# INTERNATIONAL STANDARD

# ISO 4126-7

Second edition
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# Safety devices for protection against excessive pressure —

## Part 7:
## Common data

*Dispositifs de sécurité pour protection contre les pressions excessives —*

*Partie 7: Données communes*

Reference number
ISO 4126-7:2013(E)

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# Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 4126-7 was prepared by Technical Committee ISO/TC 185, *Safety devices for protection against excessive pressure*.

This second edition cancels and replaces the first edition (ISO 4126-7:2004), which has been technically revised. It also incorporates the Technical Corrigendum ISO 4126-7:2004/Cor.1:2006.

ISO 4126 consists of the following parts, under the general title *Safety devices for protection against excessive pressure*:

— *Part 1: Safety valves*

— *Part 2: Bursting disc safety devices*

— *Part 3: Safety valves and bursting disc safety devices in combination*

— *Part 4: Pilot-operated safety valves*

— *Part 5: Controlled safety pressure relief systems (CSPRS)*

— *Part 6: Application, selection and installation of bursting disc safety devices*

— *Part 7: Common data*

— *Part 9: Application and installation of safety devices excluding stand-alone bursting disc safety devices*

— *Part 10: Sizing of safety valves for gas/liquid two-phase flow*

— *Part 11: Performance testing*[1)]

1) Under preparation.

# Safety devices for protection against excessive pressure —

# Part 7:
# Common data

## 1 Scope

This part of ISO 4126 specifies requirements for safety valves. It contains information which is common to ISO 4126-1 to ISO 4126-6 to avoid unnecessary repetition.

For flashing liquids or two-phase mixtures, see ISO 4126-10.

The user is cautioned that it is not recommended to use the ideal gas formula presented in 6.3 when the relieving temperature is greater than 90 % of the thermodynamic critical temperature and the relieving pressure is greater than 50 % of the thermodynamic critical pressure. Additionally, condensation is not considered. If condensation occurs, the method presented in 6.3 should not be used.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4126-1, *Safety devices for protection against excessive pressure — Part 1: Safety valves*

ISO 4126-2, *Safety devices for protection against excessive pressure — Part 2: Bursting disc safety devices*

ISO 4126-4, *Safety devices for protection against excessive pressure — Part 4: Pilot operated safety valves*

ISO 4126-5, *Safety devices for protection against excessive pressure — Part 5: Controlled safety pressure relief systems (CSPRS)*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4126-1, ISO 4126-2, ISO 4126-4 ISO 4126-5 and the following apply.

NOTE Pressure unit used in ISO 4126-7 is the bar (1 bar = $10^5$ Pa), quoted as gauge (relative to atmospheric pressure) or absolute as appropriate.

**3.1**
**safety valve**
valve which automatically, without the assistance of any energy other than that of the fluid concerned, discharges a quantity of the fluid so as to prevent a predetermined safe pressure being exceeded, and which is designed to re-close and prevent further flow of fluid after normal pressure conditions of service have been restored

Note 1 to entry: The valve can be characterized either by pop action (rapid opening) or by opening in proportion (not necessarily linear) to the increase in pressure over the set pressure. The use of the term safety valve in this part of ISO 4126 applies to other valve types as covered in ISO 4126-1, ISO 4126-4 and ISO 4126-5.

**3.2**
**set pressure**
predetermined pressure at which a safety valve under operating conditions commences to open

Note 1 to entry: It is the gauge pressure measured at the valve inlet at which the pressure forces tending to open the valve for the specific service conditions are in equilibrium with the forces retaining the valve disc on its seat.

**3.3**
**maximum allowable pressure, PS**
maximum pressure for which the protected equipment is designed

**3.4**
**overpressure**
pressure increase over set pressure, usually expressed as a percentage of the set pressure

**3.5**
**relieving pressure**
pressure used for the sizing of a safety valve which is greater than or equal to the set pressure plus overpressure

**3.6**
**back pressure**
pressure that exists at the outlet of a safety valve as a result of the pressure in the discharge system

Note 1 to entry: The back pressure is the sum of the superimposed and built-up back pressures.

**3.7**
**built-up back pressure**
pressure existing at the outlet of a safety valve caused by flow through the valve and the discharge system

**3.8**
**superimposed back pressure**
pressure existing at the outlet of a safety valve at the time when the device is required to operate

Note 1 to entry: It is the result of pressure in the discharge system from other sources.

**3.9**
**flow area**
minimum cross-sectional flow area (but not the smallest area between the disc and seat) between inlet and seat which is used to calculate the theoretical flow capacity, with no deduction for any obstruction

Note 1 to entry: The symbol is $A$.

**3.10**
**theoretical discharge capacity**
calculated capacity expressed in mass or volumetric units of a theoretically perfect nozzle having a cross-sectional flow area equal to the flow area of a safety valve

**3.11**
**coefficient of discharge**
value of actual discharge capacity (from tests) divided by the theoretical discharge capacity (from calculation)

**3.12**
**certified (discharge) capacity**
that portion of the measured capacity permitted to be used as a basis for the application of a safety valve

Note 1 to entry: It may, for example, equal the a)measured capacity times the de-rating factor of 0,9, or b)theoretical capacity times the coefficient of discharge times the de-rating factor of 0,9, or c)theoretical capacity times the certified de-rated coefficient of discharge.

**3.13**
**dryness fraction**
**steam quality**
measure of the relative vapour/liquid content of a steam quantity or stream. Expressed as the mass fraction or percentage of vapour

# 4 Symbols and units

**Table 1 — Symbols and their descriptions**

| Symbol | Description | Unit |
|---|---|---|
| $A$ | Flow area of a safety valve (not smallest area between the disc and seat) | $mm^2$ |
| $C$ | Function of the isentropic exponent, $k$ | – |
| $K_b$ | Theoretical capacity correction factor for subcritical flow | – |
| $K_d$ | Coefficient of discharge [a] | – |
| $K_{dr}$ | Certified de-rated coefficient of discharge ($K_d$ × 0,9) [a] | – |
| $K_v$ | Viscosity correction factor | – |
| $k$ | Isentropic exponent at relieving pressure and temperature | – |
| $M$ | Molar mass | kg/kmol |
| $n$ | Number of tests | – |
| $p_o$ | Relieving pressure - absolute | bar (abs) |
| $p_b$ | Back pressure - absolute | bar (abs) |
| $p_c$ | Thermodynamic critical pressure - absolute | bar (abs) |
| $p_r$ | Reduced pressure | – |
| $PS$ | Maximum allowable pressure | bar (abs) |
| $\dot{Q}_m$ | Mass flow rate | kg/h |
| $q_m$ | Theoretical specific discharge capacity | $kg/(h{\cdot}mm^2)$ |
| $q'_m$ | Specific discharge capacity determined by tests | $kg/(h{\cdot}mm^2)$ |
| $R$ | Universal gas constant | J/K-mol |
| $Re$ | Reynolds number | – |
| $T_o$ | Relieving temperature | K |
| $T_c$ | Thermodynamic critical temperature | K |
| $T_r$ | Reduced temperature | – |
| $\mu_0$ | Dynamic viscosity | Pa·s |
| $v_o$ | Specific volume at relieving pressure and temperature | $m^3/kg$ |
| $x_0$ | Dryness fraction of wet steam at the valve inlet at relieving pressure and temperature [b] | – |
| $k_s$ | Steam pressure coefficient | $h{\cdot}mm^2$ bar (abs)/kg |
| Z | Compressibility factor at relieving pressure and temperature | – |

[a] $K_d$ and $K_{dr}$ are expressed as 0,xxx.

[b] $x_0$ is expressed as 0,xx.

# 5 Determination of safety valve performance

## 5.1 Determination of coefficient of discharge

The coefficient of discharge, $K_d$, is calculated from the following:

$$K_d = \frac{\sum_{1}^{n}\left(\frac{q'_m}{q_m}\right)}{n} \quad (1)$$

$K_d$ shall be calculated up to three significant decimal places. Any rounding shall be down.

## 5.2 Critical and subcritical flow

The theoretical flow of a gas or vapour through an orifice, such as the flow area of a safety valve, increases as the downstream pressure is decreased to the critical pressure, until critical flow is achieved. Further decrease in downstream pressure will not result in any further increase in flow.

Critical flow occurs when

$$\frac{p_b}{p_o} \le \left(\frac{2}{k+1}\right)^{(k/(k-1))} \quad (2)$$

and subcritical flow occurs when

$$\frac{p_b}{p_o} > \left(\frac{2}{k+1}\right)^{(k/(k-1))} \quad (3)$$

## 5.3 Discharge capacity at critical flow

### 5.3.1 Discharge capacity for steam

$$q_m = 0{,}2883\, C \sqrt{\frac{p_o}{v_o}} \quad (4)$$

Formula (4) allows the use of steam tables to obtain the specific volume of steam at various pressures and temperatures. The user is cautioned that the direct use of this equation can lead to an error of more than 20 % as the temperature approaches the saturated or supercritical condition. An error of less than 1 % can only be achieved at a steam temperature at least higher than 30 °C above saturation condition or higher than the result of 30+($p_0$-200), in °C, using $p_o$ in bar above saturation or supercritical condition. A method including lower temperatures is described hereafter.

Alternatively, the above equation can be rearranged as follows:

$$q_m = \frac{p_o}{k_s} \quad (5)$$

where $k_s$ is the steam pressure coefficient.

$$k_s = \frac{\sqrt{p_o\, v_o}}{0{,}2883\, C} \quad (6)$$

NOTE 1 $$0,2883 = \frac{\sqrt{R}}{10} = \frac{\sqrt{8,3143}}{10} \quad (7)$$

Values for the steam pressure coefficient, $k_S$, can be obtained in Table 2. See 6.3.1 for background on the development of Table 2.

This is applicable to dry saturated and superheated steam. Dry saturated steam in this context refers to steam with a minimum dryness fraction of 98 % where $C$ is a function of the isentropic exponent at the relieving conditions.

$$C = 3,948 \sqrt{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}} \quad (8)$$

NOTE 2 $$3,948 = \frac{3600}{\sqrt{10^5 \times \sqrt{R}}} \quad (9)$$

The value of $k$ used to determine $C$ shall be based on the actual flowing conditions at the pressure relief device inlet and shall be determined from Table 3.

### 5.3.2 Discharge capacity for any gas under critical flow conditions

$$q_m = p_o\, C \sqrt{\frac{M}{ZT_o}} = 0,2883\, C \sqrt{\frac{p_o}{v_o}} \quad (10)$$

See Figure 1 for values of $Z$.

$$C = 3,948 \sqrt{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}} \quad (11)$$

See Table 3 for rounded values for $C$.

## 5.4 Discharge capacity for any gas at subcritical flow

$$q_m = p_o\, C\, K_b \sqrt{\frac{M}{ZT_o}} = 0,2883\, C\, K_b \sqrt{\frac{p_o}{v_o}} \quad (12)$$

$$K_b = \sqrt{\frac{\frac{2k}{k-1}\left[\left(\frac{p_b}{p_o}\right)^{\frac{2}{k}} - \left(\frac{p_b}{p_o}\right)^{\frac{k+1}{k}}\right]}{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}} \quad (13)$$

See Table 4 for $K_b$ values.

## 5.5 Discharge capacity for non-flashing liquid as the test medium in the turbulent zone where the Reynolds number *Re* is equal to or greater than 80 000

$$q_m = 1,61 \sqrt{\left(\frac{p_o - p_b}{v_o}\right)} \quad (14)$$

NOTE

$$1{,}61 = \frac{3600\sqrt{2}}{10\sqrt{10^5}} \quad (15)$$

# 6 Sizing of safety valves

## 6.1 General

The certified de-rated coefficient of discharge $K_{dr}$ of the safety valve shall be not greater than 90 % of the coefficient of discharge $K_d$ determined by test:

$$K_{dr} \leq 0{,}9\ K_d \quad (16)$$

It is not permitted to calculate the capacity with a lower overpressure than that at which the tests to determine flow characteristics were carried out although it is permissible to calculate the capacity at a higher relieving pressure.

Valves having a certified de-rated coefficient of discharge established on critical flow at the test back pressure may not have the same certified de-rated coefficient of discharge at a higher back pressure; see ISO 4126-1, ISO 4126-3, ISO 4126-4 or ISO 4126-5, as applicable, for requirements for the certification of the coefficient of discharge of various valve types.

## 6.2 Valves for gas or vapour relief

No distinction is made between substances commonly referred to as vapours: the term “gas” is used to describe both gas and vapour.

To calculate the capacity for any gas, the area and the coefficient of discharge shall be assumed to be constant and the equations given in Clause 5 shall be used.

## 6.3 Calculation of capacity

The ideal gas formula presented in 6.3 should not be used when the relieving temperature is greater than 90 % of the thermodynamic critical temperature and the relieving pressure is greater than 50 % of the thermodynamic critical pressure. Additionally, condensation is not considered. If condensation occurs, the method presented in 6.3 should not be used.

NOTE 1 The equation to be applied depends on the fluid to be discharged.

NOTE 2 See Annex A for example calculations.

### 6.3.1 Capacity calculation for (saturated, superheated or supercritical) steam at critical flow

$$\dot{Q}_m = 0{,}2883\ C A K_{dr} \sqrt{\frac{p_o}{v_o}} \quad (17)$$

Formula (17) allows the use of steam tables to obtain the specific volume of steam at various pressures and temperatures. The user is cautioned that the direct use of this equation can lead to an error of more than 20 % as the temperature approaches the saturated or supercritical condition. An error of less than 1 % can only be achieved at a steam temperature at least higher than 30°C above saturation condition or higher than the result of 30+($p_0$-200), in °C, using $p_0$ in bar above saturation or supercritical condition. A method including lower temperatures is described hereafter.

Alternatively, the above equation can be rearranged as follows:

$$\dot{Q}_m = \frac{A K_{dr} p_o}{k_s} \quad (18)$$

where $k_s$ is the steam pressure coefficient,

$$k_s = \frac{\sqrt{p_o v_o}}{0{,}2883 C} \quad (19)$$

Values for the steam pressure coefficient, $k_s$, can be obtained in Table 2. The values of Table 2 were established by iterative calculations on nozzle flow using the following procedure:

a) Isentropic expansion from a nozzle inlet pressure to several assumed throat pressures was calculated.

b) The mass flow rate per unit throat area (the ratio of the nozzle throat velocity to the coincident specific volume) was calculated for each assumed throat pressure.

c) The actual thermodynamic properties of steam according to IAPWS-IF97[1] were used for each assumed throat pressure.

d) The iterative calculation procedure stops when the maximum of mass flow is detected, this value was used for establishing the value of $k_s$.

### 6.3.2 Capacity calculations for wet steam

The following equation is applicable only to homogenous wet steam of dryness fraction of 90 % and over.

$$\dot{Q}_m = \frac{0{,}2883 C A K_{dr} \sqrt{\frac{p_o}{v_o}}}{\sqrt{x_o}} \quad (20)$$

Alternatively, the above equation can be rearranged as follows:

$$\dot{Q}_m = \frac{A K_{dr} p_o}{k_s \sqrt{x_o}} \quad (21)$$

where $k_s$ is the steam pressure coefficient,

$$k_s = \frac{\sqrt{p_o v_o}}{0{,}2883 C} \quad (22)$$

Values for the steam pressure coefficient, $k_s$, can be obtained in Table 2. The values of Table 2 were established by iterative calculations on nozzle flow using the following procedure:

a) Isentropic expansion from a nozzle inlet pressure to several assumed throat pressures was calculated.

b) The mass flow rate per unit throat area (the ratio of the nozzle throat velocity to the coincident specific volume) was calculated for each assumed throat pressure.

c) The actual thermodynamic properties of steam according to IAPWS-IF97[1] were used for each assumed throat pressure.

d) The iterative calculation procedure stops when the maximum of mass flow is detected, this value was used for establishing the value of $k_s$.

#### 6.3.3 Capacity calculations for gaseous media

##### 6.3.3.1 Capacity calculations for gaseous media at critical flow

$$\dot{Q}_m = p_o C A K_{dr} \sqrt{\frac{M}{Z T_o}} = 0,2883 C A K_{dr} \sqrt{\frac{p_o}{v_o}} \quad (23)$$

$$A = \frac{\dot{Q}_m}{p_o C K_{dr} \sqrt{\frac{M}{Z T_o}}} = \frac{\dot{Q}_m}{0,2883 C K_{dr} \sqrt{\frac{p_o}{v_o}}} \quad (24)$$

##### 6.3.3.2 Capacity calculations for gaseous media at subcritical flow

$$\dot{Q}_m = p_o C A K_{dr} K_b \sqrt{\frac{M}{Z T_o}} = 0,2883 C A K_{dr} K_b \sqrt{\frac{p_o}{v_o}} \quad (25)$$

NOTE To determine $K_b$ see equation in 5.4 and Table 4.

See Figure 1 for values of *Z.*

#### 6.3.4 Capacity calculations for liquids

$$\dot{Q}_m = 1,61 K_{dr} K_v A \sqrt{\frac{p_o - p_b}{v_o}} \quad (26)$$

See Figure 2 for values of $K_v$.

## 7 Thermodynamic properties

### 7.1 Steam data

The steam pressure coefficient data are given in Table 2.

### 7.2 Value of *C* as a function of *k*

The values of factor *C* as a function of the isentropic exponent are given in Table 3.

### 7.3 Theoretical capacity correction factors for sub-critical flow ($K_b$)

The theoretical capacity correction factors for sub-critical flow ($K_b$) are given in Table 4.

**Table 2 — Steam pressure coefficient data, $k_S$**

**Pressure: atmospheric - 2 bar (abs) — Temperature: Saturated - 750 °C**

| PRESS bar (abs) | SAT Temp C | Sat. Steam | 105 | 110 | 120 | 130 | 150 | 200 | 250 | 300 | 350 | 400 | 500 | 600 | 700 | 750 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1,05** | **101,0** | 3,832 | 3,839 | 3,866 | 3,918 | 3,970 | 4,072 | 4,314 | 4,540 | 4,756 | 4,961 | 5,158 | 5,531 | 5,880 | 6,210 | 6,368 |
| **1,06** | **101,2** | 3,538 | 3,540 | 3,565 | 3,613 | 3,661 | 3,755 | 3,978 | 4,187 | 4,386 | 4,575 | 4,757 | 5,102 | 5,424 | 5,728 | 5,875 |
| **1,07** | **101,5** | 3,313 | 3,313 | 3,333 | 3,379 | 3,423 | 3,511 | 3,720 | 3,916 | 4,102 | 4,279 | 4,449 | 4,772 | 5,073 | 5,358 | 5,495 |
| **1,08** | **101,8** | 3,133 | 3,134 | 3,149 | 3,192 | 3,234 | 3,317 | 3,515 | 3,700 | 3,875 | 4,043 | 4,204 | 4,509 | 4,794 | 5,064 | 5,193 |
| **1,09** | **102,0** | 2,987 | 2,988 | 2,999 | 3,039 | 3,079 | 3,159 | 3,347 | 3,523 | 3,690 | 3,850 | 4,004 | 4,294 | 4,566 | 4,823 | 4,946 |
| **1,10** | **102,3** | 2,865 | 2,866 | 2,873 | 2,912 | 2,950 | 3,026 | 3,206 | 3,375 | 3,536 | 3,689 | 3,836 | 4,114 | 4,375 | 4,621 | 4,740 |
| **1,12** | **102,8** | 2,672 | 2,673 | 2,673 | 2,710 | 2,745 | 2,816 | 2,984 | 3,141 | 3,291 | 3,434 | 3,571 | 3,830 | 4,074 | 4,303 | 4,414 |
| **1,14** | **103,3** | 2,527 | 2,528 | 2,528 | 2,557 | 2,590 | 2,657 | 2,816 | 2,964 | 3,106 | 3,241 | 3,370 | 3,615 | 3,845 | 4,062 | 4,167 |
| **1,16** | **103,8** | 2,413 | 2,414 | 2,415 | 2,436 | 2,468 | 2,532 | 2,683 | 2,825 | 2,960 | 3,089 | 3,213 | 3,447 | 3,666 | 3,874 | 3,973 |
| **1,18** | **104,3** | 2,322 | 2,323 | 2,325 | 2,339 | 2,370 | 2,431 | 2,577 | 2,713 | 2,843 | 2,967 | 3,086 | 3,311 | 3,522 | 3,722 | 3,818 |
| **1,20** | **104,8** | 2,248 | 2,248 | 2,251 | 2,260 | 2,290 | 2,348 | 2,489 | 2,621 | 2,746 | 2,866 | 2,981 | 3,199 | 3,403 | 3,597 | 3,690 |
| **1,25** | **106,0** | 2,112 | - | 2,114 | 2,112 | 2,139 | 2,195 | 2,326 | 2,450 | 2,567 | 2,680 | 2,788 | 2,992 | 3,184 | 3,365 | 3,452 |
| **1,30** | **107,1** | 2,021 | - | 2,023 | 2,023 | 2,037 | 2,090 | 2,215 | 2,333 | 2,445 | 2,553 | 2,656 | 2,851 | 3,034 | 3,208 | 3,291 |
| **1,35** | **108,2** | 1,958 | - | 1,959 | 1,961 | 1,964 | 2,015 | 2,136 | 2,250 | 2,359 | 2,462 | 2,562 | 2,751 | 2,928 | 3,096 | 3,177 |
| **1,40** | **109,3** | 1,913 | - | 1,914 | 1,918 | 1,913 | 1,960 | 2,078 | 2,189 | 2,295 | 2,396 | 2,494 | 2,678 | 2,851 | 3,015 | 3,095 |
| **1,45** | **110,3** | 1,882 | - | - | 1,887 | 1,884 | 1,919 | 2,035 | 2,144 | 2,248 | 2,347 | 2,443 | 2,624 | 2,794 | 2,956 | 3,033 |
| **1,50** | **111,4** | 1,860 | - | - | 1,865 | 1,863 | 1,888 | 2,003 | 2,110 | 2,213 | 2,311 | 2,405 | 2,584 | 2,752 | 2,911 | 2,988 |
| **1,60** | **113,3** | 1,836 | - | - | 1,840 | 1,841 | 1,849 | 1,961 | 2,066 | 2,167 | 2,263 | 2,356 | 2,532 | 2,698 | 2,855 | 2,931 |
| **1,70** | **115,1** | 1,829 | - | - | 1,833 | 1,836 | 1,828 | 1,939 | 2,044 | 2,144 | 2,239 | 2,331 | 2,506 | 2,671 | 2,828 | 2,903 |
| **1,80** | **116,9** | 1,834 | - | - | 1,836 | 1,838 | 1,832 | 1,930 | 2,035 | 2,134 | 2,230 | 2,322 | 2,497 | 2,662 | 2,819 | 2,895 |
| **1,90** | **118,6** | 1,835 | - | - | 1,836 | 1,841 | 1,836 | 1,930 | 2,035 | 2,135 | 2,231 | 2,323 | 2,499 | 2,665 | 2,819 | 2,894 |
| **2,00** | **120,2** | 1,838 | - | - | - | 1,844 | 1,840 | 1,928 | 2,033 | 2,133 | 2,229 | 2,321 | 2,497 | 2,662 | 2,819 | 2,894 |

NOTE 1 Use linear interpolation for intermediate values of temperature and pressure.

NOTE 2 The temperature increment was selected in such a way to limit the maximum error from linear interpolation to 1 %.

**Table 2 — Steam pressure coefficient data, $k_S$ *(continued)***

**Pressure: 2 - 40 bar (abs) — Temperature: Saturated - 280 °C**

| PRESS bar (abs) | SAT Temp C | Sat. Steam | 140 | 150 | 160 | 170 | 180 | 190 | 200 | 210 | 220 | 230 | 240 | 250 | 260 | 270 | 280 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2** | **120,2** | 1,838 | 1,844 | 1,840 | 1,840 | 1,862 | 1,884 | 1,906 | 1,928 | 1,950 | 1,971 | 1,992 | 2,013 | 2,033 | 2,054 | 2,074 | 2,094 |
| **3** | **133,5** | 1,860 | 1,865 | 1,868 | 1,866 | 1,861 | 1,880 | 1,902 | 1,924 | 1,945 | 1,967 | 1,988 | 2,009 | 2,030 | 2,051 | 2,071 | 2,091 |
| **4** | **143,6** | 1,876 | - | 1,881 | 1,885 | 1,883 | 1,878 | 1,897 | 1,919 | 1,941 | 1,963 | 1,985 | 2,006 | 2,027 | 2,048 | 2,068 | 2,088 |
| **5** | **151,8** | 1,888 | - | - | 1,894 | 1,897 | 1,896 | 1,893 | 1,915 | 1,937 | 1,959 | 1,981 | 2,002 | 2,024 | 2,045 | 2,065 | 2,086 |
| **6** | **158,8** | 1,898 | - | - | 1,899 | 1,906 | 1,908 | 1,905 | 1,910 | 1,933 | 1,955 | 1,977 | 1,999 | 2,020 | 2,041 | 2,062 | 2,083 |
| **7** | **165,0** | 1,906 | - | - | - | 1,911 | 1,916 | 1,916 | 1,912 | 1,928 | 1,951 | 1,973 | 1,995 | 2,017 | 2,038 | 2,059 | 2,080 |
| **8** | **170,4** | 1,913 | - | - | - | - | 1,921 | 1,924 | 1,922 | 1,924 | 1,947 | 1,969 | 1,991 | 2,013 | 2,035 | 2,056 | 2,077 |
| **9** | **175,4** | 1,919 | - | - | - | - | 1,923 | 1,929 | 1,930 | 1,927 | 1,943 | 1,965 | 1,988 | 2,010 | 2,032 | 2,053 | 2,075 |
| **10** | **179,9** | 1,924 | - | - | - | - | 1,924 | 1,932 | 1,936 | 1,934 | 1,938 | 1,961 | 1,984 | 2,006 | 2,028 | 2,050 | 2,072 |
| **11** | **184,1** | 1,928 | - | - | - | - | - | 1,934 | 1,940 | 1,941 | 1,937 | 1,957 | 1,980 | 2,003 | 2,025 | 2,047 | 2,069 |
| **12** | **188,0** | 1,932 | - | - | - | - | - | 1,934 | 1,943 | 1,945 | 1,944 | 1,953 | 1,976 | 1,999 | 2,022 | 2,044 | 2,066 |
| **13** | **191,6** | 1,936 | - | - | - | - | - | - | 1,944 | 1,949 | 1,949 | 1,949 | 1,973 | 1,996 | 2,018 | 2,041 | 2,063 |
| **14** | **195,0** | 1,939 | - | - | - | - | - | - | 1,944 | 1,951 | 1,953 | 1,950 | 1,969 | 1,992 | 2,015 | 2,038 | 2,060 |
| **15** | **198,3** | 1,942 | - | - | - | - | - | - | 1,944 | 1,953 | 1,956 | 1,955 | 1,965 | 1,988 | 2,012 | 2,034 | 2,057 |
| **16** | **201,4** | 1,944 | - | - | - | - | - | - | - | 1,953 | 1,959 | 1,959 | 1,961 | 1,985 | 2,008 | 2,031 | 2,054 |
| **17** | **204,3** | 1,946 | - | - | - | - | - | - | - | 1,953 | 1,960 | 1,962 | 1,960 | 1,981 | 2,005 | 2,028 | 2,051 |
| **18** | **207,1** | 1,949 | - | - | - | - | - | - | - | 1,952 | 1,961 | 1,965 | 1,963 | 1,977 | 2,001 | 2,025 | 2,048 |
| **19** | **209,8** | 1,950 | - | - | - | - | - | - | - | 1,951 | 1,962 | 1,966 | 1,966 | 1,973 | 1,998 | 2,021 | 2,045 |
| **20** | **212,4** | 1,952 | - | - | - | - | - | - | - | - | 1,961 | 1,968 | 1,969 | 1,970 | 1,994 | 2,018 | 2,041 |
| **21** | **214,9** | 1,954 | - | - | - | - | - | - | - | - | 1,961 | 1,968 | 1,971 | 1,969 | 1,990 | 2,014 | 2,038 |
| **22** | **217,3** | 1,955 | - | - | - | - | - | - | - | - | 1,959 | 1,969 | 1,973 | 1,972 | 1,987 | 2,011 | 2,035 |
| **23** | **219,6** | 1,956 | - | - | - | - | - | - | - | - | 1,957 | 1,969 | 1,974 | 1,974 | 1,983 | 2,008 | 2,032 |
| **24** | **221,8** | 1,957 | - | - | - | - | - | - | - | - | - | 1,968 | 1,975 | 1,976 | 1,979 | 2,004 | 2,029 |
| **25** | **224,0** | 1,958 | - | - | - | - | - | - | - | - | - | 1,967 | 1,975 | 1,978 | 1,977 | 2,001 | 2,025 |
| **26** | **226,1** | 1,959 | - | - | - | - | - | - | - | - | - | 1,965 | 1,975 | 1,979 | 1,978 | 1,997 | 2,022 |
| **28** | **230,1** | 1,961 | - | - | - | - | - | - | - | - | - | - | 1,974 | 1,980 | 1,981 | 1,990 | 2,015 |
| **30** | **233,9** | 1,962 | - | - | - | - | - | - | - | - | - | - | 1,971 | 1,980 | 1,983 | 1,984 | 2,008 |

**Table 2** *(continued)*

| PRESS bar (abs) | SAT Temp C | Sat. Steam | 140 | 150 | 160 | 170 | 180 | 190 | 200 | 210 | 220 | 230 | 240 | 250 | 260 | 270 | 280 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **32** | **237,5** | 1,963 | - | - | - | - | - | - | - | - | - | - | 1,967 | 1,979 | 1,984 | 1,985 | 2,002 |
| **34** | **240,9** | 1,964 | - | - | - | - | - | - | - | - | - | - | - | 1,977 | 1,985 | 1,987 | 1,995 |
| **36** | **244,2** | 1,964 | - | - | - | - | - | - | - | - | - | - | - | 1,974 | 1,984 | 1,988 | 1,989 |
| **38** | **247,3** | 1,964 | - | - | - | - | - | - | - | - | - | - | - | 1,969 | 1,982 | 1,988 | 1,989 |
| **40** | **250,4** | 1,964 | - | - | - | - | - | - | - | - | - | - | - | - | 1,979 | 1,987 | 1,990 |

NOTE 1 Use linear interpolation for intermediate values of temperature and pressure.

NOTE 2 The temperature increment was selected in such a way to limit the maximum error from linear interpolation to 1 %.

**Table 2 — Steam pressure coefficient data, $k_S$ *(continued)***

**Pressure: 2 - 40 bar (abs) — Temperature: 280 °C – 750 °C**

| PRESS bar (abs) | 280 | 290 | 300 | 310 | 320 | 340 | 360 | 380 | 400 | 450 | 500 | 550 | 600 | 650 | 700 | 750 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2** | 2,094 | 2,114 | 2,133 | 2,153 | 2,172 | 2,210 | 2,248 | 2,285 | 2,321 | 2,410 | 2,497 | 2,580 | 2,662 | 2,741 | 2,819 | 2,894 |
| **3** | 2,091 | 2,111 | 2,131 | 2,150 | 2,170 | 2,208 | 2,246 | 2,283 | 2,320 | 2,409 | 2,496 | 2,580 | 2,661 | 2,741 | 2,818 | 2,894 |
| **4** | 2,088 | 2,109 | 2,128 | 2,148 | 2,168 | 2,206 | 2,244 | 2,282 | 2,318 | 2,408 | 2,495 | 2,579 | 2,661 | 2,740 | 2,818 | 2,894 |
| **5** | 2,086 | 2,106 | 2,126 | 2,146 | 2,165 | 2,204 | 2,242 | 2,280 | 2,317 | 2,407 | 2,494 | 2,578 | 2,660 | 2,740 | 2,817 | 2,893 |
| **6** | 2,083 | 2,103 | 2,124 | 2,144 | 2,163 | 2,202 | 2,241 | 2,278 | 2,315 | 2,406 | 2,493 | 2,577 | 2,659 | 2,739 | 2,817 | 2,893 |
| **7** | 2,080 | 2,101 | 2,121 | 2,141 | 2,161 | 2,200 | 2,239 | 2,277 | 2,314 | 2,404 | 2,492 | 2,577 | 2,659 | 2,739 | 2,817 | 2,893 |
| **8** | 2,077 | 2,098 | 2,119 | 2,139 | 2,159 | 2,198 | 2,237 | 2,275 | 2,312 | 2,403 | 2,491 | 2,576 | 2,658 | 2,738 | 2,816 | 2,892 |
| **9** | 2,075 | 2,095 | 2,116 | 2,136 | 2,157 | 2,196 | 2,235 | 2,273 | 2,311 | 2,402 | 2,490 | 2,575 | 2,657 | 2,738 | 2,816 | 2,892 |
| **10** | 2,072 | 2,093 | 2,114 | 2,134 | 2,154 | 2,194 | 2,233 | 2,272 | 2,309 | 2,401 | 2,489 | 2,574 | 2,657 | 2,737 | 2,815 | 2,892 |
| **11** | 2,069 | 2,090 | 2,111 | 2,132 | 2,152 | 2,192 | 2,232 | 2,270 | 2,308 | 2,400 | 2,488 | 2,573 | 2,656 | 2,737 | 2,815 | 2,891 |
| **12** | 2,066 | 2,087 | 2,108 | 2,129 | 2,150 | 2,190 | 2,230 | 2,268 | 2,306 | 2,399 | 2,487 | 2,573 | 2,656 | 2,736 | 2,814 | 2,891 |
| **13** | 2,063 | 2,085 | 2,106 | 2,127 | 2,148 | 2,188 | 2,228 | 2,267 | 2,305 | 2,397 | 2,486 | 2,572 | 2,655 | 2,735 | 2,814 | 2,890 |
| **14** | 2,060 | 2,082 | 2,103 | 2,124 | 2,145 | 2,186 | 2,226 | 2,265 | 2,303 | 2,396 | 2,485 | 2,571 | 2,654 | 2,735 | 2,814 | 2,890 |
| **15** | 2,057 | 2,079 | 2,101 | 2,122 | 2,143 | 2,184 | 2,224 | 2,263 | 2,302 | 2,395 | 2,484 | 2,570 | 2,654 | 2,734 | 2,813 | 2,890 |
| **16** | 2,054 | 2,076 | 2,098 | 2,119 | 2,141 | 2,182 | 2,222 | 2,262 | 2,300 | 2,394 | 2,483 | 2,570 | 2,653 | 2,734 | 2,813 | 2,889 |
| **17** | 2,051 | 2,073 | 2,095 | 2,117 | 2,138 | 2,180 | 2,220 | 2,260 | 2,299 | 2,393 | 2,482 | 2,569 | 2,652 | 2,733 | 2,812 | 2,889 |
| **18** | 2,048 | 2,070 | 2,093 | 2,114 | 2,136 | 2,178 | 2,219 | 2,258 | 2,297 | 2,391 | 2,481 | 2,568 | 2,652 | 2,733 | 2,812 | 2,889 |
| **19** | 2,045 | 2,067 | 2,090 | 2,112 | 2,133 | 2,176 | 2,217 | 2,257 | 2,296 | 2,390 | 2,480 | 2,567 | 2,651 | 2,732 | 2,811 | 2,888 |
| **20** | 2,041 | 2,064 | 2,087 | 2,109 | 2,131 | 2,174 | 2,215 | 2,255 | 2,294 | 2,389 | 2,479 | 2,566 | 2,650 | 2,732 | 2,811 | 2,888 |
| **21** | 2,038 | 2,062 | 2,084 | 2,107 | 2,129 | 2,171 | 2,213 | 2,253 | 2,293 | 2,388 | 2,478 | 2,566 | 2,650 | 2,731 | 2,810 | 2,887 |
| **22** | 2,035 | 2,059 | 2,082 | 2,104 | 2,126 | 2,169 | 2,211 | 2,251 | 2,291 | 2,386 | 2,477 | 2,565 | 2,649 | 2,731 | 2,810 | 2,887 |
| **23** | 2,032 | 2,056 | 2,079 | 2,101 | 2,124 | 2,167 | 2,209 | 2,250 | 2,290 | 2,385 | 2,476 | 2,564 | 2,648 | 2,730 | 2,809 | 2,887 |
| **24** | 2,029 | 2,052 | 2,076 | 2,099 | 2,121 | 2,165 | 2,207 | 2,248 | 2,288 | 2,384 | 2,476 | 2,563 | 2,648 | 2,730 | 2,809 | 2,886 |
| **25** | 2,025 | 2,049 | 2,073 | 2,096 | 2,119 | 2,163 | 2,205 | 2,246 | 2,286 | 2,383 | 2,475 | 2,562 | 2,647 | 2,729 | 2,809 | 2,886 |
| **26** | 2,022 | 2,046 | 2,070 | 2,094 | 2,116 | 2,161 | 2,203 | 2,245 | 2,285 | 2,382 | 2,474 | 2,562 | 2,646 | 2,729 | 2,808 | 2,886 |
| **28** | 2,015 | 2,040 | 2,064 | 2,088 | 2,111 | 2,156 | 2,199 | 2,241 | 2,282 | 2,379 | 2,472 | 2,560 | 2,645 | 2,727 | 2,807 | 2,885 |
| **30** | 2,008 | 2,034 | 2,058 | 2,083 | 2,106 | 2,152 | 2,195 | 2,238 | 2,279 | 2,377 | 2,470 | 2,558 | 2,644 | 2,726 | 2,806 | 2,884 |

**Table 2** *(continued)*

| PRESS bar (abs) | 280 | 290 | 300 | 310 | 320 | 340 | 360 | 380 | 400 | 450 | 500 | 550 | 600 | 650 | 700 | 750 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **32** | 2,002 | 2,027 | 2,053 | 2,077 | 2,101 | 2,147 | 2,191 | 2,234 | 2,275 | 2,374 | 2,468 | 2,557 | 2,643 | 2,725 | 2,805 | 2,883 |
| **34** | 1,995 | 2,021 | 2,046 | 2,071 | 2,096 | 2,143 | 2,187 | 2,230 | 2,272 | 2,372 | 2,466 | 2,555 | 2,641 | 2,724 | 2,805 | 2,883 |
| **36** | 1,989 | 2,014 | 2,040 | 2,066 | 2,090 | 2,138 | 2,183 | 2,227 | 2,269 | 2,369 | 2,464 | 2,554 | 2,640 | 2,723 | 2,804 | 2,882 |
| **38** | 1,989 | 2,007 | 2,034 | 2,060 | 2,085 | 2,133 | 2,179 | 2,223 | 2,266 | 2,367 | 2,462 | 2,552 | 2,639 | 2,722 | 2,803 | 2,881 |
| **40** | 1,990 | 2,000 | 2,027 | 2,054 | 2,079 | 2,129 | 2,175 | 2,220 | 2,262 | 2,364 | 2,460 | 2,551 | 2,637 | 2,721 | 2,802 | 2,880 |

NOTE 1 Use linear interpolation for intermediate values of temperature and pressure

NOTE 2 The temperature increment was selected in such a way to limit the maximum error from linear interpolation to 1 %.

**Table 2 — Steam pressure coefficient data, $k_S$ (*continued*)**

**Pressure: 40 - 220 bar (abs) — Temperature: Saturated - 420 °C**

| PRESS bar (abs) | SAT Temp C | Sat. Steam | 280 | 290 | 300 | 310 | 320 | 330 | 340 | 350 | 360 | 370 | 380 | 390 | 400 | 410 | 420 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **40** | **250,4** | 1,964 | 1,990 | 2,000 | 2,027 | 2,054 | 2,079 | 2,104 | 2,129 | 2,152 | 2,175 | 2,198 | 2,220 | 2,241 | 2,262 | 2,283 | 2,304 |
| **50** | **263,9** | 1,962 | 1,986 | 1,991 | 1,995 | 2,023 | 2,051 | 2,078 | 2,104 | 2,129 | 2,154 | 2,178 | 2,201 | 2,224 | 2,246 | 2,268 | 2,289 |
| **60** | **275,6** | 1,956 | 1,967 | 1,982 | 1,989 | 1,992 | 2,020 | 2,049 | 2,078 | 2,105 | 2,131 | 2,156 | 2,181 | 2,205 | 2,228 | 2,251 | 2,274 |
| **65** | **280,9** | 1,953 | - | 1,972 | 1,984 | 1,989 | 2,004 | 2,034 | 2,064 | 2,092 | 2,119 | 2,145 | 2,171 | 2,195 | 2,219 | 2,243 | 2,266 |
| **70** | **285,8** | 1,949 | - | 1,959 | 1,977 | 1,985 | 1,989 | 2,019 | 2,049 | 2,079 | 2,107 | 2,134 | 2,160 | 2,186 | 2,210 | 2,234 | 2,258 |
| **75** | **290,5** | 1,944 | - | - | 1,966 | 1,979 | 1,984 | 2,002 | 2,035 | 2,065 | 2,095 | 2,123 | 2,150 | 2,176 | 2,201 | 2,226 | 2,250 |
| **80** | **295,0** | 1,939 | - | - | 1,952 | 1,971 | 1,980 | 1,986 | 2,019 | 2,051 | 2,082 | 2,111 | 2,139 | 2,166 | 2,192 | 2,217 | 2,241 |
| **85** | **299,3** | 1,933 | - | - | 1,936 | 1,960 | 1,974 | 1,979 | 2,003 | 2,037 | 2,069 | 2,099 | 2,128 | 2,155 | 2,182 | 2,208 | 2,233 |
| **90** | **303,3** | 1,927 | - | - | - | 1,947 | 1,966 | 1,974 | 1,987 | 2,022 | 2,055 | 2,086 | 2,116 | 2,145 | 2,172 | 2,199 | 2,224 |
| **95** | **307,3** | 1,921 | - | - | - | 1,931 | 1,955 | 1,968 | 1,973 | 2,006 | 2,041 | 2,074 | 2,105 | 2,134 | 2,162 | 2,189 | 2,215 |
| **100** | **311,0** | 1,915 | - | - | - | - | 1,942 | 1,960 | 1,967 | 1,990 | 2,026 | 2,060 | 2,092 | 2,123 | 2,152 | 2,180 | 2,207 |
| **105** | **314,6** | 1,908 | - | - | - | - | 1,926 | 1,950 | 1,961 | 1,973 | 2,011 | 2,046 | 2,080 | 2,111 | 2,141 | 2,170 | 2,198 |
| **110** | **318,1** | 1,900 | - | - | - | - | 1,908 | 1,938 | 1,953 | 1,961 | 1,995 | 2,032 | 2,067 | 2,100 | 2,131 | 2,160 | 2,188 |
| **115** | **321,4** | 1,892 | - | - | - | - | - | 1,924 | 1,944 | 1,953 | 1,979 | 2,017 | 2,054 | 2,088 | 2,120 | 2,150 | 2,179 |
| **120** | **324,7** | 1,884 | - | - | - | - | - | 1,906 | 1,934 | 1,946 | 1,962 | 2,002 | 2,040 | 2,075 | 2,108 | 2,140 | 2,170 |
| **125** | **327,8** | 1,876 | - | - | - | - | - | 1,886 | 1,921 | 1,938 | 1,948 | 1,987 | 2,026 | 2,063 | 2,097 | 2,129 | 2,160 |
| **130** | **330,9** | 1,867 | - | - | - | - | - | - | 1,906 | 1,928 | 1,938 | 1,971 | 2,011 | 2,049 | 2,085 | 2,118 | 2,150 |
| **135** | **333,8** | 1,857 | - | - | - | - | - | - | 1,888 | 1,917 | 1,931 | 1,954 | 1,996 | 2,036 | 2,073 | 2,107 | 2,140 |
| **140** | **336,7** | 1,847 | - | - | - | - | - | - | 1,865 | 1,904 | 1,922 | 1,936 | 1,981 | 2,022 | 2,060 | 2,096 | 2,129 |
| **145** | **339,5** | 1,837 | - | - | - | - | - | - | 1,840 | 1,889 | 1,912 | 1,922 | 1,965 | 2,008 | 2,047 | 2,084 | 2,119 |
| **150** | **342,2** | 1,826 | - | - | - | - | - | - | - | 1,871 | 1,901 | 1,912 | 1,948 | 1,993 | 2,034 | 2,072 | 2,108 |
| **155** | **344,8** | 1,814 | - | - | - | - | - | - | - | 1,849 | 1,888 | 1,905 | 1,930 | 1,978 | 2,020 | 2,060 | 2,097 |
| **160** | **347,4** | 1,802 | - | - | - | - | - | - | - | 1,823 | 1,874 | 1,895 | 1,912 | 1,963 | 2,007 | 2,047 | 2,086 |
| **165** | **349,9** | 1,789 | - | - | - | - | - | - | - | 1,793 | 1,857 | 1,884 | 1,897 | 1,946 | 1,993 | 2,034 | 2,074 |
| **170** | **352,3** | 1,775 | - | - | - | - | - | - | - | - | 1,836 | 1,872 | 1,886 | 1,929 | 1,978 | 2,022 | 2,062 |
| **175** | **354,7** | 1,761 | - | - | - | - | - | - | - | - | 1,811 | 1,859 | 1,877 | 1,910 | 1,963 | 2,008 | 2,050 |
| **180** | **357,0** | 1,745 | - | - | - | - | - | - | - | - | 1,782 | 1,843 | 1,867 | 1,891 | 1,947 | 1,994 | 2,038 |

**Table 2** *(continued)*

| PRESS bar (abs) | SAT Temp C | Sat. Steam | 280 | 290 | 300 | 310 | 320 | 330 | 340 | 350 | 360 | 370 | 380 | 390 | 400 | 410 | 420 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **185** | **359,3** | 1,728 | - | - | - | - | - | - | - | - | 1,740 | 1,824 | 1,855 | 1,874 | 1,930 | 1,980 | 2,025 |
| **190** | **361,5** | 1,709 | - | - | - | - | - | - | - | - | - | 1,801 | 1,842 | 1,860 | 1,913 | 1,965 | 2,012 |
| **195** | **363,6** | 1,689 | - | - | - | - | - | - | - | - | - | 1,775 | 1,828 | 1,847 | 1,895 | 1,950 | 1,999 |
| **200** | **365,7** | 1,665 | - | - | - | - | - | - | - | - | - | 1,743 | 1,811 | 1,836 | 1,876 | 1,935 | 1,985 |
| **205** | **367,8** | 1,638 | - | - | - | - | - | - | - | - | - | 1,698 | 1,791 | 1,824 | 1,857 | 1,919 | 1,971 |
| **210** | **369,8** | 1,605 | - | - | - | - | - | - | - | - | - | 1,616 | 1,768 | 1,811 | 1,839 | 1,902 | 1,956 |
| **215** | **371,8** | 1,559 | - | - | - | - | - | - | - | - | - | - | 1,742 | 1,795 | 1,823 | 1,885 | 1,942 |
| **220** | **373,7** | 1,459 | - | - | - | - | - | - | - | - | - | - | 1,710 | 1,778 | 1,807 | 1,866 | 1,926 |

NOTE 1 Use linear interpolation for intermediate values of temperature and pressure.

NOTE 2 The temperature increment was selected in such a way to limit the maximum error from linear interpolation to 1 %.

**Table 2 — Steam pressure coefficient data, $k_S$ (*continued*)**

**Pressure: 40 - 420 bar (abs) — Temperature: 380 °C - 750 °C**

| PRESS bar (abs) | 380 | 390 | 400 | 410 | 420 | 440 | 460 | 480 | 500 | 520 | 550 | 600 | 650 | 700 | 750 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **40** | 2,220 | 2,241 | 2,262 | 2,283 | 2,304 | 2,344 | 2,384 | 2,422 | 2,460 | 2,497 | 2,551 | 2,637 | 2,721 | 2,802 | 2,880 |
| **60** | 2,181 | 2,205 | 2,228 | 2,251 | 2,274 | 2,317 | 2,359 | 2,400 | 2,439 | 2,478 | 2,534 | 2,624 | 2,710 | 2,793 | 2,873 |
| **80** | 2,139 | 2,166 | 2,192 | 2,217 | 2,241 | 2,288 | 2,333 | 2,376 | 2,418 | 2,459 | 2,517 | 2,611 | 2,699 | 2,784 | 2,865 |
| **100** | 2,092 | 2,123 | 2,152 | 2,180 | 2,207 | 2,258 | 2,306 | 2,352 | 2,396 | 2,439 | 2,500 | 2,597 | 2,688 | 2,774 | 2,857 |
| **120** | 2,040 | 2,075 | 2,108 | 2,140 | 2,170 | 2,226 | 2,278 | 2,327 | 2,374 | 2,419 | 2,483 | 2,583 | 2,676 | 2,765 | 2,849 |
| **140** | 1,981 | 2,022 | 2,060 | 2,096 | 2,129 | 2,191 | 2,248 | 2,300 | 2,350 | 2,397 | 2,464 | 2,568 | 2,665 | 2,755 | 2,841 |
| **160** | 1,912 | 1,963 | 2,007 | 2,047 | 2,086 | 2,154 | 2,216 | 2,273 | 2,326 | 2,376 | 2,446 | 2,553 | 2,653 | 2,745 | 2,833 |
| **180** | 1,867 | 1,891 | 1,947 | 1,994 | 2,038 | 2,115 | 2,182 | 2,244 | 2,300 | 2,353 | 2,427 | 2,538 | 2,641 | 2,736 | 2,825 |
| **200** | 1,811 | 1,836 | 1,876 | 1,935 | 1,985 | 2,072 | 2,147 | 2,213 | 2,273 | 2,329 | 2,407 | 2,523 | 2,628 | 2,726 | 2,817 |
| **210** | 1,768 | 1,811 | 1,839 | 1,902 | 1,956 | 2,050 | 2,128 | 2,197 | 2,260 | 2,317 | 2,397 | 2,515 | 2,622 | 2,721 | 2,813 |
| **220** | 1,710 | 1,778 | 1,807 | 1,866 | 1,926 | 2,026 | 2,109 | 2,181 | 2,246 | 2,305 | 2,386 | 2,508 | 2,616 | 2,716 | 2,809 |
| **230** | 1,611 | 1,737 | 1,776 | 1,828 | 1,895 | 2,002 | 2,089 | 2,165 | 2,232 | 2,293 | 2,376 | 2,500 | 2,610 | 2,711 | 2,804 |
| **240** | 1,311 | 1,682 | 1,744 | 1,789 | 1,861 | 1,976 | 2,069 | 2,148 | 2,217 | 2,280 | 2,366 | 2,492 | 2,603 | 2,705 | 2,800 |
| **250** | 1,183 | 1,607 | 1,704 | 1,750 | 1,825 | 1,950 | 2,048 | 2,130 | 2,202 | 2,267 | 2,355 | 2,484 | 2,597 | 2,700 | 2,796 |
| **260** | 1,087 | 1,481 | 1,655 | 1,708 | 1,785 | 1,922 | 2,027 | 2,112 | 2,187 | 2,254 | 2,344 | 2,476 | 2,591 | 2,695 | 2,792 |
| **270** | 0,990 | 1,327 | 1,594 | 1,670 | 1,741 | 1,892 | 2,004 | 2,094 | 2,172 | 2,241 | 2,333 | 2,467 | 2,584 | 2,690 | 2,788 |
| **280** | 0,926 | 1,194 | 1,513 | 1,623 | 1,697 | 1,861 | 1,981 | 2,076 | 2,157 | 2,228 | 2,322 | 2,459 | 2,578 | 2,685 | 2,783 |
| **290** | 0,881 | 1,089 | 1,402 | 1,567 | 1,656 | 1,829 | 1,957 | 2,057 | 2,140 | 2,214 | 2,311 | 2,451 | 2,571 | 2,680 | 2,779 |
| **300** | 0,849 | 1,017 | 1,273 | 1,499 | 1,608 | 1,796 | 1,932 | 2,037 | 2,124 | 2,200 | 2,300 | 2,442 | 2,565 | 2,674 | 2,775 |
| **320** | 0,805 | 0,928 | 1,102 | 1,332 | 1,501 | 1,723 | 1,879 | 1,997 | 2,091 | 2,172 | 2,277 | 2,425 | 2,552 | 2,664 | 2,766 |
| **340** | 0,778 | 0,877 | 1,012 | 1,192 | 1,380 | 1,647 | 1,823 | 1,954 | 2,056 | 2,143 | 2,254 | 2,408 | 2,538 | 2,653 | 2,758 |
| **360** | 0,761 | 0,844 | 0,954 | 1,097 | 1,270 | 1,566 | 1,765 | 1,909 | 2,021 | 2,113 | 2,230 | 2,391 | 2,525 | 2,643 | 2,749 |
| **380** | 0,750 | 0,822 | 0,916 | 1,036 | 1,186 | 1,485 | 1,706 | 1,862 | 1,984 | 2,082 | 2,206 | 2,373 | 2,511 | 2,632 | 2,741 |
| **400** | 0,743 | 0,808 | 0,890 | 0,995 | 1,124 | 1,409 | 1,645 | 1,815 | 1,946 | 2,051 | 2,181 | 2,355 | 2,498 | 2,621 | 2,732 |
| **420** | 0,740 | 0,798 | 0,872 | 0,965 | 1,079 | 1,343 | 1,585 | 1,768 | 1,908 | 2,019 | 2,156 | 2,337 | 2,484 | 2,610 | 2,723 |

NOTE 1 Use linear interpolation for intermediate values of temperature and pressure.

NOTE 2 The temperature increment was selected in such a way to limit the maximum error from linear interpolation to 1 %.

**Table 3 — Value of *C* as a function of *k***

| *k* | *C* | *k* | *C* | *k* | *C* | *k* | *C* | *k* | *C* | *k* | *C* | *k* | *C* | *k* | *C* | *k* | *C* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,40 | 1,647 | 0,60 | 1,957 | 0,80 | 2,198 | 1,001 | 2,395 | 1,20 | 2,560 | 1,40 | 2,703 | 1,60 | 2,829 | 1,80 | 2,940 | 2,00 | 3,039 |
| 0,41 | 1,665 | 0,61 | 1,971 | 0,81 | 2,209 | 1,01 | 2,404 | 1,21 | 2.568 | 1,41 | 2,710 | 1,61 | 2,834 | 1,81 | 2,945 | 2,01 | 3,044 |
| 0,42 | 1,682 | 0,62 | 1,984 | 0,82 | 2,219 | 1,02 | 2,412 | 1,22 | 2,576 | 1,42 | 2,717 | 1,62 | 2,840 | 1,82 | 2,950 | 2,02 | 3,049 |
| 0,43 | 1,700 | 0,63 | 1,997 | 0,83 | 2,230 | 1,03 | 2,421 | 1,23 | 2,583 | 1,43 | 2,723 | 1,63 | 2,846 | 1,83 | 2,955 | 2,03 | 3,053 |
| 0,44 | 1,717 | 0,64 | 2,010 | 0,84 | 2,240 | 1,04 | 2,430 | 1,24 | 2,591 | 1,44 | 2,730 | 1,64 | 2,852 | 1,84 | 2,960 | 2,04 | 3,058 |
| 0,45 | 1,733 | 0,65 | 2,023 | 0,85 | 2,251 | 1,05 | 2,439 | 1,25 | 2,598 | 1,45 | 2,736 | 1,65 | 2,858 | 1,85 | 2,965 | 2,05 | 3,063 |
| 0,46 | 1,750 | 0,66 | 2,035 | 0,86 | 2,261 | 1,06 | 2,447 | 1,26 | 2,605 | 1,46 | 2,743 | 1,66 | 2,863 | 1,86 | 2,971 | 2,06 | 3,067 |
| 0,47 | 1,766 | 0,67 | 2,048 | 0,87 | 2,271 | 1,07 | 2,456 | 1,27 | 2,613 | 1,47 | 2,749 | 1,67 | 2,869 | 1,87 | 2,976 | 2,07 | 3,072 |
| 0,48 | 1,782 | 0,68 | 2,060 | 0,88 | 2,281 | 1,08 | 2,464 | 1,28 | 2,620 | 1,48 | 2,755 | 1,68 | 2,874 | 1,88 | 2,981 | 2,08 | 3,076 |
| 0,49 | 1,798 | 0,69 | 2,072 | 0,89 | 2,291 | 1,09 | 2,472 | 1,29 | 2,627 | 1,49 | 2,762 | 1,69 | 2,880 | 1,89 | 2,986 | 2,09 | 3,081 |
| 0,50 | 1,813 | 0,70 | 2,084 | 0,90 | 2,301 | 1,10 | 2,481 | 1,30 | 2,634 | 1,50 | 2,768 | 1,70 | 2,886 | 1,90 | 2,991 | 2,10 | 3,085 |
| 0,51 | 1,829 | 0,71 | 2,096 | 0,91 | 2,311 | 1,11 | 2,489 | 1,31 | 2,641 | 1,51 | 2,774 | 1,71 | 2,891 | 1,91 | 2,996 | 2,11 | 3,090 |
| 0,52 | 1,844 | 0,72 | 2,108 | 0,92 | 2,320 | 1,12 | 2,497 | 1,32 | 2,649 | 1,52 | 2,780 | 1,72 | 2,897 | 1,92 | 3,001 | 2,12 | 3,094 |
| 0,53 | 1,858 | 0,73 | 2,120 | 0,93 | 2,330 | 1,13 | 2,505 | 1,33 | 2,656 | 1,53 | 2,786 | 1,73 | 2,902 | 1,93 | 3,006 | 2,13 | 3,099 |
| 0,54 | 1,873 | 0,74 | 2,131 | 0,94 | 2,339 | 1,14 | 2,513 | 1,34 | 2,663 | 1,54 | 2,793 | 1,74 | 2,908 | 1,94 | 3,010 | 2,14 | 3,103 |
| 0,55 | 1,888 | 0,75 | 2,143 | 0,95 | 2,349 | 1,15 | 2,521 | 1,35 | 2,669 | 1,55 | 2,799 | 1,75 | 2,913 | 1,95 | 3,015 | 2,15 | 3,107 |
| 0,56 | 1,902 | 0,76 | 2,154 | 0,96 | 2,358 | 1,16 | 2,529 | 1,36 | 2,676 | 1,56 | 2,805 | 1,76 | 2,918 | 1,96 | 3,020 | 2,16 | 3,112 |
| 0,57 | 1,916 | 0,77 | 2,165 | 0,97 | 2,367 | 1,17 | 2,537 | 1,37 | 2,683 | 1,57 | 2,811 | 1,77 | 2,924 | 1,97 | 3,025 | 2,17 | 3,116 |
| 0,58 | 1,930 | 0,78 | 2,176 | 0,98 | 2,376 | 1,18 | 2,545 | 1,38 | 2,690 | 1,58 | 2,817 | 1,78 | 2,929 | 1,98 | 3,030 | 2,18 | 3,121 |
| 0,59 | 1,944 | 0,79 | 2,187 | 0,99 | 2,386 | 1,19 | 2,553 | 1,39 | 2,697 | 1,59 | 2,823 | 1,79 | 2,934 | 1,99 | 3,034 | 2,19 | 3,125 |
| - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2,20 | 3,129 |

**Table 4 — Theoretical capacity correction factors for sub-critical flow ($K_b$)**

| $k$ > | 0,4 | 0,5 | 0,6 | 0,7 | 0,8 | 0,9 | 1,001 | 1,1 | 1,2 | 1,3 | 1,4 | 1,5 | 1,6 | 1,7 | 1,8 | 1,9 | 2,0 | 2,1 | 2,2 | < $k$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $p_b/p_o$ | | | | | | | | | | | | | | | | | | | | $p_b/p_o$ |
| 0,45 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1,000 | 0,999 | 0,999 | 0,45 |
| 0,50 | - | - | - | - | - | - | - | - | - | - | - | | 1,000 | 0,999 | 0,998 | 0,996 | 0,994 | 0,992 | 0,989 | 0,50 |
| 0,55 | - | - | - | - | - | - | - | - | | 1,000 | 0,999 | 0,997 | 0,994 | 0,991 | 0,987 | 0,983 | 0,979 | 0,975 | 0,971 | 0,55 |
| 0,60 | - | - | - | - | - | - | 1,000 | 0,999 | 0,997 | 0,993 | 0,989 | 0,983 | 0,978 | 0,972 | 0,967 | 0,961 | 0,955 | 0,950 | 0,945 | 0,60 |
| 0,65 | - | - | - | | 0,999 | 0,999 | 0,995 | 0,989 | 0,982 | 0,974 | 0,967 | 0,959 | 0,951 | 0,943 | 0,936 | 0,929 | 0,922 | 0,915 | 0,909 | 0,65 |
| 0,70 | - | | 0,999 | 0,999 | 0,993 | 9,985 | 0,975 | 0,964 | 0,953 | 0,943 | 0,932 | 0,922 | 0,913 | 0,903 | 0,895 | 0,886 | 0,878 | 0,871 | 0,864 | 0,70 |
| 0,75 | - | 1,000 | 0,995 | 0,983 | 0,968 | 0,953 | 0,938 | 0,923 | 0,909 | 0,896 | 0,884 | 0,872 | 0,861 | 0,851 | 0,841 | 0,832 | 0,824 | 0,815 | 0,808 | 0,75 |
| 0,80 | 0,999 | 0,985 | 0,965 | 0,942 | 0,921 | 0,900 | 0,881 | 0,864 | 0,847 | 0,832 | 0,819 | 0,806 | 0,794 | 0,783 | 0,773 | 0,764 | 0,755 | 0,747 | 0,739 | 0,80 |
| 0,82 | 0,992 | 0,970 | 0,944 | 0,918 | 0,894 | 0,872 | 0,851 | 0,833 | 0,817 | 0,801 | 0,787 | 0,774 | 0,762 | 0,752 | 0,741 | 0,732 | 0,723 | 0,715 | 0,707 | 0,82 |
| 0,84 | 0,979 | 0,948 | 0,917 | 0,888 | 0,862 | 0,839 | 0,818 | 0,799 | 0,782 | 0,766 | 0,752 | 0,739 | 0,727 | 0,716 | 0,706 | 0,697 | 0,688 | 0,680 | 0,672 | 0,84 |
| 0,86 | 0,957 | 0,919 | 0,884 | 0,852 | 0,825 | 0,800 | 0,778 | 0,759 | 0,742 | 0,727 | 0,712 | 0,700 | 0,688 | 0,677 | 0,677 | 0,658 | 0,649 | 0,641 | 0,634 | 0,86 |
| 0,88 | 0,924 | 0,880 | 0,842 | 0,809 | 0,780 | 0,755 | 0,733 | 0,714 | 0,697 | 0,682 | 0,668 | 0,655 | 0,644 | 0,633 | 0,624 | 0,615 | 0,606 | 0,599 | 0,592 | 0,88 |
| 0,90 | 0,880 | 0,831 | 0,791 | 0,757 | 0,728 | 0,703 | 0,681 | 0,662 | 0,645 | 0,631 | 0,617 | 0,605 | 0,594 | 0,584 | 0,575 | 0,566 | 0,558 | 0,551 | 0,544 | 0,90 |
| 0,92 | 0,820 | 0,769 | 0,727 | 0,693 | 0,664 | 0,640 | 0,619 | 0,601 | 0,585 | 0,571 | 0,559 | 0,547 | 0,537 | 0,527 | 0,519 | 0,511 | 0,504 | 0,497 | 0,490 | 0,92 |
| 0,94 | 0,739 | 0,687 | 0,647 | 0,614 | 0,587 | 0,564 | 0,545 | 0,528 | 0,514 | 0,501 | 0,489 | 0,479 | 0,470 | 0,461 | 0,453 | 0,446 | 0,440 | 0,434 | 0,428 | 0,94 |
| 0,96 | 0,628 | 0,579 | 0,542 | 0,513 | 0,489 | 0,469 | 0,452 | 0,438 | 0,425 | 0,414 | 0,404 | 0,395 | 0,387 | 0,380 | 0,373 | 0,367 | 0,362 | 0,357 | 0,352 | 0,96 |
| 0,98 | 0,462 | 0,422 | 0,393 | 0,371 | 0,352 | 0,337 | 0,325 | 0,314 | 0,305 | 0,296 | 0,289 | 0,282 | 0,277 | 0,271 | 0,266 | 0,262 | 0,258 | 0,254 | 0,251 | 0,98 |
| 1,00 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 1,00 |

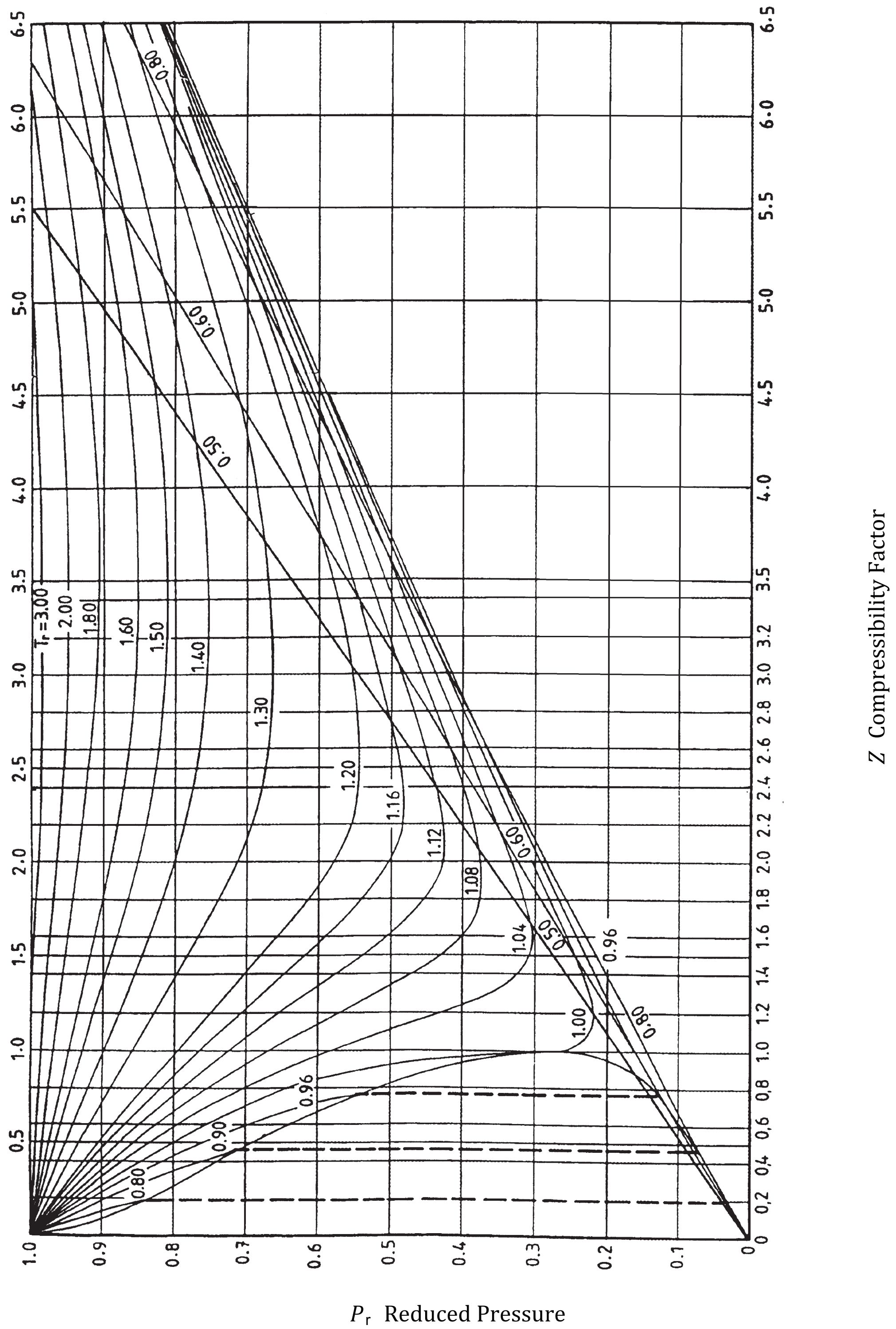
### 7.4 Estimating chart for compressibility factor, *Z*

The estimating chart which shows the compressibility factor *Z* depending on the reduced pressure is given in Figure 1.

The reduced pressure and reduced temperature can be calculated using Formula (27) and Formula (28) respectively.

$$p_r = \frac{p_o}{p_c} \quad (27)$$

$$T_r = \frac{T_o}{T_c} \quad (28)$$




**Key**

$P_r$ Reduced pressure

$T_r$ Reduced temperature

$Z$ Compressibility factor

**Figure 1 — Estimating chart for compressibility factor, *Z***

## 7.5 Capacity correction factor for viscosity, $K_v$

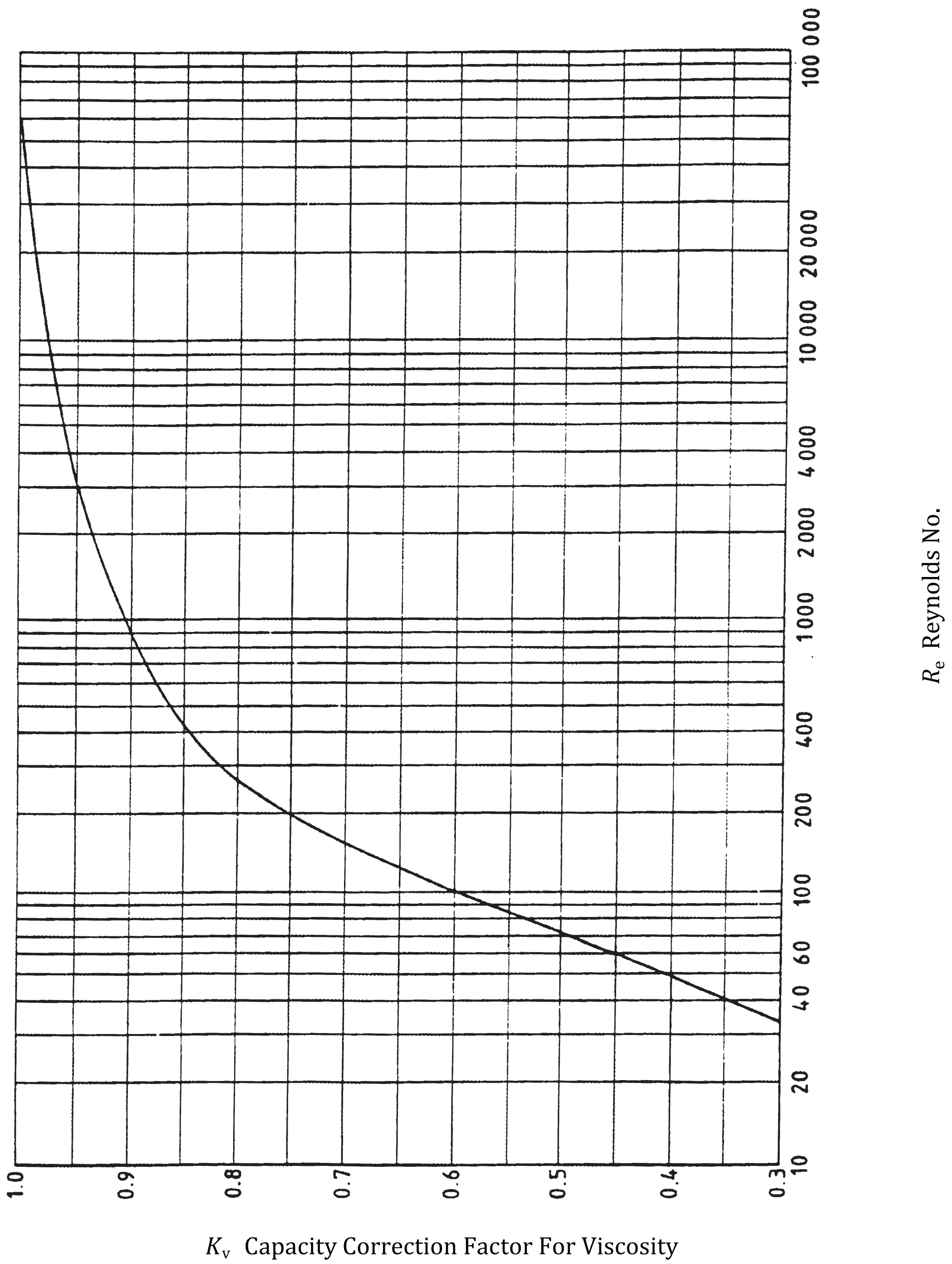
**7.5.1** The capacity correction factor for viscosity, $K_v$ is shown in Figure 2.

**7.5.2** The following equation can also be used to determine $K_v$. It is an approximate curve fit for the graph in Figure 2 and users should check the results for agreement with the curve. The equation should not be used to extrapolate data beyond the curve axes' limits.

$$K_v = \left( 0{,}9935 + \frac{2{,}878}{Re^{0{,}5}} + \frac{342{,}75}{Re^{1{,}5}} \right)^{-1{,}0} \quad (29)$$

**7.5.3** Formula (30) can be used to calculate Reynolds Number.

$$Re = \left( \frac{Q_m}{3{,}6\mu_o} \right) \sqrt{\frac{4}{\pi A}} \quad (30)$$




**Key**

$K_V$ Capacity correction factor for viscosity

*Re* Reynolds number

**Figure 2 — Capacity correction factor for viscosity, $K_V$**

## 7.6 Properties of gases

The properties of gases are given in Table 5.

**Table 5 — Properties of gases**

| Gas | Symbol | Molecular mass, $M$ kg/kmol | Isentropic exponent, $k$ at 1,013 bar (abs) and 15°C | Critical pressure, $p_c$ Pressure bar (abs) | Critical temperature, $T_c$ | Critical pressure ratio |
|---|---|---|---|---|---|---|
| | | | | | $K$ | |
| Acetylene | $C_2H_2$ | 26,02 | 1,26 | 62,82 | 309,15 | 0,553 |
| Air | - | 28,96 | 1,40 | 37,69 | 132,45 | 0,528 |
| Ammonia | $NH_3$ | 17,03 | 1,31 | 112,98 | 405,55 | 0,544 |
| Argon | A (or Ar) | 39,91 | 1,66 | 48,64 | 151,15 | 0,488 |
| n-Butane | $C_4H_{10}$ | 58,08 | 1,11 | 36,48 | 426,15 | 0,583 |
| Carbon dioxide | $CO_2$ | 44,00 | 1,30 | 73,97 | 304,25 | 0,546 |
| Carbon monoxide | CO | 28,00 | 1,40 | 35,46 | 134,15 | 0,528 |
| Chlorine | $Cl_2$ | 70,91 | 1,35 | 77,11 | 417,15 | 0,537 |
| Chlorodifluromethane (R-22) | $CHClF_2$ | 86,47 | 1,18 | 49,14 | 370,15 | 0,568 |
| Ethane | $C_2H_6$ | 30,05 | 1,22 | 49,45 | 305,25 | 0,561 |
| Ethylene | $C_2H_4$ | 28,03 | 1,25 | 51,57 | 282,85 | 0,555 |
| Hydrogen | $H_2$ | 2,015 | 1,41 | 12,97 | 33,25 | 0,527 |
| Hydrogen chloride | HCl | 36,46 | 1,41 | 82,68 | 324,55 | 0,527 |
| Hydrogen sulphide | $H_2S$ | 34,08 | 1,32 | 90,08 | 373,55 | 0,542 |
| Isobutane | $CH(CH_3)_3$ | 58,08 | 1,11 | 37,49 | 407,15 | 0,583 |
| Methane | $CH_4$ | 16,03 | 1,31 | 46,41 | 190,65 | 0,544 |
| Methyl chloride | $CH_3Cl$ | 50,48 | 1,28 | 66,47 | 416,25 | 0,549 |
| Nitrogen | $N_2$ | 28,02 | 1,40 | 33,94 | 126,05 | 0,528 |
| Nitrous oxide | $N_2O$ | 44,02 | 1,30 | 72,65 | 309,65 | 0,546 |
| Oxygen | $O_2$ | 32,00 | 1,40 | 50,36 | 154,35 | 0,528 |
| Propane | $C_3H_8$ | 44,06 | 1,13 | 43,57 | 368,75 | 0,578 |
| Propylene | $C_3H_6$ | 42,05 | 1,15 | 46,60 | 365,45 | 0,574 |
| Suphur dioxide | $SO_2$ | 64,07 | 1,29 | 78,73 | 430,35 | 0,548 |

# 8 Minimum requirements for helical compression springs

## 8.1 General

The spring manufacturer shall, if requested, supply a certificate stating that the springs have been made from the prescribed material, and have been tested in accordance with ISO 4126-7.

The allowable stresses shall be based on previous satisfactory experience and the current understanding of the behaviour of spring materials taking into consideration the temperature of the spring, the environment and the amount of relaxation, which is permissible in service.

## 8.2 Materials

Safety valve spring materials shall be suitable for the intended service conditions.

## 8.3 Marking

Springs shall be marked by suitable means to ensure positive identification. When the identification method is metal stamping or etching, it shall be confined to the inactive coils.

In the case of stock springs, when the above is not practicable, identification shall be by a tag or other suitable method.

## 8.4 Dimensions

Subclause 8.4 provides dimensional requirements for helical springs. Deviations to these requirements are permitted if the springs design can be proven fit for service.

### 8.4.1 Proportion

The proportion of the unloaded length to the mean diameter of the spring shall not exceed five to one.

### 8.4.2 Spring index

The spring index, i.e. the mean diameter of the coil divided by the diameter of the section, shall be within the range 3 to 12.

### 8.4.3 Coil spacing

The pitch of the coils shall be regular. The spring compression shall be no greater than 80 % of the nominal (calculated) deflection from the free length to the solid length.

### 8.4.4 End coils

Springs with nominally parallel ends shall have both ends of each spring closed against the adjacent full coils, and ground.

The ends of the springs shall present a flat bearing surface of between 270° and 300° of the circumference at right angles to the axis [see Figure 3 e)], so that when placed on end on a horizontal plane the springs shall be within the limits shown in Figures 3 a) and 3 c).

Smooth consistent tapers to smooth edges shall be provided with a coil tip thickness approximately equal to one quarter of the section (bar/wire) diameter.

The end coils shall not encroach upon the specified inside and outside diameters [see Figure 3 e)].

Springs with other than nominally parallel ends are allowed if the criteria for springs with nominally parallel ends are met when the spring plate(s)/button(s) is (are) fitted [see Figures 3 b) and 3 d)].

## 8.5 Spring plates/buttons

The spring plates/buttons shall have a location, which allows the spring to rotate freely.

## 8.6 Inspection, testing and tolerances

### 8.6.1 Permanent set

All springs shall be tested for permanent set. The permanent set of the spring is defined as the change in the spring's free length as a result of a series of compression cycles to solid in accordance with the safety valve manufacturer's specification or other appropriate standard. The spring shall be compressed to solid at least three times before determining the initial free length. The spring shall then be compressed to solid at least three more times before measuring the final free length. The permanent set shall not exceed 0,5 % of the initial free length.

### 8.6.2 Dimensional checks

Each spring shall be subjected to the following minimum checks:

a) load/length at the maximum compression at which the spring will be used, or the spring rate over a given range below 80 % of the calculated total deflection, in the linear range;

b) dimensional check of coil diameter and free length;

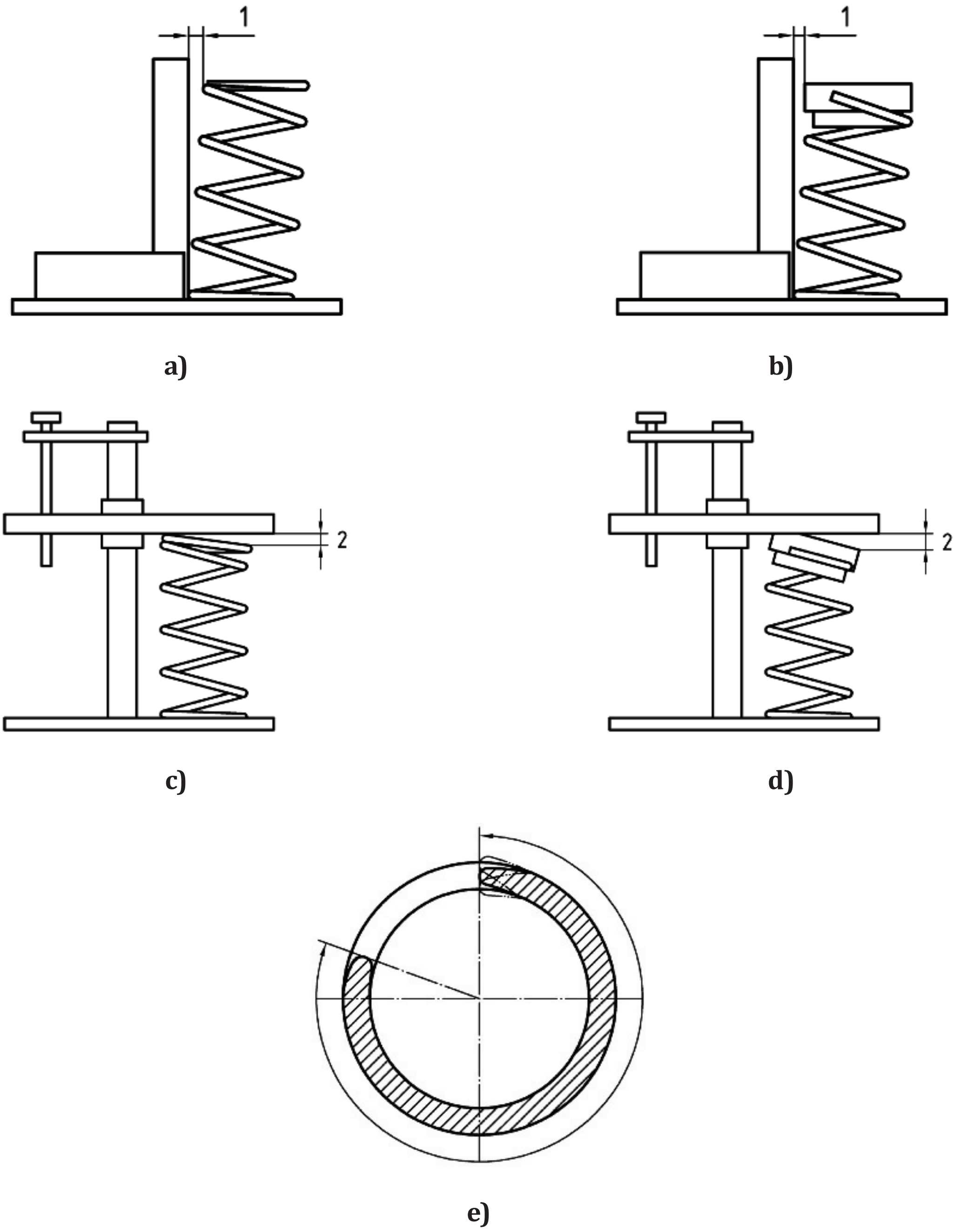
c) dimensional check for end squareness; by standing the spring on a surface plate against a square and measuring the maximum deviation between the top end coil and the square;

With springs having nominally parallel ends this shall be repeated with the spring reversed end for end [see Figures 3 a) and 3 b)].

d) dimensional check for end parallelism, where appropriate; by standing the spring on a surface plate and measuring the difference between the levels of the lowest and highest points of the surface of the upper end.

These measurements shall be repeated with the spring reversed end for end where applicable [see Figures 3 a) and 3 b)].

The constants ‘e’ and ‘f’ in Figure 3 are to be determined by the valve manufacturer.




**Key**

1 = *e* x free length

2 = *f* x mean diameter of spring

NOTE 1 When the end coil of the spring toes out from the spring outside diameter or into the inside diameter, the toe in or out portion shall be ground to match the spring outside diameter or inside diameter as applicable.

NOTE 2 The flat bearing surface at the end of the spring shall be between 300° and 270° of the circumference.

**Figure 3 — Illustration of an end coil**

#### 8.6.3 Tolerances

The tolerances shall be determined by the valve and spring manufacturers.

## 9 Minimum requirements for safety valve disc springs

### 9.1 General

The spring manufacturer shall, if requested, supply a certificate stating that the disc springs have been made from the prescribed material, and have been tested in accordance with ISO 4126-7.

The allowable stresses shall be based on previous satisfactory experience and the current understanding of the behaviour of spring materials taking into consideration the temperature of the spring, the environment and the amount of relaxation, which is permissible in service.

Disc spring stacks, as well as discs, shall be well guided.

### 9.2 Materials

Safety valve disc spring material shall be suitable for the intended service conditions.

### 9.3 Marking

Springs shall be marked by suitable means to ensure positive identification. When the identification method is metal stamping or etching, it shall be confined to the lowest stress areas.

During assembly, maintenance and repair of a valve, unless instructions specifically indicate otherwise, each disc spring in the stack shall be marked in such a way that their exact relative positions can be maintained.

### 9.4 Dimensions

#### 9.4.1 Disc spring compression

The disc spring compression shall not be greater than 80 % of the nominal (calculated) deflection from the free height to the flat position.

#### 9.4.2 End squareness and parallelism

The ends of the disc spring stack shall be square and parallel within the limits agreed between the spring maker and the valve manufacturer.

### 9.5 Inspection, testing and tolerances

#### 9.5.1 Permanent set

All springs shall be tested for permanent set. Each individual disc spring shall be pre-set by compressing it to the flat position. The complete spring stack shall then be compressed at least three times so that each disc reaches the flat position before determining the initial free length. The spring stack shall then be compressed three more times to the same position to determine the final free length. The permanent set shall not exceed 0,5 % of the initial free length.

#### 9.5.2 Load-deflection measurement

After pre-setting and permanent set measurement of each disc spring stack, the load-deflection characteristics shall be measured and certified by the spring maker to verify that the agreed tolerances are met.

# Annex A
(informative)

# Examples of capacity calculations for various media

NOTE For symbols and units refer to Clause 4.

## A.1 Capacity calculations for gaseous media at critical flow (see 6.3.3.1)

EXAMPLE 1 Calculate the flow area of a safety valve to be used on a vessel holding nitrogen gas with a maximum allowable pressure, PS of 55 bar gauge (5,5 MPa).

| | |
|---|---|
| Safety valve certified de-rated coefficient of discharge [$K_{dr}$] at 10 % overpressure | = 0,87 |
| Molar mass of the gas [$M$] | = 28,02 |
| Isentropic exponent of the gas [$k$] | = 1,40 |
| Gas relieving temperature | = 20 °C |
| Required gas flow capacity | = 18 000 kg/h |
| Set pressure | = 55 barg (5,5 MPa) |
| Back pressure | atmospheric |
| $T_o$ | $= 20 + 273 = 293$ K |
| $p_o$ | $= [55 \times 1{,}1] + 1 = 61{,}5$ bar (abs) |

Since $\frac{p_b}{p_o} \leq \left(\frac{2}{k+1}\right)^{(k/(k-1))}$ the flow is critical.

The required area, $A = \dfrac{Q_m}{p_o C K_{dr} \sqrt{\dfrac{M}{Z T_o}}}$

$$C = 3{,}948 \sqrt{1{,}4 \text{x} \left(\frac{2}{1{,}4+1}\right)^{(1{,}4+1)/(1{,}4-1)}} = 2{,}7$$

Values for factor $C$ can also be obtained from Table 3.

Compressibility factor, $Z$, may be estimated from published data.

The calculation involved is as follows:

Reduced pressure, $P_r = \dfrac{p_o}{p_c}$

where:

$p_c$ is the critical pressure = 33,94 bar (abs.) = 3,394 MPa abs (from a thermodynamics handbook).

Reduced temperature, $T_r = \dfrac{T_o}{T_c}$

where:

$T_c$ is the critical temperature = 126,05 K (from a thermodynamics handbook)

$p_r$ = 61,5/33,94 = 1,81

$T_r$ = 293/126,05 = 2,32

$Z$ = 0,975 (from Figure 1)

$$A = \frac{18\ 000}{61,5 \times 2,7 \times 0,87 \times \sqrt{\dfrac{28,02}{0,975 \times 293}}} = 397,85\ \text{mm}^2$$

EXAMPLE 2 Where $K_{dr}$ is certified at 5 % overpressure and the relieving pressure remains at 110 % of PS as in example 1.

Calculate the flow area of the valve to be used on a vessel holding nitrogen gas with a maximum allowable pressure, PS of 55 bar gauge (5,5 MPa):

Safety valve certified de-rated coefficient of discharge [$K_{dr}$] at 5 % overpressure = 0,87

| | |
|---|---|
| Molar mass of the gas [$M$] | = 28,02 |
| Isentropic exponent of the gas [$k$] | = 1,40 |
| Gas relieving temperature | = 20 °C |
| Required gas flow capacity | = 18 000 kg/h |
| Safety valve set pressure | = 55 barg (5,5 MPa) |
| Back pressure | atmospheric |

$T_o = 20 + 273 = 293$ K

$p_o = [\ 55 \times 1,1\ ] + 1 = 61,5\ \text{bar (abs)} = 6,15\ \text{MPa (abs)}$

Since $\dfrac{p_b}{p_o} \le \left(\dfrac{2}{k+1}\right)^{(k/(k-1))}$ the flow is critical.

The required area, $A = \dfrac{Q_m}{p_o\, CK_{dr}\sqrt{\dfrac{M}{ZT_o}}}$

$$C = 3,948\ \sqrt{1,4\mathrm{x}(\frac{2}{1,4+1})^{(1,4+1)/(1,4-1)}} = 2,7$$

Values for factor $C$ can also be obtained from Table 3.

Compressibility factor, $Z$, may be estimated from published data. The calculation involved is as follows:

Reduced pressure, $P_r = \dfrac{p_o}{p_c}$

where:

$p_c$ is the critical pressure = 33,94 bar (abs.) = 3,394 MPa abs (from a thermodynamics handbook).

Reduced temperature, $T_r = \dfrac{T_o}{T_c}$

where:

$T_c$ is the critical temperature = 126,05 K (from a thermodynamics handbook)

$p_r$ = 61,5/33,94 = 1,81

$T_r$ = 293/126,05 = 2,32

$Z$ = 0,975 (from Figure 1)

$$A = \frac{18000}{61,5\times 2,7\times 0,87\times 0,989\sqrt{\dfrac{28,02}{0,975\ \times\ 293}}} = 437,471\ \mathrm{mm}^2$$

## A.2 Capacity calculations for gaseous media at subcritical flow (see 6.3.3.2)

EXAMPLE Using values from the previous example (i.e. critical flow) calculate the required discharge area if the back pressure is increased from atmospheric to 36,0 bar gauge 3,6 MPa and the certified derated coefficient of discharge is 0,80 in the new conditions.

Since $\dfrac{p_b}{p_o} > \left(\dfrac{2}{k+1}\right)^{(k/(k-1))}$ the flow is subcritical.

NOTE $\dfrac{p_b}{p_o} = \dfrac{36+1}{(55\ \times\ 1,1)+1} = 0,60$

The required area:

$$A = \frac{Q_m}{p_o CK_{dr} K_b\sqrt{\dfrac{M}{ZT_o}}}$$

$$K_b = \sqrt{\frac{\frac{2k}{k-1}\left[\left(\frac{p_b}{p_o}\right)^{\frac{2}{k}} - \left(\frac{p_b}{p_o}\right)^{\frac{k+1}{k}}\right]}{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}} = 0,989$$

($K_b$ can be either calculated or obtained from Table 4)

$$A = \left(18\ 000 / (61,5 \times 2,7 \times 0,8 \times 0,989)\sqrt{(28,02 / (0,975 \times 293)}\right) = 437,471\ \text{mm}^2$$

## A.3 Capacity calculations for liquids (see 6.3.4)

EXAMPLE Calculate the valve flow area, necessary to discharge oil given the following conditions.

Safety valve certified derated coefficient of discharge [$K_{dr}$] at 10 % overpressure = 0,65.

| | |
|---|---|
| Required oil flow capacity at 10 % overpressure [$Q_m$] | = 45 000 kg/h |
| Specific volume [$v_o$] | = 0,001 075 27 $m^3$/kg = 1/density |
| Dynamic viscosity [$\mu_o$] | = 0,5 Pa·s |
| Set pressure | = 30 bar gauge (3 MPa) |
| Back pressure | = 3 bar gauge (0,3 MPa) |

Applicable equation

$$Q_m = 1,61 K_{dr} K_v A \sqrt{\frac{p_o - p_b}{v_o}}$$

Calculate the flow area assuming a non-viscous fluid (i.e. neglecting viscosity). Note that this may be an iterative procedure. $K_v$ is a function of the flow area so a $K_v$ value must be assumed and a check later made that the final calculated flow area is large enough.

$$K_v = 1$$

$$A = \left(\frac{Q_m}{1,6 K_{dr}}\right)\sqrt{\frac{v}{p_o - p_b}}$$

$$p_o - p_b = [30 \times (1 + 10 / 100) + 1] - (3 + 1) = 30\ \text{bar}_{(3\text{MPa})}$$

$$A = \left(\frac{45\ 000}{1,61 \times 0,65}\right)\sqrt{\frac{0,001\ 075\ 27}{30}} = 257,43\ \text{mm}^2$$

1) Select the next larger orifice A’, in this case: A’ = 380 $mm^2$ and obtain the minimum value of the viscosity correction factor.

$$K_{vm} = \frac{A}{A'}$$

$$\text{minimum } K_{vm} = \frac{257,43}{380} = 0,68$$

2) Calculate the Reynolds number (*Re*) for the given flow capacity and the selected orifice.

$$Re = \left(\frac{Q_m}{3,6\mu_o}\right)\sqrt{\frac{4}{\pi A'}}$$

$$A = \left(\frac{45\ 000}{3,6 \times 0,5}\right)\sqrt{\frac{4}{\pi \times 380}} = 1\ 447$$

From Figure 2

$$K_v = 0,92 > 0,68$$

3) If, as in the example above, minimum $K_{vm} \leq K_v$ the selected area is sufficient to discharge the given flow rate. If this is not true, repeat 1) and 2) above.

# Bibliography

[1] IAPWS-IF97, *IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam*

[2] ISO 4126-10, *Safety devices for protection against excessive pressure — Part 10: Sizing of safety valves for gas/liquid two-phase flow*