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BRITISH STANDARD

BS EN
10028-2:1993

Specification for

Flat products made of steels for pressure purposes —

Part 2: Non-alloy and alloy steels with specified elevated temperature properties

The European Standard EN 10028-2:1992 has the status of a British Standard

UDC 669.14.018.44-41:621.642-98

Cooperating organizations

The European Committee for Standardization (CEN), under whose supervision this European Standard was prepared, comprises the national standards organizations of the following countries:

Austria	Oesterreichisches Normungsinstitut
Belgium	Institut belge de normalisation
Denmark	Dansk Standardiseringsraad
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France	Association française de normalisation
Germany	Deutsches Institut für Normung e.V.
Greece	Hellenic Organization for Standardization
Iceland	Technological Institute of Iceland
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Spain	Asociación Española de Normalización y Certificación
Sweden	Standardiseringskommissionen i Sverige Switzerland
	Association suisse de normalisation
United Kingdom	British Standards Institution

This British Standard, having been prepared under the direction of the Iron and Steel Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 15 February 1993

The following BSI references relate to the work on this standard:
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Contents

National foreword

This British Standard has been prepared under the direction of the Iron and Steel Standards Policy Committee and is the English language version of EN 10028-2 *Flat products made of steels for pressure purposes — Part 2: Non-alloy and alloy steels with specified elevated temperature properties* published by the European Committee for Standardization (CEN).

This British Standard supersedes BS 1501-1 which is withdrawn. It also supersedes part of BS 1501-2. Amendment No. 3 to BS 1501-2 will be published simultaneously with this British Standard.

National Annex NC of this British Standard specifies non-conflicting national additional steels.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 20 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 10028-2

December 1992

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Descriptors: Iron and steel products, metal plates, strips, unalloyed steels, heat resistant steels, pressure equipment, designation, specifications, delivery condition, tests, marking

English version

Flat products made of steels for pressure purposes — Part 2: Non-alloy and alloy steels with specified elevated temperature properties

Produits plats en aciers pour appareils à pression — Partie 2: Aciers non alliés et alliés avec caractéristiques spécifiées à température élevée

Flacherzeugnisse aus Druckbehälterstählen — Teil 2: Unlegierte und legierte warmfeste Stähle

This European Standard was approved by CEN on 1992-12-21. CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Foreword

This European Standard has been prepared by ECISS/TC 22 “Steels for pressure purposes — Qualities”, the Secretariat of which is held by Normenausschuß Eisen und Stahl (FES) im DIN.

Within the framework of the ECISS (European Committee for Iron and Steel Standardization) programme of work, TC 22 was allocated the task of revising EURONORM 28-85 “Steel plate, sheet and strip with elevated temperature properties — Technical delivery conditions” and (where relevant to pressure vessel fabrication) EURONORM 113-72 “Weldable fine-grain structural steels” and replacing them with a European Standard.

At its meeting in November 1990, ECISS/TC 22 approved this document. The following ECISS members were represented at the meeting:

Austria, Finland, France, Germany, Italy, Norway, Sweden, United Kingdom.

This European Standard was adopted and in accordance with the CEN/CENELEC Internal Regulations, the following countries are bound to implement this European Standard:

Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 1993, and conflicting national standards shall be withdrawn at the latest by June 1993.

Contents

NOTE The clauses marked with two points (. .) contain information relating to agreements that may be made at the time of ordering.

1 Scope

1.1 This Part 2 of EN 10028 specifies requirements for flat products for pressure purposes made of weldable non-alloy and alloy steels with elevated temperature properties as specified in Table 1.

1.2 The requirements of EN 10028-1 also apply.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

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

EN 10028-1, *Flat products made of steels for pressure purposes — Part 1: General requirements.*

3 Definitions

See EN 10028-1.

4 Dimensions and tolerances on dimensions

See EN 10028-1.

5 Calculation of mass

See EN 10028-1.

6 Designation and ordering

See EN 10028-1.

7 Classification into grades

This EN covers the steel grades given in Table 1. In accordance with EN 10020, grades P235GH, P265GH, P295GH and P335GH are non alloy quality steels and grades 16 Mo 3, 13 CrMo 4-5, 10 CrMo 9-10 and 11 CrMo 9-10 are alloy special steels.

8 Requirements

8.1 Steelmaking process

See EN 10028-1.

8.2 Delivery condition

8.2.1 . . Unless otherwise agreed at the time of ordering, the products covered by this EN shall be supplied in the usual conditions given in Table 3.

8.2.2 Normalizing may be replaced by normalizing rolling for steel grades P235GH, P265GH, P295GH and P355GH. This means that the requirements have to be met again even after subsequent normalizing.

8.2.3 . . If specially agreed, products made of steel grades P235GH, P265GH, P295GH, P355GH and 16 Mo 3 may also be delivered in the untreated condition. Products made of steel grades 13 CrMo 4-5, 10 CrMo 9-10 and 11 CrMo 9-10 may be supplied in the tempered or normalized condition or, in exceptional cases, in the untreated condition if so agreed. (Annex B contains heat treatment information for the purchaser.)

In these cases, the test pieces shall be tested in the usual delivery condition as indicated in Table 3.

NOTE The testing of the test pieces in a simulated heat treated condition does not discharge the processor from the obligation of providing proof of the specified properties in the finished product.

Table 1 — Chemical composition (cast analysis)

Steel grade		Classification[a]	% by mass[b]													
Name	Material number		C	Si	Mn	P	S	$Al_{ges.}$	Cr	Cu[c]	Mo	Nb	Ni	Ti	V	Cr + Cu + Mo + Ni
				max.		max.				max.			max.			max.
P235GH	1.0345	UQ	max. 0,16	0,35	0,40 to 1,20	0,030	0,025	min. 0,020	max. 0,30	0,30	max. 0,08	0,010	0,30	0,03	0,02	0,70
P265GH	1.0425	UQ	max. 0,20	0,40	0,50 to 1,40	0,030	0,025	min. 0,020	max. 0,30	0,30	max. 0,08	0,010	0,30	0,03	0,02	0,70
P295GH	1.0481	UQ	0,08 to 0,20	0,40	0,90 to 1,50	0,030	0,025	min. 0,020	max. 0,30	0,30	max. 0,08	0,010	0,30	0,03	0,02	0,70
P355GH	1.0473	UQ	0,10 to 0,22	0,60	1,00 to 1,70	0,030	0,025	min. 0,020	max. 0,30	0,30	max. 0,08	0,010	0,30	0,03	0,02	0,70
16 Mo 3	1.5415	LE	0,12 to 0,20	0,35	0,40 to 0,90	0,030	0,025	[d]	max. 0,30	0,30	0,25 to 0,35	—	0,30	—	—	—
13 CrMo 4-5	1.7335	LE	0,08 to 0,18	0,35	0,40 to 1,00	0,030	0,025	[d]	0,70 to 1,15[e]	0,30	0,40 to 0,60	—	—	—	—	—
10 CrMo 9-10	1.7380	LE	0,08[f] to 0,14[g]	0,50	0,40 to 0,80	0,030	0,025	[d]	2,00 to 2,50	0,30	0,90 to 1,10	—	—	—	—	—
11 CrMo 9-10	1.7383	LE	0,08[f] to 0,15	0,50	0,40 to 0,80	0,030	0,025	[d]	2,00 to 2,50	0,30	0,90 to 1,10	—	—	—	—	—

[a] UQ = non-alloy quality steel; LE = alloy special steel.

[b] Elements not listed in this table shall not be intentionally added to the steel without the agreement of the purchaser except for finishing the cast. All appropriate measures shall be taken to prevent the addition from scrap or other materials used in steelmaking of these elements which may adversely affect the mechanical properties and usability.

[c] . . A lower Cu content and a maximum tin content may be agreed upon at the time of ordering, e. g. with regard to formability.

[d] The Al content of the cast shall be determined and given in the inspection document.

[e] . . If resistance to pressurized hydrogen is of importance, a minimum percentage by mass of Cr of 0,80 % may be agreed upon at the time of ordering.

[f] . . For product thicknesses less than 10 mm, a minimum content of 0,60 % C may be agreed upon at the time of ordering.

[g] . . For product thicknesses greater than 150 mm, a maximum content of 0,17 % C may be agreed upon at the time of ordering.

8.3 Chemical composition

8.3.1 The requirements of Table 1 shall apply for the chemical composition determined from the cast analysis.

8.3.2 The product analysis may deviate from the specified values for the cast analysis as specified in Table 1 by the values given in Table 2.

Table 2 — Permissible deviations in the results of the product analysis from specified values applicable to the cast analysis (see Table 1)

Element	Specified value in the cast analysis according to Table 1 % by mass	Permissible deviations[a] of the product analysis from the specified values listed in Table 1 for the cast analysis % by mass
C	# 0,22	± 0,02
Si	# 0,35	+ 0,05
	> 0,35 to # 0,60	+ 0,06
Mn	# 1,00	± 0,05
	> 1,00 to # 1,70	± 0,10
P	# 0,030	+ 0,005
S	# 0,025	+ 0,005
Al	$ 0,020	– 0,005
Cr	# 1,00	± 0,05
	> 1,00 to # 2,50	± 0,10
Mo	# 0,35	± 0,03
	> 0,35 to # 1,10	± 0,04
Cu	# 0,30	+ 0,05
Nb	# 0,010	+ 0,005
Ni	# 0,30	+ 0,05
Ti	# 0,03	+ 0,01
V	# 0,02	+ 0,01

[a] If several product analyses are carried out for one cast and if, in this case, values for an individual element are established which fall outside the permitted range for the chemical composition, then it is only permissible that the values either exceed the maximum permitted value or fall short of the minimum permitted value. It is not acceptable for both to apply for one cast.

8.3.3 . . A maximum value for the carbon equivalent may be agreed upon at the time of ordering for steel grades P235GH, P265GH, P295GH and P355GH.

8.4 Mechanical properties

The values given in Table 3 and Table 4 (see also EN 10028-1) shall apply.

Annex A gives preliminary data for the purchaser about creep and stress rupture properties.

8.5 Surface condition

See EN 10028-1.

8.6 Internal soundness

See EN 10028-1.

9 Testing

See EN 10028-1.

9.1 Type and content of inspection documents

See EN 10028-1.

9.2 Tests to be carried out

See EN 10028-1.

9.3 Number of tests

See EN 10028-1.

9.4 Sampling and sample preparation

See EN 10028-1.

9.5 Test procedures

See EN 10028-1.

9.6 Re-tests

See EN 10028-1.

10 Marking

See EN 10028-1.

Table 3 — Mechanical properties (applicable to transverse test pieces)

Steel grade		Usual delivery condition[a]	Product thickness		Yield point[b] R_{eH}	Tensile strength R_m	Elongation after fracture ($L_o = 5.65\sqrt{S_o}$) A	Impact energy (quenched test pieces) KV	
Name	Material number		mm over	up to	N/mm² min.	N/mm²	% min.	Test temperature °C	Mean value from three test pieces min.
P235GH	1.0345	N[c]		16	235	360 to 480	25[e]	0	27
			16	40	225				
			40	60	215				
			60	100	200				
			100	150	185	350 to 480	24		
			150		[d]	[d]	[d]		[d]
P265GH	1.0425	N[c]		16	265	410 to 530	23[f]	0	27
			16	40	255				
			40	60	245				
			60	100	215				
			100	150	200	400 to 530	22		
			150		[d]	[d]	[d]		[d]
P295GH	1.0481	N[c]		16	295	460 to 580	22	0	27
			16	40	290				
			40	60	285				
			60	100	260				
			100	150	235	440 to 570	21		
			150		[d]	[d]	[d]		[d]
P355GH	1.0473	N[c]		16	355	510 to 650	21	0	27
			16	40	345				
			40	60	335				
			60	100	315	490 to 630	20		
			100	150	295	480 to 630			
			150		[d]	[d]	[d]		[d]
16 Mo 3	1.5415	N[g]		16	275	440 to 590	24	+ 20	31[h]
			16	40	270				
			40	60	260		23		
			60	100	240	430 to 560	22		
			100	150	220	420 to 570	19		27[h]
			150		[d]	[d]	[d]		[d]

Table 3 — Mechanical properties (applicable to transverse test pieces)

Steel grade		Usual delivery condition[a]	Product thickness		Yield point[b] R_{eH}	Tensile strength R_m	Elongation after fracture ($L_o = 5.65\sqrt{S_o}$)	Impact energy (quenched test pieces) KV	
Name	Material number		mm over	mm up to	N/mm² min.	N/mm²	*A* % min.	Test temperature °C	Mean value from three test pieces min.
13 CrMo 4 – 5	1.7335	N + T		16	300	450 to 600	20	+20	31[i]
			16	60	295				
		N + T or QA or QL	60	100	275	440 to 590	19		27[h]
		QL	100	150	255	430 to 580			
			150		[d]	[d]	[d]		[d]
10 CrMo 9 – 10	1.7380	N + T		16	310	480 to 630	18	+ 20	31
			16	40	300				
			40	60	290				
		N + T or QA or QL	60	100	270	470 to 620	17		27
		QL	100	150	250	460 to 610			
			150		[d]	[d]	[d]		[d]
11 CrMo 9 – 10	1.7383	N + T or QA or QL		60	310	520 to 670	18	+ 20	31[i]
		QL	60	100			17		27[h]

[a] N = normalized; QA = air quenched; QL = liquid quenched; T = tempered.

[b] Until the yield point criteria are harmonized in the various national codes, determination of R_{eH} may be replaced by determination of $R_{p0,2}$. In this case, 10 N/mm² lower minimum values apply for $R_{p0,2}$.

[c] See **8.2.2**.

[d] . . On agreement.

[e] If, for product thicknesses greater than 2 to less than 3 mm, the elongation after fracture has been determined on tensile test pieces with a gauge length L_o = 80 mm and a width of 20 mm, a minimum value of 19 % applies for product thicknesses greater than 2 to 2.5 mm and a minimum value of 20 % for product thicknesses greater than 2.5 to less than 3 mm.

[f] If, for product thicknesses greater than 2 to less than3 mm, the elongation after fracture has been determined on tensile test pieces with a gauge length L_o = 80 mm and a width of 20 mm, a minimum value of 17 % applies for product thicknesses greater than 2 to 2,5 mm and a minimum value of 18 % for product thicknesses greater than 2.5 to less than 3 mm.

[g] This steel may also be supplied in the N + T condition at the discretion of the manufacturer.

[h] . . If a test at 0 °C has been agreed, a minimum value of 24 J applies.

[i] . . If a test at 0 °C has been agreed, a minimum value of 27 J applies.

Table 4 — 0,2 % proof stress at elevated temperatures[a]

Steel grade	Product thickness		0,2 % proof stress at temperature, °C									
Name	mm		50	100	150	200	250	300	350	400	450	500
	over	up to	N/mm² min.									
P235GH		60	206	190	180	170	150	130	120	110	—	—
	60	100	191	175	165	160	140	125	115	105	—	—
	100	150	176	160	155	150	130	115	110	100	—	—
P265GH		60	234	215	205	195	175	155	140	130	—	—
	60	100	207	195	185	175	160	145	135	125	—	—
	100	150	192	180	175	165	155	135	130	120	—	—
P295GH		60	272	250	235	225	205	185	170	155	—	—
	60	100	249	230	220	210	195	180	165	145	—	—
	100	150	226	210	200	195	185	170	155	135	—	—
P355GH		60	318	290	270	255	235	215	200	180	—	—
	60	100	298	270	255	240	220	200	190	165	—	—
	100	150	278	250	240	230	210	195	175	155	—	—
16 Mo 3		60	—	—	—	215	200	170	160	150	145	140
	60	100	—	—	—	200	185	165	155	145	140	135
	100	150	—	—	—	190	175	155	145	140	135	130
13 CrMo 4 – 5		60	—	—	—	230	220	205	190	180	170	165
	60	100	—	—	—	220	210	195	185	175	165	160
	100	150	—	—	—	210	200	185	175	170	160	155
10 CrMo 9 –10		60	—	—	—	245	230	220	210	200	190	180
	60	100	—	—	—	225	220	210	195	185	175	165
	100	150	—	—	—	215	205	195	185	175	165	155
11 CrMo 9 –10		100	—	—	—	—	255	235	225	215	205	195

[a] The 0,2 % proof stress values given in this table have not been derived from the evaluation methods given in ISO 2605-1.

Annex A (informative)
Preliminary reference data for the long-term creep and stress rupture values

NOTE 1 The values given in Table A.1 are only for information purposes. If referred to in regulations, however, they will be binding for calculation purposes.
NOTE 2 The 1 % creep strain and creep strength values given up to the elevated temperatures listed in Table A.1 do not mean that the steels can be used in continuous duty up to these temperatures. The governing factor is the total stressing during operation, particularly the oxidation conditions.

Table A.1

Steel grade	Temperature	1 % creep stress for[b]		Creep strength for[c]		
		10 000 h	100 000 h	10 000 h	100 000 h	200 000 h
Name	°C	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
	380	164	118	229	165	145
P235GH	390	150	106	211	148	129
P265GH	400	136	95	191	132	115
	410	124	84	174	118	101
	420	113	73	158	103	89
	430	101	65	142	91	78
	440	91	57	127	79	67
	450	80	49	113	69	57
	460	72	42	100	59	48
	470	62	35	86	50	40
	480	53	30	75	42	33
P295GH	380	195	153	291	227	206
P355GH	390	182	137	266	203	181
	400	167	118	243	179	157
	410	150	105	221	157	135
	420	135	92	200	136	115
	430	120	80	180	117	97
	440	107	69	161	100	82
	450	93	59	143	85	70
	460	83	51	126	73	60
	470	71	44	110	63	52
	480	63	38	96	55	44
	490	55	33	84	47	37
	500	49	29	74	41	30
16 Mo 3	450	216	167	298	239	217
	460	199	146	273	208	188
	470	182	126	247	178	159
	480	166	107	222	148	130
	490	149	89	196	123	105
	500	132	73	171	101	84
	510	115	59	147	81	69
	520	99	46	125	66	55
	530	84	36	102	53	45

Table A.1

Steel grade	Temperature	1 % creep stress for[b]		Creep strength for[c]		
		10 000 h	100 000 h	10 000 h	100 000 h	200 000 h
Name	°C	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
13 CrMo 4 – 5	450	245	191	370	285	260
	460	228	172	348	251	226
	470	210	152	328	220	195
	480	193	133	304	190	167
	490	173	116	273	163	139
	500	157	98	239	137	115
	510	139	83	209	116	96
	520	122	70	179	94	76
	530	106	57	154	78	62
	540	90	46	129	61	50
	550	76	36	109	49	39
	560	64	30	91	40	32
	570	53	24	76	33	26
10 CrMo 9 – 10	450	240	166	306	221	201
	460	219	155	286	205	186
	470	200	145	264	188	169
	480	180	130	241	170	152
	490	163	116	219	152	136
	500	147	103	196	135	120
	510	132	90	176	118	105
	520	119	78	156	103	91
	530	107	68	138	90	79
	540	94	58	122	78	68
	550	83	49	108	68	58
	560	73	41	96	58	50
	570	65	35	85	51	43
	580	57	30	75	44	37
	590	50	26	68	38	32
	600	44	22	61	34	28
11 CrMo 9 – 10	450				221	
	460				205	
	470				188	
	480				170	
	490				152	
	500				135	
	510				118	
	520				103	

[a] The values listed in the table are mean values from the scatter range determined previously which will be assessed from time to time after further test results are available and corrected if necessary. From available documentation on long-term creep tests, it may be assumed that the lower limit of this scatter range is about 20 % lower than the mean value given at the temperatures stated for the steel grades in the table.

[b] This is the stress relative to the initial cross-section leading to a permanent elongation of 1 % after l0 000 and 100 000 hours (h).

[c] This is the stress relative to the initial cross-section leading to fracture after l0 000, 100 000 and 200 000 hours (h).

Annex B (informative)
Guidance for heat treatment

Table B.1 gives reference data for the temperatures to be used in the heat treatment.

NOTE The conditions for stress relief annealing are currently being discussed by experts from CEN/TC54 "Unfired pressure vessels" and ECISS/TC22 "Steels for pressure purposes". The results of these discussions will probably be published initially as an annex to the EN on unfired pressure vessels and subsequently in a revised version of EN 10028-2. Until then, the relevant annex of the EN on unfired pressure vessels may contain additional or deviating data or requirements relating to the annealing treatment of steels.

Table B.1 — Guidance for heat treatment

Steel grade	Temperature range for		
Name	Normalizing[a]	Quenching	
		Austenitizing	Tempering[b]
P235GH	890 to 950	—	—
P265GH	890 to 950	—	—
P295GH	890 to 950	—	—
P355GH	890 to 950	—	—
16 Mo 3	890 to 950	—	— [c]
13 CrMo 4 – 5	—	890 to 950	630 to 730
10 CrMo 9 – 10	—	920 to 980	680 to 760
11 CrMo 9 – 10	—	920 to 980	670 to 750

[a] When normalizing, after the required temperatures have been attained over the whole cross-section, no further holding is necessary and should be generally avoided.

[b] When tempering, the specified temperatures shall be maintained for at least 30 minutes when they have been attained over the whole cross-section.

[c] In certain cases, tempering at 590 to 650 °C may be necessary.

National annex NA (informative)
Committees responsible

The United Kingdom participation in the preparation of this European Standard was entrusted by the Iron and Steel Standards Policy Committee (ISM/-) to Technical Committee ISM/73, upon which the following bodies were represented.

Associated Offices Technical Committee
BEAMA Ltd.
British Compressed Air Society
British Forging Industry Association
British Gas plc
British Steel Industry
Electricity Supply Industry in United Kingdom
Engineering Equipment and Materials Users' Association
Lloyd's Register of Shipping
Power Generation Contractors' Association (BEAMA Ltd.)
Process Plant Association
The Welding Institute
Coopted members

National annex NB (informative) Cross-references

Publication referred to	Corresponding British Standard
EN 10020:1988	BS EN 10020:1991 *Definition and classification of grades of steel*
EN 10028-1:1992	BS EN 10028-1 *Specification for flat products made of steels for pressure purposes* Part 1:1992 *General requirements*

National annex NC (normative) Non-conflicting national additions

(This part of this European Standard applies only for the United Kingdom version of this standard.)

NC.1 General

Steel 161 grades 360, 400, 430 and steels 271, 281, 621 and 660 described in this annex are available and widely used in the United Kingdom.

NC.2 Supply condition

Steel 161 shall be supplied in the as-rolled or normalized condition in thicknesses up to and including 40 mm thick, at the manufacturers' discretion. Above 40 mm thick steel 161 shall be supplied in the normalized condition.

Steels 271, 281, 621 and 660 shall be supplied, normalized and tempered, in accordance with Table NC.1.

NC.3 Chemical composition

The chemical composition (cast analysis) of the steels shall be within the limits given in Table NC.2 and Table NC.3.

NC.4 Mechanical properties at room temperature

The mechanical properties at room temperature of the steels shall be within limits given in Table NC.4 and Table NC.5 (see also clause **NC.5**).

NC.5 Impact values

Impact values of steels 271, 281 and 621 shall be as given in Table NC.6.

NC.6 Elevated temperature yield strength or 0,2 % proof stress

The minimum yield strength or 0,2 % proof stress of the steels shall be as given in Table NC.7 and Table NC.8.

NC.7 Stress rupture values (informative)

Stress rupture values for steels 161, 271, 621 and 660 are given in Table NC.9, Table NC.10 and Table NC.11 for information only.

NC.8 Other requirements

All other requirements for the steels shall be in accordance with EN 10028-1 and EN 10028-2

Table NC.1 — Normalizing and tempering ranges for steels 271, 281, 621 and 660

Steel	Temperature range	
	Normalizing °C	Tempering °C
271	890 to 950	640 to 680
281	890 to 950	640 to 680
621	900 to 960	650 to 720
660	940 to 980	680 to 720

Table NC.2 — Chemical composition (cast analysis) of steel 161

Grade	Carbon	Silicon		Manganese		Phosphorus	Sulfur	Chromium	Copper	Molybdenum	Nickel
	max.	min.	max.	min.	max.	max.	max.	max.	max.	max.	max.
	%	%	%	%	%	%	%	%	%	%	%
360	0,17	0,10	0,35	0,40	1,20	0,030	0,030	0,25	0,30	0,10	0,30
400	0,20	0,10	0,35	0,50	1,30	0,030	0,030	0,25	0,30	0,10	0,30
430	0,25	0,10	0,35	0,60	1,40	0,030	0,030	0,25	0,30	0,10	0,30
								Total 0,70 % max. applies to all grades			

Table NC.3 — Chemical composition (cast analysis) of steels 271, 281, 621, and 660

Steel	Carbon		Silicon		Manganese		Phosphorus		Sulfur		Chromium		Molybdenum		Nickel		Copper		Aluminium (metal)[a]		Vanadium	
	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
271	0,11	0,17	—	0,40	1,10	1,50	—	0,025	—	0,015	0,40	0,70	0,24	0,30	—	0,80	—	0,30	—	0,020	0,04	0,12
281	0,08	0,14	—	0,40	1,00	1,50	—	0,025	—	0,015	0,40	0,70	0,24	0,30	0,60	1,00	—	0,30	—	0,020	0,04	0,12
621	0,09	0,17	0,50	0,80	0,40	0,65	—	0,025	—	0,015	1,00	1,50	0,45	0,60	—	0,30	—	0,30	—	0,020	—	—
660	0,08	0,13	—	0,30	0,60	1,00	—	0,025	—	0,015	0,25	0,50	0,50	0,70	—	0,30	—	0,20	—	0,020	0,22	0,28

[a] Where a maximum aluminium (metal) content of 0,012 % or 0,020 % is specified, determination of the total aluminium content, provided that it does not exceed the specified value, shall be deemed to meet this requirement. In cases of dispute, the metallic aluminium content shall be determined.

Table NC.4 — Mechanical properties at room temperature of steel 161

Grade	Nominal plate thickness		Tensile strength R_m		Yield strength R_e	*Elongation A*
	Over	Up to and including	min.	max.	min.	min.
	mm	mm	N/mm^2	N/mm^2	N/mm^2	%
360	3	16	360	480	205	26
	16	40			195	26
	40	63			185	25
	63	100			175	24
	100	150			170	24
	3	16	400	520	225	24
	16	40			215	24
400	40	63			205	23
	63	100			200	22
	100	150			195	22
	3	16	430	550	250	23
	16	40			240	23
430	40	63			230	22
	63	100			220	21
	100	150			210	21

Table NC.5 — Mechanical properties at room temperature of steels 271, 281, 621 and 660

Steel	Nominal plate thickness		Tensile strength, R_m		Yield strength R_e	*Elongation A*
	Over	Up to and including	min.	max.	min.	min.
	mm	mm	N/mm²	N/mm²	N/mm²	%
271	—	25	640	760	500	16
	25	75	610	730	460	16
	75	150	590	690	430	16
281	—	25	640	760	500	16
	25	75	610	730	460	16
	75	150	590	690	430	16
621	—	75	515	690	340	18
	75	100	500	670	320	16
	100	150	490	650	310	16
660	—	100	460	610	310	19

Table NC.6 — Transverse Charpy V-notch impact values of steels for use at room temperature or elevated temperatures

Steel	Nominal plate thickness	Impact test values		
	Up to and including	Test temperature	Minimum average of 3	Minimum individual value
	mm	°C	J	J
271	150	0	27	19
281	150	– 40	27	19
621	100	20	27	19

Table NC.7 — Minimum yield strength (R_{eL}) or 0,2 % proof stress ($R_{p0,2}$) values at elevated temperatures of steel 161

Steel	Grade	Nominal plate thickness[a]		Minimum yield stress R_{eL} or 0,2 % proof stress $R_{p0,2}$ at temperature °C					
		Over	Up to and including	150	200	250	300	350	400
		mm	mm	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
161	360	3	16	172	168	150	124	117	115
		16	40	169	162	144	124	117	115
		40	63	158	152	141	124	117	115
		63	100	148	144	136	124	117	155
	400	3	16	200	195	174	145	137	133
		16	40	192	185	165	145	137	133
		40	63	182	175	162	145	137	133
		63	100	170	166	157	145	137	133
	430	3	16	222	215	192	161	153	148
		16	40	210	202	181	161	153	148
		63	100	186	181	172	161	153	148

[a] The values for plates of steel 161 over 100 mm thickness shall be the values specified for plates of thicknesses between 63 mm and 100 mm reduced by 1 % for each 5 mm, or part thereof, increase in thickness over 100 mm

Table NC.8 — Minimum yield strength (R_e) or 0,2 % proof stress ($R_{p0,2}$) at elevated temperatures of steels 271, 281, 621 and 660

Steel	Nominal plate thickness		R_e or $R_{p0,2}$ at temperature °C									
	Over	Up to and including	100	150	200	250	300	350	400	450	500	550
	mm	mm	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
271	—	25	420	406	398	389	374	363	351	347	314	—
	25	75	402	389	380	372	354	343	332	329	301	—
	75	150	363	349	341	332	310	301	292	289	266	—
281	—	25	420	406	398	389	374	363	351	347	314	—
	25	75	402	389	380	372	354	343	332	329	301	—
	75	150	363	349	341	332	310	301	292	289	266	—
621	—	75	315	305	291	280	266	255	251	245	238	227
	75	100	300	290	277	265	250	238	234	228	221	211
	100	150	290	280	268	256	239	227	222	217	211	201
660	—	100	282	276	267	241	225	216	209	203	200	197

Table NC.9 — Stress rupture values for steel 161

Average stress N/mm² to produce rupture in:							
Temp. °C	10 000h N/mm²	30 000h N/mm²	50 000h N/mm²	100 000h N/mm²	150 000h N/mm²	200 000h N/mm²	250 000h N/mm²
380	277	251	238	219	207	199*	192*
390	255	228	215	196	184	175*	167*
400	233	206	193	173	160	151*	143*
410	213	185	171	151	137	128*	121*
420	193	164	150	129	116	107*	101*
430	173	144	129	109	98*	90*	84*
440	154	124	110	92	82*	76*	71*
450	136	107	94	78	70*	64*	60*
460	118	91	80	67	60*	55*	50*
470	102	99	69	57	50*	44*	—
480	89	68	60	48	(39)	—	—
490	77	59	51	—	—	—	—
500	68	51	41	—	—	—	—
510	60	41	—	—	—	—	—
520	52	—	—	—	—	—	—

NOTE 1 Asterisks indicate where values have been obtained by either “extended time” or “extended stress” extrapolation, respectively.
NOTE 2 Data based on PD 6525-1:1990.

Table NC.10 — Stress rupture values for steels 271 and 281

Temperature	Average stress, N/mm², to produce rupture in:											
	10 000 h		30 000 h		100 000 h		150 000 h		200 000 h		250 000 h	
°C	271	281	271	281	271	281	271	281	271	281	271	281
400	454*	363*	435*	351*	417*	334*	407*	325*	399*	318*	391*	311*
410	445*	356*	425*	340*	405*	324*	394*	314*	385*	308*	377*	302*
420	432*	345*	411*	329*	388*	310*	377*	301*	368*	294*	360*	288*
430	415	332	392	314	367	294	355*	284*	346*	276*	337*	269*
440	394	315	371	299	341	272	328*	263*	318*	255*	303*	248*
450	371	296	346	276	309	247	296*	237*	287*	230*	273*	224*
460	346	277	316	254	272	218	258*	206*	249*	198*	240*	191*
470	321	256	284	227	235	188	219*	176*	208*	167*	199*	160*
480	294	235	252	201	201	161*	183*	146*	171*	136*	161*	128*
490	265	212	219	177	168	134*	152*	121*	141*	113*	132*	106*
500	234	188	189	152	139	111*	124*	100*	113*	90*	105*	84*
510	205	164	157	127	113	90*	99*	80*	88*	71*	80*	65*
520	177	141	137	103	90	72*	75*	61*	66*	52*	58*	45*
530	150	120	106	85	70	57	58*	46	50*	40	42*	35*
540	125	100	85	68	53	43	42*	34	34*	28	27*	24*
550	102	81	68	54	39	31	30*	23	23*	19	16*	14*
560	83	66	52	42	—	—	—	—	—	—	—	—
570	69	55	42	34	—	—	—	—	—	—	—	—

NOTE 1 Asterisks indicate where values have been obtained by either “extended time” or “extended stress” extrapolation, respectively.
NOTE 2 Data based on PD 6525-1:1990.
NOTE 3 Stresses corresponding to 1 % total strain in 10 000 h and 100 000 h can be assumed to be not less than two-thirds of the stresses corresponding to creep rupture under the same conditions of time and temperature.

Table NC.11 — Stress rupture values for steels 621 and 660

Temperature	Average stress, N/mm², to produce rupture in:											
	10 000 h		30 000 h		100 000 h		150 000 h		200 000 h		250 000 h	
°C	621	660	621	660	621	660	621	660	621	660	621	660
450	373	380	333	352	290	321	276	309	265*	301*	257*	295*
460	343	353	305	326	262	294	247	282	237*	274*	229*	267*
470	315	328	277	300	235	268	220	256	210*	247	202*	240*
480	287	304	250	276	208	242	193	230	183*	221	175*	214*
490	261	280	224	251	181	217	167	205	156*	196	148*	189*
500	238	257	198	227	155	193	140	181	129*	172	121*	166*
510	210	234	172	204	129	170	114	158	103*	150	95*	144*
520	185	212	147	182	103	149	89	138	79*	130	72*	125*
530	160	190	122	161	80	130	68*	120	61*	113	56*	108*
540	136	170	97	142	62	113	53*	104	49*	98	46*	93*
550	112	151	76	125	49	99	44	90	41	85	39	80*
560	88	133	59	109	42	86	38	77	36*	71	34*	65*
570	69	118	48	96	36	73	33	61	32*	—	31*	—
580	55	104	41	84	32	—	30	—	29*	—	28*	—
590	46	92	36	71	29	—	27	—	—	—	—	—
600	39	81	32	—	—	—	—	—	—	—	—	—
610	35	—	29	—	—	—	—	—	—	—	—	—
620	31	—	—	—	—	—	—	—	—	—	—	—
630	29	—	—	—	—	—	—	—	—	—	—	—

NOTE 1 Asterisks indicate where values have been obtained by either “extended time” or “extended stress” extrapolation, respectively.

NOTE 2 Data based on PD 6525-1:1990.

NOTE 3 The stress rupture values in the above table were derived from data generated by testing stress rupture specimens in air and in some cases at temperatures where significant oxidation of the specimen will have occurred.

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