INTERNATIONAL STANDARD

**ISO 9327-2**

First edition
1999-06-15

# Steel forgings and rolled or forged bars for pressure purposes — Technical delivery conditions —

## Part 2:
Non-alloy and alloy (Mo, Cr and CrMo) steels with specified elevated temperature properties

*Pièces forgées et barres laminées ou forgées en acier pour appareils à pression — Conditions techniques de livraison —*

*Partie 2: Aciers non alliés et alliés (Mo, Cr et CrMo) avec caractéristiques spécifiées à température élevée*

Reference number
ISO 9327-2:1999(E)

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 9327-2 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 10, *Steel for pressure purposes*.

This first edition, together with parts 1 and 3 to 5 of ISO 9327, cancels and replaces ISO 2604-1:1975.

ISO 9327 consists of the following parts, under the general title *Steel forgings and rolled or forged bars for pressure purposes — Technical delivery conditions*:

— *Part 1: General requirements*

— *Part 2: Non-alloy and alloy (Mo, Cr and CrMo) steels with specified elevated temperature properties*

— *Part 3: Nickel steels with specified low temperature properties*

— *Part 4: Weldable fine grain steels with high proof strength*

— *Part 5: Stainless steels*

# Steel forgings and rolled or forged bars for pressure purposes — Technical delivery conditions —

# Part 2:
Non-alloy and alloy (Mo, Cr and CrMo) steels with specified elevated temperature properties

## 1 Scope

**1.1** This part of ISO 9327 applies to forgings and rolled or forged bars in thicknesses up to 250 mm (partly up to 500 mm) manufactured from the steels listed in Table 1 and to be delivered according to the specifications given in ISO 9327-1.

**1.2** This part of ISO 9327 covers the following data:

a) in Table 1 the limits for

- — the chemical composition according to the cast analysis;
- — the tensile properties at room temperature;
- — the impact properties;
- — the indications on the usual heat treatment condition at the time of delivery;

b) in Table 2 the permissible product analysis tolerances on the limiting values given for the cast analysis;

c) in Table 3 the minimum elevated temperature proof strength values (see C.4 of ISO 9327-1:1998);

d) in Table 4 the estimated average stress rupture properties;

e) in Table 5 the estimated average strength values for 1 % plastic strain.

## 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 9327. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 9327 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 148:1983, *Steel — Charpy impact test (V-notch).*

ISO 4948-1:1982, *Steels — Classification — Part 1: Classification of steel into unalloyed and alloy steels based on chemical composition.*

ISO/TR 4949:1989, *Steel names based on letter symbols.*

ISO 9327-1, *Steel forgings and rolled or forged bars for pressure purposes — Technical delivery conditions — Part 1: General requirements*.

ISO/TR 15461:1997, *Steel forgings — Testing frequency, sampling conditions and test methods for mechanical tests.*

## 3 Terms and definitions

For the purposes of this part of ISO 9327, the terms and definitions given in ISO 9327-1 apply.

## 4 Ordering

See ISO 9327-1.

## 5 Requirements

See ISO 9327-1 and Tables 1 to 5.

## 6 Inspection, testing and conformity of products

See ISO 9327-1.

## 7 Marking

See ISO 9327-1.

## Table 1 — Chemical composition (cast analysis), room temperature mechanical properties and heat treatment conditions

| Line No. | Steel type | | Chemical composition [b] % by mass | | | | | | | | | Mechanical properties at room temperature [c] | | | | | | | | | Usual reference heat treatment conditions | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | "new" | "old" | C | Si | Mn | P max. | S max. | $Al_{total}$ | Cr | Mo | Others | Thickness of the ruling section [d] $t_R$ | $R_e$ min. | $R_m$ | $A$ min. DIR: x | $A$ min. DIR: y | $KV$ [e] min. DIR: x-y | $KV$ [e] min. DIR: y-x | $KV$ [e] min. DIR: at | Symbol [f] | Austenitizing or solution temperature | Cooling in [g] | Tempering | Cooling in [g] |
| | Designation [a] in accordance with ISO/TR 4949 | ISO 2604-1 | | | | | | | | | | mm | N/mm² | N/mm² | % | % | J | J | °C | | °C | | °C | |
| 1 | PH 26 | F 9 | ≤ 0,20 | ≤ 0,35 | 0,50 to 1,40 | 0,035 | 0,030 | ≥ 0,020 | ≤ 0,30 | ≤ 0,08 | Cu ≤ 0,30 [h] Ni ≤ 0,30 | ≤ 16 | 265 | 410 to 530 | 26 | 24 | | | | | | | | |
| | | | | | | | | | | | | 16 < $t_R$ ≤ 40 | 255 | | 26 | 24 | | | | | 890 to 950 | a | — | — |
| | | | | | | | | | | | | 40 < $t_R$ ≤ 60 | 245 | | 25 | 23 | 40 | 27 | 0 | N or Q + T | 880 to 930 | o, w | 580 to 650 | a, f |
| | | | | | | | | | | | | 60 < $t_R$ ≤ 100 | 215 | | 24 | 22 | | | | | | | | |
| | | | | | | | | | | | | 100 < $t_R$ ≤ 150 | 200 | 390 to 520 | 24 | 22 | | | | | | | | |
| | | | | | | | | | | | | 150 < $t_R$ ≤ 250 | 200 | | 23 | 21 | | | | | | | | |
| 2 | PH 29 | F 13 | ≤ 0,20 [i] | ≤ 0,40 | 0,90 to 1,50 | 0,035 | 0,030 | ≥ 0,020 | ≤ 0,30 | ≤ 0,08 | Cu ≤ 0,30 [h] Ni ≤ 0,30 | ≤ 16 | 290 | 460 to 580 | 24 | 22 | | | | | | | | |
| | | | | | | | | | | | | 16 < $t_R$ ≤ 40 | 285 | | 24 | 22 | | | | | | | | |
| | | | | | | | | | | | | 40 < $t_R$ ≤ 60 | 280 | | 24 | 22 | 40 | 27 | 0 | N | 890 to 950 | a | — | — |
| | | | | | | | | | | | | 60 < $t_R$ ≤ 100 | 255 | | 23 | 21 | | | | or | 880 to 920 | o, w | 580 to 650 | a, f |
| | | | | | | | | | | | | 100 < $t_R$ ≤ 150 | 230 | 440 to 570 | 23 | 21 | | | | Q + T | | | | |
| | | | | | | | | | | | | 150 < $t_R$ ≤ 250 | 220 | | 22 | 20 | | | | | | | | |
| 3 | PH 31 | F 18 | ≤ 0,20 [i] | 0,10 to 0,50 | 0,90 to 1,60 | 0,035 | 0,030 | ≥ 0,020 | ≤ 0,30 | ≤ 0,08 | Cu ≤ 0,30 [h] Ni ≤ 0,30 | ≤ 16 | 315 | 490 to 610 | 23 | 21 | | | | | | | | |
| | | | | | | | | | | | | 16 < $t_R$ ≤ 40 | 310 | | 23 | 21 | | | | | 890 to 950 | a | — | — |
| | | | | | | | | | | | | 40 < $t_R$ ≤ 60 | 305 | | 23 | 21 | 40 | 27 | 0 | N | 880 to 920 | o, w | 580 to 650 | a, f |
| | | | | | | | | | | | | 60 < $t_R$ ≤ 100 | 280 | | 22 | 20 | | | | or | | | | |
| | | | | | | | | | | | | 100 < $t_R$ ≤ 150 | 255 | 470 to 600 | 22 | 20 | | | | Q + T | | | | |
| | | | | | | | | | | | | 150 < $t_R$ ≤ 250 | 245 | 460 to 590 | 21 | 19 | | | | | | | | |
| 4 | 16Mo3 | F 26 | 0,12 to 0,20 | ≤ 0,35 | 0,40 to 0,90 | 0,035 | 0,030 | i | ≤ 0,30 | 0,25 to 0,35 | Cu ≤ 0,30 | ≤ 40 | 270 | 450 to 600 | 26 | 24 | | | | | | | | |
| | | | | | | | | | | | | 40 < $t_R$ ≤ 60 | 260 | | 25 | 23 | | | | N | 890 to 950 | a | — | — |
| | | | | | | | | | | | | 60 < $t_R$ ≤ 100 | 240 | 430 to 580 | 24 | 22 | 40 | 27 | 20 | or N + T | 890 to 950 | a | 600 to 650 | a, f |
| | | | | | | | | | | | | 100 < $t_R$ ≤ 250 | 220 | 420 to 570 | 21 | 19 | | | | or Q + T | 880 to 920 | o, w | 600 to 650 | a, f |
| 5 | 20MnMoNi5 | — | 0,17 to 0,23 | ≤ 0,40 | 1,15 to 1,50 | 0,035 | 0,030 | j | ≤0,25 | 0,45 to 0,60 | 0,40 to 1,00 Ni, V ≤ 0,03 | ≤ 150 | 420 | 580 to 730 | 18 | 16 | | | | | | | | |
| | | | | | | | | | | | | 150 < $t_R$ ≤ 300 | 390 | 550 to 700 | 18 | 16 | 50 | 35 | 20 | N + T or Q + T | 850 to 925 | a, w | 620 to 675 | a, f |
| | | | | | | | | | | | | 300 < $t_R$ ≤ 500 | 360 | | 18 | 16 | | | | | | | | |
| 6 | 14CrMo4-5 | F 32 | 0,08 to 0,18 | ≤ 0,35 | 0,40 to 1,00 | 0,035 | 0,030 | i | 0,70 to 1,15 | 0,40 to 0,60 | Cu ≤ 0,30 | ≤ 40 | 300 | 450 to 600 | 22 | 20 | | | | | | | | |
| | | | | | | | | | | | | 40 < $t_R$ ≤ 60 | 300 | | 21 | 19 | 40 | 27 | 20 | N + T or Q + T | 890 to 950 | a, o, w | 600 to 650 | a, f |
| | | | | | | | | | | | | 60 < $t_R$ ≤ 100 | 275 | 440 to 590 | 20 | 18 | | | | | | | | |
| | | | | | | | | | | | | 100 < $t_R$ ≤ 250 | 255 | 430 to 580 | 20 | 18 | | | | | | | | |
| 7 | 13CrMo9-10 | F 34 | 0,08 to 0,15 [k] | ≤ 0,50 | 0,40 to 0,70 | 0,035 | 0,030 | i | 2,00 to 2,50 | 0,90 to 1,10 | Cu ≤ 0,30 | ≤ 60 | 265 | 480 to 620 | 20 | 18 | | | | | | | | |
| | | | | | | | | | | | | 60 < $t_R$ ≤ 100 | 260 | 470 to 620 | 20 | 18 | 40 | 27 | 20 | N + T or Q + T | 920 to 980 | a, o, w | 680 to 750 | a, f |
| | | | | | | | | | | | | 100 < $t_R$ ≤ 150 | 250 | 460 to 610 | 20 | 18 | | | | | | | | |
| | | | | | | | | | | | | 150 < $t_R$ ≤ 300 | 240 | 450 to 600 | 20 | 18 | | | | | | | | |

## Table 1 — *(concluded)*

| Line No. | Steel type | | Chemical composition [b] % by mass | | | | | | | | | Mechanical properties at room temperature [c] | | | | | | | | | Usual reference heat treatment conditions | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | "new" | "old" | C | Si | Mn | P max. | S max. | $Al_{total}$ | Cr | Mo | Others | Thickness of the ruling section [d] $t_R$ | $R_e$ min. | $R_m$ | $A$ min. DIR: x | $A$ min. DIR: y | $KV$ [e] min. DIR: x-y | $KV$ [e] min. DIR: y-x | $KV$ [e] min. DIR: at | Symbol [f] | Austenitizing or solution temperature | Cooling in [g] | Tempering | Cooling in [g] |
| | Designation [a] in accordance with | | | | | | | | | | | | | | | | | | | | | | | | |
| | ISO/TR 4949 | ISO 2604-1 | | | | | | | | | | mm | N/mm² | N/mm² | % | % | J | J | °C | | °C | | °C | |
| 8 | X12CrMo5-1 | F 37 | 0,08 to 0,15 | ≤ 0,50 | 0,30 to 0,60 | 0,035 | 0,030 | i | 4,00 to 6,00 | 0,45 to 0,65 | | ≤ 150 | 175 | 430 to 580 | 20 | 18 | — | — | — | A | 850 to 880 | f | — | — |
| 9 | X20CrMoV12-1 | F 40 | 0,17 to 0,23 | ≤ 0,40 | 0,30 to 1,00 | 0,035 | 0,030 | ≤ 0,025 | 10,00 to 12,50 | 0,80 to 1,20 | 0,30 to 1,00 Ni 0,20 to 0,35 V | ≤ 100 | 500 | 700 to 850 | 16 | 14 | 39 | 27 | 20 | N + T or Q + T | 1 020 to 1 070 | a, o, w | 730 to 780 | |
| | | | | | | | | | | | | $100 < t_R \leq 200$ | 500 | 700 to 850 | 16 | 14 | 31 | 27 | 20 | | | | | |
| | | | | | | | | | | | | $200 < t_R \leq 300$ | 500 | 700 to 850 | 14 | 14 | 27 | 24 | 20 | | | | | |

a All data on designations in this part of ISO 9327 are to be regarded as preliminary (see NOTE 2 of 4.1 in ISO 9327-1:1999). According to ISO 4948-2 the steels in lines 1 to 3 are non-alloy quality steels, the steels in lines 4 to 9 alloy special steels.

b See 5.2.1.1 of ISO 9327-1:1999.

c $R_e$ is the yield strength (where a yield phenomenon occurs either the upper yield strength $R_{eH}$ or the 0,2 % proof strength shall be recorded);

$R_m$ is the tensile strength;

$A$ is the percentage elongation after fracture on gauge length;

$L_o$ is the gauge length = 5,65 $\sqrt{S_o}$;

$KV$ is the Charpy V-notch impact energy.

DIR:x, DIR:x-y, DIR:y and DIR:y-x are the directions of the test piece in relation to the main direction of grain flow. For detailed explanations see Table 5 and Figures 9 and 10 of ISO/TR 15461:1997.

d The thickness ranges given here apply for the as heat-treated thickness of ruling sections with rectangular cross-section, a width to thickness ratio of ⩾ 2 and a length to thickness ratio of ⩾ 4. For ruling sections of other shapes the equivalent thickness shall be determined according to annex A of ISO 9327-1:1999, or be agreed upon at the time of enquiry and order.

NOTE The designer should observe that because of machining allowances, the as heat-treated thickness of the ruling section is normally greater than the finished size.

e Average of three tests. One of the individual values may be below the specified minimum average, provided it is not less than 70 % of this value. The values apply to standard 10 mm × 10 mm Charpy V-notch impact test pieces (see ISO 148).

f N = normalized (austenitizing with subsequent cooling in air);

T = tempered;

Q = quenched;

A = annealed (austenitizing with subsequent furnace cooling).

g a = air; o = oil; w = water; f = furnace.

h The sum of Cr+Cu+Mo+Ni shall not exceed 0,70 %.

i When Option C.5 in ISO 9327-1:1999 – mandatory minimum elevated temperature proof strength values – is ordered, the carbon content of steel PH 29 shall be 0,14 % to 0,20 % and that of steel PH 31 0,15 % to 0,20 %.

j Though the aluminium content is not specified, it shall be given in the document.

k For product thicknesses < 60 mm the lower limit may by agreement be reduced to 0,06 % C; for thicknesses > 15 mm the upper limit may, by agreement, be increased to 0,17 % C.

**Table 2 — Permissible product analysis tolerances on the limiting values given in Table 1 for the cast analysis**

| Element | Specified limits, cast analysis<br>% by mass | Permissible tolerance[a]<br>% by mass |
|---|---|---|
| **C** | ⩽ 0,23 | ± 0,03 |
| **Si** | ⩽0,50 | ± 0,05 |
| **Mn** | ⩽ 1,60 | ± 0,10 |
| **P** | ⩽ 0,035 | + 0,005 |
| **S** | ⩽ 0,030 | + 0,005 |
| **Al** | ⩾ 0,025 | ± 0,005 |
| **Cr** | < 10,00 | ± 0,10 |
| | ⩾ 10,00 ⩽ 12,50 | ± 0,15 |
| **Cu** | ⩽ 0,30 | + 0,05 |
| **Ni** | ⩽ 1,00 | ± 0,03 |
| **Mo** | ⩽ 0,60 | ± 0,03 |
| | > 0,60 ⩽ 1,20 | ± 0,05 |
| **V** | ⩽ 0,35 | ± 0,03 |

[a] The deviations, other than when maxima only are specified, apply either above or below the specified limits of the range but not both above and below for the same element from different sample products from the same cast. When maxima only are specified, the deviations are positive only. The values are valid only if the samples were selected according to C.5 of ISO 9327-1:1999.

**Table 3 — Minimum 0,2% proof strength ($R_{p0,2}$) values at elevated temperature for steels according to Table 1[a]**

| Steel type | Reference heat treatment section[b] | Thickness of the ruling section[c] $t_R$ | $R_{p0,2}$ min. N/mm$^2$ Temperature °C | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 |
| PH 26 | N or Q+T | $t_R \leqslant 16$ | 216 | 194 | 171 | 152 | 141 | 134 | 130 | — | — | — |
| | | $16 < t_R \leqslant 40$ | 213 | 192 | 171 | 152 | 141 | 134 | 130 | — | — | — |
| | | $40 < t_R \leqslant 60$ | 204 | 188 | 171 | 152 | 141 | 134 | 130 | — | — | — |
| | | $60 < t_R \leqslant 100$ | 204 | 188 | 171 | 152 | 141 | 134 | 130 | — | — | — |
| | | $100 < t_R \leqslant 150$ | 197 | 182 | 166 | 147 | 136 | 129 | 125 | — | — | — |
| | | $150 < t_R \leqslant 250$ | 197 | 182 | 166 | 147 | 136 | 129 | 125 | — | — | — |
| PH 29 | N or Q+T | $\leqslant 16$ | 247 | 223 | 198 | 177 | 167 | 158 | 153 | — | — | — |
| | | $16 < t_R \leqslant 40$ | 242 | 220 | 198 | 177 | 167 | 158 | 153 | — | — | — |
| | | $40 < t_R \leqslant 60$ | 236 | 217 | 198 | 177 | 167 | 158 | 153 | — | — | — |
| | | $60 < t_R \leqslant 100$ | 236 | 217 | 198 | 177 | 167 | 158 | 153 | — | — | — |
| | | $100 < t_R \leqslant 150$ | 223 | 205 | 187 | 167 | 157 | 148 | 144 | — | — | — |
| | | $150 < t_R \leqslant 250$ | 213 | 195 | 177 | 157 | 147 | 138 | 134 | — | — | — |
| PH 31 | N or Q+T | $t_R \leqslant 16$ | 265 | 240 | 213 | 192 | 182 | 173 | 168 | — | — | — |
| | | $16 < t_R \leqslant 40$ | 260 | 237 | 213 | 192 | 182 | 173 | 168 | — | — | — |
| | | $40 < t_R \leqslant 60$ | 256 | 234 | 213 | 192 | 182 | 173 | 168 | — | — | — |
| | | $60 < t_R \leqslant 100$ | 256 | 234 | 213 | 192 | 182 | 173 | 168 | — | — | — |
| | | $100 < t_R \leqslant 150$ | 243 | 222 | 203 | 182 | 172 | 163 | 158 | — | — | — |
| | | $150 < t_R \leqslant 250$ | 233 | 212 | 193 | 172 | 162 | 153 | 148 | — | — | — |
| 16Mo3 | N or N+T or Q+T | $\leqslant 60$ | 237 | 224 | 205 | 173 | 159 | 155 | 150 | 145 | — | — |
| | | $60 < t_R \leqslant 100$ | 225 | 212 | 195 | 162 | 147 | 143 | 137 | 132 | — | — |
| | | $100 < t_R \leqslant 250$ | 219 | 207 | 189 | 156 | 140 | 135 | 130 | 125 | — | — |
| 20MnMoNi5 | Q+T | $\leqslant 300$ | — | 360 | — | 350 | 343 | — | — | — | — | — |
| | | $300 < t_R \leqslant 500$ | — | 350 | — | 330 | 314 | — | — | — | — | — |
| 14CrMo4-5 | N+T or Q+T | $\leqslant 60$ | 240 | 230 | 218 | 94 | 181 | 176 | 172 | 167 | 160 | 155 |
| | | $60 < t_R \leqslant 100$ | 230 | 220 | 208 | 183 | 169 | 164 | 160 | 156 | 150 | 146 |
| | | $100 < t_R \leqslant 250$ | 220 | 210 | 200 | 172 | 158 | 153 | 150 | 146 | 140 | 136 |
| 13CrMo9-10 | N+T or Q+T | $\leqslant 60$ | 241 | 233 | 224 | 219 | 212 | 207 | 194 | 180 | 160 | 137 |
| | | $60 < t_R \leqslant 100$ | 229 | 221 | 212 | 207 | 201 | 196 | 183 | 170 | 151 | 130 |
| | | $100 < t_R \leqslant 150$ | 217 | 209 | 200 | 195 | 190 | 185 | 172 | 160 | 142 | 124 |
| | | $150 < t_R \leqslant 300$ | 205 | 197 | 188 | 183 | 179 | 174 | 161 | 150 | 133 | 118 |
| 12CrMo20-5 | A | $\leqslant 60$ | | 118 | 116 | 115 | 114 | 113 | 111 | — | — | — |
| X20CrMoV12-1 | N+T or Q+T | $\leqslant 300$ | 390 | 362 | 340 | 328 | 322 | 316 | 302 | 280 | — | — |

[a] See C.4 of ISO 9327-1:1999.

[b] A = annealed; N = normalized; Q = quenched; T = tempered. For temperatures and cooling conditions see Table 1.

[c] See Table 1, footnote d.

## Table 4 — Stress rupture properties at elevated temperatures for steels according to Table 1

| Steel type | Heat treatment[a] | Rupture time | Estimated average stresses for rupture[b] N/mm² Temperature, °C | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | h | 380 | 390 | 400 | 410 | 420 | 430 | 440 | 450 | 460 | 470 | 480 | 490 | 500 | 510 | 520 | 530 | 540 | 550 | 560 | 570 | 580 | 590 | 600 |
| PH 26 | N or Q+T | 10 000 | 213 | 197 | 181 | 166 | 151 | 138 | 125 | 112 | 100 | 89 | 78 | 67 | 57 | | | | | | | | | | |
| | | 30 000 | 192 | 176 | 161 | 147 | 133 | 120 | 107 | 95 | 84 | 73 | 63 | 52 | 42 | | | | | | | | | | |
| | | 50 000 | 183 | 167 | 152 | 138 | 125 | 112 | 100 | 88 | 77 | 66 | 56* | 45* | 35* | | | | | | | | | | |
| | | 100 000 | 171* | 155* | 141* | 127* | 114* | 102* | 90* | 78* | 67* | 57* | 47* | 36* | | | | | | | | | | | |
| | | 150 000 | 164* | 149* | 134* | 121* | 108* | 96* | 84* | 73* | 62* | 52* | 41* | 29* | | | | | | | | | | | |
| | | 200 000 | 159* | 144* | 130* | 116* | 104* | 92* | 80* | 69* | 58* | 48* | 37* | 23* | | | | | | | | | | | |
| | | 250 000 | 155* | 140* | 126* | 113* | 101* | 89* | 77* | 66* | 55* | 45* | 34* | | | | | | | | | | | | |
| PH 29 PH 31 | N or Q+T | 10 000 | 291 | 266 | 243 | 221 | 200 | 180 | 161 | 143 | 126 | 110 | 96 | 84 | 74 | | | | | | | | | | |
| | | 30 000 | 262 | 237 | 214 | 192 | 171 | 151 | 132 | 115 | 99 | 86 | 74 | 65 | 57 | | | | | | | | | | |
| | | 50 000 | 248 | 223 | 200 | 177 | 156 | 136 | 118 | 102 | 87 | 75 | 65 | 57 | 50 | | | | | | | | | | |
| | | 100 000 | 227 | 203 | 179 | 157 | 136 | 117 | 100 | 85 | 73 | 63 | 55 | (47) | (41) | | | | | | | | | | |
| | | 150 000 | 215 | 190 | 167 | 144 | 124 | 105 | 89 | 76 | 65 | 56 | (49) | (42) | (34) | | | | | | | | | | |
| | | 200 000 | 206* | 181* | 157* | 135* | 115* | 97* | 82* | 70* | 60* | 52* | (44)* | (37)* | | | | | | | | | | | |
| | | 250 000 | 199* | 174* | 150* | 128* | 108* | 91* | 77* | 66* | 56* | (48)* | (41)* | (32)* | | | | | | | | | | | |
| 16Mo3 | N or N+T or Q+T | 10 000 | | | | | | | | 298 | 273 | 247 | 222 | 196 | 171 | 147 | 125 | 102 | | | | | | | |
| | | 30 000 | | | | | | | | 273 | 244 | 216 | 187 | 159 | 134 | 113 | 93 | 76 | | | | | | | |
| | | 50 000 | | | | | | | | 260 | 229 | 200 | 172 | 144 | 119 | 99 | 80 | 66 | | | | | | | |
| | | 100 000 | | | | | | | | 239* | 208* | 178* | 148 | 123 | 101 | 81 | 66 | 53* | | | | | | | |
| | | 150 000 | | | | | | | | 226* | 197* | 168* | 139* | 114* | 91* | 74* | 60* | 48* | | | | | | | |
| | | 200 000 | | | | | | | | 217* | 188* | 159* | 130* | 105* | 84* | 69* | 55* | 45* | | | | | | | |
| | | 250 000 | | | | | | | | 210* | 180* | 151* | 124* | 100* | 80* | 65* | 52* | (42)* | | | | | | | |
| 14CrMo4-5 | N+T or Q+T | 10 000 | | | | | | | | (407) | (371) | (338) | 304 | 273 | 239 | 209 | 179 | 154 | 129 | 109 | 91 | 76 | 64 | 53 | 44 |
| | | 30 000 | | | | | | | | (371) | (336) | (301) | 267 | 233 | 200 | 169 | 140 | 116 | 96 | 79 | 66 | 54 | 44 | 36 | (29) |
| | | 50 000 | | | | | | | | (339) | (307) | (273) | 239 | 207 | 177 | 149 | 124 | 101 | 82 | 68 | 55 | 45 | | | |
| | | 100 000 | | | | | | | | (326) | (286) | (247) | 210 | 177 | 146 | 121 | 99 | 81 | 67 | 54 | 43 | 35 | | | |
| | | 150 000 | | | | | | | | (312) | (270) | (210) | 194* | 161* | 132* | 108* | 87* | 71 | 57 | 46 | 38 | (31) | | | |
| | | 200 000 | | | | | | | | (298) | (255) | (197) | 180* | 148* | 122* | 99* | 79* | 64* | 52* | 42* | 34* | (28)* | | | |
| | | 250 000 | | | | | | | | (292) | (247) | (186) | 170* | 139* | 114* | 91* | 74* | 59* | 48* | 39* | 32* | (26)* | | | |

**Table 4 — *(concluded)***

| Steel type | Heat treatment[a] | Rupture time | Estimated average stresses for rupture[b] N/mm² Temperature, °C | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | h | 380 | 390 | 400 | 410 | 420 | 430 | 440 | 450 | 460 | 470 | 480 | 490 | 500 | 510 | 520 | 530 | 540 | 550 | 560 | 570 | 580 | 590 | 600 |
| 13CrMo9-10 | N+T or Q+T | 10 000 | | | | | | | | (309) | (285) | (263) | 240 | 219 | 196 | 176 | 155 | 137 | 122 | 108 | 96 | 85 | 76 | 68 | 61 |
| | | 30 000 | | | | | | | | (276)* | (254)* | 322* | 213 | 192 | 172 | 152 | 134 | 118 | 103 | 90 | 79 | 70 | 61 | 54 | 48 |
| | | 50 000 | | | | | | | | (257)* | 236* | 217* | 197* | 177* | 158* | 139* | 123* | 107 | 93 | 80 | 71 | 62 | 54 | 47 | 42 |
| | | 100 000 | | | | | | | | 221* | 204* | 186* | 170* | 153* | 137* | 122* | 107* | 93 | 79 | 69 | 59 | 51 | 44 | (38) | (34) |
| | | 150 000 | | | | | | | | 209* | 192* | 175* | 153* | 141* | 126* | 110* | 95* | 82* | 73* | 63* | 54* | 47 | 40 | (35) | (30) |
| | | 200 000 | | | | | | | | 203* | 186* | 169* | 152* | 135* | 119* | 103* | 89* | 77* | 68* | 58* | 50* | 43* | (37)* | (32)* | (28)* |
| | | 250 000 | | | | | | | | 198* | 181* | 164* | 147* | 130* | 113* | 98* | 84* | 74* | 64* | 55* | 47* | 41* | (35)* | (30)* | (26)* |
| X20CrMoV12-1 | N+T or Q+T | 10 000 | | | | | | | | | | | | | 294 | 274 | 253 | 232 | 213 | 192 | 173 | 154 | 136 | 119 | 101 |
| | | 30 000 | | | | | | | | | | | | | 271 | 250 | 228 | 208 | 187 | 167 | 148 | 130 | 113 | 97 | 81 |
| | | 50 000 | | | | | | | | | | | | | 261 | 238 | 217 | 195 | 175 | 155 | 136 | 119 | 102 | 87 | 74 |
| | | 100 000 | | | | | | | | | | | | | 248 | 225 | 202 | 180 | 159 | 139 | 121 | 104 | 88 | 75 | 63 |
| | | 150 000 | | | | | | | | | | | | | 239* | 219* | 197* | 175* | 150* | 128* | 110* | 94* | 80* | 68* | 57* |
| | | 200 000 | | | | | | | | | | | | | 234* | 213* | 190* | 167* | 143* | 122* | 104* | 89* | 76* | 64* | 53* |
| | | 250 000 | | | | | | | | | | | | | 229* | 208* | 185* | 161 | 137 | 117* | 100* | 84* | 72* | 60* | 50* |

[a] A = annealed; N = normalized; Q = quenched; T = tempered. For temperatures and cooling conditions see Table 1.

[b] Values with an asterisk have involved extended time extrapolation; values in parentheses have involved extended stress extrapolation.

NOTE Inclusion of creep rupture values up to high temperatures does not mean that products can be used in continuous duty up to these temperatures. The governing factor is the total stressing during operation.

## Table 5 — Strength for 1 % plastic strain at elevated temperatures for steels according to Table 1

| Steel type | Heat treatment[a] | Time | Estimated average strength for 1 % plastic strain [b] N/mm² Temperature, °C | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | h | 380 | 390 | 400 | 410 | 420 | 430 | 440 | 450 | 460 | 470 | 480 | 490 | 500 | 510 | 520 | 530 | 540 | 550 | 560 | 570 | 580 | 590 | 600 |
| PH 26 | N or | 10 000 | 164 | 150 | 136 | 124 | 113 | 101 | 91 | 80 | 72 | 62 | 53 | | | | | | | | | | | | |
| | Q+T | 100 000 | 118 | 106 | 95 | 84 | 73 | 65 | 57 | 49 | 42 | 35 | 30 | | | | | | | | | | | | |
| PH 29, | N or Q+T | 10 000 | 195 | 182 | 167 | 150 | 135 | 120 | 107 | 93 | 83 | 71 | 63 | 55 | 49 | | | | | | | | | | |
| PH 31 | | 100 000 | 153 | 137 | 118 | 105 | 92 | 80 | 69 | 59 | 51 | 44 | 38 | 33 | 29 | | | | | | | | | | |
| 16Mo3 | N or N+T | 10 000 | | | | | | | | 216 | 199 | 182 | 166 | 149 | 132 | 115 | 99 | 84 | | | | | | | |
| | or Q+T | 100 000 | | | | | | | | 167 | 146 | 126 | 107 | 89 | 73 | 59 | 46 | 36 | | | | | | | |
| 14CrMo4-5 | N+T or | 10 000 | | | | | | | | 245 | 228 | 210 | 193 | 173 | 157 | 139 | 122 | 106 | 90 | 76 | 64 | 53 | | | |
| | Q+T | 100 000 | | | | | | | | 191 | 172 | 152 | 133 | 116 | 98 | 83 | 70 | 57 | 46 | 35 | 30 | 24 | | | |
| 13CrMo9-10 | N+T or | 10 000 | | | | | | | | 240 | 219 | 200 | 180 | 163 | 147 | 132 | 119 | 107 | 94 | 83 | 73 | 65 | 57 | 50 | 44 |
| | Q+T | 100 000 | | | | | | | | 166 | 155 | 145 | 130 | 116 | 103 | 90 | 78 | 68 | 58 | 49 | 41 | 35 | 30 | 26 | 22 |

[a] A = annealed; N = normalized; Q = quenched; T = tempered. For temperatures and cooling conditions see Table 1.

[b] These values were not derived from an assesment of international data. They come from DIN 17155 and are also specified in EN 10028-2.

NOTE Inclusion of 1 % creep strain values up to high temperatures does not mean that products can be used in continuous duty up to these temperatures. The governing factor is the total stressing during operation.

# Bibliography

[1] ISO 2604-1:1975[1)], *Steel products for pressure purposes — Quality requirements — Part 1: Forgings.*

[2] EN 10028-2:1992, *Flat products made of steels for pressure purposes — Part 2: Non-alloy and alloy steels with specified elevated temperature properties.*

[3] DIN 17155:1983[2)], *Plate and strip of steels for elevated temperatures — Technical delivery conditions.*

1) To be replaced by ISO 9327 parts 1 to 5.

2) Replaced in 1992 by EN 10028-2.

ICS 77.140.30; 77.140.85

Price based on 10 pages