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# Elevated temperature properties for steels for pressure purposes

## Part 1. Stress rupture properties

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Propriétés à températures élevées des aciers pour appareils à pression  
Partie 1. Propriétés de rupture sous contrainte

Eigenschaften von Stählen für den Einsatz unter Druck bei hohen Temperaturen  
Teil 1. Zeitstandverhalten

|                            |
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| Confirmed<br>December 2011 |
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## Foreword

This Part of this Published Document has been prepared under the direction of the Iron and Steel Standards Policy Committee. It is the result of work carried out by the Elevated and Low Temperature Properties of Steel Panel ISM/73/-/1, with support from the Department of Trade and Industry. It is considered of advantage to bring together into one document the elevated temperature stress rupture values found in several separate British Standards dealing with steels for pressure purposes.

It is intended that a second Part of this Published Document be produced covering elevated temperature proof stress values for steels.

Attention is drawn to clause 3 which both states the need for the supply of latest data (3.1) and establishes the authority of the values given (3.2).

This Part of this Published Document, is related to the International Standard Technical Report ISO/TR 7468 (1978) 'Summary of average stress rupture properties of wrought steels for boilers and pressure vessels'.

**Amendment No. 1**  
**published and effective from 15 February 1994**  
**to PD 6525 : Part 1 : 1990**

**Elevated temperature properties for steels for**  
**pressure purposes**  
**Part 1. Stress rupture properties**

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**Instructions for the insertion of new and revised pages**

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The issue number on the attached pages indicates the relationship of the page to the original standard. Issue 2 indicates a revised page to replace the original page of the same number. Vertical sidelining on replacement pages indicates that a change (or changes) has been made at that point. Where only one of two backed-up pages has been revised, the appropriate text has been reprinted on the reverse so that the original sheet may be removed from the standard.

**Page**

|         |                                                   |
|---------|---------------------------------------------------|
| 3 and 4 | Replace existing pages                            |
| 9       | Replace existing page (page 10 unchanged on back) |
| 87a     | Insert new page (page 87 unchanged on front)      |
| 87b     | Insert new page (page 88 unchanged on back)       |
| 90      | Insert new page (page 89 unchanged on front)      |

**AMD 7977/February 1994**

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| 34 16 % Cr 16 % NiMoNb (1971)                         | 76   |                                                                               |      |
| (a) Conditions of steel to which the properties apply | 76   | 1 C Steel Semi and Si killed (1974)                                           | 11   |
| (b) Quantity and duration of data used in assessment  | 76   | 2 C Steel Si and Al killed (1974)                                             | 13   |
| (c) Average rupture stresses                          | 76   | 3 C-Mn Steel (1974)                                                           | 15   |
| 35 30 % Ni 20 % CrTiAl (1972)                         | 76   | 4 0.3 % Mo (1975)                                                             | 17   |
| (a) Conditions of steel to which the properties apply | 76   | 5 0.5 % Mo (1975)                                                             | 19   |
| (b) Quantity and duration of data used in assessment  | 78   | 6 NiCrMoV                                                                     | 21   |
| (c) Average rupture stresses                          | 78   | 7 MnCrMoV                                                                     | 23   |
| 36 25 % Cr 20 % Ni (1988)                             | 78   | 8 ½ % Cr ½ % Mo ¼ % V (1987)                                                  | 25   |
| (a) Conditions of steel to which the properties apply | 78   | 9 1 % CrMo (Normalized) (1988)                                                | 27   |
| (b) Quantity and duration of data used in assessment  | 78   | 10 1 % CrMo (Normalized and Tempered) (1988)                                  | 29   |
| (c) Average rupture stresses                          | 78   | 11 1¼ % CrMo (Normalized and Tempered) (1988)                                 | 31   |
| 37 0.4 % C 1¼ % CrMo (Notched properties) (1979)      | 80   | 12 0.4 % C 1¼ % CrMo (1975)                                                   | 33   |
| (a) Conditions of steel to which the properties apply | 80   | 13 0.4 % C 1¼ % CrMoV (1979)                                                  | 35   |
| (b) Quantity and duration of data used in assessment  | 80   | 14 1 % CrMoVTiB (1979)                                                        | 37   |
| (c) Average rupture stresses                          | 80   | 15 2¼ % CrMo (Annealed) (1969)                                                | 39   |
| 38 0.4 % C 1¼ % CrMoV (Notched properties) (1975)     | 80   | 16 2¼ % CrMo (Normalized and Tempered ≤ 720 °C) (1988)                        | 41   |
| (a) Conditions of steel to which the properties apply | 82   | 17 2¼ % CrMo (Normalized and Tempered ≤ 750 °C) (1988)                        | 43   |
| (b) Quantity and duration of data used in assessment  | 82   | 18 5 % CrMo (Annealed) (1974)                                                 | 45   |
| (c) Average rupture stresses                          | 82   | 19 5 % CrMo (Normalized and Tempered) (1974)                                  | 47   |
| 39 1 % CrMoVTiB (Notched properties) (1975)           | 82   | 20 9 % CrMo (Annealed) (1974)                                                 | 49   |
| (a) Conditions of steel to which the properties apply | 82   | 21 9 % CrMo (Normalized and Tempered) (1987)                                  | 51   |
| (b) Quantity and duration of data used in assessment  | 82   | 22 12 % CrMoV ( $R_m$ 690 N/mm <sup>2</sup> to 840 N/mm <sup>2</sup> ) (1988) | 53   |
| (c) Average rupture stresses                          | 84   | 23 18 % Cr 8 % Ni (1987)                                                      | 55   |
| 40 Steel 91 (1992)                                    | 84   | 24 18 % Cr 8 % NiN (1974)                                                     | 57   |
| (a) Conditions of steel to which the properties apply | 84   | 25 18 % Cr 12 % NiMo (1982)                                                   | 59   |
| (b) Quantity and duration of data used in assessment  | 84   | 26 18 % Cr 12 % NiMoB (1982)                                                  | 61   |
| (c) Average rupture stresses                          | 84   | 27 18 % Cr 12 % NiMoN (1974)                                                  | 63   |
| 40 Steel 91 (1992)                                    | 86   | 28 18 % Cr 10 % NiTi (Heat treatment 950 °C to 1070 °C) (1987)                | 65   |
| (a) Conditions of steel to which the properties apply | 86   | 29 18 % Cr 10 % NiTi (Heat treatment 1070 °C to 1140 °C) (1987)               | 67   |
| (b) Quantity and duration of data used in assessment  | 86   | 30 18 % Cr 12 % NiNb (Heat treatment 950 °C to 1070 °C) (1988)                | 69   |
| (c) Average rupture stresses                          | 86   | 31 18 % Cr 12 % NiNb (Heat treatment 1070 °C to 1125 °C) (1988)               | 71   |
| 40 Steel 91 (1992)                                    | 87a  | 32 18 % Cr 10 % NiNbN (1974)                                                  | 73   |
| (a) Conditions of steel to which the properties apply | 87a  | 33 15 % Cr 10 % Ni 6 % MnNbV (1988)                                           | 75   |
| (b) Quantity and duration of data used in assessment  | 87a  | 34 16 % Cr 16 % NiMoNb (1971)                                                 | 77   |
| (c) Average rupture stresses                          | 87a  | 35 30 % Ni 20 % CrTiAl (1972)                                                 | 79   |
|                                                       | 87a  | 36 25 % Cr 20 % Ni (1988)                                                     | 81   |
|                                                       | 87a  | 37 0.4 % C 1¼ % CrMo (Notched properties) (1979)                              | 83   |
|                                                       |      | 38 0.4 % C 1¼ % CrMoV (Notched properties) (1975)                             | 85   |
|                                                       |      | 39 1 % CrMoVTiB (Notched properties) (1975)                                   | 87   |
|                                                       | 40   | Steel 91 (1992)                                                               | 87b  |

## 1 Scope

This Part of PD 6525 collates average stress rupture values for wrought carbon, ferritic alloy and austenitic steels contained in several British Standard specifications and other data assessments where elevated temperature properties are required. The steels are arranged in increasing alloy content. Indexes list the steels as given in the specifications for plates, sections and bars, forgings, bars for bolting and tubes/pipes respectively.

NOTE. The titles of publications referred to in this Published Document are listed on the inside back cover.

## 2 Data assessment

The stress rupture values given in this Part of PD 6525 have been obtained from a series of data assessments carried out by ISM/73/-/1 (see note 4 of clause 4).

Also contained in this Part of PD 6525 are indexes which relate British Standard specifications to the steels for which stress rupture values are given in this Published Document. The indexes are as follows:

|           |            |                           |
|-----------|------------|---------------------------|
| BS 1501 : | Part 1 :   | see index 1 ;             |
|           | : Part 2 : | see index 1 ;             |
|           | : Part 3 : | see index 1 ;             |
| BS 1502 : |            | see index 2 ;             |
| BS 1503 : |            | see index 3 ;             |
| BS 1506 : |            | see index 4 and index 7 ; |
| BS 3059 : | Part 2 :   | see index 5 ;             |
| BS 3602 : | Part 1 :   | see index 5 ;             |
| BS 3602 : | Part 2 :   | see index 5 ;             |
| BS 3604 : | Part 1 :   | see index 5 ;             |
| BS 3605 : |            | see index 5 ;             |

Stress rupture values are also given for other steels; from data assessments carried out, namely:

- (a) those which are being introduced in revisions of the above British Standards (see 3.2);
- (b) for steels currently not in British Standards (see index 6);
- (c) for bolting steels, properties from notched test specimens (see index 7).

However, for some steels included in British Standards, stress rupture data assessments have not been carried out, principally due to lack of data. Hence such steels, e.g. type 309S16 in BS 1501 : Part 3, are not listed in this Published Document.

The stress rupture values given for each steel are considered to be applicable to all wrought product forms, since the data assessments were based usually on information from a variety of wrought product forms.

## 3 Stress rupture values

### 3.1 Relation to data assessments

The stress rupture values given in this Part of PD 6525 are based on the assessment of test results provided by various laboratories in the UK and abroad. The validity of the values given depends on the range and amounts of data available. Therefore, in order that further assessments may be carried out to verify or modify these values so that they are relevant to the long service durations, it is important that data continue to be made available. The test results should be supported by information relating to steelmaking, product form, composition and heat treatment details. Appendix A gives a complete list of the information which should be provided when submitting data. The absence of full background details should not deter submission of test data.

The data should be submitted to:

British Standards Institution  
ISM/73/-/1 Secretariat  
3 York Street  
Manchester  
M2 2AT.

### 3.2 Relation to values in product standards

The collation of stress rupture values for wrought steels in this Part of PD 6525 represents the most recent assessment carried out for each steel and, as a result of the policy of keeping British Standards up to date, revisions will be introduced into this document as further assessments are carried out and validated by the appropriate BSI committee. In view of the fact that the product standards requiring the inclusion of stress rupture values will also be revised, there will be occasions when the stress rupture values in this document differ from those in the product standards for any given steel. Furthermore, steel designations may be changed and new steels may be introduced following revision, which could outdate some of the information given in this document.

In all cases therefore, it is essential that the stress rupture values given in the relevant product standard (as opposed to those given in this Part of PD 6525) be applied.

## 4 Notes to the stress rupture values

### 4.1 General

The notes given in 4.2 to 4.5 apply to the stress rupture values for all steels detailed in tables 1 to 40 inclusive.

### 4.2 Note 1. Year of approval of properties

The date that is shown in parentheses alongside the title/grade of the steel indicates the year of approval of its properties.

## Index 5. Tubes/pipes

| British Standard | Designation         | Page of PD 6525 |
|------------------|---------------------|-----------------|
| BS 3059 : Part 2 | Steel 360           | 12              |
|                  | Steel 440           | 14              |
|                  | Steel 243           | 16              |
|                  | Steel 620-460       | 26              |
|                  | Steel 622-490       | 42              |
|                  | Steel 629-470       | 48              |
|                  | Steel 629-590       | 50              |
|                  | Steel 762           | 52              |
|                  | Steel 304S51        | 54              |
|                  | Steel 316S51        | 58              |
|                  | Steel 316S52        | 60              |
|                  | Steel 321S51 (1010) | 64              |
|                  | Steel 321S51 (1105) | 66              |
|                  | Steel 347S51        | 68              |
|                  | Steel 215S15        | 74              |
| BS 3602 : Part 1 | Steel 360           | 12              |
|                  | Steel 430           | 12              |
|                  | Steel 500 Nb        | 14              |
| BS 3602 : Part 2 | Steel 410           | 12              |
|                  | Steel 460           | 14              |
| BS 3604 : Part 1 | Steel 620-440       | 28              |
|                  | Steel 621           | 30              |
|                  | Steel 660           | 24              |
|                  | Steel 622           | 42              |
|                  | Steel 625           | 44              |
|                  | Steel 629-470       | 48              |
|                  | Steel 629-590       | 50              |
|                  | Steel 762           | 52              |
| BS 3605          | Steel 304S59        | 54              |
|                  | Steel 316S59        | 58              |
|                  | Steel 321S59 (1010) | 64              |
|                  | Steel 321S59 (1105) | 66              |
|                  | Steel 347S59        | 68              |
|                  | Steel 215S15        | 74              |

## Index 6. Steels not currently in British Standards

| Designation                                                                | Page of PD 6525 |
|----------------------------------------------------------------------------|-----------------|
| Steel 245                                                                  | 18              |
| Steel 622 (Annealed)                                                       | 38              |
| Steel 622 (Normalized and Tempered $\leq 720^{\circ}\text{C}$ )            | 40              |
| Steel 347S (Heat treatment $1010^{\circ}\text{C} - 1125^{\circ}\text{C}$ ) | 70              |
| Steel 347N                                                                 | 72              |
| Steel 16-16 MoNb                                                           | 76              |
| Alloy 800                                                                  | 78              |
| Steel 91                                                                   | 87a             |

## Index 7. Stress rupture values for notched bars to BS 3500 : Part 1

| British Standard | Designation   | Page of PD 6525 |
|------------------|---------------|-----------------|
| BS 1506          | Steel 631-850 | 82              |
|                  | Steel 671-850 | 84              |
|                  | Steel 681-820 | 86              |

Table 1. C Steel Semi and Si killed (1974) (note 1)

## (a) Conditions of steel to which the properties apply

|                      | Details of materials tested                               |                         | Specified ranges (see note 2) |         |
|----------------------|-----------------------------------------------------------|-------------------------|-------------------------------|---------|
|                      |                                                           |                         | Minimum                       | Maximum |
| Chemical composition | C                                                         | % (m/m)<br>0.07 to 0.24 | —                             | 0.25    |
|                      | Si                                                        | 0.005 to 0.330          | —                             | 0.35    |
|                      | Mn                                                        | 0.32 to 0.80            | 0.40                          | 1.40    |
|                      | P                                                         | 0.003 to 0.048          | —                             | 0.045   |
|                      | S                                                         | 0.003 to 0.05           | —                             | 0.045   |
|                      |                                                           |                         |                               |         |
| Heat treatment       | °C<br>1. 899 to 950 AC<br>2. 850 to 920 AC + T 500 to 690 |                         | AR or Norm.                   |         |

## (b) Quantity and duration of data used in assessment (see note 3)

| Temperature | Test duration                   |                          |                          |                          |                          |                           |               |
|-------------|---------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|---------------------------|---------------|
|             | h<br><10 000                    | h<br>10 000 to<br>20 000 | h<br>20 000 to<br>30 000 | h<br>30 000 to<br>50 000 | h<br>50 000 to<br>70 000 | h<br>70 000 to<br>100 000 | h<br>>100 000 |
|             | Number of test points available |                          |                          |                          |                          |                           |               |
| °C          |                                 |                          |                          |                          |                          |                           |               |
| 400         | 281(11)                         | 34(7)                    | 10(8)                    | 11(8)                    | 2(4)                     | 1(1)                      | —             |
| 450         | 445(16)                         | 45(10)                   | 6(10)                    | 5(2)                     | (3)                      | (1)                       | —             |
| 500         | 455(8)                          | 27(6)                    | 11(5)                    | 3(6)                     | (4)                      | (3)                       | —             |

( ) Figures in parentheses denote unbroken tests.

## (c) Average rupture stresses

| Temperature | 10 000 h          | 30 000 h          | 50 000 h          | 100 000 h         | 150 000 h         | 200 000 h         | 250 000 h         |
|-------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| °C          | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> |
| 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               | 79                | 69                | 57                | 50*               | 44*               | —                 |
| 480         | 89                | 68                | 60                | 48                | (39)              | —                 | —                 |
| 490         | 77                | 59                | 51                | —                 | —                 | —                 | —                 |
| 500         | 68                | 51                | 41                | —                 | —                 | —                 | —                 |
| 510         | 60                | 41                | —                 | —                 | —                 | —                 | —                 |
| 520         | 52                | —                 | —                 | —                 | —                 | —                 | —                 |

\*Values which have involved extended time extrapolation (see note 4(a)).

( ) Values which have involved extended stress extrapolation (see note 4(b)).

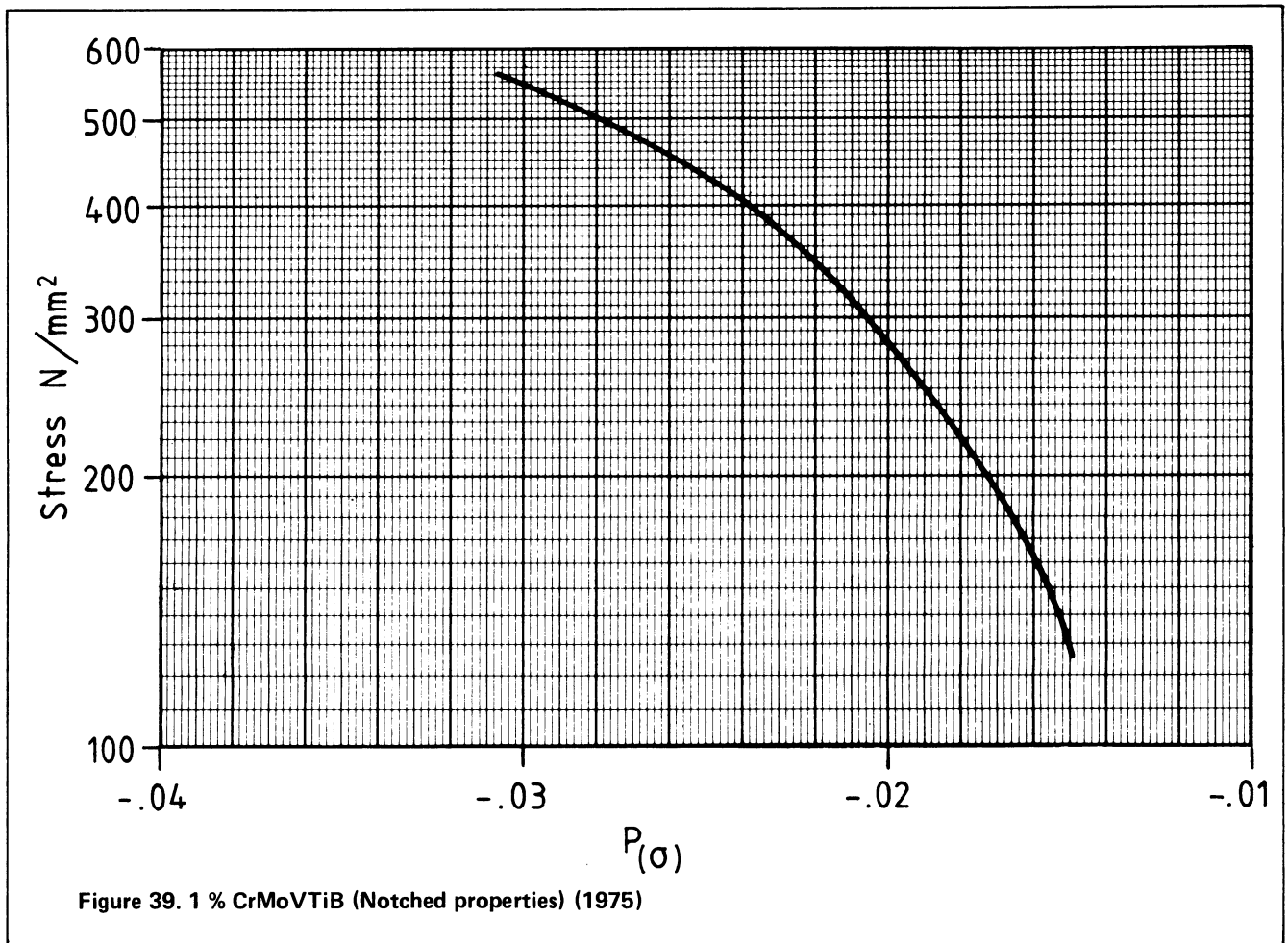


**Table 40. Steel 91 (1992)**

(a) Conditions of steel to which the properties apply

|                      | Details of materials tested                                                                                                                         |                | Specified ranges (see note 2)          |         |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|----------------|----------------------------------------|---------|
|                      |                                                                                                                                                     |                | Minimum                                | Maximum |
| Chemical composition |                                                                                                                                                     | % (m/m)        | % (m/m)                                | % (m/m) |
|                      | C                                                                                                                                                   | 0.08 to 0.12   | 0.08                                   | 0.12    |
|                      | Si                                                                                                                                                  | 0.08 to 0.67   | 0.20                                   | 0.50    |
|                      | Mn                                                                                                                                                  | 0.36 to 0.59   | 0.30                                   | 0.60    |
|                      | P                                                                                                                                                   | 0.001 to 0.021 | —                                      | 0.020   |
|                      | S                                                                                                                                                   | 0.001 to 0.010 | —                                      | 0.020   |
|                      | Cr                                                                                                                                                  | 8.05 to 9.45   | 8.00                                   | 9.50    |
|                      | Mo                                                                                                                                                  | 0.85 to 1.09   | 0.85                                   | 1.05    |
|                      | Ni                                                                                                                                                  | 0.02 to 0.29   | —                                      | 0.40    |
|                      | N                                                                                                                                                   | 0.030 to 0.069 | 0.030                                  | 0.070   |
|                      | Nb                                                                                                                                                  | 0.054 to 0.15  | 0.06                                   | 0.10    |
|                      | V                                                                                                                                                   | 0.18 to 0.26   | 0.18                                   | 0.25    |
|                      | Al                                                                                                                                                  | —              | —                                      | 0.03    |
| Heat treatment       | °C<br>1. 1040 to 1120 Ac +<br>T 735 to 780<br>2. 1040 to 1070 AC +<br>T 730 to 760 +<br>T 740 to 770                                                |                | °C<br>N 1040 to 1090 +<br>T 730 to 790 |         |
|                      | NOTE. The heat treatment maximum temperatures reflect the need for quality control and, for tempering, the need to reduce the risk of re-hardening. |                |                                        |         |

(b) Quantity and duration of data used in assessment (see note 3)

| Temperature                                      | Test duration                   |                             |                             |                             |                             |                              |               |
|--------------------------------------------------|---------------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|------------------------------|---------------|
|                                                  | h<br>< 10 000                   | h<br>10 000<br>to<br>20 000 | h<br>20 000<br>to<br>30 000 | h<br>30 000<br>to<br>50 000 | h<br>50 000<br>to<br>70 000 | h<br>70 000<br>to<br>100 000 | h<br>>100 000 |
|                                                  | Number of test points available |                             |                             |                             |                             |                              |               |
| °C                                               |                                 |                             |                             |                             |                             |                              |               |
| 500                                              | 61 (3)                          | 5 (3)                       | (4)                         | (6)                         | 1 (3)                       | (1)                          | —             |
| 538/40                                           | 16 (1)                          | 4 (3)                       | 1 (1)                       | (4)                         | (3)                         | 1 (1)                        | —             |
| 550                                              | 163 (13)                        | 9 (11)                      | 5                           | 4 (1)                       | 1 (1)                       | —                            | —             |
| 593                                              | 36 (1)                          | 7 (1)                       | 2 (5)                       | 3                           | 1                           | —                            | —             |
| 600                                              | 197 (10)                        | 8 (3)                       | 3 (1)                       | 2 (8)                       | 2 (4)                       | (4)                          | —             |
| 646/649/650                                      | 200 (6)                         | 15 (5)                      | 7                           | —                           | —                           | —                            | —             |
| 700/704                                          | 27                              | 3                           | 1                           | —                           | —                           | —                            | —             |
| ( ) Figure in parentheses denote unbroken tests. |                                 |                             |                             |                             |                             |                              |               |

(c) Average rupture stresses

| Temperature | 10 000 h          | 30 000 h          | 50 000 h          | 100 000 h         | 150 000 h         | 200 000 h         | 250 000 h         |
|-------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| °C          | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> |
| 490         | 302               | 284               | 276               | 265               | 259               | 254*              | 250*              |
| 500         | 283               | 266               | 258               | 247               | 240               | 236*              | 232*              |
| 510         | 265               | 248               | 240               | 229               | 222               | 218*              | 214*              |
| 520         | 248               | 231               | 223               | 212               | 205               | 200*              | 197*              |
| 530         | 230               | 213               | 205               | 194               | 188               | 183*              | 180*              |
| 540         | 214               | 197               | 189               | 178               | 171               | 167*              | 163*              |
| 550         | 197               | 181               | 173               | 162               | 155               | 151*              | 147*              |
| 560         | 182               | 165               | 157               | 146               | 140               | 136*              | 132*              |
| 570         | 166               | 150               | 142               | 132               | 126*              | 121*              | 118*              |
| 580         | 151               | 135               | 128               | 118               | 112               | 108*              | 105*              |
| 590         | 137               | 122               | 115               | 105               | 100               | 96*               | 93*               |
| 600         | 124               | 109               | 102               | 94                | 89                | 85*               | 83*               |
| 610         | 111               | 97                | 91                | 83                | 78                | 75*               | 73*               |
| 620         | 99                | 87                | 81                | 74                | 69                | 67*               | 64*               |
| 630         | 89                | 77                | 72                | 65*               | 61*               | 58*               | 56*               |
| 640         | 79                | 68                | 64                | 57*               | 54*               | 51*               | 49*               |
| 650         | 71                | 60                | 56                | 50*               | 46*               | 43*               | 41*               |
| 660         | 63                | 53                | 49                | 42*               | 37*               | —                 | —                 |
| 670         | 55                | 46                | 41                | —                 | —                 | —                 | —                 |
| 680         | 48                | 37                | —                 | —                 | —                 | —                 | —                 |
| 690         | 41                | —                 | —                 | —                 | —                 | —                 | —                 |

\* Values which have involved extended time extrapolation (see note 4(a)).

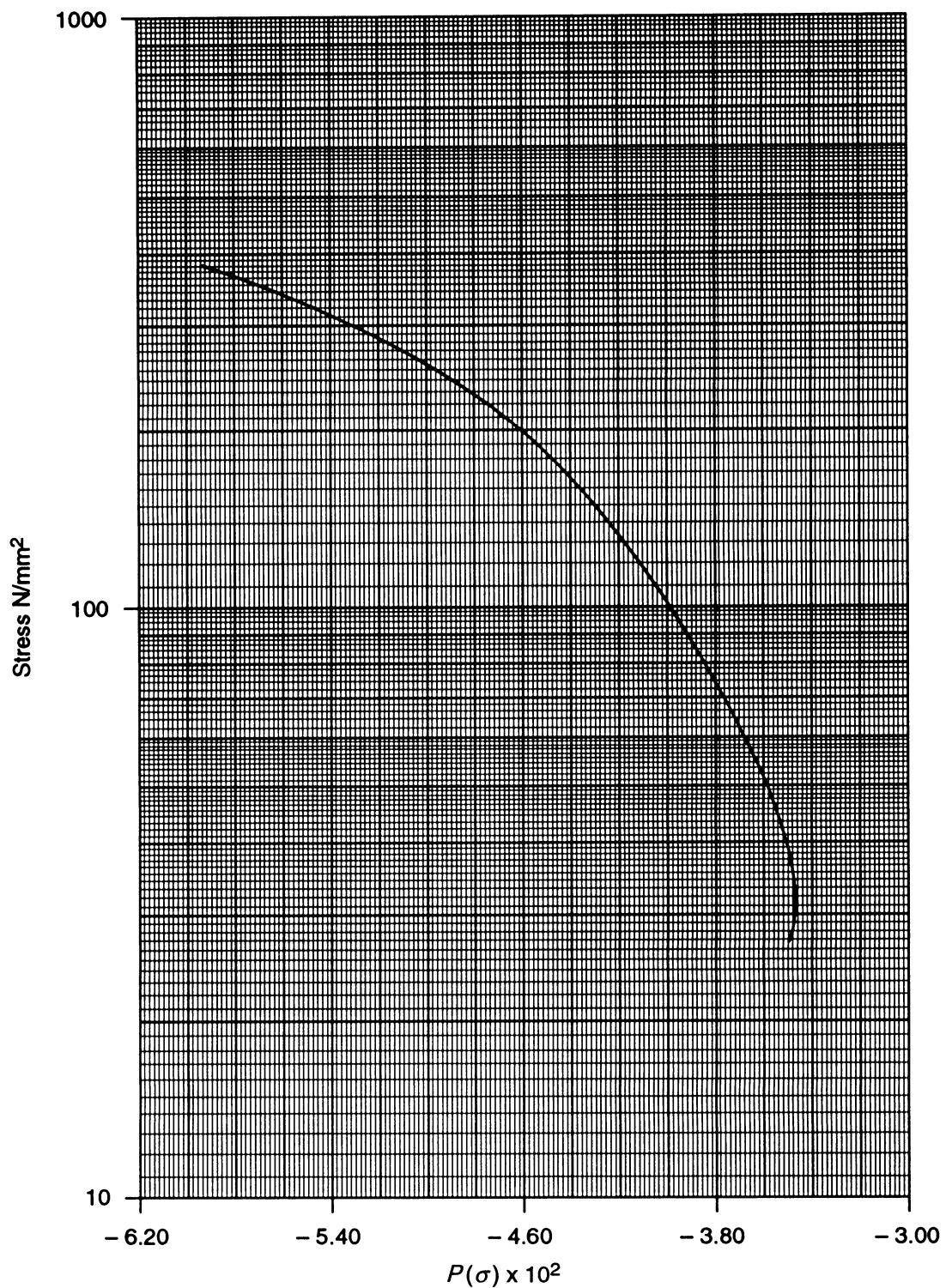


Figure 40. Steel 91 (1992)

## Appendices

### Appendix A. Request form for stress rupture/creep data (see 3.1)

Please provide stress rupture/creep data according to the following categories, and send to : British Standards Institution, ISM/73/-/1 Secretariat, 3 York Street, Manchester. M2 2AT.

#### 1. Manufacturing details

Cast No.:

Code No.:

Steelmaker:

Testing laboratory:

Steelmaking process, including any secondary process:

De-oxidation practice:

Concast/ingot size:

Concast/ingot weight:

Product form:

Product dimensions:

(Outside diameter and thickness for tube)

Product process route:

#### 2. Chemical composition

(a) State whether information provided is cast or product composition:

(b) Detailed chemical composition data to include\*:

C, Si, Mn, P, S, Cr, Mo, Ni, Al, As, B, Bi, Co, Cu, N, Nb, Pb, Sb, Sn, Ti, V, W, Zr.

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\*Where known.

**3. Heat treatment of test sample or piece**

- (a) Pretreatments\*:
- (b) Austenitizing treatment\*:  
(Solution treatment)  
Actual temperature\*:  
Time at temperature\*:  
Cooling medium\*:  
Cooling rate and temperature range over which measured if controlled cooled\*:
- (c) Tempering treatment\*:  
Actual temperature\*:  
Time at temperature\*:  
Cooling medium\*:  
Cooling rate and temperature range over which measured if controlled cooled\*:
- (d) Any subsequent treatments, e.g. post-weld heat treatment(s)\*:

**4. Test results**

- (a) Test piece location,:  
e.g. transverse
- (b) Test piece dimensions:
- (c) Elevated temperature stress rupture/creep data:  
(to include test temperature, stress, duration, A, Z)  
(Please state whether test is completed or test piece unbroken at duration stated.)  
(Please state the time to specific creep strain(s) ,  
e.g. 0.05 %, 0.1 %, 0.2 %, 0.5 %, 1 %.)
- (d) Testing standard:
- (e) Laboratory accreditation:
- (f) Test atmosphere:

NOTE. Whenever possible, the room and elevated temperature proof and tensile properties for the same batch of material should also be provided.

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\*Indicate if treatments are works or laboratory treatments.

## Appendix B. Constants for the equation of the master curve and constants to the parametric equation

The constants for the equation of the master curve and to the parametric equation are as follows (see clause 5).

| Steel                                                                              | Page No. | Constants for the equation of the master curve |               |                |                 |                 | Constants for the parametric equation |                      |                          |
|------------------------------------------------------------------------------------|----------|------------------------------------------------|---------------|----------------|-----------------|-----------------|---------------------------------------|----------------------|--------------------------|
|                                                                                    |          | <i>a</i>                                       | <i>b</i>      | <i>c</i>       | <i>d</i>        | <i>e</i>        | <i>r</i>                              | <i>T<sub>a</sub></i> | log <i>t<sub>a</sub></i> |
| C Semi and Si killed                                                               | 11       | -1.258375287                                   | 2.614840508   | -2.058339119   | 0.7172185779    | -0.09393693507  | 1                                     | 500                  | 10.678713799             |
| C Si and Al killed                                                                 | 13       | 12083.43750                                    | 11945.41016   | -5041.642090   | 277.0161743     | —               | -1                                    | 0                    | -20.580183029            |
| C-Mn                                                                               | 15       | -0.6656401157                                  | 1.416657686   | -1.151554346   | 0.4130830467    | -0.05579527840  | 1                                     | 500                  | 10.658872604             |
| 0.3 % Mo                                                                           | 17       | —                                              | —             | —              | —               | —               | -1                                    | 0                    | -23.46                   |
| 0.5 % Mo                                                                           | 19       | -15.9188175                                    | 1638.47802    | -587.796264    | —               | —               | -1                                    | 650                  | -1.3147382               |
| NiCrMoV                                                                            | —        | —                                              | —             | —              | —               | —               | —                                     | —                    | —                        |
| MnCrMoV                                                                            | —        | —                                              | —             | —              | —               | —               | —                                     | —                    | —                        |
| ½ % Cr ½ % Mo ¼ % V                                                                | 25       | -1.730246782                                   | 3.300741434   | -2.387772322   | 0.7668237090    | -0.09273781627  | 1                                     | 520                  | 13.783925056             |
| 1 % CrMo (Norm.)                                                                   | 27       | 7297.777344                                    | -7238.721680  | 3306.159668    | -568.9218750    | —               | -1                                    | 600                  | -2.6099286079            |
| 1 % CrMo (Norm. + T)                                                               | 29       | 0.0666840937                                   | -0.1434341073 | 0.07376483083  | -0.01308391150  | —               | 1                                     | 280                  | 20.328840256             |
| 1¼ % CrMo (Norm. + T)                                                              | 31       | 0.0666840937                                   | -0.1434341073 | 0.07376483083  | -0.01308391150  | —               | 1                                     | 280                  | 20.328840256             |
| 0.4 % C 1¼ % CrMo                                                                  | 33       | -58488.13213                                   | 107347.2301   | -71847.65041   | 21171.74394     | -2332.020504    | -1                                    | 650                  | -1.1164713224            |
| 0.4 % C 1¼ % CrMoV                                                                 | 35       | -29.54915810                                   | 49.96889496   | -31.70220566   | 8.939930916     | -0.9461904168   | 1                                     | 650                  | 8.9767904282             |
| 1 % CrMoVTiB                                                                       | 37       | -231.7584540                                   | 402.8051885   | -262.3310961   | 75.87412322     | -8.224261141    | 1                                     | 750                  | 6.4636992905             |
| 2¼ % CrMo (Annealed)                                                               | 39       | —                                              | —             | —              | —               | —               | 1                                     | 400                  | 15.41                    |
| 2¼ % CrMo (Norm. + T ≤ 720 °C)                                                     | 41       | -1.386920571                                   | 2.832926035   | -2.196207523   | 0.7565333843    | -0.09841170162  | 1                                     | 610                  | 10.395759583             |
| 2¼ % CrMo (Norm. + T ≤ 750 °C)                                                     | 43       | -0.5246057510                                  | 1.046909690   | -0.8198743463  | 0.2890807092    | -0.03939661011  | 1                                     | 610                  | 10.360854149             |
| 5 % CrMo (Annealed)                                                                | 45       | —                                              | —             | —              | —               | —               | 1                                     | 400                  | 14.57                    |
| 5 % CrMo (Norm. + T)                                                               | 47       | —                                              | —             | —              | —               | —               | 1                                     | 650                  | 8.985                    |
| 9 % CrMo (Annealed)                                                                | 49       | -0.8064230084                                  | 1.757547379   | -1.457643270   | 0.5326023102    | -0.07343267649  | 1                                     | 600                  | 11.695010185             |
| 9 % CrMo (Norm. + T)                                                               | 51       | 0.1114614084                                   | -0.2219061404 | 0.1145877466   | -0.01637363806  | -0.001907426864 | 1                                     | 560                  | 14.172191620             |
| 12 % CrMoV ( <i>R<sub>m</sub></i> 690 N/mm <sup>2</sup> to 840 N/mm <sup>2</sup> ) | 53       | -0.4286341369                                  | 0.9403277040  | -0.8039016724  | 0.3014570773    | -0.04262292758  | 1                                     | 610                  | 12.751610756             |
| 18 % Cr 8 % Ni                                                                     | 55       | 0.2020732909                                   | -0.4409566820 | 0.3286471069   | -0.1085945144   | 0.01317540463   | 1                                     | 0                    | 25.241230011             |
| 18 % Cr 8 % NiN                                                                    | 57       | -0.07566214353                                 | 0.06060781330 | -0.01138103660 | -0.001937349210 | —               | 1                                     | 500                  | 10.873614311             |
| Steel 91 (1992)                                                                    | 87a      | -0.4938277900                                  | 0.9749886394  | -0.7671017051  | 0.2668407261    | -0.03513864124  | 1                                     | 370                  | 24.755538940             |

**Amendment No. 2**  
**published and effective from 15 December 1995**  
**to PD 6525 : Part 1 : 1990**

**Elevated temperature properties for steels for pressure purposes**  
**Part 1. Stress rupture properties**

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**Instructions for the insertion of new and revised pages**

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The issue number on the attached page indicates the relationship of the page to the original standard. Issue 2 indicates the revised page to replace the original page of the same number. Vertical sidelining on the replacement page indicates that a change (or changes) has been made at that point. Where only one of two backed-up pages has been revised, the appropriate text has been reprinted on the reverse so that the original sheet may be removed from the standard.

**Page**

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|-----------|-----------------------------------------------|
| 18        | Replace existing page (page 17 is unchanged). |
| 45 and 46 | Replace existing pages.                       |
| 69        | Replace existing page (page 70 is unchanged). |
| 91        | Replace existing page (page 92 is unchanged). |

**AMD 8802/December 1995**

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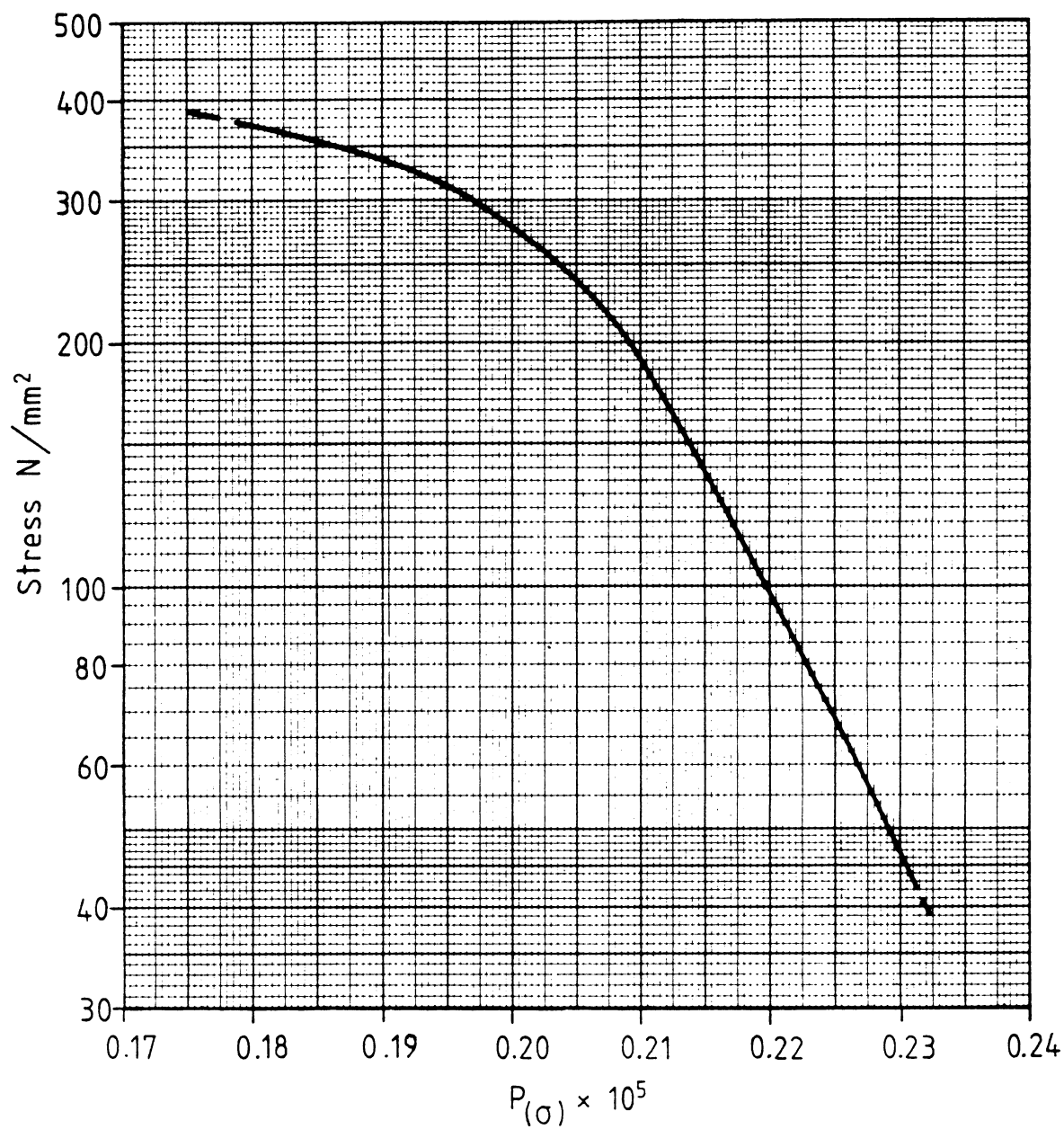


Figure 4. 0.3 % Mo (1975)



**Table 5. 0.5 % Mo (1975) (note 1)**

(a) Conditions of steel to which the properties apply

|                      | Details of materials tested                                                                              |                | Specified ranges (see note 2)         |         |
|----------------------|----------------------------------------------------------------------------------------------------------|----------------|---------------------------------------|---------|
|                      |                                                                                                          |                | Minimum                               | Maximum |
| Chemical composition | C                                                                                                        | 0.07 to 0.26   | —                                     | 0.25    |
|                      | Si                                                                                                       | 0.01 to 0.34   | 0.15                                  | 0.40    |
|                      | Mn                                                                                                       | 0.42 to 0.78   | —                                     | 0.90    |
|                      | P                                                                                                        | 0.008 to 0.036 | —                                     | 0.040   |
|                      | S                                                                                                        | 0.007 to 0.048 | —                                     | 0.040   |
|                      | Mo                                                                                                       | 0.40 to 0.61   | 0.45                                  | 0.65    |
|                      | Al (tot.)                                                                                                | 0.002 to 0.018 | —                                     | 0.012   |
| Heat treatment       | °C<br>1. Cold drawn + T 720<br>2. 720 to 871 FC<br>3. 900 to 1100 AC<br>4. 880 to 1093 AC + T 600 to 710 |                | °C<br>900 to 940 AC +<br>T 600 to 650 |         |

(b) Quantity and duration of data used in assessment (see note 3)

| Temperature | Test duration                   |                          |                          |                          |                          |                           |               |
|-------------|---------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|---------------------------|---------------|
|             | h<br><10 000                    | h<br>10 000 to<br>20 000 | h<br>20 000 to<br>30 000 | h<br>30 000 to<br>50 000 | h<br>50 000 to<br>70 000 | h<br>70 000 to<br>100 000 | h<br>>100 000 |
|             | Number of test points available |                          |                          |                          |                          |                           |               |
| °C          |                                 |                          |                          |                          |                          |                           |               |
| 450/454     | 38(9)                           | 16(4)                    | 7(1)                     | 6(5)                     | (12)                     | —                         | —             |
| 500         | 95(2)                           | 15(7)                    | 12(6)                    | 3(4)                     | 1(2)                     | —                         | —             |
| 550         | 82(1)                           | 12(5)                    | 5(2)                     | 3(1)                     | 1(2)                     | —                         | —             |

( ) Figures in parentheses denote unbroken tests.

(c) Average rupture stresses

| Temperature | 10 000 h          | 30 000 h          | 50 000 h          | 100 000 h         | 150 000 h         | 200 000 h         | 250 000 h         |
|-------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| °C          | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> |
| 450         | 327               | 307               | 298               | 286               | 280               | 275*              | 271*              |
| 460         | 297               | 276               | 267               | 254               | 247               | 242*              | 238*              |
| 470         | 269               | 247               | 237               | 224               | 217               | 212*              | 208*              |
| 480         | 243               | 220               | 210               | 196               | 189*              | 183*              | 179*              |
| 490         | 218               | 195               | 184               | 170               | 162*              | 157*              | 153*              |
| 500         | 195               | 171               | 160               | 146               | 138*              | 132*              | 128*              |
| 510         | 173               | 148               | 137               | 123               | 115*              | 110*              | 105*              |
| 520         | 152               | 127               | 116               | 102               | 94*               | 88*               | 84*               |
| 530         | 133               | 108               | 97                | 82                | 74*               | 68*               | 64*               |
| 540         | 114               | 89                | 78                | 63                | (54)*             | —                 | —                 |
| 550         | 97                | 71                | 60                | —                 | —                 | —                 | —                 |
| 560         | 80                | (53)              | —                 | —                 | —                 | —                 | —                 |
| 570         | 64                | —                 | —                 | —                 | —                 | —                 | —                 |

\*Values which have involved extended time extrapolation (see note 4(a)).  
( ) Values which have involved extended stress extrapolation (see note 4(b)).



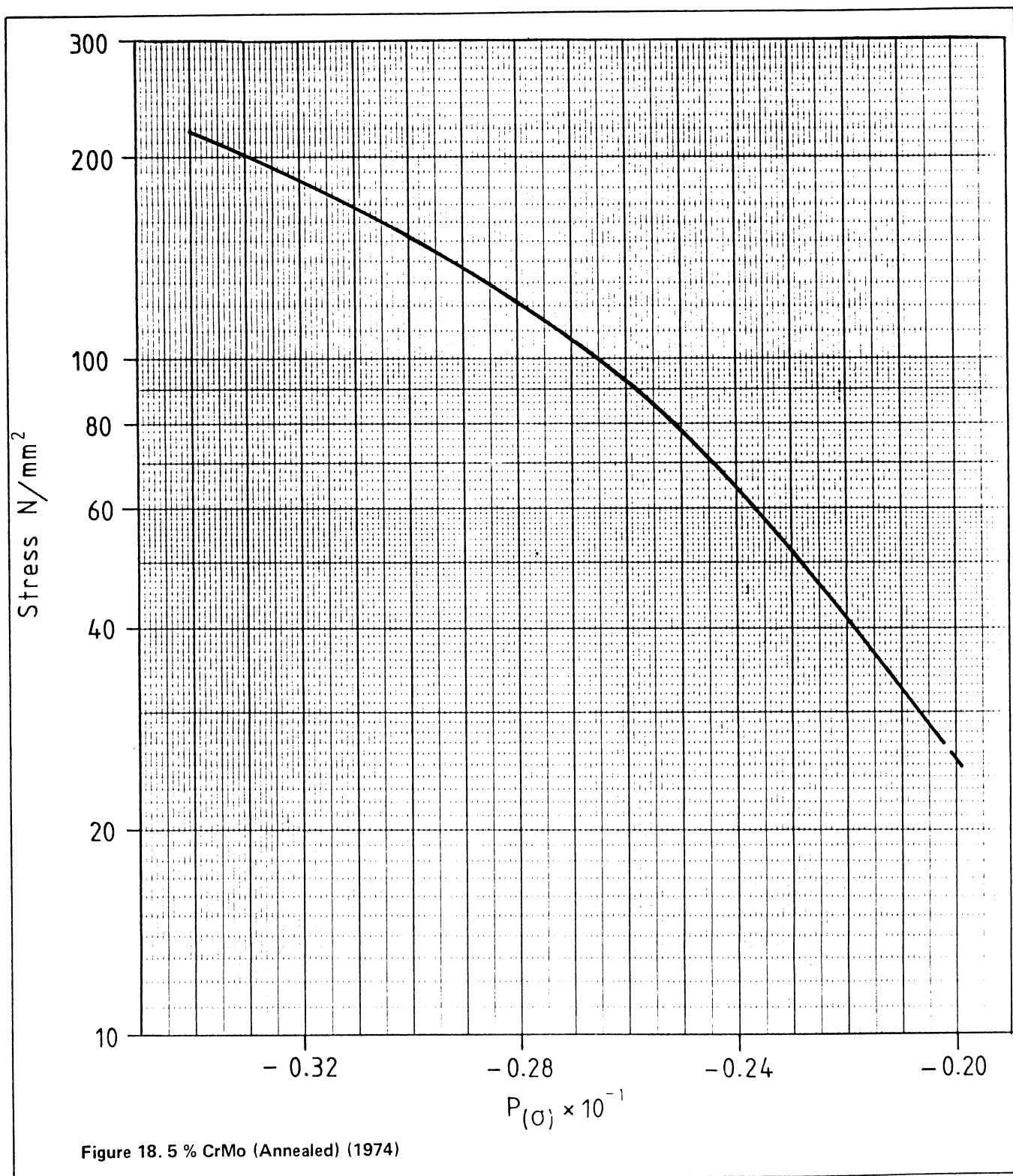




Table 19. 5 % CrMo (Normalized and Tempered) (1974) (note 1)

(a) Conditions of steel to which the properties apply

|                      | Details of materials tested                                                                  |                                                                                                                             | Specified ranges (see note 2)                          |                                                                   |
|----------------------|----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|-------------------------------------------------------------------|
|                      |                                                                                              |                                                                                                                             | Minimum                                                | Maximum                                                           |
| Chemical composition | C<br>Si<br>Mn<br>P<br>S<br>Cr<br>Mo                                                          | % (m/m)<br>0.08 to 0.13<br>0.24 to 1.43<br>0.26 to 0.49<br>0.011 to 0.025<br>0.003 to 0.023<br>4.61 to 5.44<br>0.44 to 0.58 | % (m/m)<br>—<br>0.15<br>0.30<br>—<br>—<br>4.00<br>0.45 | % (m/m)<br>0.18<br>0.50<br>0.80<br>0.040<br>0.040<br>6.00<br>0.65 |
| Heat treatment       | °C<br>1. 950 WQ + T 680<br>2. 900 to 960 AC + T 650 to 760<br>3. 900 AC<br>4. 980 OQ + T 730 |                                                                                                                             | °C<br>925 to 975 +<br>T 650 to 775                     |                                                                   |

(b) Quantity and duration of data used in assessment (see note 3)

| Temperature | Test duration                   |                  |                  |                  |                  |                   |           |
|-------------|---------------------------------|------------------|------------------|------------------|------------------|-------------------|-----------|
|             | h                               | h                | h                | h                | h                | h                 | h         |
|             | < 10 000                        | 10 000 to 20 000 | 20 000 to 30 000 | 30 000 to 50 000 | 50 000 to 70 000 | 70 000 to 100 000 | > 100 000 |
|             | Number of test points available |                  |                  |                  |                  |                   |           |
| °C          |                                 |                  |                  |                  |                  |                   |           |
| 500         | 34(2)                           | 7(1)             | 1(1)             | (1)              | —                | —                 | —         |
| 550         | 84(6)                           | 4(2)             | 1                | —                | —                | —                 | —         |
| 575         | 36(1)                           | 2(4)             | (2)              | —                | —                | —                 | —         |
| 600         | 80                              | 9(4)             | 1(1)             | —                | —                | —                 | —         |

( ) Figures in parentheses denote unbroken tests.

(c) Average rupture stresses

| Temperature | 10 000 h          | 30 000 h          | 50 000 h          | 100 000 h         | 150 000 h         | 200 000 h         | 250 000 h         |
|-------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| °C          | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> |
| 450         | —                 | —                 | —                 | 276*              | 252*              | 237*              | 226*              |
| 460         | —                 | 273*              | 247*              | 218*              | 202*              | 192*              | 183*              |
| 470         | 262               | 221*              | 204*              | 181*              | 167*              | 158*              | 152*              |
| 480         | 220               | 187               | 172*              | 153*              | 142*              | 135*              | 129*              |
| 490         | 190               | 160               | 148*              | 132*              | 122*              | 114*              | 108*              |
| 500         | 164               | 140               | 129*              | 113*              | 103*              | 96*               | 90*               |
| 510         | 145               | 123               | 112*              | 96*               | 86*               | 80*               | 75*               |
| 520         | 129               | 107               | 96*               | 81*               | 73*               | 68*               | 64*               |
| 530         | 114               | 92                | 82*               | 70*               | 62*               | 57*               | 53*               |
| 540         | 100               | 80                | 71*               | 59*               | 52*               | 47*               | 44*               |
| 550         | 88                | 70                | 62*               | 50*               | 44*               | 40*               | (37)*             |
| 560         | 77                | 61                | 53*               | 43*               | (38)*             | (36)*             | —                 |
| 570         | 68                | 52                | 45*               | (37)*             | —                 | —                 | —                 |
| 580         | 60                | 45                | 39*               | —                 | —                 | —                 | —                 |
| 590         | 53                | 39                | —                 | —                 | —                 | —                 | —                 |
| 600         | 46                | (35)              | —                 | —                 | —                 | —                 | —                 |
| 610         | 40                | —                 | —                 | —                 | —                 | —                 | —                 |
| 620         | (36)              | —                 | —                 | —                 | —                 | —                 | —                 |

\* Values which have involved extended time extrapolation (see note 4(a)).  
( ) Values which have involved extended stress extrapolation (see note 4(b)).



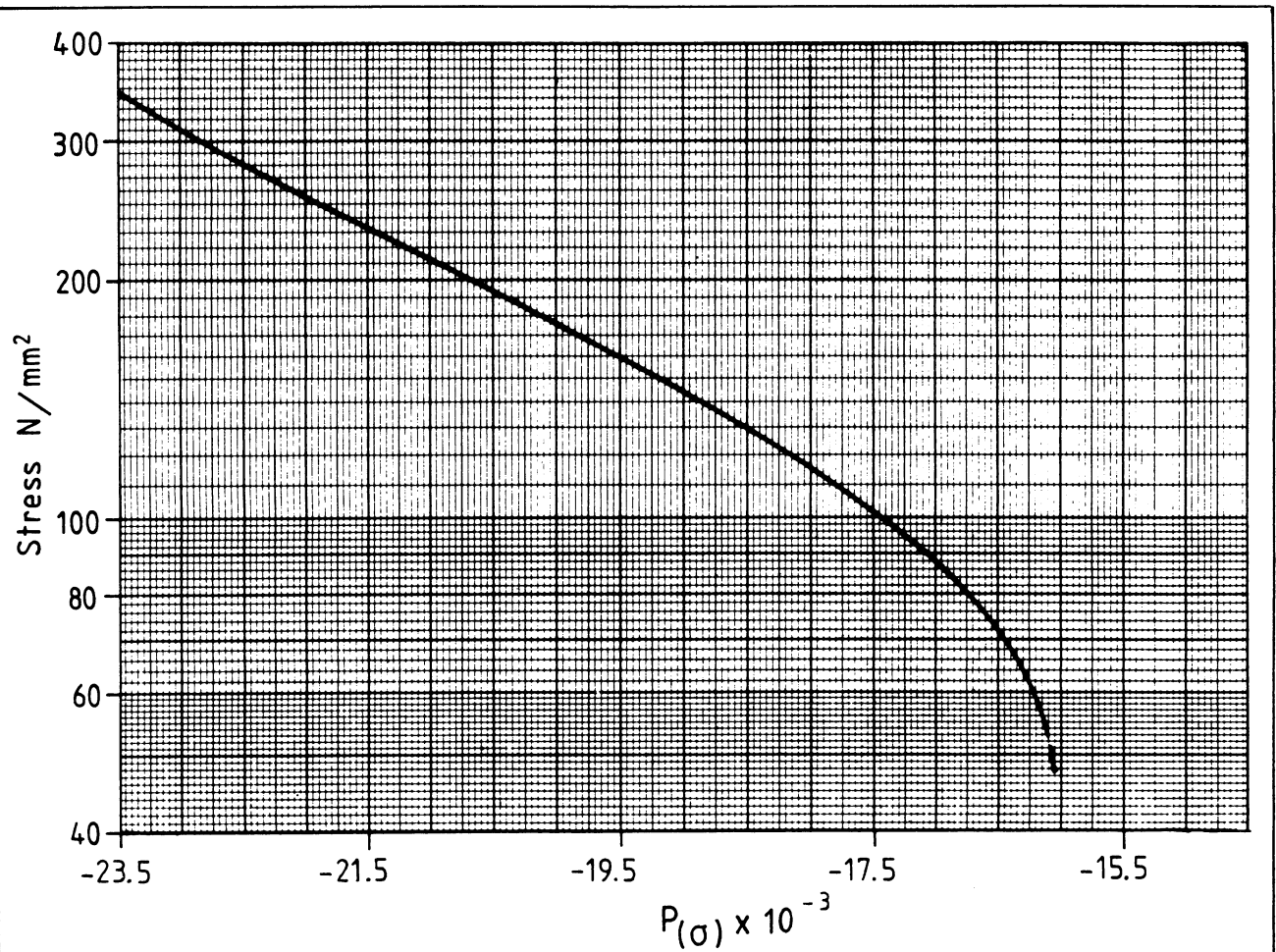


Figure 30. 18 % Cr 12 % NiNb (Heat treatment 950 °C to 1070 °C) (1988)



Table 31. 18 % Cr 12 % NiNb (Heat treatment 1070 °C to 1125 °C) (1988) (note 1)

## (a) Conditions of steel to which the properties apply

|                      | Details of materials tested |                | Specified ranges (see note 2) |              |
|----------------------|-----------------------------|----------------|-------------------------------|--------------|
|                      |                             |                | Minimum                       | Maximum      |
| Chemical composition |                             | % (m/m)        | % (m/m)                       | % (m/m)      |
|                      | C                           | 0.04 to 0.082  | 0.04                          | 0.10         |
|                      | Si                          | 0.20 to 0.78   | —                             | 1.00         |
|                      | Mn                          | 0.31 to 1.90   | —                             | 2.00         |
|                      | P                           | 0.006 to 0.029 | —                             | 0.045        |
|                      | S                           | 0.004 to 0.022 | —                             | 0.030        |
|                      | Cr                          | 16.90 to 18.80 | 17.0                          | 19.0         |
|                      | Ni                          | 10.10 to 13.55 | 9.0                           | 14.0         |
| Heat treatment       | Nb                          | 0.39 to 1.14   | 10 x % C                      | 1.20         |
|                      | °C                          | 1080 to 1121   | °C                            | 1070 to 1125 |

## (b) Quantity and duration of data used in assessment (see note 3)

| Temperature                                       | Test duration |                  |                  |                  |                  |                   |           |
|---------------------------------------------------|---------------|------------------|------------------|------------------|------------------|-------------------|-----------|
|                                                   | h             | h                | h                | h                | h                | h                 | h         |
|                                                   | < 10 000      | 10 000 to 20 000 | 20 000 to 30 000 | 30 000 to 50 000 | 50 000 to 70 000 | 70 000 to 100 000 | > 100 000 |
| Number of test points available                   |               |                  |                  |                  |                  |                   |           |
| °C                                                |               |                  |                  |                  |                  |                   |           |
| 600                                               | 65(3)         | 6(1)             | 1                | —                | 2                | (1)               | —         |
| 625                                               | 19            | 1                | —                | (1)              | —                | —                 | —         |
| 649/650                                           | 220(3)        | 19(3)            | 4(1)             | 2                | —                | (1)               | 1         |
| 700                                               | 52(3)         | 6                | 1(1)             | (1)              | 1                | (2)               | —         |
| ( ) Figures in parentheses denote unbroken tests. |               |                  |                  |                  |                  |                   |           |

## (c) Average rupture stresses

| Temperature | 10 000 h          | 30 000 h          | 50 000 h          | 100 000 h         | 150 000 h         | 200 000 h         | 250 000 h         |
|-------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| °C          | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> | N/mm <sup>2</sup> |
| 540         | 253               | 220*              | 205*              | 186*              | 176*              | 169*              | 164*              |
| 550         | 237               | 204*              | 190*              | 172*              | 163*              | 156*              | 151*              |
| 560         | 221               | 190*              | 176*              | 159*              | 150*              | 144*              | 139*              |
| 570         | 206               | 176*              | 163*              | 147*              | 138*              | 132*              | 128*              |
| 580         | 192               | 163               | 151*              | 135*              | 127*              | 122*              | 117*              |
| 590         | 178               | 151               | 139*              | 125*              | 117*              | 112*              | 108*              |
| 600         | 166               | 139               | 129*              | 115*              | 107*              | 102*              | 99*               |
| 610         | 154               | 129               | 118               | 106*              | 99*               | 94*               | 90*               |
| 620         | 142               | 119               | 109               | 97*               | 90*               | 86*               | 83*               |
| 630         | 132               | 109               | 100               | 89*               | 83*               | 78*               | 75*               |
| 640         | 122               | 101               | 92                | 81*               | 75*               | 71*               | 68*               |
| 650         | 112               | 93                | 84                | 74*               | 68*               | 64*               | 61*               |
| 660         | 104               | 85                | 77                | 67*               | 62*               | 59*               | 55*               |
| 670         | 96                | 78                | 70                | 61*               | 55*               | (51)*             | (47)*             |
| 680         | 88                | 71                | 64                | 54*               | (48)*             | —                 | —                 |
| 690         | 81                | 64                | 57                | —                 | —                 | —                 | —                 |
| 700         | 74                | 58                | (50)              | —                 | —                 | —                 | —                 |
| 710         | 68                | (51)              | —                 | —                 | —                 | —                 | —                 |
| 720         | 61                | —                 | —                 | —                 | —                 | —                 | —                 |
| 730         | 55                | —                 | —                 | —                 | —                 | —                 | —                 |

\*Values which have involved extended time extrapolation (see note 4(a)).

( ) Values which have involved extended stress extrapolation (see note 4(b)).



| Steel                                                    | Page No. | Constants for the equation of the master curve |                |                |                 |                 | Constants for the parametric equation |                      |                          |
|----------------------------------------------------------|----------|------------------------------------------------|----------------|----------------|-----------------|-----------------|---------------------------------------|----------------------|--------------------------|
|                                                          |          | <i>a</i>                                       | <i>b</i>       | <i>c</i>       | <i>d</i>        | <i>e</i>        | <i>r</i>                              | <i>T<sub>a</sub></i> | log <i>t<sub>a</sub></i> |
| 18 % Cr 12 % NiMo                                        | 59       | -0.03349032626                                 | 0.05688297004  | -0.06532787532 | 0.02911172807   | -0.004703271668 | 1                                     | 0                    | 25.763597489             |
| 18 % Cr 12 % NiMoB                                       | 61       | 0.5363081694                                   | -1.045994639   | 0.7316621542   | -0.2258302420   | 0.02557507460   | 1                                     | 0                    | 26.223617554             |
| 18 % Cr 12 % NiMoN                                       | 63       | 379488.5625                                    | -683745.1875   | 464988.6875    | -139595.5625    | 15554.23242     | -1                                    | 550                  | -6.0411744118            |
| 18 % Cr 10 % NiTi<br>(Heat treatment 950 °C to 1070 °C)  | 65       | 0.005118919536                                 | -0.03954263031 | 0.02576294728  | -0.007168778218 | 0.0005460219108 | 1                                     | 0                    | 21.785516739             |
| 18 % Cr 10 % NiTi<br>(Heat treatment 1070 °C to 1140 °C) | 67       | 20463.96289                                    | -13077.15625   | -2728.328125   | 4433.528320     | -974.2594604    | -1                                    | 510                  | -3.9669008255            |
| 18 % Cr 12 % NiNb<br>(Heat treatment 950 °C to 1070 °C)  | 69       | 0.02552033961                                  | -0.1317141056  | 0.1342087686   | -0.05484899506  | 0.007650834508  | 1                                     | 340                  | 14.446140289             |
| 18 % Cr 12 % NiNb<br>(Heat treatment 1070 °C to 1125 °C) | 71       | -108856.8984                                   | 252363.5625    | -182577.3125   | 57694.46875     | -6863.740723    | -1                                    | 0                    | -14.445973396            |
| 18 % Cr 10 % NiNbN                                       | 73       | -2.290895700                                   | 4.143799305    | -2.824598551   | 0.8542976975    | -0.09702614695  | 1                                     | 400                  | 14.914063454             |
| 15 % Cr 10 % Ni 6 % MnNbV                                | 75       | -336414.5313                                   | 799872.0625    | -654687.0625   | 234517.4219     | -31193.52930    | -1                                    | 0                    | -18.431352615            |
| 16 % Cr 16 % NiMoNb                                      | 77       | -                                              | -              | -              | -               | -               | 1                                     | 700                  | 8.715                    |
| 30 % Ni 20 % CrTiAl                                      | 79       | -                                              | -              | -              | -               | -               | -1                                    | 250                  | 12.5485                  |
| 25 % Cr 20 % Ni                                          | 81       | 2380.403320                                    | 4522.662109    | -7219.988281   | 3388.112793     | -539.2338867    | -1                                    | 710                  | -1.4756911993            |
| 0.4 % C 1¼ % CrMo (Notched properties)                   | 83       | -36536.66406                                   | 70050.70313    | -47128.35156   | 13944.21484     | -1546.441406    | -1                                    | 550                  | -2.8784015179            |
| 0.4 % C 1¼ % CrMoV (Notched properties)                  | 85       | -                                              | -              | -              | -               | -               | -1                                    | 0                    | 20                       |
| 1 % CrMoVTiB (Notched properties)                        | 87       | -                                              | -              | -              | -               | -               | 1                                     | 600                  | 8.3204                   |







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| (a) Conditions of steel to which the properties apply                                     | 10   | (c) Average rupture stresses                                    | 30   |
| (b) Quantity and duration of data used in assessment                                      | 10   | 12 <i>0.4 % C 1% CrMo (1975)</i>                                | 32   |
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| 2 <i>C Steel Si and Al killed (1974)</i>                                                  | 12   | (b) Quantity and duration of data used in assessment            | 32   |
| (a) Conditions of steel to which the properties apply                                     | 12   | (c) Average rupture stresses                                    | 32   |
| (b) Quantity and duration of data used in assessment                                      | 12   | 13 <i>0.4 % C 1% CrMoV (1979)</i>                               | 34   |
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| (a) Conditions of steel to which the properties apply                                     | 14   | (c) Average rupture stresses                                    | 34   |
| (b) Quantity and duration of data used in assessment                                      | 14   | 14 <i>1 % CrMo VTiB (1979)</i>                                  | 36   |
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| 4 <i>0.3 % Mo (1975)</i>                                                                  | 16   | (b) Quantity and duration of data used in assessment            | 36   |
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| 5 <i>0.5 % Mo (1975)</i>                                                                  | 18   | (b) Quantity and duration of data used in assessment            | 38   |
| (a) Conditions of steel to which the properties apply                                     | 18   | (c) Average rupture stresses                                    | 38   |
| (b) Quantity and duration of data used in assessment                                      | 18   |                                                                 |      |
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| (c) Average rupture stresses                                                      | 38   | 25 18 % Cr 12 % NiMo (1982)                                        | 58   |
| 16 2¼ % CrMo (Normalized and Tempered<br>≤ 720 °C) (1988)                         | 40   | (a) Conditions of steel to which the properties<br>apply           | 58   |
| (a) Conditions of steel to which the properties<br>apply                          | 40   | (b) Quantity and duration of data used in<br>assessment            | 58   |
| (b) Quantity and duration of data used in<br>assessment                           | 40   | (c) Average rupture stresses                                       | 58   |
| (c) Average rupture stresses                                                      | 40   | 26 18 % Cr 12 % NiMoB (1982)                                       | 60   |
| 17 2¼ % CrMo (Normalized and Tempered<br>≤ 750 °C) (1988)                         | 42   | (a) Conditions of steel to which the properties<br>apply           | 60   |
| (a) Conditions of steel to which the properties<br>apply                          | 42   | (b) Quantity and duration of data used in<br>assessment            | 60   |
| (b) Quantity and duration of data used in<br>assessment                           | 42   | (c) Average rupture stresses                                       | 60   |
| (c) Average rupture stresses                                                      | 42   | 27 18 % Cr 12 % NiMoN (1974)                                       | 62   |
| 18 5 % CrMo (Annealed) (1974)                                                     | 44   | (a) Conditions of steel to which the properties<br>apply           | 62   |
| (a) Conditions of steel to which the properties<br>apply                          | 44   | (b) Quantity and duration of data used in<br>assessment            | 62   |
| (b) Quantity and duration of data used in<br>assessment                           | 44   | (c) Average rupture stresses                                       | 62   |
| (c) Average rupture stresses                                                      | 44   | 28 18 % Cr 10 % NiTi (Heat treatment 950 °C to<br>1070 °C) (1987)  | 64   |
| 19 5 % CrMo (Normalized and Tempered) (1974)                                      | 46   | (a) Conditions of steel to which the properties<br>apply           | 64   |
| (a) Conditions of steel to which the properties<br>apply                          | 46   | (b) Quantity and duration of data used in<br>assessment            | 64   |
| (b) Quantity and duration of data used in<br>assessment                           | 46   | (c) Average rupture stresses                                       | 64   |
| (c) Average rupture stresses                                                      | 46   | 29 18 % Cr 10 % NiTi (Heat treatment<br>1070 °C to 1140 °C) (1987) | 66   |
| 20 9 % CrMo (Annealed) (1974)                                                     | 48   | (a) Conditions of steel to which the properties<br>apply           | 66   |
| (a) Conditions of steel to which the properties<br>apply                          | 48   | (b) Quantity and duration of data used in<br>assessment            | 66   |
| (b) Quantity and duration of data used in<br>assessment                           | 48   | (c) Average rupture stresses                                       | 66   |
| (c) Average rupture stresses                                                      | 48   | 30 18 % Cr 12 % NiNb (Heat treatment 950 °C to<br>1070 °C) (1988)  | 68   |
| 21 9 % CrMo (Normalized and Tempered) (1987)                                      | 50   | (a) Conditions of steel to which the properties<br>apply           | 68   |
| (a) Conditions of steel to which the properties<br>apply                          | 50   | (b) Quantity and duration of data used in<br>assessment            | 68   |
| (b) Quantity and duration of data used in<br>assessment                           | 50   | (c) Average rupture stresses                                       | 68   |
| (c) Average rupture stresses                                                      | 50   | 31 18 % Cr 12 % NiNb (Heat treatment<br>1070 °C to 1125 °C) (1988) | 70   |
| 22 12 % CrMo V ( $R_m$ 690 N/mm <sup>2</sup> to<br>840 N/mm <sup>2</sup> ) (1988) | 52   | (a) Conditions of steel to which the properties<br>apply           | 70   |
| (a) Conditions of steel to which the properties<br>apply                          | 52   | (b) Quantity and duration of data used in<br>assessment            | 70   |
| (b) Quantity and duration of data used in<br>assessment                           | 52   | (c) Average rupture stresses                                       | 70   |
| (c) Average rupture stresses                                                      | 52   | 32 18 % Cr 10 % NiNbN (1974)                                       | 72   |
| 23 18 % Cr 8 % Ni (1987)                                                          | 54   | (a) Conditions of steel to which the properties<br>apply           | 72   |
| (a) Conditions of steel to which the properties<br>apply                          | 54   | (b) Quantity and duration of data used in<br>assessment            | 72   |
| (b) Quantity and duration of data used in<br>assessment                           | 54   | (c) Average rupture stresses                                       | 72   |
| (c) Average rupture stresses                                                      | 54   | 33 15 % Cr 10 % Ni 6 % MnNbV (1988)                                | 74   |
| 24 18 % Cr 8 % NiN (1974)                                                         | 56   | (a) Conditions of steel to which the properties<br>apply           | 74   |
| (a) Conditions of steel to which the properties<br>apply                          | 56   | (b) Quantity and duration of data used in<br>assessment            | 74   |
| (b) Quantity and duration of data used in<br>assessment                           | 56   | (c) Average rupture stresses                                       | 74   |
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| 34 16 % Cr 16 % NiMoNb (1971)                         | 76   |                                                                               |      |
| (a) Conditions of steel to which the properties apply | 76   | 1 C Steel Semi and Si killed (1974)                                           | 11   |
| (b) Quantity and duration of data used in assessment  | 76   | 2 C Steel Si and Al killed (1974)                                             | 13   |
| (c) Average rupture stresses                          | 76   | 3 C-Mn Steel (1974)                                                           | 15   |
| 35 30 % Ni 20 % CrTiAl (1972)                         | 76   | 4 0.3 % Mo (1975)                                                             | 17   |
| (a) Conditions of steel to which the properties apply | 76   | 5 0.5 % Mo (1975)                                                             | 19   |
| (b) Quantity and duration of data used in assessment  | 78   | 6 NiCrMoV                                                                     | 21   |
| (c) Average rupture stresses                          | 78   | 7 MnCrMoV                                                                     | 23   |
| 36 25 % Cr 20 % Ni (1988)                             | 78   | 8 ½ % Cr ½ % Mo ¼ % V (1987)                                                  | 25   |
| (a) Conditions of steel to which the properties apply | 78   | 9 1 % CrMo (Normalized) (1988)                                                | 27   |
| (b) Quantity and duration of data used in assessment  | 78   | 10 1 % CrMo (Normalized and Tempered) (1988)                                  | 29   |
| (c) Average rupture stresses                          | 80   | 11 1¼ % CrMo (Normalized and Tempered) (1988)                                 | 31   |
| 37 0.4 % C 1¼ % CrMo (Notched properties) (1979)      | 80   | 12 0.4 % C 1¼ % CrMo (1975)                                                   | 33   |
| (a) Conditions of steel to which the properties apply | 80   | 13 0.4 % C 1¼ % CrMoV (1979)                                                  | 35   |
| (b) Quantity and duration of data used in assessment  | 80   | 14 1 % CrMoVTiB (1979)                                                        | 37   |
| (c) Average rupture stresses                          | 80   | 15 2¼ % CrMo (Annealed) (1969)                                                | 39   |
| 38 0.4 % C 1¼ % CrMoV (Notched properties) (1975)     | 80   | 16 2¼ % CrMo (Normalized and Tempered ≤ 720 °C) (1988)                        | 41   |
| (a) Conditions of steel to which the properties apply | 82   | 17 2¼ % CrMo (Normalized and Tempered ≤ 750 °C) (1988)                        | 43   |
| (b) Quantity and duration of data used in assessment  | 82   | 18 5 % CrMo (Annealed) (1974)                                                 | 45   |
| (c) Average rupture stresses                          | 82   | 19 5 % CrMo (Normalized and Tempered) (1974)                                  | 47   |
| 39 1 % CrMoVTiB (Notched properties) (1975)           | 82   | 20 9 % CrMo (Annealed) (1974)                                                 | 49   |
| (a) Conditions of steel to which the properties apply | 82   | 21 9 % CrMo (Normalized and Tempered) (1987)                                  | 51   |
| (b) Quantity and duration of data used in assessment  | 82   | 22 12 % CrMoV ( $R_m$ 690 N/mm <sup>2</sup> to 840 N/mm <sup>2</sup> ) (1988) | 53   |
| (c) Average rupture stresses                          | 84   | 23 18 % Cr 8 % Ni (1987)                                                      | 55   |
|                                                       | 84   | 24 18 % Cr 8 % NiN (1974)                                                     | 57   |
|                                                       | 84   | 25 18 % Cr 12 % NiMo (1982)                                                   | 59   |
|                                                       | 84   | 26 18 % Cr 12 % NiMoB (1982)                                                  | 61   |
|                                                       | 84   | 27 18 % Cr 12 % NiMoN (1974)                                                  | 63   |
|                                                       | 86   | 28 18 % Cr 10 % NiTi (Heat treatment 950 °C to 1070 °C) (1987)                | 65   |
|                                                       | 86   | 29 18 % Cr 10 % NiTi (Heat treatment 1070 °C to 1140 °C) (1987)               | 67   |
|                                                       | 86   | 30 18 % Cr 12 % NiNb (Heat treatment 950 °C to 1070 °C) (1988)                | 69   |
|                                                       | 86   | 31 18 % Cr 12 % NiNb (Heat treatment 1070 °C to 1125 °C) (1988)               | 71   |
|                                                       |      | 32 18 % Cr 10 % NiNbN (1974)                                                  | 73   |
|                                                       |      | 33 15 % Cr 10 % Ni 6 % MnNbV (1988)                                           | 75   |
|                                                       |      | 34 16 % Cr 16 % NiMoNb (1971)                                                 | 77   |
|                                                       |      | 35 30 % Ni 20 % CrTiAl (1972)                                                 | 79   |
|                                                       |      | 36 25 % Cr 20 % Ni (1988)                                                     | 81   |
|                                                       |      | 37 0.4 % C 1¼ % CrMo (Notched properties) (1979)                              | 83   |
|                                                       |      | 38 0.4 % C 1¼ % CrMoV (Notched properties) (1975)                             | 85   |
|                                                       |      | 39 1 % CrMoVTiB (Notched properties) (1975)                                   | 87   |

## 1 Scope

This Part of PD 6525 collates average stress rupture values for wrought carbon, ferritic alloy and austenitic steels contained in several British Standard specifications and other data assessments where elevated temperature properties are required. The steels are arranged in increasing alloy content. Indexes list the steels as given in the specifications for plates, sections and bars, forgings, bars for bolting and tubes/pipes respectively.

NOTE. The titles of publications referred to in this Published Document are listed on the inside back cover.

## 2 Data assessment

The stress rupture values given in this Part of PD 6525 have been obtained from a series of data assessments carried out by ISM/73/-/1 (see note 4 of clause 4).

Also contained in this Part of PD 6525 are indexes which relate British Standard specifications to the steels for which stress rupture values are given in this Published Document. The indexes are as follows:

|                    |                           |
|--------------------|---------------------------|
| BS 1501 : Part 1 : | see index 1 ;             |
| : Part 2 :         | see index 1 ;             |
| : Part 3 :         | see index 1 ;             |
| BS 1502 :          | see index 2 ;             |
| BS 1503 :          | see index 3 ;             |
| BS 1506 :          | see index 4 and index 7 ; |
| BS 3059 : Part 2 : | see index 5 ;             |
| BS 3602 : Part 1 : | see index 5 ;             |
| BS 3602 : Part 2 : | see index 5 ;             |
| BS 3604 : Part 1 : | see index 5 ;             |
| BS 3605 :          | see index 5 ;             |

Stress rupture values are also given for other steels; from data assessments carried out, namely:

- (a) those which are being introduced in revisions of the above British Standards (see 3.2);
- (b) for steels currently not in British Standards (see index 6);
- (c) for bolting steels, properties from notched test specimens (see index 7).

However, for some steels included in British Standards, stress rupture data assessments have not been carried out, principally due to lack of data. Hence such steels, e.g. type 309S16 in BS 1501 : Part 3, are not listed in this Published Document.

The stress rupture values given for each steel are considered to be applicable to all wrought product forms, since the data assessments were based usually on information from a variety of wrought product forms.

## 3 Stress rupture values

### 3.1 Relation to data assessments

The stress rupture values given in this Part of PD 6525 are based on the assessment of test results provided by various laboratories in the UK and abroad. The validity of the values given depends on the range and amounts of data available. Therefore, in order that further assessments may be carried out to verify or modify these values so that they are relevant to the long service durations, it is important that data continue to be made available. The test results should be supported by information relating to steelmaking, product form, composition and heat treatment details. Appendix A gives a complete list of the information which should be provided when submitting data. The absence of full background details should not deter submission of test data.

The data should be submitted to:

British Standards Institution  
ISM/73/-/1 Secretariat  
3 York Street  
Manchester  
M2 2AT.

### 3.2 Relation to values in product standards

The collation of stress rupture values for wrought steels in this Part of PD 6525 represents the most recent assessment carried out for each steel and, as a result of the policy of keeping British Standards up to date, revisions will be introduced into this document as further assessments are carried out and validated by the appropriate BSI committee. In view of the fact that the product standards requiring the inclusion of stress rupture values will also be revised, there will be occasions when the stress rupture values in this document differ from those in the product standards for any given steel. Furthermore, steel designations may be changed and new steels may be introduced following revision, which could outdate some of the information given in this document.

In all cases therefore, it is essential that the stress rupture values given in the relevant product standard (as opposed to those given in this Part of PD 6525) be applied.

## 4 Notes to the stress rupture values

### 4.1 General

The notes given in 4.2 to 4.5 apply to the stress rupture values for all steels detailed in tables 1 to 39 inclusive.

### 4.2 Note 1. Year of approval of properties

The date that is shown in parentheses alongside the title/grade of the steel indicates the year of approval of its properties.

### 4.3 Note 2. Chemical composition/heat treatment

The limits of chemical composition and heat treatment for which the properties apply are the specified ranges covered by the various standards which contain that particular grade of steel. In the case of steels not included in British Standards (see index 6), the chemical composition/heat treatment for which the stress rupture values are considered to apply are given as those for an alternative grade of the same steel type, where this exists, or, in such cases as 0.5 % Mo (see table 5) and 30 % Ni 20 % CrTiAl (see table 35), they are as those given in previous editions of the relevant standard(s). No account has been taken of the cast to product variations allowed by the standards.

### 4.4 Note 3. Quantity and duration of data

The quantity and duration of data in these tables are the data used in the assessments, from which the average stress rupture values were derived.

The stress rupture values for steel MnCrMoV (see indexes 1, 2 and 3 and table 7) and steel NiCrMoV (see index 1 and table 6) were not obtained by the standard procedure and therefore the standard form of master curve and equations are not available. The information shown for these steels is the quantity and duration of the data known to be available at the time of the most recent data collection for these steels.

The asterisks (see note 4(a)) in the average stress rupture tables are based on the total data available which always exceeds that shown in these tables. Further information may be available by reference to BSI Panel ISM/73/-/1.

### 4.5 Note 4. Average stress rupture values

The values given in these tables are the average stress rupture values derived in accordance with the method given in the annex to ISO 6303 : 1981. The exceptions to this rule are for steels MnCrMoV (see table 7), NiCrMoV (see table 6), 1¼ % CrMo (see table 11), 2¼ % CrMo (Annealed) (see table 15), 0.4 % C 1¼ % CrMoV (Notched properties) (see table 38) and 1 % CrMoVTiB (Notched properties) (see table 39). The values shown for these steels have been determined either by non-standard methods or, in the case of 1¼ % CrMo, by reference to a similar steel grade. Test data normally show a  $\pm 20$  % scatter about the average values.

The extent to which test data can be extrapolated reliably depends on the number and duration of the tests. Three basic factors are involved: temperature, time and stress. Experience suggests that reliable extrapolations may be made, covering a range of  $\pm 25$  °C about each test temperature, provided that there are test data on at least five casts of steel and that the longest test of each series exceeds a certain minimum duration (see ISO 6303 : 1981). The confidence which can be placed upon such properties will be related to the extent of extrapolation. Two forms of extrapolation are recognized:

#### (a) Extended time extrapolation

Extrapolations exceeding approximately three times certain maximum test durations are described as extended time extrapolations. Stress rupture properties are normally listed at the time intervals shown in table 0, which defines the durations beyond which 'extended time extrapolation' is applied.

Values which have involved extended time extrapolation are marked with an asterisk in the tables of estimated average rupture stresses contained in this Part of PD 6525. When such values are used, account should be taken of the quantity and duration of the test data on which they are based.

#### (b) Extended stress extrapolation

This applies when values have been obtained by extending the parametric master curves to stresses beyond the range for which tests were carried out. Experience suggests that reliable extrapolation may be made up to 10 % beyond the range of stress values used to derive the master curve. Stress values greater than 10 % different from the range of the test data used in the assessment are not given. Extended stress extrapolation is indicated by the broken line extensions of the master curves.

Values which have involved extended stress extrapolation are marked with parentheses in the tables of estimated average rupture stresses contained in this Part of PD 6525. When such values are used, account should be taken of the quantity and duration of the test data on which they are based.

**Table 0. Durations beyond which extended time extrapolation is applied**

| Test duration (in h)<br>exceeded by data points<br>from 5* casts at<br>temperatures within<br>25 °C of that specified | 10 000 | 20 000 | 30 000  | 50 000  | 70 000  | 80 000  |
|-----------------------------------------------------------------------------------------------------------------------|--------|--------|---------|---------|---------|---------|
| Durations (in h)<br>beyond which<br>'extended time<br>extrapolation' is<br>applied                                    | 30 000 | 50 000 | 100 000 | 150 000 | 200 000 | 250 000 |

\*Results from tests in progress may be included when above the lower 20 % scatter band limit at the appropriate duration.

## 5 Master curves

The master curve for each steel represents the average rupture stress values over the range of time, temperature and stress values used in the assessment (see figures 1 to 39) as a function of stress and in the form of a time and temperature parameter, as follows:

$$P_{(\sigma)} = a + b(\log \sigma) + c(\log \sigma)^2 + d(\log \sigma)^3 + e(\log \sigma)^4$$

$$= \frac{\log t - \log ta}{(T - Ta)^r}$$

where

- $P_{(\sigma)}$  is the creep rupture parameter;
- $T$  is the temperature (in K);
- $t$  is the time to rupture (in h);
- $\sigma$  is the stress (in N/mm<sup>2</sup>);
- $r$  is a temperature exponent (see appendix B);
- $a$  to  $e$  are constants (see note 2).

NOTE 1. Values read off the graphs presented in this Part of PD 6525 may be subject to discrepancies introduced by the method of reproduction. In all cases the values presented in tabular form should be taken as being correct.

NOTE 2. The constants for the equation of the master curve (see appendix B) have been derived from a given set of data for each steel, using the VAX 8200 computer at British Steel plc, Swinden Laboratories. It is known that the use of a different type of computer may give slight differences in the numerical values of these constants. However, the resultant effect on the derived average rupture stress values based on the use of 11 significant figures in the calculations is insignificant.

## 6 Abbreviations used in the indexes and tables

The following abbreviations are used in the indexes and in tables 1 to 39.

|         |                   |
|---------|-------------------|
| AC :    | air cooled;       |
| FC :    | furnace cooled;   |
| Q :     | quenched;         |
| OQ :    | oil quenched;     |
| WQ :    | water quenched;   |
| T :     | tempered;         |
| ST :    | solution treated; |
| Rm :    | tensile strength; |
| AR :    | as rolled;        |
| Norm. : | normalized.       |