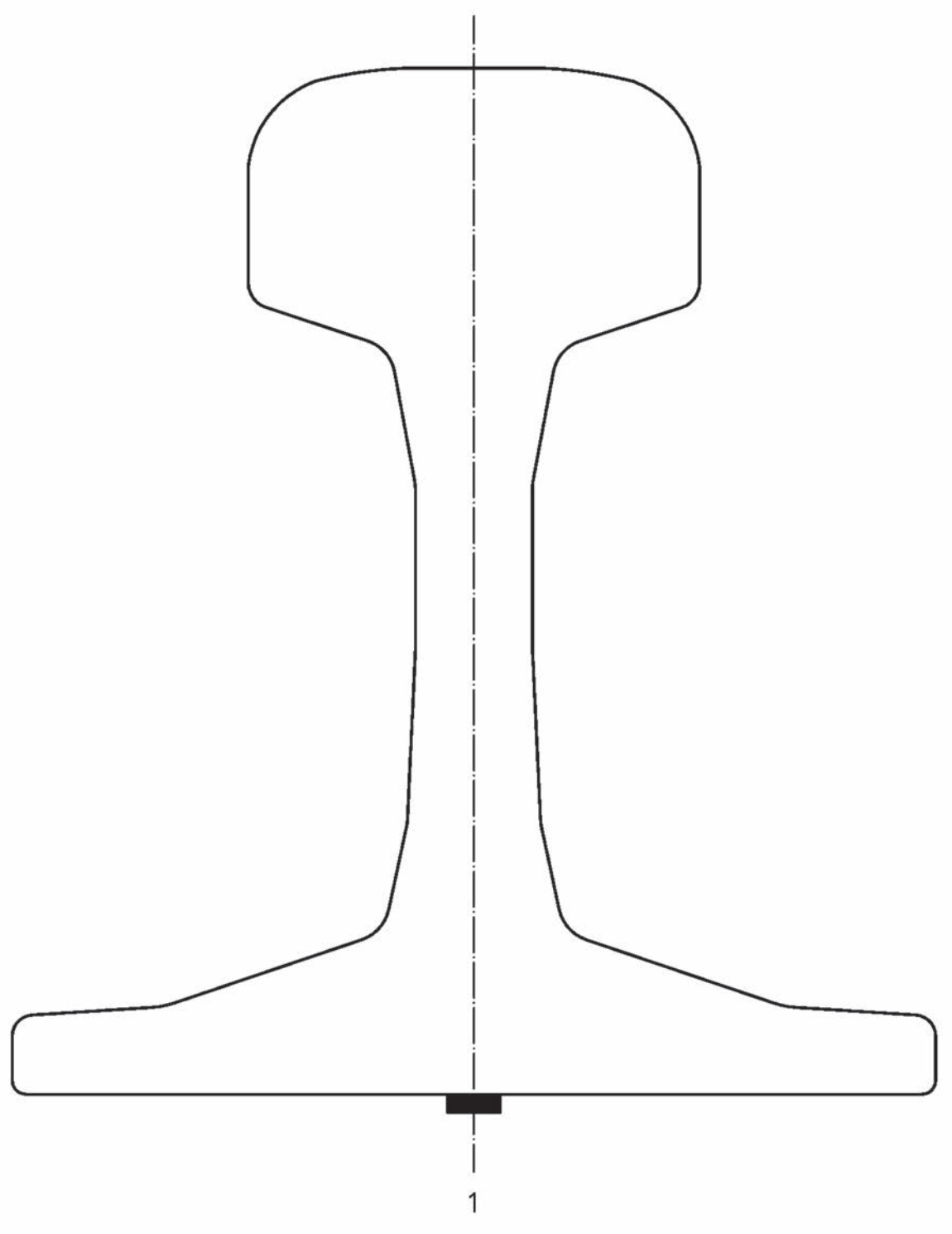


Figure E.1 — Location of strain gauge to measure rail foot surface longitudinal residual stresses

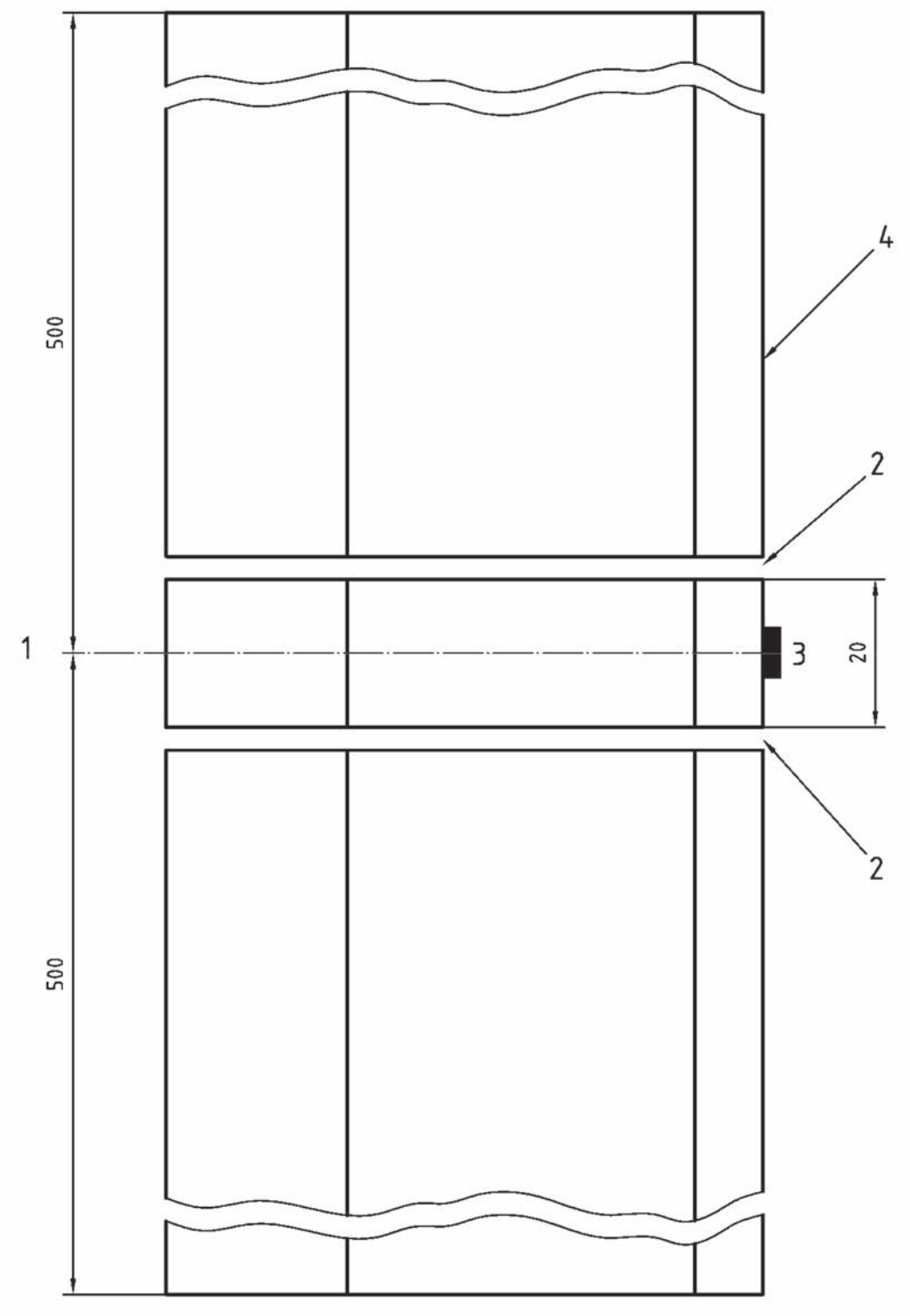


Figure E.2 — Slice removed from the rail

Annex F
(normative)

Standard test method for the determination of the plane strain fracture toughness (K_{Ic}) of rails

F.1 Test methods

This test shall be performed in accordance with the requirements of ASTM E399 except where superseded by the requirements specified in this International Standard. The requirements specified in this annex apply only to the determination of plane strain fracture toughness of railway rail steels covered by the definitions and requirements of this International Standard.

F.2 Test pieces

F.2.1 The location of the test piece in the rail's transverse section is shown in Figure F.1.

F.2.2 The thickness "B" of all test pieces shall be 25 mm. For any rail head transverse profile, the test piece width "*W*" shall be the maximum achievable of the following dimensions:

— 40 mm;

— 45 mm;

— 50 mm.

F.3 Test conditions

NOTE It is recommended that the chevron notch in ASTM E399 is used to avoid crack front curvature problems.

F.3.1 Fatigue pre-cracking shall be carried out in the temperature range between +15 °C to +25 °C, using a stress ratio in the range between 0 and +0,1. Fatigue pre-cracking shall be carried out at a cyclic frequency in the range between 15 Hz and 120 Hz. The final crack length to test piece width ratio shall be in the range between 0,45 to 0,55 and during the last 1,25 mm of crack growth K_{max}, shall be in the range between 18 MPa $m^{1/2}$ and 22 MPa $m^{1/2}$.

F.3.2 The single edge notched bend test piece shall be loaded under displacement control using three-point bending with a loading span (*S*) equal to four times the test piece width (*W*).

F.3.3 Tests shall be performed at a test temperature of –20 °C ±2 °C. Test piece temperature shall be measured using a beadless thermocouple, spot-welded to the test piece at the location shown in Figure F.2.

F.4 Analysis of test data

F.4.1 The calculation of K_Q shall be in accordance with ASTM E399. The checks made to establish whether this value is a valid K_{Ic} shall be in accordance with ASTM E399 except for the requirements of F.4.2 to F.4.6.

F.4.2 P_{max}/P_Q shall be less than 1,10 for force-crack mouth opening curves where pop-in does not occur before the intersection of the curve with the 95 % secant. There shall be no P_{max}/P_Q criterion for other types of curve.

F.4.3 The linearity of force-crack mouth opening curves Ia, Ib, IIa and III (see Figure F.3) shall be checked in the following manner:

— measure the distance (v_1) between the tangent OA and the force-crack mouth opening curve at a constant force of $0{,}8P_Q$;

— measure the distance (v) between the tangent OA and the force-crack mouth opening curve at a constant force of P_Q.

For a test result to be valid, $v_1 \leq 0{,}25v$.

F.4.4 The linearity of force-crack mouth opening curves IIb and IIc (see Figure F.3) shall be checked in the following manner:

— measure the distance between the tangent OA and the force-crack mouth opening curve at constant forces of $0{,}8P_Q$ and P_Q, recording these values as v_1^* and v^*, respectively;

— measure the crack mouth opening values arising from all "pop-ins" that occur up to P_Q. This is done by

  — measuring the horizontal distance travelled along the crack mouth opening axis between the start and finish of each "pop-in", and

  — sum the values for "pop-ins" occurring below $0{,}8P_Q$ and for those occurring between $0{,}8P_Q$ and P_Q, recording them as Σv_{1pi} and Σv_{pi}, respectively.

For a test result to be valid, $[v_1^* - \Sigma v_{1pi}] \leq 0{,}25\ [v^* - (\Sigma v_{pi} + \Sigma v_{1pi})]$.

F.4.5 The linearity criterion cannot be applied to force-crack mouth opening curve IV.

F.4.6 For all force-crack mouth opening curves, the K_Q value shall be subjected to the validity check that the test piece thickness (B) and crack length (a) are equal to, or greater than, the value of $2{,}5\ (K_Q/R_{p0,2})^2$, where $R_{p0,2}$ is 0,2 % proof stress at the fracture test temperature of −20 °C.

F.5 Reporting of results

All measurements required to calculate the test result and to show that the test conditions were as specified in the test procedure shall be recorded.

All results shall be reported as either K_{Ic} values K^*_Q values or K_Q values; where K^*_Q values are those K_Q values which failed the validity criteria due only to one or more of the following:

a) $P_{max}/P_Q > 1{,}1$;

b) exceedance of the $2{,}5\ (K_Q/R_{p0,2})^2$ criterion;

c) crack mouth opening displacement-force relationship.

The mean and standard deviation of both K_{Ic} and K^*_Q results shall be recorded. For each grade of rail tested, these results shall be included in a table with the following information.

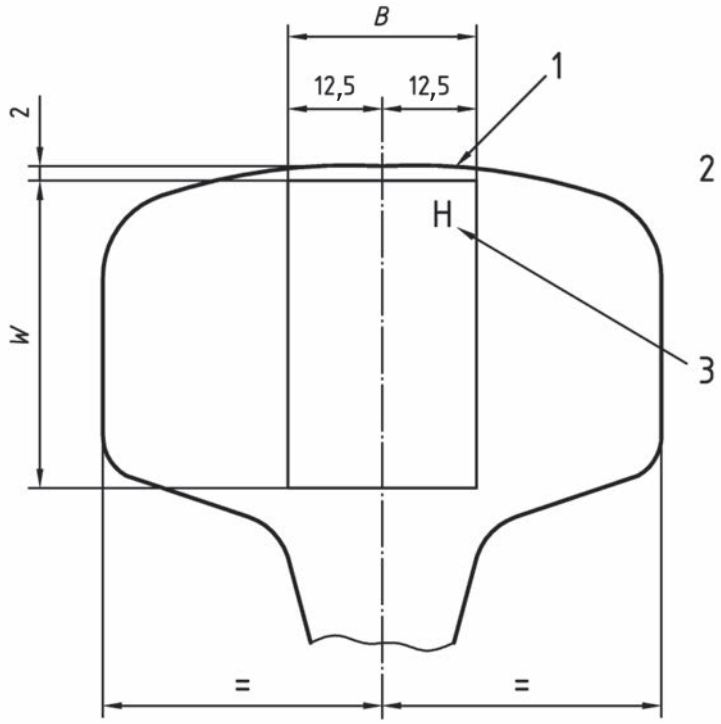
Steel Grade	0,2 % proof Strength at –20 °C (MPa)	Mean K_{Ic} (MPa m$^{1/2}$)	Number of K_{Ic} results	Sample standard deviation (MPa m$^{1/2}$)	Mean K_Q (MPa m$^{1/2}$)	Number of K_Q results	Sample standard deviation (MPa m$^{1/2}$)

The value to be used for the acceptance criteria is that of the mean K_{Ic} and shall be based on a minimum of five K_{Ic} values.

When five K_{Ic} values have not been obtained, any K^*_Q values shall be included with any K_{Ic} values in the mean value to be used for the acceptance criteria. In this event, the number of test results shall be at least 10.

All values of K_{Ic} and K^*_Q shall be above the minimum value specified in Table 14.

Dimensions in millimetres



Key

1 notch machined in this face

2 section through rail head

3 letter "H" to be stamped on end face of test piece as shown

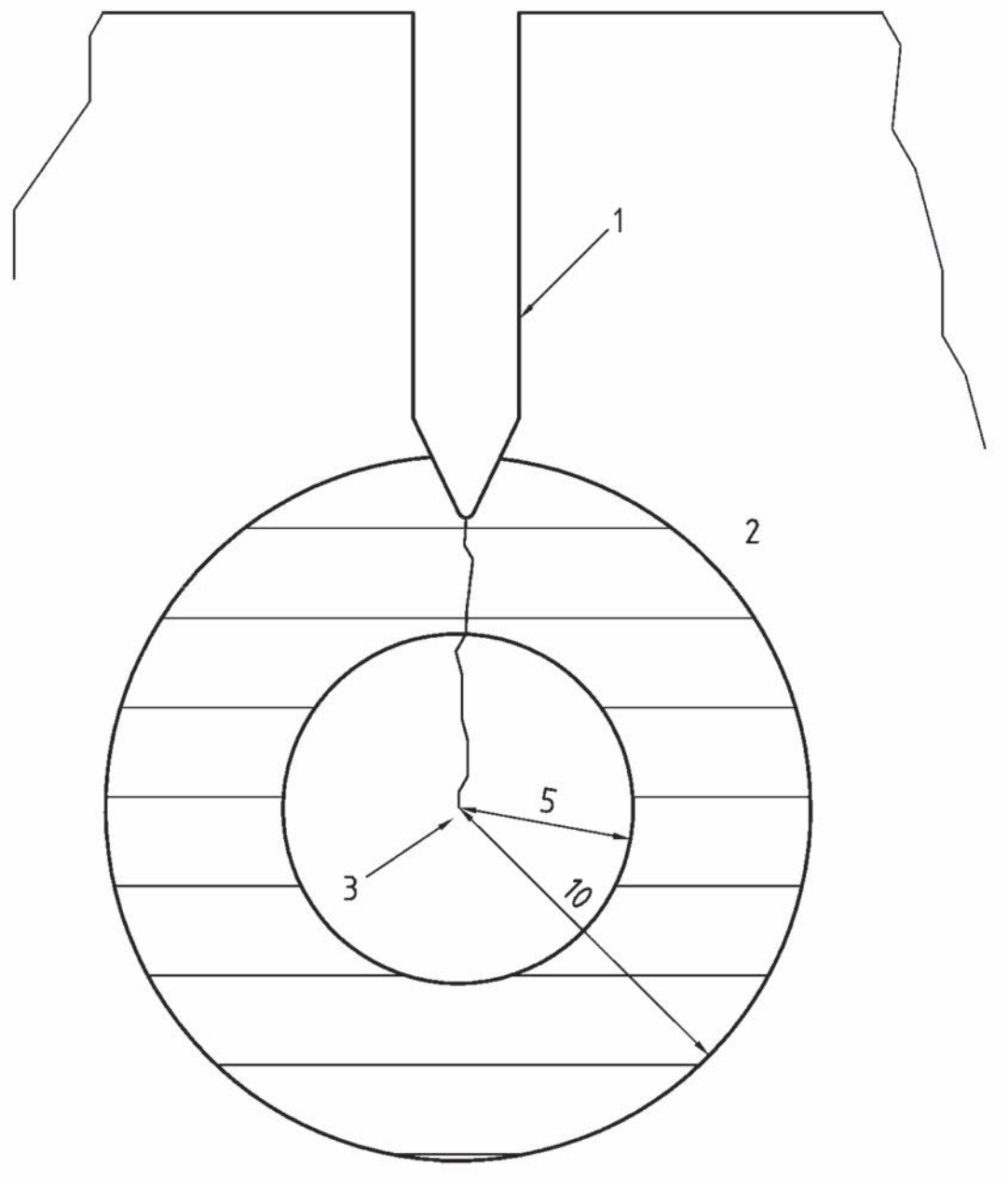
B = 25 mm

W See F.2.2.

NOTE For all other test piece proportions, see ASTM E399.

Figure F.1 — Location and section of fracture toughness test pieces

Dimensions in millimetres

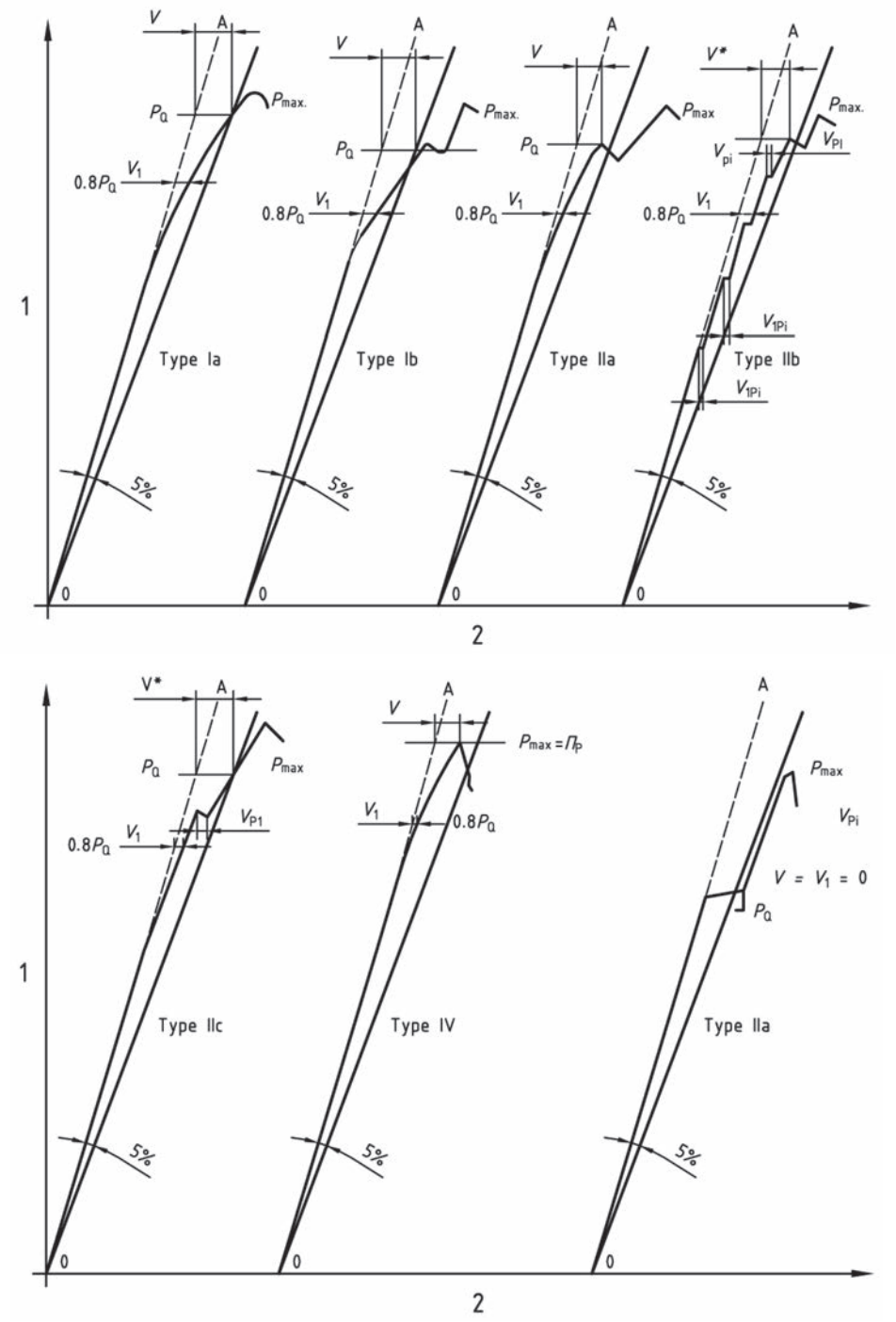


Key

1 notch
2 thermocouple to be placed in the shaded zone
3 fatigue crack tip

Figure F.2 — Location of thermocouple on fracture toughness specimens

Dimensions in millimetres



Key

1 force, P

2 crack mouth opening displacement (v)

Figure F.3 — Force — Crack mouth opening curves

Annex G
(normative)

Profile and drilling gauges

The gauges for manufacture are shown in the figures which are summarized in Table G.1.

Table G.1 — Summary of figures

Figure G.1	Datum references for tolerances
Figure G.2	Datum references for decision
Figure G.3	Height of rail
Figure G.4	Width or rail head
Figure G.5	Crown profile
Figure G.6 and G.7	Asymmetry
Figure G.8	Fishing height HF
Figure G.9	Web thickness
Figure G.10	Width of rail foot
Figure G.11	Foot toe thickness
Figure G.12 and G.13	Drilling gauges

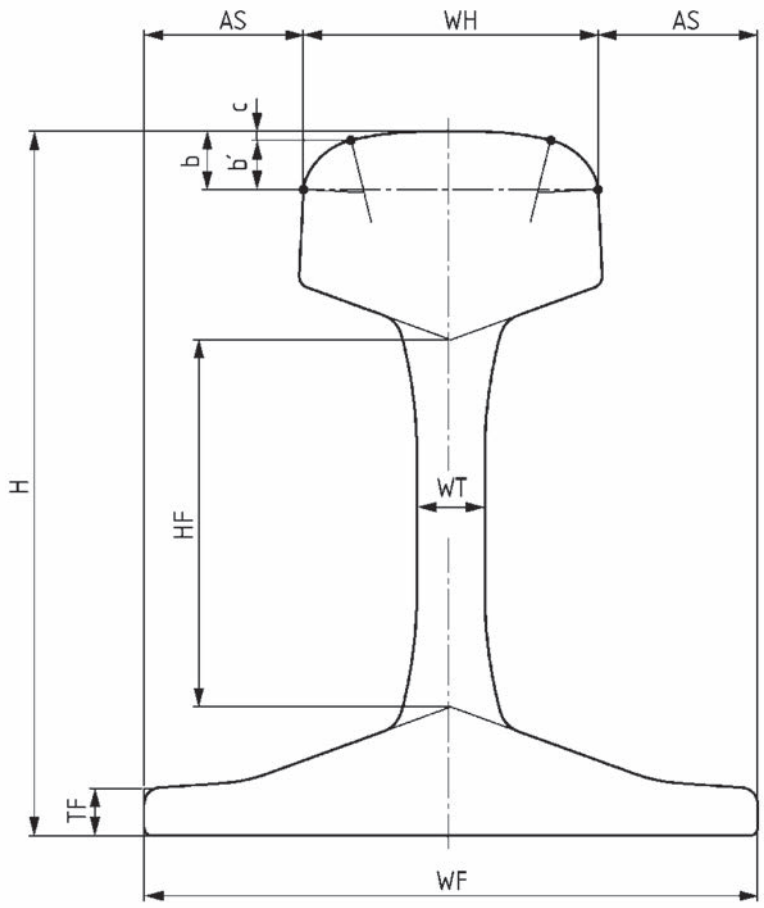
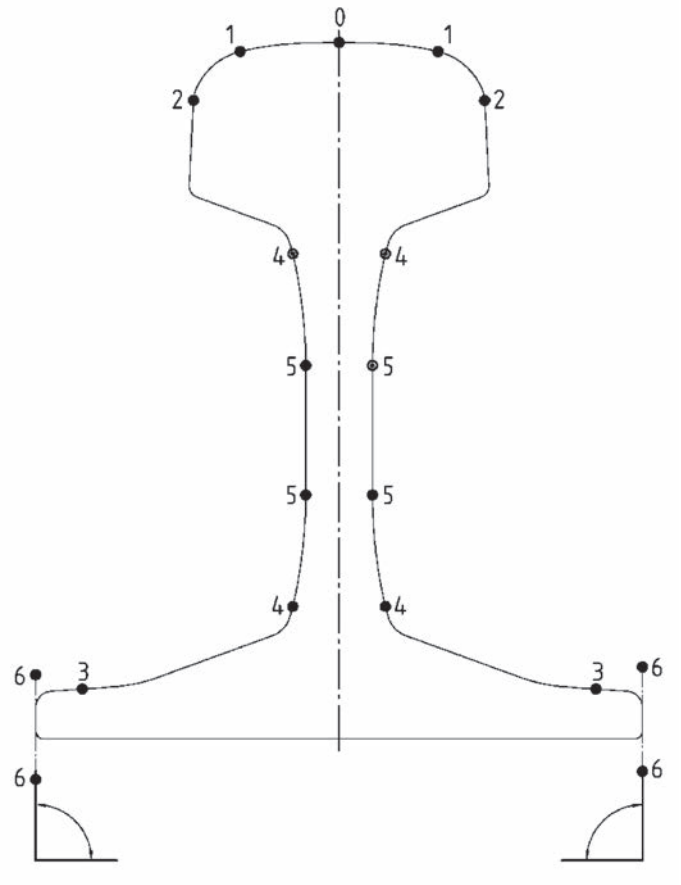


Figure G.1 — Datum references for tolerances (see Table 2)



Datum	Reference			Figure number
0	height:	– must not	+ must pass	Figure G.3
0	crown profile:	– must	+ must not pass the wedge	Figure G.5
1	width of rail head:	– must not	+ must touch	Figure G.4
2	rail asymmetry:	– must not	+ must touch	Figure G.6 Figure G.7
4, 5	height of fish plating:	– must	+ must not touch	Figure G.8
5	web thickness:	– must not	+ must pass	Figure G.9
3, 6	foot toe thickness must touch foot edge	must be into the ± range		Figure G.11
6	width of rail foot:	– must not	+ must pass	Figure G.10

Figure G.2 — Datum references for decision