

Wrought steels for mechanical and allied engineering purposes — Requirements for carbon, carbon manganese and alloy hot worked or cold finished steels

ICS 77.140.20

Committees responsible for this Published Document

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- Confederation of British Metalforming
- Institute of Spring Technology
- Ministry of Defence
- National Association of Steel Stockholders
- National Physical Laboratory
- Society of Motor Manufacturer’s and Traders Association
- UK Steel Association

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Contents

	Page
Committees responsible	Inside front cover
Foreword	ii
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 Designation	2
5 Information to be supplied by the purchaser	3
6 Manufacturing process	4
7 Requirements	4
8 Inspection and testing	10
9 Marking	13
10 Specific requirements for as-rolled and normalized steels and for steels supplied as cold finished bar	13
11 Specific requirements for quenched and tempered steels including steels capable of surface hardening by nitriding for special applications	26
12 Specific requirements for case hardening steels	34
13 Specific requirements for tolerances	36
Annex A (informative) Table showing correlation between steels from BS 970-1:1983, PD 970:2001 and current nationally adopted European Standards	41
Bibliography	46
Figure 1 — Types of mill edge (convex and concave)	37
Figure 2 — Rhomboid edge condition	38
Figure 3 — Edge camber of wide flats	39
Table 1 — Permitted variations of product analysis from specified range	6
Table 2 — Reference symbols for tensile strength ranges of hardened and tempered material	7
Table 3a — Surface quality classes	9
Table 3b — Surface quality classes for cold finished flats	10
Table 4 — Hot rolled and hot rolled + normalized steels: chemical composition and mechanical property requirements	14
Table 5 — Normalizing requirements	15
Table 6 — Steels supplied as cold finished bar: chemical composition and mechanical property requirements	16
Table 7 — Quenched and tempered steels including steels capable of surface hardening by nitriding: chemical composition and mechanical property requirements	26
Table 8 — Quenched and tempered steels: heat treatment and maximum hardness requirements in the softened condition	32
Table 9 — Hardenability requirements for 708H37	33
Table 10 — Case hardening alloy steels: chemical composition and hardenability requirements	34
Table 11 — Case hardening carbon manganese and low alloy steels: chemical composition and mechanical property requirements	35
Table 12 — Case hardening steels: heat treatment and maximum hardness requirements	36
Table 13 — Thickness tolerances for wide flats	37
Table 14 — Deviation from squareness of edges for wide flats (see Figure 1 and Figure 2)	38
Table 15 — Tolerances for hot rolled round, square and hexagon bars suitable for cold finishing	40

Foreword

Published document PD 970:2001 was prepared by Technical Committee ISE/31 as a revision of BS 970:1996 to cover those steels from BS 970-1:1996 and BS 970-3:1991 for which there is a current regular demand but no equivalent within current European Standards.

BS 970-1:1996 is current but has been partially replaced by BS EN 10084:1998, BS EN 10087:1999, BS EN 10095:1999 and BS EN 10250-4:2000. BS 970-2:1988 is current but will be replaced by BS EN 10089. BS 970-3:1991 is withdrawn and has been replaced by BS EN 10277:1999 and BS EN 10278:1999. BS 970-4 is withdrawn and has been replaced by BS EN 10090:1998.

The series of European Standards listed below covers heat treatable and engineering steels for both black and cold finished bar that were present in BS 970-1:1996 and BS 970-3:1991, or other European Standards.

It was recognised, however, that several specifications in regular use in the UK did not have equivalents in the new European Standards and the withdrawal of BS 970 in which they were listed had resulted in them not being identified within any current document.

Steel grades

BS EN 10083	<i>Quenched and tempered steels</i>
BS EN 10083-1	<i>Technical delivery conditions for special steels</i>
BS EN 10083-2	<i>Technical delivery conditions for unalloyed quality steels</i>
BS EN 10083-3	<i>Technical delivery conditions for boron steels</i>
BS EN 10084	<i>Case hardening steels — Technical delivery conditions</i>
prEN 10085	<i>Nitriding steels — Technical delivery conditions</i>
BS EN 10087	<i>Free cutting steels — Technical delivery conditions for semi-finished products, hot-rolled bars and rods</i>
BS EN 10088	<i>Stainless steels</i>
BS EN 10088-1	<i>List of stainless steels</i>
BS EN 10088-3	<i>Technical delivery conditions for semi-finished products, bars, rods and sections for general purposes</i>
prEN 10089	<i>Hot-rolled steels for quenched and tempered springs — Technical delivery conditions</i>
BS EN 10090	<i>Valve steels and alloys for internal combustion engines</i>
BS EN 10095	<i>Heat resisting steels and nickel alloys</i>
BS EN 10250	<i>Open steel die forgings for general engineering purposes</i>
BS EN 10250-2	<i>Non-alloy quality and special steels</i>
BS EN 10250-3	<i>Alloy special steels</i>
BS EN 10250-4	<i>Stainless steels</i>
BS EN 10254	<i>Steel closed die forgings — General technical delivery conditions</i>
BS EN 10267	<i>Ferritic-pearlitic steels for precipitation hardening from hot-working temperatures</i>
BS EN 10277	<i>Bright steel products — Technical delivery conditions</i>
BS EN 10277-1	<i>General</i>
BS EN 10277-2	<i>Steels for general engineering purposes</i>
BS EN 10277-3	<i>Free-cutting steels</i>
BS EN 10277-4	<i>Case-hardening steels</i>
BS EN 10277-5	<i>Steels for quenching and tempering</i>
BS EN ISO 683	<i>Heat-treated steels, alloy steels and free-cutting steels</i>
BS EN ISO 683-17	<i>Ball and roller bearing steels</i>

Dimensions, tolerances and surface quality

prEN 10058	<i>Hot rolled flat steel bars for general purposes — Dimensions and tolerances on shape and dimensions</i>
prEN 10059	<i>Hot rolled square steel bars for general purposes — Dimensions and tolerances on shape and dimensions</i>
prEN 10060	<i>Hot rolled round steel bars — Dimensions and tolerances on shape and dimensions</i>
prEN 10061	<i>Hot rolled hexagon steel bars — Dimensions and tolerances on shape and dimensions</i>
BS EN 10221	<i>Surface quality classes for hot-rolled bars and rods — Technical delivery conditions</i>
BS EN 10250	<i>Open steel die forgings for general engineering purposes</i>
BS EN 10250-1	<i>General requirements</i>
BS EN 10278	<i>Dimensions and tolerances of bright steel products</i>

Any steel grade that has previously appeared in BS 970 and is now specified as an equivalent grade in one of the above European Standards and is cross-referenced in Annex A.

Annex A is informative.

This Published Document does not purport to include all the necessary provisions of a contract. Users of this Published Document are responsible for its correct application.

Compliance with this Published Document does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 46, an inside back cover and a back cover.

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1 Scope

This Published Document specifies the technical delivery requirements for the following wrought semi-finished products manufactured from a range of carbon, carbon manganese and low alloy steels and free-cutting, case-hardening and through hardened steels for special applications:

- blooms;
- billets;
- slabs;
- bars;
- rod;
- flats and wide flats.

NOTE These wrought steels may be supplied in the hot formed condition or as chemically treated black bar. Cold finished bar may be subjected to pre- or post-thermal treatment.

It does not specify any boron, micro-alloyed, stainless steels or any products delivered as forgings, which are all covered by other standards (see Foreword).

It does not apply to as-cast products.

PD 970 is presented in the style of a European Standard and references other European Standards (e.g. test methods) wherever possible. The traditional 7 digit alphanumeric UK designation is maintained, though it is important to note that the “A”, “M” and “H” system (nominally representing Analysis, Mechanical and Hardenability) should not be confused with other nomenclature. This applies equally to the conventional tensile strength range designations, namely “P” through to “Z” which are still used in this document.

Certain other aspects such as requirements for steelmaking, deoxidation and grain size etc. have been revised to reflect modern technology.

There are certain steel grades indigenous to the UK, that are not specified in other European Standards but for which there is still substantial demand. It is such grades that are specified in PD 970.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this Published Document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 131-1, *Notched bar tests — The Izod impact test of metals.*

BS 4490, *Methods for micrographic determination of the grain size of steel.*

BS EN 10020, *Definition and classification of grades of steel.*

BS EN 10021, *General technical delivery requirements for steel and iron products.*

BS EN 10052, *Vocabulary of heat treatment terms for ferrous products.*

BS EN 10079, *Definition of steel products.*

BS EN 10204, *Metallic products — Types of inspection documents.*

BS EN 10278, *Dimensions and tolerances of bright steel products.*

BS EN 10002-1, *Tensile testing of metallic materials — Part 1: Method of test at ambient temperature.*

BS EN 10045-1, *Charpy impact test on metallic materials — Part 1: Test method (V- and U-notches).*

BS EN 10109-1, *Metallic materials — Hardness test — Part 1: Rockwell test (scales A, B, C, D, E, F, G, H, K) and Rockwell superficial test (scales 15N, 30N, 45N, 15T, 30T and 45T).*

BS EN 20286-2, *ISO system of limits and fits — Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts.*

BS EN ISO 642, *Steel hardenability test by end quenching (Jominy test).*

BS EN ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method.*

BS EN ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method.*

DD ENV 606, *Bar coded transport and handling labels for steel products.*

NF A 04-106, *Iron and steel — Methods for the determination of the non-metallic inclusion content of steel — Part 2: Microscopic methods with standard series.*

DIN 50602, *Metallographic examination — Microscopic examination of special steels using standard diagrams to assess the content of non-metallic inclusions.*

ISO 4967, *Steel — Determination of content of non-metallic inclusions — Micrographic method using standard diagrams.*

SS 11 11 16, *Steel — Methods for determining non-metallic inclusion content — Jernkontoret's inclusion Table 2 for determining non-metallic inclusions.*

ASTM E 45, *Test methods for determining the inclusion contents of steel.*

prEN 10058, *Hot rolled flat steel bars for general purposes — Dimensions and tolerances on shape and dimensions.*

prEN 10059, *Hot rolled square steel bars for general purposes — Dimensions and tolerances on shape and dimensions.*

prEN 10060, *Hot rolled round steel bars — Dimensions and tolerances on shape and dimensions.*

prEN 10061, *Hot rolled hexagon steel bars — Dimensions and tolerances on shape and dimensions.*

3 Terms and definitions

For the purpose of this Published Document the terms and definitions given in BS EN 10020, BS EN 10021, BS EN 10052 and BS EN 10079 and the following apply.

3.1

ruling section

equivalent diameter of that portion of the product at the time of heat treatment that is most important in relation to mechanical properties

3.2

limiting ruling section

largest diameter in which certain specified mechanical properties are achieved after a specified heat treatment

3.3

equivalent diameter

for any product, or part of a product, the diameter at the time of heat treatment of a hypothetical very long bar, effectively of infinite length and uniform circular cross-section, which, if subjected to the same cooling conditions as the product (that is, the same initial and final temperature and same cooling medium) would have a cooling rate at its axis equivalent to that at the slowest cooling position in the product or relevant part

4 Designation

The steel grades shall be designated in accordance with the system used previously in BS 970. “A” grades shall refer to close limits of chemical composition where no mechanical properties or hardenability are required. “M” and “H” grades shall refer to mechanical and hardenability requirements which are specified in combination with a chemical composition which may be wider than that given for “A” grades.

NOTE Material may be ordered and supplied without heat treatment where appropriate test pieces have been heat treated and tested to prove the capability of the material to meet the required properties.

The actual supply condition of the material shall be agreed and stated on the enquiry and order.

5 Information to be supplied by the purchaser

5.1 Mandatory information

The following information shall be supplied by the purchaser at the time of enquiry and order:

- a) the quantity to be delivered, e.g. 2 t;
- b) the shape of the product e.g. round, hexagon, flat;
- c) the dimensions and tolerances on dimensions and shape;
- d) the number of this Published Document (PD 970);
- e) the intended applications of the billets and bars, e.g. re-rolling, cold drawing, metal coating;
- f) steel grade;
- g) if ordered to the mechanical property requirements of **10.1**, the limiting ruling section required for non free-cutting steels (see Table 4);
- h) if ordered to the requirements of **10.2**, the condition, the size, and where appropriate, the tensile strength ranges required (see Table 6);
- i) if ordered to the mechanical property requirements of clause **11**, the ruling section and tensile strength ranges required (see Table 7);
- j) if ordered to the hardenability requirements of clause **11** or clause **12**, the hardness value(s) at the required distances (see Table 9 and Table 10);
- k) the delivery condition of the material to be supplied (see **6.3**).

5.2 Options

If any options are required they shall be agreed at the time of enquiry and order. If the purchaser does not indicate his wish to implement one or more of these options, the supplier shall supply the following in accordance with the basic specification of this Published Document (see **5.1**):

- a) any requirement on steelmaking process (see **6.1**);
- b) any requirement on re-melted steel (see **6.1**);
- c) any requirement on deoxidation (see **6.2**);
- d) any requirement concerning minimum reduction ratio of rolled products (see **6.3.2**);
- e) any requirement for the sulfur content if different from the standard limits (see **7.1.2**);
- f) if a steel containing lead (or other element having similar effect) is required (see **7.1.3**);
- g) any additional cast/product analysis (see **7.1.5**);
- h) size of test bar (see **7.2.1**);
- i) any special requirement on grain size and the method of measurement (see **7.3.1**);
- j) any special requirement concerning determination of non-metallic inclusion content (see **7.3.2**);
- k) any requirement on shearability for billets, slabs and bars;
- l) any requirement for internal soundness (see **7.4**);
- m) any requirements relating to surface quality, surface defects and their removal (see **7.5.1** for hot rolled products and **7.5.2** for cold finished products);
- n) any requirement concerning suitability of bars, flats and rod for cold finishing (see **7.5.1.2**);
- o) any requirement on surface removal for subsequent plating (see **7.5.2.1**);
- p) any requirement on decarburization (see **7.6**);
- q) whether Izod impact is required (see **8.2.2**);
- r) location of test pieces (see **8.2.4.2**);
- s) any requirement on the type of inspection document, in accordance with BS EN 10204 (see **8.5**);
- t) any requirements concerning special marking of the products (see clause **9**);
- u) tolerances for semi-finished product (see **13.1**);
- v) whether sawn ends are required (see **13.4**).

6 Manufacturing process

6.1 Melting process

The preferred melting process shall be via the EAF (Electric Arc Furnace) or BOS (Basic Oxygen Steelmaking) route at the steelmaker's discretion. The mixed air, open hearth and Bessemer processes shall NOT be permitted.

NOTE Steelmaking and refining may be carried out in a ladle or ladle furnace. Re-melted steels [using VAR (Vacuum Arc Re-melting) and ESR (Electro Slag Re-melting)] may be specified at the time of enquiry and order.

6.2 Deoxidation

The steels covered by this Published Document (including substitutes for those traditionally produced as rimming, balanced or semi-killed) shall be killed.

NOTE They are in general, produced by continuous casting, although killed ingot steels may be supplied.

Unless otherwise agreed at the time of enquiry and order, the killing technique shall be left to the discretion of the steelmaker.

6.3 Condition of material on delivery

6.3.1 General

Blooms, billets, slabs, black bars and rod shall be supplied as rolled or as forged unless otherwise agreed at the time of enquiry and order.

Cold finished bars shall be as supplied in the condition stated on the order.

Normalized or quenched and tempered bars, including those that are subsequently cold drawn, shall be supplied to the specified mechanical properties and in the condition stated in the order.

NOTE Material used in the non heat treated condition may be supplied to Brinell hardness values, by agreement at the time of enquiry and order.

6.3.2 Reduction ratio

Where central soundness in the end product is important, the purchaser shall be made aware that a minimum reduction ratio of 4:1 from the cast product (based on cross sectional area) is required.

NOTE For hot rolled or forged bar products a minimum reduction ratio can be agreed.

6.4 Heat treatment

The heat treatment to be given to the test bars and to material required in the finally heat treated condition, shall be as specified in Table 5, Table 8 and Table 12.

7 Requirements

7.1 Chemical composition

7.1.1 Composition ranges

The chemical composition of the steel, based on cast analysis, shall conform to the requirements of the appropriate material specification as given in the relevant tables.

Table 4	Hot rolled and hot rolled + normalized steels
Table 6	Steels supplied as cold finished bar
Table 7	Quenched and tempered steels including nitriding grades
Table 9	Hardenability requirements for 708H37
Table 10	Case hardening alloy steels with hardenability requirements
Table 11	Case hardening carbon manganese and low alloy steels with mechanical property requirements

7.1.2 Sulfur and phosphorus contents

Carbon, carbon manganese and low alloy steels shall be supplied with sulfur and phosphorus contents of 0.035 % maximum.

NOTE 1 If specified at the time of enquiry and order, a controlled sulfur range of 0.020 % to 0.040 % may be specified to improve machinability (see 7.1.3).

NOTE 2 Where specifically ordered, a lower content of sulfur and phosphorus, with each element at 0.025 % maximum, may be supplied. This is recommended for certain alloy nitriding steels and for tensile strengths of 1 225 MPa and greater. Other limits may be agreed at the time of enquiry and order.

7.1.3 Steels with improved machinability characteristics

Steels containing lead may be supplied by agreement and the agreed lead range shall be stated at the time of enquiry and order. In the absence of this agreement the lead range shall be not less than 0.12 % nor greater than 0.35 % on the cast analysis, and shall be evenly and finely distributed.

The addition of any other elements such as bismuth, selenium and tellurium, which may be added to improve machinability properties of certain steels, shall be agreed at the time of enquiry and order.

7.1.4 Residual elements

Elements not specified in the specification(s) called up by the order shall not be added to the steel without the agreement of the purchaser, other than for the purpose of finishing the heat or to achieve anticipated or specified properties.

NOTE Relevant specifications are included in this Published Document.

In carbon, carbon manganese and alloy steels, the following maxima shall be considered as incidental: chromium (Cr) 0.40 %, nickel (Ni) 0.40 %, copper (Cu) 0.35 %, molybdenum (Mo) 0.10 %, $\%Cu + (10 \times \%Sn) = 0.60 \% \text{ max.}$

7.1.5 Product analysis

The permissible deviations in the product analysis in relation to the specified limits for cast analysis shall be as specified in Table 1.

The purchaser can specify at the time of enquiry and order that the chemical composition on product analysis shall be verified.

Table 1 — Permitted variations of product analysis from specified range

Element	Permissible maximum content in the cast analysis	Permissible deviation ^a
C	≤0.30	±0.02
	>0.30, ≤0.50	±0.03
	>0.50, ≤1.05	±0.04
Si	≤0.40	+0.03
Mn	≤1.00	±0.04
	>1.00, ≤1.70	±0.06
P	≤0.025	+0.005
	>0.025, ≤0.040	+0.006
	>0.040, ≤0.060	+0.008
S	≤0.025	+0.005
	>0.025, ≤0.040	±0.006
	>0.040, ≤0.060	±0.008
	>0.060, ≤0.10	±0.010
	>0.10, ≤0.30	±0.03
S	0.02 to 0.04 controlled range	+0.006, −0.003
Cr	≤2.00	±0.05
	>2.00, ≤3.50	±0.10
Mo	≤0.30	±0.03
	>0.30, ≤0.65	±0.04
Ni	≤2.00	±0.05
	>2.00, ≤5.00	±0.07
^a ± means that in one cast the deviation may occur over the upper value or under the lower value of the specified ranges but not both at the same time.		

7.2 Mechanical properties

7.2.1 General

For through hardened steels, the mechanical properties attainable from any steel composition and heat treatment shall be dependent on the ruling section.

The individual steel specifications of this Published Document show the limiting ruling section to which the stated mechanical properties apply, and the purchaser shall select a steel which is specified to give the required properties in the appropriate ruling section at the time of heat treatment.

Because of the effect of section size, the properties for carbon and carbon manganese case-hardening steels are given for different test bar sizes in the oil-quenched condition, i.e. 13 mm, 19 mm and 29 mm, however the 19 mm size shall be used except by agreement.

NOTE 1 It is customary to test steel to specified mechanical properties using a standard size of test bar.

NOTE 2 For alloy case hardening steels, verification of hardenability can be provided by calculation or by testing at the suppliers discretion. Hardenability bands for these steels are included in clause 12. These hardenability bands may be used as a guide to estimate the tensile strength of a ruling section at the time of heat treatment.

When “M” grade steels are ordered, the properties given shall be for a test bar of 19 mm.

NOTE 3 All the specified mechanical properties in this Published Document refer to tests taken in the longitudinal direction.

7.2.2 Reference symbols for tensile strength ranges of quenched and tempered material

The various tensile ranges for the different specifications shall be designated with the reference symbols “P” to “Z”, as given in Table 2.

Table 2 — Reference symbols for tensile strength ranges of hardened and tempered material

Reference symbol	Tensile strength MPa
P	550 to 700
Q	625 to 775
R	700 to 850
S	775 to 925
T	850 to 1 000
U	925 to 1 075
V	1 000 to 1 150
W	1 075 to 1 225
X	1 150 to 1 300
Y	1 225 to 1 375
Z	1 550 minimum

NOTE 1 This method of specifying tensile strength is different to that used in all European Standards where properties for different section thicknesses are specified.

NOTE 2 It is important to note that these letters should not be confused with the letters used in European steel designations as given in BS EN 10027-1.

7.3 Technological properties

7.3.1 Structure and grain size

Steels shall be supplied either coarse or fine grained at the suppliers discretion unless agreed otherwise at the time of enquiry and order. Fine grained steels shall normally be aluminium (Al) treated though other methods may be used.

The hardenability (for “H” grades) and impact toughness (where specified for “M” grades) specified in this standard shall apply only to aluminium treated fine grained steels.

If a coarse grained steel is required, any associated hardenability, toughness or impact property requirements shall be agreed separately.

Case carburizing steels shall be supplied fine grained (aluminium treated) unless specifically ordered otherwise.

Aluminium treated steels shall be considered fine grained if the total Al content is 0.015 % or greater. However, in cases of dispute, or when specifically requested, the grain size shall be measured in accordance with BS 4490 (or EURONORM 103).

7.3.2 Cleanliness

If required, specifications for the degree of freedom from non-metallic inclusions and their methods of determination shall be agreed at the time of enquiry and order.

If the purchaser does not specify on the order which method is to be used for determining the non-metallic inclusion content, the supplier shall select any appropriate method from one of the following: ASTM E 45, ISO 4967, DIN 50602, NF A 04-106 or SS 11 11 16.

7.4 Internal soundness

Requirements for internal soundness shall be agreed at the time of enquiry and order.

7.5 Surface finish and quality

7.5.1 *Hot rolled products*

7.5.1.1 *Surface finish*

All products shall have a finish appropriate to the forming processes applied.

NOTE Minor surface imperfections, which may occur under normal manufacturing conditions, may be present.

7.5.1.2 *Surface quality*

Where appropriate, requirements relating to the surface quality of the products shall be agreed at the time of enquiry and order.

If suitability for cold finishing is required, this shall be agreed at the time of enquiry and order.

The permissible defect depth and when appropriate, the method of removal, shall be agreed at the time of enquiry and order.

The removal of surface defects from the wrought product by scarfing or their repair by welding shall not be permitted. Scarfing of semi-finished products shall be permitted providing it is not deleterious to the product.

NOTE It is more difficult to detect and eliminate surface discontinuities from coiled products than from cut lengths. This should be taken into account when agreements on surface quality are made.

7.5.2 *Cold finished products*

7.5.2.1 *Surface finish*

Drawn products shall have a smooth, scale free surface. Products in the final heat treated condition shall be free from loose surface scale; their surface might be discoloured or darker.

Isolated pores, pits and grooves can be present; in the case of rounds, their depth shall not exceed 50 % of the ordered tolerance class measured on the actual diameter.

In the case of hexagons, squares and flats, in accordance with BS EN 20286-2, the depth of surface imperfections shall not be greater than ISO tolerance h11 measured on the actual size.

NOTE For hexagons, squares, flats and profiles with special cross-sections it is not possible to achieve, for manufacturing reasons, the same quality of surface finish as for round cross-sections.

Material requiring subsequent plating shall be subjected to surface removal, as agreed at the time of enquiry and order.

7.5.2.2 *Surface quality*

Since surface defects cannot be completely avoided in the manufacture of hot rolled products and since they are retained when drawing, agreements shall be made regarding surface quality.

The surface quality of the products shall be one of the classes according to Table 3a or Table 3b as appropriate. If there is no agreement at the time of enquiry and order, the supplier shall deliver in accordance with surface quality class 1.

NOTE As surface defects cannot be eliminated without removal of material, it is recommended that a minimum stock removal of 2 % per side should be removed. Products in the “technically crack free by manufacture” condition shall only be available in the machined or machined and ground conditions.

Table 3a — Surface quality classes^a

Class	Permissible defect depth ^b	Maximum delivered weight in excess of specified defect level	Product form ^c			
			Rounds	Squares	Hexagons	Flats
1	Max. 0.3 mm for $d \leq 15$ mm; max. 0.02 d for $15 < d \leq 100$ mm	4 %	+	+	+	+ ^c
2	Max. 0.3 mm for $d \leq 15$ mm; max. 0.02 d for $15 < d \leq 75$ mm; max 1.5 mm for $d > 75$ mm	1 %	+	+ (for $d \leq 20$ mm) ^d	+ (for $d \leq 20$ mm) ^d	—
3	Max. 0.2 mm for $d \leq 20$ mm; max. 0.01 d for $20 < d \leq 75$ mm; max 0.75 mm for $d > 75$ mm	1 %	+	—	—	—
4	Technically crack free by manufacture	0.2 %	+	—	—	—
NOTE Class 1 refers to cold finished products from hot rolled bar subject to visual inspection. Class 2 refers to drawn products from hot rolled bar subject to non-destructive testing. Class 3 is generally produced by surface removal.						
^a d is the nominal diameter of bar and distance across flats of squares and hexagons. ^b Maximum defect depth refers to respective section (width or thickness). ^c + indicates available in these classes, — indicates not available in these classes. ^d Crack detection with eddy current device is not possible for $d > 20$ mm or $d > 50$ mm as indicated.						

Table 3b — Surface quality classes for cold finished flats

	Class			
	1		2	
	Wider or flat face	Narrower or edge face	Wider or flat face	Narrower or edge face
Permissible defect depth	Maximum defect depth 0.15 mm on thickness up to 20 mm, then 0.75 % on thickness over 20 mm	Maximum defect depth 0.75 % of ordered width	Maximum defect depth 0.2 mm on thickness up to 20 mm, then 1.0 % on thickness over 20 mm	Maximum defect depth 1.0 % of ordered width

7.6 Decarburization levels

Levels of decarburization and their method of measurement (e.g. EURONORM 104) shall be specified at the time of enquiry and order.

8 Inspection and testing

8.1 Tensile strength of 1 225 MPa or greater

Where the tensile strength of alloy steel is specified as 1 225 MPa minimum or more, the test bar shall be machined to test piece size, plus a grinding allowance if required, before heat treatment. In such cases, the properties obtained shall be representative of those parts that are heat treated in the same ruling section as that of the test piece, and shall not represent larger ruling sections.

8.2 Selection and preparation of test bars for tensile and impact tests

8.2.1 *Material not supplied in the finally heat treated condition*

Where the ruling section of the material does not differ appreciably from that of the parts to be produced, test samples shall be taken directly from the material and heat treated in the original size. Alternatively, when it is considered either by the purchaser or supplier that the results of heat treating in the original size would not be representative of the properties that would be obtained on the parts to be produced, test samples shall be forged and/or machined to test bars of a diameter (or equivalent diameter) corresponding to the ruling section of the parts at the time of heat treatment.

For the purpose of subsequent orders, these tests shall be taken as representing all sizes of material from the same cast where the ruling section of the parts does not exceed the ruling section of the test bar already tested.

8.2.2 *Bars for machining supplied in the finally heat treated or cold drawn condition*

The samples shall be cut from the heat treated bars or cold drawn bars and shall not be further heat treated or mechanically worked after their removal.

One tensile test and, where relevant, three Charpy 2 mm V-notch impact tests shall be taken from each batch of bars of similar size from the same cast and heat treated together, when applicable.

NOTE The Izod impact test may be used instead of the Charpy V-notch test.

8.2.3 *Steels for case hardening*

8.2.3.1 *Size of test bar*

The test bar size shall be 19 mm in diameter.

NOTE For carbon and carbon manganese steels, 13 mm or 29 mm diameter test bars may be used by agreement.

8.2.3.2 Selection of samples

One test sample shall be selected to represent each cast. If the size of the test sample is greater than the specified test bar size, test bars shall be prepared by forging and/or machining to that size; but for sizes smaller than 13 mm diameter, the test bar shall be heat treated in the full section of the sample.

NOTE 1 The properties specified in clause 12 apply only to ruling sections equivalent to the preferred test bars. When components of different ruling section are carburized and heat treated, different core properties may be obtained.

NOTE 2 Attention is also drawn to the influence of several factors such as steel composition, ruling section and heat treatment, on the hardness of the case. For example, even if a low core strength suffices it may be necessary to use an alloy steel for acceptable case hardenability of the largest section sizes.

8.2.3.3 Heat treatment of test bars

8.2.3.3.1 Carbon and carbon manganese steels

The test bars shall be blank carburized for at least 1 h at the hardening temperature given in Table 12 (900 °C to 930 °C) and quenched in a suitable quenchant.

8.2.3.3.2 Alloy steels

The test bars shall be blank carburized for at least 1 h at a temperature between 880 °C and 930 °C. After cooling to room temperature, they shall be reheated to the single quenching temperature, as stated in Table 12 and quenched in a suitable quenchant.

8.2.4 Location of test pieces for mechanical testing

8.2.4.1 General

In the general case where longitudinal tests are required, the test piece shall be prepared in accordance with the following.

- a) For ruling sections up to and including 25 mm, the test piece shall be machined coaxially from the test bars.
- b) For ruling sections over 25 mm, the longitudinal axis of the test pieces shall be 12.5 mm from the surface of the test bars.

8.2.4.2 Transverse and other tests

When transverse tests or tests in other directions are required, the location of the test pieces and values for mechanical properties shall be agreed between the purchaser and supplier at the time of enquiry and order.

8.3 Frequency of other tests

8.3.1 Number of hardness tests

The supplier shall carry out sufficient tests in accordance with the relevant clauses of this Published Document in order to ensure that the material conforms to the specified hardness.

8.3.2 Number of hardenability tests

Unless otherwise agreed the hardenability measurements may be determined by calculation. If testing is required, one test sample selected to represent each cast shall be reduced by forging or rolling to a size not greater than 38 mm diameter, which shall represent the full cross-section of the material. The test bar shall also be of sufficient size to ensure the complete removal of decarburization in machining to the standard test piece of 25 mm diameter.

8.3.3 Number of grain size tests

When a grain controlled steel is required and verification is requested, one test sample for the determination of austenitic grain size shall be selected to represent each cast.