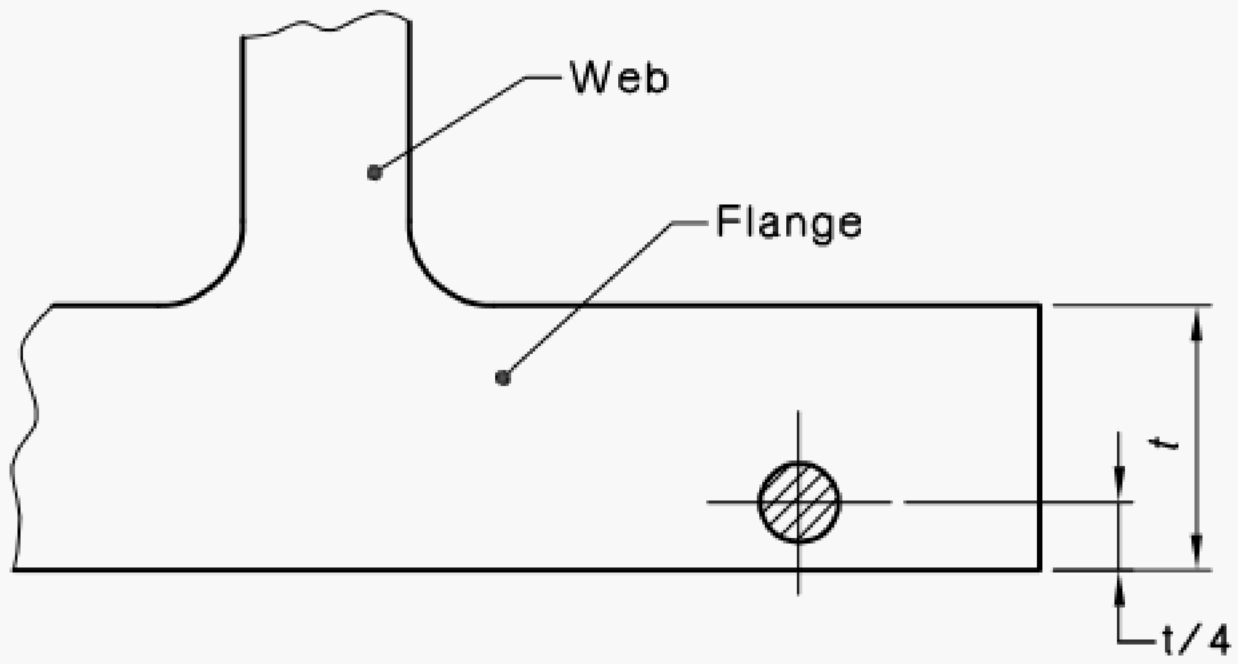
FIGURE J1 SECTIONS—LOCATION OF TEST PIECES FOR TENSILE TESTING IN A FLANGE OR WEB



(a) Full thickness test piece where $t \leqslant 50$ mm



(b) Round test piece where $t \leqslant 50$ mm

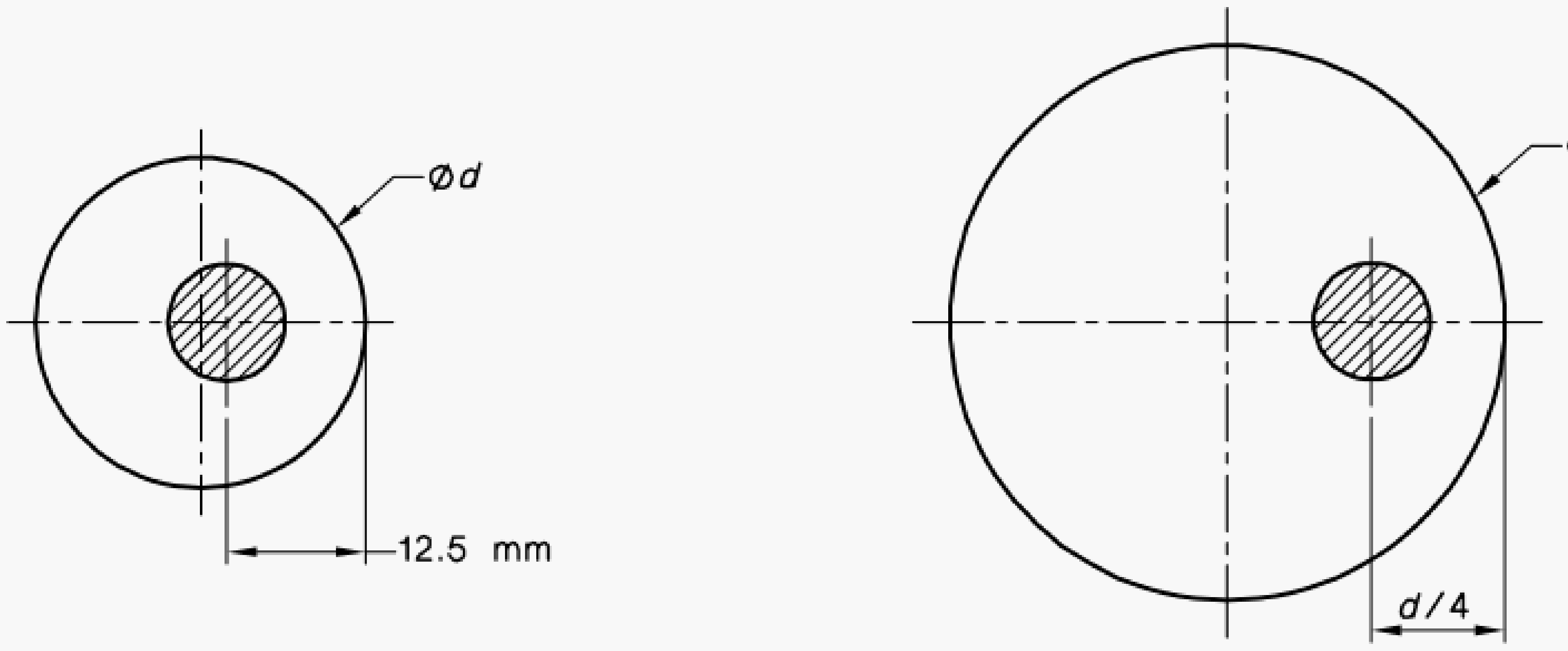


(c) Round test piece where $t > 50$ mm

FIGURE J2 SECTIONS—LOCATION OF TEST PIECES FOR TENSILE TESTING IN THE THICKNESS OF FLANGE

(a) Full section test piece

(b) Round test piece where $d \leqslant 25$ mm



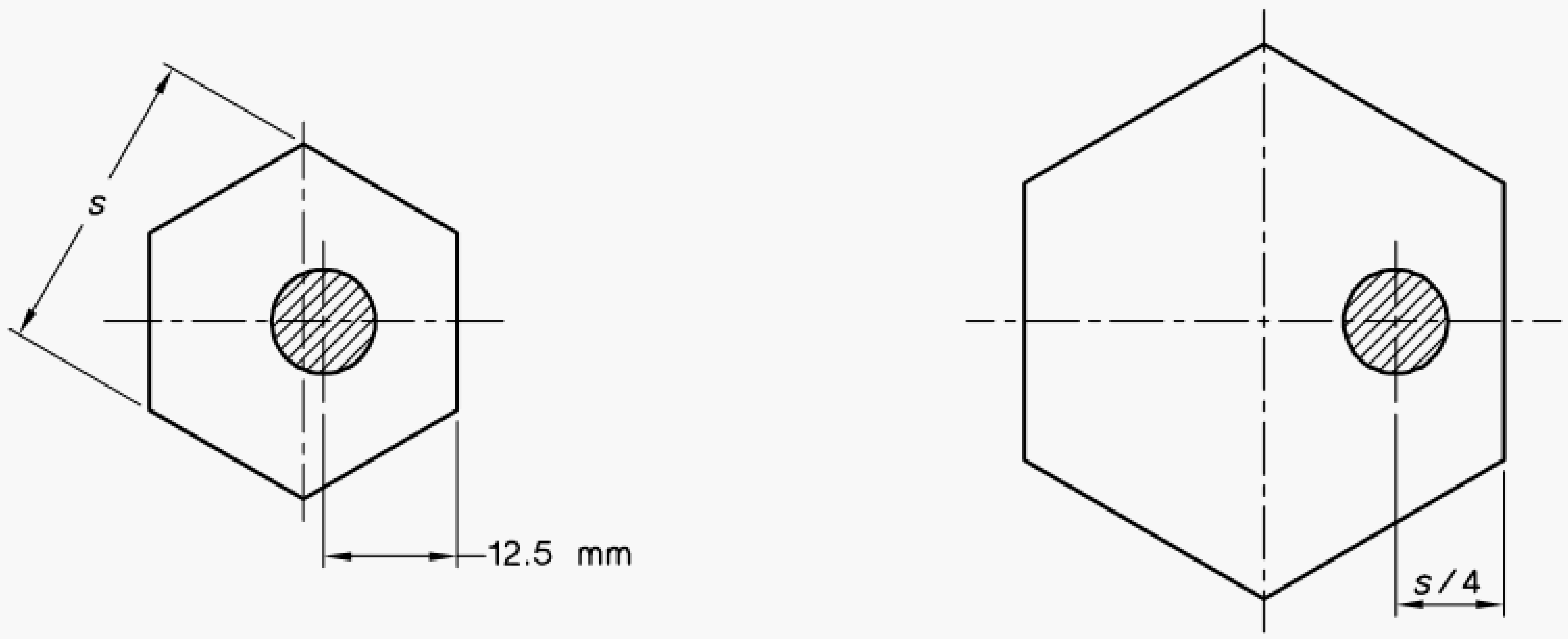
(c) Round test piece where $d > 25$ mm and $\leqslant 50$ mm

(d) Round test piece where $d > 50$ mm

FIGURE J3 ROUND BAR AND ROD—LOCATION OF TEST PIECES FOR TENSILE TESTING

(a) Full section test piece

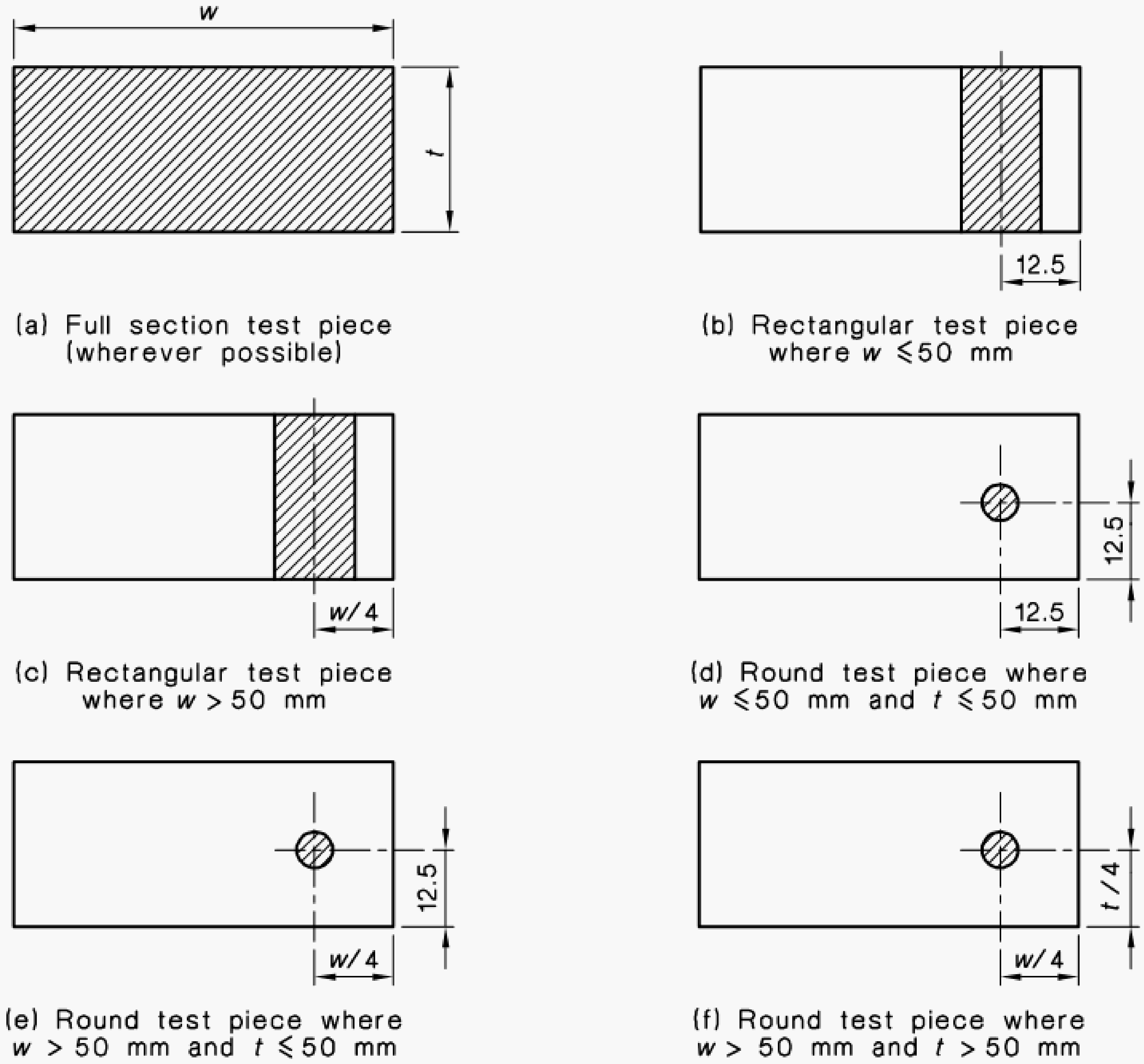
(b) Round test piece where $s \leqslant 25$ mm



(c) Round test piece where $s > 25$ mm and $\leqslant 50$ mm

(d) Round test piece where $s > 50$ mm

FIGURE J4 HEXAGONAL BAR—LOCATION OF TEST PIECES FOR TENSILE TESTING



(a) Full section test piece (wherever possible)

(b) Rectangular test piece where $w \leqslant 50$ mm

(c) Rectangular test piece where $w > 50$ mm

(d) Round test piece where $w \leqslant 50$ mm and $t \leqslant 50$ mm

(e) Round test piece where $w > 50$ mm and $t \leqslant 50$ mm

(f) Round test piece where $w > 50$ mm and $t > 50$ mm

FIGURE J5 RECTANGULAR BAR—LOCATION OF TEST PIECES FOR TENSILE TESTING

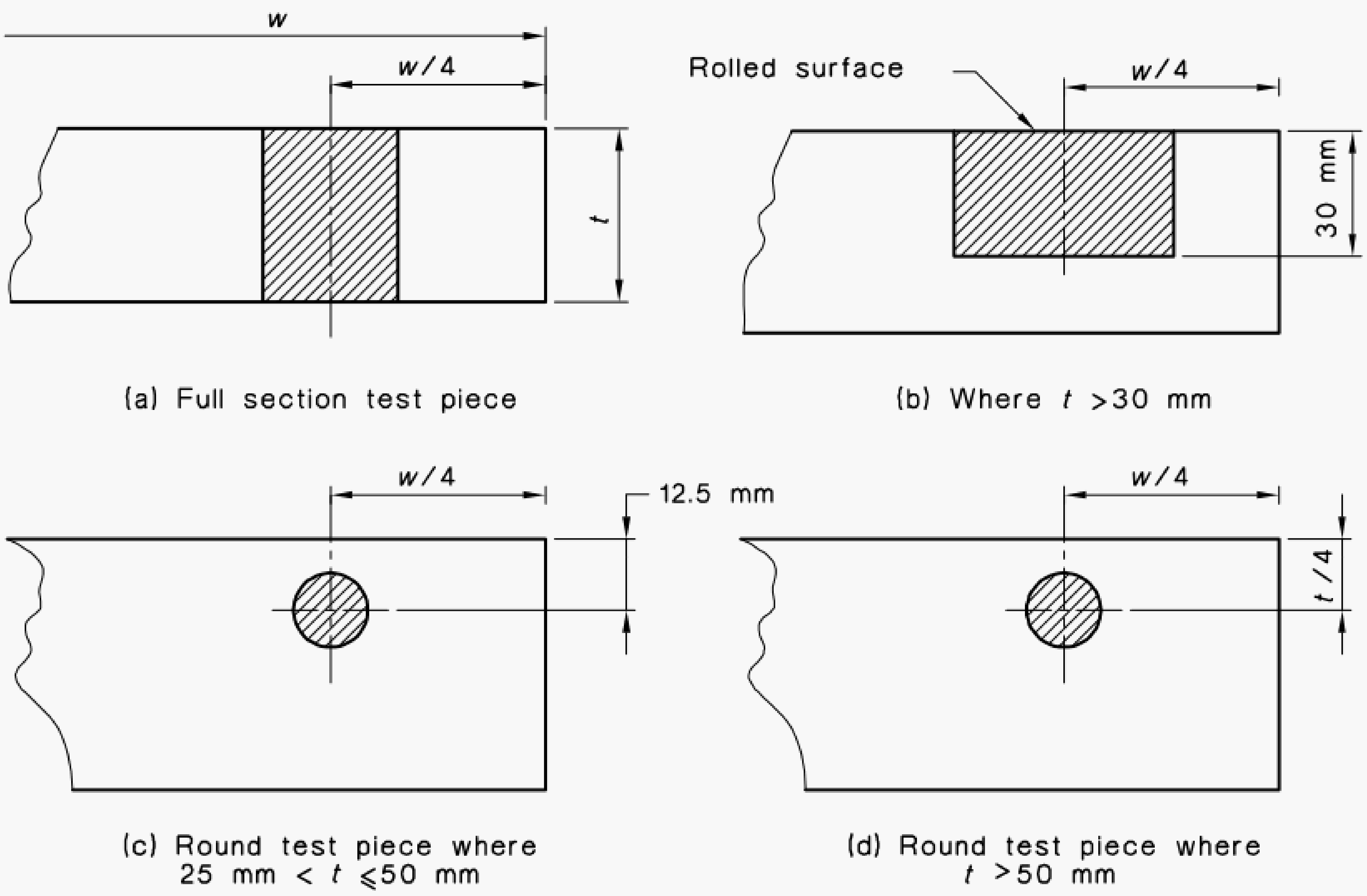
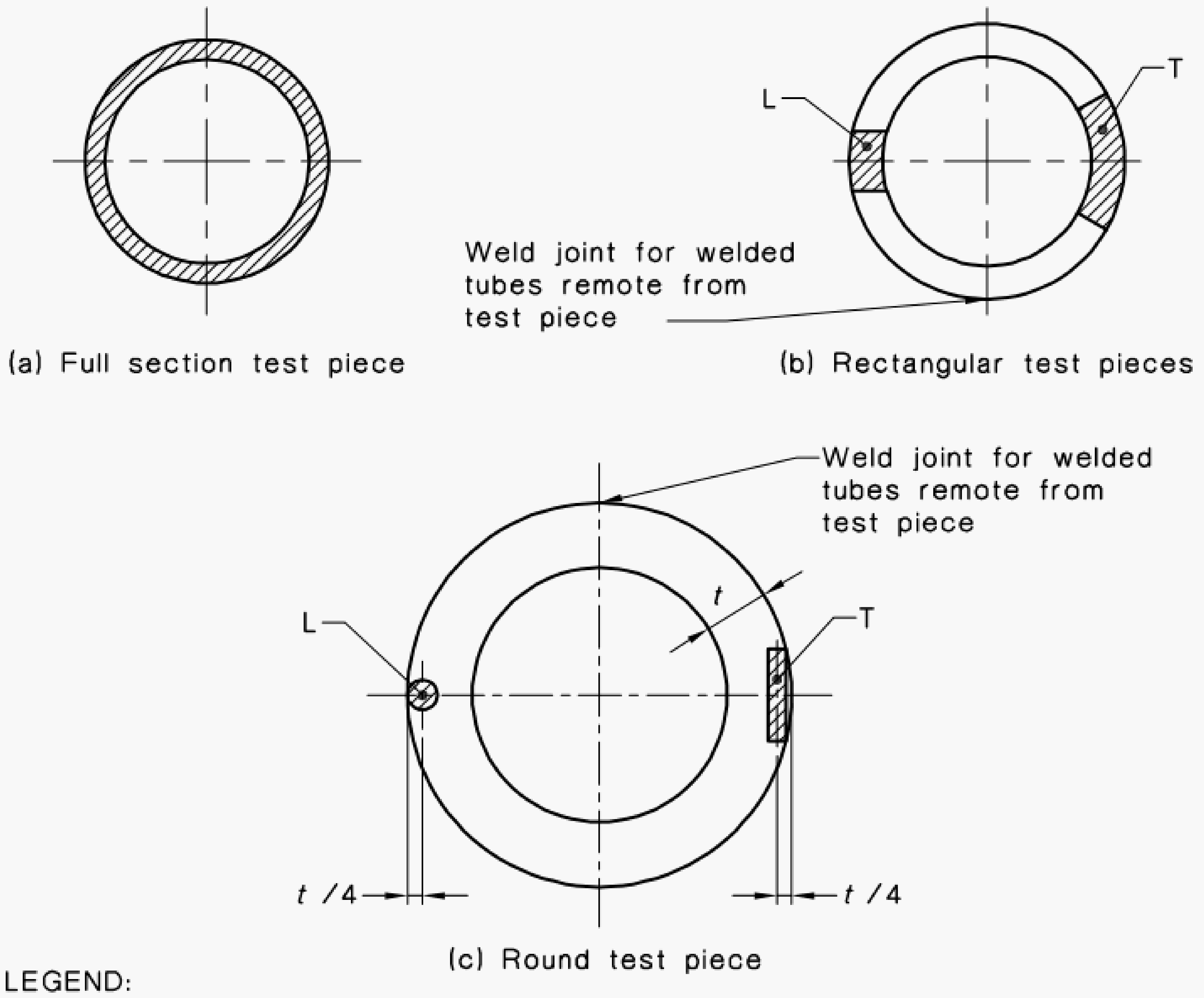
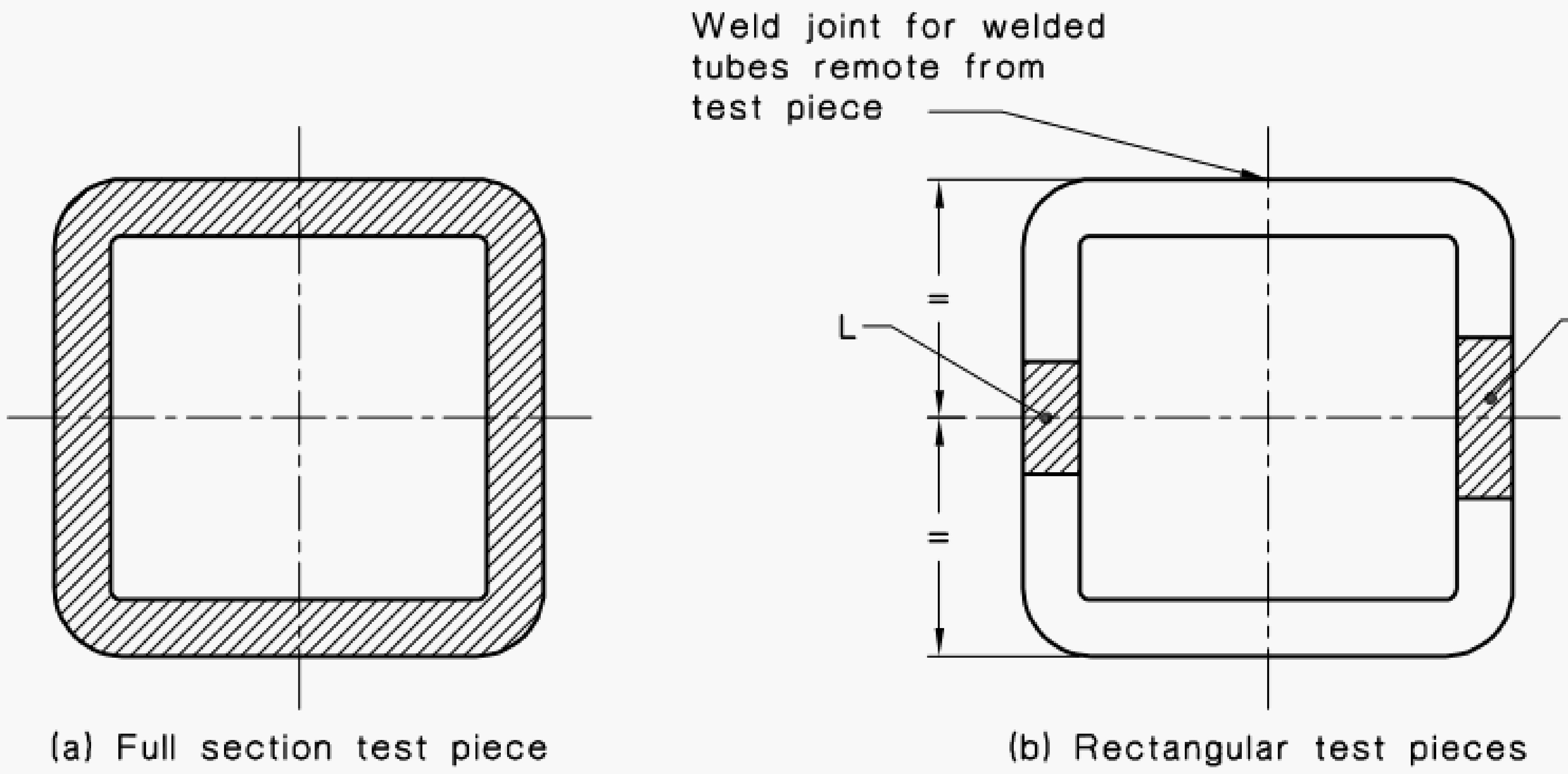


FIGURE J6 FLAT PRODUCTS—LOCATION OF TEST PIECES FOR TENSILE TESTING



LEGEND:
L = Longitudinal test piece
T = Transverse test piece

FIGURE J7 TUBULAR PRODUCTS—LOCATION OF TEST PIECES FOR TENSILE TESTING OF TUBES AND CIRCULAR HOLLOW SECTIONS



LEGEND:
L = Longitudinal test piece
T = Transverse test piece

FIGURE J8 TUBULAR PRODUCTS—LOCATION OF TEST PIECES FOR TENSILE TESTING OF HOLLOW SECTIONS

NOTES

NOTES

Standards Australia

Standards Australia is an independent company, limited by guarantee, which prepares and publishes most of the voluntary technical and commercial standards used in Australia. These standards are developed through an open process of consultation and consensus, in which all interested parties are invited to participate. Through a Memorandum of Understanding with the Commonwealth government, Standards Australia is recognized as Australia's peak national standards body. For further information on Standards Australia visit us at

www.standards.org.au

Australian Standards

Australian Standards are prepared by committees of experts from industry, governments, consumers and other relevant sectors. The requirements or recommendations contained in published Standards are a consensus of the views of representative interests and also take account of comments received from other sources. They reflect the latest scientific and industry experience. Australian Standards are kept under continuous review after publication and are updated regularly to take account of changing technology.

International Involvement

Standards Australia is responsible for ensuring that the Australian viewpoint is considered in the formulation of international Standards and that the latest international experience is incorporated in national Standards. This role is vital in assisting local industry to compete in international markets. Standards Australia represents Australia at both ISO (The International Organization for Standardization) and the International Electrotechnical Commission (IEC).

Electronic Standards

All Australian Standards are available in electronic editions, either downloaded individually from our web site, or via On-Line and DVD subscription services. For more information phone 1300 65 46 46 or visit Standards Web Shop at

www.standards.com.au

STANDARDS AUSTRALIA

GPO Box 5420 Sydney NSW 2001

Administration Phone (02) 8206 6000 Fax (02) 8206 6001 Email mail@standards.com.au

Customer Service Phone 1300 65 46 46 Fax 1300 65 49 49 Email sales@standards.com.au

Internet www.standards.org.au

ISBN 0 7337 6780 X

Printed in Australia

This page has been left blank intentionally.