ECCC RECOMMENDATIONS - VOLUME 2 Part I [Issue 8]

GENERAL TERMS AND TERMINOLOGY AND ITEMS SPECIFIC TO PARENT MATERIAL

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GENERAL TERMS AND TERMINOLOGY AND ITEMS SPECIFIC TO PARENT MATERIAL

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ABSTRACT

Volume 2 Part I lists those terms and terminology which apply generally for the items considered by the ECCC Working Groups. The document includes terms and terminology for source of data, parent materials, test types, test results and data assessment.

Part I is considered to be the 'master reference' for Parts II and III and therefore general terms and terminology are not repeated from Part I in Parts II and III.

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Note for Users

The terms identified in Volume 2 have been classified according to a degree of value with a consideration based on availability for existing data and further information which could be available to support existing information. The classifications used in Volume 4 are:

- M - Mandatory (without which test data will not be accepted)
- R - Recommended (data to improve the quality/pedigree of the test result)
- O - Optional (additional potentially useful information).

SECTION 0

IDENTIFICATION OF SOURCE OF TEST RESULTS AND MATERIAL IDENTIFICATION CODE

The following codes shall be used in sequence to form the full code for each (set of) test result(s).

0.1 Country Code - of origin of test result - select from Table 0.1

This code represents the country of the test result (Table 0.1) - the origin of the test material can be determined by reference to 1.2.1, 1.4.4 and 1.6.1.

0.2 Laboratory Code - select from Table 0.2

Lists produced by member(s) of the Management Committee are appended as Table 0.2. The test laboratory is defined as the location of the test data which may or may not be the same as the production source.

0.3 Material Code

This represents the identification code used within each laboratory for each 'batch' of material tested and should be unique to each (set of) test result(s) from each laboratory. This could be the cast number of the melt, a code given by the laboratory etc. In special cases, the same code can be used by different laboratories provided that the material tested is the same in all aspects. The code used by each laboratory should allow the full manufacturing and thermo-mechanical and heat treatment history to be traceable within the organisation associated with that laboratory.

Example

GB.02.3A3N

SECTION 1

MATERIAL DETAILS

SCOPE - to identify the material tested in terms of quality (material type), source, treatment(s) and supporting metadata.

1.1 Material Type

1.1.1 Broad Classification - select from Table 1.1 (see also Table 1.5).

1.1.2 Alloy Name*

Generic material title, e.g. 2¼Cr1Mo.

1.1.3 Specification and Grade Name*

Refers to the specification to which the material was produced, e.g. DIN 17240, and its grade name, e.g. X22 CrMoV 12.1

1.1.4 Trade or Proprietary Name*

* At least one of these items of information shall be supplied to identify the material tested.

1.2 Material Source

1.2.1 Supplier/Material Manufacturer (and location)

The name of the organization responsible for production of the primary melt to which the cast/heat number (1.2.2) is assigned. The (works) location at which the primary melt was produced shall be included in parentheses.

1.2.2 Cast/Heat Number

The numerical/alphanumeric reference identifying within the manufacturer's organization (1.2.1) the primary melt from which the material tested originated.

1.2.3 Batch Number

Refers to any sub-codes appended to cast/heat number used to identify a particular part of the primary melt, e.g. ingot number or strand number (and location within) for continuously cast production.

1.3 Manufacturing Details

1.3.1 Primary melt process - select and use code from Table 1.3.1.A.

This is the melt stage to produce usable material (which may however be remelted before end use - see 1.3.3).

Note: two process types may be used as part of primary melting process, e.g. BEA + AOD or BEA + LR

1.3.2 Deoxidation process used - select from Table 1.3.1.B.

1.3.3 Secondary melt process - if used, select from Table 1.3.1.C.

This refers to a specific stage involving remelting after solidification of the primary melt.

1.3.4 Ingot or Continuous Cast

1.3.5 Cast/Heat Weight

1.3.5.1 Primary

Cast/Heat Weight of Primary Melt (1.2.2).

1.3.5.2 Secondary

Cast/Heat Weight of Secondary Melt (1.3.3).

1.3.6 Ingot or Unit Weight

Individual ingot weight or lot weight of continuously cast product.

1.3.7 Steelmaking date(s) DD/MM/YY

1.3.7.1 Primary Melt

Date of manufacture of primary melt.*

1.3.7.2 Secondary Melt

Date of manufacture of secondary melt.*

*This may be an approximate date, e.g. year only.

1.4 Product Details

1.4.1 Product Form – select from Table 1.4.1.

Record particular identifying number when different from 1.2.2.

1.4.2 Product Dimensions

Descriptive dimensions of product form in 1.4.1 stating, e.g. width, thickness, wall thickness, diameter etc.

1.4.3 Processing Route

For production of product in 1.4.1 from primary unit, e.g. ingot or billet.

Examples: rolling : forging : extruding etc.

1.4.4 Product Manufacturer

Record if different from cast/heat producer of 1.2.1.

1.4.5 Date(s) of product manufacture

Applies principally to 'one-off' products, e.g. rotor forgings, castings.

1.5 Chemical Composition

Choose elements from Table 1.5.

1.5.1 Cast/Heat

Composition of primary and/or secondary melt (1.3.1 or 1.3.3).

1.5.2 Product

Composition of product form from which test specimens were prepared (1.4.1).

NB : for chemical composition data particular to a location in a product, this should be indicated.

It should be clearly stated whether composition quoted is for melt, i.e. 1.5.1 or for product, i.e. 1.5.2. When for the product and from particular location(s), this should be stated.

1.6 Heat Treatment

1.6.1 Location of heat treatment

State whether manufacturers works (see 1.4.1) or in laboratory.

1.6.2 Size heat treated

Size of piece heat treated (see 1.4.1, 1.4.2 and 1.6.1).

1.6.3 Heat treatment details – temperature, time, cooling rate and coolant used – See Table 1.6.3.

Time(s) of heat treatment is (are) not mandatory but it is recommended that the information is provided (see Table 1.6.3).

1.7 Material Details – the orientation and location of the sample from which test specimens are machined (see also Section 3.1.2.1).

A statement (or sketch) to identify the position and orientation of the sample from which test specimens are machined, e.g. rim of rotor in tangential direction. Alternatively, the information may also be provided as part of test specimen details if it relates more specifically to the test specimen, e.g. one quarter thickness and longitudinal with respect to a plate (see at 3.1.2.1).

1.8 Supporting or Metadata Data

1.8.0 Testpiece Identifier

This is a specific identifier for tensile test piece(s) when different or additional to the material code at 0.3.

1.8.1 Tensile Properties

State test temperature(s) to which values in 1.8.1.1-1.8.1.7 apply.

1.8.1.1 Lower Yield Strength

1.8.1.2 Upper Yield Strength

1.8.1.3 0.2% Proof Strength

1.8.1.4 1.0% Proof Strength

1.8.1.5 Tensile Strength

1.8.1.6 Elongation

Value recorded should be referenced to the gauge length or $\sqrt{S_o}$ ratio over which it was measured.

1.8.1.7 Reduction of Area

1.8.2 Impact Properties

State form and size and notch type of specimen used, energy value recorded (indicate if normalised to a unit area value) and test temperature(s).

1.8.2.1 Room Temperature Impact Value

1.8.2.2 Transition Data

Examples
- temperature for XX% brittle (^{o}C at % FA)
- temperature for specified energy value (^{o}C at J)

1.8.3 Hardness

State hardness test type – H_V, H_B, R_C, R_B, Other, please specify.

1.8.3.1 Following Heat Treatment (1.6.3)

1.8.3.2 Post Test

1.8.4 Grain size

State whether ferrite (+ pearlite fraction) or prior austenite grain size.

1.8.5 Microstructure*

Either as resulting from heat treatment sequence (1.6.3), i.e. 1.8.5.1 or after testing i.e. 1.8.5.2. State main microstructural constituents and (approximate) volume fractions.

1.8.5.1 Following heat treatment (1.6.3)*

1.8.5.2 Post test

* For the microstructure determined (and phases present), it is required that it should be stated whether this was determined from the heat treated product (see1.6) or from a simulation heat treatment applied for the testpiece material.

SECTION 2

TEST TYPES

2.1 Stress Rupture Test

A test under constant load at a specified temperature until fracture occurs or test is discontinued.

The test may also be carried out with a constant stress.

The measurements recorded shall be:-

(i) Hours elapsed either to fracture (B) or some shorter time designated as either the most recent available duration (C) or the time at which the test was discontinued (UB).

(ii) Test Temperature - specified/measured/true.

(a) 'specified' = temperature selected for test.

(b) 'measured'= temperature shown by instrument/recording device.

(c) 'true' = estimate of the true test piece temperature, which is the measured temperature corrected for all systematic errors.

where all of these systematic errors are allowed for, by correction, in the recording system, then 'measured' = ‘true’.

(iii) Temperature Deviation = difference between any two temperatures and in particular:-

(a) 'total' = specified temperature - actual temperature.

(b) 'measured'= specified temperature - indicated temperature.

(iv) Elongation, over a specified length, of fractured test piece.

(v) Reduction of area of fractured test piece.

(vi) Number of campaigns used during test = number of times the test piece is reloaded to the initial load/stress during the overall period of the test.

When the test is carried out using a notched test piece normally (iv) and (v) above will not apply.

A notched rupture test is similar to that for a stress to rupture test, except that the test piece used contains one or more circumferential notches, located in the parallel section; perpendicular to the applied load direction.

In the most common case of a single notch, this is placed usually in the middle of the parallel section of the test piece. Various notch types are available, e.g. V-notch and the Bridgman or semi circular notch. The V-notch which is the most commonly used, is described by two diameters, that of the parallel section and at the root of the notch, the radius at the root of the notch, and the notch angle - see Figure 3.2. The diameters, the notch angle and the notch root radius are used to determine the elastic stress concentration factor (see Section 4.4.1).

The number of notches, the notch type used and relevant dimensions must be reported.

2.2 Creep Rupture Test

As per stress rupture test with measurement of extension as a function of test duration over a specified gauge length. (See also 2.3 Creep Test.) Strain values are calculated using the extension measurements and the reference length - see 3.3.2(i)-(iii) and Volume 3 Part I.

2.3 Creep Test

A test carried out either under constant load or constant stress, at a specified temperature, to determine the time dependent increase in strain, Fig. 2.1(i). If the test proceeds to fracture, it shall be classified as a creep rupture test - 2.2 above. The increase in displacement as a function of time may be measured either by an extensometer or by removing the test piece from the test machine at intervals to carry out measurements at room temperature - in both cases over a specified length.

Measurement of displacement (see 2.2) during a creep test by means of an extensometer shall be deemed an 'uninterrupted test', even though the actual values may be taken only at selected intervals during a campaign. An 'uninterrupted' test may be made up of several campaigns - see 2.1(vi).

Measurement of displacement after removal of the test piece from the test machine shall be deemed an 'interrupted test' (see 2.2).

There are four phases to an uninterrupted creep test during which measurements are made viz:-

(i) Set up or cold loading phase at room temperature.

(ii) Loading phase at test temperature.

(iii) Creep test phase.

(iv) Unloading phase with intermediate or final unloading for the determination of back displacement corresponding to ($\varepsilon_e + \varepsilon_k$).

In the interrupted creep test the permanent strain ε_{per} is measured. In the uninterrupted test ε_p or ε_f (and ε_i) are measured in the usual case.

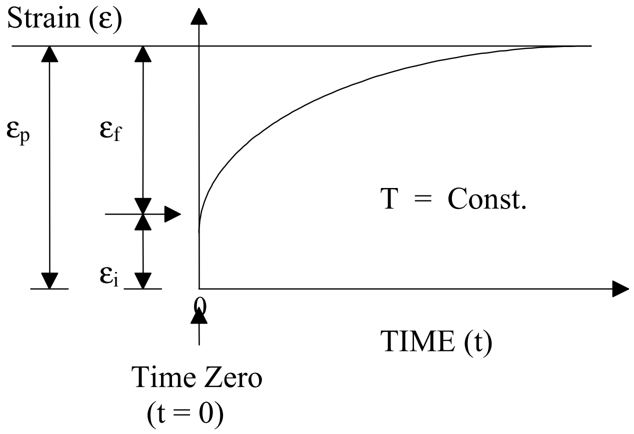
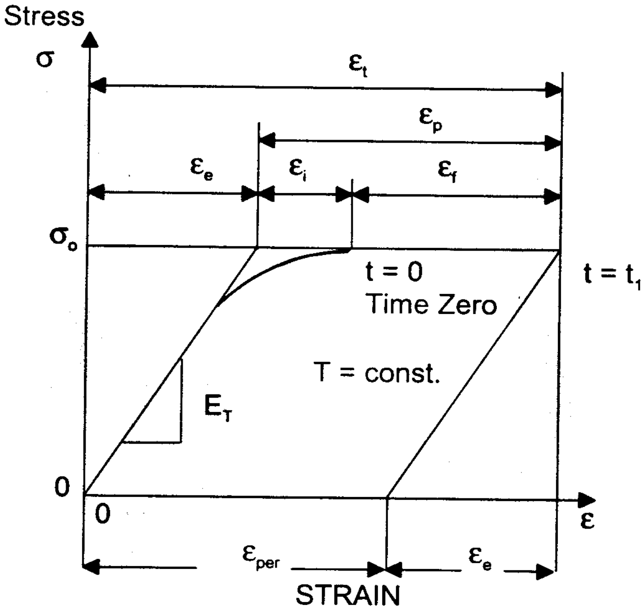


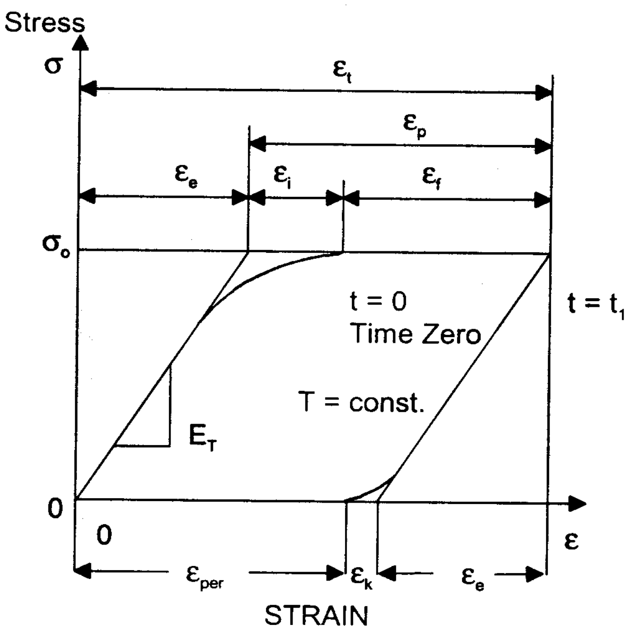
Fig. 2.1 (i) CREEP CURVE (see 2.3)

Fig. 2.1 and Section 4 define various measurements which are required to be made. With particular reference to the uninterrupted test, the elastic modulus, E, can be measured and recorded at room temperature on the creep test piece (phase (i)) or be obtained from another source, e.g. tensile test on the same or related batch of material or from published data for the material type (Table 1.1) tested. For both uninterrupted and interrupted tests, elastic modulus values $E_{T(S)}$ and initial plastic strain ε_i, may also be recorded at the test temperature as part of the loading phase (phase (ii)) - Fig. 2.1(iii). $E_{T(S)}$ can be also determined in phase (iv). Further, $E_{T(S)}$ and ε_i may be determined in a hot tensile test performed on the same batch of material with similar loading rate as in phase (ii) of the creep test.

In the normal case the anelastic strain ε_k is relatively small and therefore may be neglected, thus $\varepsilon_p \approx \varepsilon_{per}$ (Fig. 2.1(ii)). However, if ε_k is not neglected $\varepsilon_p = \varepsilon_{per} + \varepsilon_k$ (Fig. 2.1(iii)). In this case, to relate the results from interrupted and uninterrupted tests, note needs to be taken of the parameter ε_k.



(ii)



(iii)

Fig.2.1: STRESS STRAIN CURVE FOR CREEP WITH (ii) AND WITHOUT (iii) NEGLIGIBLE ANELASTIC STRAIN ε_K

(see next page for list of descriptors used in Fig.2.1)

Fig. 2.1 - DESCRIPTORS

$E_{T(S)}$	-	Static Elastic Modulus at test temperature
σ_o	-	Applied stress*
ε_t	-	Total strain
ε_f	-	Creep strain
ε_p	-	Total plastic strain (non proportional strain)
ε_{per}	-	Permanent strain
ε_i	-	Initial plastic strain
ε_e	-	Elastic strain
ε_k	-	Anelastic strain (recovery strain)
Time Zero, t = 0	-	Start of creep test (phase (iii))
Initial Total Strain (ε_o)	=	$\varepsilon_e + \varepsilon_i$
Total Strain (ε_t)	=	$\varepsilon_o + \varepsilon_f$
Total Plastic Strain (ε_p)	=	$\varepsilon_i + \varepsilon_f$
Total Back Strain	=	$\varepsilon_e + \varepsilon_k$ (measured after unloading (phase (iv)) of the uninterrupted test)

*Stress applied to initial cross section measured at room temperature

2.4 Stress Relaxation

2.4.1 Uniaxial Relaxation Test

A test carried out at a constant strain value, measuring the time based changes in stress. At time zero, the total strain is $\varepsilon_e + \varepsilon_i$ - see Fig. 2.1, p2.3. As the test progresses, the total strain (ε_t) = $\varepsilon_e + \varepsilon_i + \varepsilon_f$, i.e. a proportion of the original ε_e is replaced by ε_f.

There are three phases to a stress relaxation test. Phases (i) and (ii) are identical to those used in the creep test, see 2.3 above except that on loading at the test temperature the initial or applied stress is determined when $\varepsilon_e + \varepsilon_i$ = total strain (ε_t) value required, e.g. 0.15%, Fig. 2.4(i).

Phase (iii) is the stress relaxation phase (see Fig. 2.4(ii)) during which the stress is adjusted to maintain the total strain at the control value, within experimental limits. As per the creep test, the descriptors given with Fig. 2.1 apply also to the stress relaxation test. Time zero occurs immediately at the end of the loading phase, i.e. when $\varepsilon_e + \varepsilon_i$ = selected control strain value (ε_t).

2.4.2 Model Bolt Relaxation Test

Bolted joint models consist of a bolt, two nuts and a cylindrical flange of the same material (of the same cast preferred). The loading of the bolt to the required total initial strain value (ε_o) is conducted in a special device at room temperature by twisting one nut. Then the models are heated up to the test temperature, at a maximum heating rate of 100 °C/h.

The relaxation phase begins (time zero) when the test temperature is reached. After the test is completed and the assembly is dismantled by mechanical destruction of one of the nuts, elastic recovery is determined at RT by measuring the length contraction of the bolt. From such data the residual stress at the test temperature can be calculated. A test series consists of for example five models, which are exposed at the same test conditions for different durations.

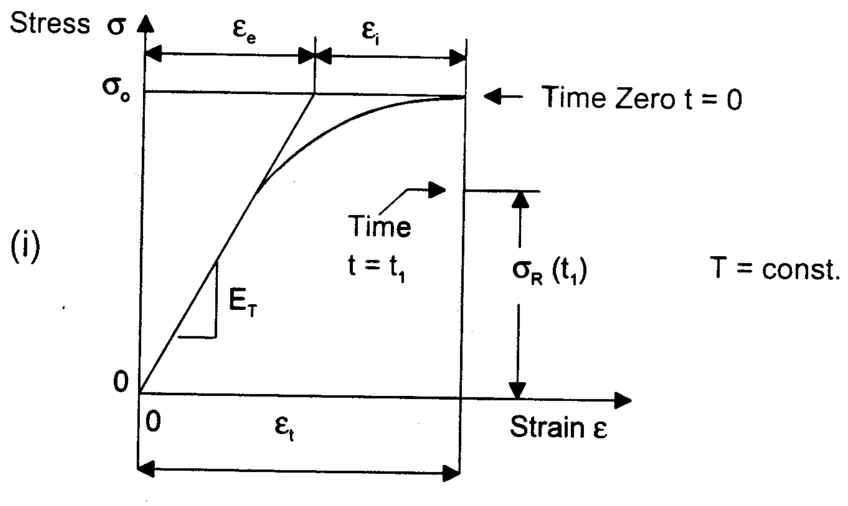
To measure the difference in length after loading and dismantling, two types of models/methods are used:-

Type (a) Mechanical length measurement between the ends of the bolts (the reference length of the model used must be considered, evaluation by single comparison of the measured elongation at the end tips and strain gauges on the shaft of the bolt).

Type (b) Application of strain gauges on the shaft of the bolt (both before and after thermal exposure, the bolt must be accessible by two lateral openings in the flange).

The calculated initial stress at time zero at the test temperature, σ_o, is determined using the elastic modulus for the test temperature, $E_{T(S)}$, determined in a hot tensile test performed at the same loading (strain) rate as that used to load the bolt at room temperature, i.e., $\sigma_o = \varepsilon_{eRT}.E_{T(S)}$.

Traditionally, the remaining stress is determined using the elastic unloading strain measured at room temperature at the end of the test and $E_{T(S)}$, i.e. $\sigma_R = \varepsilon_{eRT}.E_{T(S)}$. New evidence suggests that calculation of σ_R in this way may be unnecessarily conservative, and that the relaxed stress should be determined using the dynamic elastic modulus for the test temperature, $E_{T(D)}$, such that $\sigma_R = \varepsilon_{eRT}.E_{T(D)}$. In future, it will, therefore, be important to know which value of modulus has been used to determine relaxed stress in model bolt relaxation tests.



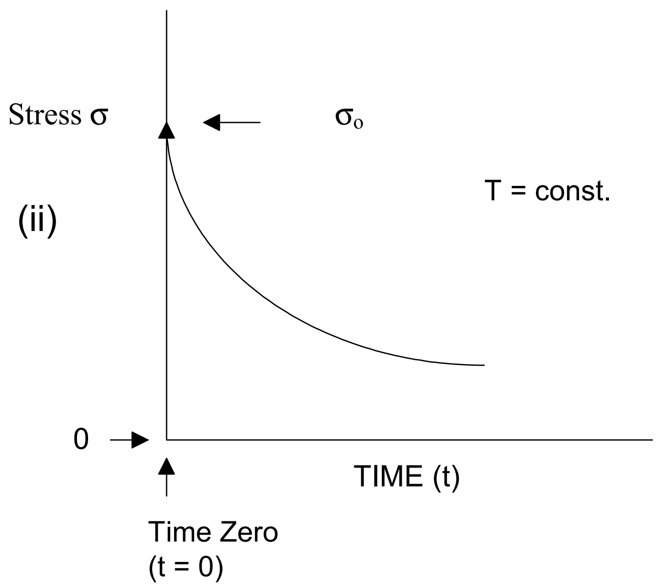


Fig.2.4: STRESS STRAIN CURVE (i) AND STRESS TIME CURVE (STRESS RELAXATION CURVE) (ii) FOR A RELAXATION TEST (see 2.4)

SECTION 3

TEST DETAILS

SCOPE - to define the details required to describe fully the test carried out.

3.0 Test Standard

State testing standard used (see Vol. 3 - Table 3).

3.1 Test Piece Details

3.1.1 Test piece identifier.

3.1.2 Location and direction of test piece in products (see 1.4.2 and 1.6.2).

The following terms shall be recognised to describe the orientation of the axis of the test piece with respect to the product (Section 1.4) from which it is made.

(i) Longitudinal (L) - test piece axis is parallel to the major working direction of the product. This can be determined by macroscopic grain flow if not known from information received.

(ii) Transverse (Tr) - test piece axis is normal to the major working direction in the plane of the product.

(iii) Through Thickness (TT) - test piece axis is orientated through the thickness of the product, normal to the plane of the product.

Other terms which may be used, e.g. axial, tangential and circumferential are considered to be special cases of (i) and (ii) above. When such terms are used they should be accompanied by a descriptive diagram to show exact location and direction.

3.1.3 Dimensions and type of test piece tested (see also Section 4).

(i) Parallel length and diameter (or section).

(ii) Gauge length used (extensometer length).

(iii) Reference length - see Figs.3 and 3.1 on page 3.6.

(iv) Type and dimensions of notch (when used) - see examples in Figs. 3.2 and 3.3 on page 3.7.

(v) Transition radius.

(vi) Special features of test piece, e.g. combined plain and notched; extensometer location ridges, etc. - see example in Fig.3.4 on page 3.8.

(vii) Special/particular test piece form used (as drawing provided), e.g. tubular, double diameter welded specimen, etc.

(viii) For bolted joint model

- model bolt type
- reference or cylinder length
- diameter of cylinder length
- area ratio between cylinder and flange

3.2 Test Conditions

3.2.1 Temperature

(i) Specified value and units.

(ii) Actual value and range achieved.

(iii) Heating rate or heating time.

(iv) Soak period before load applied.

(v) Cooling rate or cooling time at end of each campaign (see 2.1(vi)) and/or end of test or state normal laboratory practice, e.g. cooled in still air.

(vi) Laboratory temperature control limits

(vii) Thermocouple type used.

(viii) Thermocouple calibration - errors

- total error
- systematic error
- uncertainty

The total temperature error is the difference between the indicated temperature and the true temperature of a thermocouple. This error contains systematic and random components.

(a) Systematic Error
The systematic error can be determined during the calibration of a thermocouple. It is the mean of repeated measurements of the difference between the indicated temperature and the true temperature of the thermocouple. For a discussion on parameters which determine the magnitude of this error, see Volume 3 Part I, Appendix 1, Section 2.3.

The systematic error of a thermocouple may be accounted for in the overall temperature measurement system so that the indicated temperature equates to the true temperature, at the point of measurement, except for any uncertainty.

(b) Uncertainty

Associated with all physical measurements there is some level of uncertainty, deriving from the natural scatter in results at each stage of measurement. For thermocouple calibrations there may be several measurement stages between the national standard and the working thermocouple. An 'error budget' should be calculated to estimate the uncertainty associated with the working thermocouple, expressed as $\pm$ X °C.

A procedure for estimating uncertainty for temperature measurements from thermocouples is included in Volume 3 Part I, Appendix 1.

3.2.2 Stress/Load and Strain

(i) Applied stress or initial stress (σ_o).
Not applicable for model bolt testing

(ii) Stress relaxation strain.

- (a) Specified
- (b) Actual (ε_t)
- (c) Uniaxial or model bolt (see 2.4)
- (d) Initial plastic strain (ε_i)
- (e) Control band used.

(iii) Extensometer

- means of location on specimen
- calibration details
- gauge length

(iv) Displacement measurement - bolted joint model

- method used
- calibration

3.2.3 Machine Details

(i) Machine type

(ii) Number of strings in machine

(iii) Number of test pieces per string

3.2.4 Load Measurement System

3.2.5 Calibration

3.2.6 Atmosphere Used (air assumed if not stated)

3.2.7 Loading Method (stress relaxation only)

3.2.8 Loading Rate (stress relaxation only)

3.3 Test Results

3.3.1 All Test Types

(i) Test duration (t).
- as per (iii) below
- as per 3.3.2 (iv) or 3.3.2 (v)

(ii) Number of campaigns/interruptions (2.1(vi))

(iii) Current test condition (choose one).
- test continuing (C)
- fractured (B)
- discontinued (UB)

*(iv) Ductility value
- elongation (A_u)
- reduction of area (Z_u)
- at notch plane (Z_{un})

*(v) Position of fracture in parallel or gauge length of plain testpiece

*Does not apply for stress relaxation tests nor creep tests, i.e. those not taken to rupture.

3.3.2 Creep Tests

(i) Initial plastic strain

(ii) Creep strain (ε_f) at 3.3.1 (i)

(iii) Total plastic strain (ε_p) at 3.3.1 (i)

**(iv) Time to specific creep strain.

**(v) Time to specific plastic strain

**(vi) Stress to a specific creep strain.

**(vii) Stress to total plastic strain.

** These are assessed results – see Section 4.6.

3.3.3 Stress Relaxation Tests

(i) Calculated initial stress in model bolt test at time zero at the test temperature (σ_{oc})

(ii) Residual elastic strain at time t

(iii) Remaining or residual stress at time (σ_R).

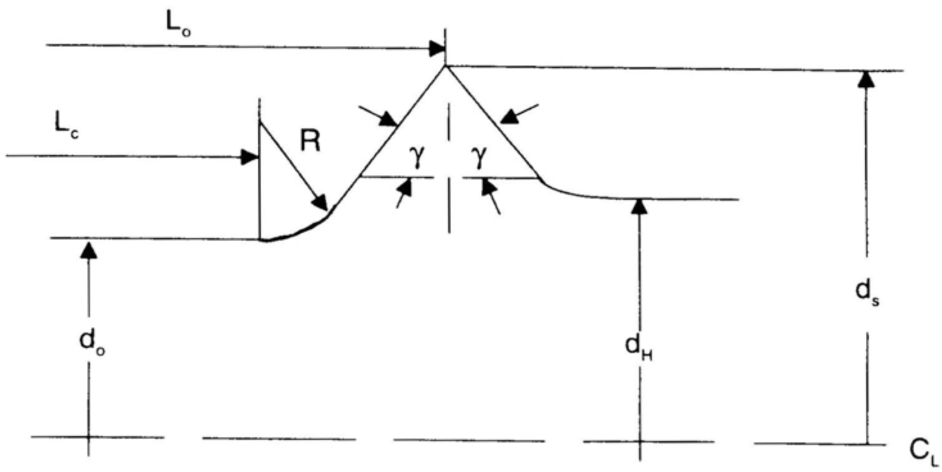
**(iv) Stress relaxed (σ_{rel}) = reduction (difference) since time zero to time t

**(v) Relaxation rate at (or over) a specified duration (range) ($R_{rel}t^{-1}$).

** These are assessed results – see Section 4.6.

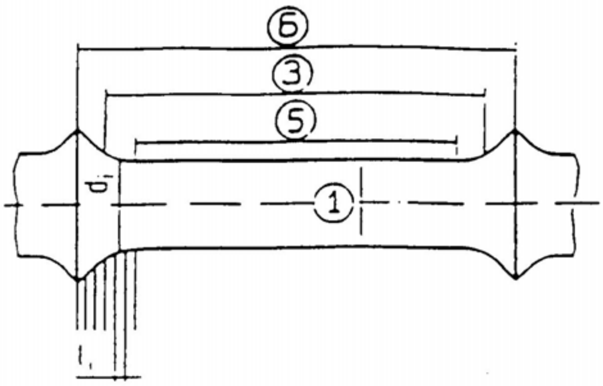
3.3.4 Quality of Testing

All defects in specimens or testing which are considered to be non-standard, e.g. temperature fluctuations outwith specified and/or control bands, or to have an influence on the results of the test, e.g. specimen defect revealed only after testing, shall be recorded and referenced to the particular specimen (or specimens where the defect is general to a string of tests or furnace load).



C_L = centre line of specimen

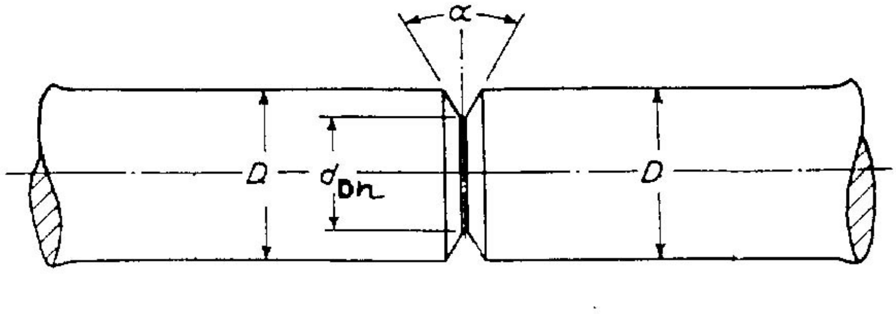
FIG.3: DIMENSIONS OF RIDGED SPECIMEN FOR DETERMINATION OF REFERENCE LENGTH



$L_r = L_c + 2\sum_i\left[(d/d_i)^{2n} l_i\right]$ if the value of n is not known, n = 5

where n = creep exponent

FIG.3.1: CALCULATION OF REFERENCE LENGTH



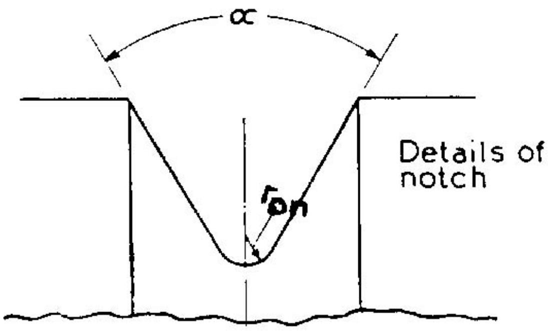


FIG.3.2: EXAMPLE OF V-NOTCHED TEST PIECE OF CIRCULAR CROSS SECTION

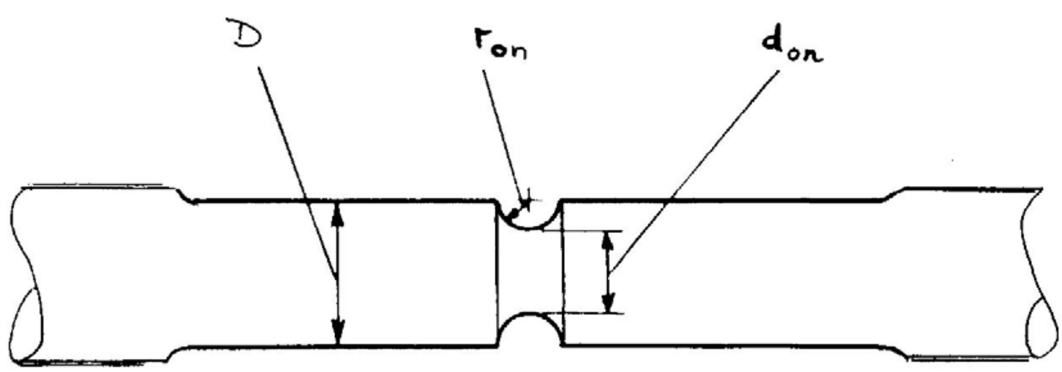


FIG.3.3: EXAMPLE OF "BRIDGEMAN" TYPE NOTCHED TEST PIECE

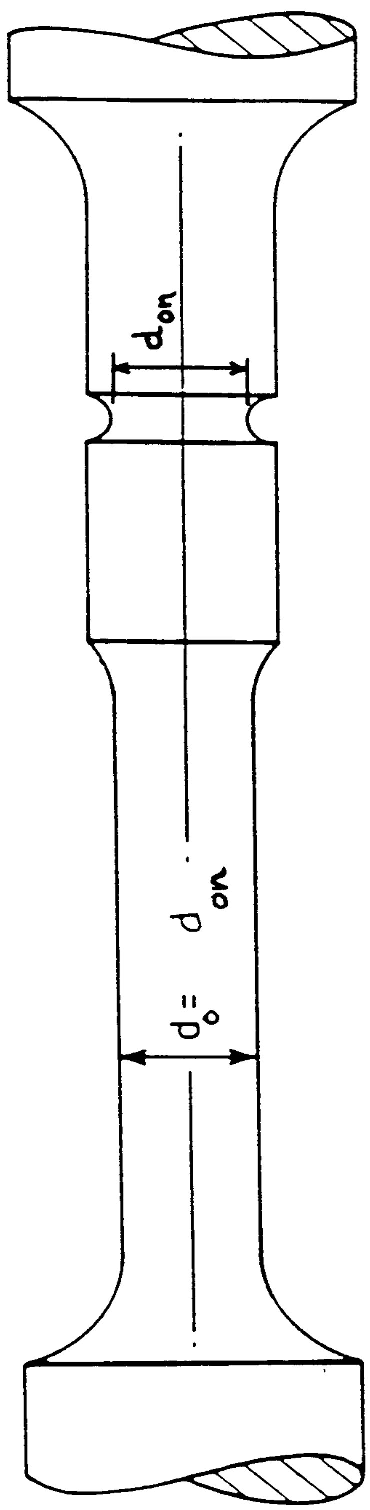


FIG 3.4 EXAMPLE OF COMBINED PLAIN AND NOTCHED TEST PIECE

SECTION 4

STANDARD TERMS AND SYMBOLS

NAME	UNIT(S)	SYMBOL
4.1 Manufacture (Section 1.3)		
See Table 1.3.1 for descriptors and symbols for material production.		
Ingot Cast	-	I
Continuous Cast	-	C
Cast/Heat/Ingot/Unit Weight	-	kg
Product Dimensions (1.4)	mm	mm
4.2 Chemical Analysis (Section 1.5)		
See Table 1.5 and report Elements in order as given	wt%	ISO TR6306:1989 (BS6200 Part 4)
4.3 Test Material Processing and Background/ Metadata Data (Sections 1.6 and 1.7)		
Heat Treatment		
Temperature	Degree Celsius (°C)	T
Time	Hours (h)	t
Cooling Rate (also for Heating Rate - see 3.2.1 (iii))	°C/h	
Air Cooled	( )	AC
Oil Quenched	( )	OQ
Water Quenched	( )	WQ
Water Spray	( )	WSQ
Furnace Cooled	( )	FC
Annealed	( )	A

( ) specify actual value of cooling rate if known or section cooled (1.6.2.).

NAME	UNIT(S)	SYMBOL
Tensile Properties (1.8.1)		
Test temperature	°C	
0.2% Proof Strength	MPa	$R_{p0.2}$
Yield Strength	MPa	R_e
- upper	MPa	R_{eH}
- lower	MPa	R_{eL}
X% Proof Strength	MPa	R_{pX}
Tensile Strength	MPa	R_m
Elongation After Fracture	%	A
Reduction of Area After Fracture	%	Z
Impact Properties (1.8.2)		
Type of Specimen and Notch Form		V or U as subscript
Energy Absorbed	Joule	C_v
Energy/Unit Area	Joule/mm^2	A_v
Transition Data	°C at % FA °C at J	FATT% TTj
Hardness (1.8.3)		
Vickers	Hardness Number and Load Used	eg HV30
Brinell	Hardness Number	HBS (steel ball) HBW (WC ball)
Rockwell	Hardness Number and indenter type	R_c or R_B

NAME	UNIT(S)	SYMBOL
Grain Size (1.8.4)		
Ferrite	mm	di (mean linear intercept)
Prior Austenite	ASTM Grain Size No.	Grain Size No.
Microstructure (1.8.5) - see note		
(Phases present as %)		
Ferrite	%	Ferrite
Austenite	%	Austenite
Bainite	%	Bainite
Martensite	%	Martensite
Pearlite	%	Pearlite
Carbide Type	%	(type to be indicated)
Sigma Phase	%	Sigma (estimated)
Laves Phase	%	Laves (estimated)

Note

For the microstructure determined (and phases present), it is required that it should be stated whether this was determined from the heat treated product (see 1.6) or from a simulation heat treatment for the testpiece material.

NAME	UNIT(S)	SYMBOL
4.4 Test Details		
4.4.1 Test Piece (Section 3.1)		
Dimensions	mm	
Initial diameter of cross section of the parallel length of a cylindrical test piece	“	d_o
Instantaneous diameter	“	d
Final diameter within necked region of after fracture	“	d_u
Thickness	“	a
Width	“	b
Diameter of tubular specimens	“	o.d. i.d.
Diameter of parallel section of notched test piece	“	D
Diameter of barrel behind ridge/collar (Fig. 3)	“	d_H
Diameter at ridge/collar tip (Fig. 3)	“	d_s
Angle of ridge/collar (Fig. 3)	Degree (°)	γ
Original Gauge Length	mm	L_o
Parallel (or cylinder) length	“	L_c
Extensometer Gauge Length	“	L_e
Reference Length	“	L_r
Transition Radius to Grip End	“	r
Cross Section Area at Notch Root	mm^2	S_{on}
Cross Section Area at Flange	mm^2	S_o [flange]
Cross Section Area of Bolt	mm^2	S_o[bolt]
Initial Notch Root Radius	mm	r_{on}

NAME	UNIT(S)	SYMBOL
Initial Diameter at Notch Root	mm	d_{on}
Final Diameter at Notch Root		d_{un}
Notch Angle	degree (°)	α
Elastic Stress Concentration Factor for Notched Test Piece		K_t
Directionality		
Longitudinal	-	L
Transverse	-	Tr
Through Thickness	-	TT
Location in Test Material*		
Axial/Centre/Core		
Mid Radial		
Etc.		

*Since this is product dependent, it should be stated in written or diagrammatic form, along with the test results.

4.4.2 Machine Details (see 3.2.3)

4.4.2.1 Type (3.2.3 (i))

SE : Servo electrical

SH : Servo hydraulic

DW : Dead weight - includes lever loaded

SM : Servo mechanical

4.4.2.2 Load Application and Measurement (3.2.4)

W : Direct application of weights

L : Application of load via calibrated lever system

LC : Load cell with electronic or electrical conditioning and indication

4.4.2.3 Loading Method (3.2.7)

E1 : Loading in strain control to the specified total strain value

E2 : Loading in strain control to the total strain value that corresponds to a pre-defined stress

F1 : Loading in load control to a pre-defined stress value, then change into strain control keeping the strain value corresponding to the pre-defined stress constant

F2 : Loading in load control to a pre-defined total strain value, change to strain control and keep this strain value

If other method(s) employed, use descriptive text.

4.4.2.4 Loading Rate (3.2.8)

The loading rate corresponding to the selected loading method (4.4.2.3) should be entered, i.e. methods E1 and E2 require strain rates in %/s, F1 and F2 loading rates in MPa/s.

NAME	UNIT(S)	SYMBOL
4.5 Test Results (Section 3.3)		
Test Temperature	Degree Celsius (°C)	T
Heating Rate (for bolted joint model)	°C/h	
Thermocouple Type	Code	Code Letter e.g. 'R'
Initial or Applied Stress or Stress at Time Zero	MPa	σ_o
Calculated Initial Stress (for model bolts)		σ_o*
Test continuing	-	C
Test broken	-	B
Test discontinued	-	UB
Remaining/Residual Stress†	MPa	σ_R
Stress Reduction (σ_o-σ_R)	MPa	σ_{rel}
Elastic Modulus		
- at RT (static modulus)	GPa	E_S
- (dynamic modulus)	GPa	E_D
- at T (static modulus)	GPa	$E_{T(S)}$
- (dynamic modulus)	GPa	$E_{T(D)}$
Strain (see Fig. 2.1)		
Elastic		ε_e
Initial Plastic		ε_i
Total Plastic		ε_p
Creep		ε_f

NAME	UNIT(S)	SYMBOL
Total		ε_t
Anelastic (e.g. Fig. 2.1 (ii))		ε_k
Creep Strain Rate	h^{-1}	ε_f
Minimum Creep Strain Rate	h^{-1}	ε_f (min)
Time Zero	h	t_o
Test Duration (since time zero)	h	t
Creep Rupture Time - plain test piece	h	t_u
- notched test piece		t_{un}
Time to Creep Strain	h	$T_{f\varepsilon}$ *(1)
Time to Total Plastic Strain	h	$T_{p\varepsilon}$ *(1)
Time to X%	h	t_x%
Elongation at Rupture	%	A_u
Reduction of Area at Rupture	%	Z_u

(1) The symbol ε in this case represents digit(s) indicating the amount of strain in % e.g. 0.2.

4.6 Assessed Results

Assessed results are those results derived by calculation/interpolation from the test results. In addition to the main symbol for each type of assessed result, designations for time (t) and temperature (T) are added to define the conditions applying for the particular assessed result.

The following terms and symbols thus apply:-

NAME	UNIT(S)	SYMBOL
Rupture Strength	MPa	$R_{u/t/T}$
Strength for Specific Creep Strain	MPa	$R_{f\varepsilon/t/T}$
Strength for Specific Plastic Strain	MPa	$R_{p\varepsilon/t/T}$
Notch Rupture Strength	MPa	$R_{u/n/D/t/T}$
(D = DIN and may be replaced by B = BS or A = ASTM to designate notch dimensions used)		
Notch to Plain Strength Ratio	-	NPSR
Notch to Plain Life (Duration) Ratio	-	NPLR
Calculated initial stress (model bolt test)	MPa	σ_{oc}
Relaxation Rate	MPa/h	$R_{rel}t^{-1}$
Predicted Time to Rupture	h	$t_u{}^*$
Predicted Time to Specific Creep Strain	h	$t_{f\varepsilon}{}^*$
Predicted Time to Specific Total Plastic Strain	h	$t_{p\varepsilon}{}^*$
Relaxation Strength	MPa	$R_{R/t/T}$

SECTION 5

DATA ASSESSMENT - DEFINITIONS OF TERMS USED

5.1 Terms Used in Data Assessment

CRDA	creep rupture data assessment
CSDA	creep strength data assessment
SRDA	stress relaxation data assessment
PAT	post assessment test
t_r*	predicted rupture time
$t_{f\varepsilon}$*	predicted time to specific creep strain
$t_{p\varepsilon}$*	predicted time to specific total plastic strain
$t_{r[max]}$	the time of the longest duration (T, σ, t) data co-ordinate
$t_{r[min]}$	the time of the shortest duration (T, σ, t) data co-ordinate
T_{max}	the highest temperature for which data have been collected
T_{min}	the lowest temperature for which data have been collected
T_{main}	the temperature with the largest number of data points
$T_{max[10\%]}$	the highest temperature for which there are greater than 10% data points
$T_{min[10\%]}$	the lowest temperature for which there are greater than 10% data points
n	the stress index in the expression $\varepsilon = C\ \sigma_o^n$, where C is constant for a given material and temperature (usually n is used with reference to the minimum creep rate, i.e. $\varepsilon_{min} = C\ \sigma_o^n$ - "Norton's Law")
$n_{f\varepsilon}$	the slope of log $t_{f\varepsilon}$ versus log σ_o for a given σ_o, i.e. $n_{f\varepsilon} = -\partial(\log t_{f\varepsilon})/\partial(\log \sigma_o)$

$n_{p\varepsilon}$	the slope of log $t_{p\varepsilon}$ versus log σ_o for a given σ_o, i.e. $n_{p\varepsilon} = -\partial(\log t_{p\varepsilon})/\partial(\log \sigma_o)$
n_r	the slope of log t_r* versus log $\sigma_o$for a given σ_o, i.e. $n_r = -\partial(\log t_r^*)/\partial(\log \sigma_o)$
$\sigma_{o[max]}$	the highest stress for which data exists in the data set
$\sigma_{o[min]}$	the lowest stress for which data exists in the data set
A-SRLT	residual log time divided by the standard deviation for all the n_A residual log times at all temperatures, i.e. A-SRLT = $\{(\log t_r - \log t_r^*)\}/s_{[A\text{-}RLT]}$
I-SRLT	residual log time divided by the standard deviation for all the n_I residual log times at the temperature of interest, i.e. I-SRLT = $\{(\log t_r - \log t_r^*)\}/s_{[I\text{-}RLT]}$
$S_{[A\text{-}RLT]}$	standard deviation of all the n_A residual log times at all temperatures, i.e. $S_{[A\text{-}RLT]} = \sqrt{\{\Sigma_i (\log t_{ri} - \log t_r{*}_i)^2/n_A - 1)\}}$, where i = 1, 2, ... n_A
$S_{[I\text{-}RLT]}$	standard deviation for all the n_I residual log times at the temperatures of interest, i.e. $S_{[I\text{-}RLT]} = \sqrt{\{\Sigma_i (\log t_{rj} - \log t_r{*}_j)^2/n_A - 1)\}}$, where j = 1, 2, ... n_I
RLA	Residual Life Assessment: All activities needed to establish the further exploitability of a given target component
Reference material	Material which is suitable to be used for comparison with a weld or a PE material
Reference Curve	Mathematical model describing the creep behaviour of a reference material
PE	Post exposure
LDAR	Linear damage accumulation rule
CSC	Concept of similar curves
CRL	Computation of residual life

TABLE 0.1
COUNTRY CODES

COUNTRY NAME	BS EN ISO 3166-1:1998 CODE
Australia	AU
Austria	AT
Belgium	BE
Canada	CA
China	CN
Cyprus	CY
Czech Republic	CZ
Czechoslovakia *	CS
Denmark	DK
Estonia	EE
Finland	FI
France	FR
German Democratic Republic *	DD
German Federal Republic *	DE
Germany	DE
Greece	GR
Greenland	GL
Hungary	HU
Iceland	IS
India	IN
Ireland	IE
Italy	IT
Japan	LV
Latvia	JP
Liechtenstein	LI
Lithuania	LT
Luxembourg	LU
Malta	MT
Monaco	MC
Netherlands	NL
Norway	NO
Poland	PL
Portugal	PT
Romania	RO
Russia	RU
Slovakia	SK
Slovenia	SI
South Africa	ZA
Spain	ES
Sweden	SE
Switzerland	CH
United Kingdom	GB
United States	US
USSR *	SU
European Union	EU

* Country name no longer in use

TABLE 0.2
LABORATORY CODES

Country	Code	Laboratory : Place
Austria	AT.01	Voest Alpine Stahl Linz GmbH : Linz
	AT.02	Böhler Edelstahl GmbH : Kapfenberg
	AT.03	Schoeller-Bleckmann : Ternitz
	AT.04	Metallwerk Plansee GmbH : Reute
	AT.05	Österr. Forschungszentrum Seibersdorf GmbH : Seibersdorf
	AT.06	Abt. Werkstoffkunde u. Schweibtechnik Technische Universität Graz : Graz
	AT.07	Inst. f. Metallkunde u. Werkstoffprüfung, Montanuniversität Leoben : Leoben
	AT.08	Inst. f. Werkstoffkunde u. Materialprüfung, TU Wien : Wien
	AT.09	Inst. f. physkal. Chemie, Uni Wien : Wien
Belgium	BE.01	Laborelec : Linkebeek
	BE.02	Belgian Welding Institute : Ghent
Denmark	DK.01	Forskningscenter RISØ : Roskilde
Czech Republic	CZ.01	Vitkovice – R&D : Ostrava - Vitkovice
	CZ.02	SVUM : Prague
Finland	FI.01	VTT : Helsinki
France	FR.01	Vallourec
	FR.02	ALSTOM Power (Stein Industrie)
	FR.03	Aubert et Duval
	FR.04	SERMA Belfort
	FR.05	Electricité de France
	FR.06	CEA : Saclay
Germany	DE.01	Institut für Werkstoffkunde : Darmstadt
	DE.02	Staatl. Materialprüfungsanstalt : Stuttgart
	DE.03	Siemens AG : Mülheim
	DE.04	ALSTOM Power (ABB Kraftwerk AG) : Mannheim
	DE.05	Salzgitter Mannesmann Forschung : Duisburg
	DE.06	ALSTOM Power (ALSTOM Energie) : Nurnberg (formerly MAN Energie)
	DE.07	Arbeitsgemeinschaft für Warmfeste Stähle
	DE.08	Siempelkamp Prüf- und Gutachter-Gesellschaft : Dresden
Great Britain	GB.01	ERA Technology Ltd. : Leatherhead
	GB.02	Corus (British Steel), Swinden Technology Centre : Rotherham
	GB.03	ALSTOM Power (ALSTOM Energy) : Rugby (formerly GEC Alsthom)
	GB.04	Bodycote : Newcastle upon Tyne (formerly Rolls Royce IRD)
	GB.05	Mitsui Babcock Technology ; Renfrew
	GB.06	Incotest : Hereford

	GB.07	National Engineering Laboratory : East Kilbride
	GB.08	Serco, Warrington
Italy	IT.01	Centro Sviluppo Materiali SpA : Roma
	IT.02	Istituto Scientifico Breda : Milano
	IT.03	Dalmine Laboratory Service : Dalmine (BG)
	IT.04	CESI : Piacenza
	IT.05	CNR-IENI : Cinisello Balsamo (Mi)
	IT.06	Ansaldo GIE : Legnano (Mi)
	IT.07	ENEA CRE Casaccia : Roma
	IT.08	ENEL DSR : Milano
	IT.09	Nuovo Pignone : Firenze
	IT.10	CESI (CISE) : Segrate (Mi)
	IT.11	Università Politecnico delle Marche : Ancona
	IT.12	Avio : Torino (former FIAT Avio)
	IT.13	Falck Servizi - Sesto San Giovanni (Mi)
	IT.14	Societa Italiana Acciai per Utensili (SIAU)
	IT.15	Politecnico di Milano
Netherlands	NL.01	TNO-Metals Research Institute : Apeldoorn
	NL.02	DSM Services : Geleen
Portugal	PT.01	Instituto de Soldadura e Qualidade (ISQ)
Slovakia	SK.01	VUZ-PI SR: Bratislava
Sweden	SW.01	KIMAB : Stockholm (formerly SIMR)
	SW02	Outokumpu Stainless : Avesta
	SW03	Sandvik Materials Technology : Sandviken
Switzerland	CH.01	ALSTOM Power (ABB Power Generation Ltd) : Baden
	CH.02	Sulzer Innotec AG : Winterthur
European Union	EU.01	CEC Joint Research Centre : Petten

NOTE

For laboratories supplying data which are not included in the above list, please apply to the editor of this document for an appropriate Code.

TABLE 1.1

MATERIAL TYPE CLASSIFICATION

CARBON	(Mn ≤0.8%)
CARBON-MANGANESE	(Mn >0.8≤2.0%)
MICROALLOYED	
LOW ALLOY FERRITIC	(Cr≤5%)
HIGH ALLOY FERRITIC	(Cr >5≤13% + alloys of Mo, V, Nb etc.)
AUSTENITIC STAINLESS	
FERRITIC STAINLESS	
DUPLEX STAINLESS	
NICKEL BASE	

TABLE 1.3.1

MELTING PROCESS DETAILS

A PRIMARY MELTING

Open Hearth	(OH)
Basic Open Hearth	(BOH)
Acid Open Hearth	(AOH)
Electric Arc (state if <u>not</u> basic)	(EA)
Basic Oxygen	(BOF)
Argon Oxygen Decarburisation	(AOD)
Induction Melted	(IM)
Laboratory (induction) Melted	(LM)
Vacuum Induction Melted	(VIM)
Ladle Refined	(LR)

B DEOXIDATION IN PRIMARY MELT

Rimmed Steel	(R)
Semi Killed	(SK)
Fully Killed	(FK)
Aluminium Deoxidised	(A)
Silicon Deoxidised	(S)
Vacuum Carbon Deoxidised	(VCD)

C SECONDARY MELTING

Remelted	(R)
Vacuum Arc Remelted	(VAR)
Electro (Slag) Flux Remelted	(EFR)

TABLE 1.4.1

PRODUCT FORM

BAR (ROD) - produced by longitudinal rolling or forging

PLATE

FORGING

TUBE (o.d. ≤75 mm)

PIPE (o.d. >75 mm)

SHEET

STRIP

WIRE

CONCAST PRODUCT

CASTING

TABLE 1.5

REPORTING OF COMPOSITION

All elements included in this table should be reported where known for each material tested. The mandatory elements represent the minimum that should be reported for each material type. Where other deliberate additions are made for alloying purpose(s), these are also regarded as mandatory (see Note 1).

Material Type (Table 1.1)	**Mandatory**	**Recommended(2)**	**Optional**
Carbon	C, Si, Mn	P, S	Al(3), N(3), Cr, Mo, Ni, V, As, B, Sb, Sn, Ti, Cu
Carbon Manganese	C, Si, Mn	P, S	Al(3), N(3), Cr, Mo, Ni, V, As, B, Sb, Sn, Ti, Cu
Microalloyed	C, Si, Mn, Nb(1), Ti(1), V(1), Al(1)	P, S	N(3), Cr, Mo, Ni, As, B, Sb, Sn, Cu
Low Alloy Ferritic	C, Si, Mn, Cr(1), Mo(1), V(1)	P, S, Ni	Al(3), N(3), As, B, Cu, Sb, Sn, Ti
High Alloy Ferritic	C, Si, Mn, Cr, Mo(1), V(1), Nb(1), W(1)	P, S, Ni	Al, N, As, B, Cu, Sb, Sn, Ti
Austenitic Stainless	C, Si, Mn, Cr, Ni, Mo(1), Nb(1), Ti(1), B(1), N(1)	P, S	As, Cu, Sb, Sn, V, REM(4)
Ferritic Stainless	C, Si, Mn, Cr, Mo(1), Ni(1), Al(1)	P, S, N	As, B, Cu, Sb, Sn, V, Ti
Duplex Stainless	C, Si, Mn, Cr, Mo, Ni, Cu(1), N(1)	P, S	
Nickel Base, e.g. Nimonic 80A	C, Si, Mn, Fe, Cr, Al, Ti, Co(1), B(1), Ta(1), W(1), Y(1)	P, S	N, As, Sn, Pb, Mg

(1) Elements are mandatory if it is an alloying element and/or included in formal specification for actual or related steel type, e.g. 12% Cr MoV – otherwise such elements are in recommended category.

(2) The elements included as recommended shall be mandatory for all new material test programmes started since 1.1.95.

(3) The information provided shall make it clear whether % given refers to total, soluble and/or insoluble fractions.

(4) REM = rare earth metals.

TABLE 1.6.3

HEAT TREATMENT DETAILS

Heat Treatment Stage	Temp ^{o}C	Time(1) h	Cooling Rate* ^{o}C/min or Code (see 4.3 on p4.1)	Cooling Medium
1 2 3				
↓				
n				

* Special note shall be made if isothermal treatment(s) used

(1) Time(s) for each heat treatment stage is not a mandatory requirement, but should be stated in the heat treatment record when know.