FLOWSERVE GESTRA

GESTRA

Guide

Experience In Motion

1st English Edition, 2006

Preface

For three decades now, the GESTRA Guide (in German) has been an important reference work in the field of steam and condensate technology. The continuing strong interest in this useful technical guide has encouraged us to publish a revised edition this year - in book form and on CD-ROM - together with an English translation.
With regard to the content, we have kept to the proven basic concept of the book. Units and conversion tables have been updated to reflect today's standards and current usage, whilst units not officially permitted are marked accordingly. The chapters on “Standards” and “Acceptance Conditions” comply with the European EN standards, and the American standards according to ASME have been considered.
Special thanks are due to all the staff members who contributed towards the success of this book over the years.

GESTRA AG
Bremen, 2006

FLOWSERVE® GESTRA

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FLOWSERVE
GESTRA
GESTRA Steam Systems
Valves
Industrial Electronics, Automation
Special Equipment
and Vessels for Heat Recovery
Services

1 Piping

1.1 General

1.1.1. PN/Class
Like the PN figure, the Class specification is a characteristic quantity for the mechanical and dimensional properties of a component.

PN levels:
PN 2,5, PN 6, PN 10, PN 16, PN 25, PN 40, PN 63, PN 100, PN 160, PN 250, PN 320, PN 400

Class levels:
Class 25, Class 75, Class 125, Class 150, Class 250, Class 300, Class 600, Class 900, Class 1500, Class 2500, Class 4500

The PN figure is commonly used wherever the pressure is expressed in bar. According to the standard (DIN EN 1333), the numerical value which follows the letters PN is not a measurable value. As a rule, however, it corresponds to the maximum permissible pressure of the component at 20 °C. For some materials, e.g. austenites, the maximum permissible pressure at 20 °C can be lower than the PN number. For the Class figures, the pressures were initially specified in psig. Nowadays, the pressures are increasingly being expressed in bar for Class. In this system, the maximum permissible pressure of the component at 20 °C differs according to material. This pressure is not indicated by the numbers following the word Class.
By way of example, the following table shows the maximum permissible pressures of flanges made of comparable EN and ASTM materials at 20 °C.

Flange, PN 40		Flange, Class 300		
EN material	Perm. pressure	ASTM material	Permissible pressure	
	[bar]		[psig]	[bar]
1.0460	40	A105	740	51.1
1.5415	40	A182 F1	695	48.0
1.4404	40	A182 F316L	600	41.4

Fig. 1

The maximum permissible pressure PS of a component depends on several influencing factors: PN or Class level, design and material of the component, temperature etc. (see also Section 1.5 “Pressure/temperature rating”.

1.1.2 Test pressure PT
The pressure to which the component is subjected for testing purposes (proof of pressure integrity).

1.1.3 Maximum permissible pressure PS
The maximum design pressure for which the component - referred to a certain temperature - is designed (see also Section 1.5 "Pressure/temperature rating").

1.1.4 Minimum/maximum permissible temperature TS
The minimum/maximum operating temperature for which the component - referred to a certain pressure - is designed (see also Section 1.5 “Pressure/temperature rating”).

1.1.5 Pressure/temperature rating (p/T rating)

Since the strength of materials decreases with increasing temperature, the maximum permissible pressure PS for a component is not a fixed value but depends to a great extent on the temperature. Similarly, the maximum permissible temperature TS differs according to the expected pressure. For components, there are thus generally a large number of value pairs for PS and TS.
This interdependency of the maximum permissible pressure PS and the maximum permissible temperature TS is known as the “p/T rating”. Pressure/temperature ratings are specified in the corresponding standards, e.g. in DIN EN 1092-1 for flanges with PN classification.

1.1.6 Nominal size DN/NPS

Both the DN and NPS figures specify the standard connection size of a component.
The number after the letters DN indicates the internal diameter (inside width) of the connection drill-hole of a component (e.g. of a flange) in millimetres, whereas the number after the letters NPS expresses this measurement in inches. However, this is an approximate value that has been roughly rounded up or down. The actual internal diameter varies according to the PN or Class level.

DN 10	DN 50	DN 150	DN 400	DN 800	DN 1400	DN 2200	DN 3200
DN 15	DN 60	DN 200	DN 450	DN 900	DN 1500	DN 2400	DN 3400
DN 20	DN 65	DN 250	DN 500	DN 1000	DN 1600	DN 2600	DN 3600
DN 25	DN 80	DN 300	DN 600	DN 1100	DN 1800	DN 2800	DN 3800
DN 32	DN 100	DN 350	DN 700	DN 1200	DN 2000	DN 3000	DN 4000
DN 40	DN 125						

Fig. 2a DN levels

NPS 1/2	NPS 2	NPS 6	NPS 16	NPS 28	NPS 38	NPS 46	NPS 54
NPS 3/4	NPS 2 1/2	NPS 8	NPS 18	NPS 30	NPS 40	NPS 48	NPS 56
NPS 1	NPS 3	NPS 10	NPS 20	NPS 32	NPS 42	NPS 50	NPS 58
NPS 1 1/4	NPS 4	NPS 12	NPS 24	NPS 34	NPS 44	NPS 52	NPS 60
NPS 1 1/2	NPS 5	NPS 14	NPS 26	NPS 36			

Fig. 2b NPS levels

1.1.7 Identification of pipes

DIN 2403 defines the identification of pipes according to the fluid conveyed. The fluids are divided into 10 colour groups, depending on their general properties. For details and implementation procedures, see the standard.

Fluid conveyed	Group	Colour	
Water	1	*Yellow green*	RAL 6018
Steam	2	*Flame red*	RAL 3000
Air	3	*Silver grey*	RAL 7001
Combustible gases	4	*Rapeseed yellow* [1)]	RAL 1021
Non-combustible gases	5	*Rapeseed yellow* [2)]	RAL 1021
Acids	6	*Pastel orange*	RAL 2003
Alkalis	7	*Red lilac*	RAL 4001
Combustible liquids	8	*Ochre brown* [3)]	RAL 8001
Non-combustible liquids	9	*Ochre brown* [4)]	RAL 8001
Oxygen	0	*Sky blue*	RAL 5015

1) *Rapeseed yellow or rapeseed yellow with the additional tint flame red* (RAL 3000).
2) *Rapeseed yellow with the additional tint jet black* (RAL 9005) *or jet black* (RAL 9005).
3) *Ochre brown or ochre brown with the additional tint flame red* (RAL 3000).
4) *Ochre brown with the additional tint jet black* (RAL 9005) *or jet black* (RAL 9005).

Fig. 3 Identification of pipes

1.2 Pressure Losses

1.2.1 Introduction

The pressure drop in a pipe is the result of all the individual losses of all pipeline components, such as pipes, fittings and valves, from the influence of the geodetic head and from changes in the cross-section. In the case of gases, the change in volume caused by expansion must also be taken into account. This can be neglected, however, provided that the pressure drop is only a few percent of the absolute pressure. Under this prerequisite, calculation of the pressure losses is the same for liquids and gases.

We can say quite generally that

$$\Delta p = C \frac{\rho w^2}{2} \qquad (1)$$

Substituting $C = \lambda \frac{l}{d}$

the pressure loss caused by the wall friction for pipes is then

$$\Delta p = \lambda \frac{l}{d} \frac{\rho w^2}{2} \qquad (2)$$

For valves and fittings, C = ζ and so

$$\Delta p = \zeta \frac{\rho w^2}{2} \qquad (3)$$

In another common notation for equation (1), the proportionality factor C is replaced by $\zeta \cdot a$ – where a is known as the body factor.

We then obtain

$$\Delta p = \zeta a \frac{\rho w^2}{2} \qquad (1a)$$

With a = l/d for pipes, then

$$\Delta p = \zeta \frac{l}{d} \frac{\rho w^2}{2} \qquad (2a)$$

For valves and fittings, a = 1: consequently

$$\Delta p = \zeta \frac{\rho w^2}{2} \qquad (3a)$$

The ζ value in (2a) corresponds to the λ value in (2), and so equations (3) and (3a) are also identical.

1.2.2 Definition of terms

1.2.2.1 Reynolds number *Re*

The dimensionless quantity *Re* is the ratio of inertial forces to viscose forces. It provides an indication of the type of fluid flow: the flow is laminar for *Re* < 2000, possibly turbulent for *Re* ≥ 2000 and usually turbulent from *Re* > 2300 in industrial piping.

$$Re = \frac{w\,d}{\nu} \qquad (4)$$

w = characteristic fluid velocity

$$Re = \frac{\rho\,w\,d}{\eta} \qquad (4a)$$

d = typical length dimension

$$Re = \frac{4\,\rho\,\dot{V}}{\pi\,\eta\,d} \qquad (4b)$$

ν = kinematic fluid viscosity

$$\nu = \frac{\eta}{\rho} \qquad \rho = \frac{\gamma}{g} \qquad w = \frac{\dot{V}}{A} \qquad A = \frac{d^2\pi}{4}$$

1.2.2.2 Pipe friction coefficient λ

The relationships outlined here are described mathematically by the “laws of friction in fluid flow” resulting from the work of various researchers. These laws are usually presented graphically in the log-log system.

The pressure loss Δp caused by friction in a pipe is proportional to the specific pipe length l/d and also proportional to the dynamic pressure of the flow $\rho\, w^2/2$. As a proportionality factor, the pipe friction coefficient λ is introduced.

$$\Delta p = \lambda \,\frac{l}{d}\, \frac{\rho\, w^2}{2} \qquad (2)$$

The pipe friction coefficient λ is a function of the Reynolds number *Re* and, in certain ranges, is also influenced by the pipe roughness. In the laminar range, λ is only dependent on *Re*; the influence of the roughness can be neglected. For turbulent flow, we differentiate between hydraulically smooth pipes, hydraulically rough pipes and a transitional zone. For hydraulically smooth pipes, λ is only dependent on *Re*. For pipes that are completely rough, the roughness is the sole influencing factor. In the transitional zone, the λ value is influenced by both *Re* and the roughness.

1.2.2.3 Resistance coefficient ζ

The pressure loss Δp in valves and fittings is proportional to the dynamic pressure $\frac{\rho w^2}{2}$.

As a proportionality factor, the resistance coefficient ζ is introduced.

$$\Delta p = \zeta \frac{\rho w^2}{2} \qquad (3)$$

For several single resistances of the same nominal size, the pressure loss becomes

$$\Delta p = \Sigma \zeta \frac{\rho w^2}{2} \qquad (5)$$

The resistance coefficient ζ is determined empirically and can be taken from tables or diagrams. Unless stated otherwise, it must always be referred to the nominal connection size of the valves or screwed connection and to the nominal size of the pipes to be connected.

1.2.2.4 Equivalent pipe length

In calculations, it is possible to substitute the flow resistance caused by pipeline components, such as valves and fittings, by equivalent pipe lengths. For this, we consider the familiar equations:

Equation (3) for valves $\qquad \Delta p_1 = \zeta \frac{\rho w^2}{2}$

Equation (2) for pipes $\qquad \Delta p_2 = \lambda \frac{l}{d} \frac{\rho w^2}{2}$

With $\Delta p_1 = \Delta p_2$ we obtain $\zeta = \lambda \frac{l}{d}$ and then

$$l = \frac{\zeta}{\gamma} d \qquad (6)$$

With this equivalent pipe length l according to (6) plus the length of actual pipe, the pressure loss of the entire pipe can be calculated in one step using (2).

1.2.2.5 Geodetic head (liquid level)

Routing a pipe upwards or downwards changes the potential energy of the fluid conveyed. According to the law of energy conservation - Bernoulli effect - the pressure must then also change. Through an appropriate arrangement of the pipework, it is for example possible to influence the working pressure for a steam trap.

1.2.2.3 Changes in cross-section

Changes in cross-section affect the kinetic energy and, according to Bernoulli, also the pressure of the fluid. If a pipe is of varying diameter, then the pressure losses caused by wall friction must be calculated separately for each cross-section and the associated pipe length. Moreover, the pressure changes in the cross-sectional transitions must also be determined.

1.2.2.7 Pressure loss, static head

From equation (1) with SI units, we obtain the pressure loss Δp in the SI unit Pascal (Pa). For conversion to the commonly used unit "bar": 1 bar = 10^5 Pa

$\Delta p = C \frac{\rho w^2}{2}$	Δp in Pa	(1)	C	flow resistance coefficient	-
			ρ	density	kg/m^3
$\Delta p = \frac{C}{10^5} \frac{\rho w^2}{2}$	Δp in bar		w	velocity	m/s
			g	gravity acceleration	m/s^2

Pipe friction resistances are still expressed as static heads H_v in m (pressure head losses).

With the units agreed above, the following applies:

$H_v = C \frac{w^2}{2g}$	H_v in m
$\Delta p = H_v \rho g$	Δp in Pa
$\Delta p = H_v \frac{\rho g}{10^5}$	Δp in bar

1.2.3 Pressure drop in steam lines

$$\Delta p = C \frac{\rho w^2}{2}$$

Valves and fittings: C = ζ
Pipes: $C = \lambda \, l/d$ where $\lambda = 0.0206$ according to Eberle

The flow resistance coefficients C for all pipeline components of the same nominal size are read from Fig. 4. The total pressure drop Δp in bar can be determined from the sum of all individual components ΣC and the operating data; see Fig. 5.

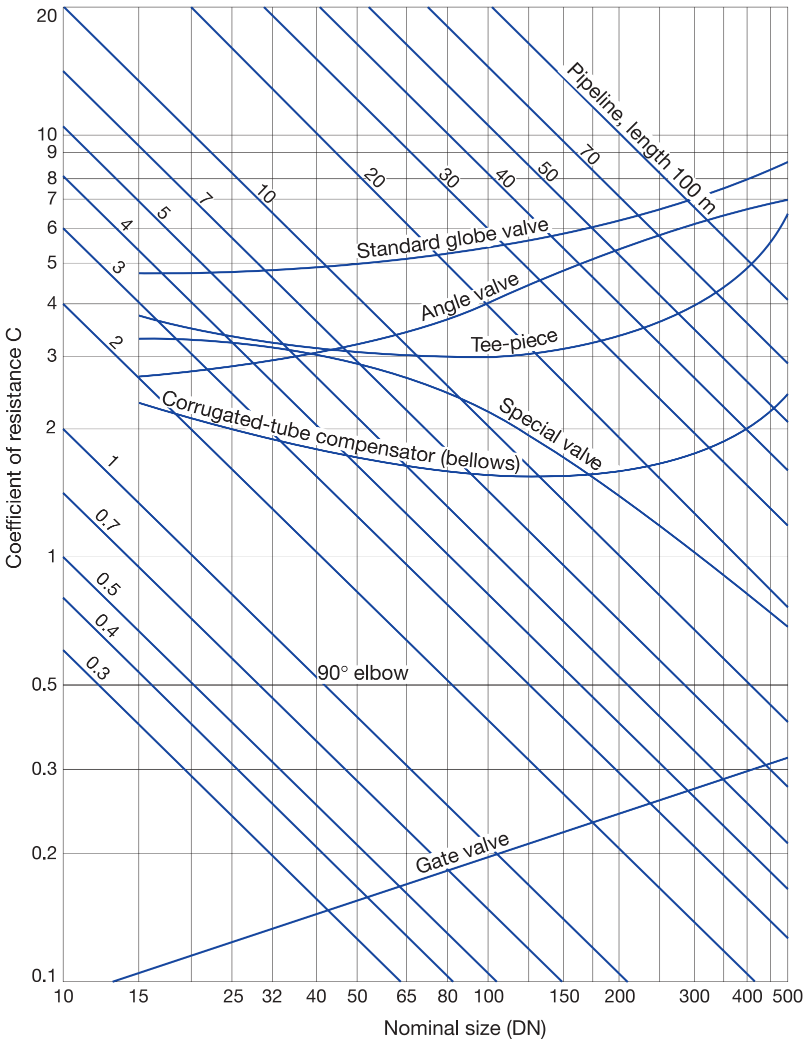


Fig. 4

Example:
Pipeline components DN 50

Pipeline, length 20 m	C = 8.1
1 angle valve	C = 3.3
2 special valves	C = 5.6
1 tee-piece	C = 3.1
2 elbows, 90°	C = 1.0
	ΣC = 21.1

Operating data

Temperature	t = 300 °C
Abs. steam pressure	p = 16 bar
Velocity	w = 40 m/s
Result:	Δp = 1.1 bar

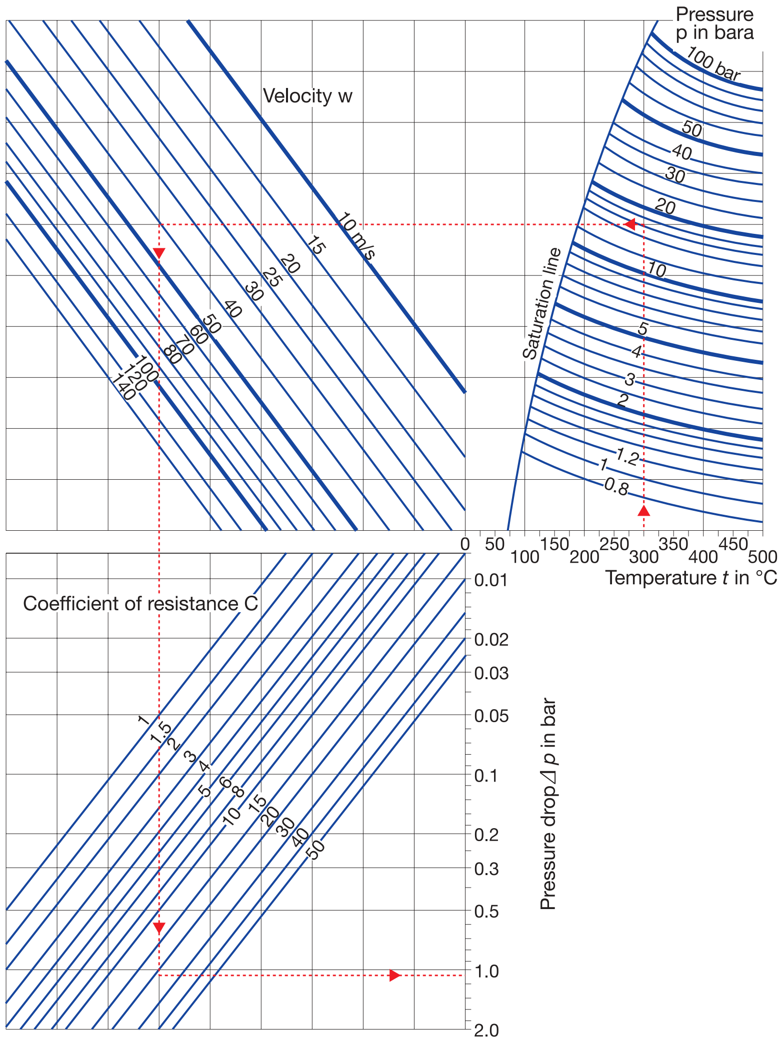


Fig. 5

1.2.4 Flow resistance in straight water pipes

Static head

$$H_v = C \frac{w^2}{2g}$$

where $C = \lambda\, l/d$

Volume flow

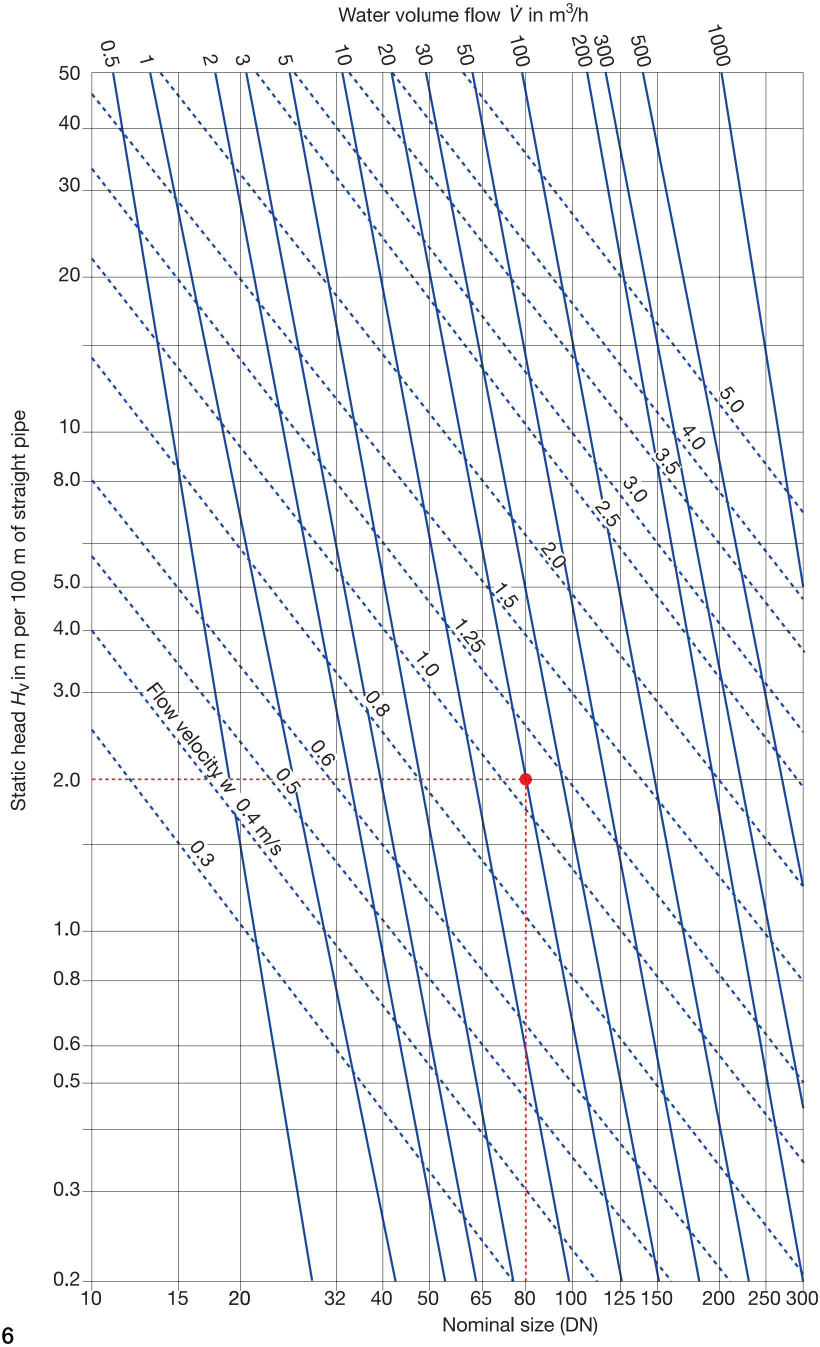
$$\dot{V} = w \cdot A = w\, d^2 \pi/4$$

Fig. 6 applies for cold water and new pipes of grey cast iron. The pressure head losses H_V must be multiplied by

0.8 for new rolled steel pipes
1.25 for older, slightly corroded steel pipes
1.7 for pipes with encrustation, where the constricted cross-section is relevant.

Example:
Cast iron pipe DN 80
Volume flow $\dot{V}$= 20 m^3/h

Result according to Fig. 6:
Static head H_V = 2.0 m/100m
Flow velocity w = 1.1 m/s



Water volume flow $\dot{V}$ in m³/h
0.5
1
2
3
5
10
20
30
50
100
200
300
500
1000
Static head H_V in m per 100 m of straight pipe
50
40
30
20
10
8.0
5.0
4.0
3.0
2.0
1.0
0.8
0.6
0.5
0.3
0.2
Flow velocity w
0.3
0.4 m/s
0.5
0.6
0.8
1.0
1.25
1.5
2.0
2.5
3.0
3.5
4.0
5.0
10
15
20
32
40
50
65
80
100
125
150
200
250
300
Nominal size (DN)

Fig. 6

1.3 Determining the Nominal Sizes of Pipes

1.3.1 General notes on calculation

The parameters given are usually the volume flowrate and a permissible pressure drop; the necessary pipe diameter is the figure needed. For the calculation, we approach the problem the other way round. We select a diameter and ascertain the pressure loss or flow rate. If necessary, the calculation is reiterated with a corrected diameter. For the initial computational approach, the diameter can be calculated by assuming a velocity from the flow rate.

Flash and exhaust steam lines, flash steam in condensate lines		15 – 25 m/s
Saturated steam lines		
	up to 1 bar	≤ 10 m/s
	1 to 2 bar	10 – 15 m/s
	2 to 5 bar abs	15 – 25 m/s
	5 to 10 bar abs	25 – 35 m/s
	10 to 40 bars abs	35 – 40 m/s
	40 bar abs	≤ 60 m/s
Superheated steam lines of low capacity		approx. 35 m/s
Superheated steam lines of medium capacity		40 – 50 m/s
Superheated steam lines of high capacity		50 – 65 m/s
Feedwater suction lines		0.5 – 1.0 m/s
Feedwater pressure lines		1.5 – 3.5 m/s
Cooling water suction lines		0.7 – 1.5 m/s
Cooling water pressure lines		1.0 – 5.5 m/s
Drinking and service water lines		1.0 – 2.0 m/s
Compressed air lines		15 m/s

Fig. 7 Guideline values for flow velocities

1.3.2 Flowrates in pipes

The volume flow is calculated from the following relationships:

$$\dot{V} = w \cdot A = w\, d^2 \pi/4$$

$\dot{V}$	volume flow	m^3/s
w	velocity	m/s
A	cross-sectional area	m^2
d	inside pipe diameter	m

$$\dot{V} = \frac{w\, d^2}{354}$$

$\dot{V}$	volume flow	m^3/h
w	velocity	m/s
d	inside pipe diameter	mm

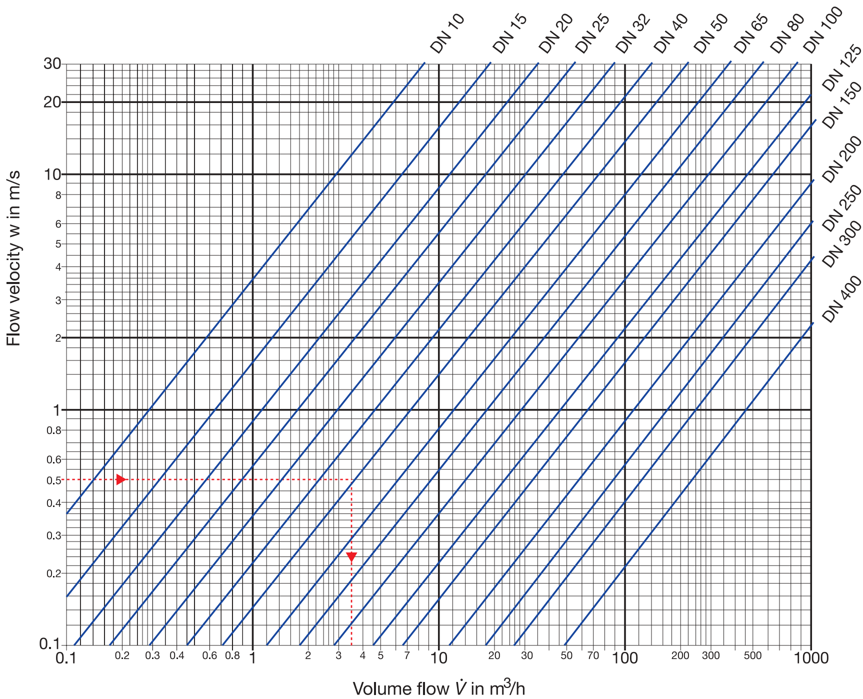


Fig. 8

Example: Condensate line between heat exchangers and steam traps.

Recommended velocity	0.5 m/s
Existing pipe	DN 50
Maximum condensate flowrate	3.6 m^3/h

1.3.3 Flow velocity in steam lines

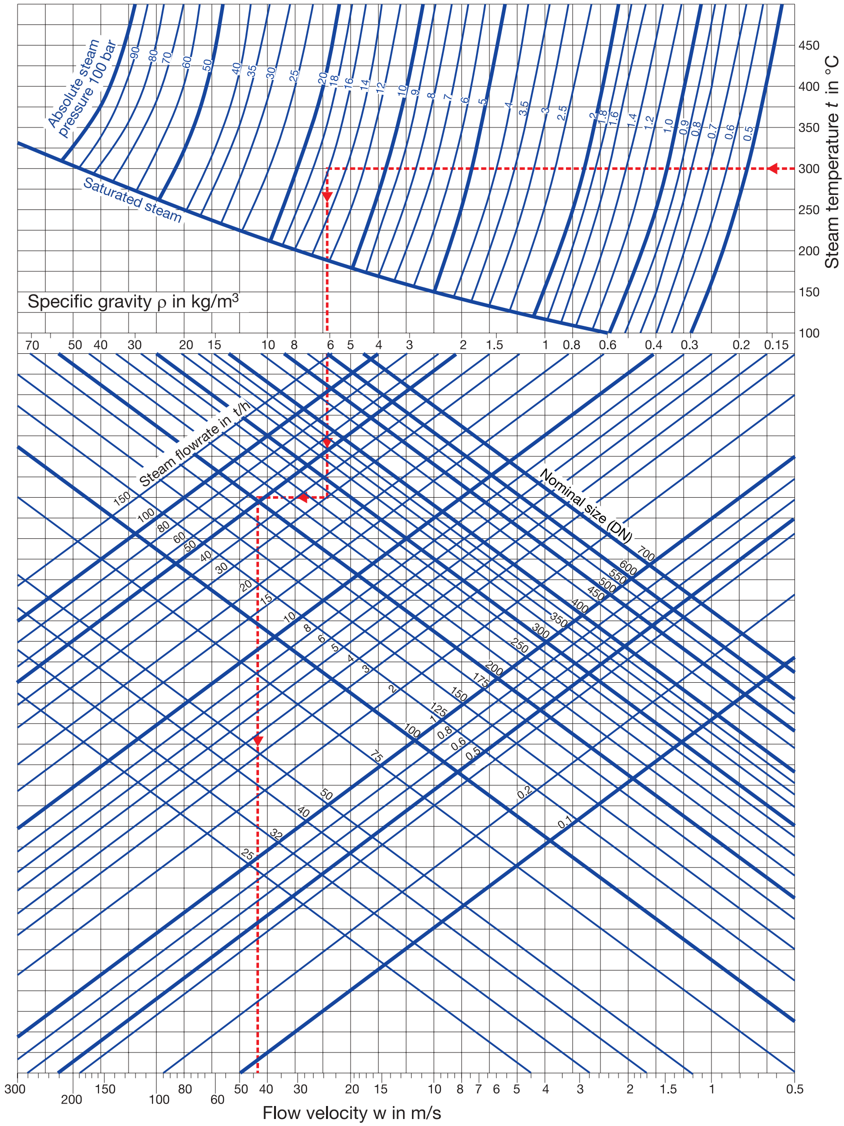


Fig. 9

Example:	Steam temperature	300 °C	Result according to Fig. 9:
	Absolute steam pressure	16 bar	Flow velocity w = 43 m/s
	Steam flowrate	30 t/h	
	Nominal size	DN 200	

1.3.4 Condensate lines

In steam-heated heat exchangers, the evaporation heat and, if applicable, the superheat is extracted from the heating steam. From the amount of condensate and other operating data, we obtain the required size of the steam trap, the expected flash steam, the nominal size of the condensate line (which is not always the same nominal size as the trap), and the size of the flash vessel needed for utilization of the flash steam.

1.3.4.1 Calculating the amount of condensate

The condensate flow $\dot{M}$ in kg/h produced in a heat exchanger is often an unknown quantity. First of all, we calculate the heat flow $\dot{Q}$ in kJ/h.
For a mass flow $\dot{m}$ with the specific heat capacity *c* for warming up from t_1 to t_2 degrees Celsius (for c, see Chapter 3 “Properties of Substances”), this heat demand per unit time is:

$$\dot{Q} = \dot{m}\, c\, (t_2 - t_1)$$

If the mass flow $\dot{m}$ is to be warmed up to boiling point t_s and evaporated, then the specific evaporation heat *r* of the substance to be heated must be taken into account.

$$\dot{Q} = \dot{m}\, c\, (t_s - t_1) + \dot{m}\, r$$

The condensate flow $\dot{M}$ is obtained from the following equation. The evaporation heat *r* is given by the steam tables.

$$\dot{M} = \dot{Q}/r$$

For approximate calculations, the evaporation heat is taken to be $r \approx 2100$ kJ/kg. An additional amount of condensate from heat losses is considered through the correction factor x = 1.25.

$$\dot{M} = \frac{\dot{Q}}{r} \cdot x$$

The condensate flow $\dot{M}$ can also be calculated from the heating surface *A* and the heat transfer coefficient *k*. In the following equation, T_S is the steam temperature, t_1 und t_2 are the temperatures of the substance to be heated and *r* is the specific evaporation heat of the steam.

$$\dot{M} = \frac{A \cdot k\, (t_S - \frac{(t_1 + t_2)}{2})}{r}$$

The arithmetic mean of the temperatures is sufficiently accurate for

$$\frac{t_S - t_1}{t_S - t_2} \geq 0.5 \text{ or } \leq 2$$

The mean temperature difference is precisely

$$t_m = \frac{(t_S - t_1) - (t_S - t_2)}{\ln \frac{t_S - t_1}{t_S - t_2}}$$

1.3.4.2 Calculating the flash steam

The condensate produced in a heat exchanger has the boiling point belonging to the corresponding pressure. However, not only the evaporation heat is used in the heat exchanger but also a part of the sensible heat, causing a reduction in the temperature of the condensate which can amount to a few degrees. Another, though negligible, decrease in temperature results from the heat losses in the pipe leading to the steam trap.

Nevertheless, for approximate calculations, it should be assumed that the condensate reaches the steam trap at boiling point. Then, it is solely the enthalpy difference (the sensible heat released) corresponding to the working pressure (pressure before trap minus pressure after trap) that is decisive for how much flash steam is produced per kg of condensate (Fig. 10).

For the purposes of calculation:

$$\dot{M}_D = \dot{M} \frac{h'_1 - h'_2}{r_2}$$

$\dot{M}_D$	flash steam flow	kg/h
$\dot{M}$	condensate flow	kg/h
h'_1	enthalpy of the condensate before flashing	kJ/kg
h'_2	enthalpy of the condensate after flashing	kJ/kg
r_2	evaporation heat	kJ/kg

1.3.4.3 Nominal sizes of condensate lines

The diameter of the piping between the heat exchanger and the steam trap is normally chosen to fit the nominal size of the trap. When choosing the diameter of the condensate line downstream of the trap, flashing has to be considered.

If the condensate is produced with high undercooling and if the working pressure of the steam trap is correspondingly low, then little or no flash steam will be formed. For the usual working pressures and the corresponding enthalpy differences, the amount of flashing can be very large and the residual condensate flow negligibly small. In such cases, only the flash steam determines the pipe cross-section. For determination by table, see Fig. 11.

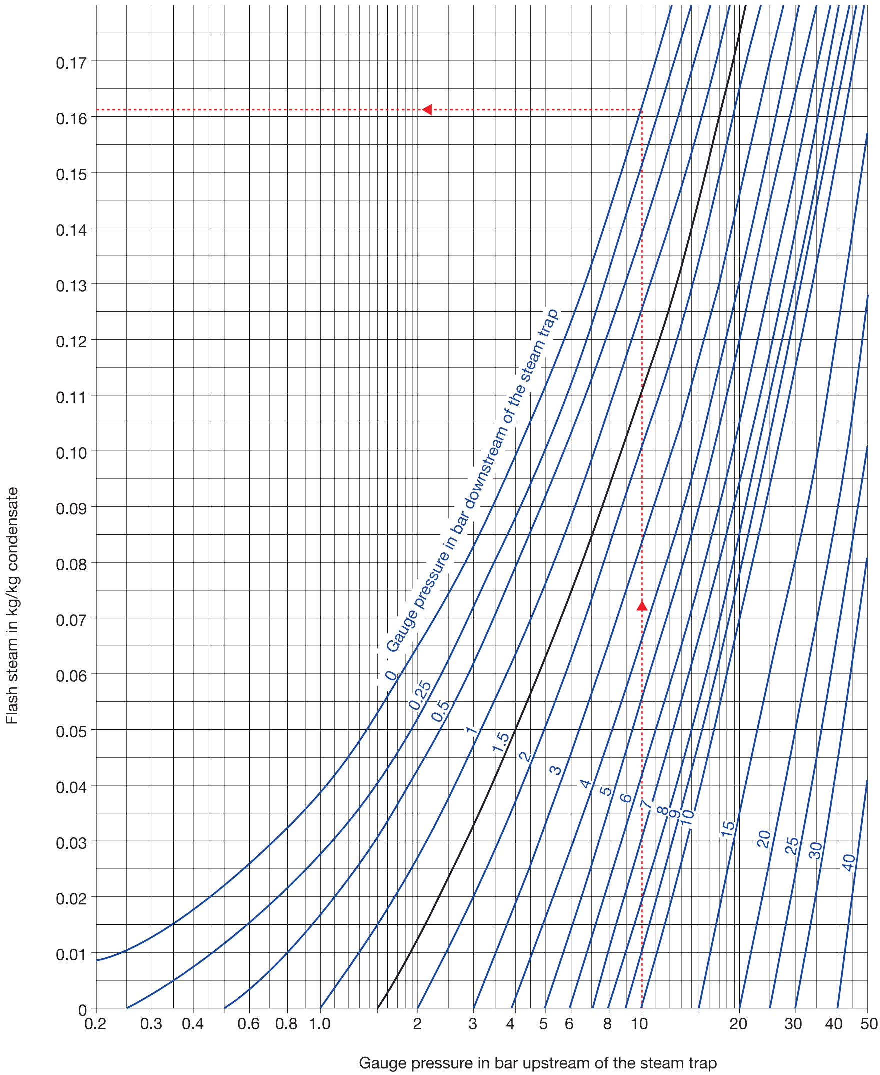


Fig. 10 Flash steam diagram
Amount of flash steam formed when boiling condensate is reduced in pressure

Example:	Gauge pressure upstream of steam trap	10 bar
	Gauge pressure downstream of steam trap	0 bar
	Flash steam	0.162 kg/kg
	equivalent to	16.2%

State of the condensate before flashing		Pressure at the end of the condensate line [bar absolute]																					
Pressure bara	Related boiling temperature °C	0.2	0.5	0.8	1.0	1.2	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6	7	8	9	10	12	15	18	20
1.0	99	35.7	16.0	7.4																			
1.2	104	37.9	18.0	10.0	6.1																		
1.5	111	40.1	20.6	12.9	9.5	6.8																	
2.0	120	44.2	23.5	15.8	12.6	10.3	7.6																
2.5	127	46.8	25.5	17.7	14.5	12.3	9.2	5.3															
3.0	133	48.8	27.1	19.2	16.0	13.9	10.7	7.3	4.5														
3.5	138	50.4	28.4	20.4	17.1	15.0	11.9	8.5	6.0	3.8													
4.0	143	52.0	29.6	21.5	18.2	18.0	12.9	9.7	7.3	5.3	3.5												
4.5	147	53.3	30.5	22.3	19.0	16.9	13.7	10.5	8.1	6.3	4.7	3.0											
5	151	54.3	31.5	23.1	19.8	17.7	14.4	11.2	8.9	7.1	5.6	4.2	2.8										
6	155	55.7	32.3	23.9	20.5	18.4	15.2	11.9	9.6	7.9	6.5	5.1	4.0	2.7									
7	158	56.5	33.0	24.5	21.1	18.9	15.7	12.4	10.1	8.4	7.0	5.7	4.6	3.5	2.1								
8	170	59.9	35.5	26.7	23.1	20.9	17.6	14.2	11.9	10.2	8.9	7.7	6.7	5.8	4.8	4.0							
9	175	61.3	36.4	27.5	23.9	21.7	18.3	14.9	12.6	10.9	9.5	8.4	7.4	6.6	5.5	4.8	2.4						
10	179	62.3	37.2	28.2	24.6	22.3	18.9	15.5	13.1	11.4	10.0	8.9	7.9	7.1	6.0	5.3	3.3	2.1					
12	187	64.4	38.7	29.5	25.7	23.5	19.9	16.5	14.1	12.3	11.0	9.8	8.9	8.0	7.0	6.2	4.5	3.6	2.8				
15	197	66.9	40.5	31.0	27.2	24.8	21.5	17.7	15.2	13.4	12.0	10.8	9.9	9.1	8.0	7.2	5.6	4.8	4.2	2.9			
18	206	69.0	42.0	32.3	28.4	26.0	22.3	18.7	16.2	14.3	12.9	11.7	10.8	9.9	8.8	8.0	6.5	5.7	5.1	3.9	2.5		
20	211	70.2	42.9	33.0	29.0	26.6	22.9	19.2	16.7	14.8	13.4	12.2	11.2	10.4	9.2	8.4	7.0	6.2	5.6	4.4	3.1	1.7	
25	223	72.9	44.8	34.7	30.6	28.1	24.2	20.4	17.9	15.9	14.5	13.2	12.2	11.4	10.2	9.3	7.9	7.1	6.5	5.4	4.2	3.1	2.5
30	233	75.1	46.3	36.0	31.8	29.2	25.3	21.4	18.8	16.8	15.3	14.0	13.0	12.1	10.9	10.0	8.6	7.8	7.2	6.1	4.9	4.0	3.4
35	241	76.8	47.5	37.0	32.7	30.1	26.1	22.1	19.5	17.5	15.9	14.6	13.6	12.7	11.4	10.5	9.2	8.4	7.8	6.7	5.5	4.5	4.0
40	249	78.5	48.7	38.0	33.6	31.0	26.9	22.9	20.1	18.1	16.5	15.2	14.1	13.2	12.0	11.0	9.7	8.6	8.2	7.1	6.0	5.0	4.5
45	256	80.0	49.7	38.8	34.4	31.7	27.5	23.5	20.7	18.6	17.0	15.7	14.6	13.7	12.4	11.4	10.1	9.3	8.6	7.5	6.3	5.4	4.9
50	263	81.4	50.7	39.6	35.2	32.5	28.2	24.1	21.2	19.1	17.5	16.2	15.1	14.2	12.8	11.8	10.5	9.6	9.0	7.9	6.7	5.7	5.2

To determine the actual diameter (mm), the above values must be multiplied with the following factors:

kg/h	100	200	300	400	500	600	700	800	900	1,000	1,500	2,000	3,000	5,000	8,000	10,000	15,000	20,000
Factor	1.0	1.4	1.7	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.9	4.5	5.5	7.1	8.9	10.0	12.2	14.1

Fig. 11 Sizing of condensate lines
Basic assumptions for determining the inside pipe diameter:
1. Only the flash steam amount is considered.
2. The flow velocity of the flash steam is assumed to be 15 m/s.

1.4 Expansion of Pipes

Pipelines increase in length when bearing hot fluids. To prevent excessive forces occurring at the fixed mounting points, a suitable expansion joint is provided. For the heat expansion between two points on a pipe, the straight-line distance between the points is taken. The shape of the piping between the points has no effect.

$$\Delta l = l_0 \alpha \Delta t$$

α = expansion coefficient

Expansion diagram for pipes of mild steel

Example: A pipe with a length of 45 m undergoes a temperature change of 265 K. According to Fig. 12, this results in a change in length - elongation - of 156 mm.

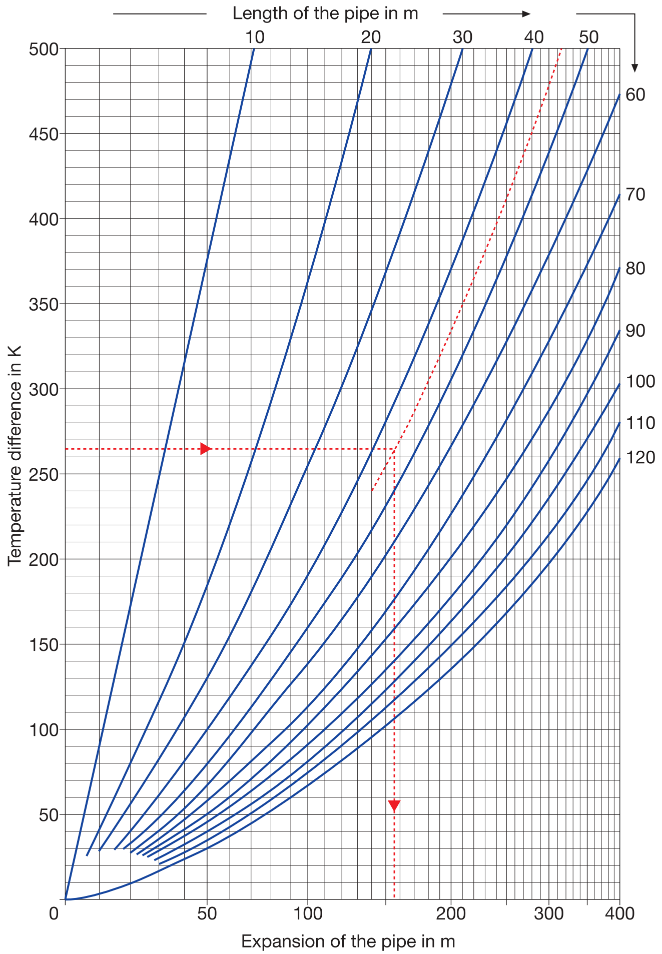


Fig. 12

Pipe leg compensator, leg length

Pipe leg and U-bend compensators are manufactured from the same material as the pipe. A change in the length of the straight pipe section leads to outward displacement of the pipe leg which is at right angles to the main pipe section. The pipes are pre-stressed during manufacture by 50 % of the expected expansion. Fig. 13 applies for heating pipes according to DIN EN 10220.

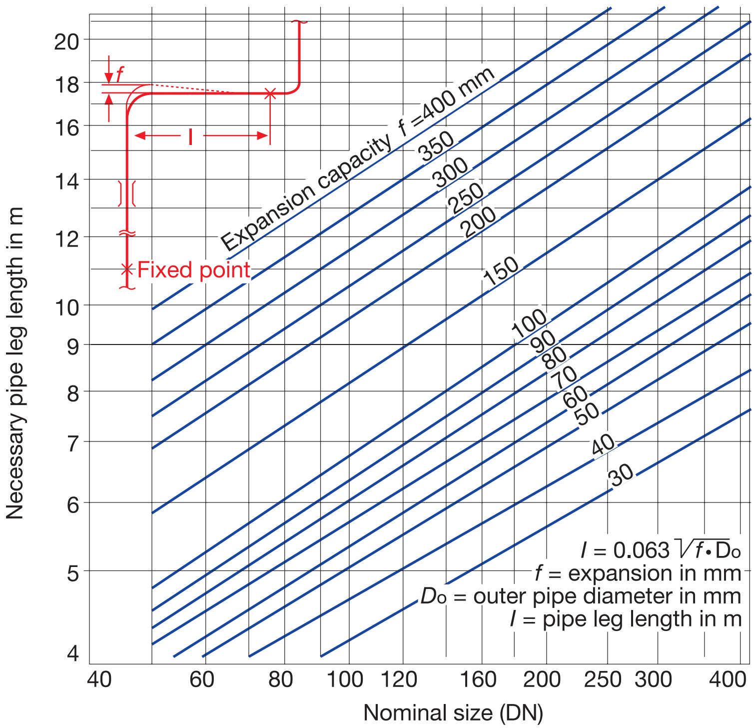


Fig. 13

Compensation pipe bend, expansion capacity

Compensation pipe bends are produced as smooth pipes in bellows and wave-shaped bends. They are suited to the highest pressures and temperatures and offer particularly reliable expansion compensation. The pipes are pre-stressed during manufacture by 50 % of the expected expansion. Fig. 14 applies for a pipe temperature of t = 200 °C.

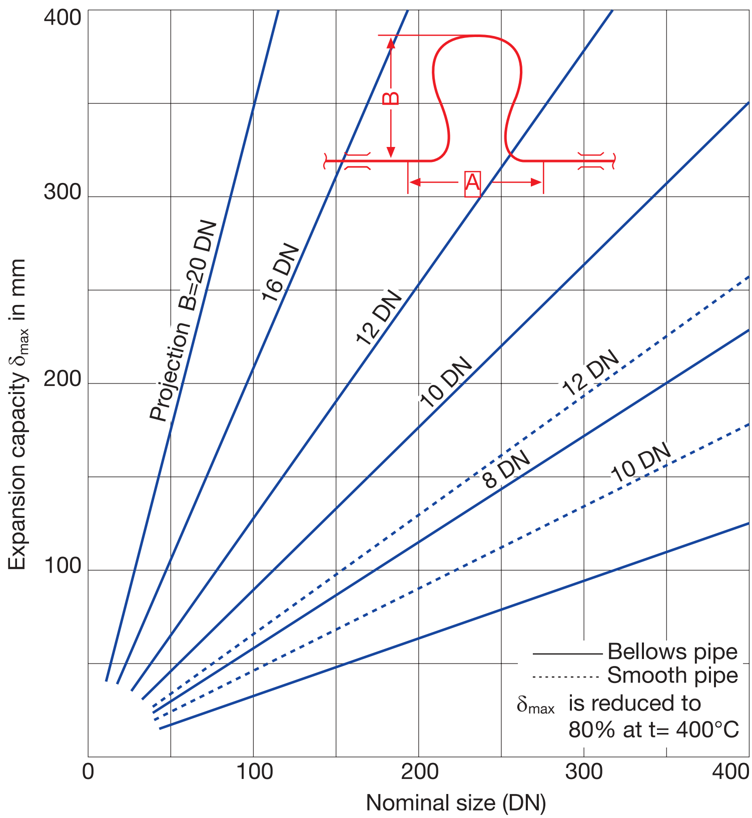


Fig. 14

1.5 Heat Loss of Insulated Pipes

Heat loss per 1 metre of pipe length:
Inside a building:

$$Q_i = k_f \cdot f_d \, (t_M - t_e)$$

Outdoors:

$$\dot{Q}_f = k_f \cdot f_d \cdot f_W \, (t_M - t_e)$$

$\dot{Q}$	heat loss	W/m
k_f	heat transfer coefficient for flat walls	$W/m^2\ K$
f_d	diameter factor for correcting k_f	m^2/m
t_M	temperature of the medium	°C
t_e	temperature of the environment	°C
f_w	wind factor	

k_f, f_d and f_w are obtained from the diagrams of Fig. 15
if the following data are known:

insulation thickness s
thermal conductivity λ
outside diameter of the pipe d_o
For the thermal conductivity λ see the chapter "Properties of Substances"
Guideline value: λ = 0.058 W/m K

Example: Insulation thickness s = 40 mm
Thermal conductivity λ = 0.058 W/m K
Outside diameter of the pipe d_o = 48.3 mm
Temperature of the medium t_M = 160 °C
Temperature of the environment t_e = 20 °C
Reading off the chart: $k_f = 1.25\ W/m^2\ K$
$f_d = 0.27\ m^2/m$
$f_w = 1.068$

Result: Indoors: $\dot{Q}_i = 1.25 \cdot 0.27\ (160 - 20) = 47.3$ W/m
Outdoors: $\dot{Q}_f = 1.25 \cdot 0.27 \cdot 1.068\ (160 - 20) = 50.5$ W/m

Flanges and pipe supports cause additional heat losses. Insulated flanges are treated as continuous pipes, whereas insulated flanges with flange caps are considered by an allowance of 1 m on the pipe length. Pipe supports increase the heat losses indoors by ≈15 % and outdoors by ≈25 %.

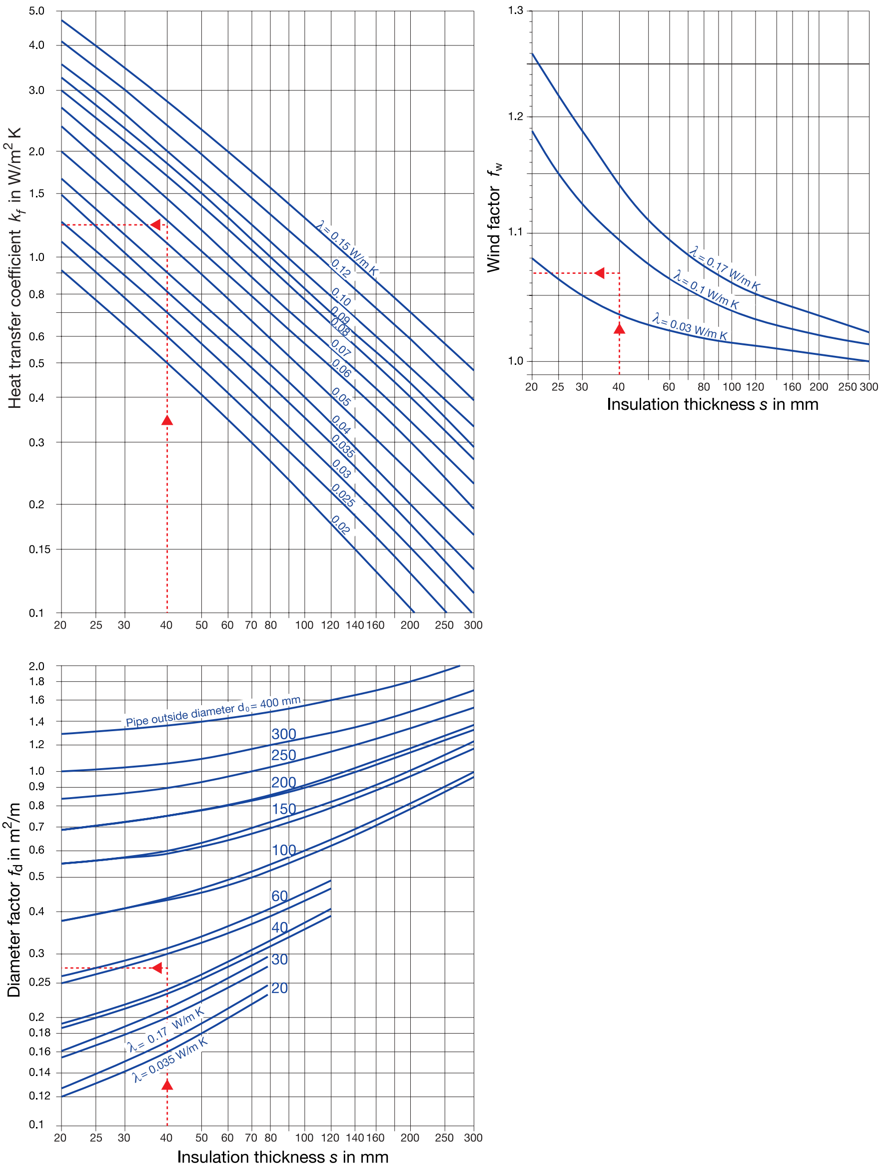


Fig. 15 Heat transfer coefficient k_f, diameter factor f_d, wind factor f_W.

1.6 Temperature Drop in Steam Lines

Temperature drop in Kelvin per metre of pipe length:

$$\Delta t = \frac{\dot{Q}}{c_p \, \dot{m}}$$

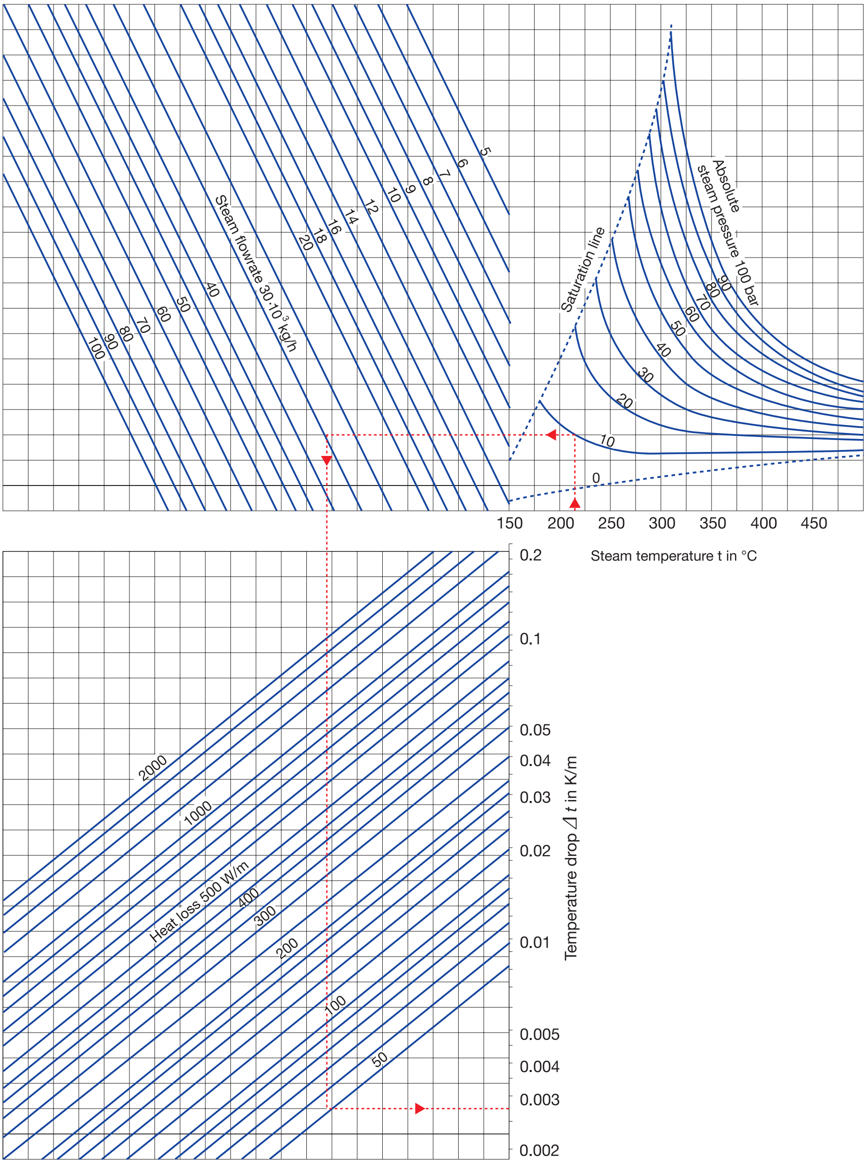
Δt	temperature drop	K/m
$\dot{Q}$	heat loss	W/m
c_p	specific heat capacity at constant pressure	Ws/kg K
$\dot{m}$	steam flowrate in t/h	kg/s

The temperature drop Δt can be obtained from Fig. 16.
First the heat loss must be determined according to Fig. 15.

Example:

Steam temperature	220 °C
Steam pressure, absolute	10 bar
Steam flowrate	$30 \cdot 10^3$ kg/h = 8.33 kg/s
Heat loss	50.5 W/m

Result from Fig. 15: Temperature drop Δt = 0.0028 K/m



Steam flowrate 30·10³ kg/h
5
6
7
8
9
10
12
14
16
18
20
40
50
60
70
80
90
100
Saturation line
Absolute steam pressure 100 bar
90
80
70
60
50
40
30
20
10
0
150
200
250
300
350
400
450
Steam temperature t in °C
0.2
0.1
0.05
0.04
0.03
0.02
0.01
0.005
0.004
0.003
0.002
Temperature drop Δt in K/m
2000
1000
Heat loss 500 W/m
400
300
200
100
50

Fig. 16

1.7 Support Spans, Wall Distances

The support span of a pipe depends on the degree of sagging. Adequate drainage must be ensured. As a result, the sagging also determines the minimum gradient. The permissible sagging depends on the operational conditions. The wall distances for lines routed along buildings must be kept as small as possible. Insulation and pipe flanges must remain accessible.

Nominal size	DN 25		DN 40		DN 50		DN 80		DN 100		DN 150	
Wall thickness of the pipe s in mm	2.0	4.0	2.0	4.0	2.0	4.5	2.3	5.6	2.6	6.3	2.6	7.1
	Permissible support spans, L1 in m											
Empty pipe, not insulated	2.9	2.9	3.5	3.5	4.5	4.4	5.5	5.4	6.3	6.2	7.6	7.5
Pipe filled with water, not insulated	2.7	2.8	3.1	3.3	3.9	4.1	4.6	5.0	5.1	5.6	5.8	6.6
Pipe filled with water, insulated to DD 40	2.0	2.2	2.5	2.3	3.2	3.6	4.0	4.5	4.6	5.2	5.4	6.3
Pipe filled with water, insulated to DD 80	1.8	2.0	2.8	3.2	2.9	3.3	3.7	4.3	4.4	5.0	5.2	6.1

Nominal size	DN 200		DN 250		DN 300		DN 350		DN 400		DN 500	
Wall thickness of the pipe s in mm	2.9	7.1	2.9	7.1	2.9	8.0	3.2	8.8	3.2	10.0	4.0	11.0
	Permissible support spans, L1 in m											
Empty pipe, not insulated	8.7	8.7	9.7	9.7	10.6	10.6	11.1	11.1	11.9	11.8	13.3	13.2
Pipe filled with water, not insulated	6.5	7.4	6.9	8.0	7.3	8.7	7.7	9.1	8.0	9.7	8.9	10.7
Pipe filled with water, insulated to DD 40	6.1	7.1	6.6	7.7	7.0	8.4	7.4	8.8	7.7	9.5	8.7	10.5
Pipe filled with water, insulated to DD 80	5.9	6.9	6.5	7.6	6.9	8.3	7.3	8.7	7.6	9.4	8.6	10.4

Fig. 17 Permissible support spans in m for steel pipes
according to AD 2000 - Bulletin HP 100 R.

Nominal width	DN25	DN32	DN40	DN50	DN65	DN80	DN100	DN125	DN150	DN200	DN250
Support span	100	110	125	140	150	165	185	215	225	260	300

Fig. 18 Support spans in cm for PVC piping, rigid PVC up to 20 °C
(based on empirical values)

1.8 Waterhammer

Every plant should be so constructed as to prevent waterhammer. If this is not possible, arrangements to prevent waterhammer must be provided. There are two types of waterhammer: Hydraulic waterhammer occurs in plants with cold liquids, e.g. through the rapid closing of a line (a stop valve closing too suddenly). Thermal waterhammer arises in steam and condensate installations or in hot-water systems. This is caused when the steam bubbles produced through a drop in pressure or entrained steam arrive in colder parts of the plant containing condensate. There the bubbles condense instantly, leading to implosions. Faulty equipment, improper operating and inappropriate installation may also cause waterhammer. For suitable installations, see Chapter 4 “Connection Examples” as well as the GESTRA Condensate Manual.

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2 Heat Transfer

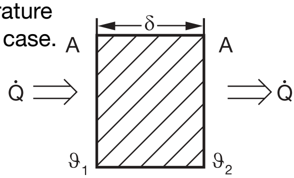
2.1 Fundamentals

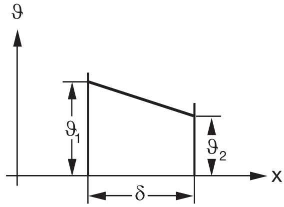
2.1.1 General

Problems involving heat transfer can be represented by simple equations, determined empirically or by calculation, if we group the large number of influencing quantities together to form characteristic coefficients and numbers. An overview is given by DIN 1341, with more detailed information being provided by the relevant technical literature.
Heat transfer necessitates a temperature difference and may take place through the mechanisms of conduction, convection and radiation. Heat transfer is possible in these three modes at any boundary layer between bodies at different temperatures.

2.1.2 Heat conduction through a flat wall

The linear change in temperature applies for the steady-state case.





According to Fourier's Law:

$$\dot{Q} = -A\,\lambda\,\frac{d\vartheta}{dx}$$

For a linear temperature curve, i.e.

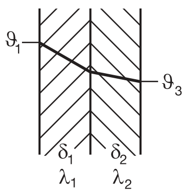
$$\frac{d\vartheta}{dx} = \frac{(\vartheta_1 - \vartheta_2)}{\delta}$$ this yields

$$\dot{Q} = A\,\frac{\lambda}{\delta}\,(\vartheta_1 - \vartheta_2)$$

This equation applies for heat conduction in flat walls, and is also sufficiently accurate for thin-walled pipes.

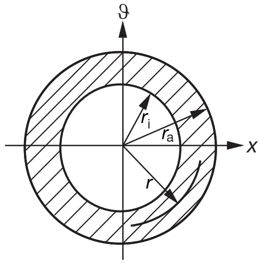
For heat conduction in multilayer walls, the equation is expanded to:

$$\dot{Q} = \frac{A\,(\vartheta_1 - \vartheta_{n+1})}{\frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \ldots + \frac{\delta_n}{\lambda_n}}$$



2.1.3 Heat conduction through a pipe wall

$$\dot{Q} = -A\,\lambda\,\frac{d\vartheta}{dx}$$



For a simple pipe wall, with

$A = 2\,\pi\,r\,l$ and $x = r$,we obtain

$$\dot{Q} = -2\,\pi\,r\,l\,\lambda\,\frac{d\vartheta}{dr}$$

$$d\vartheta = -\frac{\dot{Q}}{2\,\pi\,l\,\lambda} \cdot \frac{dr}{r}$$

With $r_i \rightarrow \vartheta = \vartheta_i$ and $r_a \rightarrow \vartheta = \vartheta_a$ this yields

$$\vartheta_i - \vartheta_a = \frac{\dot{Q}}{2\,\pi\,l\,\lambda} \cdot \ln\frac{r_a}{r_i}$$

$$\dot{Q} = 2\,\pi\,l\,\lambda\,\frac{\vartheta_i - \vartheta_a}{\ln\frac{r_a}{r_i}}$$

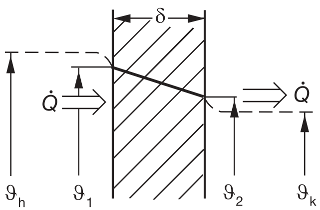
For multilayer pipe walls, we can therefore say:

$$\dot{Q} = 2\,\pi\,l\,\frac{\vartheta_i - \vartheta_{n+1}}{\frac{1}{\lambda_1}\cdot\ln\frac{r_2}{r_1} + \frac{1}{\lambda_2}\cdot\ln\frac{r_3}{r_2} + \ldots + \frac{1}{\lambda_n}\cdot\ln\frac{r_{n+1}}{r_n}}$$

2.1.4 Heat transmission

The transmission of the heat contained in flowing gases or liquids into a wall takes place by conduction and convection. The process is influenced by the flow conditions. The heat transmission coefficient α considers all values that cannot be accommodated by calculation. The heat exchange between the wall and the hot flowing medium is obtained as

$$\dot{Q} = A\,\alpha\,(\vartheta_h - \vartheta_1)$$



2.1.5 Heat transfer

In the technical applications of heat transfer in heat exchangers, preheaters, condensers etc., the term “heat transfer” is used to mean the following processes:

Heat transmission from the flowing medium to the pipe wall

$$\dot{Q} = A \cdot \alpha_1(\vartheta_h - \vartheta_1)$$

Heat conduction within the pipe wall (thin-walled pipes; see Section 2.1.2)

$$\dot{Q} = A \frac{\lambda}{\delta}(\vartheta_1 - \vartheta_2)$$

Heat transmission from the pipe wall to the other flowing medium

$$\dot{Q} = A \cdot \alpha_2(\vartheta_2 - \vartheta_k)$$

For a uniform heat flow (steady-state case), $\dot{Q}$ is a constant. Addition of the three equations yields:

$$(\vartheta_h - \vartheta_k) = \frac{\dot{Q}}{A}\left(\frac{1}{\alpha_1} + \frac{\delta}{\lambda} + \frac{1}{\alpha_2}\right)$$

At the same time, $\frac{1}{\alpha_1} + \frac{\delta}{\lambda} + \frac{1}{\alpha_2} = \frac{1}{k}$

$$k = \frac{1}{\frac{1}{\alpha_1} + \frac{\delta}{\lambda} + \frac{1}{\alpha_2}}$$

This heat transfer coefficient *k* yields the equation for heat transfer as

$$\boxed{\dot{Q} = A \cdot k\,(\vartheta_h - \vartheta_1)}$$

For *k* values, see Figs. 21 - 23.

For a dividing wall consisting of several layers, the overall heat transfer coefficient is therefore

$$k = \frac{1}{\frac{1}{\alpha_1} + \frac{1}{\alpha_2} + \frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \ldots + \frac{\delta_n}{\lambda_n}}$$

2.1.6 Heat radiation

For heat transfer by radiation, the Stefan-Boltzmann Law applies:

$$\boxed{\dot{Q}_s = C \cdot A_s\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right]}$$

C unit conductance in $W/m^2\,K^4$
A_S radiant heating area in m^2
T_1 absolute temperature of the radiant surface in K
T_2 absolute temperature of the radiated surface in K

In practice, the heat radiation component is often neglected. The calculation then considers solely the heat transferred by contact.

2.2 Typical Heat Data

2.2.1 Thermal conductivity coefficients

The thermal conductivity coefficient λ is a physical characteristic, expressed in the unit W/m K or J/m s K, which depends on various factors, such as temperature, pressure, moisture, structural compounds etc. Here the λ value indicates what heat flow in W or J/s passes through a layer of a certain substance 1 m thick when the surfaces with an area of 1 m^2 exhibit a temperature difference of 1 K. For the range of λ values for some common substances, see Fig. 19. Further details are provided in Chapter 3 "Properties of Substances". Factors for converting into other units are given in Chapter 6 "Units, Symbols, Conversion Tables".

Liquids	λ = 0.12...0,58	W/m K
Air	λ = 0.02	W/m K
Gases	λ = 0.01...0.23	W/m K
Insulating materials	λ = 0.03...0.12	W/m K
Alloys	λ = 12... 145	W/m K
Pure metals	λ = 7... 419	W/m K

Fig. 19

2.2.2 Heat transmission coefficients

The heat transmission coefficient α is, amongst other things, a function of the flow velocity *w*, and thus also of the Reynolds number *Re*. It is determined empirically, taken from tables, or calculated with the aid of characteristic numbers.

Boiling water with vertical walls	$\alpha = 3489$	W/m^2 K
Boiling water with horizontal walls	$\alpha = 1745$	W/m^2 K
Flue gas	$\alpha = 4.7 \cdot w^{0.8}$	W/m^2 K
Superheated steam	$\alpha = 52 \cdot w^{0.8}$	W/m^2 K
Highly compressed air with intercoolers	$\alpha = 233 \cdot w^{0.8}$	W/m^2 K
Air in air preheaters	$\alpha = 5.8 \cdot w^{0.8}$	W/m^2 K
Condensing steam	$\alpha = 11630$	W/m^2 K
Water flowing in preheaters, coolers etc.	$\alpha = 3489 \cdot w^{0.8}$	W/m^2 K

Fig. 20 Average values for use in approximate calculations
w = flow velocity in m/s

2.2.3 Heat transfer coefficients

The factors determining the heat transfer are the k value (see Section 2.1.5), the arrangement of the pipes, and the direction of flow (uniflow, counterflow, crossflow). The following *k* values are intended to provide reference values for approximate calculations.

Heating medium	Wall	Heated medium	Heat transfer coefficient k $W/m^2 K$
Water	Cast iron	Air (smoke)	8
Water	Wrought iron	Air (smoke)	12
Water	Copper	Air (smoke)	13
Water	Cast iron	Water	291
Water	Wrought iron	Water	349
Water	Copper	Water	407
Air	Cast iron	Air	6
Air	Wrought iron	Air	8
Air	Copper	Air	10
Steam	Cast iron	Air	12
Steam	Wrought iron	Air	14
Steam	Copper	Air	16
Steam	Cast iron	Water	907
Steam	Wrought iron	Water	1047
Steam	Copper	Water	1163

Fig. 21 Reference values for calculations of heating coils, preheaters etc.

Saturated steam pressure(absolut) bar	Immersion evaporator min.	k-values W/m² K typical	max.
2	1047	1454	1919
4	1861	2384	3140
6	2500	2908	3722
8	2733	3198	4129
10	2791	3315	4303
	Circulation evaporator		
2	2326	2733	3489
4	3489	3954	4594
6	4129	4536	5175
8	4594	4943	5466
10	4826	5234	5815

Fig. 22 Heat transfer coefficients for evaporators and steam converters
The *k* values are expressed in relation to the saturated steam pressure! The typical values were obtained as average values from a large number of examinations, whilst the minimum and maximum values indicate the fluctuation range encountered in practice for various installations.

Type	Medium in the pipes	Medium outside the pipes	*k* value W/m² K
Tubular preheaters	Cold water	Condensing steam	814 to 1047
Tubular heat exchangers	Water	Water	291 to 349
Tubular condensers	Water	Condensing petrol vapour	233 to 582
Tubular aftercooler	Liquid petrol	Water or petrol	145 to 291
Tubular heat exchangers	Crude oil or tar	Condensing petrol vapour	87 to 291
Tubular heat exchangers	Crude oil or tar	Crude oil or tar	58 to 174
Box coolers	Oil distillate	Water	58 to 116
Convection oven	Crude oil or tar	Flue gases	23 to 41
Stills	Crude oil or tar	Flue gases	17 to 23
Tubular coolers	Reformed gases	Water	17 to 29
Tubular coolers	Water	Air and gases	8 to 14
Tubular boilers	Air and gases	Flue gases	6 to 12

Fig. 23 Heat transfer coefficients - empirical values of the oil industry
Typical values for the usual flow velocities and good maintenance condition of the equipment in continuous operation. Varying states of cleanliness of the heating or cooling surfaces, special design features, and abnormal flow velocities can lead to appreciably different results.

Page

3 Properties of Substances

To some extent, the properties of substances given here are average values obtained from various sources. All information is correct to the best of our knowledge.

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3 Properties of Substances

3.1 Density

3.1.1 General

The weight density γ (specific gravity) with the units of the systems applied in the past was, for example, used in static calculations. In the international system of units (SI), the density ρ is generally used.
The acceleration due to gravity g is hence only used in equations if there really is a gravitational effect.
Fig. 24 provides a comparison of density and weight density for water at 4 °C and 1013 mbar.
The following relations apply here:

$\rho = m/V$
$\gamma = G/V$
$\gamma = \rho \cdot g_n$
$1\,\text{kp} = 1\,\text{kg} \cdot g_n$

ρ density
γ weight density (specific gravity)
m mass
G weight
V volume
g_n standard value of the acceleration due to gravity (g_n = 9.80665 m/s^2)

Unitary system	Density ρ	Weight density γ
m-kp-s	$102 \frac{\text{kp s}^2}{\text{m}^4}$	$1000 \frac{\text{kp}}{\text{m}^3}$
m-kg-s-(kp)*	$1000 \frac{\text{kg}}{\text{m}^3}$	$1000 \frac{\text{kp}}{\text{m}^3}$
International system of units m-kg-s-A-K-mol-cd	$1000 \frac{\text{kg}}{\text{m}^3}$	$9810 \frac{\text{N}}{\text{m}^3}$

Fig. 24

* Earlier "transitional system" used by preference in technology, with kilopond as the unit of force instead of Newton (N) and kilogram as the unit of mass.

From Fig. 24 and the relation $\gamma = \rho \cdot g_n$, we see that both the numerical value and the unit change by the factor g_n for the transformation from weight density to density in the m-kp-s system. In this system, the mass is a derived quantity. In contrast, only the unit changes in the m-kg-s-(kp) system, because 1 kp = 1 kg $\cdot$ g_n. The numerical value - 1000 in the example of Fig. 24 - remains the same for both the density and weight density of any substance. As already mentioned, only the density ρ is used in the international system of units and the additional factor g_n is introduced for the special case of a weight acting vertically, without calculating the product $\rho \cdot g$ separately.

The density can be determined quickly and easily with the aid of a hydrometer (also known as an aerometer, or densimeter). Fig. 25 shows the conversion formulae for various hydrometers.

Scale	Reference temperature	Density ρ kg/l	Remark
Baumé (rational scale)	15 °C	$\rho = \frac{144.3}{144.3 - n}$	For liquids lighter than water, the hydrometer degrees *n* must be substituted into the formula with a negative sign.
Brix-Fischer	15.625 °C	$\rho = \frac{400}{400 - n}$	
A.P.I. (American Petroleum Institute)	60 °F	$\rho = \frac{141.5}{131.5 + n}$	For liquids lighter than water
Twaddell	15.56 °C	$\rho = \frac{200 + n}{200}$	For liquids heavier than water

Fig. 25 Conversion formulae for various hydrometer scales

Formerly, density was often expressed in Baumé degrees. However, degrees Baumé (°Bé) is not a unit as such. By immersing a hydrometer into pure water and then into an aqueous solution of salt, Antoine Baumé obtained two fixed points, which he interpolated linearly. The numerical values of the fixed points were chosen according to whether the hydrometer was to be used for liquids heavier or lighter than water.

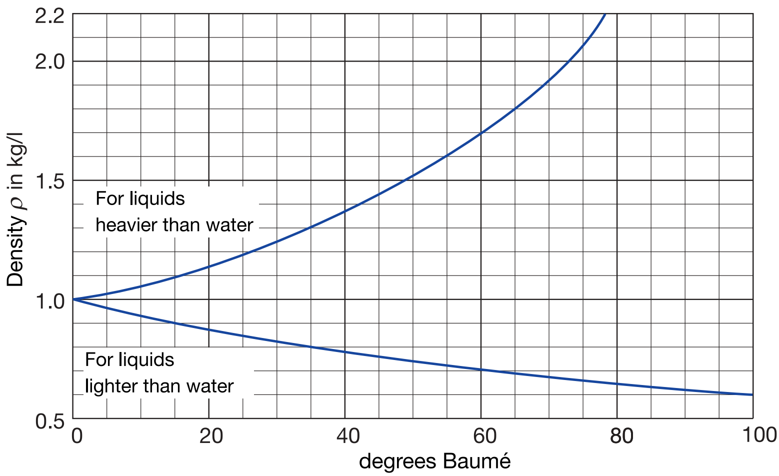

Fig. 26 Relationship between density and Baumé degrees

3.1.2 Density *ρ (t)* of various liquids

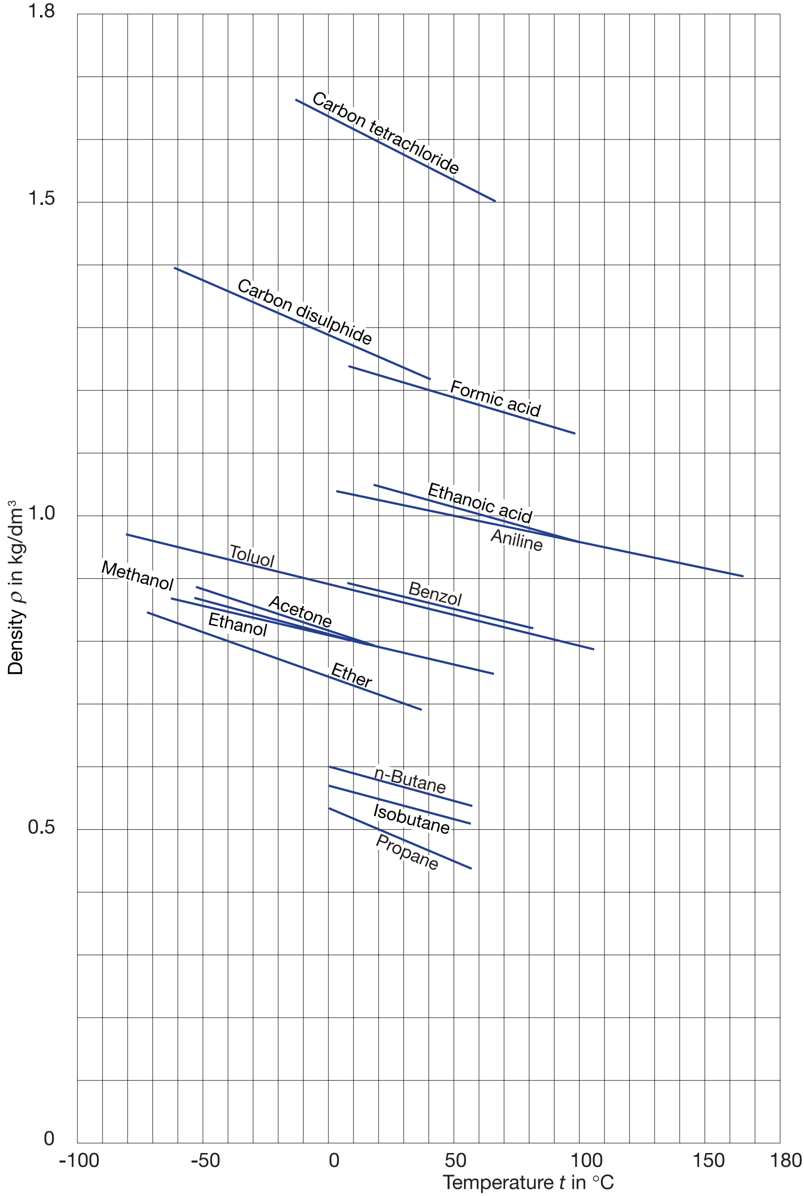

Fig. 27

3.1.3 Density of aqueous solutions as a function of concentration

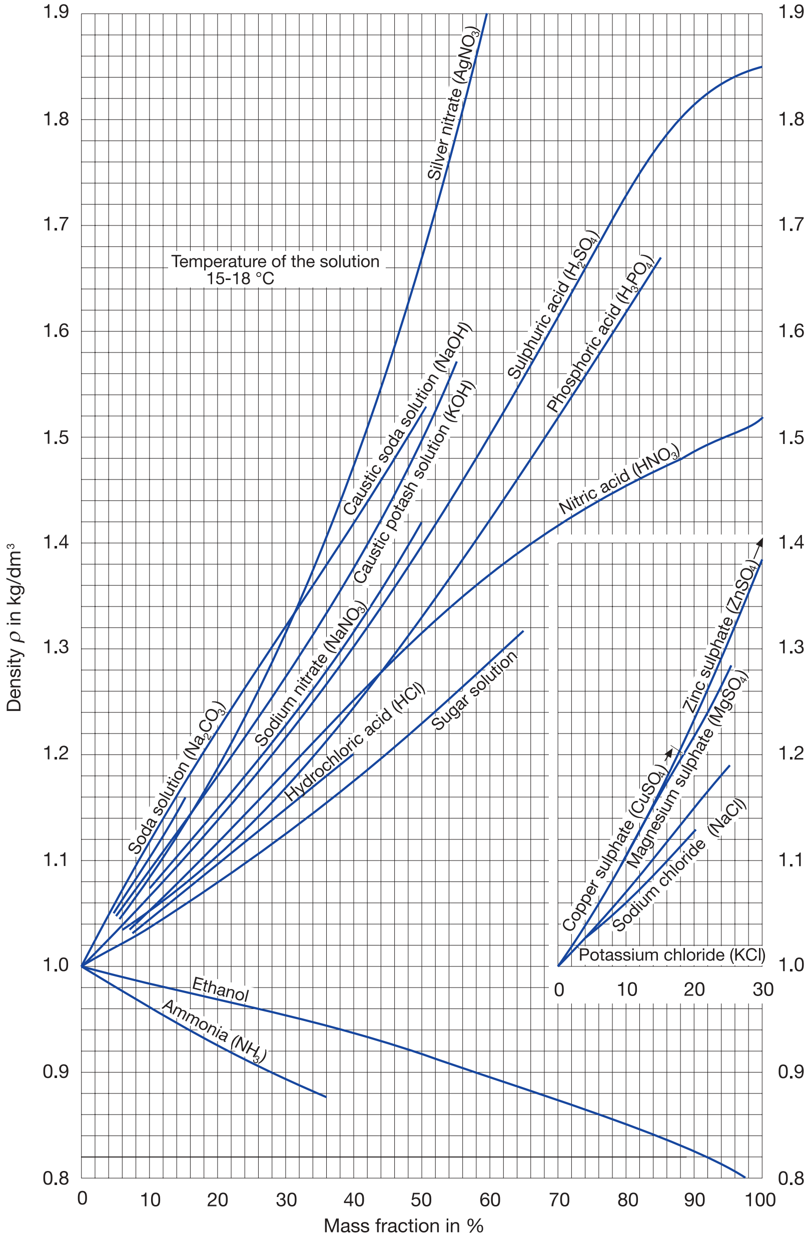

Fig. 28

3.1.4 Density and specific volume of gases

In the international system of units, the specific volume is the reciprocal of the density.

$$v = 1/\rho \text{ in } m^3/kg \qquad \rho = m/V \qquad V = v \cdot m$$

For real gases in the range of standard conditions, the general equation of state for ideal gases can be applied. Here it must be noted that a correction must be made for higher pressures or in the vicinity of the dewpoint. By means of the compressibility factor K, the behaviour of real gases can then be referred to that of ideal gases ($p \cdot v = K \cdot R_i \cdot T$).

$$\frac{p_1 \cdot v_1}{T_1} = \frac{p_2 \cdot v_2}{T_2} = \text{constant} = R_i \qquad v = \frac{R_i \cdot T}{p} \qquad \rho = \frac{1}{v} = \frac{p}{R_i \cdot T}$$

Numerical values for the density - e.g. those in Fig. 29 - usually refer to the standard condition of zero °C and 1013.25 mbar. When calculating the density for a different set of conditions, the following numerical value equation is often used. It is derived from the general equation of state; for this reason, the limitations regarding pressure and dewpoint of the gases apply.

$$\rho = \frac{270\, p}{T} \cdot \rho_o$$

ρ	kg/m^3	density in the operational state
ρ_o	kg/m^3	standard density
p	bar	absolute pressure
T	K	temperature (T = 273 + t)

Air ($0.78\ N_2 + 0.21\ O_2$ +...)	1.293	Ethane C_2H_6	1.356
Oxygen O_2	1.429	Propylene C_3H_2	1.915
Nitrogen N_2	1.251	C_mH_n*	1.392
Carbon monoxide CO	1.250	Coke-oven and grid gas	0.50
Carbon dioxide CO_2	1.977	Producer gas	1.15
Hydrogen H_2	0.090	Blast furnace gas	1.27
Methane CH_4	0.717	Water gas	0.69
Acetylene C_2H_2	1.171	Ammonia NH_3	0.77
Ethylene C_2H_4	1.261	Sulphur dioxide SO_2	2.92

Fig. 29 Standard density ρ_0 of various gases in kg/m^3

* Composition in parts by volume: $0.80\ C_2H_4 + 0.20\ C_3H_6$

For a mixture of various gases, the following relationship applies:

$$\rho_{o\ mixture} = \frac{n_1 \cdot \rho_{o1} + n_2 \cdot \rho_{o2} + \ldots}{n_1 + n_2 + \ldots}$$

ρ_{o1}, ρ_{o2}	densities of the separate gases
n_1, n_2	parts by volume of the separate gases

3.2 Viscosity

3.2.1 Viscosity of liquids

The viscosity exerts an influence on the flow processes and thus on the pressure drop in the flowing media. Viscosity is that characteristic of a liquid or gaseous substance of accommodating a shear stress that is dependent on the speed profile, through the mechanism of shear deformation. In addition to the internal friction forces which hinder the motion, inertial forces are also active in the flowing process. Accordingly, two types of viscosity are specified:

Dynamic viscosity η

This is a measure for the internal friction resulting from mutual displacement of adjacent molecules, defined according to the Newtonian friction law, with the derived SI unit “pascal-second” (Pa · s)

$$1 \text{ Pa} \cdot \text{s} = 1 \ \frac{\text{N s}}{\text{m}^2}$$

Kinematic viscosity ν

This is a measure for the simultaneous effect of frictional and inertial forces, defined as the quotient of dynamic viscosity and density ($\nu = \eta/\rho$, where $\rho = \gamma/g$), with the unit

$$\frac{\text{m}^2}{\text{s}}$$

In addition to these legal units, the physical units according to the cm-g-s system and also conventional units of the viscosity measurement apparatus are also occasionally encountered, for example:

Physical units

$$\frac{\text{dyn s}}{\text{cm}^2} = 1 \text{ poise (1 P)} = 100 \text{ centipoise (100 cP) for } \eta$$

$$\frac{\text{cm}^2}{\text{s}} = 1 \text{ stokes (1 St)} = 100 \text{ centistokes (100 cSt) for } \nu$$

Conventional units

Germany:	Engler numbers	°E
England:	Redwood seconds	second
USA:	Saybolt Universal Seconds	SUS or SSU

The Redwood and Saybolt scales express the time in seconds needed by the test fluid to run out of defined containers. The Engler numbers express the time needed by 200 cm^3 of test fluid to run out of a container in relation to 200 cm^3 of distilled water at 20 °C.

Some useful unit conversions

$$\text{for } \eta\text{: } 1 \text{ Pa} \cdot \text{s} = 1 \frac{\text{N s}}{\text{m}^2} = 1 \frac{\text{kg}}{\text{m s}} = 10 \frac{\text{g}}{\text{cm s}} = 10 \text{ P}$$

$$1 \frac{\text{kp s}}{\text{m}^2} = 9.81 \frac{\text{N s}}{\text{m}^2} = 98.1 \frac{\text{dyn s}}{\text{cm}^2} = 98.1 \text{ P}$$

$$1 \frac{\text{dyn s}}{\text{cm}^2} = 1 \frac{\text{g}}{\text{cm s}} = 1 \text{ P}$$

$$\text{for } \nu\text{: } 1 \frac{\text{m}^2}{\text{s}} = 10^4 \frac{\text{cm}^2}{\text{s}} = 10^4 \text{ St} = 10^6 \text{cSt} = 10^6 \frac{\text{mm}^2}{\text{s}}$$

The conversion from conventional units - e.g. to mm^2/s (= cSt) - is imprecise. Physical measurement values can be converted to conventional units with the aid of conversion tables. Fig. 30 gives the corresponding values of the conventional scales for various values of ν in mm^2/s.
Pure water at 20 °C has a dynamic viscosity $\eta = 1.002 \cdot 10^{-6}$ Pa · s and a kinematic viscosity $\nu = 1.0038$ mm^2/s.

Kinematic viscosity ν mm^2/s	Relative run-out time E_t °E	Equivalent Redwoos No.I viscosity (at 70 °F) seconds	Equivalent Saybolt viscosity (at 100 °F) SUS
2.0	1.119	–	32.6
3.0	1.217	–	36.0
4.0	1.307	35	39.2
5.0	1.394	38	42.4
6.0	1.480	41	45.6
7.0	1.566	43	48.8
8.0	1.653	46	52.1
9.0	1.742	49	55.4
10	1.843	52	58.8
12	2.022	58	66.0
14	2.222	65	73.5
16	2.432	71	81.4
18	2.650	78	89.5
20	2.876	85	97.8
22	3.11	93	106.3
24	3.35	100	115.0
26	3.59	108	123.7
28	3.83	116	132.6
30	4.08	123	141.5
35	4.71	143	164.0
40	5.35	164	186.8
45	6.00	184	210
50	6.65	204	233
55	7.30	224	256
60	7.95	244	279
100	13.20	406	463

Fig. 30 Conversion table for viscosity figures
For the Engler viscometer, the influence of temperature is not considered in the conversion. For the Saybolt viscometer, the run-out times at 210 °F are specified as being 1 % higher than at 100 °F, and for the Redwood no. I viscometer at 200 °F as 2 to 3% higher than at 70 °F.

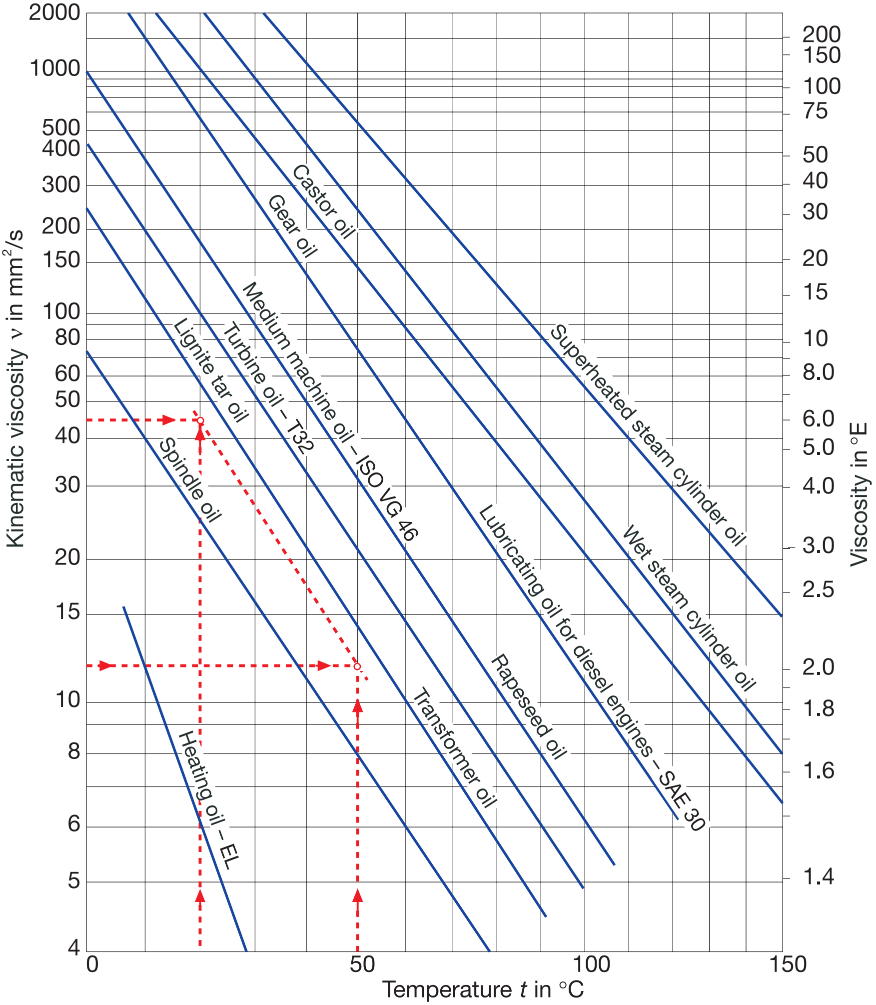

Fig. 31 **Relationship between viscosity and temperature**

Liquid		10 °C	30 °C	50 °C	70 °C	90 °C
Acetone		0.45	0.37	0.31		
Ethanol		1.85	1.27	0.90		
Benzol		0.87	0.64	0.50		
Glycerol	at 20 °C: 11.9	–	4.9	–		
Phenol	at 20 °C: 10.9	–	6.5	3.2		
Pyridine		1.14	0.85	–		
Carbon disulphide		0.31	0.27	–		
Carbon tetrachloride		0.71	0.53	0.41		
Tetraline	at 20 °C: 2.06	–	–	1.34		
Toluol		0.77	0.60	0.49		
Xylol (typical values)		0.91	0.70	0.56		
Crude oils (reference values):						
Argentina	ρ = 939 kg/m^3	–	–	600	200	50
Mexico	ρ = 940 kg/m^3	–	800	250	90	32
Germany, Hanover	ρ = 941 kg/m^3	–	500	125	42	14,5
Baku	ρ = 929 kg/m^3	–	260	80	31	12
Texas		300	80	30	14	–
Romania	ρ = 940 kg/m^3	270	70	25	12	5.5
Iran		140	35	13	6.5	3
Borneo		19	9	5	3.2	1.9
Galicia	ρ = 855 kg/m^3	12.5	6	3.5	2.3	1.4
Heavy lignite tar		–	–	300	60	14
Light lignite tar		120	30	10	5	2.4
Coke tar from hard coal		–	220	60	22	9
Low-temperature tar from Ruhr coking coal		–	170	25	7.5	2.4

Fig. 32 Kinematic viscosity of some liquids at various temperatures (10^6 ν in m^2/s)

Liquid		10^6 ν m^2/s	ρ kg/m^3
Spirits	95%	1.94	809
	90%	2.19	823
	85%	2.46	836
Naphthalene, pure		0.905	979
Benzene		0.80-0.76	700-740
Olive oil		117.00	920
Castor oil		1480.00	970
Turpentine oil		1.86	875
Nitric acid			
	25%	1.16	1150
	40%	1.31	1250
	91%	0.95	1500
Sulphuric acid			
	25%	1.66	1182
	50%	3.06	1399
	75%	10.0	1674
	100%	14.7	1836

Liquid		10^6 ν m^2/s	ρ kg/m^3
Beer		1.15	1020-1040
Milk		2.90	1030
Wine		1.15	990-1000
Solution of common salt in water			
	5% NaCl	1.17	1036
	10% NaCl	1.25	1073
	20% NaCl	1.64	1150
Paraffin (kerosene)		1.75-2.85	800-825
Petrol (gasoline)		0.82	737
		0.61	708
		0.46	680

Fig. 33 Kinematic viscosity and density of various liquids at 15 °C

3.2.2 Viscosity of gases and steam

The types and characteristics of viscosity mentioned in Section 3.2.1 for liquids also apply here. However, the density and kinematic viscosity of gases and steam are dependent on pressure, whilst the numerical value of the dynamic viscosity at pressures of up to 10 bar absolute and constant temperatures only changes by less than 1 %. For this reason, calculation with the dynamic viscosity η (*t*) is preferred for gases and vapours. Corresponding data is given in the diagrams of Figs. 34 and 35.

In the range up to 10 bar absolute, η changes by less than 1 %. However, at higher pressures and with an air temperature of e.g. 20 °C

for *p*	1	80	120	160	200	bar absolute
$10^6\ \eta$	18.5	20.0	23.5	27.5	32.5	Pa · s

An adequate approximation for the dynamic viscosity of gas mixtures can be obtained for all temperatures from the following equation:

$$\eta_{mixture} \approx \frac{n_1\,\eta_1 Z_1 + n_2\,\eta_2 Z_2 + \ldots}{n_1 Z_1 + n_2 Z_2 + \ldots}$$

n_1, n_2 parts by volume of the separate gases
η_1,η_2 dynamic viscosity of the separate gases
Z_1, Z_2 constant

According to Herning-Zipperer, the constants Z_1 and Z_2 of the gases contained in the mixture are as follows:

Gas type	N_2	CO	CO_2	H_2	CH_4	C_mH_n*
Constant	59	62	116	8	55	96

* Composition in parts by volume: 0.80 C_2H_4 + 0.20 C_3H_6

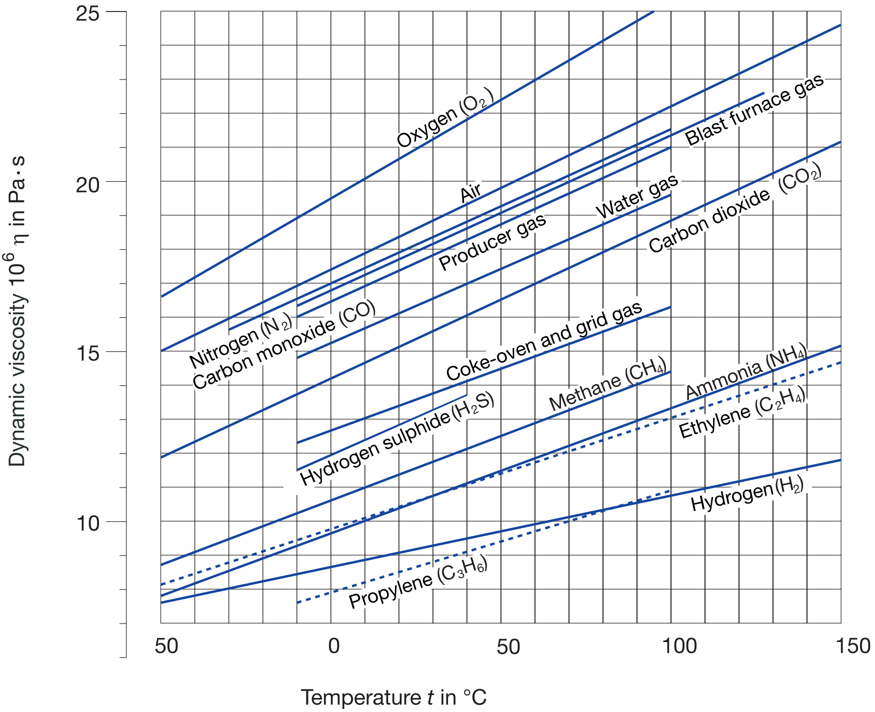

Fig. 34 **Dynamic viscosity of some gases at various temperatures**

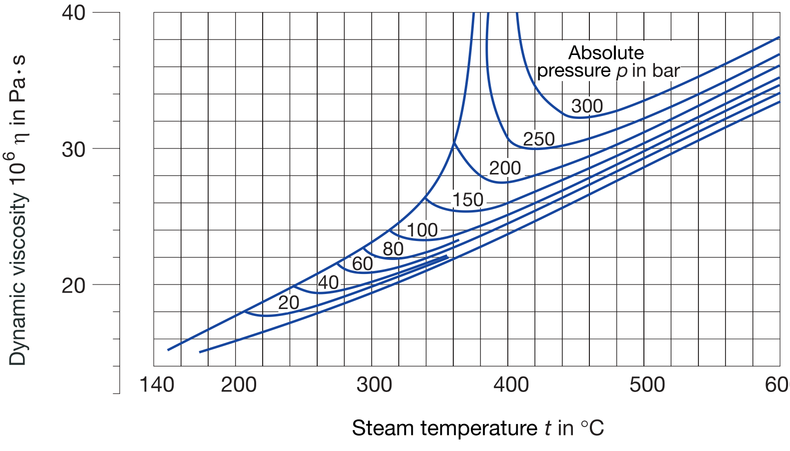

Fig. 35 **Dynamic viscosity of steam at various temperatures (according to Timroth)**

3.3 Various Properties of Substances

3.3.1 Solid and liquid substances ρ, t_0, t_S, λ, c

Column 1: Referred to +20 °C (* for +15 °C)
Column 2: Values with * are softening or setting points.
Column 3: Referred to 1013.25 mbar. For substances for which there is no liquid phase (sublimation): numerical values in brackets.
Column 4: Referred to 20 °C or to the temperatures given next to the substance names.
Column 5: Typical values for temperatures between 0 and 100 °C.

Column Substance	1 Density ρ kg/dm³	2 Melting point t_o °C	3 Boiling point t_s °C	4 Thermal conductivity λ W/mK	5 Specific heat c kJ/kg K
Acetone	0.791	-94.8	56.2	0.162	2.156
Alcohol, ethyl (95 vol.%)	0,789	-114.2	78.3	0.167	2.395
Alcohol, methyl (95 vol.%)	0.792	-97.6	64.7	0.202	2.495
Aluminium, pure (99.5%)	2.73	658.5	2270	221	0.909
Aluminium, cast	2.56	658	~ 2200	209	0.904
Aluminium oxide	3.96	2046	2980	–	0.080
Ammonia water (25%)	0.91	-77.8	-33.5	0.494	4.19
Ammonium chloride	1.52	–	–	–	–
Asbestos, pure	2.1...2.8	1500	–	0.17...0.19	0.816
Asbestos sheets	2.0	–	–	0.7	0.75
Ashes	0.7	from 500*	–	0.70	0.80
Asphalt (pitch)	1.1...1.5	27*...57*	–	0.70	0.92
Bakelite	1.33	–	–	0.23	1.604
Benzene	0.71	-150	90...100	0.16	2.09
Benzol	0.879	5.4	80.2	0.14	1.80
Bitumen (tar)	1.1	60*...160*	–	0.167	1.63
Board, asbestos	1.2	–	–	0.1...0.16	0.84
Board, cardboard	0.8	–	–	0.07...0.22	1.26
Boiler scale	2.4...2.6	~ 1200	~ 2800	0.08...2.3	0.80
Brass	8.4...8.7	900...980	2300	81...116	0.385
Bronze, aluminium	7.7	1050	2300	83	0.435
Bronze, phosphor	8.8	950	–	35...81	0.360
Bronze, tin	8.73...8.85	1020...1070	–	35...151	0.381
Carbon disulphide	1.10	-111.8	46.3	0.16	1.01
Carbon, pure	3.51	–	(3540)	8.4	0.854
Carbon tetrachloride	1.594	-22.9	76.7	0.107	1.26
Carborundum stone	3.12	> 2200	–	15.2	–
Cast steel	7.86	~ 1350	2500	52	0.502
Caustic potash solution (27%)	1.26	–	–	–	3.60
Caustic soda solution (66%)	1.70	–	–	–	3.77
Celluloid	1.38	–	–	0.21	1.26

Fig. 36

Column Substance	1 Density ρ kg/dm³	2 Melting point t_o °C	3 Boiling point t_s °C	4 Thermal conductivity λ W/mK	5 Specific heat c kJ/kg K
Chalky sandstone	1.80...1.92	1500*	2600	0.9...1.0	0.71
Chromium	7.1	1765	2660	–	0.452
Clay, dry	1.8	1600	2980	0.84	0.833
Clay, wet	2.6	1600	2980	1.10...2.2	0.92
Clinker	2.6...2.7	1600*	–	0.5...0.9	0.84
Coal, hard	1.2...1.5	–	–	0.16...0.27	1.01
Glance coal	1.2...1.7	–	–	0.33	1.09
Lump coal	1.2...1.5	–	–	0.21	1.26
Coal dust	0.6...0.75	–	–	0.19	1.30
Coal briquettes	1.25...1.3	–	–	0.29	1.59
Concrete, gravel	1.8...2.3	–	–	1.28	0.88
Concrete, pumice stone	1.2	–	–	0.47	1.01
Concrete, slag	0.8...1.2	–	–	0.5...0.7	0.92
Constantan	8.89	~ 1600	2400	22.7	0.410
Copper, pure	8.93	1083	2595	393	0.389
Copper, rolled	8.9...9.0	1080	2310	372	0.389
Cork sheets	0.1...0.3	–	–	0.03...0.06	1.59
Corundum	4.0	2050	2950	0.7	0.850
Diamond	3.51	–	(3540)	8.4	0.603
Diatomite	2.0...2.6	> 1000	–	0.06...0.17	0.88
Ether, diethyl (abs.)	0.714	-116.3	34.6	0.138	2.336
Ether, sulphuric	0.73	-129	35	0.14	2.26
Fats	0.92...0.94	30...175	~ 300	0.21	0.63...0.75
Felt	0.15...0.3	–	–	0.03...0.07	–
Fibre	1.0...1.5	–	–	0.21	1.26
Fireclay brick	1.85...2.2	1400*...1700*	2900	0.5	0.80...0.88
Glass, window	2.4...3.0	~ 700	2600	0.76...0.80	0.75...0.80
Glass, plexiglass	1.2	80*	–	0.19	1.88
Glycerol	1.26	19 or 0*	290	0.28	2.43
Granite	2.6...3.0	1400*...1600*	–	2.9...4.1	0.84
Graphite, natural	1.8...2.3	–	(3900)	12...174	0.82
Gunmetal (red bronze)	8.5...8.7	950	2300	60	0.381
Gutta-percha	0.96...1.02	148	180	0.19	–
Gypsum, burnt, powdered	1.81...1.82	1450	–	0.24	1.09
Gypsum, cast, dry	0.97	450	–	0.43...0.6	0.84
Hemp fibres, dry	0.045	–	–	0.049	–
Hydrochloric acid (25%)	1.15	14	102	0.47	3.14
Ice at 0 °C	0.917	0	100	2.23	2.110
Iron, cast (grey cast iron)	7.25	1132...1350	2500	42...63	0.532... ...0.540
Iron, pure	7.86	1533	2730	71	0.465
Iron, wrought	7.79...7.85	~ 1200	2500	58	0.477
Jute fibres, loose, ruffled	0.056	–	–	0.036	1.34
Lead, cast	11.25...11.37	326	1525	35	0.130

Fig. 36 Continued

Column Substance	1 Density ρ kg/dm³	2 Melting point t_o °C	3 Boiling point t_s °C	4 Thermal conductivity λ W/mK	5 Specific heat c kJ/kg K
Lead, red	8.6...9.1	900	–	0.7	0.25
Lead, pure	11.34	327.4	1692	27.1	0.1310
Lime, burnt	0.9...1.3	2570	–	0.84	–
Lime, slaked	1.15...1.25	–	–	–	–
Limestone (amorphous)	2.46...2.84	destr. 825	–	0.15...2.3	0.909
Linoleum	1.15...1.3	–	–	0.15...0.19	–
Magnesia (magnesium oxide)	3.2...3.6	2642	2800	13.4	1.01
Magnesia powder	0.3...0.4	2642	2800	0.06...0.07	0.96
Magnesite	3.0...5.1	1600-1800	–	1.34	1.09
Magnesium, pure	1.74	650	1102	172	1.034
Manganese	7.3	1244	2152	50	0.498
Marble	2.5...2.8	1290...1340*	2870	2.1...3.5	0.80...1.01
Mercury	13.55	-38.89	357.25	8.4	0.138
Mica	2.9...3.1	1300	–	0.42	0.88
Naphthalene	1.145	80.2	217.9	0.30	1.281
Nickel, pure	8.8	1453	3177	87	0.414
Nitric acid (100%)	1.52	-47	86	0.53	1.72
Oil, heating/fuel	0.84...0.92*	-5	175...350	0.12	1.97
Oil, linseed	0.94*	-20	316	0.15	1.97
Oil, machine	0.91	-5	380...400	0.126	1.67
Paper, cellophane	1.42	–	–	0.17	1.47
Paper, cellulose	0.7...1.1	–	–	0.07...0.14	1.34
Paraffin	0.87...0.93	35...52	300	0.21...0.29	3.27
Peat, air-dry	0.5...0.9	–	–	0.06...0.08	1.88
Phenol	1.3...1.7	40.9	181.2	0.22	1.63
Phosphorus, red	2.20	590	200	–	0.84...1.05
Phosphorus, white	1.83	44.2	287	–	0.75...0.84
Platinum	21.4	1774	3804	71	0.1331
Porcelain	2.3...2.5	1670	–	0.8...1.9	0.80...0.92
Quartz	2.1...2.65	1470	2590	1.26	0.80...0.92
Rubber, foam	0.06...0.09	–	–	0.06	–
Rubber, hard	1.2...1.8	–	–	0.15...0.17	1.42
Salt, sat. solution of table salt	1.2	–18	108	0.48	3.27
Salt, table	2.1...2.4	801	1465	–	0.92
Sandstone, artificial	1.9...2.5	~ 1650	–	1.7	0.92
Sandstone, natural	2.6...2.7	1500*...1600*	2600	1.3...1.9	0.92
Silk, artificial	1.25...1.6	–	–	0.049	–
Silk, raw	1.56	–	–	0.042	2.307
Silver, pure	10.50	960.5	2170	419	0.234
Slag, blast furnace	2.6...3.3	1300...1430	–	0.10...0.17	–
Slag, boiler	1.7	~ 1350	–	0.14...0.16	–
Snow, loose (at 0 °C)	0.1	0	100	0.05...2.2	2.1

Fig. 36 Continued

Column Substance	1 Density ρ kg/dm³	2 Melting point t_o °C	3 Boiling point t_s °C	4 Thermal conductivityλ W/mK	5 Specific heat *c* kJ/kg K
Soapstone	2.6...2.8	1400*	–	2.7...3.4	0.88
Soda, calcined	2.53	850	–	0.6	3.60
Soda, crystalline	1.45	–	–	0.6	3.56
Soot	1.6...1.7	–	(3540)	0.07...1.2	–
Spirits (95 vol.%)	0.83	-90	78	0.16	2.39
Stearin	0.94	43...68	350	–	–
Steel, C (structural)	7.84...7.85	1470...1500	2500	47...58	0.477
Steel, Cr (VM)	7.7...7.75	1480	2500	21...40	0.46...0.50
Steel, Cr-Ni (VA, VCN)	7.7...7.88	1370...1500	2500	13...16	0.494
Steel, Cr-Ni-Mn (BM)	6.4	1550	2600	20	0.498
Steel, Ni	7.85	1480	2500	~ 47	0.486
Sulphur, crystalline	1.96	118.95	444.6	0.29	0.720
Sulphur, natural	1.96...2.07	112.8	444.6	0.27	0.75
Sulphuric acid (96%)	1.84	10.5	338	0.50	1.47
Sulphurous acid	1.49	-73	-10	0.20	1.34
Tar from hard coal	1.20	-15	300	0.19	1.67
Tin, pure	7.28	231.8	2430	65	0.230
Titanium	4.43	1727	>3000	–	0.611
Toluol	0.868	-94.5	110.6	0.141	1.72
Tungsten	19.1	3380	6000	163	0.134
Vanadium	5.6	1726	3000	–	0.50
Wax	0.96...1.04	46	65...70	0.084	3.43
Wool, asbestos	0.3	1100*	–	0.09	–
Wool, cotton, dry	1.47...1.50	–	–	0.07	1.273
Wood-fibre boards	1.52...1.60	–	–	0.06...0.07	–
Wool, glass	0.1	400*	–	0.06	0.80
Wool, sheep	0.2	–	–	0.041	1.72
Wool, slag	0.2...0.3	1500*	–	0.03...0.06	0.75
Wool, viscose staple fibre	1.5	–	–	0.08	1.357
Xylol, meta-	0.864	-47.9	139.2	0.142	1.717
Xylol, ortho-	0.879	-25.3	144.4	0.144	1.733
Xylol, para-	0.861	13.3	138.4	0.13	1.700
Zinc, cast	6.86	419	920	110	0.38
Zinc, injection-moulded	6.8	393	~ 1000	140	0.38
Zinc, pure	7.14	419.4	907	121	0.389

Fig. 36 Continued

3.3.2 Gases and vapours

Referred to 0 °C and 1013.25 mbar

Gas or vapour	Chemical symbol	Molar mass M kg/kmol	Density ρ'' kg/m³	Relative density (S.G.) ρ''/ρ_{air} for air = 1	Volume ν'' m³/kg	Melting point: Temperature t_o °C	Melting point: Fusion heat kJ/kg	Boiling point: Temperature t_s °C	Boiling point: Evaporation heat r kJ/kg	Boiling point: Density of the liquid ρ' kg/dm³	Gas constant R J/(kg K)	Thermal conductivity coefficient λ W/(m K)	Specific heat[1] c_p kJ/(kg K)	Specific heat[1] c_v kJ/(kg K)	Specific heat[1] C_p kJ/(m³ K)	Specific heat[1] C_v kJ/(m³ K)	Adiabatic exponent[1] $x = c_p/c_v$
Acetone	C_3H_6O	58.08	2.590	2.003	0.386	- 94.8	96.3	+ 56.2	523.4	0.749	143.2	0.0097	1.239	1.097	3.211	2.839	1.131
Acetylene	C_2H_2	26.04	1.171	0.906	0.854	- 83.3	96.3	- 83.6	829.0	0.613	319.4	0.0184	1.616	1.298	1.892	1.520	1.245
Air (dry)	–	(28.96)	1.293	1.000	0.774	- 213	–	- 192.3	196.8	0.875	287.0	0.0243	1.005	0.716	1.298	0.925	1.404
Alcohol, ethyl	C_2H_6O	46.07	2.055	2.590	0.487	- 114.2	108.0	+ 78.3	845.7	0.747	180.5	0.0138	1.524	1.344	3.132	2.763	1.134
Alcohol, methyl	CH_4O	32.04	1.429	1.106	0.700	- 97.6	103.0	+ 64.7	1101.1	0.737	259.5	0.0140	1.340	1.080	1.913	1.545	1.240
Ammonia	NH_3	17.03	0.771	0.597	1.296	- 77.9	339.1	- 33.4	1369.1	0.680	488.2	0.0217	2.056	1.566	1.587	1.210	1.313
Argon	Ar	39.94	1.784	1.378	0.561	- 189.3	29.3	- 185.9	159.1	1.820	208.2	0.0163	0.519	0.314	0.925	0.557	1.665
Ethane	C_2H_6	30.07	1.356	1.049	0.738	- 183.3	93.0	- 88.6	489.9	0.546	276.5	0.0180	1.650	1.373	2.236	1.863	1.201
Ether, diethyl	$C_4H_{10}O$	74.12	3.307	2.558	0.302	- 116.3	100.5	- 34.6	360.1	0.698	112.2	0.0126	1.444	1.331	4.777	4.405	1.085
Ethylene	C_2H_4	28.05	1.261	0.975	0.793	- 169.5	104.7	- 103.7	523.4	0.568	296.5	0.0167	1.461	1.164	1.892	1.507	1.255
Benzol	C_6H_6	78.11	3.485	2.695	0.287	+ 5.4	127.7	+ 80.1	394.4	0.894	106.5	0.0088	0.950	0.846	3.312	2.939	1.127
Blast furnace gas[2]	–	(28.33)	≈ 1.26	0.977	≈ 0.791	- 210	–	- 170	–	–	≈ 293.2	0.0219	1.009	0.716	1.277	0.904	1.410
Butane	C_4H_{10}	58.12	2.593	2.005	0.386	- 138.4	77.5	- 0.5	385.6	0.602	143.1	0.0138	1.599	1.457	4.145	3.722	1.114
Carbon dioxide	CO_2	44.01	1.977	1.529	0.506	- 56.6	184.2	- 78.2	573.6	1.219	189.0	0.0142	0.816	0.628	1.616	1.243	1.300
Carbon disulphide	CS_2	76.14	3.397	2.628	0.294	- 111.5	57.8	+ 46.3	351.7	1.193	109.2	0.0067	0.582	0.473	1.976	1.608	1.230
Carbon monoxide	CO	28.01	1.250	0.967	0.800	- 205.0	30.1	- 191.6	217.7	0.801	296.8	0.0222	1.038	0.741	1.298	0.925	1.401
Carbon tetrachloride	CCl_4	153.84	6.863	5.308	0.146	- 22.9	16.3	+ 76.7	195.1	1.481	54.0	–	0.523	0.469	3.592	3.220	1.116
Chlorine	Cl	70.91	3.164	2.447	0.316	- 100.5	188.4	- 34.0	259.6	1.512	117.3	0.0085	0.473	0.356	1.499	1.126	1.329
Flue gas[2]	–	(29.30)	≈ 1.34	1.033	≈ 0.749	- 200	–	- 180	–	–	≈ 277.5	–	1.009	0.729	1.348	0.976	1.380
Hydrogen chloride	HCl	36.47	1.639	1.268	0.610	- 111.2	56.1	- 84.8	443.8	1.135	228.0	0.0084	0.795	0.569	1.302	0.934	1.397
Helium	He	4.003	0.179	0.138	5.602	- 270.7	3.52	- 268.9	20.9	0.125	2077.1	0.1434	5.200	3.123	0.929	0.557	1.665
Hydrogen	H_2	2.02	0.090	0.070	11.127	- 259.2	58.2	- 252.8	460.5	0.071	4124.5	0.1754	14.051	9.931	1.264	0.892	1.415
Hydrogen sulphide	H_2S	34.08	1.251	1.191	0.650	- 85.6	69.5	- 60.4	548.5	0.957	244.0	0.0126	0.992	0.749	1.239	0.938	1.324
Methane	CH_4	16.04	0.717	0.555	1.395	- 182.5	58.6	- 161.5	510.4	0.415	518.3	0.0306	2.165	1.645	1.553	1.181	1.316
Nitrogen	N_2	28.02	1.250	0.967	0.800	- 210.5	25.7	- 195.7	201.0	0.810	296.7	0.0238	1.038	0.729	1.298	0.913	1.425
Oxygen	O_2	32.00	1.429	1.105	0.700	- 218.8	13.82	- 182.9	213.5	1.131	259.9	0.0242	0.909	0.649	1.298	0.925	1.400
Producer gas[2]	–	(25.70)	≈ 1.15	0.886	≈ 0.873	- 210	–	- 170	–	–	≈ 323.6	0.0216	1.160	0.833	1.327	0.959	1.388
Propane	C_3H_8	44.09	2.019	1.562	0.495	- 187.7	80.0	- 42.1	426.2	0.585	188.6	0.0151	1.549	1.361	3.128	2.747	1.138
Propylene	C_3H_6	42.08	1.877	1.452	0.530	- 185.0	70.0	- 47.8	438.4	0.686	197.6	–	1.424	1.227	2.671	2.303	1.160
Sulphur dioxide	SO_2	64.07	2.926	2.264	0.342	- 75.5	116.8	- 10.0	401.9	1.460	129.8	0.0084	0.586	0.456	1.717	1.336	1.284
Sulphur trioxide	SO_3	80.07	3.572	2.763	0.280	+ 16.8	311.9	+ 44.8	519.2	1.311	103.9	–	0.607	0.502	2.169	1.796	1.208
Toluol	C_7H_8	92.13	4.110	3.179	0.243	- 94.5	72.0	+ 110.6	355.9	0.781	90.2	0.0129	1.030	0.938	4.233	3.856	1.098
Town gas[2]	–	≈ (11.7)	≈ 0.52	≈ 0.39	≈ 1.92	- 230	–	- 210	–	–	≈ 713	0.0605	2.646	1.934	1.377	1.005	1.369
Water	H_2O	18.02	0.804	0.622	1.244	0.0	332.4	+ 100.0	2256.3	0.958	461.5	0.0251	1.842	1.382	1.482	1.114	1.332

Fig. 37

1 Averaged between 0 ...1013 mbar

2 For approximate calculations only

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3.3.3 Refrigerants

In addition to the classic refrigerants – such as sulphur dioxide (SO_2), methyl chloride (CH_3Cl) and ammonia (NH_3) - which do not meet all the safety requirements, owing to their chemical and physical effects, and the chlorofluorohydrocarbons (CFCs) known as safety refrigerants under the trademark “Freon”, refrigerating brines are also used in industry.

Refrigerating brines are aqueous salt solutions, e.g. of table salt, calcium chloride or magnesium chloride. They are used for indirect cooling to low temperatures, when water is no longer suitable or when other compounds – e.g. hydrocarbons – cannot be used because of increasing viscosity or because the solidification point is reached.

Solute	Mass fraction%	Density ρ kg/l	Associated point on the ice curve	Specific heat c kJ/kg K				
–	–	20°	°C	+20°	0°	-10°	-20°	-30°
NaCl	10	1.071	- 6.8	3.735	3.705			
	15	1.108	-11.5	3.567	3.546	3.534		
	20	1.148	-17.5	3.425	3.408	3.400		
	25	1.189	-11.2	3.295	3.278	3.270	3.329	
$CaCl_2$	15	1.129	-10.1					
	20	1.177	-17	3.123	3.077	3.052		
	25	1.228	-27.8	2.943	2.893	2.868	2.843	
	30	1.282	-51.5	2.788	2.738	2.713	2.688	2.663
$MgCl_2$	10	1.083	- 7.7	3.605	3.571			
	15	1.128	-16.4	3.341	3.291	3.270	3.245	
	20	1.176	-30.7	3.111	3.056	3.031	3.010	2.981
	25	1.225	-24.0	2.901	2.851	2.826	2.801	
	30	1.278	-16.2	2.705	2.650	2.625		

Fig. 38a

Solute	Dynamic viscosity η Pa s · 10^{-3}					Thermal conductivity coefficient λ W/m K			
–	+20°	0°	-10°	-20°	-30°	0°	-10°	-20°	-30°
NaCl	1.18	2.06				0.557	–	–	–
	1.37	2.35	3.33			0.552	0.536	–	–
	1.57	2.75	4.12			0.547	0.531	–	–
	1.86	3.33	5.20			0.542	0.527	–	–
$CaCl_2$	1.47	2.55	4.12			0.549	0.534	–	–
	1.86	3.14	4.90			0.543	0.528	–	–
	2.55	4.02	6.28	10.10		0.537	0.522	0.509	0.495
	3.63	5.69	9.12	14.71	22.06	0.531	0.516	0.504	0.490
$MgCl_2$	1.47	2.75				0.540	–	–	–
	1.96	3.82	5.39			0.527	0.511	–	–
	2.65	5.30	8.04	11.67		0.514	0.498	0.480	0.462
	4.12	8.34	13.24	21.18		0.501	0.485	0.469	–
	6.37	13.14	22.36			0.488	0.473	–	–

Fig. 38b

3.3.4 Thermal conductivity λ (*t*) for metals

The values of the metals rise and fall with the degree of purity. Moreover, they are dependent on the structure. The manufacturing process and the treatment therefore exert a considerable influence.

Metals	Properties at 20 °C ρ $\frac{kg}{m^3}$	c_p $\frac{kJ}{kg\,K}$	λ $\frac{W}{m\,K}$	Thermal conductivity λ in W/m K, Reference temperature in °C: 0	100	200	300	400
Pure aluminium	2700	0.896	229	229	229	229	229	
Duraluminium	2780	0.883	164	159	181	194		
Tin, pure	7280	0.226	64	66	59	57		
Zinc, pure	7130	0.381	112	113	110	106	101	93
Copper, pure	8930	0.381	385	386	379	373	369	364
Brass, 70 Cu, 30 Zn	8500	0.385	112	107	128	144	148	148
Bronze, 75 Cu, 25 Sn	8650	0.343	26					
Aluminium bronze, 95 Cu, 5 Al	8650	0.410	83					
Gunmetal, 85 Cu, 9 Sn, 6 Zn	8700	0.385	60	58	71			
Iron, pure	7870	0.452	72	73	67	62	55	49
Cast iron, C ≈ 4 %	7250	0.42	52					
Forged steel, C < 0.5 %	7830	0.46	59	59	57	52	48	44
Carbon steel, C ≈ 0.5 %	7820	0.465	53	55	52	49	44	42
Carbon steel, C ≈ 1.5 %	7740	0.486	36	36	36	36	35	34
Nickel steel, invar, Ni = 36 %	8120	0.46	11					
Chrome steel, Cr = 10 %	7760	0.46	31	31	31	31	30	24
Chrome steel, Cr = 20 %	7670	0.46	23	23	23	23	23	29
Chrome nickel steel, 18 Cr, 8 Ni	7800	0.46	16	16	17	17	19	20

Fig. 39

3.3.5 Thermal conductivity λ *(t)* for insulating materials

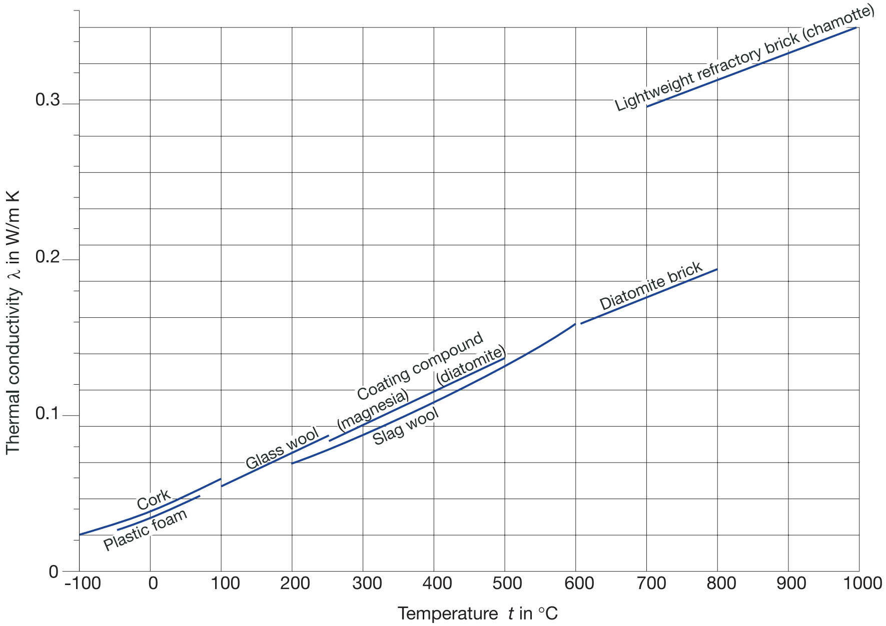


Fig. 40

3.4 Humidity of air

For a particular temperature, air can only hold a certain amount of moisture in the form of water vapour.

Example:

a) When saturated with water vapour (= 100 % relative air humidity), air at 23 °C has a moisture content of 21 g/m³.

b) Air at 23 °C with a relative air humidity of 70 % contains about 14.5 g/m³ of moisture and can be cooled down to about 17 °C (dashed line). This is the corresponding dew-point; if cooled further, the water vapour will condense.

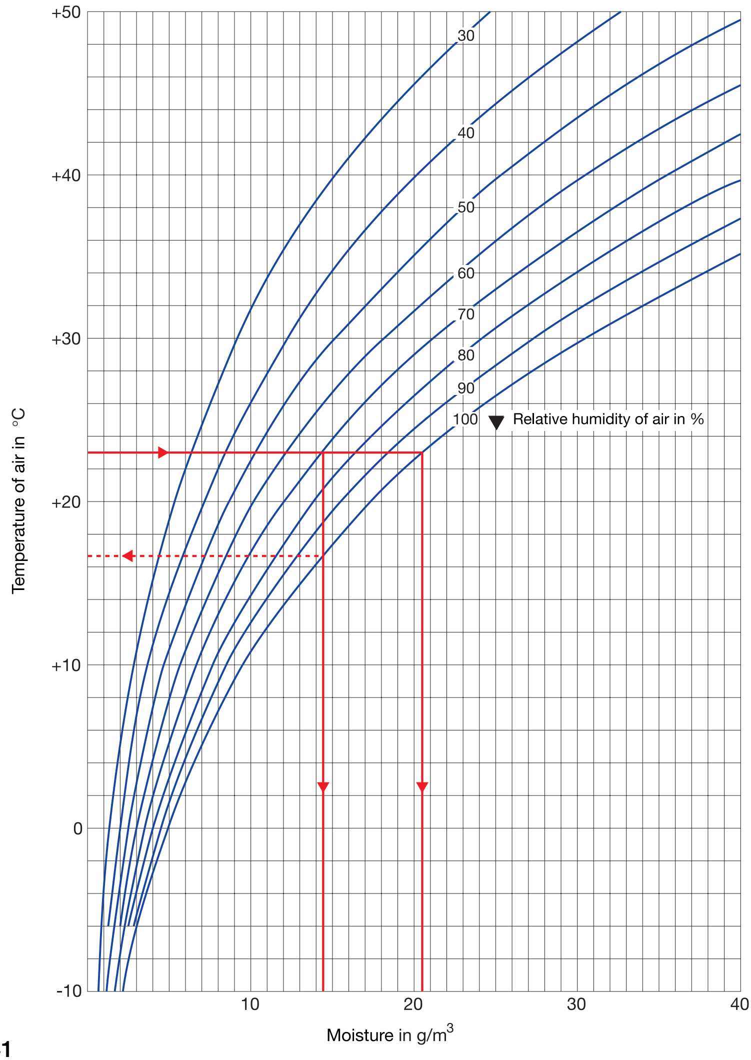


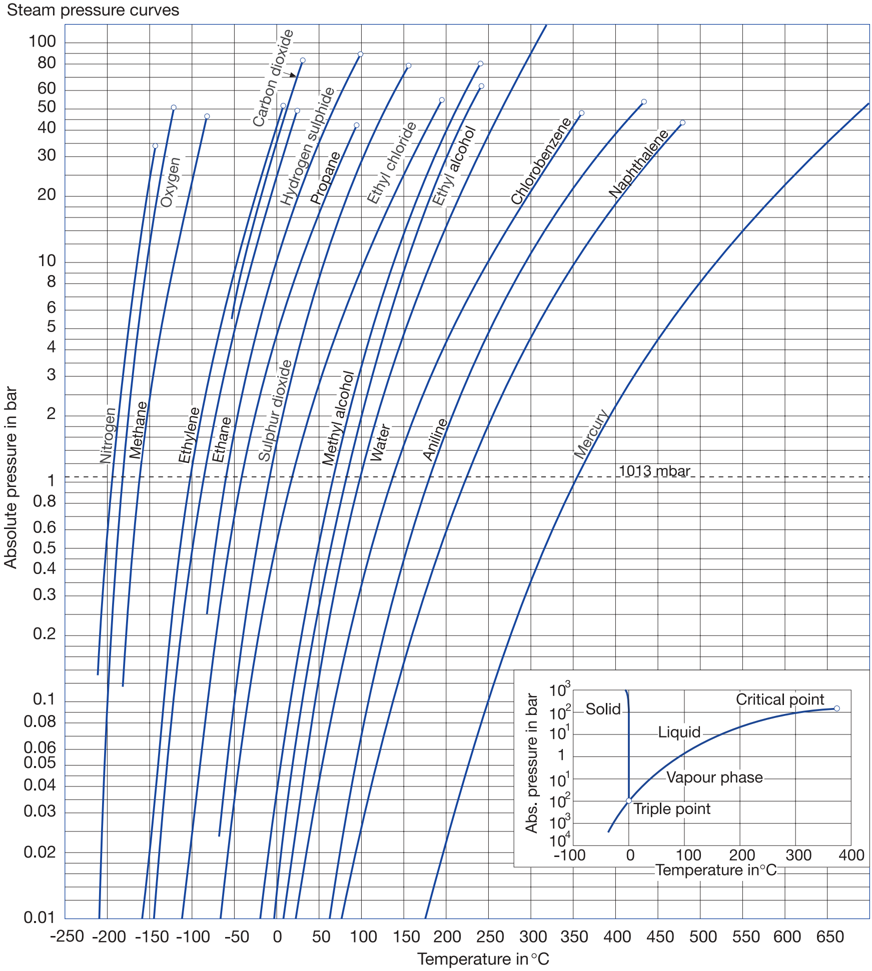
Fig. 41

3.5 Steam pressure curves of important substances

Fig. 43 contains the steam pressure curves of the substances named in Fig. 42 together with their chemical formulae; the curves for other substances can be added, often with perfectly adequate accuracy, if at least two or three points are known. Note that intersections with the existing curves are possible. In Fig. 43, the boiling points at 1013 mbar are indicated by the dashed line. Critical points are marked with a circle.

Substance	Formula	Substance	Formula
Nitrogen	N_2	Ethyl chloride	C_2H_5Cl
Oxygen	O_2	Methyl alcohol	CH_3OH
Methane	CH_4	Ethyl alcohol	C_2H_5OH
Ethylene	C_2H_4	Water	H_2O
Carbon dioxide	CO_2	Chlorobenzene	C_6H_5Cl
Ethane	C_2H_6	Aniline	$C_6H_5 \cdot NH_2$
Hydrogen sulphide	H_2S	Naphthalene	$C_{10}H_8$
Propane	C_3H_8	Mercury	Hg
Sulphur dioxide	SO_2		

Fig. 42



Steam pressure curves
Absolute pressure in bar
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1
0.8
0.6
0.5
0.4
0.3
0.2
0.1
0.08
0.06
0.05
0.04
0.03
0.02
0.01
-250 -200 -150 -100 -50 0 50 100 150 200 250 300 350 400 450 500 550 600 650
Temperature in °C
Nitrogen
Methane
Oxygen
Ethylene
Ethane
Carbon dioxide
Hydrogen sulphide
Sulphur dioxide
Propane
Methyl alcohol
Water
Ethyl chloride
Ethyl alcohol
Aniline
Chlorobenzene
Mercury
Naphthalene
1013 mbar
Abs. pressure in bar
10^3
10^2
10^1
1
10^1
10^2
10^3
10^4
Solid
Liquid
Critical point
Vapour phase
Triple point
-100 0 100 200 300 400
Temperature in °C

Fig. 43

3.6 Steam tables

The following tables are taken from the "h,s diagram" (enthalpy-entropy diagram) according to Mollier.

3.6.1 Saturation pressure table

Absolute pressure p bar	Temperature t_s °C	Specific volume of boiling water ν' m³/kg	Specific steam volume ν'' m³/kg	Steam density ρ'' kg/m³	Enthalpy of water h' kJ/kg	Enthalpy of steam h'' kJ/kg	Evaporation heat r kJ/kg
0.010	6.98	0.0010001	129.20	0.00774	29.34	2514.4	2485.0
0.015	13.04	0.0010006	87.98	0.01137	54.71	2525.5	2470.7
0.020	17.51	0.0010012	67.01	0.01492	73.46	2533.6	2460.2
0.025	21.10	0.0010020	54.26	0.01843	88.45	2540.2	2451.7
0.030	24.10	0.0010027	45.67	0.02190	101.00	2545.6	2444.6
0.035	26.69	0.0010033	39.48	0.02533	111.85	2550.4	2438.5
0.040	28.98	0.0010040	34.80	0.02873	121.41	2554.5	2433.1
0.045	31.04	0.0010046	31.14	0.03211	129.99	2558.2	2428.2
0.050	32.90	0.0010052	28.19	0.03547	137.77	2561.6	2423.8
0.055	34.61	0.0010058	25.77	0.03880	144.91	2564.7	2419.8
0.060	36.18	0.0010064	23.74	0.04212	151.50	2567.5	2416.0
0.065	37.65	0.0010069	22.02	0.04542	157.64	2570.2	2412.5
0.070	39.03	0.0010074	20.53	0.04871	163.38	2572.6	2409.2
0.075	40.32	0.0010079	19.24	0.05198	168.77	2574.9	2406.2
0.080	41.53	0.0010084	18.10	0.05523	173.86	2577.1	2403.2
0.085	42.69	0.0010089	17.10	0.05848	178.69	2579.2	2400.5
0.090	43.79	0.0010094	16.20	0.06171	183.28	2581.1	2397.9
0.095	44.83	0.0010098	15.40	0.06493	187.65	2583.0	2395.3
0.10	45.83	0.0010102	14.67	0.06814	191.83	2584.8	2392.9
0.15	54.00	0.0010140	10.02	0.09977	225.97	2599.2	2373.2
0.20	60.09	0.0010172	7.650	0.1307	251.45	2609.9	2358.4
0.25	64.99	0.0010199	6.204	0.1612	271.99	2618.3	2346.4
0.30	69.12	0.0010223	5.229	0.1912	289.30	2625.4	2336.1
0.40	75.89	0.0010265	3.993	0.2504	317.65	2636.9	2319.2
0.45	78.74	0.0010284	3.576	0.2796	329.64	2641.7	2312.0
0.50	81.35	0.0010301	3.240	0.3086	340.56	2646.0	2305.4
0.55	83.74	0.0010317	2.964	0.3374	350.61	2649.9	2299.3
0.60	85.95	0.0010333	2.732	0.3661	359.93	2653.6	2293.6
0.65	88.02	0.0010347	2.535	0.3945	368.62	2656.9	2288.3
0.70	89.96	0.0010361	2.365	0.4229	376.77	2660.1	2283.3
0.75	91.79	0.0010375	2.217	0.4511	384.45	2663.0	2278.6
0.80	93.51	0.0010387	2.087	0.4792	391.72	2665.8	2274.0
0.85	95.15	0.0010400	1.972	0.5071	398.63	2668.4	2269.8
0.90	96.71	0.0010412	1.869	0.5350	405.21	2670.9	2265.6
0.95	98.20	0.0010423	1.777	0.5627	411.49	2673.2	2261.7
1.00	99.63	0.0010434	1.694	0.5904	417.51	2675.4	2257.9

Fig. 44

Absolute pressure p bar	Tempe-rature t_s °C	Specific volume of boiling water v' m^3/kg	Specific steam volume v'' m^3/kg	Steam density ρ'' kg/m^3	Enthalpy of water h' kJ/kg	Enthalpy of steam h'' kJ/kg	Evapo-ration heat r kJ/kg
1.5	111.37	0.0010530	1.159	0.8628	467.13	2693.4	2226.2
2.0	120.23	0.0010608	0.8854	1.129	504.70	2706.3	2201.6
2.5	127.43	0.0010675	0.7184	1.392	535.34	2716.4	2181.0
3.0	133.54	0.0010735	0.6056	1.651	561.43	2724.7	2163.2
3.5	138.87	0.0010789	0.5240	1.908	584.27	2731.6	2147.4
4.0	143.62	0.0010839	0.4622	2.163	604.67	2737.6	2133.0
4.5	147.92	0.0010885	0.4138	2.417	623.16	2742.9	2119.7
5.0	151.84	0.0010928	0.3747	2.669	640.12	2747.5	2107.4
5.5	155.46	–	0.3426	2.920	655.78	2751.7	2095.9
6.0	158.84	0.0011009	0.3155	3.170	670.42	2755.5	2085.0
6.5	161.99	–	0.2925	3.419	684.12	2758.8	2074.0
7.0	164.96	0.0011082	0.2727	3.667	697.06	2762.0	2064.9
7.5	167.75	–	0.2554	3.915	709.29	2764.8	2055.5
8.0	170.41	0.0011150	0.2403	4.162	720.94	2767.5	2046.5
8.5	172.94	–	0.2268	4.409	732.02	2769.9	2037.9
9.0	175.36	0.0011213	0.2148	4.655	742.64	2772.1	2029.5
9.5	177.66	–	0.2040	4.901	752.81	2774.2	2021.4
10.0	179.88	0.0011274	0.1943	5.147	762.61	2776.2	2013.6
11	184.07	0.0011331	0.1747	5.637	781.13	2779.7	1998.5
12	187.96	0.0011386	0.1632	6.127	798.43	2782.7	1984.3
13	191.61	0.0011438	0.1511	6.617	814.70	2785.4	1970.7
14	195.04	0.0011489	0.1407	7.106	830.08	2787.8	1957.7
15	198.29	0.0011539	0.1317	7.596	844.67	2789.9	1945.2
16	201.37	0.0011586	0.1237	8.085	858.56	2791.7	1933.2
17	204.31	0.0011633	0.1166	8.575	871.84	2793.4	1921.5
18	207.11	0.0011678	0.1103	9.065	884.58	2794.8	1910.3
19	209.80	0.0011723	0.1047	9.555	896.81	2796.1	1899.3
20	212.37	0.0011766	0.09954	10.05	908.59	2797.2	1886.6
21	214.85	0.0011809	0.09489	10.54	919.96	2798.2	1878.2
22	217.24	0.0011850	0.09065	11.03	930.95	2799.1	1868.1
23	219.55	0.0011892	0.08677	11.52	941.60	2799.8	1858.2
24	221.78	0.0011932	0.08320	12.02	951.93	2800.4	1848.5
25	223.94	0.0011972	0.07991	12.51	961.96	2800.9	1839.0
26	226.04	0.0012011	0.07686	13.01	971.72	2801.4	1829.6
27	228.07	0.0012050	0.07402	13.51	981.22	2801.7	1820.5
28	230.05	0.0012088	0.07139	14.01	990.48	2802.0	1811.5

Fig. 44

Absolute pressure p bar	Tempe-rature t_s °C	Specific volume of boiling water ν' m³/kg	Specific steam volume ν" m³/kg	Steam density ρ" kg/m³	Enthalpy of water h' kJ/kg	Enthalpy of steam h'' kJ/kg	Evapo-ration heat r kJ/kg
29	231.97	0.0012126	0.06893	14.51	999.53	2802.2	1802.6
30	233.84	0.0012163	0.06663	15.01	1008.4	2802.3	1793.9
32	237.45	0.0012237	0.06244	16.02	1025.4	2802.3	1776.9
34	240.88	0.0012310	0.05873	17.03	1041.8	2802.1	1760.3
36	244.16	0.0012381	0.05541	18.05	1057.6	2801.7	1744.2
38	247.31	0.0012451	0.05244	19.07	1072.7	2801.1	1728.4
40	250.33	0.0012521	0.04975	20.10	1087.4	2800.3	1712.9
42	253.24	0.0012589	0.04731	21.14	1101.6	2799.4	1697.8
44	256.05	0.0012657	0.04508	22.18	1115.4	2798.3	1682.9
46	258.75	0.0012725	0.04304	23.24	1128.8	2797.0	1668.3
48	261.37	0.0012792	0.04116	24.29	1141.8	2795.7	1653.9
50	263.91	0.0012858	0.03943	25.36	1154.5	2794.2	1639.7
55	269.93	0.0013023	0.03563	28.07	1184.9	2789.9	1605.0
60	275.55	0.0013187	0.03244	30.83	1213.7	2785.0	1571.3
65	280.82	0.0013350	0.02972	33.65	1241.1	2779.5	1538.4
70	285.79	0.0013513	0.02737	36.53	1267.4	2773.5	1506.0
75	290.50	0.0013677	0.02533	39.48	1292.7	2766.9	1474.2
80	294.97	0.0013842	0.02353	42.51	1317.1	2759.9	1442.8
85	299.23	0.0014009	0.02193	56.61	1340.7	2752.5	1411.7
90	303.31	0.0014179	0.02050	48.79	1363.7	2744.6	1380.9
95	307.21	0.0014351	0.01921	52.06	1386.1	2736.4	1350.2
100	310.96	0.0014526	0.01804	55.43	1408.0	2727.7	1319.7
110	318.05	0.0014887	0.01601	62.48	1450.6	2709.3	1258.7
120	324.65	0.0015268	0.01428	70.01	1491.8	2689.2	1197.4
130	330.83	0.0015672	0.01280	78.14	1532.0	2667.0	1135.0
140	336.64	0.0016106	0.01150	86.99	1571.6	2642.4	1070.7
150	342.13	0.0016579	0.01034	96.71	1611.0	2615.0	1004.0
160	347.33	0.0017103	0.009308	107.4	1650.5	2584.9	934.3
170	352.26	0.0017696	0.008371	119.5	1691.7	2551.6	859.9
180	356.96	0.0018399	0.007489	133.4	1734.8	2513.9	779.1
190	361.43	0.0019260	0.006678	149.8	1778.7	2470.6	692.0
200	365.70	0.0020370	0.005877	170.2	1826.5	2418.4	591.9
220	373.69	0.0026714	0.003728	268.3	2011.1	2195.6	184.5
221.20	374.15	0.00317	0.00317	315.5	2107.4	2107.4	0

Fig. 44

3.6.2 Specific enthalpy of superheated steam

Pressure *p* bar	Specific enthalpy in kJ/kg for a steam temperature in °C 200	220	240	260	280	300	320	340	Specific enthalpy in kJ/kg for a steam temperature in °C 360	380	400	420	440	460	480	500	Pressure *p* bar
1	2875.4	2915.0	2954.6	2994.4	3034.4	3074.5	3114.8	3155.3	3196.0	3237.0	3278.2	3319.7	3361.4	3403.4	3445.6	3488.1	1
2	2870.5	2910.8	2951.1	2991.4	3031.7	3072.1	3112.6	3153.3	3194.2	3235.4	3276.7	3318.3	3360.1	3402.1	3444.5	3487.0	2
3	2865.5	2906.6	2947.5	2988.2	3028.9	3069.7	3110.5	3151.4	3192.4	3233.7	3275.2	3316.8	3358.8	3400.9	3443.3	3486.0	3
4	2860.4	2902.3	2943.9	2985.1	3026.2	3067.2	3108.3	3149.4	3190.6	3232.1	3273.6	3315.4	3557.4	3399.7	3442.1	3484.9	4
5	2855.1	2898.0	2940.1	2981.9	3023.4	3064.8	3106.1	3147.4	3188.8	3230.4	3272.1	3314.0	3356.1	3398.4	3441.0	3483.8	5
6	2849.7	2893.5	2936.4	2978.7	3020.6	3062.3	3103,9	3145.4	3187.0	3228.7	3270.6	3312.6	3354.8	3397.2	3439.8	3482.7	6
7	2844.2	2888.9	2932.5	2975.4	3017.7	3059.8	3101.6	3143.4	3185.2	3227.1	3269.0	3311.2	3353.4	3395.9	3439.6	3481.6	7
8	2838.6	2884.2	2928.6	2972.1	3014.9	3057.3	3099.4	3141.4	3183.4	3225.4	3267.5	3309.7	3352.1	3394.7	3437.5	3480.5	8
9	2832.7	2879.5	2924.6	2968.7	3012.0	3054.7	3097.1	3139.4	3181.6	3223.7	3266.0	3308.3	3350.8	3393.5	3436.3	3479.4	9
10	2826.8	2874.6	2920.6	2965.2	3009.0	3052.1	3094.9	3137.4	3179.7	3222.0	3264.4	3306.9	3349.5	3392.2	3435.1	3478.3	10
11	2820.7	2869.6	2916.4	2961.8	3006.0	3049.6	3092.6	3135.3	3177.9	3220.3	3262.9	3305.4	3348.1	3391.0	3434.0	3477.2	11
12	2814.4	2864.5	2912.2	2958.2	3003.0	3046.9	3090.3	3133.2	3176.0	3218.7	3261.3	3304.0	3346.8	3389.7	3432.8	3476.1	12
13	2808.0	2859.3	2908.0	2954.7	3000.0	3044.3	3088.0	3131.2	3174.1	3217.0	3259.2	3302.5	3345.4	3388.5	3431.6	3475.0	13
14	2801.4	2854.0	2903.6	2951.0	2996.9	3041.6	3085.6	3129.1	3172.3	3215.3	3258.2	3301.1	3344.1	3387.2	3430.5	3473.9	14
15	2794.7	2848.6	2899.2	2947.3	2993.7	3038.9	3083.3	3127.0	3170.4	3213.5	3256.6	3299.7	3342.8	3386.0	3429.3	3472.8	15
16	–	2843.1	2894.7	2943.6	2990.6	3036.2	3080.9	3124.9	3168.5	3211.8	3255.0	3298.2	3341.4	3384.7	3428.1	3471.7	16
18	–	2831.7	2885.4	2935.9	2984.1	3030.7	3076.1	3120.6	3164.7	3208.4	3251.9	3295.3	3338.7	3382.2	3425.8	3469.5	18
20	–	2819.9	2875.9	2928.1	2977.5	3025.0	3071.2	3116.3	3160.8	3204.9	3248.7	3292.4	3336.0	3379.7	3423.4	3467.3	20
22	–	2807.5	2866.0	2920.0	2970.8	3019.3	3066.2	3112.0	3156.9	3201.4	3245.5	3289.4	3333.3	3377.1	3421.1	3465.1	22
24	–	–	2855.7	2911.6	2963.8	3013.4	3061.1	3107.5	3153.0	3197.8	3242.3	3386.5	3330.6	3374.6	3418.7	3462.9	24
26	–	–	2845.2	2903.0	2956.7	3007.4	3056.0	3103.0	3149.0	3194.3	3239.0	3283.5	3327.8	3372.1	3416.3	3460.6	26
28	–	–	2834.2	2894.2	2949.5	3001.3	3050.8	3098.5	3145.0	3190.7	3235.8	3280.5	3325.1	3369.5	3413.9	3458.4	28
30	–	–	2822.9	2885.1	2942.0	2995.1	3045.4	3093.9	3140.9	3187.0	3232.5	3277.5	3322.3	3367.0	3411.6	3456.2	30
32	–	–	2811.2	2875.8	2934.4	2988.7	3040.0	3089.2	3136.8	3183.4	3229.2	3274.5	3319.5	3364.4	3409.2	3454.0	32
34	–	–	–	2866.2	2926.6	2982.2	3034.5	3084.4	3132.7	3179.7	3225.9	3271.5	3316.8	3361.8	3406.8	3451.7	34
36	–	–	–	2856.3	2918.6	2975.6	3028.9	3079.6	3128.4	3175.9	3222.5	3268.4	3314.0	3359.2	3404.4	3449.5	36
38	–	–	–	2846.1	2910.4	2968.9	3023.3	3074.8	3124.2	3172.2	3219.1	3265.4	3311.2	3356.6	3402.0	3447.2	38
40	–	–	–	2835.6	2902.0	2962.0	3017.5	3069.8	3119.9	3168.4	3215.7	3262.3	3308.3	3354.0	3399.6	3445.0	40
42	–	–	–	2824.8	2893.5	2955.0	3011.6	3064.8	3115.5	3164.5	3212.3	3259.2	3305.5	3351.4	3397.7	3442.7	42
44	–	–	–	2813.6	2884.7	2947.8	3005.7	3059.7	3111.1	3160.6	3208.8	3256.0	3302.6	3348.8	3394.7	3440.5	44
46	–	–	–	2802.0	2875.6	2940.5	2999.6	3054.6	3106.7	3156.7	3205.3	3252.9	3299.8	3346.2	3392.3	3438.2	46
48	–	–	–	–	2866.4	2933.1	2993.4	3049.4	3102.2	3152.8	3201.8	3249.7	3296.9	3343.5	3389.8	3435.9	48
50	–	–	–	–	2856.9	2925.5	2987.2	3044.1	3097.6	3148.8	3198.3	3246.6	3294.0	3340.9	3387.4	3433.7	50
55	–	–	–	–	2831.8	2905.7	2971.0	3030.5	3085.9	3138.6	3189.3	3238.5	3286.7	3334.2	3381.2	3427.9	55
60	–	–	–	–	2804.9	2885.0	2954.2	3016.5	3074.0	3128.3	3180.1	3230.3	3279.3	3327.4	3375.0	3422.2	60
70	–	–	–	–	–	2839.4	2918.3	2987.0	3049.1	3106.7	3161.2	3213.5	3264.2	3313.7	3362.4	3410.6	70
80	–	–	–	–	–	2786.8	2878.7	2955.3	3022.7	3084.2	3141.6	3196.2	3248.7	3299.7	3349.6	3398.8	80
90	–	–	–	–	–	–	2834.3	2920.9	2994.8	3060.5	3121.2	3178.2	3232.7	3285.3	3336.5	3386.8	90
100	–	–	–	–	–	–	2783.5	2883.4	2964.8	3035.7	3099.9	3159.7	3216.2	3270.5	3323.2	3374.6	100
110	–	–	–	–	–	–	2723.5	2841.7	2932.8	3009.6	3077.8	3140.5	3199.4	3255.5	3309.6	3362.2	110
120	–	–	–	–	–	–	–	2794.7	2898.1	2982.0	3054.8	3120.7	3182.0	3240.0	3295.7	3349.6	
130	–	–	–	–	–	–	–	2740.6	2860.2	2952.7	3030.7	3100.2	3164.1	3224.2	3281.6	3336.8	130
140	–	–	–	–	–	–	–	2675.7	2818.1	2921.4	3005.6	3079.0	3145.8	3208.1	3267.1	3323.8	140
150	–	–	–	–	–	–	–	–	2770.8	2887.7	2979.1	3057.0	3126.9	3191.5	3252.4	3310.6	150
160	–	–	–	–	–	–	–	–	2716.5	2851.1	2951.3	3034.2	3107.5	3174.5	3237.4	3297.1	160
180	–	–	–	–	–	–	–	–	2569.1	2766.6	2890.3	2985.8	3066.9	3139.4	3206.5	3269.6	180
200	–	–	–	–	–	–	–	–	–	2660.2	2820.5	2932.9	3023.7	3102.7	3174.4	3241.1	200
250	–	–	–	–	–	–	–	–	–	–	2582.0	2774.1	2901.7	3002.3	3088.5	3165.9	250

Fig. 45

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3.6.3 Specific volume of superheated steam

Pressure p bar	Specific volume in m³/kg for a steam temperature in °C																Pressure p bar
	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500	
1	2.172	2.266	2.359	2.453	2.546	2.639	2.732	2.824	2.917	3.010	3.102	3.195	3.288	3.380	3.473	3.565	1
2	1.0804	1.1280	1.1753	1.2224	1.2693	1.3162	1.3629	1.4095	1.4561	1.5027	1.5492	1.5956	1.6421	1.6885	1.7349	1.7812	2
3	0.7164	0.7486	0.7805	0.8123	0.8438	0.8753	0.9066	0.9379	0.9691	1.0003	1.0314	1.0625	1.0935	1.1245	1.1556	1.1865	3
4	0.5343	0.5589	0.5831	0.6072	0.6311	0.6549	0.6785	0.7021	0.7256	0.7491	0.7725	0.7959	0.8192	0.8426	0.8659	0.8892	4
5	0.4250	0.4450	0.4647	0.4841	0.5034	0.5226	0.5416	0.5606	0.5795	0.5984	0.6172	0.6359	0.6547	0.6734	0.6921	0.7108	5
6	0.3520	0.3690	0.3857	0.4021	0.4183	0.4344	0.4504	0.4663	0.4821	0.4979	0.5136	0.5293	0.5450	0.5606	0.5762	0.5918	6
7	0.2929	0.3147	0.3292	0.3435	0.3575	0.3714	0.3852	0.3989	0.4125	0.4261	0.4396	0.4531	0.4666	0.4801	0.4935	0.5069	7
8	0.2608	0.2740	0.2869	0.1995	0.3119	0.3241	0.3363	0.3483	0.3603	0.3723	0.3842	0.3960	0.4078	0.4196	0.4314	0.4432	8
9	0.2303	0.2423	0.2539	0.2653	0.2764	0.2874	0.2983	0.3090	0.3197	0.3304	0.3410	0.3516	0.3621	0.3726	0.3831	0.3936	9
10	0.2059	0.2169	0.2276	0.2379	0.2480	0.2580	0.2678	0.2776	0.2873	0.2969	0.3065	0.3160	0.3256	0.3350	0.3445	0.3540	10
11	0.1859	0.1961	0.2060	0.2155	0.2248	0.2339	0.2429	0.2518	0.2607	0.2695	0.2782	0.2870	0.2956	0.3043	0.3129	0.3215	11
12	0.1692	0.1788	0.1879	0.1968	0.2054	0.2139	0.2222	0.2304	0.2386	0.2467	0.2547	0.2627	0.2707	0.2787	0.2866	0.2945	12
13	0.1551	0.1641	0.1727	0.1810	0.1890	0.1969	0.2046	0.2123	0.2198	0.2273	0.2348	0.2422	0.2496	0.2570	0.2643	0.2716	13
14	0.1429	0.1515	0.1596	0.1674	0.1749	0.1823	0.1896	0.1967	0.2038	0.2108	0.2177	0.2246	0.2315	0.2384	0.2452	0.2520	14
15	0.1324	0.1406	0.1483	0.1556	0.1628	0.1697	0.1765	0.1832	0.1898	0.1964	0.2029	0.2094	0.2158	0.2223	0.2287	0.2350	15
16	–	0.1310	0.1383	0.1453	0.1521	0.1587	0.1651	0.1714	0.1777	0.1838	0.1900	0.1961	0.2021	0.2082	0.2142	0.2202	16
18	–	0.1150	0.1217	0.1282	0.1343	0.1402	0.1460	0.1517	0.1573	0.1629	0.1684	0.1738	0.1793	0.1847	0.1900	0.1954	18
20	–	0.1021	0.1084	0.1144	0.1200	0.1255	0.1308	0.1360	0.1411	0.1461	0.1511	0.1561	0.1610	0.1659	0.1707	0.1756	20
22	–	0.09152	0.09752	0.10309	0.10837	0.11343	0.11833	0.12311	0.12780	0.13243	0.13700	0.14152	0.14602	0.15048	0.15492	0.15934	22
24	–	–	0.08839	0.09367	0.09863	0.10336	0.10793	0.11237	0.11672	0.12100	0.12522	0.12940	0.13355	0.13766	0.14175	0.14582	24
26	–	–	0.08064	0.08567	0.09037	0.09483	0.09912	0.10328	0.10734	0.11133	0.11526	0.11914	0.12299	0.12681	0.13061	0.13438	26
28	–	–	0.07397	0.07880	0.08328	0.08751	0.09156	0.09548	0.09929	0.10303	0.10671	0.11035	0.11395	0.11752	0.12106	0.12458	28
30	–	–	0.06816	0.07283	0.07712	0.08116	0.08500	0.08871	0.09232	0.09584	0.09931	0.10273	0.10611	0.10946	0.11278	0.11608	30
32	–	–	0.06305	0.06759	0.07173	0.07559	0.07926	0.08279	0.08621	0.08955	0.09283	0.09606	0.09925	0.10241	0.10554	0.10865	32
34	–	–	–	0.06295	0.06695	0.07068	0.07419	0.07756	0.08082	0.08400	0.08711	0.09017	0.09319	0.09618	0.09915	0.10209	34
36	–	–	–	0.05880	0.06270	0.06630	0.06968	0.07291	0.07603	0.07906	0.08202	0.08494	0.08781	0.09065	0.09347	0.09626	36
38	–	–	–	0.05508	0.05888	0.06237	0.06564	0.06875	0.07174	0.07464	0.07747	0.08025	0.08300	0.08570	0.08838	0.09104	38
40	–	–	–	0.05172	0.05544	0.05883	0.06200	0.06499	0.06787	0.07066	0.07338	0.07604	0.07866	0.08125	0.08381	0.08634	40
42	–	–	–	0.04865	0.05231	0.05562	0.05870	0.06160	0.06437	0.06706	0.06967	0.07222	0.07474	0.07722	0.07967	0.08209	42
44	–	–	–	0.04585	0.04946	0.05270	0.05569	0.05850	0.06119	0.06378	0.06630	0.06876	0.07117	0.07355	0.07590	0.07823	44
46	–	–	–	0.04328	0.04685	0.05003	0.05294	0.05568	0.05828	0.06079	0.06321	0.06559	0.06791	0.07020	0.07247	0.07470	46
48	–	–	–	–	0.04444	0.04757	0.05042	0.05309	0.05561	0.05604	0.06039	0.06268	0.06493	0.06714	0.06931	0.07147	48
50	–	–	–	–	0.04222	0.04530	0.04810	0.05070	0.05316	0.05551	0.05779	0.06001	0.06218	0.06431	0.06642	0.06849	50
55	–	–	–	–	0.03733	0.04034	0.04302	0.04549	0.04780	0.05001	0.05213	0.05419	0.05620	0.05817	0.06011	0.06202	55
60	–	–	–	–	0.03317	0.03614	0.03874	0.04111	0.04330	0.04539	0.04738	0.04931	0.05118	0.05302	0.05482	0.05659	60
70	–	–	–	–	–	0.02946	0.03198	0.03420	0.03623	0.03812	0.03992	0.04165	0.04331	0.04494	0.04653	0.04809	70
80	–	–	–	–	–	0.02426	0.02681	0.02896	0.03088	0.03265	0.03431	0.03589	0.03740	0.03887	0.04030	0.04170	80
90	–	–	–	–	–	–	0.02269	0.02484	0.02669	0.02837	0.02993	0.03140	0.03280	0.03415	0.03546	0.03674	90
100	–	–	–	–	–	–	0.01926	0.02147	0.02331	0.02493	0.02641	0.02779	0.02911	0.03036	0.03158	0.03276	100
110	–	–	–	–	–	–	0.01628	0.01864	0.02049	0.02208	0.02351	0.02483	0.02608	0.02726	0.02840	0.02950	110
120	–	–	–	–	–	–	–	0.01619	0.01811	0.01969	0.02108	0.02236	0.02355	0.02467	0.02575	0.02679	
130	–	–	–	–	–	–	–	0.01401	0.01604	0.01764	0.01902	0.02025	0.02140	0.02247	0.02350	0.02440	130
140	–	–	–	–	–	–	–	0.01200	0.01421	0.01586	0.01723	0.01844	0.01955	0.02059	0.02157	0.02251	140
150	–	–	–	–	–	–	–	–	0.01256	0.01428	0.01566	0.01686	0.01794	0.01895	0.01989	0.02080	150
160	–	–	–	–	–	–	–	–	0.01104	0.01287	0.01427	0.01546	0.01653	0.01751	0.01842	0.01929	160
180	–	–	–	–	–	–	–	–	0.008104	0.01040	0.01191	0.01311	0.01416	0.01510	0.01597	0.01678	180
200	–	–	–	–	–	–	–	–	–	0.008246	0.009947	0.01120	0.01224	0.01315	0.01399	0.01477	200
250	–	–	–	–	–	–	–	–	–	–	0.006014	0.007580	0.008696	0.009609	0.01041	0.01113	250

Fig. 46

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3.6.4 h,s diagram for steam according to Mollier

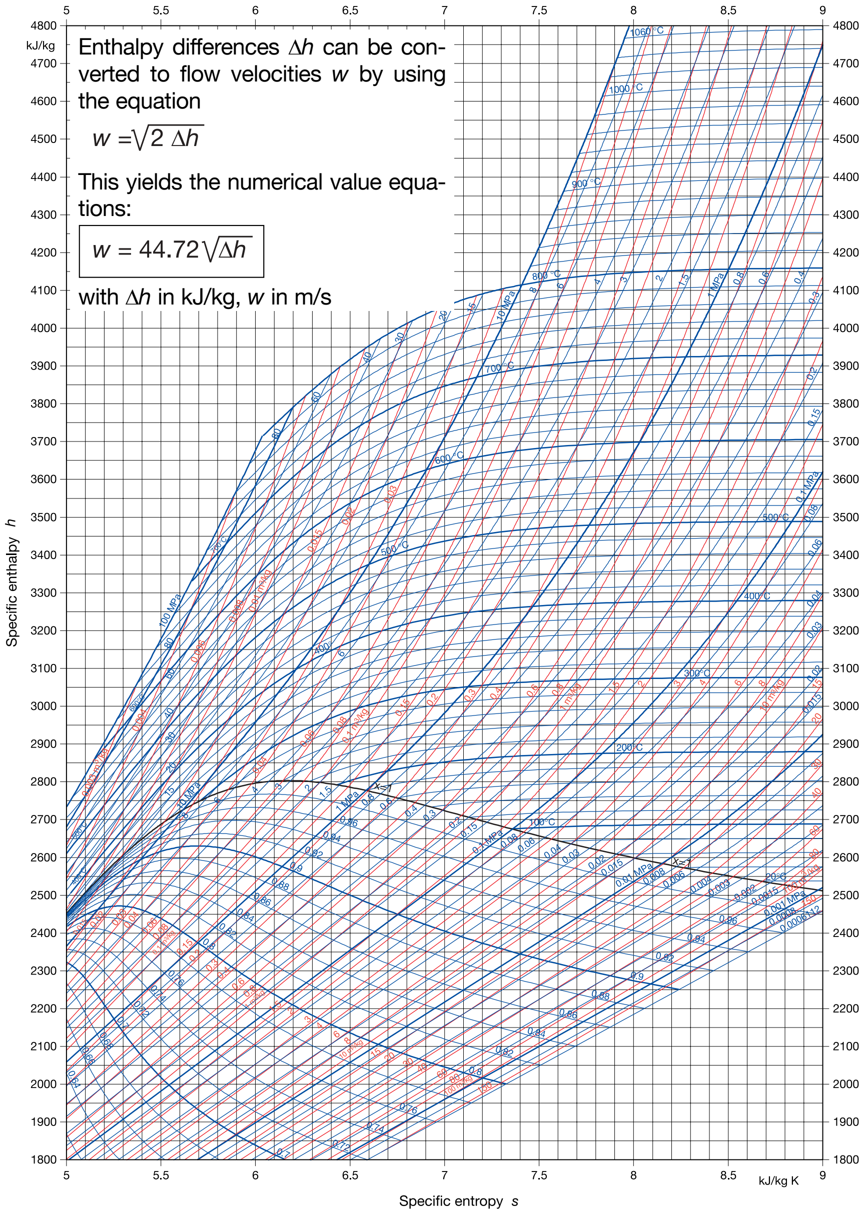

Fig. 47 **h,s diagram (Mollier diagram)**
Source: University of Applied Sciences, Zittau/Görlitz

Page

4 Connection Examples for Heating and Cooling Systems

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GESTRA Steam Systems

Valves

Industrial Electronics, Automation

Special Equipment
and Vessels for Heat Recovery

Services

4 Connection Examples for Heating and Cooling Systems

4.1 Fundamentals

4.1.1 Symbols for thermal power plants

Taken from DIN 2481: “Thermal Power Plants; Graphical Symbols”. The layout and presentation of the various drawings must be adapted as required to suit the corresponding purpose. If there are several alternatives, the presentation that is simple, clear and understandable is to be preferred.

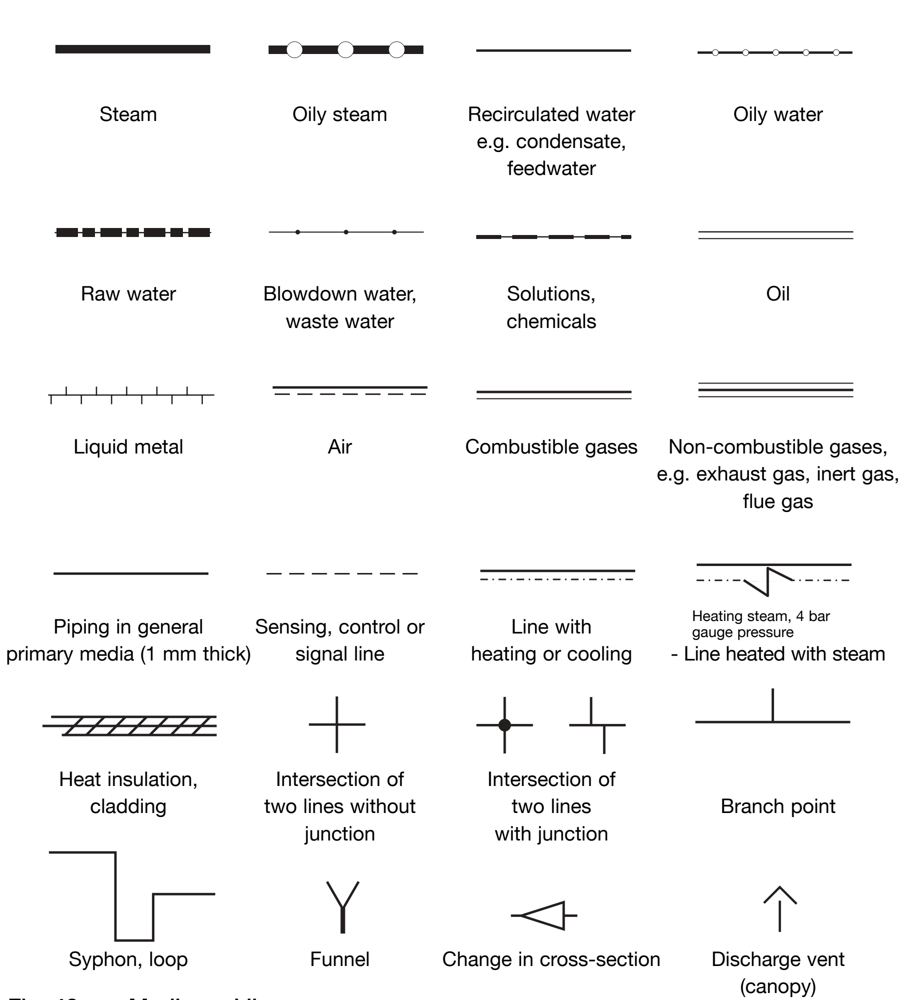


Fig. 48 Media and lines

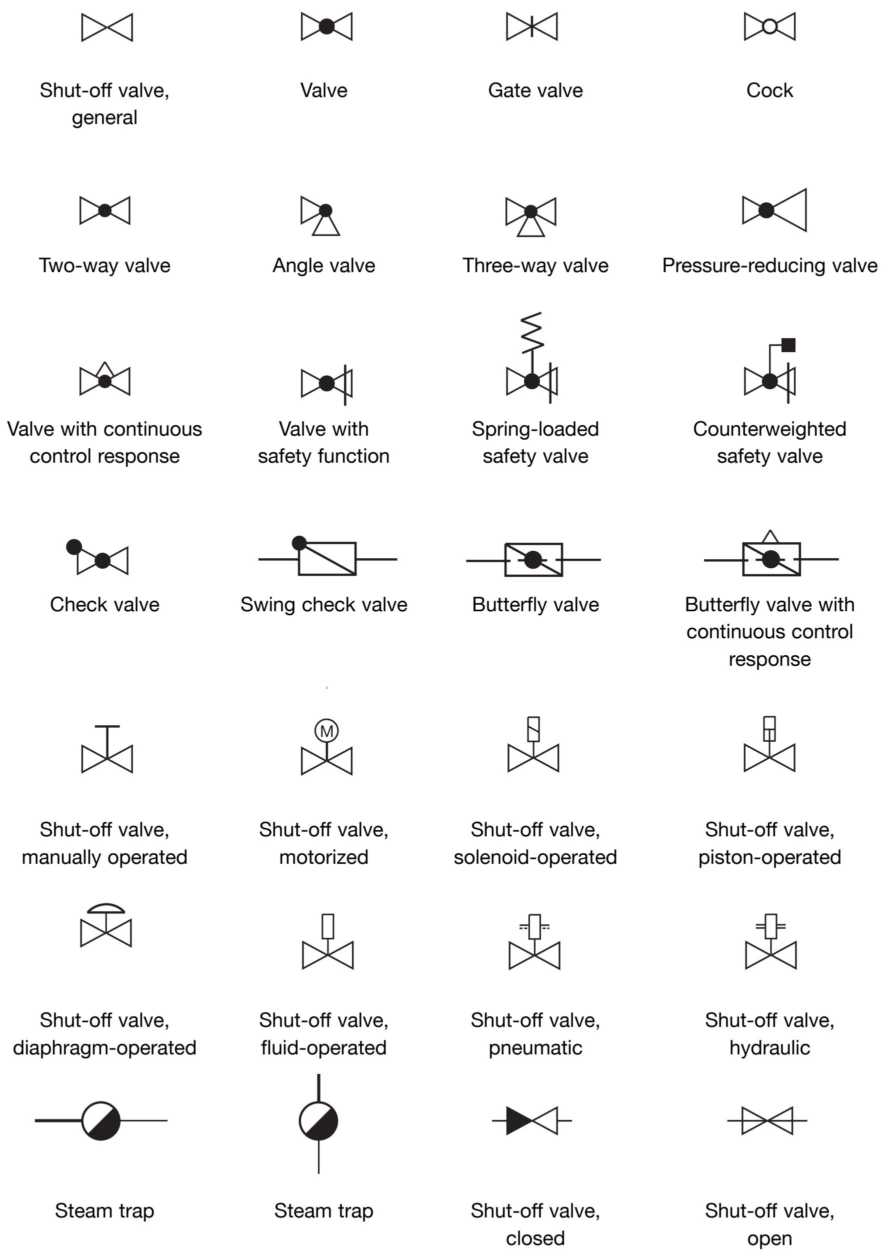


Fig. 49 Valves

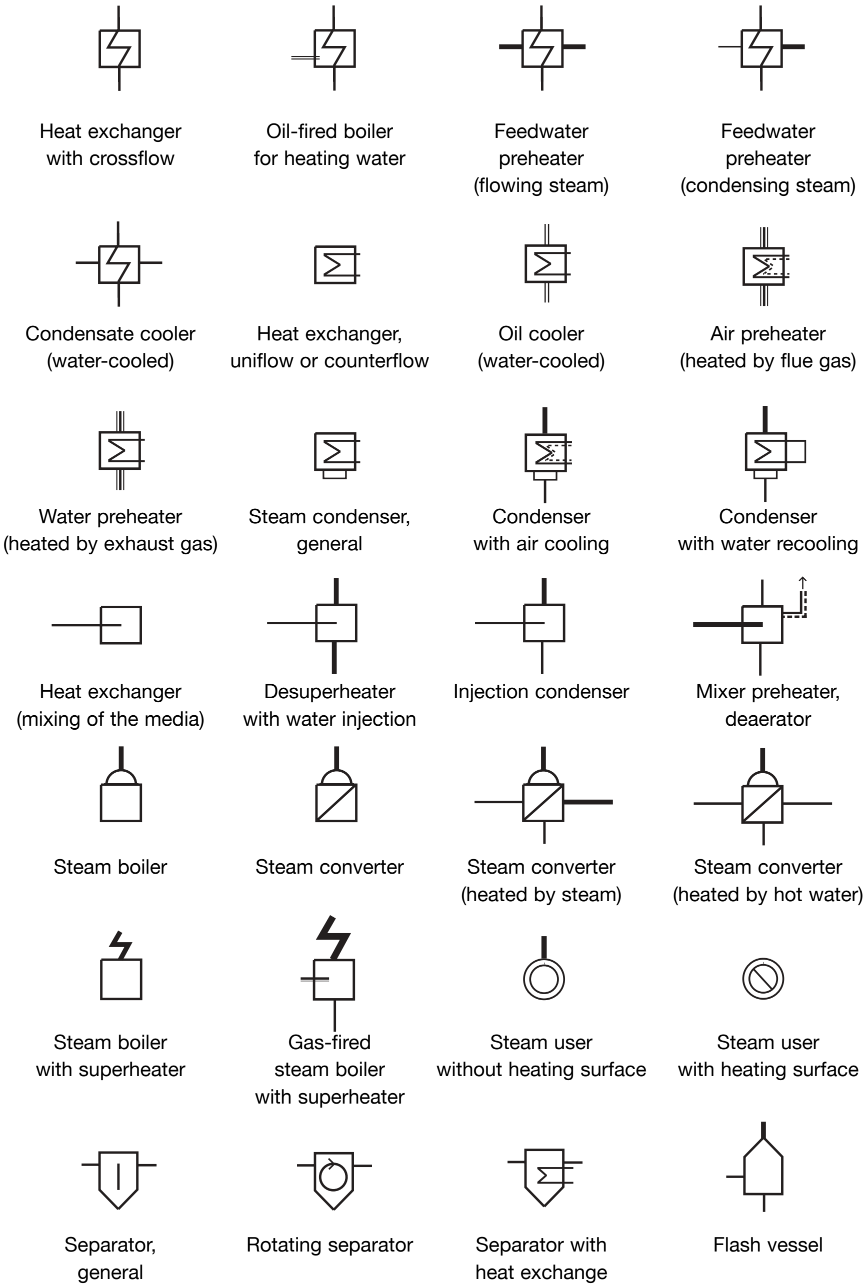


Fig. 50 Boilers, heat exchangers and equipment

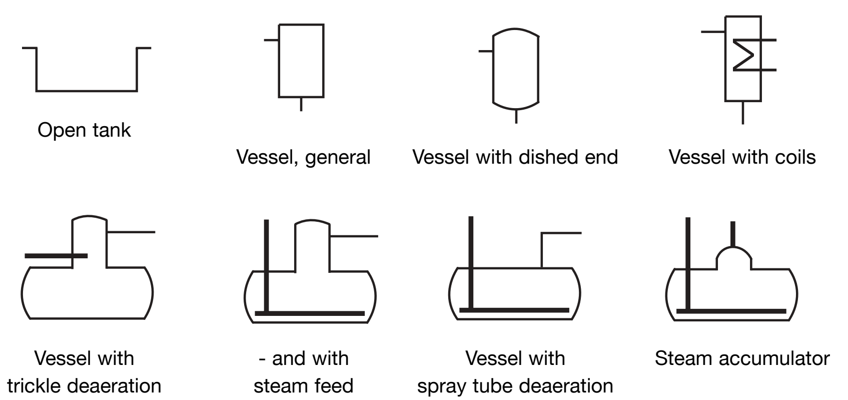


Fig. 51 Vessels

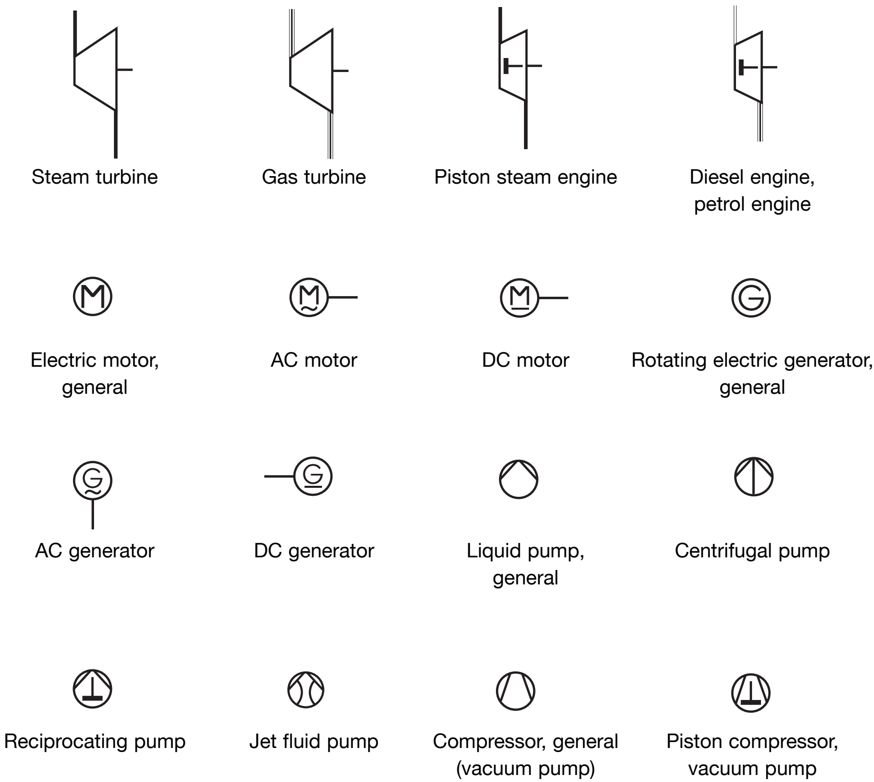


Fig. 52 Machines

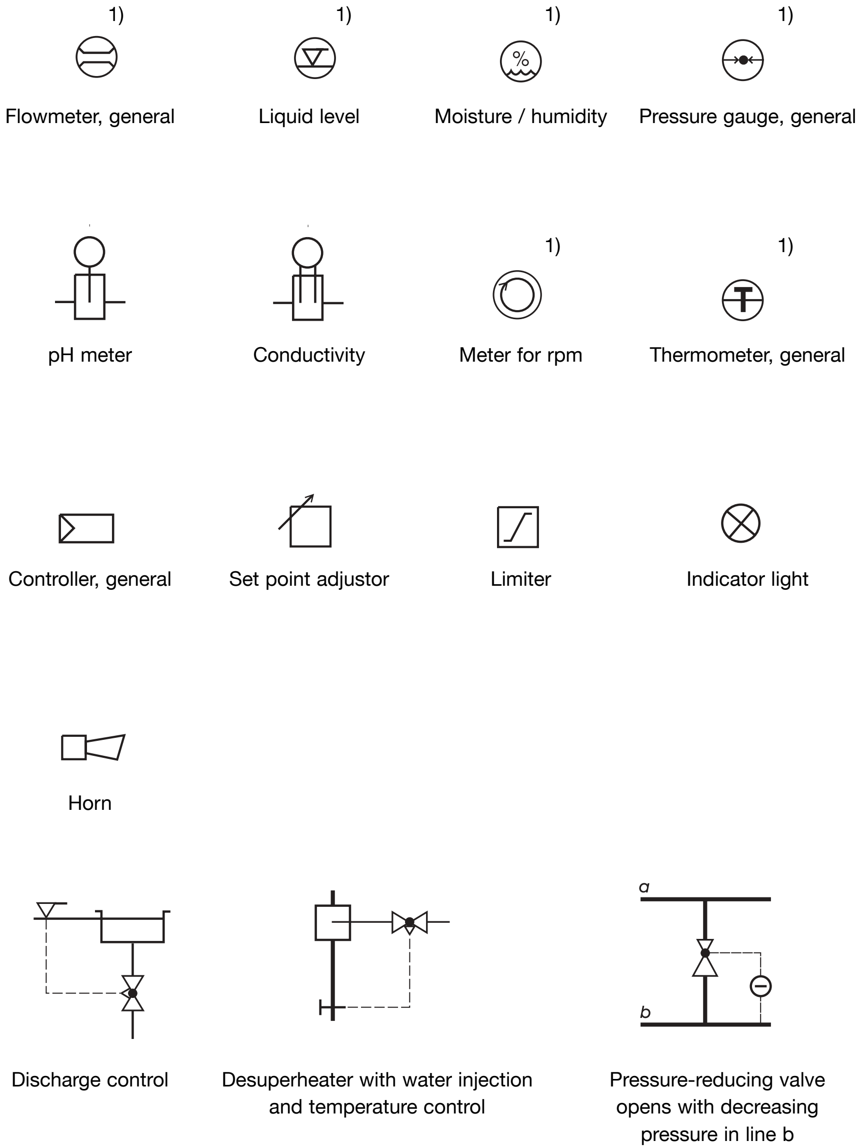


Fig. 53 **Measurement and control**

1) These symbols are also used without the surrounding circle.

4.1.2 International symbols and abbreviations

These symbols and abbreviations make it possible to produce simple and clear plans for the instrumentation of a plant by omitting the technical details of the equipment used. All important details are compiled in separate documents, e.g. in the tender documents, in the technical specification or in detailed engineering drawings.

Symbols

Process lines
- Steam
- Water
- Air

Instrument lines
- Lines, general
- Capillary systems
- Pneumatic signalling lines
- Electrical signalling lines

Circular symbols for equipment
- Locally fitted
- Panel mounting
- Rack mounting

Letters used in multi-letter symbols

as first letter		as successive letters	
C	Conductivity (Q_L)	A	Alarm
D	Density	C	Control
F	Flowrate, quantity	D	Difference[1]
H	Hand (manual oper.)	G	Gauge (sightglass)
L	Level	I	Indicating
M	Moisture	R	Recording
P	Pressure	S	Switching[2]
S	Speed, velocity, frequency	T	Transmitter
T	Temperature	V	Valve

1) PD = pressure difference; TD = temperature difference etc.
2) S = Switch (switching) can also mean Safety.

Example for the composition and meaning of a multi-letter symbol: The quantity to be measured, e.g. pressure (P), is to be indicated (I) and controlled (C). Then PIC-110 means: Pressure Indicating Controller for control circuit 110.

Fig. 54 Partial overview, based on ANSI/ISA-5.1 (see also *DIN 19227-17-2)*

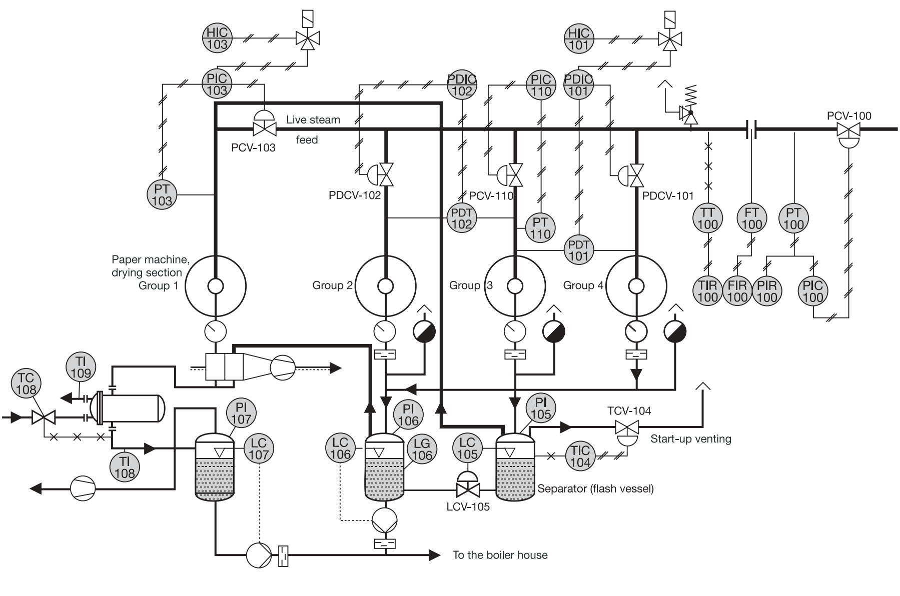


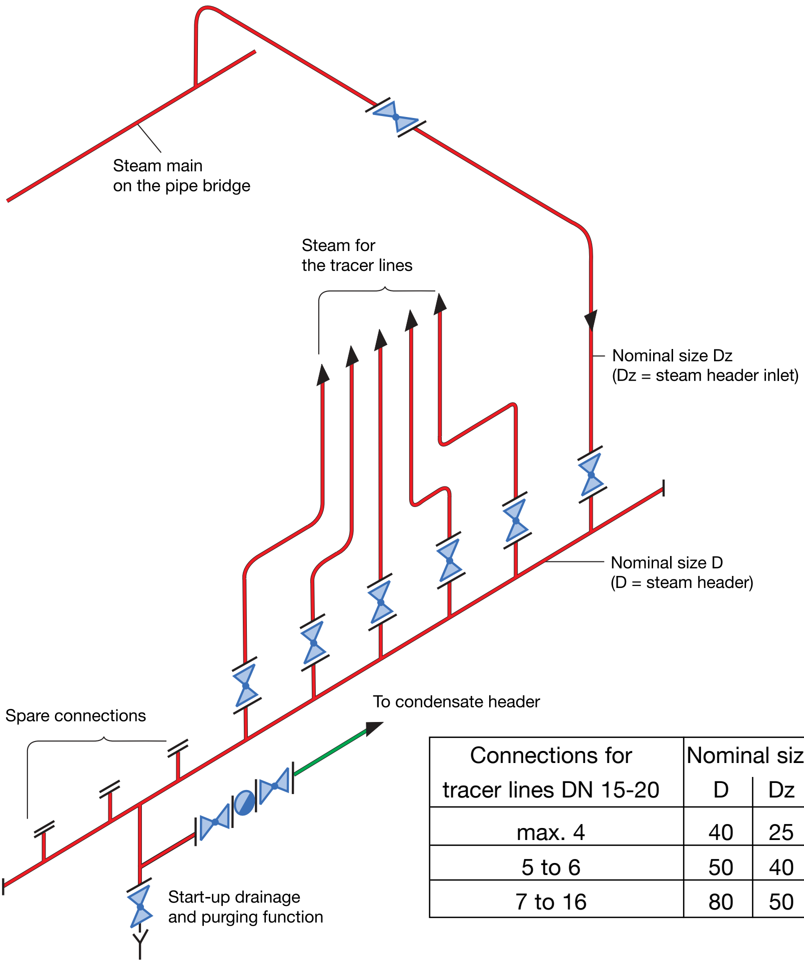
Fig. 55 Example for application of the multi-letter symbols

4.2 Connection examples for steam and condensate systems

4.2.1 Steam trapping

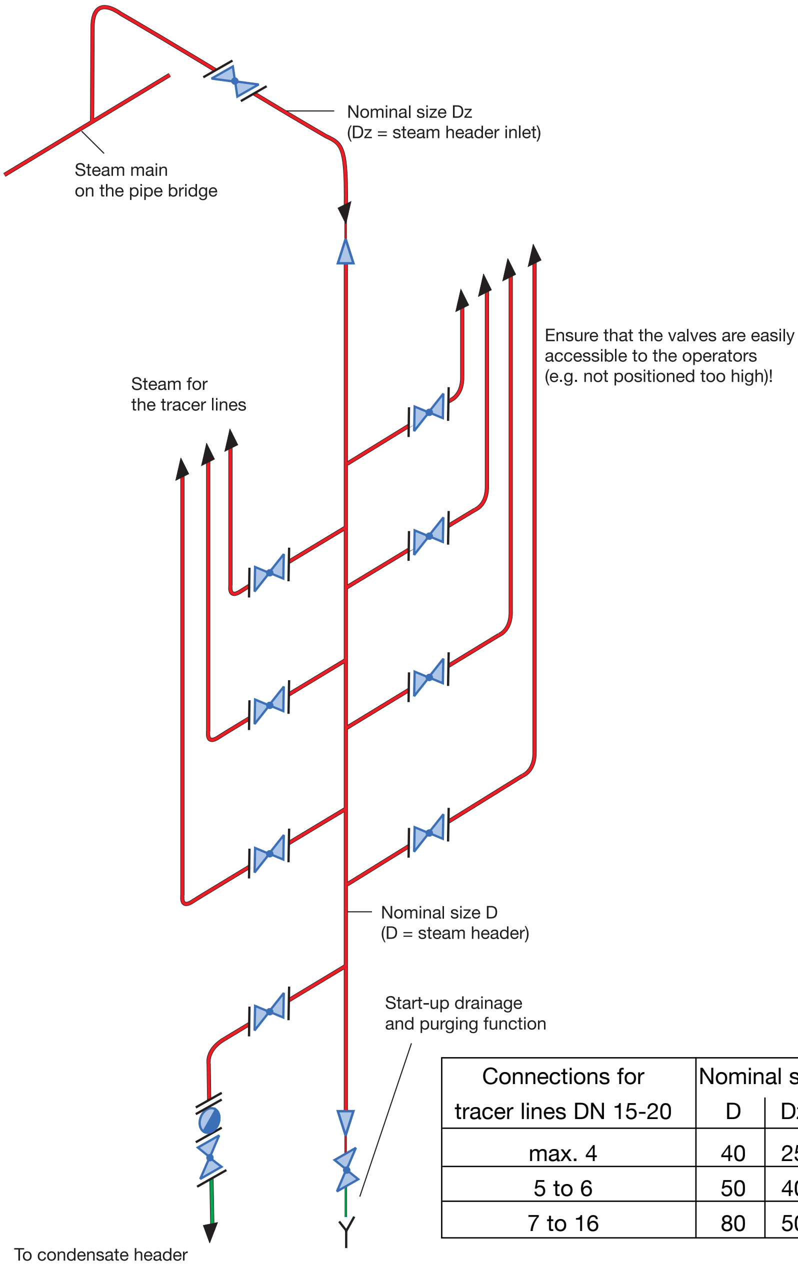
4.2.1.1 Steam header

The steam feed for several users, heat exchangers or tracer lines is grouped together to form steam header stations at main points, separated according to pressure ratings. Steam headers must be arranged so that operating and maintenance can easily be performed from the ground or from platforms. The steam supply lines must be drained continuously at the lowest points and at the ends.



Connections for tracer lines DN 15-20	Nominal size D	Nominal size Dz
max. 4	40	25
5 to 6	50	40
7 to 16	80	50

Fig. 56 Horizontal arrangement of the steam header
Example of a tracer system: here the outgoing steam lines are grouped together to bundles and insulated collectively.



Connections for tracer lines DN 15-20	Nominal size D	Nominal size Dz
max. 4	40	25
5 to 6	50	40
7 to 16	80	50

Fig. 57 Vertical arrangement of the steam header
Example of a tracer system: in confined spaces or at pillars and supports.

4.2.1.2 Steam-line drainage

Drain points should always be provided at low points, in front of risers, at the end of the line and, in the case of horizontal lines, at regular distances of not more than 100 m (300 ft). With due consideration of the pressure ratings, the drain lines are connected to the nearest condensate header. However, this is not worthwhile if the drain points are located too far away. In such cases, the condensate is simply discharged into the open.

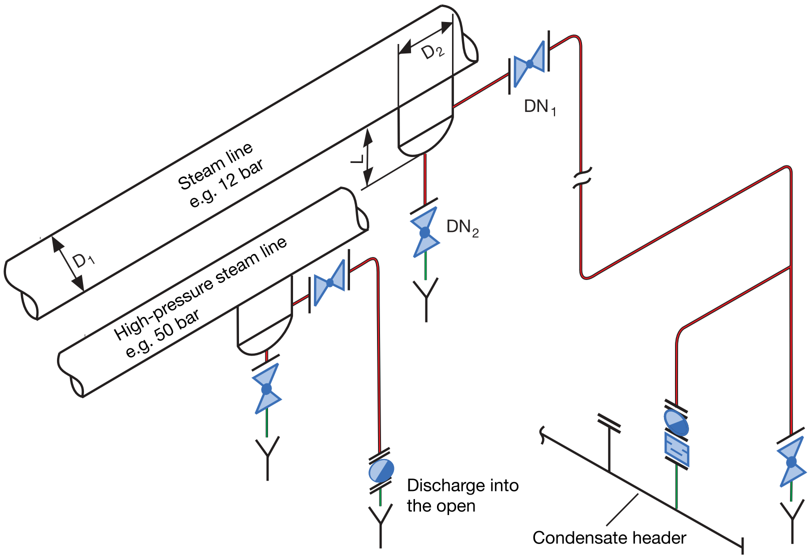


Fig. 58 Even a single high-pressure line (e.g. 50 bar) is discharged to the open air to prevent high back pressures arising in the medium- and low-pressure condensate systems in the event of damage. In addition, steps must be taken to prevent the possible obstruction of visibility through flash steam and the danger of scalding.

D_1	mm	50	65	80	100	125	150	200	250	300	350	400	450	500	600
	in	2	2 1/2	3	4	5	6	8	10	12	14	16	18	20	24
D_2	mm	50	65	80	80	80	100	150	150	200	200	200	250	250	250
	in	2	2 1/2	3	3	3	4	6	6	8	8	8	10	10	10
L	mm	for all DN: L ≥ 250													
DN_1	mm	20	20	20	20	20	20	20	20	20	20	20	20	20	20
DN_2	mm	20	25	25	40	40	40	40	50	50	50	50	50	50	50

Fig. 59 **Nominal sizes of the steam and drain lines**

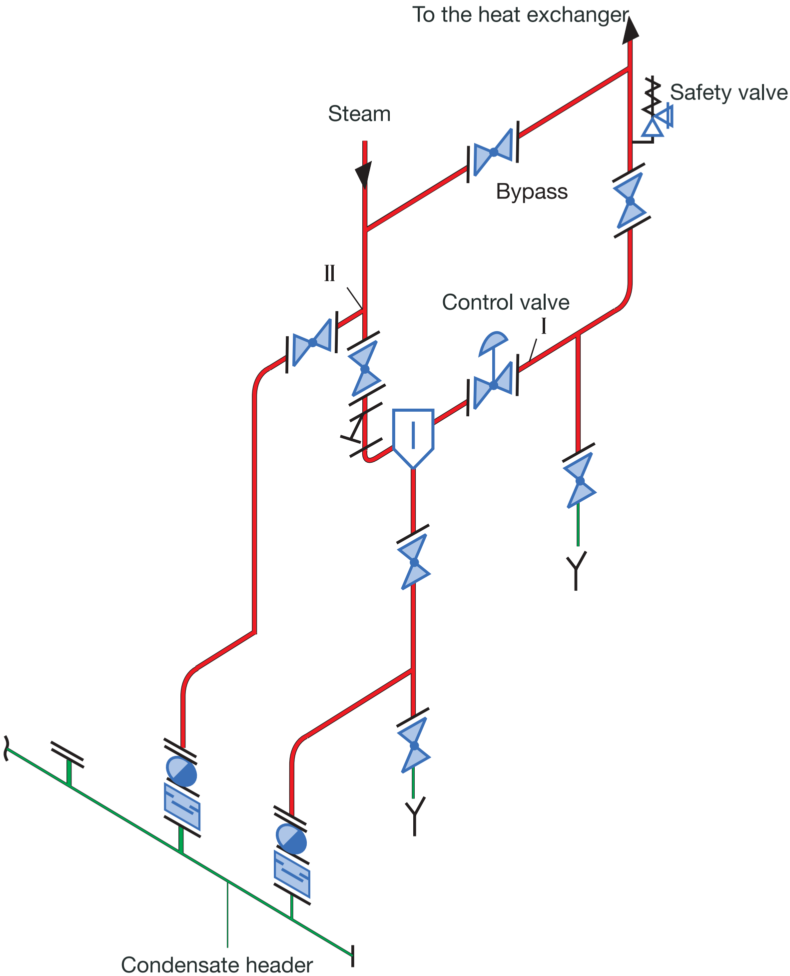
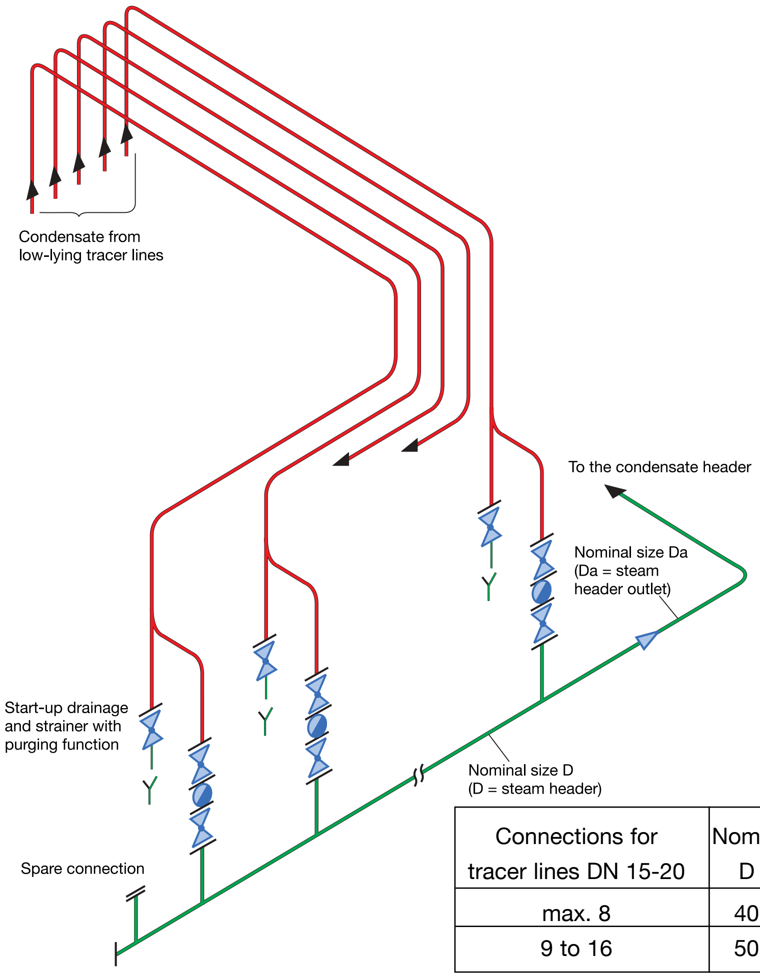


Fig. 60 Drainage of a steam regulating station
This group of valves, for a heat exchanger controlled on the steam side, is drained via branch-off point I upstream of the steam control valve with the aid of the steam drier. At the same time, any water droplets and dirt particles are separated off. This protects the control valve effectively against erosion. The steam drier is drained continuously by means of a ball float trap. If necessary, the bypass is drained by a thermostatic trap. Branch-off point II is normally shut off, as it is only used as a drain point when the steam for the heat exchanger must be supplied via the bypass (e.g. during maintenance work).

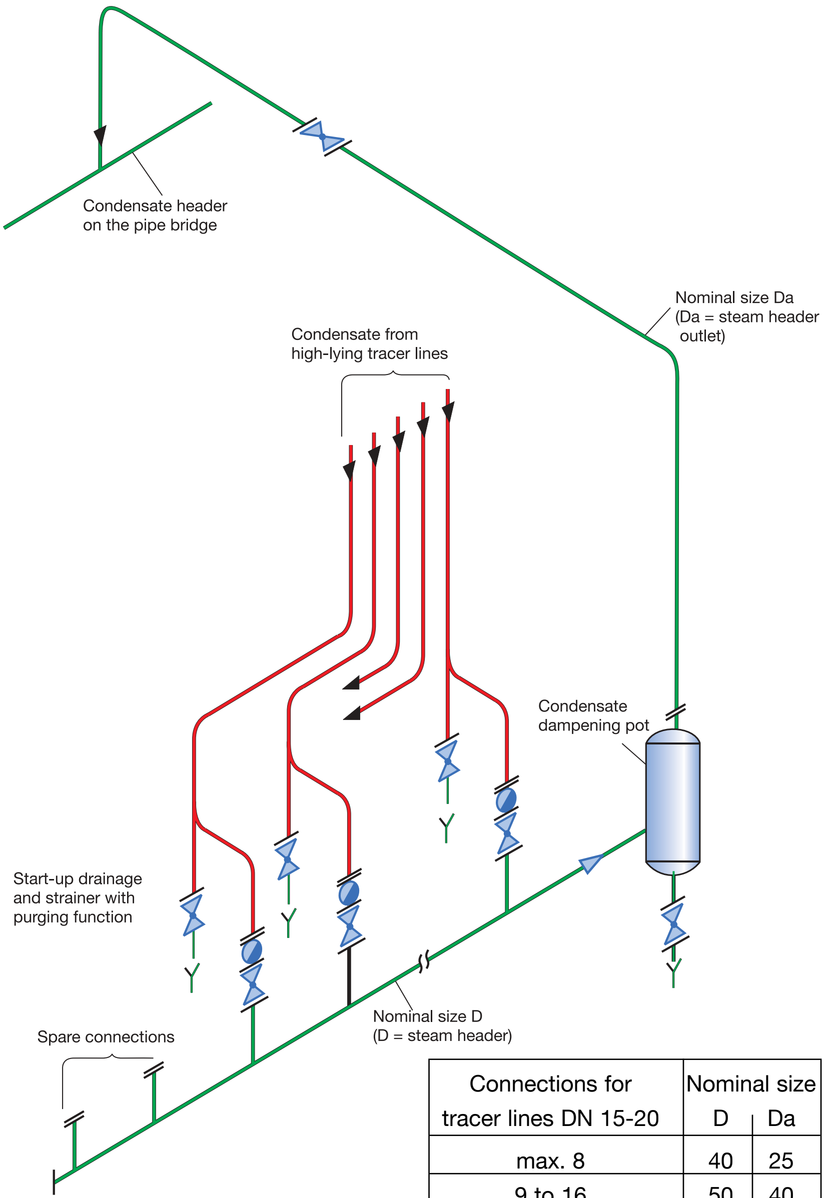
4.2.1.3 Condensate collecting stations

The condensate arising in heat exchangers, tracer lines, steam headers and at other drain points with the same pressure rating is, as far as possible, routed to condensate collecting stations located centrally. Separation according to pressure rating is advisable to prevent inadmissible back pressures in condensate systems with lower pressure ratings. At risers, it is necessary to install a condensate dampening pot, to ensure condensate transport with low noise and no waterhammer (Fig. 62). A condensate dampening pot is superfluous if the collecting tank is installed vertically for reasons of space and the rising header is submerged in the collector (Fig. 63).



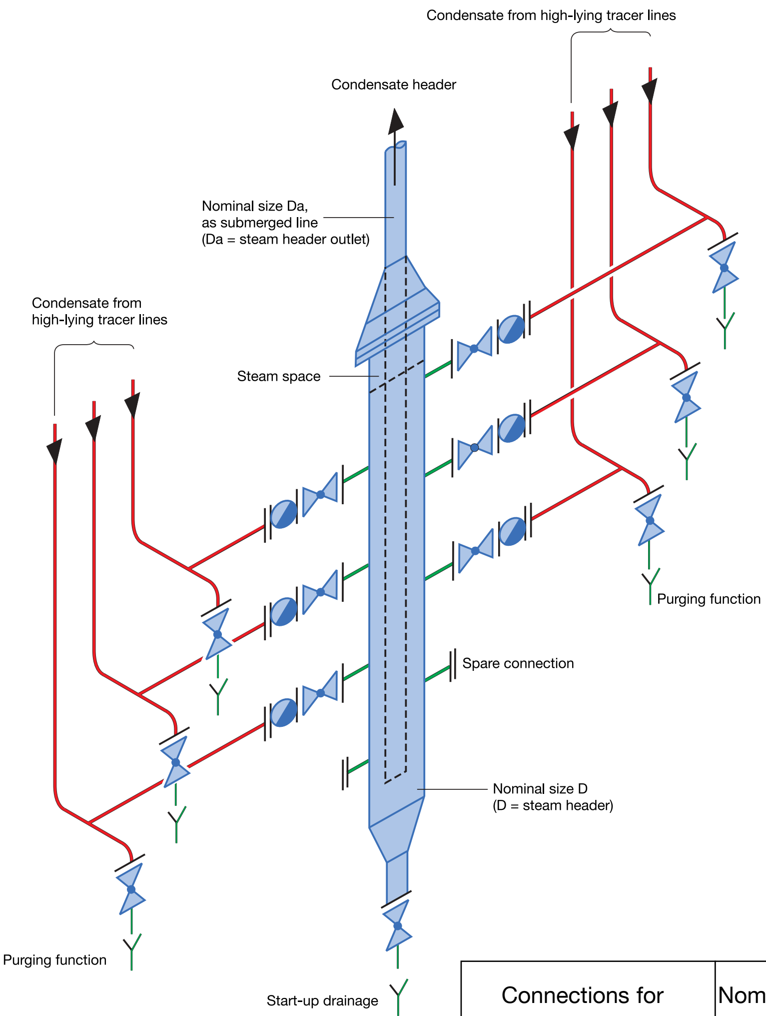
Connections for tracer lines DN 15-20	Nominal size D	Nominal size Da
max. 8	40	25
9 to 16	50	40

Fig. 61 Arrangement of the condensate collector
e.g. for low-lying tracer lines and low-lying condensate headers (bundles).



Connections for tracer lines DN 15-20	Nominal size D	Nominal size Da
max. 8	40	25
9 to 16	50	40

Fig. 62 Arrangement of the condensate collector
with condensate dampening pot, e.g. for high-lying tracer lines and a high-lying condensate header (pipe bridges).



Connections for tracer lines DN 15-20	Nominal size D	Nominal size Da
max. 8	50	25
9 to 16	65	40

Fig. 63 Vertical arrangement of the condensate collector
For use in confined spaces and at pillars and supports. Drawbacks: unfavourable operating and servicing heights.
Benefits: the rising header extends down into the collector as a submerged tube. A steam space with sufficient buffering effect is formed.

4.2.1.4 Flash vessel

In the connection example shown in Fig. 63, the condensate is routed from several steam users into a flash vessel and the flash steam arising as a result is fed into e.g. a low-pressure system. For more flash vessel configurations and other possibilities, see Section 4.2.2.

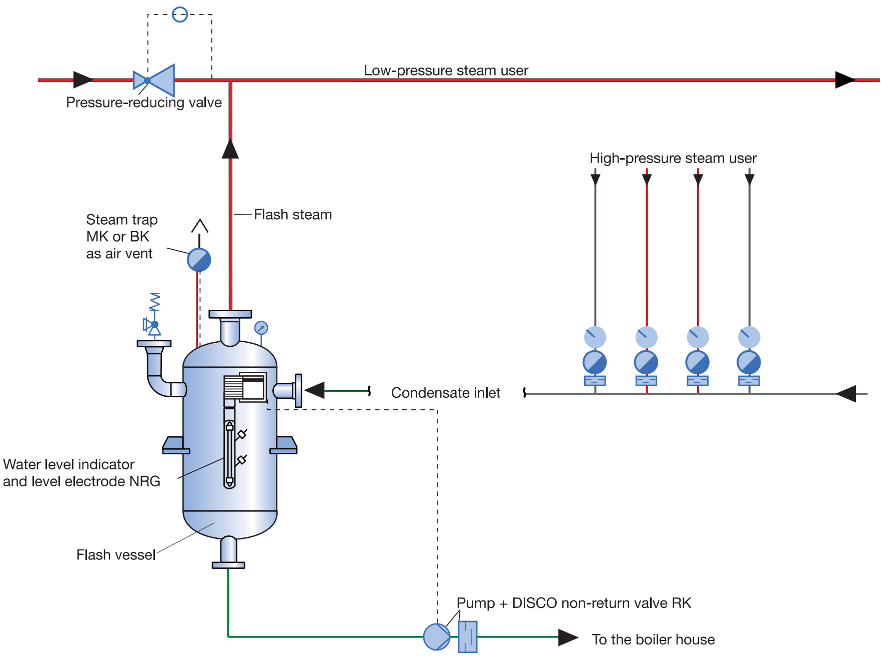


Fig. 64 Flash-steam recovery system

Individual trapping for a group of HP steam users. The condensate first flows into the flash vessel. The flash steam, and live steam fed in as required via the pressure-reducing valve, are used to heat downstream LP steam users. Here the recirculation of the condensate from the flash vessel to the boiler house takes place via a pump controlled by the level in the flash vessel. A level electrode with integrated amplifier is used to drive the pump. The discharge of condensate from the flash vessel can also be effected by a float trap if the service pressure is sufficiently high and the condensate need not be lifted.

4.2.1.5 Group or individual trapping

Group trapping should be avoided.
Although only a single steam trap is needed, namely in the condensate header, considerable malfunctions are to be expected.

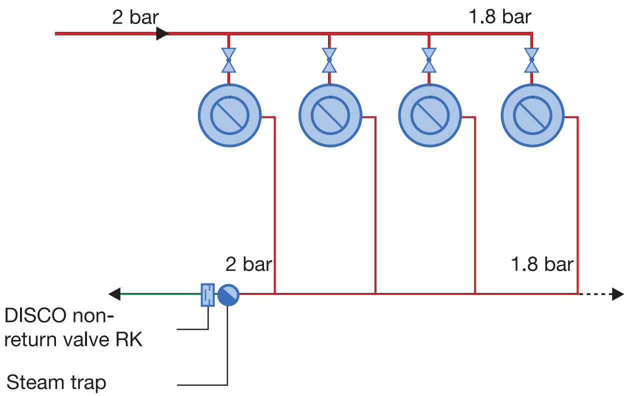


Fig. 65 The disadvantages of group trapping
Pressure drops through each control valve and heat exchanger will inevitably be different. This leads to one or more heat exchangers being short-circuited on the condensate side. Condensate will bank up and waterhammer will occur. Control of the heat exchanger on the steam side is not even possible if the flow in the condensate header takes place in the direction indicated by the dashed line.

Only the individual trapping of all heat exchangers will ensure proper condensate discharge. Several steam traps are then required, but each heat exchanger can be controlled on the steam side and higher temperatures can be achieved.

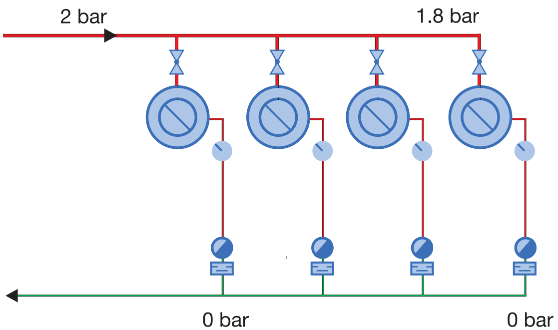


Fig. 66 The advantages of separate trapping
Separate drainage ensures condensate discharge without banking-up. Individual steam-side control is then possible. Banking-up and waterhammer in the heating spaces is prevented. Additionally installed RK non-return valves stop condensate returning to the heat exchanger from the header when, for example, the steam pressure in the heat exchanger drops owing to the control valve throttling or closing. Vaposcopes downstream of the heating surfaces permit visual monitoring. Banking-up is detected reliably.

The influence of the geodetic head on the performance of a steam trap must be conside-red with special care for low-pressure systems.

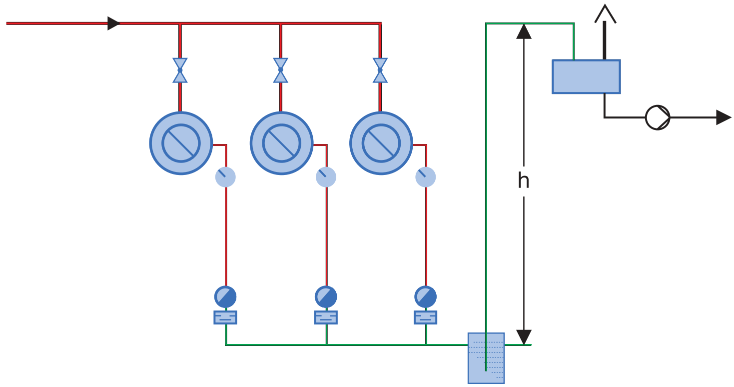


Fig. 67 Influence of the geodetic delivery head
If the condensate downstream of a trap is lifted, the differential pressure (working pressure) is reduced by approximately 1 bar for 7 m of lift, or 2 psi for 3 feet of lift. To ensure low-noise and hammer-free condensate discharge in risers, it is necessary to install a condensate dampening pot.

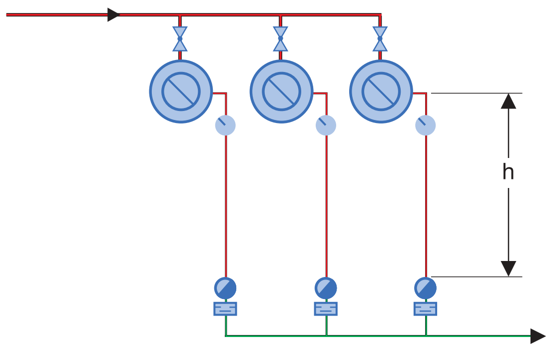


Fig. 68 Influence of the geodetic supply head
Even for very low pressures in the heat exchanger, proper discharge via steam trap is possible here: the suction head provides added differential pressure for the steam trap.

4.2.1.6 Start-up drainage

The cold-water performance of a steam trap is greater than for hot water. For this reason, the traps can also be used for the start-up drainage of steam-heated heat exchangers.
A special problem is presented, for instance, by the start-up drainage of a steam turbine. The pressure and temperature are increased very gradually according to a specified schedule, in order to protect the turbine components against damage occurring as a result of excessively fast or uneven thermal expansion. The condensate flowrates at very low pressures and temperatures are relatively high, so that a steam trap would have to be sized very large. For this reason, a special drain valve (type ZK) is recommended for this phase of the start-up procedure. Once a certain operating state has been reached during start-up, the turbine has been warmed up to such an extent that only a little condensate is produced. A thermostatic steam trap, connected in parallel to the drain valve, will then suffice.

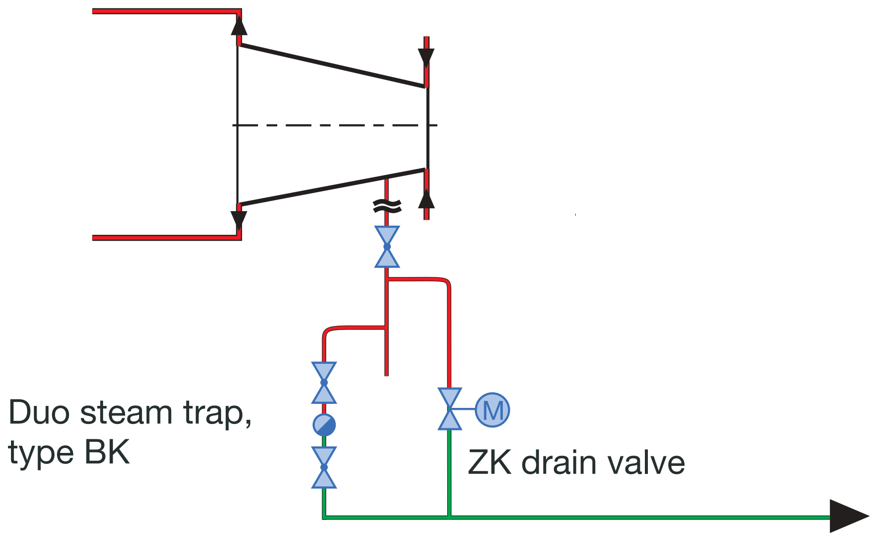


Fig. 69 Draining the wheel space of a steam turbine
Drain valve with Duo steam trap connected in parallel for a dirt-resistant connection.

Frequent and rapid start-up of various items of equipment, e.g. a long-distance steam pipeline, also necessitates the discharge of large quantities of condensate. The low amount of condensate produced in continuous operation is then discharged by a Duo steam trap connected in parallel.

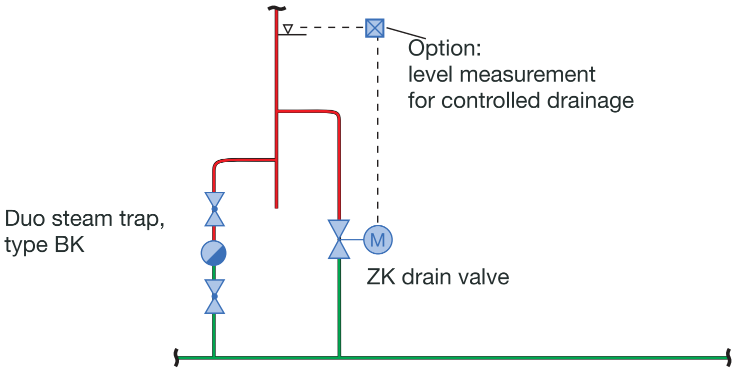


Fig. 70 Draining a long-distance steam pipeline
Here the drain valve performs the start-up drainage until the level probe detects no more water. Low condensate flowrates are discharged via a Duo steam trap connected in parallel.

4.2.1.7 Monitoring of heating surfaces and steam traps

Wherever condensate is discharged, it is advisable to monitor various operational parameters, e.g. the function of the steam traps or the performance of the heating surface. After all, live-steam losses through the steam trap are always possible. Banking-up of condensate in the heating surfaces would reduce their effectiveness. Waterhammer must be prevented, and accumulation of dirt should be detected. The causes of many malfunctions – e.g. through leakage of live steam or banking-up – can be easily recognized with the aid of the Vaposcope flowmeter.

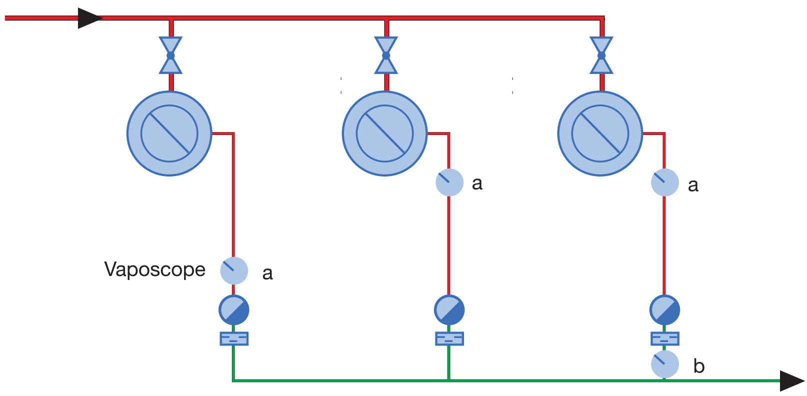


Fig. 71 Example for use of the Vaposcope
Monitoring of heating surfaces takes place at the points marked (a), with trap monitoring at point (b). Installation downstream of steam traps is useless, because the flash steam occurring there would falsify the result.

4.2.1.8 Protection against soiling

Protecting steam and condensate system against soiling means preventing foreign bodies, dirt and corrosion products from causing malfunctions and damage. For this reason, new plants are flushed before commissioning and especially sensitive valves and units are only installed after the flushing procedure has been completed. Of course, this does not exclude the accumulation of dirt during later operation.

Occasionally – e.g. at heat exchangers – direct drain points become necessary in addition to the drainage via steam traps. The intention is to avert the need to interrupt the heating process in the event of malfunctions on the condensate side. In such cases, the condensate can temporarily be discharged to the open. If the pipe branches are installed correctly, increased protection against soiling can be achieved with the added possibility of being able to purge the dirt from the plant.

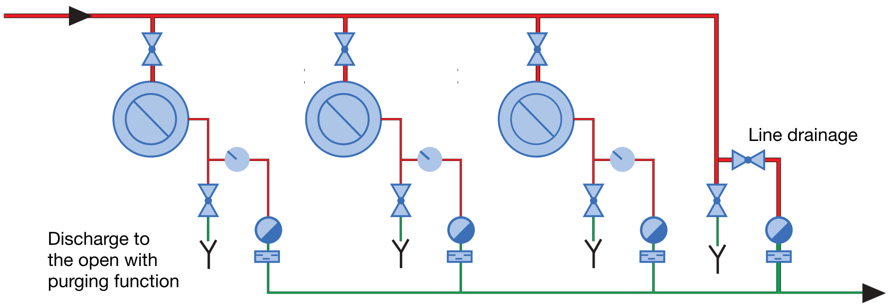


Fig. 72 Drainage for a group of heat exchangers

Additional free drain points.

The lines leading to the steam traps branch off to the side. The dirt collects in the vertical pipe ends leading to the shut-off valves, from where it can be purged.

4.2.1.9 Frost resistance

Making an outside installation resistant to freezing (i.e. “winterising” it) means protecting endangered plant components against freezing, shielding products against thickening and congealing, providing drain points, and generally taking all steps necessary to exclude the damage caused by freezing. For this reason, such plants must be heated, the piping laid with a fall, and water pockets avoided if possible. Drain points are needed at all low points, at tanks and at other collecting points. Furthermore, the pipeline components must also be resistant to freezing by virtue of their materials. In refinery plants, the heavy products are heated by tracer pipes, e.g. with steam at 12 bar. For the heating of the other plant components, a steam pressure of approx. 2.5 bar is adequate and more economical (lower temperatures to be maintained, higher heat of evaporation). If there is any danger of overheating the product, the tracer line is provided as spacer tracing.

For liquids with a pour point (solidification point) of 0 °C, the heating should be kept at a minimum temperature of 3 °C. For products with a higher solidification point, the minimum temperature should lie approx. 5 °C above the solidification point.

In general, steam traps should be mounted so that the pipe connecting the trap to the collecting point is as short as possible. In the case of longer pipe sections downstream of the traps combined with a low amount of condensate, there is a danger of freezing. If the drainage takes place via a steam trap to the open air, then the outlet section must be kept as short as possible to prevent freezing from the outlet. If it is not possible to avoid water pockets, e.g. because of a header lying higher, then drainage must be provided at the low points of the line.

4.2.2 Using the sensible heat of the condensate

In a steam-heated heat exchanger, the evaporation heat and, if applicable, the superheat is extracted from the heating steam. If we neglect the utilization of the sensible heat by condensate undercooling in the heating surface, then all the entire sensible heat is lost during open-air discharge.

Since the condensate can only store a certain quantity of heat (which varies with pressure) and any condensate discharge necessitates a pressure drop, part of the initial sensible heat is released downstream of the steam trap. This inevitably leads to flashing; part of the condensate becomes flash steam. Of the sensible heat lost from the heating process, a part is shed with the condensate and a part with the flash steam.

To prevent these heat losses, the flash steam is used for warming up heat exchangers downstream and the entire condensate is routed to the boiler feedwater system. A few typical connection examples are given below.

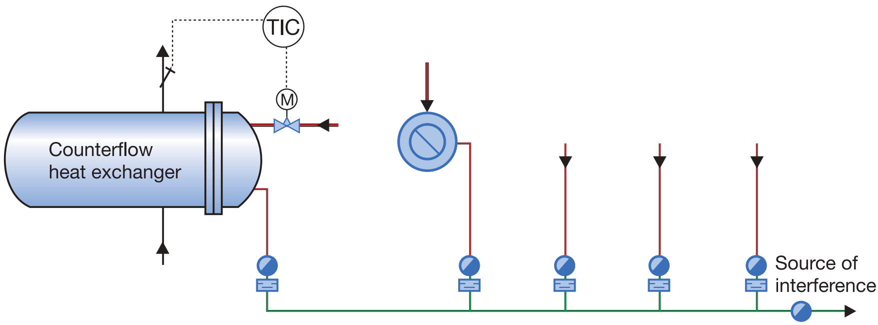


Fig. 73 Common errors in connection

If the hot condensate (t = 100 °C) is allowed to flow out of the heat exchanger directly into the open collecting tank, then flash steam is released. This results in heat losses, which are sometimes accepted deliberately. However, it is annoying that these steam losses are visible and cannot be differentiated from live-steam losses. Attempts to remedy the situation often lead to a faulty connection. The steam trap installed additionally in the header forces the condensation of the flash steam in the pipe. For the other traps, this causes a back pressure which can rise to be as high as the upstream pressure. Although it may have functioned perfectly until this point, the condensate discharge is then considerably perturbed.

Conclusions:

No series connection of steam traps. Utilize the flash steam in downstream heat exchangers, and return the condensate to the boiler house. Check that the heating surfaces are not subject to banking-up, and detect any live-steam losses at steam traps through the installation of sightglasses, type GESTRA Vaposcope.

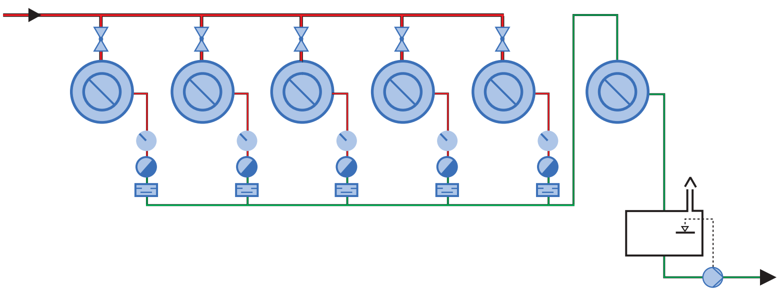


Fig. 74 Condensate undercooling

The operational conditions in each individual case must be considered to decide which arrangement for using the sensible heat of the condensate is most suitable. If the heat demand plays a minor role, with precise temperature control not being so important, the connection shown here may be appropriate as the simplest solution. The sensible heat of the condensate produced in the heat exchanger is used in a heating surface following directly downstream in such a manner that the condensate flows into the condensate tank with a temperature below 100 °C; flashing is hence excluded. The downstream heating surface cannot be controlled, however. The available quantity of heat fluctuates with the amount of condensate.

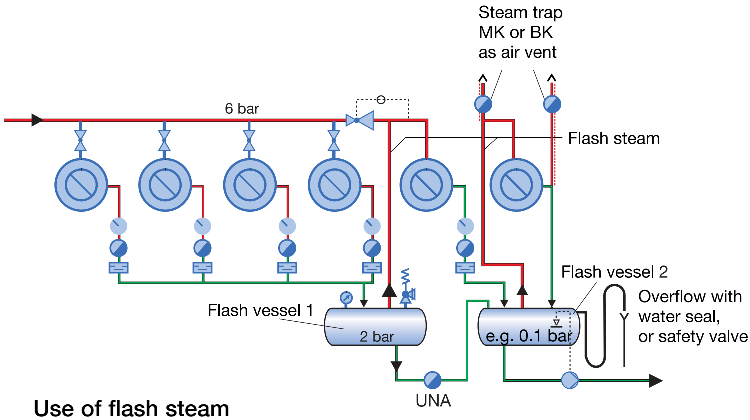


Fig. 75 Use of flash steam

Flash vessel connections permit multiple condensate flashing to freely definable back pressures. The flash steam produced through the sensible heat released in the corresponding pressure stage is separated from the residual condensate and used for the steam operation of the downstream heat exchangers. At the same time, simultaneous condensate return to the boiler house ensures a targeted and economical utilization of the sensible heat.

The condensate from the heat exchanger group heated by 6-bar steam is routed to flash vessel 1 and, from there, passed to flash vessel 2 under level control. The condensate return from flash vessel 2 to the boiler house is performed by a pump, also with level control.

The steam pressure in the first flash vessel is kept constant by feeding in pressure-reduced live steam from the 6-bar system. Drainage takes place into flash vessel 2.

Owing to the low pressure, the second flash-vessel stage is switched to thermosyphon circulation. In order that this heat cycle can function without a differential pressure, the heating surface condensate must be discharged below the level of flash vessel 2 and perfect venting must be ensured, e.g. through a steam trap.

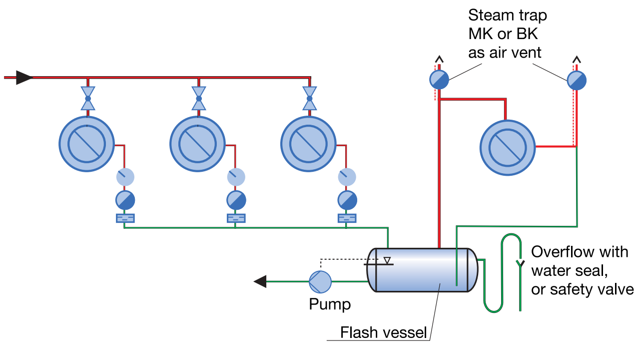


Fig. 76 Simple flash steam recovery with thermosyphon circulation

The amount of flash steam depends on the condensate flowrate and cannot be adapted to suit varying demand.

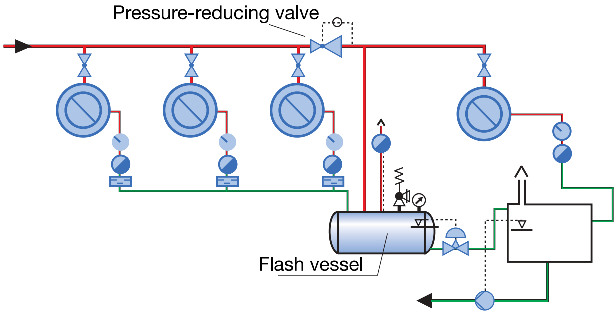


Fig. 77 Use of flash steam
If the steam supply from the flash vessel is not sufficient for the downstream heating surface, live steam is added via the pressure-reducing valve.

4.2.3 Air-venting of steam users

For steam and condensate systems, it must always be expected that air and other gases will pass into circulation despite repeated deaeration of the boiler feedwater. In addition, air ingress from the outside is also to be expected, especially during periods when the plant has been shut down.

Air and other gases in a heat exchanger reduce the efficiency, lead to corrosion, and sometimes hinder the condensate discharge process. In the case of simple heat exchangers that are drained via suitable steam traps - e.g. the GESTRA steam traps MK and BK - adequate venting at start-up and during continuous operation is ensured together with the condensate discharge.

In large-volume steam systems and in heat exchangers of a complex configuration, however, air and gas pockets that do not reach the steam trap may be formed. The steam traps mentioned above are also suitable for the additional automatic venting of such steam spaces. Their function as air vents is based on the fact that the partial pressure of the steam drops with a rising proportion of air. At the same time, the steam temperature also falls, whilst the total pressure of the steam/air mixture remains constant. For the thermostatic steam traps MK and BK, this results in an opening signal. Through an uninsulated pipe section between the steam space and air vent, the air-venting capacity is increased.

A number of typical cases are presented below.

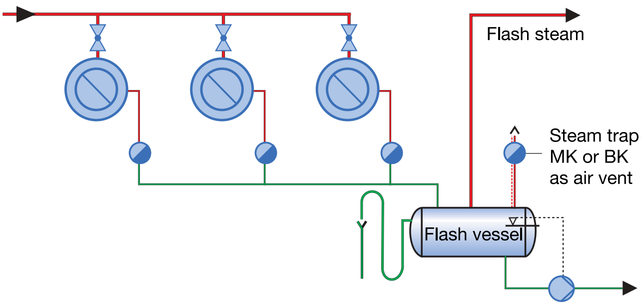


Fig. 78 GESTRA steam trap as air vent at the flash vessel
This arrangement prevents non-condensable gases from passing into the downstream heat exchangers together with the flash steam.

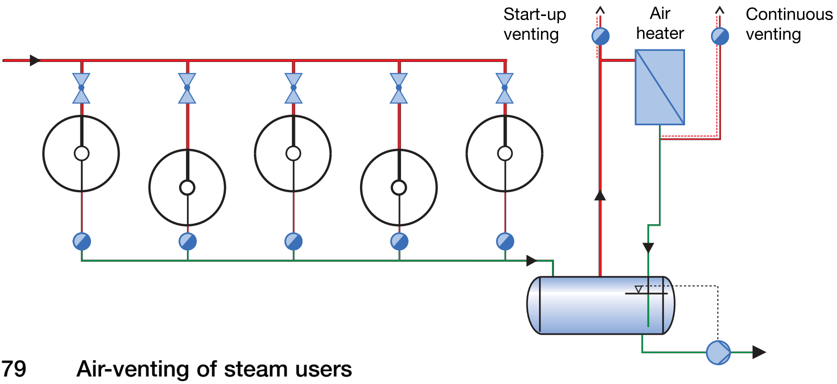


Fig. 79 **Air-venting of steam users**
The air heater in the thermosyphon circuit that is heated with flash steam requires flawless start-up and continuous venting to ensure that the practically unpressurized heat cycle (i.e. without differential pressure) can function at all.

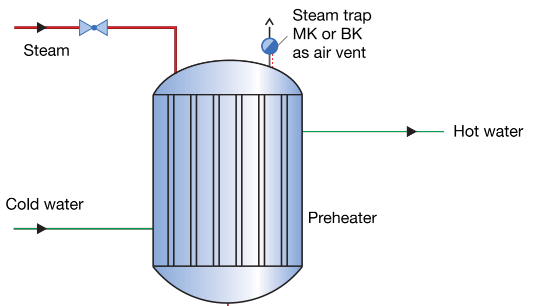


Fig. 80 GESTRA steam trap as air vent at a vertical preheater

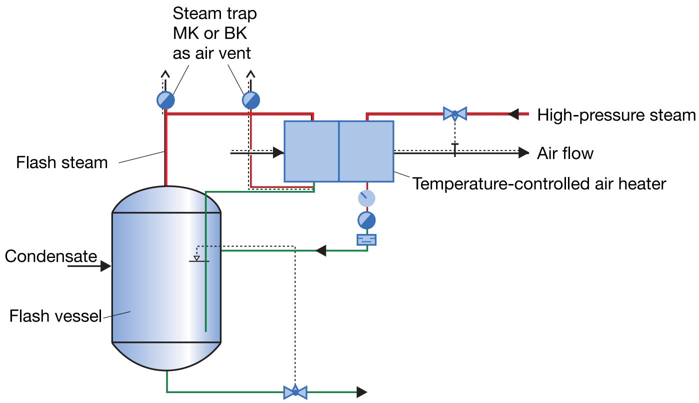


Fig. 81 GESTRA steam trap as air vent for the preliminary stage of an air heater heated by the flash steam

4.2.4 Measures against waterhammer

Examples from practice: Figures 82 to 87 a) show equipment components in which waterhammer can occur. Figures 82 to 87 b) depict improvements which help to prevent or reduce waterhammer.

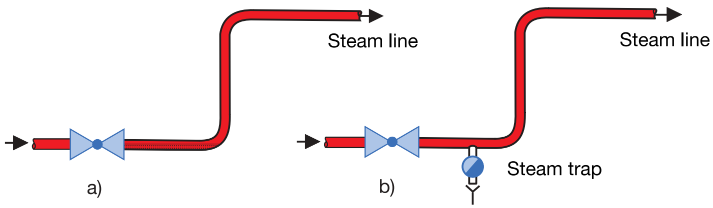


Fig. Waterhammer in steam lines

a) Whenever the stop valve is closed, the steam remaining in the line condenses. The condensate collects in the lower part of the line and cools down. When the valve is reopened, the inflowing steam meets the condensate. The result is waterhammer.

b) If the run of the pipe cannot be changed, the line should be drained, even if it is relatively short (see Section 4.2.1.2).

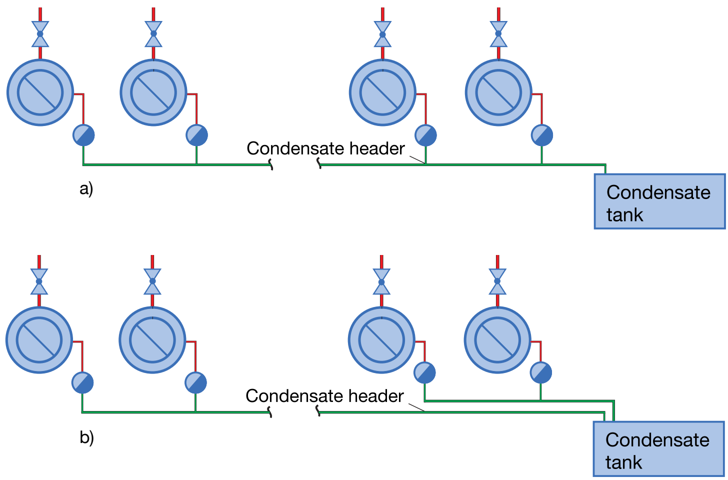


Fig. 83 Waterhammer in condensate lines

a) The condensate from the heat exchanger on the far end cools down strongly on its way to the condensate tank. The condensate with the flash steam from the heat exchangers that are closer to the condensate tank mixes with this cold condensate. The flash steam condenses abruptly and waterhammer will result.

b) Waterhammer can be avoided if the condensate is sent to the condensate tank via separate headers. Condensate from heat exchangers using different steam pressures should also be fed to the condensate tank by separate headers.

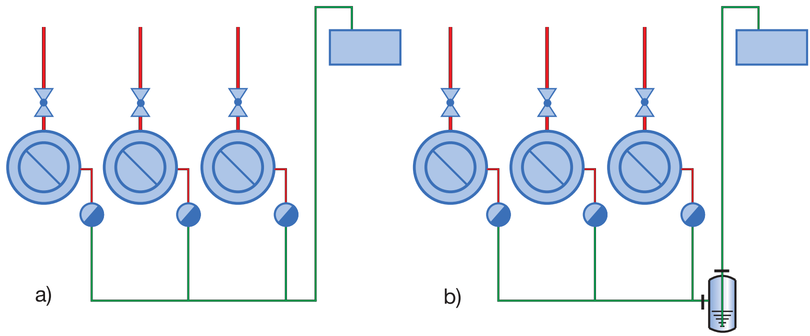


Fig. 84 Waterhammer if condensate is lifted

a) Waterhammer often occurs if condensate if lifted.

b) The remedy is to install a condensate dampening pot, which by its cushioning effect neutralizes the waterhammer.

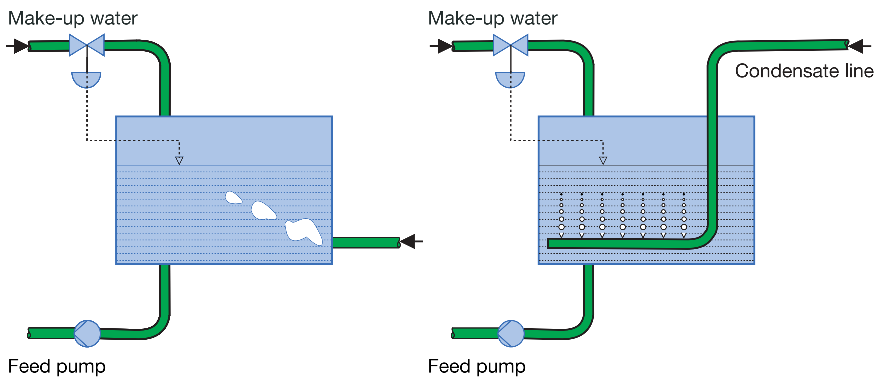


Fig. 85 Waterhammer on discharging condensate into feedwater tanks

a) Normally, flash steam is produced downstream of the steam trap. In order that it is not lost, the condensate with the flash steam can be fed into the tank below the water level. However, the flash steam then encounters relatively cold water.
When the flash steam enters the tank, it forms steam bubbles which condense quickly, leading to waterhammer and noise.
If the steam user is shut down, water is able to flow back into the condensate line. When the user is started up again, waterhammer can then result.

b) Thanks to the many small drill-holes in the inlet pipe, large steam bubbles cannot be formed. Noticeable waterhammer and noise are prevented. Routing the condensate line into the tank from above usually prevents the water from flowing back when the steam user is shut down.

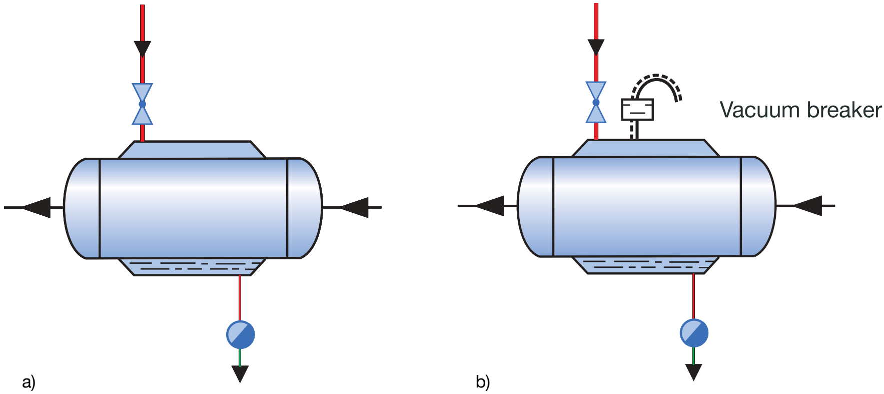


Fig. 86 Waterhammer in heat exchangers

a) If the steam supply is cut off, vacuum is formed in the steam space as the remaining steam condenses. There is a risk that condensate may then be sucked back into the heating space or not completely discharged (to say nothing of the possibility of permanent deformation of the heat exchanger).
When the plant is restarted, the steam flows across the water surface and condenses suddenly, thereby causing waterhammer.

b) Installation of a GESTRA DISCO non-return valve as a vacuum breaker prevents the formation of vacuum. The condensate cannot be sucked back, and the remaining condensate will flow off. Waterhammer is therefore avoided.

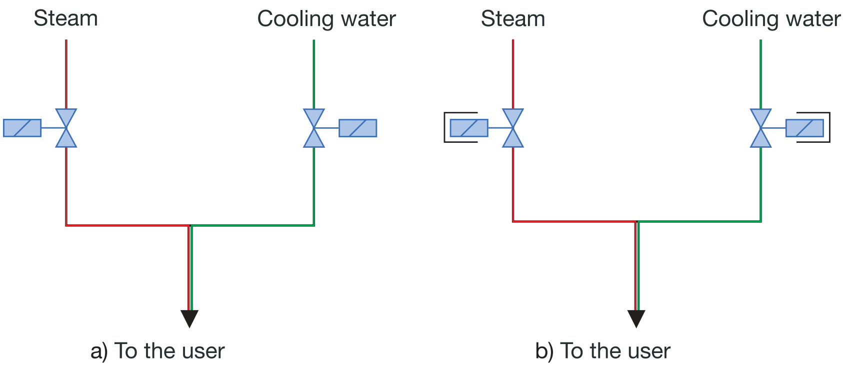


Fig. 87 Waterhammer in systems used for both heating and cooling

a) Hydraulic and thermal waterhammer is caused by the rapid opening or closing of the solenoid valves when switching over from heating to cooling mode or vice versa.

b) Through slow opening and closing of the three-way control valves, waterhammer can be prevented to a large degree. Here it is advisable to use either solenoid valves with hydraulic damping or motorized valves.

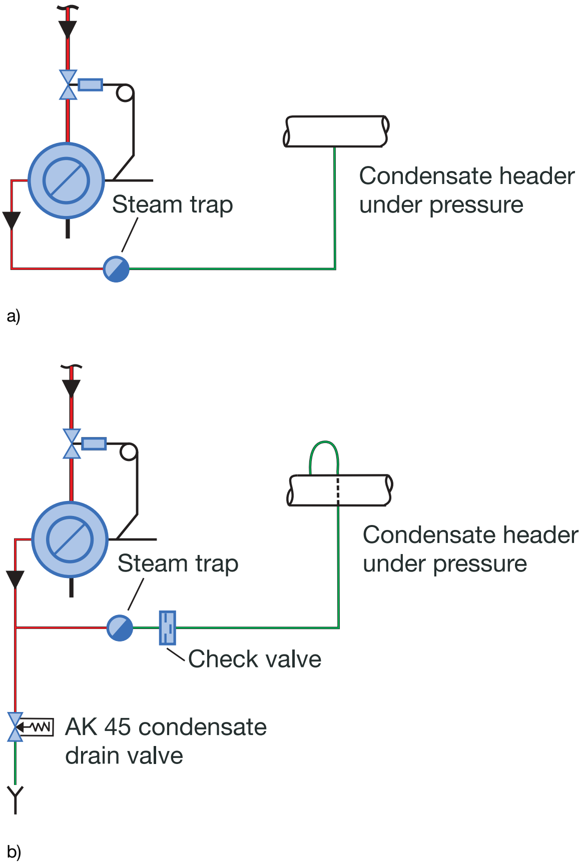


Fig. 88 Waterhammer in horizontal counterflow heat exchangers controlled on the steam side

Heat exchangers, e.g. for the preparation of hot water, are often mounted on the floor. Elevated installation on the wall or hanging from the ceiling is worthwhile, because discharge difficulties and hence waterhammer can be avoided as a result.

a) When controlled at light load, the heating surface is partly flooded, since the pressure in the heat exchanger is no longer sufficient to lift the condensate. The condensate then cools down. As soon as the supply steam controller opens up further, more steam flows in. The pressure and thus the steam temperature both increase. Steam flows over the large water surface and condenses suddenly, causing waterhammer.

b) For heat exchangers operating in batch mode (e.g. boiling apparatus, autoclaves or evaporators), fast start-up and shut-down with frequent batch changes is required. The GESTRA AK 45 permits rapid start-up, because the condensate produced at start-up can be discharged freely. Waterhammer can no longer occur. When the plant has been shut down, the GESTRA AK 45 allows the residual condensate to drain, thereby preventing frost damage and distortion through the formation of vacuum and also reducing the downtime corrosion.

4.3 Connection Examples for Heating Systems using Liquid Heating Media

4.3.1 General

In most cases, heating systems using liquid heating media have widely branched networks for supplying a large number of heat users which differ in respect of their heat demand and flow resistance. Naturally, the heating medium tends to flow through the users with the lowest resistances. To ensure distribution to match the demand of all users, the flow resistances must be adjusted so that they are balanced. Inflexible compensation of the resistances by means of orifice plates or valves is inadequate, because the loads in the system are seldom constant. If a different flowrate is needed at a particular user, i.e. the resistance must be changed there, it almost always means that all users in an uncontrolled system must be readjusted to prevent over- or underheating.

In central heating systems and district heating networks, in tracing systems and at heat exchangers, this fundamental supply problem and the need for economical utilization of the heating medium are both answered by the installation of return-temperature control valves (Kalorimat valves). Some brief considerations are presented in the following.

4.3.2 Return-temperature control valves (type Kalorimat)

The Kalorimat is a valve with direct temperature control that is installed in the heating return line of the pertinent heat user. It keeps the previously set return temperature of the heat medium constant with regard to its proportional range. If the inlet temperature is also constant, the temperature spread desired for each user is maintained.

The Kalorimat reacts to the slightest changes in the preset return temperature, e.g. as a result of a change in load, with a corresponding change in its cross-sectional area. The flow resistance of the relevant user is continuously adapted to the heat demand needed by the product. Only the quantity of heat medium needed at that particular time actually flows. The Kalorimat valve therefore acts as a flow regulator, strictly speaking as a heat flow regulator, and indirectly as a product temperature regulator. It prevents over- and underheating, short-circuits and dead zones, even in widely branched systems. As a circulation valve between the inlet manifold and return header in a tracing system, the Kalorimat stops the water located in the manifold from cooling down if heating units have been switched off. This is of significance for fast restarting of the plant. Kalorimat units at the ends of trains and systems ensure adequate circulation at low temperatures in order to provide protection against freezing.

For instance, the Kalorimat in the circulation line, e.g. for a district-heating end connection, is adjusted so that the agreed supply temperature is also maintained when consumption is interrupted.

It sometimes happens that dangerous heat accumulations occur in the piping of large systems, e.g. at light load, the consequences of which are prevented by Kalorimat valves installed as circulation valves.

4.3.3 Examples for applications of Kalorimat valves

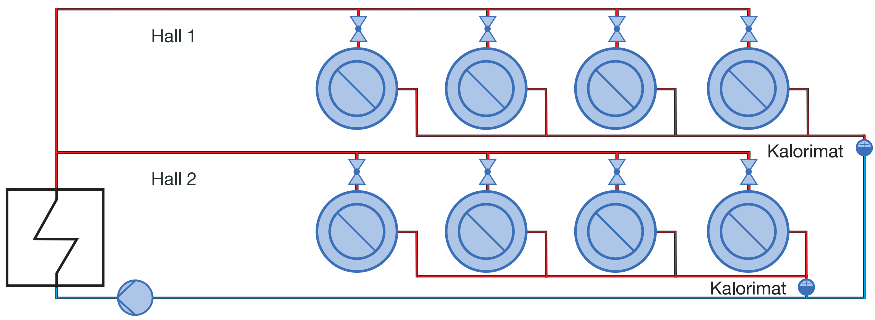


Fig. 89 Kalorimat regulation of user groups – unfavourable

An inflexible balancing by orifice plates or valves is inadequate. Differing network resistances – pipes and users – can indeed be balanced out with the aid of orifice plates or by changing the valve settings. However, if a different heating level is needed at a certain user, it may be necessary to readjust the whole network again. Kalorimat regulation of entire user groups cannot prevent unbalanced heating within the groups.
Installation of Kalorimat valves in the header return lines of the user groups only achieves balanced operation of the two user groups in relation to each other. If a new heating level is needed, e.g. for the first user in hall 2, then all users of this group must be readjusted.

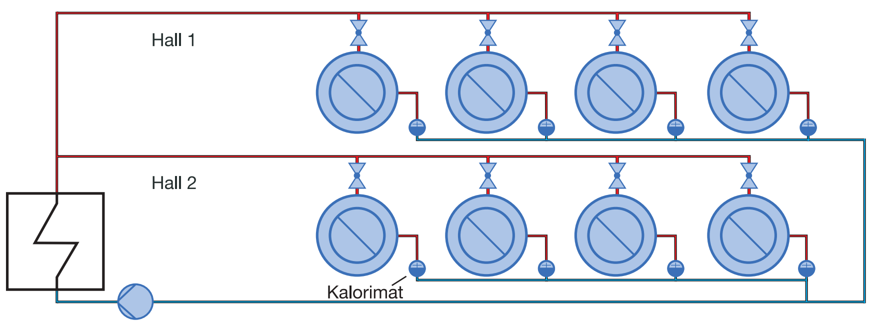


Fig. 90 Kalorimat regulation of individual users – correct

Kalorimat regulation of the individual users does away with the need for any manual adjustment. In this connection, each user is balanced individually and automatically. This ensures that the heating medium is distributed to meet the specific needs of all users. Different heating levels are possible for the various users without renewed balancing.

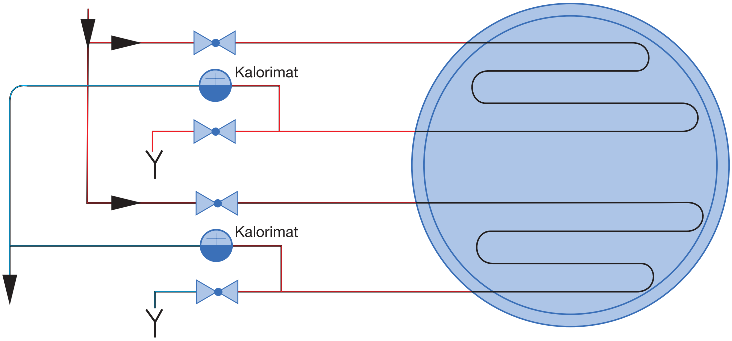


Fig. 91 Kalorimat valves at a tank heated with hot water

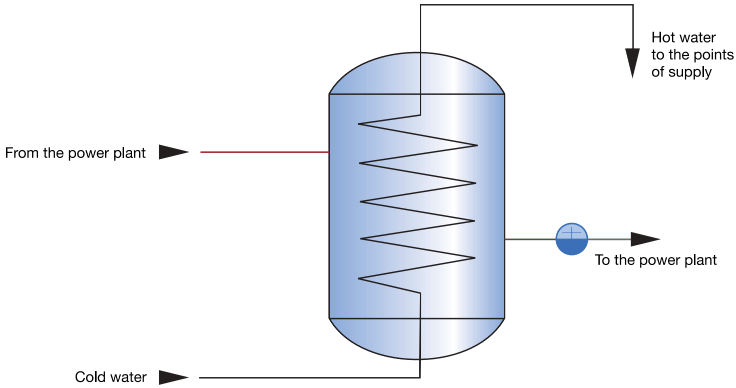


Fig. 92 Kalorimat in the outlet line of an instantaneous water heater

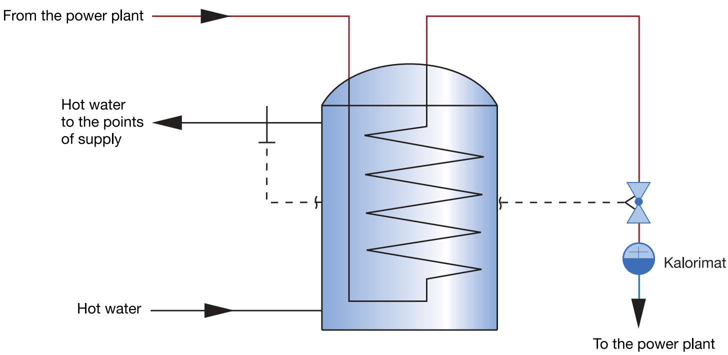


Fig. 93 Kalorimat at a thermal storage heater

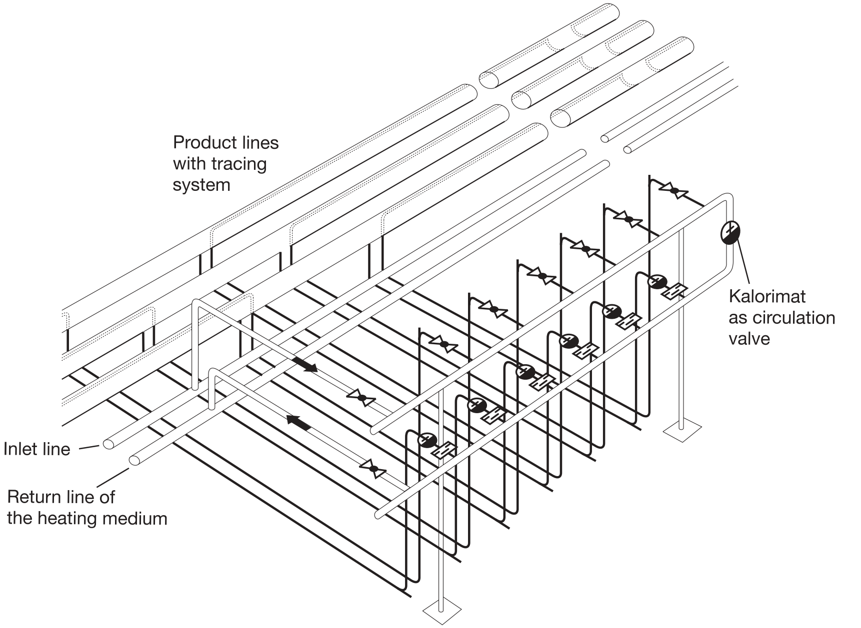


Fig. 94 Kalorimat valves in the distribution system of a hot-water tracing system.

The hot water flows via the inlet line and the manifold into the tracer pipes. It then passes back via the return header and the distribution line. On the inlet side, the tracer pipes are provided with shut-off valves. Kalorimat valves are installed in the lines at the return header. The DISCO non-return valves RK mounted there make it possible to perform maintenance and repair work without having to shut down the entire heating system.
To prevent the water in the distribution line from cooling down when heaters are switched off, a short-circuit with the return header is provided at the end of the inlet manifold; this is activated automatically at the corresponding temperature by the Kalorimat installed to act as a circulation valve.

4.4. Connection Examples for Cooling Systems using Cooling Water or Brine

4.4.1 General

In cooling water systems as in heating systems, it is necessary to balance the various flow resistances to ensure that all users are supplied in accordance with their individual requirements. Here too, inflexible adjustment of network resistances is unsatisfactory, because the loads in the system are seldom constant.

With the use of cooling-water control valves (type GESTRAMAT) at all users, a continual balancing of the flow resistances and of supply to meet demand - even for changes in load - is ensured at all times. Moreover, cooling-water control valves keep the preset return temperature constant within tight limits, so that their use also permits better utilization of the cooling capacity of the water. Practical experience has confirmed that, at most coolers, higher return temperatures of the coolant are quite admissible and can be implemented by means of cooling-water control valves. This approach yields considerable savings in cooling water and pumping power.

Example: Cooling capacity (heat flow): $\dot{Q}$ = 930 kW (= 930 kJ/s)

Cooling water temperature, inlet and outlet: t_i = 10 °C, t_o = 20 °C

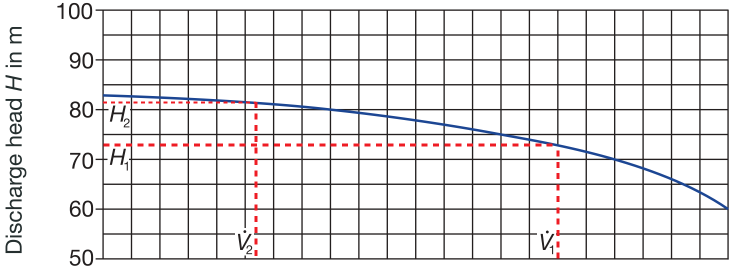
Specific heat capacity: c = 4.18 kJ/kg K

Water throughput (delivery flowrate): $\dot{V}_1 = \dfrac{\dot{Q}}{c\,(t_a - t_e)}$ = 22.2 kg/s = 80 m^3/h

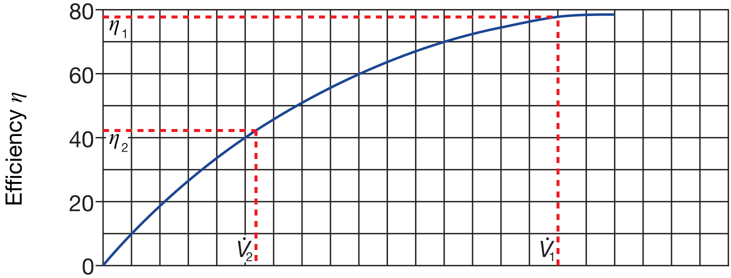
For a cooling water outlet temperature of 40 °C, the required water throughput drops to: $\dot{V}_1$ = 26.6 m^3/h

This yields savings of:

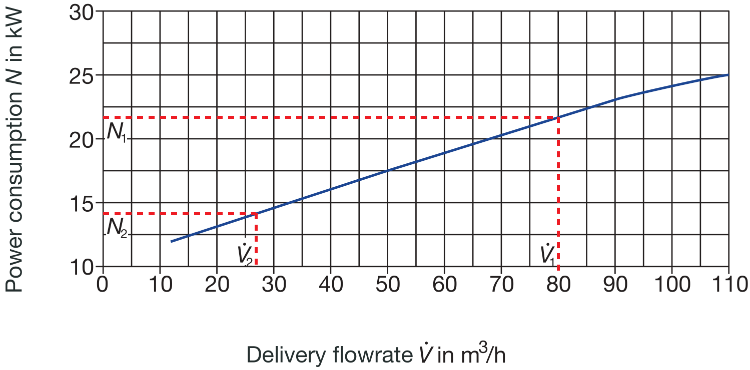
cooling water	66 %
pumping power	35 %



Characteristic curve of a commercial centrifugal pump



Pump efficiency as a function of delivery flowrate



Power consumption as a function of delivery flowrate

Fig. 95 Pump parameters in relation to flowrate

4.4.2 Cooling water control valves CW

The operational functions of cooling-water control valves (type GESTRAMAT) – also suitable for use with refrigerating brine – and Kalorimat valves (see Section 4.3.2) are comparable. From a fairly simple viewpoint, the situation can be put as follows:

The cooling-water control valve aims to have the coolant warm up to the desired return temperature. In contrast, the Kalorimat ensures that the heating medium cools down to the preset return temperature. These temperatures are kept within close bounds (+/-1 °C), even during fluctuations in load. Like the Kalorimat, the cooling-water control valve is a return-temperature limiter but, in addition, it regulates the flowrate to suit the demand. Fitting all users of a system with these control valves ensures optimum demand-oriented distribution and utilization.

Cooling-water control valves are suitable for all coolers which can be subjected to pressure; they are installed in the cooling-water return line. It is advisable to mount these units so that they cannot dry out during an interruption in operation.

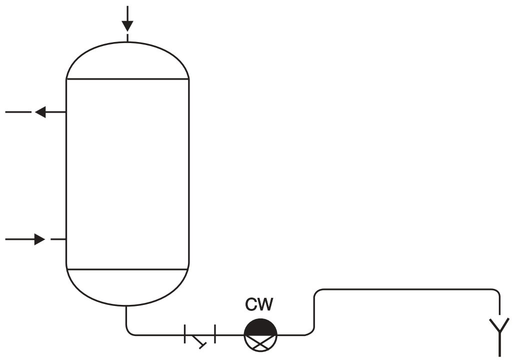


Fig. 96 Use with a counterflow cooler

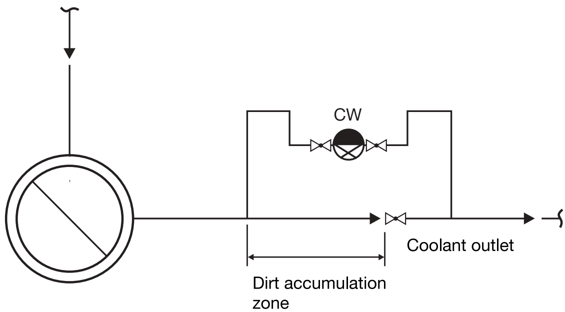


Fig. 97 Bypass configuration with closed return line

By increasing the discharge temperature to a constant presettable value, optimum use of the cooling water is achieved. Minimizing the water consumption also reduces the operating expenses and power consumption.

4.4.3 Self-acting temperature controllers (type Clorius)

Self-acting temperature control valves are used for regulating heating and cooling processes. These units are proportional controllers of a very robust design operating without auxiliary energy. A temperature feeler, acting via a capillary tube, is used to drive a control valve in relation to the product temperature. These control valves are provided as straight-through, closing, opening, and three-way types for diverting and mixing applications.

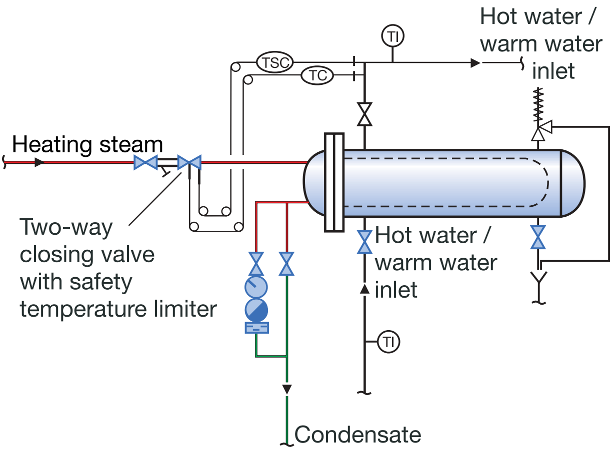


Fig. 98 Heat exchanger with control on the steam side for a constant secondary inlet temperature

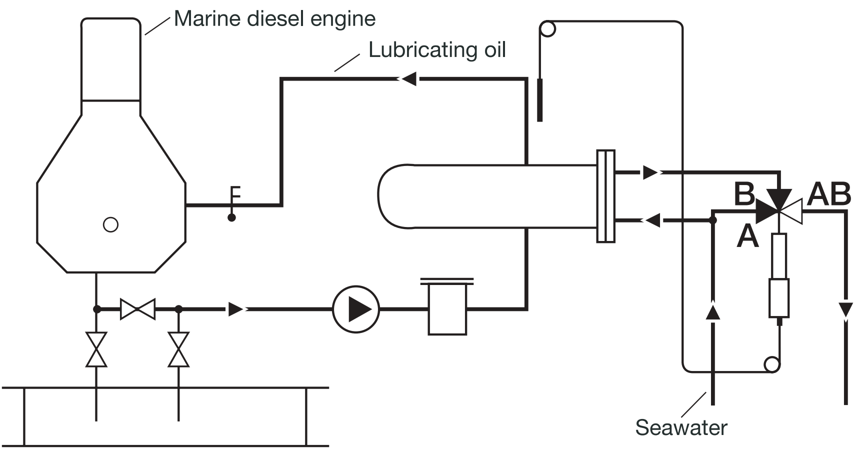


Fig. 99 Lubricating oil cooler with three-way valve in the secondary seawater cooling circuit

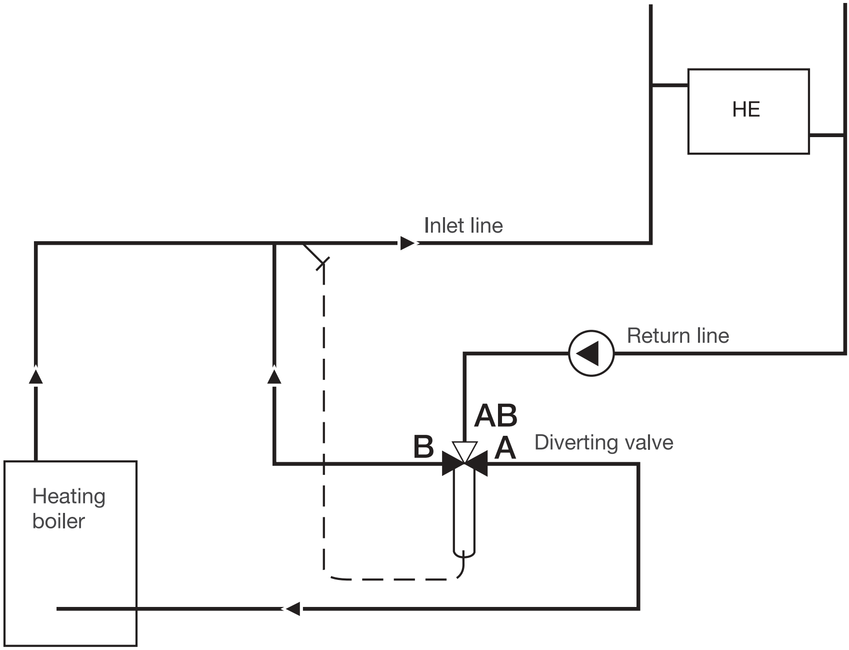


Fig. 100 Heating plant

5 Materials and Durability Tables

GESTRA Steam Systems

Valves

Industrial Electronics, Automation

Special Equipment
and Vessels for Heat Recovery

Services

5. Materials

5.1 General

5.1.1 Material numbers

In order to name materials in a clear and unambiguous manner, there are usually two identifiers: the material number and the material designation.
For the material number, various systems are employed in practice, depending on the type of material.
In many cases, the purely numerical material number is used, e.g. 1.4571.
Here the first digit indicates the main material group (1 = steel). This is followed by a dot and a four-digit sequential number.
However, alphanumeric material numbers are used for some types of materials, e.g. EN-JL1040, EN AW-6060, CW614N.

5.1.2 Material designations

The systems used for the material designation differ greatly. In many cases, the material designation is composed of the symbols for chemical elements contained in the material, together with numbers representing the relative quantities of the corresponding elements, e.g. 42CrMo4.
For other materials, the material designation is made up of symbols which have nothing to do with the composition of the material, e.g. P250GH. Detailed information on the various designation systems is given in the corresponding standards, as mentioned in the following sections.

5.1.3 Chemical elements (a useful selection)

Symbol	Element	Symbol	Element	Symbol	Element
Al	aluminium	Mn	manganese	Si	silicon
B	boron	Mo	molybdenum	Sn	tin
Bi	bismuth	N	nitrogen	Te	tellurium
C	carbon	Nb	niobium	Ti	titanium
Co	cobalt	Ni	nickel	V	vanadium
Cr	chrome	Pb	lead	W	tungsten
Cu	copper	S	sulphur	Zn	zinc
Fe	iron	Se	selenium	Zr	zirconium
Mg	magnesium				

Fig. 101

5.2 Steels

5.2.1 Designation systems

The structures and methods of the designation systems used for steels are described in the following standards:

DIN EN 10020	Definition and classification of grades of steel
DIN EN 10079	Definition of steel products
DIN EN 10027-1	Designation systems for steel – Steel names
DIN V 17006-100	Designation systems for steel – Additional symbols
DIN EN 10027-2	Designation systems for steel – Numerical system

5.2.2 Material standards

The following standards (representing only a selection) provide information on the composition, properties and semi-finished product types of steel:

DIN EN 10139	Strips, uncoated mild steel for cold forming
DIN EN 10088-2	Sheet/plates and strips of corrosion resisting steels
DIN EN 10269	Fasteners
DIN EN 10132-4	Strips of spring steel
DIN EN 10270-1	Steel wire, cold drawn
DIN EN 10270-3	Steel wire, stainless
DIN EN 10089	Steels for quenched and tempered springs
DIN EN 10113-2	Flat and long products, weldable fine-grain structural steels
DIN EN 10025	Flat and long products, non-alloy structural steels
DIN EN 10028-4	Flat products, cryogenic, for pressure vessels
DIN EN 10028-7	Flat products, corrosion resistant, for pressure vessels
DIN EN 10028-3	Flat products, weldable, normalized, for pressure vessels
DIN EN 10028-5	Flat products, weldable, thermomechanically rolled, for pressure vessels
DIN EN 10028-6	Flat products, weldable, quenched and tempered, for pressure vessels
DIN EN 10028-2	Flat products, unalloyed/alloyed, for pressure vessels
DIN EN 10213-1	Steel castings, general
DIN EN 10213-4	Castings, austenitic
DIN EN 10213-2	Castings, elevated temperatures
DIN EN 10283	Castings, corrosion resistant
DIN EN 10213-3	Castings, low temperatures
DIN EN 10088-3	Semi-finished products, bars, rods, wire, corrosion resistant
DIN 17457	Tubes, welded, austenitic
DIN EN 10217-3	Tubes, welded, alloyed fine-grain structural steels
DIN 1626	Tubes, welded, unalloyed
DIN 17458	Tubes, seamless, austenitic
DIN EN 10216-2	Tubes, seamless, elevated temperature, for pressure purposes
DIN EN 10305-1	Tubes, seamless, cold drawn, for precision applications
DIN EN 10216-3	Tubes, seamless, alloyed fine-grain structural steel, for pressure purposes
DIN 17456	Tubes, seamless, corrosion resistant
DIN EN 10216-1	Tubes, seamless, room temperature, for pressure purposes
DIN EN 10216-4	Tubes, seamless, low temperature, for pressure purposes

DIN 1629	Tubes, seamless, unalloyed
DIN EN 10222-2	Forgings, elevated temperature, for pressure vessels
DIN EN 10222-1	Forgings, open die, for pressure vessels
DIN EN 10222-5	Forgings, corrosion resistant, for pressure vessels
DIN EN 10222-4	Forgings, weldable, for pressure vessels
DIN EN 10222-3	Forgings, low temperature, for pressure vessels
DIN EN 10277-2	Bars, bright
DIN EN 10277-3	Bars, bright, free cutting steel
DIN EN 10277-4	Bars, bright, case hardening steel
DIN EN 10277-5	Bars, bright, quenching and tempering steel
DIN EN 10272	Bars, corrosion resistant, for pressure vessels
DIN EN 10087	Bars and rods, hot-rolled, free cutting steel
DIN EN 10273	Bars, hot-rolled, weldable, for pressure vessels
DIN EN 10084	Steels: case hardening steels
DIN EN 10083-1	Steels: quenching and tempering steels

5.2.3 Material selection

Mat. No.	Material designation	Standard	Application	Comparable ASTM material	Old number	Old designation
1.0425	P265GH	DIN EN 10273	Bars, hot-rolled, pressure vessels	–	–	–
1.0460	P250GH	DIN EN 10273	Bars, hot-rolled, pressure vessels	A105	1.0460	C 22.8
1.4922	X20CrMoV11-1	DIN EN 10273	Bars, hot-rolled, pressure vessels	–	1.4922	X 20 CrMoV 12 1
1.5415	16Mo3	DIN EN 10273	Bars, hot-rolled, pressure vessels	–	1.5415	15 Mo 3
1.7335	13CrMo4-5	DIN EN 10273	Bars, hot-rolled, pressure vessels	–	1.7335	13 CrMo 4 4
1.7380	10CrMo9-10	DIN EN 10273	Bars, hot-rolled, pressure vessels	–	–	–
1.4006	X12Cr13	DIN EN 10272	Bars, pressure vessels	A182 F6a	1.4006	X 10 Cr 13
1.4057	X17CrNi6-2	DIN EN 10272	Bars, pressure vessels	–	1.4057	X 20 CrNi 17 2
1.4301	X5CrNi18-10	DIN EN 10272	Bars, pressure vessels	–	–	–
1.4306	X2CrNi19-11	DIN EN 10272	Bars, pressure vessels	A182 F304L	–	–
1.4313	X3CrNiMo13-4	DIN EN 10272	Bars, pressure vessels	–	1.4313	X 4 CrNi 13 4
1.4401	X5CrNiMo17-12-2	DIN EN 10272	Bars, pressure vessels	–	–	–
1.4435	X2CrNiMo18-14-3	DIN EN 10272	Bars, pressure vessels	–	–	–
1.4462	X2CrNiMoN22-5-3	DIN EN 10272	Bars, pressure vessels	–	–	–
1.4529	X1NiCrMoCuN25-20-7	DIN EN 10272	Bars, pressure vessels	–	1.4529	X 1 NiCrMoCuN 25 20 6
1.4539	X1NiCrMoCu25-20-5	DIN EN 10272	Bars, pressure vessels	–	–	–

Fig. 102 Selection of the steels commonly used for valves and fittings (sorted by column 4 “Application”)

Mat. No.	Material designation	Standard	Application	Comparable ASTM material	Old number	Old designation
1.4541	X6CrNiTi18-10	DIN EN 10272	Bars, pressure vessels	–	–	–
1.4550	X6CrNiNb18-10	DIN EN 10272	Bars, pressure vessels	–	–	–
1.4571	X6CrNiMoTi17-12-2	DIN EN 10272	Bars, pressure vessels	–	–	–
1.4580	X6CrNiMoNb17-12-2	DIN EN 10272	Bars, pressure vessels	–	–	–
1.4006	X12Cr13	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	1.4006	X 10 Cr 13
1.4016	X6Cr17	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.4021	X20Cr13	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.4034	X46Cr13	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.4057	X17CrNi6-2	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	1.4057	X 20 CrNi 17 2
1.4104	X14CrMoS17	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	1.4104	X 12 CrMoS 17
1.4112	X90CrMoV18	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.4122	X39CrMo17-1	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	1.4122	X 35 CrMo 17
1.4301	X5CrNi18-10	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.4303	X4CrNi18-12	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	1.4303	X 5 CrNi 18 12
1.4305	X8CrNiS18-9	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.4306	X2CrNi19-11	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.4310	X10CrNI18-8	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	1.4310	X 12 CrNi 17 7
1.4313	X3CrNiMo13-4	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	1.4313	X 4 CrNi 13 4
1.4401	X5CrNiMo17-12-2	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.4404	X2CrNiMo17-12-2	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	1.4404	X 2 CrNiMo 17 13 2
1.4435	X2CrNiMo18-14-3	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.4462	X2CrNiMoN22-5-3	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.4529	X1NiCrMoCuN25-20-7	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	1.4529	X 1 NiCrMoCuN 25 20 6
1.4539	X1NiCrMoCu25-20-5	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.4541	X6CrNiTi18-10	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.4550	X6CrNiNb18-10	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.4568	X7CrNiAl17-7	DIN EN 10088-3	Bars, semi-fin.	–	–	–

Fig. 102 Selection of the steels commonly used for valves and fittings (sorted by column 4 “Application”)

Mat. No.	Material designation	Standard	Application	Comparable ASTM material	Old number	Old designation
			products, wire rods			
1.4571	X6CrNiMoTi17-12-2	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.4580	X6CrNiMoNb17-12-2	DIN EN 10088-3	Bars, semi-fin. products, wire rods	–	–	–
1.0619	GP240GH	DIN EN 10213-1	Castings	–	1.0619	GS-C 25
1.0619	GP240GH	DIN EN 10213-2	Castings	A216 WCB	1.0619	GS-C 25
1.4308	GX5CrNi19-10	DIN EN 10213-1	Castings	–	1.4308	G-X 6 CrNi 18 9
1.4308	GX5CrNi19-10	DIN EN 10213-4	Castings	A351 CF8	1.4308	G-X 6 CrNi 18 9
1.4309	GX2CrNi19-11	DIN EN 10213-4	Castings	–	–	–
1.4317	GX4CrN13-4	DIN EN 10213-1	Castings	–	–	–
1.4317	GX4CrN13-4	DIN EN 10213-2	Castings	A743 CA-6NM	–	–
1.4408	GX5CrNiMo19-11-2	DIN EN 10213-1	Castings	–	1.4408	G-X 6 CrNiMo 18 10
1.4408	GX5CrNiMo19-11-2	DIN EN 10213-4	Castings	A351 CF8M	1.4408	G-X 6 CrNiMo 18 10
1.4409	GX2CrNiMo19-11-2	DIN EN 10213-4	Castings	–	–	–
1.4552	GX5CrNiNb19-11	DIN EN 10213-1	Castings	–	1.4552	G-X 5 CrNiNb 18 9
1.4552	GX5CrNiNb19-11	DIN EN 10213-4	Castings	A351 CF8C	1.4552	G-X 5 CrNiNb 18 9
1.4581	GX5CrNiMoNb19-11-2	DIN EN 10213-1	Castings	–	1.4581	G-X 5 CrNiMoNb 18 10
1.4581	GX5CrNiMoNb19-11-2	DIN EN 10213-4	Castings	–	1.4581	G-X 5 CrNiMoNb 18 10
1.5419	G20Mo5	DIN EN 10213-1	Castings	–	1.5419	GS-22 Mo 4
1.5419	G20Mo5	DIN EN 10213-2	Castings	A217 WC1	1.5419	GS-22 Mo 4
1.7357	G17CrMo5-5	DIN EN 10213-1	Castings	–	–	–
1.7357	G17CrMo5-5	DIN EN 10213-2	Castings	A217 WC6	–	–
1.7379	G17CrMo9-10	DIN EN 10213-2	Castings	–	–	–
1.1181	C35E	DIN EN 10269	Fasteners (nuts)	A194 2H	1.1181	Ck 35
1.1181	C35E	DIN EN 10269	Fasteners (screws)	–	1.1181	Ck 35
1.1191	2C45	DIN EN 10269	Fasteners	–	–	–
1.4301	X5CrNi18-10	DIN EN 10269	Fasteners	–	–	–
1.4303	X4CrNi18-12	DIN EN 10269	Fasteners	–	1.4303	X 5 CrNi 18 12
1.4401	X5CrNiMo17-12-2	DIN EN 10269	Fasteners	–	–	–
1.4404	X2CrNiMo17-12-2	DIN EN 10269	Fasteners	–	1.4404	X 2 CrNiMo 17 13 2
1.4913	X19CrMoNbVN11-1	DIN EN 10269	Fasteners	–	–	–
1.4923	X22CrMoV12-1	DIN EN 10269	Fasteners	–	–	–
1.4980	X6NiCrTiMoVB25-15-2	DIN EN 10269	Fasteners	–	–	–
1.4986	X7CrNiMoBNb16-16	DIN EN 10269	Fasteners	–	1.4986	X8CrNiMoBNb 16 16
1.7218	25CrMo4	DIN EN 10269	Fasteners	–	–	–
1.7709	21CrMoV5-7	DIN EN 10269	Fasteners	–	–	–
1.7711	40CrMoV4-6	DIN EN 10269	Fasteners	–	1.7711	40 CrMoV 4 7
1.7225	42CrMo4	DIN EN 10269	Fasteners (nuts)	A194 7	–	–
1.7225	42CrMo4	DIN EN 10269	Fasteners (screws)	A193 B7	–	–
1.0035	S185	DIN EN 10025	Flat or long products	–	1.0035	St 33
1.0036	S235JRG1	DIN EN 10025	Flat or long products	–	1.0036	USt 37-2
1.0037	S235JR	DIN EN 10025	Flat or long products	–	1.0037	St 37-2
1.0038	S235JRG2	DIN EN 10025	Flat or long products	A283 C	1.0038	RSt 37-2
1.0044	S275JR	DIN EN 10025	Flat or long products	A36	1.0044	St 44-2

Fig. 102 Selection of the steels commonly used for valves and fittings (sorted by column 4 “Application”)

Mat. No.	Material designation	Standard	Application	Comparable ASTM material	Old number	Old designation
1.0050	E295	DIN EN 10025	Flat or long products	–	1.0050	St 50-2
1.0116	S235J2G3	DIN EN 10025	Flat or long products	–	1.0116	St 37-3 N
1.0570	S355J2G3	DIN EN 10025	Flat or long products	A573 70	1.0570	St 52-3 N
1.4006	X12Cr13	DIN EN 10088-2	Flat products	–	1.4006	X 10 Cr 13
1.4016	X6Cr17	DIN EN 10088-2	Flat products	–	–	–
1.4021	X20Cr13	DIN EN 10088-2	Flat products	–	–	–
1.4034	X46Cr13	DIN EN 10088-2	Flat products	–	–	–
1.4122	X39CrMo17-1	DIN EN 10088-2	Flat products	–	1.4122	X 35 CrMo 17
1.4301	X5CrNi18-10	DIN EN 10088-2	Flat products	–	–	–
1.4303	X4CrNi18-12	DIN EN 10088-2	Flat products	–	1.4303	X 5 CrNi 18 12
1.4305	X8CrNiS18-9	DIN EN 10088-2	Flat products	–	–	–
1.4306	X2CrNi19-11	DIN EN 10088-2	Flat products	–	–	–
1.4310	X10CrNI18-8	DIN EN 10088-2	Flat products	–	1.4310	X 12 CrNi 17 7
1.4313	X3CrNiMo13-4	DIN EN 10088-2	Flat products	–	1.4313	X 4 CrNi 13 4
1.4401	X5CrNiMo17-12-2	DIN EN 10088-2	Flat products	–	–	–
1.4404	X2CrNiMo17-12-2	DIN EN 10088-2	Flat products	–	1.4404	X 2 CrNiMo 17 13 2
1.4435	X2CrNiMo18-14-3	DIN EN 10088-2	Flat products	–	–	–
1.4462	X2CrNiMoN22-5-3	DIN EN 10088-2	Flat products	–	–	–
1.4510	X3CrTi17	DIN EN 10088-2	Flat products	–	1.4510	X 6 CrTi 17
1.4529	X1NiCrMoCuN25-20-7	DIN EN 10088-2	Flat products	–	1.4529	X 1 NiCrMoCuN 25 20 6
1.4539	X1NiCrMoCu25-20-5	DIN EN 10088-2	Flat products	–	–	–
1.4541	X6CrNiTi18-10	DIN EN 10088-2	Flat products	–	–	–
1.4550	X6CrNiNb18-10	DIN EN 10088-2	Flat products	–	–	–
1.4568	X7CrNiAl17-7	DIN EN 10088-2	Flat products	–	–	–
1.4571	X6CrNiMoTi17-12-2	DIN EN 10088-2	Flat products	–	–	–
1.4580	X6CrNiMoNb17-12-2	DIN EN 10088-2	Flat products	–	–	–
1.0425	P265GH	DIN EN 10028-2	Flat products, pressure vessels	–	1.0425	H II
1.0488	P275NL1	DIN EN 10028-3	Flat products, pressure vessels	–	1.0488	TStE 285
1.0566	P355NL1	DIN EN 10028-3	Flat products, pressure vessels	–	1.0566	TStE 355
1.4301	X5CrNi18-10	DIN EN 10028-7	Flat products, pressure vessels	–	–	–
1.4306	X2CrNi19-11	DIN EN 10028-7	Flat products, pressure vessels	–	–	–
1.4313	X3CrNiMo13-4	DIN EN 10028-7	Flat products, pressure vessels	–	1.4313	X 4 CrNi 13 4
1.4401	X5CrNiMo17-12-2	DIN EN 10028-7	Flat products, pressure vessels	–	–	–
1.4435	X2CrNiMo18-14-3	DIN EN 10028-7	Flat products, pressure vessels	–	–	–
1.4462	X2CrNiMoN22-5-3	DIN EN 10028-7	Flat products, pressure vessels	–	–	–
1.4510	X3CrTi17	DIN EN 10028-7	Flat products, pressure vessels	–	1.4510	X 6 CrTi 17
1.4529	X1NiCrMoCuN25-20-7	DIN EN 10028-7	Flat products, pressure vessels	–	1.4529	X 1 NiCrMoCuN 25 20 6
1.4539	X1NiCrMoCu25-20-5	DIN EN 10028-7	Flat products, pressure vessels	–	–	–

Fig. 102 Selection of the steels commonly used for valves and fittings (sorted by column 4 “Application”)

Mat. No.	Material designation	Standard	Application	Comparable ASTM material	Old number	Old designation
1.4541	X6CrNiTi18-10	DIN EN 10028-7	Flat products, pressure vessels	–	–	–
1.4550	X6CrNiNb18-10	DIN EN 10028-7	Flat products, pressure vessels	–	–	–
1.4571	X6CrNiMoTi17-12-2	DIN EN 10028-7	Flat products, pressure vessels	–	–	–
1.4580	X6CrNiMoNb17-12-2	DIN EN 10028-7	Flat products, pressure vessels	–	–	–
1.5415	16Mo3	DIN EN 10028-2	Flat products, pressure vessels	–	1.5415	15 Mo 3
1.7335	13CrMo4-5	DIN EN 10028-2	Flat products, pressure vessels	–	1.7335	13 CrMo 4 4
1.7380	10CrMo9-10	DIN EN 10028-2	Flat products, pressure vessels	–	–	–
1.7383	11CrMo9-10	DIN EN 10028-2	Flat products, pressure vessels	–	–	–
1.8915	P460NL1	DIN EN 10028-3	Flat products, pressure vessels	–	1.8915	TStE 460
1.8918	P460NL2	DIN EN 10028-3	Flat products, pressure vessels	–	1.8918	EStE 460
1.0352	P245GH	DIN EN 10222-2	Forgings, pressure vessels	–	–	–
1.0460	P250GH	DIN EN 10222-2	Forgings, pressure vessels	A105	1.0460	C 22.8
1.4301	X5CrNi18-10	DIN EN 10222-5	Forgings, pressure vessels	A182 F304	–	–
1.4313	X3CrNiMo13-4	DIN EN 10222-5	Forgings, pressure vessels	–	–	–
1.4401	X5CrNiMo17-12-2	DIN EN 10222-5	Forgings, pressure vessels	A182 F316	–	–
1.4404	X2CrNiMo17-12-2	DIN EN 10222-5	Forgings, pressure vessels	A182 F316L	1.4404	X 2 CrNiMo 17 13 2
1.4435	X2CrNiMo18-14-3	DIN EN 10222-5	Forgings, pressure vessels	–	–	–
1.4462	X2CrNiMoN22-5-3	DIN EN 10222-5	Forgings, pressure vessels	–	–	–
1.4529	X1NiCrMoCuN25-20-7	DIN EN 10222-5	Forgings, pressure vessels	–	1.4529	X 1 NiCrMoCuN 25 20 6
1.4539	X1NiCrMoCu25-20-5	DIN EN 10222-5	Forgings, pressure vessels	–	–	–
1.4541	X6CrNiTi18-10	DIN EN 10222-5	Forgings, pressure vessels	A182 F321	–	–
1.4550	X6CrNiNb18-10	DIN EN 10222-5	Forgings, pressure vessels	A182 F347	–	–
1.4571	X6CrNiMoTi17-12-2	DIN EN 10222-5	Forgings, pressure vessels	–	–	–
1.4903	X10CrMoVNb9-1	DIN EN 10222-2	Forgings, pressure vessels	A182 F91	–	–
1.4922	X20CrMoV11-1	DIN EN 10222-2	Forgings, pressure vessels	–	1.4922	X 20 CrMoV 12 1

Fig. 102 Selection of the steels commonly used for valves and fittings (sorted by column 4 “Application”)

Mat. No.	Material designation	Standard	Application	Comparable ASTM material	Old number	Old designation
1.5415	16Mo3	DIN EN 10222-2	Forgings, pressure vessels	A182 F1	1.5415	15 Mo 3
1.7335	13CrMo4-5	DIN EN 10222-2	Forgings, pressure vessels	A182 F12-2	1.7335	13 CrMo 4 4
1.7383	10CrMo9-10	DIN EN 10222-2	Forgings, pressure vessels	A182 F22-3	–	–
1.0254	P235TR1	DIN EN 10216-1	Tubes, seamless, pressure vessels	–	1.0254	St 37.0
1.0345	P235GH	DIN EN 10216-2	Tubes, seamless, pressure vessels	–	1.0305	St 35.8
1.0488	P275NL1	DIN EN 10216-3	Tubes, seamless, pressure vessels	–	1.0488	TStE 285
1.4922	X20CrMoV11-1	DIN EN 10216-2	Tubes, seamless, pressure vessels	–	1.4922	X 20 CrMoV 12 1
1.5415	16Mo3	DIN EN 10216-2	Tubes, seamless, pressure vessels	–	1.5415	15 Mo 3
1.7218	25CrMo4	DIN EN 10216-2	Tubes, seamless, pressure vessels	–	–	–
1.7219	26CrMo4-2	DIN EN 10216-4	Tubes, seamless, pressure vessels	–	1.7219	26 CrMo 4
1.7335	13CrMo4-5	DIN EN 10216-2	Tubes, seamless, pressure vessels	–	1.7335	13 CrMo 4 4
1.7380	10CrMo9-10	DIN EN 10216-2	Tubes, seamless, pressure vessels	–	–	–
1.8915	P460NL1	DIN EN 10216-3	Tubes, seamless, pressure vessels	–	1.8915	TStE 460

Fig. 102 Selection of the steels commonly used for valves and fittings (sorted by column 4 “Application”)

5.3 Cast Iron

5.3.1 Designation systems

The structures and methods of the designation systems used for cast iron are described in the following standard:

DIN EN 1560 Material symbols and material numbers

5.3.2 Material standards

The following standards (representing only a selection) provide information on the composition and properties of cast iron:

DIN EN 1563 Cast iron with spheroidal graphite
DIN EN 1561 Cast iron with laminated graphite
DIN EN 1562 Malleable cast irons

5.3.3 Material selection

Mat. No.	Material designation	Standard	Application	Comparable ASTM material	Old number	Old designation
EN-JL1030	EN-GJL-200	DIN EN 1561	Casting	A48 No25	0.6020	GG-20
EN-JL1040	EN-GJL-250	DIN EN 1561	Casting	A126 Class B	0.6025	GG-25
EN-JL1050	EN-GJL-300	DIN EN 1561	Casting	A48 No40B	0.6030	GG-30
EN-JL1060	EN-GJL-350	DIN EN 1561	Casting	A48 No50B	0.6035	GG-35
EN-JM1010	EN-GJMW-350-4	DIN EN 1561	Casting	–	0.8035	GTW-35-04
EN-JM1030	EN-GJMW-400-5	DIN EN 1561	Casting	–	0.8040	GTW-40-05
EN-JS1019	EN-GJS-350-22U-LT	DIN EN 1563	Casting (with test piece)	–	–	–
EN-JS1049	EN-GJS-400-18U-LT	DIN EN 1563	Casting (with test piece)	–	0.7043	GGG-40.3
EN-JS1072	EN-GJS-400-15U	DIN EN 1563	Casting (with test piece)	A536 60-40-18	0.7040	GGG-40
EN-JS1082	EN-GJS-500-7U	DIN EN 1563	Casting (with test piece)	–	0.7050	GGG-50
EN-JS1015	EN-GJS-350-22-LT	DIN EN 1563	Casting (with test piece)	–	0.7033	GGG-35.3
EN-JS1025	EN-GJS-400-18-LT	DIN EN 1563	Casting (with test piece)	–	0.7043	GGG-40.3
EN-JS1030	EN-GJS-400-15	DIN EN 1563	Casting (with test piece)	A536 60-40-18	0.7040	GGG-40
EN-JS1050	EN-GJS-500-7	DIN EN 1563	Casting (with test piece)	–	0.7050	GGG-50

Fig. 103 Selection of cast iron materials in common use (sorted by column 4 “Application”)

5.4 Aluminium Alloys

5.4.1 Designation systems

The structures and methods of the designation systems used for aluminium alloys are described in the following standards:

DIN EN 1780-2 Designation for aluminium castings
DIN EN 1780-3 Designation for aluminium castings; Writing rules
DIN EN 573-2 Chemical symbols for wrought products
DIN EN 1780-1 Material numbers for aluminium castings
DIN EN 573-1 Material numbers for wrought products

5.4.2 Material standards

The following standards (representing only a selection) provide information on the composition, properties and semi-finished product types of aluminium alloys:

DIN EN 485-2 Sheets, strips and plates
DIN EN 1706 Castings
DIN EN 573-3 Wrought products; Chemical composition
DIN EN 573-3 Wrought products; Forms of products
DIN EN 754-2 Rods and bars, cold drawn
DIN EN 755-2 Rods, bars and profiles, extruded
DIN EN 586-2 Forgings

5.4.3 Material selection

Mat. No.	Material designation	Standard	Application	Comparable ASTM material	Old number	Old designation
EN AC-44200	EN AC-Al Si12(a)	DIN EN 1706	Casting	–	3.2581	G-AlSi 12
EN AC-44300	EN AC-Al Si12(Fe)	DIN EN 1706	Casting	–	3.2582	GD-AlSi 12
EN AW-5754	EN AW-Al Mg 3	DIN EN 573-3	Wrought product	–	3.3535	AlMg 3
EN AW-6082	EN AW-Al Si1MgMn	DIN EN 573-3	Wrought product	–	3.2315	AlMgSi 1
EN AW-6060	EN AW-Al MgSi	DIN EN 754-2	Rod/bar, cold drawn	–	3.3206	AlMgSi 0,5

Fig. 104 Selection of the aluminium alloys commonly used for valves and fittings (sorted by column 4 “Application”)

5.5 Copper Alloys

5.5.1 Designation systems

The structure and method of the designation system used for copper and copper alloys are described in the following standard:

DIN EN 1412	European numbering system

5.5.2 Material standards

The following standards (representing only a selection) provide information on the composition, properties and semi-finished product types of copper alloys:

DIN EN 1652	Plates, sheets, strips and circles
DIN EN 12166	Wire
DIN EN 1982	Castings, ingots
DIN EN 12168	Hollow rods for free machining purposes
DIN EN 12449	Tubes, seamless
DIN EN 12420	Forgings
DIN EN 12165	Forging stock, wrought and unwrought
DIN EN 12164	Rods for free machining purposes
DIN EN 12167	Profiles and rectangular bars
DIN EN 12163	Rods, round/polygonal

5.5.3 Material selection

Mat. No.	Material designation	Standard	Application	Comparable ASTM material	Old number	Old designation
CC332G	CuAl10Ni3Fe2-C	DIN EN 1982	Casting	–	2.0970.01	G-CuAl 9 Ni
CC333G	CuAl10Fe5Ni5-C	DIN EN 1982	Casting	–	2.0975.01	G-CuAl 10 Ni
CC480K	CuSn10-C	DIN EN 1982	Casting	–	2.1050.01	G-CuSn 10
CC483K	CuSn12-C	DIN EN 1982	Casting	–	2.1052.01	G-CuSn 12 Zn
CC491K	CuSn5Zn5Pb5-C	DIN EN 1982	Casting	–	2.1096.01	G-CuSn 5 ZnPb
CC493K	CuSn7Zn4Pb7-C	DIN EN 1982	Casting	–	2.1090.01	G-CuSn 7 ZnPb
CC750S	CuZn33Pb2-C	DIN EN 1982	Casting	–	2.0290.01	G-CuZn 33 Pb
CW306G	CuAl10Fe3Mn2	DIN EN 12420	Forging	–	2.0936.08	CuAl 10 Fe 3 Mn 2
CW307G	CuAl10Ni5Fe4	DIN EN 12420	Forging	–	2.0966	CuAl 10 Ni 5 Fe 4
CW509L	CuZn40	DIN EN 12420	Forging	–	2.0360.08	CuZn 40
CW608N	CuZn38Pb2	DIN EN 12420	Forging	–	2.0401.08	CuZn 39 Pb 3
CW612N	CuZn39Pb2	DIN EN 12420	Forging	–	2.0380.08	CuZn 39 Pb 2
CW614N	CuZn39Pb3	DIN EN 12420	Forging	–	2.0401.08	CuZn 39 Pb 3
CW617N	CuZn40Pb2	DIN EN 12420	Forging	–	2.0402.08	CuZn 40 Pb 2
CW710R	CuZn35Ni3Mn2AlPb	DIN EN 12420	Forging	–	2.0540.08	CuZn 35 Ni 2
CW608N	CuZn38Pb2	DIN EN 12164	Rod for machining purposes	–	–	–
CW612N	CuZn39Pb2	DIN EN 12164	Rod for machining purposes	–	2.0380	CuZn 39 Pb 2
CW614N	CuZn39Pb3	DIN EN 12164	Rod for machining purposes	–	2.0401	CuZn 39 Pb 3

Fig. 105 Selection of the copper alloys commonly used for valves and fittings (sorted by column 4 "Application")

Mat. No.	Material designation	Standard	Application	Comparable ASTM material	Old number	Old designation
CW617N	CuZn40Pb2	DIN EN 12164	Rod for machining purposes	–	2.0402	CuZn 40 Pb 2
CW306G	CuAl10Fe3Mn2	DIN EN 12167	Rod, rectangular	–	2.0936	CuAl 10 Fe 3 Mn 2
CW307G	CuAl10Ni5Fe4	DIN EN 12167	Rod, rectangular	–	2.0966	CuAl 10 Ni 5 Fe 4
CW452K	CuSn6	DIN EN 12167	Rod, rectangular	–	2.1020	CuSn 6
CW453K	CuSn8	DIN EN 12167	Rod, rectangular	–	2.1030	CuSn 8
CW507L	CuZn36	DIN EN 12167	Rod, rectangular	–	2.0335	CuZn 36
CW509L	CuZn40	DIN EN 12167	Rod, rectangular	–	2.0360	CuZn 40
CW608N	CuZn38Pb2	DIN EN 12167	Rod, rectangular	–	–	–
CW612N	CuZn39Pb2	DIN EN 12167	Rod, rectangular	–	2.0380	CuZn 39 Pb 2
CW614N	CuZn39Pb3	DIN EN 12167	Rod, rectangular	–	2.0401	CuZn 39 Pb 3
CW617N	CuZn40Pb2	DIN EN 12167	Rod, rectangular	–	2.0402	CuZn 40 Pb 2
CW710R	CuZn35Ni3Mn2AlPb	DIN EN 12167	Rod, rectangular	–	2.0540	CuZn 35 Ni 2
CW306G	CuAl10Fe3Mn2	DIN EN 12163	Rod, round/ polygonal	–	2.0936	CuAl 10 Fe 3 Mn 2
CW307G	CuAl10Ni5Fe4	DIN EN 12163	Rod, round/ polygonal	–	2.0966	CuAl 10 Ni 5 Fe 4
CW452K	CuSn6	DIN EN 12163	Rod, round/ polygonal	–	2.1020	CuSn 6
CW453K	CuSn8	DIN EN 12163	Rod, round/ polygonal	–	2.1030	CuSn 8
CW459K	CuSn8P	DIN EN 12163	Rod, round/ polygonal	–	2.1030	CuSn 8
CW507L	CuZn36	DIN EN 12163	Rod, round/ polygonal	–	2.0335	CuZn 36
CW509L	CuZn40	DIN EN 12163	Rod, round/ polygonal	–	2.0360	CuZn 40
CW710R	CuZn35Ni3Mn2AlPb	DIN EN 12163	Rod, round/ polygonal	–	2.0540	CuZn 35 Ni 2

Fig. 105 Selection of the copper alloys commonly used for valves and fittings (sorted by column 4 “Application”)

5.6 Nickel Alloys

5.6.1 Material standards

The following standards (representing only a selection) provide information on the composition, properties and semi-finished product types of nickel alloys:

DIN 17750	Sheets, strips and plates
DIN 17753	Wires
DIN EN 10302	Nickel and cobalt alloys, high-temperature
DIN 17742	Wrought nickel alloys with chromium – Chemical composition
DIN 17745	Wrought alloys of nickel and iron – Chemical composition
DIN 17743	Wrought nickel alloys with copper – Chemical composition
DIN 17744	Wrought nickel alloys with molybdenum, cobalt and chromium – Chemical composition
DIN 17741	Wrought nickel alloys, low alloyed – Chemical composition
DIN 17751	Tubes
DIN 17752	Rods and bars

A number of particularly corrosion-resistant nickel alloys are known by the trademark "Hastelloy". They are used e.g. in the chemical industry, in aviation and also for valves and fittings. "Nimonic" and "Inconel" are trademarks for some high-temperature austenitic NiCr and NiCrCo alloys.

5.6.2 Material selection

Mat. No.	Material designation	Standard	Application	Comparable ASTM material
2.4600	NiMo29Cr "Hastelloy B-3"	DIN 17752	Bar	–
2.4610	NiMo16Cr16Ti "Hastelloy C-4"	DIN 17752	Bar	–
2.4617	NiMo28 "Hastelloy B-2"	DIN 17752	Bar	–
2.4669	NiCr15Fe7TiAl	DIN EN 10302	Fasteners	–
2.4819	NiMo16Cr15W	DIN 17750	Flat product	–
2.4632	NiCr20Co18Ti "Nimonic 90"	DIN EN 10302	Steel, high-temperature	–
2.4669	NiCr15Fe7TiAl "Inconel X750"	DIN EN 10302	Steel, high-temperature	–
2.4360	NiCu30Fe	DIN 17743	Wrought alloy	–
2.4816	NiCr15Fe	DIN 17742	Wrought alloy	–
2.4819	NiMo16Cr15W "Hastelloy C-276"	DIN 17744	Wrought alloy	–

Fig. 106 Selection of the nickel alloys commonly used for valves and fittings (sorted by column 4 "Application")

5.7 Titanium and Titanium Alloys

5.7.1 Material standards

The following standards (representing only a selection) provide information on the composition, properties and semi-finished product types of titanium and titanium alloys:

DIN 17860	Sheets, strips and plates
DIN 17863	Wires
DIN 17866	Tubes, welded
DIN 17861	Tubes, seamless
DIN 17864	Forgings
DIN 17862	Bars
DIN 17850	Titanium; chemical composition
DIN 17851	Titanium alloys; chemical composition

Titanium – which is used, for example, in the manufacture of chemical equipment, owing to its good anti-corrosion properties – exhibits an excellent resistance to oxidizing media. Many corrosion problems encountered with conventional materials, e.g. in conjunction with some of the acids used in the chemical industry, are solved satisfactorily when titanium is selected as the material. Pure titanium suffers practically no corrosion in chlorine and chlorinated media.
Titanium alloys have large proportions of primarily metallic alloying elements. The mechanical properties of titanium alloys are comparable to those of high-alloy steels. For this reason, it is used in the aerospace industry, for example.

5.7.2 Material selection

Mat. No.	Material designation	Standard	Application	Comparable ASTM material
3.7025	Ti 1	DIN 17862	Bar	–
3.7035	Ti 2	DIN 17862	Bar	–
3.7055	Ti 3	DIN 17862	Bar	–
3.7165	TiAl6V4	DIN 17862	Bar	B348 5
3.7235	Ti 2 Pd	DIN 17862	Bar	B348 7
3.7031	G-Ti	DIN 17865	Casting	–
3.7032	G-Ti 2 Pd	DIN 17865	Casting	–
3.7025	Ti 1	DIN 17860	Flat product	–
3.7035	Ti 2	DIN 17860	Flat product	–
3.7055	Ti 3	DIN 17860	Flat product	–
3.7165	TiAl6V4	DIN 17860	Flat product	–
3.7235	Ti 2 Pd	DIN 17860	Flat product	–
3.7025	Ti 1	DIN 17864	Forging	–
3.7035	Ti 2	DIN 17864	Forging	–
3.7055	Ti 3	DIN 17864	Forging	–
3.7165	TiAl6V4	DIN 17864	Forging	–
3.7235	Ti 2 Pd	DIN 17864	Forging	–
3.7025	Ti 1	DIN 17861	Tube, seamless	–
3.7035	Ti 2	DIN 17861	Tube, seamless	–
3.7055	Ti 3	DIN 17861	Tube, seamless	–
3.7165	TiAl6V4	DIN 17861	Tube, seamless	–
3.7235	Ti 2 Pd	DIN 17861	Tube, seamless	–

Fig. 107 Selection of the titanium materials commonly used for valves and fittings (sorted by column 4 “Application”)

5.8 Plastics

DIN EN ISO 1043-1 Symbols and abbreviated terms for basic polymers and their characteristics

DIN EN ISO 1043-2 Symbols and abbreviated terms for fillers and reinforcing materials

Acronym	Expansion	Acronym	Expansion
AB	acrylonitrile-butadiene plastic	PAK	polyacrylate
ABAK	acrylonitrile-butadiene-acrylate plastic	PAN	polyacrylonitrile
ABS	acrylonitrile-butadiene-styrene plastic	PAR	polyarylate
ACS	acrylonitrile-chlorinated polyethylene-styrene plastic	PARA	polyaryl amide
		PB	polybutene
AEPDS	acrylonitrile-(ethylene-propylene-diene)-styrene plastic	PBAK	polybutyl acrylate
		PBD	1,2-polybutadiene
AMMA	acrylonitrile-methyl-methacrylate plastic	PBN	polybutylene naphthalate
		PBT	polybutylene terephthalate
ASA	acrylonitrile-styrene-acrylate plastic	PC	polycarbonate
CA	cellulose acetate	PCCE	polycyclohexylene dimethylene cyclohexanedicarboxylate
CAB	cellulose acetate butyrate		
CAP	cellulose acetate propionate	PCL	polycaprolactone
CEF	cellulose formaldehyde resin	PCT	polycyclohexylene dimethylene terephthalate
CF	cresol-formaldehyde resin		
CMC	carboxymethyl cellulose	PCTFE	polychlorotrifluoroethylene
CN	cellulose nitrate	PDAP	polydiallyl phthalate
COC	cycloolefin copolymer	PDCPD	polydicyclopentadiene
CP	cellulose propionate	PE	polyethylene
CTA	cellulose triacetate	PEC	polyestercarbonate
EAA	ethylene-acrylic acid plastic	PEEK	polyetheretherketone
EBAK	ethylene-butyl acrylate plastic	PEEST	polyetherester
EC	ethyl cellulose	PEI	polyetherimide
EEAK	ethylene-ethyl acrylate plastic	PEK	polyetherketone
EMA	ethylene-methacrylic acid plastic	PEN	polyethylene naphthalate
EP	epoxy resin	PEOX	polyethylene oxide
E/P	ethylene-propylene plastic	PESU	polyethersulphone
ETFE	ethylene-tetrafluoroethylene plastic	PESTUR	polyesterurethane
EVAC	ethylene-vinyl acetate plastic	PET	polyethylene terephthalate
EVOH	ethylene-vinyl alcohol plastic	PEUR	polyetherurethane
FEP	perfluoro (ethylene-propylene) plastic	PF	phenol-formaldehyde resin
FF	furan-formaldehyde resin	PFA	perfluoro alkoxyl alkane resin
LCP	liquid-crystal polymer	PI	polyimide
MABS	methacrylate-acrylonitrile-butadiene-styrene plastic	PIB	polyisobutylene
		PIR	polyisocyanurate
MBS	methyl methacrylate-butadiene-styrene plastic	PK	polyketone
		PMI	polymethacrylimide
MC	methyl cellulose	PMMA	polymethyl methacrylate
MF	melamine-formaldehyde resin	PMMI	poly-N-methylmethacrylimide
MP	melamine-phenol resin	PMP	poly-4-methyl pent-1-ene
MSAN	alpha-methylstyrene-acrylonitrile plastic	PMS	poly-alpha-methylstyrene
		POM	polyoxymethylene; polyformaldehyde
PA	polyamide	PP	polypropylene
PAA	polyacrylic acid	PPE	polyphenylene ether
PAEK	polyaryletherketone	PPOX	polypropylene oxide
PAI	polyamidimide	PPS	polyphenylene sulphide

Fig. 108

Acronym	Expansion	Acronym	Expansion
PPSU	polyphenylene sulphone	SI	silicone plastic
PS	polystyrene	SMAH	styrene-maleic anhydride plastic
PSU	polysulphone	SMS	styrene-alpha-methylstyrene plastic
PTFE	polytetrafluoroethylene	UF	urea-formaldehyde resin
PTT	polytrimethylene terephthalate	UP	unsaturated polyester resin
PUR	polyurethane	VCE	vinyl chloride-ethylene plastic
PVAC	polyvinyl acetate	VCEMAK	vinyl chloride-ethylene-methyl acrylate plastic
PVAL	polyvinyl alcohol		
PVB	polyvinyl butyral	VCEVAC	vinyl chloride-ethylene-vinyl acetate plastic
PVC	polyvinyl chloride		
PVDC	polyvinylidene chloride	VCMAK	vinyl chloride-methyl acrylate plastic
PVDF	polyvinylidene fluoride	VCMMA	vinyl chloride-methyl methacrylate plastic
PVF	polyvinyl fluoride		
PVFM	polyvinyl formal	VCOAK	vinyl chloride-octyl acrylate plastic
PVK	poly-N-vinylcarbazole	VCVAC	vinyl chloride-vinyl acetate plastic
PVP	poly-N-vinylpyrrolidone	VCVDC	vinyl chloride-vinylidene chloride plastic
SAN	styrene-acrylonitrile plastic		
SB	styrene-butadiene plastic	VE	vinyl ester resin

Fig. 108 Continued

5.9 Durability Table

The durability data given in Figure 109 are based on laboratory tests, are operational results or are average values from various sources. All information is correct to the best of our knowledge.

Legend: 1 very suitable L risk of pitting corrosion
2 suitable S risk of crevice corrosion
3 not advisable

These ranking numbers can be used to make a preliminary selection of the materials for certain applications. However, practical trials may be necessary in many cases, with due consideration of the operational conditions and the function to be fulfilled by the component. For a sufficiently reliable assessment of the durability of a material, parameters such as pressure, temperature, composition of the medium, concentration and pH value are needed.

Medium	State		Durability of the materials							
	Mass per unit volume in %	°C Temperature	Grey/malleable cast iron	Steel/cast steel	Austenitic steel (1.4571)	Bronze	EPDM	NBR/Perbunan	FKM/Viton	PTFE/Teflon
Acetaldehyde	Liquid	20	3	3	1	2	2	3	3	1
Acetic anhydride	Liquid	20	3	3	1	3	3	3	3	1
Acetone	Liquid	20	1	1	1	1	1	3	3	1
Acetylene	Gas	20	1	1	1	3	1	1	1	1
Acrylonitrile	Liquid	20	1	1	1	1	1	3	2	1
Aluminium chloride	26% solution	20	3	3	3	3	1	2	1	1
Aluminium sulphate	10% solution	20	3	2	1	3	1	1	1	1
Ammonia, anhydrous	Gas	20	2	1	1	3	1	2	3	1
Ammonia, aqueous	30% solution	20	1	1	1	3	1	2	3	1
Ammonium carbonate	20% solution	20	3	3	1	3	1	1	3	1
Ammonium chloride	10% solution	20	3	3	1(L)	3	1	1	1	1
Ammonium monophosphate	10% solution	20	2	2	1	1	1	1	1	1
Ammonium nitrate	Aqueous solution	100	3	3	1	3	1	2	1	1
Ammonium sulphate	50% solution	20	3	3	1	2	1	1	1	1
Amyl acetate	50% solution	20-130	2	2	1	2	1	3	3	1
Aniline	Liquid	20-60	1	1	1	1	3	3	1	1
Apple juice	Liquid	20	3	3	1	3	1	1	1	1
Asphalt	Liquid	20-80	2	2	1	1	1	3	1	1
Barium carbonate	20 % solution	20	2	2	1	1	1	1	1	1
Barium chloride	10 % solution	20	3	2	1(L)	2	1	1	1	1
Barium sulphate	Aqueous solution	20	3	3	1	1	1	1	1	1
Beer	Aqueous solution	20	3	3	1	1	1	1	1	1

Fig. 109

Medium	State Mass per unit volume in %	°C Temperature	Durability of the materials: Grey/malleable cast iron	Steel/cast steel	Austenitic steel (1.4571)	Bronze	EPDM	NBR/Perbunan	FKM/Viton	PTFE/Teflon
Beet sugar liquor	Aqueous solution	20	2	2	1	1	1	1	1	1
Benzaldehyde	Liquid	20	3	3	1	2	1	2	1	1
Benzene	Liquid	20	1	1	1	1	3	2	1	1
Benzoic acid	Liquid	20	2	2	1	1	1	1	1	1
Benzol	Liquid	20	1	1	1	1	3	3	1	1
Boric acid	50 % solution	20	3	3	1	2	1	1	1	1
Brines	10-15 % solution	20	3	3	2	2	1	1	1	1
Bromine, wet	Liquid	20	3	3	3	2	1	3	1	1
Butane	Gas	20	2	2	1	1	2	1	1	1
Buttermilk	Aqueous solution	90	3	3	1	3	1	1	1	1
Butyl acetate	Liquid	20	1	1	1	1	2	3	3	1
Butyric acid	Solution	100	3	3	1	3	1	2	1	1
Calcium carbonate	Aqueous solution, saturated	20	2	2	1(L)	2	1	1	1	1
Calcium chloride	25 % solution	20	3	3	1	2	1	1	1	1
Calcium hydrogensulphite	4 % solution	20	3	3	2	2	1	1	1	1
Calcium hydroxide	Aqueous solution	20	1	1	1	1	1	1	1	1
Calcium sulphate	10 % solution	20	3	3	1	2	1	1	1	1
Carbolic (phenic) acid	90 % solution	20-100	3	3	1	2	3	3	1	1
Carbon dioxide, dry	Gas	20	1	1	1	1	1	1	1	1
Carbon disulphide	Gas	50	2	2	1	3	3	3	1	1
Carbon tetrachloride, wet	Liquid	20	2	2	1(L)	2	3	3	1	1
Carbonic acid	Aqueous solution	20	3	3	1	1	1	1	1	1
Castor oil	Liquid	20	2	2	1	1	3	1	1	1
Chlorine, dry	Gas	20	1	1	1	2	1	3	1	1
Chlorine water, saturated	Aqueous solution	20	3	3	3	3	1	3	1	1
Chlorine, wet	Gas	20	3	3	3	3	3	3	1	1
Chloroform, dry	Liquid	60	2	2	1	2	3	3	2	1
Chlorosulphuric acid, dry	10% solution	20	2	2	2(L)	2	3	3	3	1
Chlorosulphuric acid, wet	10% solution	20	3	3	3	3	3	3	3	1

Fig. 109 **Continued**

Medium	State Mass per unit volume in %	°C Temperature	Beständigkeit der Werkstoffe Grey/malleable cast iron	Steel/cast steel	Austenitic steel (1.4571)	Bronze	EPDM	NBR/Perbunan	FKM/Viton	PTFE/Teflon
Chromic acid	10 % solution	30	3	3	1	3	(1)	3	1	1
Copper acetate	Aqueous solution	20	3	3	1	3	1	1	1	1
Copper sulphate	Aqueous solution	20	3	3	1	2	1	1	1	1
Cresols	Aqueous solution	20	2	2	1	3	3	3	1	1
Cutting oil	Liquid	20	2	2	1	2	3	1	1	1
Diesel fuel	Liquid	20	1	1	1	1	3	1	1	1
Diethylamine	Liquid	25	1	1	1	3	1	2	3	1
Ethane	Gas	20	2	2	2	1	3	1	1	1
Ethanoic acid	25 % solution	20	3	3	1	3	1	3	3	1
Ethanoic acid, anhydrous	Liquid	20	3	3	1	2	1	1	1	1
Ether	Liquid	20	2	1	1	1	2	3	3	1
Ethyl acetate	Liquid	20	3	2	1	3	3	3	3	1
Ethyl alcohol	Liquid	20	2	2	1	1	1	1	3	1
Ethyl chloride, dry	Gas	20	2	2	1(L)	2	3	2	2	1
Ethyl chloride, wet	Gas	20	3	3	1	3	3	2	2	1
Ethylene glycol	Liquid	20	2	2	1	2	1	1	1	1
Fatty acids	Liquid	150	3	3	1	2	3	3	1	1
Fluorine, anhydrous	Gas	20	1	1	1	1	1	3	1	1
Formaldeyd	40 % solution	60	3	3	1	1	1	3	2	1
Formic acid	50-100% solution	20-70	3	3	1	2	2	3	3	1
Freons, anhydrous	Liquid	20	2	2	1	1	1	3	3	1
Fruit juices	Aqueous solution	20	3	3	1	2	1	1	1	1
Furfural	Gas	20	2	2	1	1	3	3	3	1
Glucose	Aqueous solution, conc.	20	2	2	1	1	1	1	1	1
Glycerol	Liquid	20	2	2	1	1	1	1	1	1
Glycols	Liquid	20	2	2	1	1	1	1	1	1
Heating oil, heavy	Liquid	20	2	2	1	2	3	2	1	1
Heating oil, light	Liquid	20	2	2	1	2	3	1	1	1
Heptane	Liquid	20	2	2	1	1	3	1	1	1
Hydraulic fluid	Liquid	20	2	2	1	2	3	1	1	1
Hydrobromic acid	Aqueous solution	20	3	3	3	3	1	3	1	1
Hydrochloric acid	10 % solution	20	3	3	3	3	1	2	1	1
Hydrochloric acid	32 % solution	20	3	3	3	3	1	2	1	1

Fig. 109 Continued

Medium	State Mass per unit volume in %	°C Temperature	Durability of the materials: Grey/malleable cast iron	Steel/cast steel	Austenitic steel (1.4571)	Bronze	EPDM	NBR/Perbunan	FKM/Viton	PTFE/Teflon
Hydrofluoric acid	60 % solution	20	3	3	3	3	1	1	3	1
Hydrogen	Gas	20	2	2	1	1	1	1	1	1
Hydrogen peroxide	30 % solution	20	3	3	1	3	1	3	1	1
Iron(III) chloride	10 % solution	50	3	3	3	3	1	1	1	1
Iron nitride	Aqueous solution	20	3	3	1	3	1	1	1	1
Iron(III) sulphate	10 % solution	20	3	3	1	3	1	1	1	1
Isopropyl alcohol	Liquid	20	2	2	1	1	1	2	1	1
Isopropyl ether	Liquid	20	2	1	1	1	1	2	2	1
Kerosine (paraffin)	Liquid	20	1	1	1	1	3	1	1	1
Lemon juice	15 % solution	20	3	3	1	1	1	1	3	1
Lactic acid	10-50 % solution	20	3	3	1	2	3	1	1	1
Lead acetate	25 % solution	20	3	3	1	3	1	1	1	1
Lighting gas	Gas	20	1	1	1	1	3	1	1	1
Linseed oil	Liquid	20	1	1	1	1	3	1	1	1
Magnesium sulphate	10 % solution	20	3	3	1	1	1	1	1	1
Maleic acid	50 % solution	100	3	2	1	3	1	1	1	1
Methane	Gas	100	2	2	1	1	2	1	1	1
Methyl acetate	Solution	20	2	2	1	1	3	3	3	1
Methyl alcohol	Liquid	20	2	2	1	2	1	2	2	1
Methyl chloride	Gas	100	2	2	1	1	1	3	1	1
Methyl cellulose	Aqueous solution	20	2	2	1	1	3	3	2	1
Methylene chloride	Liquid	20	3	3	1(L)	3	3	3	1	1
Milk	Liquid	20	3	3	1	1	1	1	1	1
Mineral oil	Liquid	20	2	2	1	2	3	1	1	1
Molasses	Liquid	20	3	3	1	1	1	1	1	1
Naphtha	Liquid	20	2	2	1	2	3	1	1	1
Nickel sulphate	Aqueous solution	20	3	3	1	2	1	1	1	1
Nitric acid	30 % solution	20	3	3	1	3	2	3	1	1
Nitric acid	100 % solution	20	3	3	1	3	3	3	3	1
Nitrobenzene	Liquid	20	2	2	1	2	3	3	3	1
Nitrous fumes	Gas	100	3	3	1	3	3	3	3	1
Oil (crude oil, sour)	Liquid	20	3	3	1	3	3	1	1	1
Oil (fish oil)	Liquid	150	2	2	1	1	3	1	1	1
Oil (lubricating oil)	Liquid	20	1	1	1	1	3	1	1	1

Fig. 109 Continued

Medium	State Mass per unit volume in %	°C Temperature	Durability of the materials Grey/malleable cast iron	Steel/cast steel	Austenitic steel (1.4571)	Bronze	EPDM	NBR/Perbunan	FKM/Viton	PTFE/Teflon
Oil (mineral oil, refined)	Liquid	20	2	1	1	1	3	1	1	1
Oleic acid: see fatty acid	Liquid	150	3	3	1	3	3	3	1	1
Oleum	Liquid	20	3	2	2	2	2	3	1	1
Olive oil	Liquid	100	2	2	1	1	3	2	1	1
Oxalic acid	25-50% solution	20	3	3	1	3	1	1	1	1
Oxygen	Gas	20	2	2	1	1	1	2	1	1
Ozone, dry	Gas	20	1	1	1	1	3	3	1	1
Ozone, wet	Gas	20	3	3	1	2	3	3	1	1
Palm oil	Liquid	100	3	3	1	2	3	2	1	1
Pentane	Gas	100	2	2	1	1	3	1	1	1
Perchloroethylene	Liquid	20	2	2	1(L)	3	3	3	1	1
Petroleum jelly	Liquid	20	2	2	1	2	3	1	1	1
Phenol	80 % solution	100	3	3	1	2	3	3	1	1
Phosphoric acid	10 % solution	20	3	3	1	2	1	1	1	1
Phosphoric acid	50 % solution	20	3	3	1	2	1	1	1	1
Potassium carbonate	50 % solution	20	2	2	1	2	1	1	1	1
Potassium chlorate	Aqueous solution, saturated	100	3	3	1	2	1	3	1	1
Potassium dichromate	30 % solution	20	3	3	1	3	1	2	1	1
Potassium diphosphate	20 % solution	20	1	1	1	2	1	1	1	1
Potassium hydroxide	Molten	360	2	2	1	3	3	3	3	3
Potassium hydroxide	70 % solution	100	2	2	1(S)	3	2	3	2	1
Potassium sulphate	50 % solution	50	3	3	1	2	1	1	1	1
Producer gas	Gas	20	2	2	1	2	1	1	1	1
Propane	Gas	20-80	2	2	1	1	1	1	1	1
Propanol (propyl alcohol)	solution	20	2	2	1	1	1	1	1	1
Propylene glycol	Liquid	20	2	2	1	1	1	2	1	1
Salicylic acid	20 % solution	20	3	3	1	2	1	1	1	1
Seawater	Aqueous solution	20	3	3	1	1	1	1	1	1
Soap solution	10 % solution	20	2	1	1	1	1	1	1	1
Sodium acetate	Aqueous solution	20	3	3	2	2	1	2	1	1
Sodium aluminate	Aqueous solution	20	2	2	1	2	1	1	1	1
Sodium bisulphite	50 % solution	20	3	3	1	2	1	1	1	1

Fig. 109 Continued

Medium	State Mass per unit volume in %	°C Temperature	Durability of the materials							
			Grey/malleable cast iron	Steel/cast steel	Austenitic steel (1.4571)	Bronze	EPDM	NBR/Perbunan	FKM/Viton	PTFE/Teflon
Sodium bromide	10 % solution	20	3	3	2(L)	2	1	1	1	1
Sodium chloride	20 % solution	20	3	3	1	2	1	1	1	1
Sodium chromate	20 % solution	20	2	2	1	2	1	1	1	1
Sodium hydroxide	70 % solution	20	2	2	1	3	2	1	1	1
Sodium meta-phosphate	10 % solution	20	2	2	1	2	1	1	1	1
Sodium metasilicate	10 % solution	20	3	3	1	2	1	1	1	1
Sodium peroxide	10 % solution	20	3	3	1	3	1	3	1	1
Sodium sulphate	20 % solution	20	3	3	1	3	1	1	1	1
Sodium sulphide	25 % solution	20	3	3	1	3	1	1	1	1
Sodium thiosulphate	25 % solution	20	3	3	1	3	1	3	1	1
Steam (water vapour)	Saturated steam	100	1	1	1	1	1	3	2	1
Sulphur	Molten	130	2	2	1	3	3	3	1	1
Sulphuric acid	7 % solution	20	3	3	1	3	1	1	1	1
Sulphuric acid	50 % solution	20	3	3	3	3	1	1	1	1
Sulphuric acid	98 % solution	20	2	2	1	3	3	3	2	1
Stearic acid	Liquid	100	3	3	1	2	1	1	1	1
Sugar solution	10 % solution	20	2	2	1	1	1	1	1	1
Tartaric acid	50 % solution	20	3	3	1	3	1	1	1	1
Tetraethyl lead	Liquid	20	3	3	1	2	3	3	3	1
Tin(II) chloride	20 % solution	20	3	3	3	3	1	1	1	1
Toluol	Liquid	20	1	1	1	1	3	3	2	1
Tomato juice	Aqueous solution	20	3	3	1	3	1	1	1	1
Transformer oil	Aqueous solution	20	2	1	1	2	3	1	2	1
Trichloroethylene	Aqueous solution	20	2	2	1(L)	2	3	3	1	1
Turpentine	Liquid	100	2	2	1	1	3	1	1	1
Urea	Aqueous solution, conc.	20	2	2	1	2	1	1	1	1
Vegetable oil (edible)	Liquid	20	2	2	1	1	3	1	1	1
Water, distilled (carbonic)	Liquid	20	3	3	1	1	1	1	1	1
Water (make-up water)	Liquid	20	2	2	1	1	1	1	1	1
Wax emulsion	Aqueous solution	50	2	1	1	1	3	1	1	1
Xylol	Liquid	20	2	2	1	1	3	3	1	1
Zinc sulphate	20 % solution	20-100	3	3	1	2	1	1	1	1

Fig. 109 Continued

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6 Units, Symbols, Conversion Tables

GESTRA Steam Systems

Valves

Industrial Electronics, Automation

Special Equipment
and Vessels for Heat Recovery

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6 Units, Symbols, Conversion Tables

6.1 General

6.1.1 Unitary systems

The legal units in metrology are the base units of the international system of units (SI system), the statutory units based on atomic values (as defined in § 4 of the Law on Units in Metrology), and the derived units obtained from the base units and atomic values (as defined in the implementation ordinance). The decimal multiples and submultiples formed from prefixes to these units are also legal.

Base quantity	Base unit Name	Symbol	Definition (see also DIN 1301)
length	metre	m	One metre is equal to the length of the path travelled by light in a vacuum during the time interval of 1/299,792,458 of a second.
mass	kilogram	kg	The kilogram is the only unit still defined by a physical prototype (the international prototype kilogram in Paris) instead of a measurable natural phenomenon. Note that the kilogram is the only base unit with a prefix; the gram is defined as a derived unit.
time	second	s	One second is the duration of exactly 9,192,631,770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the caesium-133 atom at a temperature of 0 K.
electrical current	ampere	A	One ampere is the constant current which, if maintained in two straight parallel conductors, of infinite length and negligible cross-section, placed 1 metre apart in a vacuum, would produce a force between these conductors equal to $2 \cdot 10^{-7}$ newtons per metre of length.
temperature	kelvin	K	One kelvin, as the unit of thermodynamic temperature (or absolute temperature), is the fraction 1/273.16 (exactly) of the thermodynamic temperature at the triple point of water.
amount of substance	mole	mol	One mole is the amount of substance which contains as many elementary entities as there are atoms in 0.012 kilograms of pure carbon-12. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.
luminous intensity	candela	cd	One candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency $540 \cdot 10^{12}$ hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

Fig. 110 SI base units

Base quantities	Base units		Unit of force	Unit of energy
length	metre	m	newton (N)	joule (J)
mass	kilogram	kg	1 N = 1 kgm/s^2	1 J = 1 Nm s
time	second	s		
electrical current	ampere	A		
thermodynamic temp.	kelvin	K		
amount of substance	mole	mol		
luminous intensity	candela	cd		

Fig. 111 International system of units (SI)

This unitary system is an extension of the MKS system. It is suitable for all areas of physics and technology, and permits the exclusive use of coherent units. All units derived from the seven base units of this system are coherent, i.e. in a relationship described by a unit equation, the only numerical factor needed for conversion is 1, for example:

Force = mass times acceleration

1 N = 1 kg · 1 m/s^2 = 1 kg m/s^2

When using the legal prefixes for multiples and submultiples of the units (which, however, should only be introduced during the final calculation), incoherent units may also be used if the numerical values obtained thereby are more convenient, for example:

1000 m = 10^3 m = 1 km

In accordance with the implementation ordinance, some older units in common use (e.g. kcal, kp, at) were admissible until 1977. As a result, these units will sometimes be encountered in the literature. Units that are not officially permitted in Germany are set in italics.

6.1.2 Physical quantities and their units

Symbol	Meaning	SI unit
A	area, cross-section	m^2
c	specific heat capacity, specific heat	J/kg K
C	unit conductance	$W/m^2\ K^4$
C	flow resistance coefficient	–
d	diameter, inside width	m
f_d	diameter factor	m^2/m
f_w	wind factor	–
g	gravity acceleration	m/s^2
G	weight (weight force) (cf. mass)	N
h, i	specific enthalpy	J/kg
H_v	static head	m
k	heat transfer coefficient	$W/m^2\ K$
l	length	m
m	mass (cf. weight)	kg
$\dot{m}$	mass flow, general	kg/s
$\dot{M}$	mass flow, condensate	kg/s
$\dot{M}_D$	mass flow, flash steam	kg/s
p	pressure	Pa (= N/m^2)
Δp	differential pressure, working pressure, pressure loss	Pa (= N/m^2)
$\dot{Q}$	heat flow	W (= J/s)
r	specific evaporation heat	J/kg
r	radius	m
Re	Reynolds number	–
s	specific entropy	J/kg K
t, θ	Celsius temperature ($t = T - T_0$; $T_0 = 273.15$ K)	°C
$\Delta t,\ \Delta\theta$	temperature difference ($\Delta t = \Delta\rho = \Delta T$)	K
T	thermodynamic temperature	K
$v,\ \nu$	specific volume	m^3/kg
V	volume	m^3
$\dot{V}$	volume flow	m^3/s
w	velocity (speed)	m/s
α	longitudinal expansion coefficient (coefficient of linear thermal expansion)	m/m K (= 1/K)
α	heat transmission coefficient	W/m^2K
γ	weight density (specific gravity)	N/m^3
δ	wall thickness, pipe/tube thickness	m
ξ	resistance coefficient	–
η	dynamic viscosity	Pa · s (= N s/m^2)
δ_1, t	Celsius temperature	°C
κ	adiabatic exponent	–
λ	thermal conductivity (coefficient)	W/m K
λ	pipe friction coefficient	–
ν	kinematic viscosity	m^2/s
ρ	density	kg/m^3
ν_1, v	specific volume	m^3/kg

Fig. 112

6.1.3 Prefixes for multiples and submultiples of the units

Decimal multiples or submultiples of the units are used to ensure that they are appropriately sized and the number is easily read and understood. In the case of decimal factors with independent names (as specified in the table below), the powers of ten are usually indicated by prefixes.

Factor	Name	Symbol	Factor	Name	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	µ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deca	da	10^{-24}	yocto	y

Fig. 113 SI prefixes.

5.1.4 Greek alphabet

Name	Upper case	Lower case	English equivalent	Name	Upper case	Lower case	English equivalent
alpha	Α	α	A	nu	Ν	ν	N
beta	Β	β	B	xi	Ξ	ξ	X
gamma	Γ	γ	G	omicron	Ο	ο	O
delta	Δ	δ	D	pi	Π	π	P
epsilon	Ε	ε	E	rho	Ρ	ρ	Rh
zeta	Ζ	ζ	Z	sigma	Σ	σ	S
eta	Η	η	E	tau	Τ	τ	T
theta	Θ	θ	Th	upsilon	Υ	υ	Y
iota	Ι	ι	I	phi	Φ	φ	Ph
kappa	Κ	κ	K	chi	Χ	χ	Ch
lambda	Λ	λ	L	psi	Ψ	ψ	Ps
mu	Μ	μ	M	omega	Ω	ω	O

Fig. 114

6.2 Unit Conversions

6.2.1 Anglo-American units

Length	1 inch (in) = 25.4 mm 1 foot (ft) = 12 in = 0.3048 m 1 yard (yd) = 3 ft = 0.9144 m 1 statute mile ("land" mile) = 1.609 km 1 nautical mile (sm = international sea mile) = 1.852 km	1 mm = 0.03937 in 1 m = 3.281 ft 1 m = 1.094 yd 1 km = 0.6214 mile 1 km = 0.540 NM
Area	1 square inch (sq in, in²) = 6.452 cm² 1 square foot (sq ft, ft²) = 144 in² = 0.0929 m² 1 square yard (sq yd, yd²) = 9 ft² = 0.8361 m² 1 square mile (sq mi, mile²) = 640 acres = 2.59 km²	1 cm² = 0.155 in² 1 m² = 10.764 ft² 1 m² = 1.196 yd² 1 km² = 0.386 mile²
Volume	1 cubic inch (cu in, in³) = 16.387 cm³ 1 cubic foot (cu ft, ft³) = 0.02832 m³ 1 cubic yard (cu yd, yd³) = 0.7646 m³ 1 register ton (reg.ton) = 100 ft³ = 2.832 m³ 1 British shipping ton = 42 ft³ = 1.189 m³ 1 US shipping ton = 40 ft³ = 1.133 m³ Great Britain 1 quart (qt) = 1.137 L 1 Imperial gallon (Imp.gal) = 4 qt = 4.546 L 1 bushel (bu) = 8 Imp.gal = 36.37 L 1 barrel = 36 Imp.gal = 163.6 L USA 1 quart (qt) = 0.946 L 1 US gallon (US gal) = 231 in³ = 4 qt = 3.785 L 1 US barrel = 42 US gal = 159 L	1 cm³ = 0.061 in³ 1 m³ = 35.31 ft³ 1 m³ = 1.308 yd³ 1 m³ = 0.353 reg.ton 1 m³ = 0.841 Brit.ship.ton 1 m³ = 0.883 US ship.ton 1 L = 0.880 qt 1 L = 0.220 Imp.gal 1 L = 0.0275 bu 1 L = 0.0061 barrel 1 L = 1.057 qt 1 L = 0.264 US gal 1 L = 0.00629 US barrel
Speed	1 foot per second (ft/s) = 0.3048 m/s = 1.097 km/h 1 mile per hour (mile/h, mph) = 0.447 m/s = 1.609 km/h 1 knot (sea mile per hour) = 0.5144 m/s = 1.852 km/h	1 m/s = 3.281 ft/s 1 km/h = 0.911 ft/s 1 m/s = 2.237 mile/h 1 km/h = 0.621 mile/h 1 m/s = 1.943 knots 1 km/h = 0.540 knot

Fig. 115

Volume flow	1 ft^3/s = 102 m^3/h 1 ft^3/min = 1.699 m^3/h *Great Britain* Imperial gallon/min (Imp.gpm, igpm) = 0.0758 L/s = 1.273 m^3/h *USA* 1 US gallon/min (USgpm) = 0.063 l/s = 0.227 m^3/h	1 m^3/h = 0.00981 ft^3/s 1 m^3/h = 0.5886 ft^3/min 1 m^3/h = 3.66 Imp.gal/min 1 m^3/h = 4.40 US gal/min
Mass	1 pound (lb) = 16 oz = 0.4536 kg 1 ounce (oz) = 28.35 g *Great Britain* 1 long ton (ton) = 20 cwt = 2240 lb = 1016 kg 1 hundredweight (cwt) = 112 lb = 50.80 kg *USA* 1 short ton (sh ton) = 2000 lb = 907.2 kg 1 long ton (ton) = 1.12 short ton = 1016 kg	1 kg = 2.2046 lb 1 kg = 35.27 oz 1 kg = 0.984 · 10^{-3} ton 1 kg = 0.0197 cwt 1 kg = 1.102 · 10^{-3} sh ton 1 kg = 0.984 · 10^{-3} ton
Mass flow	1 lb/s = 0.4536 kg/s = 1.633 t/h 1 short ton/h (sh ton/h, stph) = 907.2 kg/h 1 long ton /h (ton/h, tph) = 1016 kg/h	1 t/h = 0.6124 lb/s 1 kg/s = 2.2046 lb/s 1 kg/h = 1.102 · 10^{-3} sh ton/h 1 kg/h = 0.984 · 10^{-3} ton/h
Force	1 pound-force (lbf) = 4.4482 N 1 ton-force (tonf) = 2240 lbf = 9.964 kN	1 N = 0.2248 lbf 1 kN = 224.8 lbf 1 MN = 100.4 tonf
Pressure	1 lbf/in^2 (psi) = 6895 Pa = 0.06895 bar 1 lbf/ft^2 (psf) = 47.88 Pa = 0.04788 kPa 1 inch of mercury (in Hg) = 3386 Pa 1 inch of water (in H_2O, in WC) = 249.1 Pa	1 bar = 14.5 lbf/in^2 1kPa = 20.89 lbf/ft^2 1kPa = 0.2953 in Hg 1kPa = 4.015 in H_2O
Work Energy Heat	1 foot pound-force (ft-lbf) = 1.356 J 1 horse power hour (HPh) = 0.745 kWh 1 British Thermal Unit (BTU) = 1.055 kJ 1 BTU = 778 ft-lbf = 0.393 · 10^{-3} HPh = 0.293 · 10^{-3} kWh	1 J = 0.7376 ft-lbf 1 kWh = 1.341 Hph 1 kJ = 0.9478 BTU 1 kWh = 3413 BTU
Power	1 foot pound-force/second (ft-lbf/s) = 1.356 W 1 horse power (HP) = 0.746 kW 1 BTU/h = 0.2931 W	 1W = 0.738 ft-lbf/s 1 kW = 1.342 HP 1 W = 3.412 BTU/h

Fig. 115 Continued

6.2.2 Use of the legal units

Quantity equations with SI units [1]) also yield results in SI units. Because there is no regulation on units, however, it is important to make specimen calculations. To prevent errors when using derived units with a special name, it may be necessary to use the form resulting from the base SI units instead of the special name; for decimal multiples and submultiples of units, the prefixes are replaced by powers of 10 (except for kg, because kilogram is the base unit, not gram).

newton (N)	$1\ \text{N} = 1\ \frac{\text{kg m}}{\text{s}^2}$
pascal (Pa)	$1\ \text{Pa} = 1\ \frac{\text{N}}{\text{m}^2} = 1\ \frac{\text{kg m}}{\text{s}^2\ \text{m}^2} = 1\ \frac{\text{kg}}{\text{s}^2\ \text{m}}$
joule (J)	$1\ \text{J} = 1\ \text{Nm} = 1\ \frac{\text{kg m}^2}{\text{s}^2}$
watt (W)	$1\ \text{W} = 1\ \frac{\text{Nm}}{\text{s}} = 1\ \frac{\text{J}}{\text{s}} = \frac{\text{kg m}^2}{\text{s}^2}$
bar (bar)	$1\ \text{bar} = 0.1\ \text{MPa} = 10^5\ \frac{\text{N}}{\text{m}^2} = 10^5\ \frac{\text{kg}}{\text{s}^2\ \text{m}}$
litre (l or L)	$1\ \text{l} = 1\ \text{dm}^3 = 10^{-3}\ \text{m}^3$
gram (g)	$1\ \text{g} = \frac{1}{1000}\ \text{kg} = 10^{-3}\ \text{kg}$ (kg is the base unit)
tonne (t)	$1\ \text{t} = 1\ \text{Mg} = 10^3\ \text{kg}$

Fig. 116 Examples of units with a special name

1) The term “SI units” refers only to the base units of the international system of units (SI) and the derived (coherent) units obtained from them in the unit equation with a numerical factor of 1. For example, although the units bar, L, g and t are legal units, they are not SI units such as N, Pa, J and W.

6.3 Conversion Tables

6.3.1 Units of force

Units that are not officially permitted in Germany are set in *italics*.

	N $\frac{kg\,m}{s^2}$	kN	*dyn*	*kdyn*	*kp*	*p*	*mp*	*Mp*
1 newton	1	10^{-3}	10^{5}	10^{2}	0.102 [2]	$0.102 \cdot 10^{3}$	$0.102 \cdot 10^{6}$	$0.102 \cdot 10^{-4}$
1 kilonewton	10^{3}	1	10^{8}	10^{5}	$0.102 \cdot 10^{3}$	$0.102 \cdot 10^{6}$	$0.102 \cdot 10^{9}$	0.102
1 dyne	10^{-5}	10^{-8}	1	10^{-3}	$0.102 \cdot 10^{-5}$	$0.102 \cdot 10^{-2}$	$0.102 \cdot 10$	$0.102 \cdot 10^{-8}$
1 kilodyne	10^{-2}	10^{-5}	10^{3}	1	$0.102 \cdot 10^{-2}$	$0.102 \cdot 10$	$0.102 \cdot 10^{4}$	$0.102 \cdot 10^{-5}$
1 kilopond	9.81 [1]	$9.81 \cdot 10^{-3}$	$9.81 \cdot 10^{5}$	$9.81 \cdot 10^{2}$	1	10^{3}	10^{6}	10^{-3}
1 pond	$9.81 \cdot 10^{-3}$	$9.81 \cdot 10^{-6}$	$9.81 \cdot 10^{2}$	$9.81 \cdot 10^{-1}$	10^{-3}	1	10^{3}	10^{-6}
1 millipond	$9.81 \cdot 10^{-6}$	$9.81 \cdot 10^{-9}$	$9.81 \cdot 10^{-1}$	$9.81 \cdot 10^{-4}$	10^{-6}	10^{-3}	1	10^{-9}
1 megapond	$9.81 \cdot 10^{3}$	9.81	$9.81 \cdot 10^{8}$	$9.81 \cdot 10^{5}$	10^{3}	10^{6}	10^{9}	1

Fig. 117

1) Precise value: 9.80665

2) Precise value: 0.1019716

6.3.2 Units of pressure

Units that are not officially permitted in Germany are set in *italics*.

	N/m² (Pa)	bar	mbar	µbar	*kp/cm² (at)*	*atm*	*Torr (mmHg)*	*mm WC* [5]
1 newton per square metre	1	10^{-5}	10^{-2}	10	[1] $0.102 \cdot 10^{-4}$	[2] $0.987 \cdot 10^{-5}$	[3] $0.750 \cdot 10^{-2}$	0.102
1 bar	10^{5}	1	10^{3}	10^{6}	$0.102 \cdot 10$	0.987	$0.750 \cdot 10^{3}$	$0.102 \cdot 10^{5}$
1 millibar	10^{2}	10^{-3}	1	10^{3}	$0.102 \cdot 10^{-2}$	$0.987 \cdot 10^{-3}$	0.750	$0.102 \cdot 10^{2}$
1 microbar	10^{-1}	10^{-6}	10^{-3}	1	$0.102 \cdot 10^{-5}$	$0.987 \cdot 10^{-6}$	$0.750 \cdot 10^{-3}$	$0.102 \cdot 10^{-1}$
1 kilopond per square centimetre	$9.81 \cdot 10^{4}$ [4]	$9.81 \cdot 10^{-1}$	$9.81 \cdot 10^{2}$	$9.81 \cdot 10^{5}$	1	0.968	736	10^{4}
1 phys. atmosphere	$1.013 \cdot 10^{5}$	1.013	$1.013 \cdot 10^{3}$	$1.013 \cdot 10^{6}$	1.033	1	760	$1.033 \cdot 10^{4}$
1 torr	$1.333 \cdot 10^{2}$	$1.333 \cdot 10^{-3}$	1.333	$1.333 \cdot 10^{3}$	$1.360 \cdot 10^{-3}$	$1.316 \cdot 10^{-3}$	1	$1.360 \cdot 10$
1 millimetre of water column	9.81	$9.81 \cdot 10^{-5}$	$9.81 \cdot 10^{-2}$	$9.81 \cdot 10$	10^{-4}	$0.968 \cdot 10^{-4}$	$736 \cdot 10^{-4}$	1

Fig. 118

1) Precise value: 0.101972

2) Precise value: 0.986923

3) Precise value: 0.750062

4) Precise value: 9.80665

5) 1 mm WC = 1 kp/m²

6.3.3 Units of power

Units that are not officially permitted in Germany are set in *italics*.

	W = J/s = Nm/s	kW	mW	*erg/s*	*kpm/s*	*kcal/s*	*HP*
1 watt, joule/second, newton-metre/second	1	10^{-3}	10^{3}	10^{7}	$1.020 \cdot 10^{-1}$	$2.388 \cdot 10^{-4}$	$1.360 \cdot 10^{-3}$
1 kilowatt	10^{3}	1	10^{6}	10^{10}	$1.020 \cdot 10^{2}$	$2.388 \cdot 10^{-1}$	1.36
1 milliwatt	10^{-3}	10^{-6}	1	10^{4}	$1.020 \cdot 10^{-4}$	$2.388 \cdot 10^{-7}$	$1.360 \cdot 10^{-6}$
1 erg/second	10^{-7}	10^{-10}	10^{-4}	1	$1.020 \cdot 10^{-8}$	$2.388 \cdot 10^{-11}$	$1.360 \cdot 10^{-10}$
1 kilopond-metre/second	9.807	$9.807 \cdot 10^{-3}$	$9.807 \cdot 10^{3}$	$9.807 \cdot 10^{7}$	1	$2.342 \cdot 10^{-3}$	$1.333 \cdot 10^{-2}$
1 kilocalorie/second	$4.187 \cdot 10^{3}$	4.187	$4.187 \cdot 10^{6}$	$4.187 \cdot 10^{10}$	$4.269 \cdot 10^{2}$	1	5.692
1 horsepower	$7.355 \cdot 10^{2}$	$7.355 \cdot 10^{-1}$	$7.355 \cdot 10^{5}$	$7.355 \cdot 10^{9}$	75	$1.757 \cdot 10^{-1}$	1

Fig. 119

6.3.4 Units of work, energy and heat

Units that are not officially permitted in Germany are set in *italics.*

	J, Nm, Ws	*cal*	*kcal*	Wh	kWh	*kpm*	*erg*	*(HPh)*
1 joule, newton-meter, 1 watt-second	1	$2.388 \cdot 10^{-1}$	$2.388 \cdot 10^{-4}$	$2.788 \cdot 10^{-4}$	$2.778 \cdot 10^{-7}$	0.102	10^{7}	$3.777 \cdot 10^{-7}$
1 calorie	4.187	1	10^{-3}	$1.163 \cdot 10^{-3}$	$1.163 \cdot 10^{-6}$	$4.269 \cdot 10^{-1}$	$4.178 \cdot 10^{7}$	$1.581 \cdot 10^{-6}$
1 kilocalorie/second	$4.187 \cdot 10^{3}$	10^{3}	1	1.163	$1.163 \cdot 10^{-3}$	$4.269 \cdot 10^{2}$	$4.178 \cdot 10^{10}$	$1.581 \cdot 10^{-3}$
1 watt-hour	$3.6 \cdot 10^{3}$	$8.598 \cdot 10^{2}$	$8.598 \cdot 10^{-1}$	1	10^{-3}	$3.671 \cdot 10^{2}$	$3.6 \cdot 10^{10}$	$1.360 \cdot 10^{-3}$
1 kilowatt-hour	$3.6 \cdot 10^{6}$	$8.598 \cdot 10^{5}$	$8.598 \cdot 10^{2}$	10^{3}	1	$3.671 \cdot 10^{5}$	$3.6 \cdot 10^{13}$	1.360
1 kilopond-metre	9.807	2.342	$2.342 \cdot 10^{-3}$	$2.724 \cdot 10^{-3}$	$2.724 \cdot 10^{-6}$	1	$9.807 \cdot 10^{7}$	$3.704 \cdot 10^{-6}$
1 erg	10^{-7}	$2.388 \cdot 10^{-8}$	$2.388 \cdot 10^{-11}$	$2.778 \cdot 10^{-11}$	$2.778 \cdot 10^{-14}$	$1.020 \cdot 10^{-8}$	1	$3.777 \cdot 10^{14}$
1 horsepower-hour	$2.648 \cdot 10^{6}$	$6.234 \cdot 10^{5}$	$6.324 \cdot 10^{2}$	$7.355 \cdot 10^{2}$	$7.355 \cdot 10^{-1}$	$2.7 \cdot 10^{5}$	$2.648 \cdot 10^{13}$	1

Fig. 120 1 kJ = 1000 joules

6.3.5 Units of dynamic viscosity

Units that are not officially permitted in Germany are set in italics.

	N s/m² (Pa · s)	*P* (dPa · s)	*kp s/m²*	*kp h/m²*	*lbm/ft.sec*	*lbf.sec/ft²*
1 newton-second per square metre	1	10	0.10197	$2.833 \cdot 10^{-5}$	0.6721	$2.0885 \cdot 10^{-2}$
1 poise	0.1	1	0.010197	$2.833 \cdot 10^{-6}$	0.06721	$2.0885 \cdot 10^{-3}$
1 kilopond-second per square metre	9.807	98.07	1	$2.778 \cdot 10^{-4}$	6.5919	0.20482
1 kilopond-hour per square metre	$0.35304 \cdot 10^{5}$	$0.35304 \cdot 10^{6}$	3600	1	$2.3730 \cdot 10^{4}$	$0.73728 \cdot 10^{3}$
1 pound-mass per foot second	1.488	14.882	0.1518	$4.214 \cdot 10^{-5}$	1	0.03108
1 pound-force second per square foot	47.88	478.8	4.882	$1.3558 \cdot 10^{-3}$	32.174	1

Fig. 121

6.3.6 Units of kinematic viscosity

Units that are not officially permitted in Germany are set in *italics*.

	St	m^2/s	m^2/h	cm^2/s	*ft^2/sec*	*ft^2/h*
1 stokes	*1*	*10^{-4}*	*0.36*	*1*	*$1.0764 \cdot 10^{-3}$*	*3.875*
1 square metre per second	10^4	1	3600	10^4	10.764	$3.875 \cdot 10^4$
1 square metre per hour	2.778	$2.788 \cdot 10^{-4}$	1	2.778	$29.9 \cdot 10^{-4}$	10.764
1 square centimetre per second	1	10^{-4}	0.36	1	$1.0764 \cdot 10^{-3}$	3.875
1 square foot per second	*929.03*	*$9.2903 \cdot 10^{-2}$*	*334.45*	*929.03*	*1*	*3600*
1 square foot per hour	*0.25806*	*$0.25806 \cdot 10^{-4}$*	*$9.2903 \cdot 10^{-2}$*	*0.25806*	*$2.778 \cdot 10^{-4}$*	*1*

Fig. 122

6.3.7 Units of heat flow per unit area

Units that are not officially permitted in Germany are set in *italics*.

	kW/cm^2	*$kcal/m^2h$*	*cal/cm^2s*	BTU/in^2 sec	*BTU/ft^2 sec*	*BTU/ft^2 h*
1 kilowatt per square centimetre	1	*$8.6 \cdot 10^6$*	*238.9*	6.12	880.6	$3.17 \cdot 10^6$
1 kilocalorie per square metre and hour	*$11.63 \cdot 10^{-8}$*	*1*	*$27.78 \cdot 10^{-6}$*	*$71.17 \cdot 10^{-8}$*	*$1.024 \cdot 10^{-4}$*	*0.3687*
1 calorie per square centimetre and second	*$4.186 \cdot 10^{-3}$*	*$3.6 \cdot 10^4$*	*1*	*$2.562 \cdot 10^{-2}$*	*3.687*	*$1.327 \cdot 10^4$*
1 British thermal unit per square inch per second	*$16.34 \cdot 10^{-2}$*	*$1.405 \cdot 10^6$*	*39.05*	*1*	*144*	*$51.84 \cdot 10^4$*
1 British thermal unit per square foot per second	*$1.135 \cdot 10^{-3}$*	*$9.765 \cdot 10^3$*	*0.2713*	*$6.944 \cdot 10^{-3}$*	*1*	*3600*
1 British thermal unit per square foot per hour	*$31.54 \cdot 10^{-8}$*	*2.713*	*$75.36 \cdot 10^{-6}$*	*$1.929 \cdot 10^{-6}$*	*$2.778 \cdot 10^{-4}$*	*1*

Fig. 123

6.3.8 Units of the thermal conductivity coefficient

Units that are not officially permitted in Germany are set in *italics*.

	W/cm K	*kcal/m h K*	*cal/cm s K*	*BTU in/ft^2 h deg*	*BTU/ft.h.deg*	*BTU/in.h.deg*
1 watt per centimetre and kelvin	1	*86*	*0.2389*	693.5	57.79	4.815
1 kilocalorie per metre, hour and kelvin	*0.01163*	*1*	*$2.778 \cdot 10^{-3}$*	*8.064*	*0.6719*	*0.05599*
1 calorie per centimetre, second and kelvin	*4.1868*	*360*	*1*	*2903*	*241.9*	*20.16*
1 British thermal unit inch per square foot, hour, degree	*$1.442 \cdot 10^{-3}$*	*0.1240*	*$3.445 \cdot 10^{-4}$*	*1*	*0.08333*	*$6.944 \cdot 10^{-3}$*
1 British thermal unit per foot, hour and degree	*$1.731 \cdot 10^{-2}$*	*1.488*	*$4.134 \cdot 10^{-3}$*	*12*	*1*	*0.08333*
1 British thermal unit per inch, hour and degree	*0.2077*	*17.858*	*$4.964 \cdot 10^{-2}$*	*144*	*12*	*1*

Fig. 124

6.3.9 Units of the heat transmission and heat transfer coefficients

Units that are not officially permitted in Germany are set in *italics*.

	$W/cm^2\,K$	$W/m^2\,K$	*kcal/m² h K*	*cal/cm² s K*	*BTU/ft² h deg*
1 watt per square centimetre and kelvin	1	10^4	*8598.45*	*0.238844*	$0.1761 \cdot 10^4$
1 watt per square metre and kelvin	10^{-4}	1	*0.859845*	$2.38844 \cdot 10^{-5}$	0.1761
1 kilocalorie per square metre, hour and kelvin	$1.163 \cdot 10^{-4}$	*1.163*	*1*	$2.77778 \cdot 10^{-5}$	*0.2048*
1 calorie per square centimetre, second and kelvin	*4.1868*	$4.1868 \cdot 10^4$	$3.6 \cdot 10^4$	*1*	$0.7373 \cdot 10^4$
1 British thermal unit per square foot, hour and degree	$5.681 \cdot 10^{-4}$	*5.681*	$4.886 \cdot 10^{-4}$	$1.356 \cdot 10^{-4}$	*1*

Fig. 125

6.3.10 Units of the heat radiation coefficient

Units that are not officially permitted in Germany are set in *italics*.

	$W/cm^2\,K^4$	$W/m^2\,K^4$	*kcal/m² h K⁴*	*cal/cm² s K⁴*	*BTU /ft² h deg⁴*
1 watt per square centimetre and kelvin	1	10^4	*8598.45*	*0.238844*	$3.020 \cdot 10^2$
1 watt per square metre and kelvin	10^{-4}	1	*0.859845*	$2.38844 \cdot 10^{-5}$	$3.020 \cdot 10^{-2}$
1 kilocalorie per square metre, hour and kelvin	$1.163 \cdot 10^{-4}$	*1.163*	*1*	$2.7778 \cdot 10^{-5}$	$3.512 \cdot 10^{-2}$
1 calorie per square centimetre, second and kelvin	*4.1868*	$4.1868 \cdot 10^4$	$3.6 \cdot 10^4$	*1*	$1.264 \cdot 10^3$
1 British thermal unit per square foot, hour and degree	$3.311 \cdot 10^{-3}$	*33.11*	*28.49*	*7.908*	*1*

Fig. 126

6.3.11 Units of specific heat

Units that are not officially permitted in Germany are set in *italics*.

	J/kg K	*kcal/kg K*	*cal/g K*	kWh/kg K
1 joule per kilogram and kelvin	*11*	$2.38844 \cdot 10^{-4}$	$2.38844 \cdot 10^{-4}$	$2.77778 \cdot 10^{-7}$
1 kilocalorie per kilogram and kelvin	$4.4868 \cdot 10^3$	*1*	1	$1.16300 \cdot 10^{-3}$
1 calorie per gram and kelvin	$4.1868 \cdot 10^3$	*1*	1	$1.16300 \cdot 10^{-3}$
1 kilowatt-hour per kilogram and kelvin	$3.6 \cdot 10^{-6}$	*859.845*	859.845	1

Fig. 127 1kJ = 1000 joules

6.3.12 Conversion from kiloponds to newtons

kp	N	kp	N	kp	N	kp	N	kp	N
1	9.80665	41	402.072650	81	794.338650	121	1186.60470	161	1578.87070
2	19.613300	42	411.879300	82	804.145300	122	1196.41130	162	1588.67730
3	29.419950	43	421.685950	83	813.951950	123	1206.21800	163	1598.48400
4	39.226600	44	431.492600	84	823.758600	124	1216.02460	164	1608.29060
5	49.033250	45	441.299250	85	833.565250	125	1225.83130	165	1618.09730
6	58.839900	46	451.105900	86	843.371900	126	1235.63790	166	1627.90390
7	68.646550	47	460.912550	87	853.178550	127	1245.44460	167	1637.71060
8	78.453200	48	470.719200	88	862.985200	128	1255.25120	168	1647.51720
9	88.259850	49	480.525850	89	872.791850	129	1265.05790	169	1657.32390
10	98.066500	50	490.332500	90	882.598500	130	1274.86450	170	1667.13050
11	107.873150	51	500.139150	91	892.405150	131	1284.67120	171	1676.93720
12	117.679800	52	509.945800	92	902.211800	132	1294.47780	172	1686.74380
13	127.486450	53	519.752450	93	912.018450	133	1304.28450	173	1696.55050
14	137.293100	54	529.559100	94	921.825100	134	1314.09110	174	1706.35710
15	147.099750	55	539.365750	95	931.631750	135	1323.89780	175	1716.16380
16	156.906400	56	549.172400	96	941.438400	136	1333.70440	176	1725.97040
17	166.713050	57	558.979050	97	951.245050	137	1343.51110	177	1735.77710
18	176.519700	58	568.785700	98	961.051700	138	1353.31770	178	1745.58370
19	186.326350	59	578.592350	99	970.858350	139	1363.12440	179	1755.39040
20	196.133000	60	588.399000	100	980.665000	140	1372.93100	180	1765.19700
21	205.939650	61	598.205650	101	990.47165	141	1382.73770	181	1775.00370
22	215.746300	62	608.012300	102	1000.27830	142	1392.54430	182	1784.81030
23	225.552950	63	617.818950	103	1010.08500	143	1402.35100	183	1794.61700
24	235.359600	64	627.625600	104	1019.89160	144	1412.15760	184	1804.42360
25	245.166250	65	637.432250	105	1029.69830	145	1421.96430	185	1814.23030
26	254.972900	66	647.238900	106	1039.50490	146	1431.77090	186	1824.03690
27	264.779550	67	657.045550	107	1049.31160	147	1441.57760	187	1833.84360
28	274.586200	68	666.852200	108	1059.11820	148	1451.38420	188	1843.65020
29	284.392850	69	676.658850	109	1068.92490	149	1461.19090	189	1853.45690
30	294.199500	70	686.465500	110	1078.73150	150	1470.99750	190	1863.26350
31	304.006150	71	696.272150	111	1088.53820	151	1480.80420	191	1873.07020
32	313.812800	72	706.078800	112	1098.34480	152	1490.61080	192	1882.87680
33	323.619450	73	715.885450	113	1108.15150	153	1500.41750	193	1892.68350
34	333.426100	74	725.692100	114	1117.95810	154	1510.22410	194	1902.49010
35	343.232750	75	735.498750	115	1127.76480	155	1520.03080	195	1912.29680
36	353.039400	76	745.305400	116	1137.57140	156	1529.83740	196	1922.10340
37	362.846050	77	755.112050	117	1147.37810	157	1539.64410	197	1931.91010
38	372.652700	78	764.918700	118	1157.18470	158	1549.45070	198	1941.71670
39	382.459350	79	774.725350	119	1166.99140	159	1559.25740	199	1951.52340
40	392.266000	80	784.532000	120	1176.79800	160	1569.06400	200	1961.33000

Fig. 128

6.3.13 Conversion from bar to psi (lbf/in²)

bar	psi	bar	psi	bar	psi	bar	psi
0.01	0.15	2.00	29.01	18.00	261.07	56	812.22
0.05	0.73	2.10	30.46	18.50	268.32	57	826.73
0.10	1.45	2.20	31.91	19.00	275.58	58	841.23
0.15	2.18	2.30	33.36	19.50	282.83	59	855.74
0.20	2.90	2.40	34.81	20.00	290.08	60	870.24
0.25	3.63	2.50	36.26	21.00	304.58	61	884.74
0.30	4.35	2.60	37.71	22.00	319.09	62	899.25
0.35	5.08	2.70	39.16	23.00	333.59	63	913.75
0.40	5.80	2.80	40.61	24.00	348.10	64	928.26
0.45	6.53	2.90	42.06	25.00	362.60	65	942.76
0.50	7.25	3.00	43.51	26.00	377.10	66	957.26
0.55	7.98	3.50	50.76	27.00	391.61	67	971.77
0.60	8.70	4.00	58.02	28.00	406.11	68	986.27
0.65	9.43	4.50	65.27	29.00	420.62	69	1000.78
0.70	10.15	5.00	72.52	30.00	435.12	70	1015.28
0.75	10.88	5.50	79.77	31.00	449.62	71	1029.78
0.80	11.60	6.00	87.02	32.00	464.13	72	1044.29
0.85	12.33	6.50	94.28	33.00	478.63	73	1058.79
0.90	13.05	7.00	101.53	34.00	493.14	74	1073.30
0.95	13.78	7.50	108.78	35.00	507.64	75	1087.80
1.00	14.50	8.00	116.03	36.00	522.14	76	1102.30
1.05	15.23	8.50	123.28	37.00	536.65	77	1116.81
1.10	15.95	9.00	130.54	38.00	551.15	78	1131.31
1.15	16.68	9.50	137.79	39.00	565.66	79	1145.82
1.20	17.40	10.00	145.04	40.00	580.16	80	1160.32
1.25	18.13	10.50	152.29	41.00	594.66	81	1174.82
1.30	18.86	11.00	159.54	42.00	609.17	82	1189.33
1.35	19.58	11.50	166.80	43.00	623.67	83	1203.83
1.40	20.31	12.00	174.05	44.00	638.18	84	1218.34
1.45	21.03	12.50	181.30	45.00	652.68	85	1232.84
1.50	21.76	13.00	188.55	46.00	667.18	86	1247.34
1.55	22.48	13.50	195.80	47.00	681.69	87	1261.85
1.60	23.21	14.00	203.06	48.00	696.19	88	1276.35
1.65	23.93	14.50	210.31	49.00	710.70	89	1290.86
1.70	24.66	15.00	217.56	50.00	725.20	90	1305.36
1.75	25.38	15.50	224.81	51.00	739.70	91	1319.86
1.80	26.11	16.00	232.06	52.00	754.21	92	1334.37
1.85	26.83	16.50	239.32	53.00	768.71	93	1348.87
1.90	27.56	17.00	246.57	54.00	783.22	94	1363.38
1.95	28.28	17.50	253.82	55.00	797.72	95	1377.88

Fig. 129

6.3.14 Conversion from *kilocalories* to kilojoules

Units that are not officially permitted in Germany are set in *italics*.

kcal	kJ	*kcal*	kJ	*kcal*	kJ	*kcal*	kJ	*kcal*	kJ
1	4.18680	41	171.65880	81	339.13080	121	506.6028	161	674.0748
2	8.37360	42	175.84560	82	343.31760	122	510.7896	162	678.2616
3	12.56040	43	180.03240	83	347.50440	123	514.9764	163	682.4484
4	16.74720	44	184.21920	84	351.96120	124	519.1632	164	686.6352
5	20.93400	45	188.40600	85	355.87800	125	523.3500	165	690.8220
6	25.12080	46	192.59280	86	360.06480	126	527.5368	166	695.0088
7	29.30760	47	196.77960	87	364.25160	127	531.7236	167	699.1956
8	33.49440	48	200.96640	88	368.43840	128	535.9104	168	703.3824
9	37.68120	49	205.15320	89	372.62520	129	540.0972	169	707.5692
10	41.86800	50	209.34000	90	376.81200	130	544.2840	170	711.7560
11	46.05480	51	213.52680	91	380.99880	131	548.4708	171	715.9428
12	50.24160	52	217.71360	92	385.18560	132	552.6576	172	720.1296
13	54.42840	53	221.90040	93	389.37240	133	556.8444	173	724.3164
14	58.61520	54	226.08720	94	393.55920	134	561.0312	174	728.5032
15	62.80200	55	230.27400	95	397.74600	135	565.2180	175	732.6900
16	66.98880	56	234.46080	96	401.93280	136	569.4048	176	736.8768
17	71.17560	57	238.64760	97	406.11960	137	573.5916	177	741.0636
18	75.36240	58	242.83440	98	410.30640	138	577.7784	178	745.2504
19	79.54920	59	247.02120	99	414.49320	139	581.9652	179	749.4372
20	83.73600	60	251.20800	100	418.68000	140	586.1520	180	753.6240
21	87.92280	61	255.39480	101	422.8668	141	590.3388	181	757.8108
22	92.10960	62	259.58160	102	427.0536	142	594.5256	182	761.9976
23	96.29640	63	263.76840	103	431.2404	143	598.7124	183	766.1844
24	100.48320	64	267.95520	104	435.4272	144	602.8992	184	770.3712
25	104.67000	65	272.14200	105	439.6140	145	607.0860	185	774.5580
26	108.85680	66	276.32880	106	443.8008	146	611.2728	186	778.7448
27	113.04360	67	280.51560	107	447.9876	147	615.4596	187	782.9316
28	117.23040	68	284.70240	108	452.1744	148	619.6464	188	787.1184
29	121.41720	69	288.88920	109	456.3612	149	623.8332	189	791.3052
30	125.60400	70	293.07600	110	460.5480	150	628.0200	190	795.4920
31	129.79080	71	297.26280	111	464.7348	151	632.2068	191	799.6788
32	133.97760	72	301.44960	112	468.9216	152	636.3936	192	803.8656
33	138.16440	73	305.63640	113	473.1084	153	640.5804	193	808.0524
34	142.35120	74	309.82320	114	477.2952	154	644.7672	194	812.2392
35	146.53800	75	314.01000	115	481.4820	155	648.9540	195	816.4260
36	150.72480	76	318.19680	116	485.6688	156	653.1408	196	820.6128
37	154.91160	77	322.38360	117	489.8556	157	657.3276	197	824.7996
38	159.09840	78	326.57040	118	494.0424	158	661.5144	198	828.9864
39	163.28520	79	330.75720	119	498.2292	159	665.7012	199	833.1732
40	167.47200	80	334.94400	120	502.4160	160	669.8880	200	837.3600

Fig. 130

6.3.15 Conversion from inches to millimetres (1/64 to 1 in)

1 inch (in) = 25.4 mm. The inch is often abbreviated further to a double straight apostrophe, whilst a single straight apostrophe denotes a foot (i.e. 1' = 12").

in	in	mm	in	in	mm
0	0	0			
1/64	0.015625	0.396875	33/64	0.515625	13.096875
1/32	0.031250	0.793750	17/32	0.531250	13.493750
3/64	0.046875	1.190625	35/64	0.546875	13.890625
1/16	0.062500	1.587500	9/16	0.562500	14.287500
5/64	0.078125	1.984375	37/64	0.578125	14.684375
3/32	0.093750	2.381250	19/32	0.593750	15.081250
7/64	0.109375	2.778125	39/64	0.609375	15.478125
1/8	0.125000	3.175000	5/8	0.625000	15.875000
9/64	0.140625	3.571875	41/64	0.640625	16.271875
5/32	0.156250	3.968750	21/32	0.656250	16.668750
11/64	0.171875	4.365625	43/64	0.671875	17.065625
3/16	0.187500	4.762500	11/16	0.687500	17.462500
13/64	0.203125	5.159375	45/64	0.703125	17.859375
7/32	0.218750	5.556250	23/32	0.718750	18.256250
15/64	0.234375	5.953125	47/64	0.734375	18.653125
1/4	0.250000	6.350000	3/4	0.750000	19.050000
17/64	0.265625	6.746875	49/64	0.765625	19.446875
9/32	0.281250	7.143750	25/32	0.781250	19.843750
19/64	0.296875	7.540625	51/64	0.796875	20.240625
5/16	0.312500	7.937500	13/16	0.812500	20.637500
21/64	0.328125	8.334375	53/64	0.828125	21.034375
11/32	0.343750	8.731250	27/32	0.843750	21.431250
23/64	0.359375	9.128125	55/64	0.859375	21.828125
3/8	0.375000	9.525000	7/8	0.875000	22.225000
25/64	0.390625	9.921875	57/64	0.890625	22.621875
13/32	0.406250	10.318750	29/32	0.906250	23.018750
27/64	0.421875	10.715625	59/64	0.921875	23.415625
7/16	0.437500	11.112500	15/16	0.937500	23.812500
29/64	0.453125	11.509375	61/64	0.953125	24.209375
15/32	0.468750	11.906250	31/32	0.968750	24.606250
31/64	0.484375	12.303125	63/64	0.984375	25.003125
1/2	0.500000	12.700000	1	1	25.4

Fig. 131

6.3.16 Conversion from inches to millimetres (1 to 50 in)

1 inch (in) = 25.4 mm

in	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16
0	0.0	1.6	3.2	4.8	6.4	7.9	9.5	11.1
1	25.4	27.0	28.6	30.2	31.8	33.3	34.9	36.5
2	50.8	52.4	54.0	55.6	57.2	58.7	60.3	61.9
3	76.2	77.8	79.4	81.0	82.6	84.1	85.7	87.3
4	101.6	103.2	104.8	106.4	108.0	109.5	111.1	112.7
5	127.0	128.6	130.2	131.8	133.4	134.9	136.5	138.1
6	152.4	154.0	155.6	157.2	158.8	160.3	161.9	163.5
7	177.8	179.4	181.0	182.6	184.2	185.7	187.3	188.9
8	203.2	204.8	206.4	208.0	209.6	211.1	212.7	214.3
9	228.6	230.2	231.8	233.4	235.0	236.5	238.1	239.7
10	254.0	255.6	257.2	258.8	260.4	261.9	263.5	265.1
11	279.4	281.0	282.6	284.2	285.8	287.3	288.9	290.5
12	304.8	306.4	308.0	309.6	311.2	312.7	314.3	315.9
13	330.2	331.8	333.4	335.0	336.6	338.1	339.7	341.3
14	355.6	357.2	358.8	360.4	362.0	363.5	365.1	366.7
15	381.0	382.6	384.2	385.8	387.4	388.9	390.5	392.1
16	406.4	408.0	409.6	411.2	412.8	414.3	415.9	417.5
17	431.8	433.4	435.0	436.6	438.2	439.7	441.3	442.9
18	457.2	458.8	460.4	462.0	463.6	465.1	466.7	468.3
19	482.6	484.2	485.8	487.4	489.0	490.5	492.1	493.7
20	508.0	509.6	511.2	512.8	514.4	515.9	517.5	519.1
21	533.4	535.0	536.6	538.2	539.8	541.3	542.9	544.5
22	558.8	560.4	562.0	563.6	565.2	566.7	568.3	569.9
23	584.2	585.8	587.4	589.0	590.6	592.1	593.7	595.3
24	609.6	611.2	612.8	614.4	616.0	617.5	619.1	620.7
25	635.0	636.6	638.2	639.8	641.4	642.9	644.5	646.1
26	660.4	662.0	663.6	665.2	666.8	668.3	669.9	671.5
27	685.8	687.4	689.0	690.6	692.2	693.7	695.3	696.9
28	711.2	712.8	714.4	716.0	717.6	719.1	720.7	722.3
29	736.6	738.2	739.8	741.4	743.0	744.5	746.1	747.7
30	762.0	763.6	765.2	766.8	768.4	769.9	771.5	773.1
31	787.4	789.0	790.6	792.2	783.8	795.3	796.9	798.5
32	812.8	814.4	816.0	817.6	819.2	820.7	822.3	823.9
33	838.2	839.8	841.4	843.0	844.6	846.1	847.7	849.3
34	863.6	865.2	866.8	868.4	870.0	871.5	873.1	874.7
35	889.0	890.6	892.2	893.8	895.4	896.9	898.5	900.1
36	914.4	916.0	917.6	919.2	920.8	922.3	923.9	925.5
37	939.8	941.4	943.0	944.6	946.2	947.7	949.3	950.9
38	965.2	966.8	968.4	970.0	971.6	973.1	974.7	976.3
39	990.6	992.2	993.8	995.4	997.0	998.5	1000.1	1001.7
40	1016.0	1017.6	1019.2	1020.8	1022.4	1023.9	1025.5	1027.1
41	1041.4	1043.0	1044.6	1046.2	1047.8	1049.3	1050.9	1052.5
42	1066.8	1068.4	1070.0	1071.6	1073.2	1074.7	1076.3	1077.9
43	1092.2	1093.8	1095.4	1097.0	1098.6	1100.1	1101.7	1103.3
44	1117.6	1119.2	1120.8	1122.4	1124.0	1125.5	1127.1	1128.7
45	1143.0	1144.6	1146.2	1147.8	1149.4	1150.9	1152.5	1154.1
46	1168.4	1170.0	1171.6	1173.2	1174.8	1176.3	1177.9	1179.5
47	1193.8	1195.4	1197.0	1198.6	1200.2	1201.7	1203.3	1204.9
48	1219.2	1220.8	1222.4	1224.0	1225.6	1227.1	1228.7	1230.3
49	1244.6	1246.2	1247.8	1249.4	1251.0	1252.5	1254.1	1255.7
50	1270.0	1271.6	1273.2	1274.8	1276.4	1277.9	1279.5	1281.1

Fig. 132

1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	in
12.7	14.3	15.9	17.5	19.1	20.6	22.2	23.8	**0**
38.1	39.7	41.3	42.9	44.5	46.0	47.6	49.2	**1**
63.5	65.1	66.7	68.3	69.9	71.4	73.0	74.6	**2**
88.9	90.5	92.1	93.7	95.3	96.8	98.4	100.0	**3**
114.3	115.9	117.5	119.1	120.7	122.2	123.8	125.4	**4**
139.7	141.3	142.9	144.5	146.1	147.6	149.2	150.8	**5**
165.1	166.7	168.3	169.9	171.5	173.0	174.6	176.2	**6**
190.5	192.1	193.7	195.3	196.9	198.4	200.0	201.6	**7**
215.9	217.5	219.1	220.7	222.3	223.8	225.4	227.0	**8**
241.3	242.9	244.5	246.1	247.7	249.2	250.8	252.4	**9**
266.7	268.3	269.9	271.5	273.1	274.6	276.2	277.8	**10**
292.1	293.7	295.3	296.9	298.5	300.0	301.6	303.2	**11**
317.5	319.1	320.7	322.3	323.9	325.4	327.0	328.6	**12**
342.9	344.5	346.1	347.7	349.3	350.8	352.4	354.0	**13**
368.3	369.9	371.5	373.1	374.7	376.2	377.8	379.4	**14**
393.7	395.3	396.9	398.5	400.1	401.6	403.2	404.8	**15**
419.1	420.7	422.3	423.9	425.5	427.0	428.6	430.2	**16**
444.5	446.1	447.7	449.3	450.9	452.4	454.0	455.6	**17**
469.9	471.5	473.1	474.7	476.3	477.8	479.4	481.0	**18**
495.3	496.9	498.5	500.1	501.7	503.2	504.8	506.4	**19**
520.7	522.3	523.9	525.5	527.1	528.6	530.2	531.8	**20**
546.1	547.7	549.3	550.9	552.5	554.0	555.6	557.2	**21**
571.5	573.1	574.7	576.3	577.9	579.4	581.0	582.6	**22**
596.9	598.5	600.1	601.7	603.3	604.8	606.4	608.0	**23**
622.3	623.9	625.5	627.1	628.7	630.2	631.8	633.4	**24**
647.7	649.3	650.9	652.5	654.1	655.6	657.2	658.8	**25**
673.1	674.7	676.3	677.9	679.5	681.0	682.6	684.2	**26**
698.5	700.1	701.7	703.3	704.9	706.4	708.0	709.6	**27**
723.9	725.5	727.1	728.7	730.3	731.8	733.4	735.0	**28**
749.3	750.9	752.5	754.1	755.7	757.2	758.8	760.4	**29**
774.7	776.3	777.9	779.5	781.1	782.6	784.2	785.8	**30**
800.1	801.7	803.3	804.9	806.5	808.0	809.6	811.2	**31**
825.5	827.1	828.7	830.3	831.9	833.4	835.0	836.6	**32**
850.9	852.5	854.1	855.7	857.3	858.8	860.4	862.0	**33**
876.3	877.9	879.5	881.1	882.7	884.2	885.8	887.4	**34**
901.7	903.3	904.9	906.5	908.1	909.6	911.2	912.8	**35**
927.1	928.7	930.3	931.9	933.5	935.0	936.6	938.2	**36**
952.5	954.1	955.7	957.3	958.9	960.4	962.0	963.6	**37**
977.9	979.5	981.1	982.7	984.3	985.8	987.4	989.0	**38**
1003.3	1004.9	1006.5	1008.1	1009.7	1011.2	1012.8	1014.4	**39**
1028.7	1030.3	1031.9	1033.5	1035.1	1036.6	1038.2	1039.8	**40**
1054.1	1055.7	1057.3	1058.9	1060.5	1062.0	1063.6	1065.2	**41**
1079.5	1081.1	1082.7	1084.3	1085.9	1087.4	1089.0	1090.6	**42**
1104.9	1106.5	1108.1	1109.7	1111.3	1112.8	1114.4	1116.0	**43**
1130.3	1131.9	1133.5	1135.1	1136.7	1138.2	1139.8	1141.4	**44**
1155.7	1157.3	1158.9	1160.5	1162.1	1163.6	1165.2	1166.8	**45**
1181.1	1182.7	1184.3	1185.9	1187.5	1189.0	1190.6	1192.2	**46**
1206.5	1208.1	1209.7	1211.3	1212.9	1214.4	1216.0	1217.6	**47**
1231.9	1233.5	1235.1	1236.7	1238.3	1239.8	1241.4	1243.0	**48**
1257.3	1258.9	1260.5	1262.1	1263.7	1265.2	1266.8	1268.4	**49**
1282.7	1284.3	1285.9	1287.5	1289.1	1290.6	1292.2	1293.8	**50**

6.3.17 Conversion of temperature units

Useful conversion formulae:

$T_K = 273.15 + t_C = {}^5\!/\!_9 T_R$ — T_K Thermodynamic temperature (in kelvins)

$T_R = 459.67 + t_F = 1.8\ T_K$ — T_R Rankine temperature

$t_C = 5/9(t_F - 32) = T_K - 273.15$ — t_C Celsius temperature

$t_F = 1.8t_C + 32 = T_R - 459.67$ — t_F Fahrenheit temperature

°C		°F	°C		°F	°C		°F	°C		°F
-17.8	**0**	32.0									
-17.2	**1**	33.8	5.0	**41**	105.8	27.2	**81**	177.8	49.4	**121**	249.8
-16.7	**2**	35.6	5.6	**42**	107.6	27.8	**82**	179.6	50.0	**122**	251.6
-16.1	**3**	37.4	6.1	**43**	109.4	28.3	**83**	181.4	50.6	**123**	253.4
-15.6	**4**	39.2	6.7	**44**	111.2	28.9	**84**	183.2	51.1	**124**	255.2
-15.0	**5**	41.0	7.2	**45**	113.0	29.4	**85**	185.0	51.7	**125**	257.0
-14.4	**6**	42.8	7.8	**46**	114.8	30.0	**86**	186.8	52.2	**126**	258.8
-13.9	**7**	44.6	8.3	**47**	116.6	30.6	**87**	188.6	52.8	**127**	260.6
-13.3	**8**	46.4	8.9	**48**	118.4	31.1	**88**	190.4	53.3	**128**	262.4
-12.8	**9**	48.2	9.4	**49**	120.2	31.7	**89**	192.2	53.9	**129**	264.2
-12.2	**10**	50.0	10.0	**50**	122.0	32.2	**90**	194.0	54.4	**130**	266.0
-11.7	**11**	51.8	10.6	**51**	123.8	32.8	**91**	195.8	55.0	**131**	267.8
-11.1	**12**	53.6	11.1	**52**	125.6	33.3	**92**	197.6	55.6	**132**	269.6
-10.6	**13**	55.4	11.7	**53**	127.4	33.9	**93**	199.4	56.1	**133**	271.4
-10.0	**14**	57.2	12.2	**54**	129.2	34.4	**94**	201.2	56.7	**134**	273.2
-9.4	**15**	59.0	12.8	**55**	131.0	35.0	**95**	203.0	57.2	**135**	275.0
-8.9	**16**	60.8	13.3	**56**	132.8	35.6	**96**	204.8	57.8	**136**	276.8
-8.3	**17**	62.6	13.9	**57**	134.6	36.1	**97**	206.6	58.3	**137**	278.6
-7.8	**18**	64.4	14.4	**58**	136.4	36.7	**98**	208.4	58.9	**138**	280.4
-7.2	**19**	66.2	15.0	**59**	138.2	37.2	**99**	210.2	59.4	**139**	282.2
-6.7	**20**	68.0	15.6	**60**	140.0	37.8	**100**	212.0	60.0	**140**	284.0
-6.1	**21**	69.8	16.1	**61**	141.8	38.3	**101**	213.8	60.6	**141**	285.8
-5.6	**22**	71.6	16.7	**62**	143.6	38.9	**102**	215.6	61.1	**142**	287.6
-5.0	**23**	73.4	17.2	**63**	145.4	39.4	**103**	217.4	61.7	**143**	289.4
-4.4	**24**	75.2	17.8	**64**	147.2	40.0	**104**	219.2	62.2	**144**	291.2
-3.9	**25**	77.0	18.3	**65**	149.0	40.6	**105**	221.0	62.8	**145**	293.0
-3.3	**26**	78.8	18.9	**66**	150.8	41.1	**106**	222.8	63.3	**146**	294.8
-2.8	**27**	80.6	19.4	**67**	152.6	41.7	**107**	224.6	63.9	**147**	296.6
-2.2	**28**	82.4	20.0	**68**	154.4	42.2	**108**	226.4	64.4	**148**	298.4
-1.7	**29**	84.2	20.6	**69**	156.2	42.8	**109**	228.2	65.0	**149**	300.2
-1.1	**30**	86.0	21.1	**70**	158.0	43.3	**110**	230.0	65.6	**150**	302.0
-0.6	**31**	87.8	21.7	**71**	159.8	43.9	**111**	231.8	66.1	**151**	303.8
0	**32**	89.6	22.2	**72**	161.6	44.4	**112**	233.6	66.7	**152**	305.6
0.6	**33**	91.4	22.8	**73**	163.4	45.0	**113**	235.4	67.2	**153**	307.4
1.1	**34**	93.2	23.3	**74**	165.2	45.6	**114**	237.2	67.8	**154**	309.2
1.7	**35**	95.0	23.9	**75**	167.0	46.1	**115**	239.0	68.3	**155**	311.0
2.2	**36**	96.8	24.4	**76**	168.8	46.7	**116**	240.8	68.9	**156**	312.8
2.8	**37**	98.6	25.0	**77**	170.6	47.2	**117**	242.6	69.4	**157**	314.6
3.3	**38**	100.4	25.6	**78**	172.4	47.8	**118**	244.4	70.0	**158**	316.4
3.9	**39**	102.2	26.1	**79**	174.2	48.3	**119**	246.2	70.6	**159**	318.2
4.4	**40**	104.0	26.7	**80**	176.0	48.9	**120**	248.0	71.1	**160**	320.0

Fig. 133 Conversion table for Celsius and Fahrenheit

Example: The table line 10.0 **50** 122.0
means 50 °C = 122.0 °F or 50 °F = 10.0 °C

°C		°F	°C		°F	°C		°F	°C		°F
71.7	**161**	321.8	93.9	**201**	393.8	116.1	**241**	465.8	293	**560**	1040
72.2	**162**	323.6	94.4	**202**	395.6	116.7	**242**	467.6	299	**570**	1058
72.8	**163**	325.4	95.0	**203**	397.4	117.2	**243**	469.4	304	**580**	1076
73.3	**164**	327.2	95.6	**204**	399.2	117.8	**244**	471.2	310	**590**	1094
73.9	**165**	329.0	96.1	**205**	401.0	118.3	**245**	473.0	316	**600**	1112
74.4	**166**	330.8	96.7	**206**	402.8	118.9	**246**	474.8	321	**610**	1130
75.0	**167**	332.6	97.2	**207**	404.6	119.4	**247**	476.6	327	**620**	1148
75.6	**168**	334.4	97.8	**208**	406.4	120.0	**248**	478.4	332	**630**	1166
76.1	**169**	336.2	98.3	**209**	408.2	120.6	**249**	480.2	338	**640**	1184
76.7	**170**	338.0	98.9	**210**	410.0	121	**250**	482	343	**650**	1202
77.2	**171**	339.8	99.4	**211**	411.8	127	**260**	500	349	**660**	1220
77.8	**172**	341.6	100.0	**212**	413.6	132	**270**	518	354	**670**	1238
78.3	**173**	343.4	100.6	**213**	415.4	138	**280**	536	360	**680**	1256
78.9	**174**	345.2	101.1	**214**	417.2	143	**290**	554	366	**690**	1274
79.4	**175**	347.0	101.7	**215**	419.0	149	**300**	572	371	**700**	1292
80.0	**176**	348.8	102.2	**216**	420.8	154	**310**	590	377	**710**	1310
80.6	**177**	350.6	102.8	**217**	422.6	160	**320**	608	382	**720**	1328
81.1	**178**	352.4	103.3	**218**	424.4	166	**330**	626	388	**730**	1346
81.7	**179**	354.2	103.9	**219**	426.2	171	**340**	644	393	**740**	1364
82.2	**180**	356.0	104.4	**220**	428.0	177	**350**	662	399	**750**	1382
82.8	**181**	357.8	105.0	**221**	429.8	182	**360**	680	404	**760**	1400
83.3	**182**	359.6	105.6	**222**	431.6	188	**370**	698	410	**770**	1418
83.9	**183**	361.4	106.1	**223**	433.4	193	**380**	716	416	**780**	1436
84.4	**184**	363.2	106.7	**224**	435.2	199	**390**	734	421	**790**	1454
85.0	**185**	365.0	107.2	**225**	437.0	204	**400**	752	427	**800**	1472
85.6	**186**	366.8	107.8	**226**	438.8	210	**410**	770	432	**810**	1490
86.1	**187**	368.6	108.3	**227**	440.6	216	**420**	788	438	**820**	1508
86.7	**188**	370.4	108.9	**228**	442.4	221	**430**	806	443	**830**	1526
87.2	**189**	372.2	109.4	**229**	444.2	227	**440**	824	449	**840**	1544
87.8	**190**	374.0	110.0	**230**	446.0	232	**450**	842	454	**850**	1562
88.3	**191**	375.8	110.6	**231**	447.8	238	**460**	860	460	**860**	1580
88.9	**192**	377.6	111.1	**232**	449.6	243	**470**	878	466	**870**	1598
89.4	**193**	379.4	111.7	**233**	451.4	249	**480**	896	471	**880**	1616
90.0	**194**	381.2	112.2	**234**	453.2	254	**490**	914	477	**890**	1634
90.6	**195**	383.0	112.8	**235**	455.0	260	**500**	932	482	**900**	1652
91.1	**196**	384.8	113.3	**236**	456.8	266	**510**	950	488	**910**	1670
91.7	**197**	386.6	113.9	**237**	458.6	271	**520**	968	493	**920**	1688
92.2	**198**	388.4	114.4	**238**	460.4	277	**530**	986			
92.8	**199**	390.2	115.0	**239**	462.2	282	**540**	1004			
93.3	**200**	392.0	115.6	**240**	464.0	288	**550**	1022			

Fig. 133 Conversion table for Celsius and Fahrenheit, continued

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7 Acceptance Conditions

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7 Acceptance Conditions

7.1 Acceptance Conditions for Valves and Fittings

7.1.1 General

GESTRA has a product-specific quality assurance system as well as the necessary personnel and facilities to ensure that the products are manufactured and tested in accordance with the technical regulations. This was examined and established within the scope of the certification according to the AD 2000 bulletin HP 0.
In this way, it is guaranteed that the tests resulting from the codes and, where applicable, supplementary requirements of the customer are performed, monitored and documented by works test engineers and material stamping officers who are independent of the manufacturing department. As a rule, the necessary tests and acceptance inspections are confirmed by test certificates according to EN 10204. The applicable regulations and codes which are to govern delivery and testing and, where applicable, the required type of verification must be agreed upon beforehand, but at the latest when the purchase order is placed. Verification of specific tests is then, as a rule, no longer absolutely necessary after delivery has taken place.

Designation of the test certificate				Content of the certificate	Certificate validated by …
Item	German	English	French		
2.1	Werks-bescheinigung	Declaration of compliance with the order	Attestation de conformité à la commande	Statement of compliance with the order	the manufacturer
2.2	Werkszeugnis	Test report	Relevé de contrôle	Statement of compliance with the order, with indication of the results of non-specific tests *)	the manufacturer
3.1	Abnahmeprüf-zeugnis 3.1	Inspection certificate 3.1	Certificate de reception 3.1	Statement of compliance with the order, with indication of the results of non-specific tests **)	the manufacturer's authorized inspection representative, independent of the manufacturing department
3.2	Abnahmeprüf-zeugnis 3.2	Inspection certificate 3.2	Certificate de reception 3.2	Statement of compliance with the order, with indication of the results of non-specific tests **)	the manufacturer's authorized inspection representative, independent of the manufacturing department, and either the purchaser`s authorized inspection representative or the inspector designated by the official regulations

Fig. 134 Test certificates according to EN 10204

*) Tests chosen by the manufacturer and performed with the aim of determining whether products manufactured according to the same procedure and the same specification and regarded as homogeneous by the manufacturer meet the requirements prescribed in the order. The tested products need not necessarily originate from the same delivery.

**)Tests performed before delivery according to the technical requirements of the order on the products to be delivered, or on test subjects forming part thereof, with the aim of determining whether the products meet the requirements prescribed in the order.

7.1.2 Types of certificates

7.1.2.1 European directives

The European Union has developed concepts for product regulation and conformity assessment. These mutually supplementary concepts restrict state intervention to the minimum that is absolutely necessary, thus giving the industry the greatest possible freedom in fulfilling its obligations towards the general public.
Since 1987, some 20 directives which are based on the “New Approach” and the “Global Approach” have come into force.

7.1.2.2 Products falling under the directives

Directives belonging to the New Approach apply to products that are to be placed on (or put into service within) the single European market for the first time.
Consequently, the directives are valid for new products manufactured in the member states, for new products imported from non-EU countries, and for used and second-hand products.
There are distinctions between the various directives of the New Approach with regard to the term “product”, so that the onus is on the manufacturer to check whether his product falls within the scope of one or more directives. Products to which appreciable modifications have been made may be viewed as new products. They must fulfil the provisions of the applicable directives if they are placed on the market and put into service within the EU. Unless provided otherwise, this must be assessed individually for each case. Products that have been repaired without any change in the original performance, purpose or design do not need to be subjected to a conformity assessment according to the directives of the New Approach.

7.1.2.3 Simultaneous application of directives

Essential requirements set out in the directives of the New Approach can overlap or supplement each other; this depends on the product-related hazards covered by these requirements. The product may only be placed on the market and put into service if it complies with the provisions of all applicable directives and insofar as the conformity assessment has been carried out according to all applicable directives. If two or more directives come into question for the same product or hazard, then, following completion of a procedure which includes a risk analysis of the product in view of its intended use as defined by the manufacturer, it may be possible to waive the application of other directives.

7.1.2.4 GESTRA products – directives to be considered

- Pressure Equipment Directive 97/23/EC (abbreviated as PED)
- Potentially Explosive Atmospheres Directive 94/9/EC (named ATEX for short, after the French “ATmosphères EXplosibles”, and also called the EX Protection Directive)
- Low Voltage Directive 73/23/EEC (LVD)
- Electromagnetic Compatibility Directive 89/336/EEC (EMC)
- Transportable Pressure Equipment Directive 1999/36/EC (TPED)
- Marine Equipment Directive 96/98/EC (MED)

7.1.3 Information on the Pressure Equipment Directive 97/23/EC (PED)

The Pressure Equipment Directive (or PED for short) was implemented in national law on 29 November 1999. After expiry of the transitional period on 29 May 2002, pressure equipment (e.g. valves or tanks), may not be placed on the market within the EU if it does not comply with this regulation. Pressure equipment already in service is not affected by this requirement. The PED governs the placing on the market of pressure equipment within the EU. Here the pressure-related hazards and risks are considered.
Manufacturers of pressure equipment must undertake a categorization and assessment of their pressure equipment and its potential hazards.
With due consideration of the intended purpose of the pressure equipment and other parameters (such as nominal size, volume and pressure), a more or less substantial hazard potential is given for any item of pressure equipment.
There are 4 categories (i.e. hazard classes, see Chapter 7.1.3.1 “Categorization of the fluid groups – gases and liquids”, item 1), namely I, II, III, IV as well as an exception as per Article 3.3, into which an item of pressure equipment must be classified according to Article 10 of the PED.
The manufacturers of pressure equipment must subject each item of equipment to a so-called conformity assessment procedure before placing it on the market. For this purpose, 13 modules (A, A1, B, B1, C1, D, D1, E, E1, F, G, H, H1) are available.

For example, the PED applies for:
Equipment components with a maximum allowable pressure > 0.5 bar
Equipment components with a safety function
Vessels
Piping, including valves and fittings used in general industrial applications for the transport of fluids.

The PED does not apply to:
Simple pressure vessels (see Directive 87/404 EEC)
Equipment for the functioning of vehicles (see Directive 70/156 EEC)
Valves for tank cars and tank containers according to ADR, RID and IMO
Networks and equipment for water supply
Valves and fittings without a safety function and having a nominal size < DN 25, e.g. shut-off valves, steam traps and non-return (check) valves.

What must be observed?
- The intended use of the pressure equipment must be defined; this definition may result in certain restrictions: Permissible use in fluid group 1 and/or 2 and gaseous and/or liquid fluids (see Chapter 7.1.3.1 “Categorization of the fluid groups, gases and liquids”, items 2 - 5). Steam traps are usually classified into fluid group 2. The only exceptions are valves expressly used for purposes other than the discharge of condensate from steam lines (e.g. drainage of a natural gas pipeline).
- If pressure equipment is delivered to customers who have their own testing department, this must be contractually arranged beforehand, especially in the case of pressure vessels.
- The PED takes priority over other codes, e.g. AD, but does not exclude them.
- Not all pressure equipment is subject to CE marking. Example: a steam trap DN 50 PN for fluid group 2 (non-dangerous media, e.g. water) falls under the “SEP” exception set out in Article 3.3, is declared as not being in conformity with the PED, and therefore does not bear the CE marking.
- Declarations of conformity and CE marking must not be used if this is inadmissible (as it would be a criminal offence!)

In general form, Annex I of the PED expresses the fundamental safety requirements for pressure equipment. For the concrete implementation of these requirements, reference is made in Article 5 to the harmonized standards; if the national standards transposing the harmonized standards are applied, then it is presumed that the equipment conforms to the essential requirements.
Besides the harmonized standards, it is possible to use other codes for meeting the fundamental safety requirements for which the “presumption of conformity” is not automatically given but must be verified separately. When the PED came into force, harmonized standards were not yet available for specific applications, so that in Germany, for instance, the hitherto recognized AD code was adapted to the requirements of the PED and reintroduced as the “AD 2000” code. Whilst the PED regulates the “required condition”, the operation and the testing deadlines for the periodical inspections are not covered. These aspects have been left to the discretion of the EU member states by the European Commission. In Germany, for example, the “Plant Safety Ordinance” applies here.
Within the scope of the Plant Safety Ordinance, flexible inspection deadlines apply for the operation of pressure equipment requiring supervision; at a maximum, these are limited to the inspection deadlines applying previously in Germany. By selecting the technical condition specification for the installation of an item of pressure equipment, the operator can exert some influence on the inspection deadlines. With application of the AD 2000 code, experts generally agree that the inspection deadlines valid thus far can still be applied. Other codes may necessitate an individual assessment in some cases.
GESTRA was already certified in December 1999 by the notified body Lloyds Register (No. 0525) according to Module H. As had been the case in 1987 with the introduction of the quality management system according to ISO 9001, GESTRA was again one of the first German manufacturers of valves and fittings to implement such an important requirement. For the GESTRA pressure equipment, the fundamental safety requirements of the PED were considered with due regard for the relevant harmonized standards and, insofar applicable, the requirements of the AD 2000 code.

GESTRA information on the EX Protection Directive 94/9/EC (ATEX)
Status: June 2003
The EX Protection Directive 94/9/EC (ATEX) governs the requirements for equipment to be operated in atmospheres subject to an explosion hazard. This European directive applies as from 01.07.2003 for the operation of electrical and non-electrical units in the EU member states.
Valves and fittings must be examined for their suitability for use in explosion-endangered zones as per ATEX Directive 94/9/EC.
If the equipment does not have its own potential ignition source as per Annex II, section 1.3, it is excluded from the scope of this directive according to Article 1, paragraph 3(a) and, in conjunction with Article 10, paragraph (3), these items of equipment shall not be labelled with the CE marking in connection with the ATEX Directive 94/9/EC.
Within the scope of the applications set out in the GESTRA datasheets and due to the lack of an own potential ignition source, use of this equipment is not restricted within potentially explosive atmospheres.
For example, such GESTRA equipment is suitable for operation in the following areas: Zone 0, 1, 2 (gases) and 20, 21, 22 (dusts)
Equipment group II
Category 1, 2, 3

7.1.3.1 Categorization of the fluid groups – gases and liquids

1. Hazard classes / categories

SEP: Exception as per Article 3.3; no CE marking and no declaration of conformity. Such pressure equipment must be designed and manufactured in accordance with “sound engineering practice”.
I, II, III: The “level of hazard” determines the modules to be applied, e.g. module H.
IV: Equipment components with a safety function, e.g. safety valves, pressure limiters

2. Fluid group 1 – hazardous media:

- Explosive
- Extremely flammable
- Highly flammable
- Flammable (where the maximum allowable temperature is above flashpoint)
- Very toxic
- Toxic
- Oxidizing

3. Fluid group 2 – non-hazardous media:

All fluids not listed in fluid group 1, e.g. water, steam, air.

4. Gaseous fluids – a definition

Gases, liquefied gases, gases dissolved under pressure, vapours and also those liquids whose vapour pressure at the maximum allowable temperature is greater than 0.5 bar above normal atmospheric pressure (1013 mbar).
This also includes e.g. water/condensate at more than 111 °C, since the steam pressure for this temperature exceeds 1.5 bara. The boiling point of water at 1.5 bara = 111.37 °C (source: GESTRA Guide, steam tables)

5. Liquid fluids – a definition

Liquids having a vapour pressure at the maximum allowable temperature of not more than 0.5 bar above normal atmospheric pressure (1013 mbar).

FLOWSERVE® GESTRA

8 Flanges, Pipes

FLOWSERVE GESTRA

GESTRA Steam Systems

Valves

Industrial Electronics, Automation

Special Equipment
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Services

8 Flanges, Pipes

8.1 DIN/EN Flanges and Pipes

8.1.1 Steel pipes

The technical delivery conditions pertaining to seamless steel pipes (“tubes”) for elevated temperatures are defined in DIN EN 10216-2 and those to welded steel pipes for elevated temperatures in DIN EN 10217-2. The dimensions and masses per unit length for such steel pipes are specified in DIN EN 10220 (with regard to steel tubes for precision applications, refer to DIN EN 10305-1 to DIN EN 10305-3). See the table on the next double page.

Outside diameter [mm]			Wall thickness [mm]															
Series			1.6	1.8	2	2.3	2.6	2.9	3.2	3.6	4	4.5	5	5.4	5.6	6.3	7.1	8
1	2	3	Mass per unit length [kg/m]							Mass per unit length [kg/m]								
10.2			0.339	0.373	0.404	0.448	0.487											
	12.0		0.410	0.453	0.493	0.550	0.603	0.651	0.694									
	12.7		0.438	0.484	0.528	0.590	0.648	0.701	0.750									
13.5			0.470	0.519	0.567	0.636	0.699	0.758	0.813	0.879								
		14.0	0.489	0.542	0.592	0.664	0.731	0.794	0.852	0.923								
	16.0		0.568	0.630	0.691	0.777	0.859	0.937	1.01	1.10	1.18							
17.2			0.616	0.684	0.750	0.845	0.936	1.02	1.10	1.21	1.30	1.41						
		18.0	0.647	0.719	0.789	0.891	0.987	1.08	1.17	1.28	1.38	1.50						
	19.0		0.687	0.764	0.838	0.947	1.05	1.15	1.25	1.37	1.48	1.61	1.73					
	20.0		0.726	0.808	0.888	1.00	1.12	1.22	1.33	1.46	1.58	1.72	1.85					
21.3			0.777	0.866	0.952	1.08	1.20	1.32	1.43	1.57	1.71	1.86	2.01	2.12				
		22.0	0.805	0.897	0.996	1.12	1.24	1.37	1.48	1.63	1.78	1.94	2.10	2.21				
	25.0		0.923	1.03	1.13	1.29	1.44	1.58	1.72	1.90	2.07	2.28	2.47	2.61	2.68	2.91		
		25.4	0.939	1.05	1.15	1.31	1.46	1.61	1.75	1.94	2.11	2.32	2.52	2.66	2.73	2.97		
26.9			0.998	1.11	1.23	1.40	1.56	1.72	1.87	2.07	2.26	2.49	2.70	2.86	2.94	3.20	3.47	3.73
		30.0	1.12	1.25	1.38	1.57	1.76	1.94	2.11	2.34	2.56	2.83	3.08	3.28	3.27	3.68	4.01	4.34
	31.8		1.19	1.33	1.47	1.67	1.87	2.07	2.26	2.50	2.74	3.03	3.30	3.52	3.62	3.96	4.32	4.70
	32.0		1.20	1.34	1.48	1.68	1.89	2.08	2.27	2.52	2.76	3.05	3.33	3.54	3.65	3.99	4.36	4.74
33.7			1.27	1.42	1.56	1.78	1.99	2.20	2.41	2.67	2.93	3.24	3.54	3.77	3.88	4.26	4.66	5.07
		35.0	1.32	1.47	1.63	1.85	2.08	2.30	2.51	2.79	3.06	3.38	3.70	3.94	4.06	4.46	4.89	5.33
	38.0		1.44	1.61	1.78	2.02	2.27	2.51	2.75	3.05	3.35	3.72	4.07	4.34	4.47	4.93	5.41	5.92
	40.0		1.52	1.70	1.87	2.14	2.40	2.65	2.90	3.23	3.55	3.94	4.32	4.61	4.75	5.24	5.76	6.31
42.4			1.61	1.80	1.99	2.27	2.55	2.82	3.09	3.44	3.79	4.21	4.61	4.93	5.08	5.61	6.18	6.79
		44.5	1.69	1.90	2.10	2.39	2.69	2.98	3.26	3.63	4.00	4.44	4.87	5.21	5.37	5.94	6.55	7.20
48.3			1.84	2.06	2.28	2.61	2.93	3.25	3.56	3.97	4.37	4.86	5.34	5.71	5.90	6.53	7.21	7.95
	51.0		1.95	2.18	2.42	2.76	3.10	3.44	3.77	4.21	4.64	5.16	5.67	5.47	6.27	6.94	7.69	8.48
		54.0	2.07	2.32	2.56	2.93	3.30	3.65	4.01	4.47	4.93	5.49	6.04	6.07	6.68	7.41	8.21	9.08
	57.0		2.19	2.45	2.71	3.10	3.49	3.87	4.25	4.74	5.23	5.83	6.41	6.87	7.10	7.88	8.74	9.67
60.3			2.32	2.60	2.88	3.29	3.70	4.11	4.51	5.03	5.55	6.19	6.82	7.31	7.55	8.39	9.32	10.3
	63.5		2.44	2.74	3.03	3.47	3.90	4.33	4.76	5.32	5.87	6.55	7.21	7.74	8.00	8.89	9.88	10.9
	70.0		2.70	3.03	3.35	3.84	4.32	4.80	5.27	5.90	6.51	7.27	8.01	8.60	8.89	9.90	11.0	12.2
		73.0	2.82	3.16	3.50	4.01	4.51	5.01	5.51	6.16	6.81	7.60	8.38	9.00	9.31	10.4	11.5	12.8
76.1			2.94	3.30	3.65	4.19	4.71	5.24	5.75	6.44	7.11	7.95	8.77	9.42	9.74	10.8	12.1	13.4
		82.5	3.19	3.58	3.97	4.55	5.12	5.69	6.26	7.00	7.74	8.66	9.56	10.3	10.6	11.8	13.2	14.7
88.9			3.44	3.87	4.29	4.91	5.53	6.15	6.76	7.57	8.38	9.37	10.3	11.1	11.5	12.8	14.3	16.0
	101.6		3.95	4.43	4.91	5.63	6.35	7.06	7.77	8.70	9.63	10.8	11.9	12.8	13.3	14.8	16.5	18.5
		108	4.2	4.71	5.23	6.00	6.76	7.52	8.27	9.27	10.3	11.5	12.7	13.7	14.1	15.8	17.7	19.7
114.3			4.45	4.99	5.54	6.35	7.16	7.97	8.77	9.83	10.9	12.2	13.5	14.5	15.0	16.8	18.8	21.0
	127		4.95	5.56	6.17	7.07	7.98	8.88	9.77	11.0	12.1	13.6	15.0	16.2	16.8	18.8	21.0	23.5
	133		5.18	5.82	6.46	7.41	8.36	9.30	10.2	11.5	12.7	14.3	15.8	17.0	17.6	19.7	22.0	24.7
139.7			5.45	6.12	6.79	7.79	8.79	9.78	10.8	12.1	13.4	15.0	16.6	17.9	18.5	20.7	23.2	26.0
		141.3	5.51	6.19	6.87	7.88	8.89	9.90	10.9	12.2	13.5	15.2	16.8	18.1	18.7	21.0	23.5	26.3
		152.4	5.95	6.69	7.42	8.51	9.61	10.7	11.8	13.2	14.6	16.4	18.2	19.6	20.3	22.7	25.4	28.5
		159	6.21	6.98	7.74	8.89	10.0	11.2	12.3	13.8	15.3	17.1	19.0	20.5	21.2	23.7	26.6	29.8
168.3			6.58	7.39	8.20	9.42	10.6	11.8	13.0	14.6	16.2	18.2	20.1	21.7	22.5	25.2	28.2	31.6
		177.8		7.81	8.67	9.95	11.2	12.5	13.8	15.5	17.1	19.2	21.3	23.0	23.8	26.6	29.9	33.5
		193.7		8.52	9.46	10.9	12.3	13.6	15.0	16.9	18.7	21.0	23.3	25.1	26.0	29.1	32.7	36.6
219.1				9.65	10.7	12.3	13.9	15.5	17.0	19.1	21.2	23.8	26.4	28.5	29.5	33.1	37.1	41.6
		244.5			12.0	13.7	15.5	17.3	19.0	21.4	23.7	26.6	29.5	31.8	33.0	37.0	41.6	46.7
273					13.4	15.4	17.3	19.3	21.3	23.9	26.5	29.8	33.0	35.6	36.9	41.4	46.6	52.3
323.9							20.6	23.0	25.3	28.4	31.6	35.4	39.3	42.4	44.0	49.3	55.5	62.3
355.6							22.6	25.2	27.8	31.3	34.7	39.0	43.2	46.6	48.3	54.3	61.0	68.6
406.4							25.9	28.9	31.8	35.8	39.7	44.6	49.5	53.4	55.4	62.2	69.9	78.6
457									35.8	40.3	44.7	50.2	56.7	60.1	62.3	70.0	78.8	88.6
508									39.8	44.8	49.7	55.9	62.0	66.9	69.4	77.9	87.7	98.6
		559							43.9	49.3	54.7	61.5	68.3	73.7	76.4	85.9	96.6	109
610									47.9	53.8	59.8	67.2	74.6	80.5	83.5	93.8	106	119
		660									64.7	72.7	80.8	87.2	90.4	102	114	129
711											69.7	78.4	87.1	94.0	97.4	109	123	139

Fig. 135a Dimensions and mass per unit length (DIN EN 10220 - selection)

Series 1 Pipes for which all the accessories needed in installing the piping systems are standardized

Series 2 Pipes for which not all the accessories are standardized

Series 3 Pipes for which there is hardly any standardized accessories

FLOWSERVE GESTRA

Outside diameter [mm]			Wall thickness [mm]								Wall thickness [mm]								
Series			8.8	10	11	12.5	14.2	16	17.5	20	22.2	25	28	30	32	36	40	45	50
1	2	3	Mass per unit length [kg/m]								Mass per unit length [kg/m]								
10.2																			
	12.0																		
	12.7																		
13.5																			
		14.0																	
	16.0																		
17.2																			
		18.0																	
	19.0																		
	20.0																		
21.3																			
		22.0																	
	25.0																		
		25.4																	
26.9																			
		30.0																	
	31.8																		
	32.0																		
33.7			5.40																
		35.0	5.69																
	38.0		6.34	6.91															
	40.0		6.77	7.40															
42.4			7.29	7.99															
		44.5	7.75	8.51	9.09	9.86													
48.3			8.57	9.45	10.1	11.0													
	51.0		9.16	10.1	10.9	11.9													
		54.0	9.81	10.9	11.7	12.8	13.9												
	57.0		10.5	11.6	12.5	13.7	15.0												
60.3			11.2	12.4	13.4	14.7	16.1	17.5											
	63.5		11.9	13.2	14.2	15.7	17.3	18.7											
	70.0		13.3	14.8	16.0	17.7	19.5	21.3	22.7										
		73.0	13.9	15.5	16.8	18.7	20.6	22.5	24.0										
76.1			14.6	16.3	17.7	19.6	21.7	23.7	25.3	27.7									
		82.5	16.0	17.9	19.4	21.6	23.9	26.2	28.1	30.8	33.0								
88.9			17.4	19.5	21.1	23.6	26.2	28.8	30.8	34.0	36.5	39.4							
	101.6		20.1	22.6	24.6	27.5	30.6	33.8	36.3	40.2	43.5	47.2	50.8						
		108	21.5	24.2	26.3	29.4	32.8	36.3	39.1	43.4	47.0	51.2	55.2	57.7					
114.3			22.9	25.7	28.0	31.4	35.1	38.8	41.8	46.5	50.4	55.1	59.6	62.4	64.9				
	127		25.7	28.9	31.5	35.3	39.5	43.8	47.3	52.8	57.4	62.9	68.4	71.8	75.0	80.8			
	133		27.0	30.3	33.1	37.1	41.6	46.2	49.8	55.7	60.7	66.6	72.5	76.2	79.7	86.1	91.7		
139.7			28.4	32.0	34.9	39.2	43.9	48.8	52.7	59.0	64.3	70.7	77.1	81.2	85.0	92.1	98.4		
		141.3	28.8	32.4	35.3	39.7	44.5	49.4	53.4	59.8	65.2	71.7	78.2	82.3	86.3	93.5	99.9		
		152.4	31.2	35.1	38.4	43.1	48.4	53.8	58.2	65.3	71.3	78.5	85.9	90.6	95.0	103	111	119	
		159	32.6	36.7	40.1	45.2	50.7	56.4	61.1	68.6	74.9	82.6	90.5	95.4	100	109	117	127	
168.3			34.6	39.0	42.7	48.0	54.0	60.1	65.1	73.1	80.0	88.3	96.9	102	108	117	127	137	146
		177.8	36.7	41.4	45.2	51.0	57.3	63.8	69.2	77.8	85.2	94.2	103	109	115	126	136	147	158
		193.7	40.1	45.3	49.6	55.9	62.9	70.1	76.0	85.7	93.9	104	114	121	128	140	152	165	177
219.1			45.6	51.6	56.5	63.7	71.8	80.1	87.0	98.2	108	120	132	140	148	163	177	193	209
		244.5	51.2	57.8	63.3	71.5	80.6	90.2	98.0	111	122	135	149	159	168	185	202	221	240
273			57.3	64.9	71.1	80.3	90.6	101	110	125	137	153	169	180	190	210	230	253	275
323.9			68.4	77.4	84.9	96.0	108	121	132	150	165	184	204	217	230	256	280	310	338
355.6			75.3	85.2	93.5	106	120	134	146	166	183	204	226	241	255	284	311	345	377
406.4			86.3	97.8	107	121	137	154	168	191	210	235	261	278	295	329	361	401	439
457			97.3	110	121	137	155	174	190	216	238	266	296	316	335	374	411	457	502
508			108	123	135	153	173	194	212	241	266	298	331	354	376	419	462	514	565
		559	119	135	149	168	191	214	234	266	294	329	367	391	416	464	512	570	628
610			130	148	162	184	209	234	256	291	322	361	402	429	456	510	562	627	691
		660	141	160	176	200	226	254	277	316	349	392	436	466	496	554	612	683	752
711			152	173	190	215	244	274	299	341	377	423	472	504	536	599	662	739	815

Fig. 135b contd. Dimensions and mass per unit length (DIN EN 10220 - selection)

Series 1 Pipes for which all the accessories needed in installing the piping systems are standardized

Series 2 Pipes for which not all the accessories are standardized

Series 3 Pipes for which there is hardly any standardized accessories

FLOWSERVE GESTRA

8.1.2 Flange types

The various types of steel flanges up to PN 100 are standardized in DIN EN 1092-1. Steel flanges from PN 160 to PN 400 are defined in various DIN standards. See DIN EN 1092-2 for cast iron flanges up to PN 63.

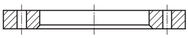
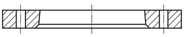
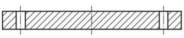
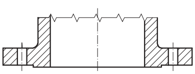
Designation	Schematic view	PN	DN																			
			10	15	20	25	32	40	50	65	80	100	125	150	200	250	300	350	400	450	500	600
Flat flange for welding	 Type 01	6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		10	See PN 40						See PN 16						X	X	X	X	X	X	X	X
		16	See PN 40						X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	See PN 40												X	X	X	X	X	X	X	X
		40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		63	See PN 100					X	X	X	X	X	X	X	X	X	X	X	–	–	–	
		100	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	–
Lapped flange for plain collar or welding collar	 Type 02 (for Type 32 and 33)	6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		10	See PN 40						See PN 16						X	X	X	X	X	X	X	X
		16	See PN 40						X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	See PN 40												X	X	X	X	X	X	X	X
		40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lapped flange for welding collar	 Type 04 (for Type 34)	10	See PN 40						See PN 16						X	X	X	X	X	X	X	X
		16	See PN 40						X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	See PN 40												X	X	X	X	X	X	X	X
		40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Blind flange	 Type 05	6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		10	See PN 40						See PN 16						X	X	X	X	X	X	X	X
		16	See PN 40						X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	See PN 40												X	X	X	X	X	X	X	X
		40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		63	See PN 100					X	X	X	X	X	X	X	X	X	X	X	–	–	–	
		100	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–	–
Welding neck flange	 Type 11	6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		10	See PN 40						See PN 16						X	X	X	X	X	X	X	X
		16	See PN 40						X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	See PN 40												X	X	X	X	X	X	X	X
		40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		63	See PN 100					X	X	X	X	X	X	X	X	X	X	X	–	–	–	
		100	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–	–
Slip-on flange with neck	 Type 12	6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–	–	–
		10	See PN 40						See PN 16						X	X	X	X	X	X	X	X
		16	See PN 40						X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	See PN 40												X	X	X	X	X	X	X	X
		40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		63	See PN 100					X	X	X	X	X	X	–	–	–	–	–	–	–	–	
		100	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–
Threaded flange with neck	 Type 13	6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–	–	–
		10	See PN 40						See PN 16						–	–	–	–	–	–	–	–
		16	See PN 40						X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	See PN 40												–	–	–	–	–	–	–	–
		40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		63	See PN 100					X	X	X	X	X	X	–	–	–	–	–	–	–	–	
		100	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–
Integral flange	 Type 21	6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		10	See PN 40						See PN 16						X	X	X	X	X	X	X	X
		16	See PN 40						X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	See PN 40												X	X	X	X	X	X	X	X
		40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		63	See PN 100					X	X	X	X	X	X	X	X	X	X	X	X	X	X	
		100	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	–

Fig. 136 Steel flanges, overview of types
(DIN EN 1092-1, DIN 2548 - DIN 2551, DIN 2627 - DIN 2629, DIN 2638 - selection)

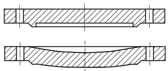
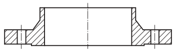
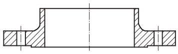
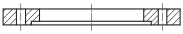
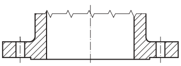
Designation	Schematic view	PN	DN																				
			10	15	20	25	32	40	50	60	65	80	100	125	150	200	250	300	350	400	450	500	600
Blind flange		10	–	–	–	–	–	See PN 16								X	X	X	X	X	X	X	X
		16	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	–	–	–	–	–	See PN 40						X	X	X	X	X	X	X	X	X	X
		40	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Type 05	63	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–
Welding neck flange		10	–	–	–	–	–	See PN 16								X	X	X	X	X	X	X	X
		16	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	–	–	–	–	–	See PN 40						X	X	X	X	X	X	X	X	X	X
		40	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Type 11	63	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–
Slip-on flange with neck		10	–	–	–	–	–	See PN 16								X	X	X	X	X	X	X	X
		16	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	–	–	–	–	–	See PN 40						X	X	X	X	X	X	X	X	X	X
		40	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Type 12	63	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–
Threaded flange with neck		10	–	–	–	–	–	See PN 16								X	X	X	X	X	X	X	X
		16	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	–	–	–	–	–	See PN 40						X	X	X	X	X	X	X	X	X	X
		40	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Type 13	63	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–
Slip-on welding flange with neck		10	–	–	–	–	–	See PN 16								X	X	X	X	X	X	X	X
		16	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	–	–	–	–	–	See PN 40						X	X	X	X	X	X	X	X	X	X
		40	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Type 14	63	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–
Lapped flange		10	–	–	–	–	–	See PN 16								X	X	X	X	X	X	X	X
		16	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	–	–	–	–	–	See PN 40						X	X	X	X	X	X	X	X	X	X
	Type 16	40	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–	–
Integral flange		10	See PN 16													X	X	X	X	X	X	X	X
		16	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	X	X	X	X	X	See PN 40						X	X	X	X	X	X	X	X	X	X
		40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Type 21	63	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–

Fig. 137 Flanges of ductile cast iron, overview of types
(DIN EN 1092-2 - selection)

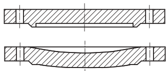
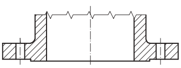
Designation	Schematic view	PN	DN																				
			10	15	20	25	32	40	50	60	65	80	100	125	150	200	250	300	350	400	450	500	600
Blind flange		6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		10	See PN 16													X	X	X	X	X	X	X	X
		16	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	See PN 40											X	X	X	X	X	X	X	X	X	X
	Type 05	40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–
Threaded flange with neck		6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		10	–	–	–	–	–	–	–	–	–	See PN 16				X	X	X	–	–	–	–	–
		16	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	–	–	–	–	–
		25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Type 13	40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Integral flange		6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		10	See PN 16													X	X	X	X	X	X	X	X
		16	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		25	See PN 40											X	X	X	X	X	X	X	X	X	X
	Type 21	40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–

Fig. 138 Flanges of grey cast iron, overview of types
(DIN EN 1092-2 - selection)

8.1.3 Flange materials and pressure/temperature rating

Steel materials for flanges and their admissible working pressures and temperatures (p/T rating) are specified in DIN EN 1092-1, whilst DIN EN 1092-2 contains the corresponding data for cast iron materials.
Some of the operating data given in the tables below are subject to certain conditions; see the relevant standards.

PN	Materials			Material	Admissible pressure *p* in [bar] for temperature *t* in [°C]					Admissible pressure *p* in [bar] for temperature *t* in [°C]											
	forged	cast	hot rolled	group	20	100	150	200	250	300	350	400	425	450	475	500	510	520	530	550	600
10	1.0038	–	1.0038	1E1	10.0	8.0	7.5	6.9	6.0	5.2											
	1.0460	1.0619	1.0425	3E0	10.0	9.3	8.7	7.8	7.1	6.4	6.0	5.8									
	1.5415	1.5419	1.5415	4E0	10.0	10.0	10.0	9.6	8.9	7.6	7.1	6.7	6.6	6.4	6.4	4.5					
16	1.0038	–	1.0038	1E1	16.0	12.8	11.9	11.0	9.7	8.3											
	1.0460	1.0619	1.0425	3E0	16.0	14.9	13.9	12.4	11.4	10.3	9.6	9.2									
	1.5415	1.5419	1.5415	4E0	16.0	16.0	16.0	15.3	14.2	12.1	11.4	10.7	10.5	10.3	10.2	7.2					
	1.7335	1.7357	1.7335	5E0	16.0	16.0	16.0	16.0	15.6	14.6	13.5	12.8	12.4	12.1	11.9	9.7	8.2	6.7	5.5		
25	1.0038	–	1.0038	1E1	25.0	20.0	18.7	17.2	15.1	13.0											
	1.0460	1.0619	1.0425	3E0	25.0	23.3	21.7	19.4	17.8	16.1	15.0	14.4									
	1.5415	1.5419	1.5415	4E0	25.0	25.0	25.0	23.9	22.2	18.9	17.8	16.7	16.4	16.1	15.9	11.2					
	1.7335	1.7357	1.7335	5E0	25.0	25.0	25.0	25.0	24.4	22.8	21.1	20.0	19.4	18.9	18.7	15.2	12.9	10.4	8.7		
	1.7383	1.7379	–	6E0	25.0	25.0	25.0	25.0	25.0	24.4	23.3	22.2	21.7	21.1	19.9	15.0	13.1	11.4	10.0		
40	1.0038	–	1.0038	1E1	40.0	32.0	29.9	27.6	24.2	20.8											
	1.0460	1.0619	1.0425	3E0	40.0	37.3	34.7	31.1	28.4	25.8	24.0	23.1									
	1.5415	1.5419	1.5415	4E0	40.0	40.0	40.0	38.2	35.6	30.2	28.4	26.7	26.3	25.8	25.4	18.0					
	1.7335	1.7357	1.7335	5E0	40.0	40.0	40.0	40.0	39.1	36.4	33.8	32.0	31.1	30.2	29.9	24.4	20.6	16.7	13.9		
	1.7383	1.7379	–	6E0	40.0	40.0	40.0	40.0	40.0	39.1	37.3	35.6	34.7	33.8	31.8	24.0	21.0	18.3	16.0		
	1.4922	1.4931	–	9E0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0		40.0		40.0				22.8	10.5
63	1.0038	–	1.0038	1E1	63.0	50.4	47.0	43.4	38.1	32.8											
	1.0460	1.0619	1.0425	3E0	63.0	58.8	54.6	49.0	44.8	40.6	37.8	36.4									
	1.5415	1.5419	1.5415	4E0	63.0	63.0	63.0	60.2	56.0	47.6	44.8	42.0	41.4	40.6	40.0	28.3					
	1.7335	1.7357	1.7335	5E0	63.0	63.0	63.0	63.0	61.6	57.4	53.2	50.4	49.0	47.6	47.0	38.4	32.5	26.3	21.8		
	1.7383	1.7379	–	6E0	63.0	63.0	63.0	63.0	63.0	61.6	58.8	56.0	54.6	53.2	50.1	37.8	33.0	28.8	25.2		
	1.4922	1.4931	–	9E0	63.0	63.0	63.0	63.0	63.0	63.0	63.0	63.0		63.0		63.0				35.8	16.5
100	1.0038	–	1.0038	1E1	100.0	80.0	74.7	68.9	60.4	52.0											
	1.0460	1.0619	1.0425	3E0	100.0	93.3	86.7	77.8	71.1	64.4	60.0	57.8									
	1.5415	1.5419	1.5415	4E0	100.0	100.0	100.0	95.6	88.9	75.6	71.1	66.7	65.8	64.4	63.6	44.9					
	1.7335	1.7357	1.7335	5E0	100.0	100.0	100.0	100.0	97.8	91.1	84.4	80.0	77.8	75.6	74.7	60.9	51.6	41.8	34.7		
	1.7383	1.7379	–	6E0	100.0	100.0	100.0	100.0	100.0	97.8	93.3	88.9	86.7	84.4	79.6	60.0	52.4	45.8	40.0		
	1.4922	1.4931	–	9E0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		100.0		100.0				56.9	26.2

Fig. 139 Operating data for ferritic steel materials
(DIN EN 1092-1 - selection)

FLOWSERVE® GESTRA

PN	Materials forged	cast	hot rolled	Material group	Admissible pressure *p* in [bar] for temperature *t* in [°C] 20	50	100	150	200	Admissible pressure *p* in [bar] for temperature *t* in [°C] 250	300	350	400	450	500	550	600
10	1.4307	1.4309	1.4306	10E0	10.0	9.3	8.4	7.6	6.9	6.4	6.0	5.7	5.6	5.5	5.3		
	1.4301	1.4308	1.4301	11E0	10.0	9.3	8.4	7.6	6.9	6.4	6.0	5.7	5.6	5.5	5.3	5.1	3.3
	1.4541	–	1.4541	12E0	10.0	10.0	9.3	8.7	8.2	7.8	7.4	7.2	6.9	6.8	6.6	6.3	3.9
	–	1.4552	1.4550	12E0	10.0	10.0	9.3	8.7	8.2	7.8	7.4	7.2	6.9	6.8	6.6	6.3	3.9
	1.4404	1.4409	1.4404	13E0	10.0	9.8	8.9	8.0	7.3	6.8	6.4	6.2	6.0	5.8	5.7		
	1.4401	1.4408	1.4401	14E0	10.0	10.0	9.3	8.4	7.8	7.3	6.9	6.7	6.4	6.3	6.2	6.0	5.2
	1.4571	–	1.4571	15E0	10.0	10.0	9.8	9.1	8.5	8.1	7.8	7.5	7.3	7.2	7.0	6.9	5.4
16	1.4307	1.4309	1.4306	10E0	16.0	14.9	13.5	12.1	11.0	10.3	9.6	9.2	8.9	8.7	8.5		
	1.4301	1.4308	1.4301	11E0	16.0	14.9	13.5	12.1	11.0	10.3	9.6	9.2	8.9	8.7	8.5	8.2	5.3
	1.4541	–	1.4541	12E0	16.0	16.0	14.9	13.9	13.2	12.4	11.9	11.4	11.1	10.8	10.6	10.1	6.3
	–	1.4552	1.4550	12E0	16.0	16.0	14.9	13.9	13.2	12.4	11.9	11.4	11.1	10.8	10.6	10.1	6.3
	1.4404	1.4409	1.4404	13E0	16.0	15.6	14.2	12.8	11.7	10.9	10.3	9.9	9.6	9.3	9.1		
	1.4401	1.4408	1.4401	14E0	16.0	16.0	14.9	13.5	12.4	11.7	11.0	10.7	10.2	10.1	9.9	9.5	8.2
	1.4571	–	1.4571	15E0	16.0	16.0	15.6	14.6	13.7	13.0	12.4	12.0	11.7	11.4	11.2	11.1	8.7
25	1.4307	1.4309	1.4306	10E0	25.0	23.3	21.1	18.9	17.2	16.1	15.0	14.3	13.9	13.7	13.3		
	1.4301	1.4308	1.4301	11E0	25.0	23.3	21.1	18.9	17.2	16.1	15.0	14.3	13.9	13.7	13.3	12.8	8.3
	1.4541	–	1.4541	12E0	25.0	25.0	23.3	21.7	20.6	19.4	18.6	17.9	17.3	16.9	16.6	15.8	9.8
	–	1.4552	1.4550	12E0	25.0	25.0	23.3	21.7	20.6	19.4	18.6	17.9	17.3	16.9	16.6	15.8	9.8
	1.4404	1.4409	1.4404	13E0	25.0	24.4	22.2	20.0	18.3	17.0	16.1	15.4	15.0	14.6	14.2		
	1.4401	1.4408	1.4401	14E0	25.0	25.0	23.3	21.1	19.4	18.3	17.2	16.7	16.0	15.8	15.4	14.9	12.9
	1.4571	–	1.4571	15E0	25.0	25.0	24.4	22.8	21.3	20.3	19.4	18.8	18.2	17.9	17.6	17.3	13.6
40	1.4307	1.4309	1.4306	10E0	40.0	37.3	33.8	30.2	27.6	25.8	24.0	22.9	22.2	21.9	21.3		
	1.4301	1.4308	1.4301	11E0	40.0	37.3	33.8	30.2	27.6	25.8	24.0	22.9	22.2	21.9	21.3	20.4	13.3
	1.4541	–	1.4541	12E0	40.0	40.0	37.3	34.7	32.9	31.1	29.7	28.6	27.7	27.0	26.5	25.2	15.6
	–	1.4552	1.4550	12E0	40.0	40.0	37.3	34.7	32.9	31.1	29.7	28.6	27.7	27.0	26.5	25.2	15.6
	1.4404	1.4409	1.4404	13E0	40.0	39.1	35.6	32.0	29.3	27.2	25.8	24.7	24.0	23.3	22.8		
	1.4401	1.4408	1.4401	14E0	40.0	40.0	37.3	33.8	31.1	29.3	27.6	26.7	25.6	25.2	24.7	23.8	20.6
	1.4571	–	1.4571	15E0	40.0	40.0	39.1	36.4	34.1	32.5	31.1	30.0	29.2	28.6	28.1	27.7	21.7
63	1.4307	1.4309	1.4306	10E0	63.0	58.8	53.2	47.6	43.4	40.6	37.8	36.1	35.0	34.4	33.6		
	1.4301	1.4308	1.4301	11E0	63.0	58.8	53.2	47.6	43.4	40.6	37.8	36.1	35.0	34.4	33.6	32.2	21.0
	1.4541	–	1.4541	12E0	63.0	63.0	58.8	54.6	51.8	49.0	46.8	45.1	43.7	42.6	41.7	39.8	24.6
	–	1.4552	1.4550	12E0	63.0	63.0	58.8	54.6	51.8	49.0	46.8	45.1	43.7	42.6	41.7	39.8	24.6
	1.4404	1.4409	1.4404	13E0	63.0	61.6	56.0	50.4	46.2	42.8	40.6	38.9	37.8	36.7	35.8		
	1.4401	1.4408	1.4401	14E0	63.0	63.0	58.8	53.2	49.0	46.2	43.4	42.0	40.3	39.8	38.9	37.5	32.5
	1.4571	–	1.4571	15E0	63.0	63.0	61.6	57.4	53.8	51.2	49.0	47.3	45.9	45.1	44.2	43.7	34.2
100	1.4307	1.4309	1.4306	10E0	100.0	93.3	84.4	75.6	68.9	64.4	60.0	57.3	55.6	54.7	53.3		
	1.4301	1.4308	1.4301	11E0	100.0	93.3	84.4	75.6	68.9	64.4	60.0	57.3	55.6	54.7	53.3	51.1	33.3
	1.4541	–	1.4541	12E0	100.0	100.0	93.3	86.7	82.2	77.8	74.2	71.6	69.3	67.6	66.2	63.1	39.1
	–	1.4552	1.4550	12E0	100.0	100.0	93.3	86.7	82.2	77.8	74.2	71.6	69.3	67.6	66.2	63.1	39.1
	1.4404	1.4409	1.4404	13E0	100.0	97.8	88.9	80.0	73.3	68.0	64.4	61.8	60.0	58.2	56.9		
	1.4401	1.4408	1.4401	14E0	100.0	100.0	93.3	84.4	77.8	73.3	68.9	66.7	64.0	63.1	61.8	59.6	51.6
	1.4571	–	1.4571	15E0	100.0	100.0	97.8	91.1	85.3	81.3	77.8	75.1	72.9	71.6	70.2	69.3	54.2

Fig. 140 Operating data for austenitic and austenitic-ferritic steel materials
(1 % yield point) (DIN EN 1092-1 - selection)

FLOWSERVE GESTRA

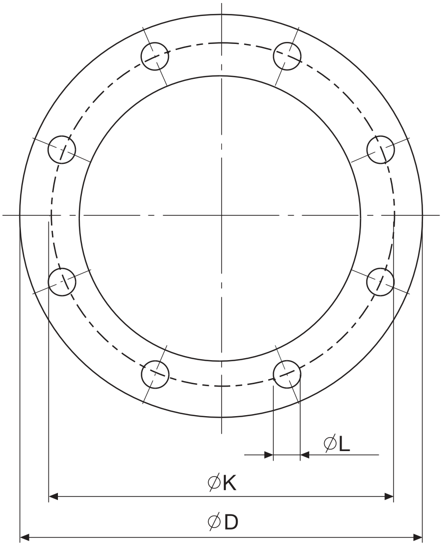
PN	Materials (old material numbers in brackets)			Admissible pressure *p* in [bar] for temperature *t* in [°C]						
				-10 to 120	150	200	230	250	300	350
6	EN-JL1030 (0.6020)	EN-JL1020 (0.6015)		6.0	5.4	5.0	4.8	4.4	3.6	
	EN-JM1110 (--)	EN-JM1130 (0.8135)		6.0	5.8	5.5		5.2	4.8	4.2
10	EN-JS1050 (0.7050)	EN-JS1060 (0.7060)		10.0	9.5	9.0		8.0	7.0	5.5
	EN-JS1010 (0.7033)	EN-JS1020 (0.7043)	EN-JS1030 (0.7040)	10.0	9.7	9.2		8.7	8.0	7.0
	EN-JL1020 (0.6015)	EN-JL1030 (0.6020)		10.0	9.0	8.4	8.0	7.4	6.0	
	EN-JM1110 (--)	EN-JM1130 (0.8135)		10.0	9.7	9.2		8.7	8.0	7.0
16	EN-JS1050 (0.7050)	EN-JS1060 (0.7060)		16.0	15.2	14.4		12.8	11.2	8.8
	EN-JS1020 (0.7043)	EN-JS1030 (0.7040)	EN-JS1010 (0.7033)	16.0	15.5	14.7		13.9	12.8	11.2
	EN-JL1020 (0.6015)	EN-JL1030 (0.6020)		16.0	14.4	13.4	12.8	11.8	9.6	
	EN-JM1110 (--)	EN-JM1130 (0.8135)		16.0	15.5	14.7		13.9	12.8	11.2
25	EN-JS1050 (0.7050)	EN-JS1060 (0.7060)		25.0	23.8	22.5		20.0	17.5	13.8
	EN-JS1020 (0.7043)	EN-JS1030 (0.7040)	EN-JS1010 (0.7033)	25.0	24.3	23.0		21.8	20.0	17.5
	EN-JL1020 (0.6015)	EN-JL1030 (0.6020)		25.0	22.5	21.0	20.0	18.5	15.0	
	EN-JM1110 (--)	EN-JM1130 (0.8135)		25.0	24.3	23.0		21.8	20.0	17.5
40	EN-JS1050 (0.7050)	EN-JS1060 (0.7060)		40.0	38.0	36.0		32.0	28.0	22.0
	EN-JS1020 (0.7043)	EN-JS1030 (0.7040)	EN-JS1010 (0.7033)	40.0	38.8	36.8		34.8	32.0	28.0
	EN-JL1020 (0.6015)	EN-JL1030 (0.6020)		40.0	36.0	33.6	32.0	29.6	24.0	
	EN-JM1110 (--)	EN-JM1130 (0.8135)		40.0	38.8	36.8		34.8	32.0	28.0
63	EN-JS1050 (0.7050)	EN-JS1060 (0.7060)		63.0	60.8	57.6		51.2	44.8	35.2
	EN-JS1020 (0.7043)	EN-JS1030 (0.7040)	EN-JS1010 (0.7033)	63.0	62.0	58.8		55.6	51.2	44.8

Fig. 141 Operating data for cast iron materials
(DIN EN 1092-2 - selection)

8.1.4 Flange connection dimensions

The dimensions for steel flanges up to PN 100 are specified in DIN EN 1092-1, and for grey cast iron flanges in DIN EN 1092-2.

For selected PN and DN ranges, the principal connection dimensions of the flanges are given in the tables below. Unless specified otherwise, the data apply for all flange types (welding neck flanges, integral flanges etc.) and all sealing surface variants (raised face, groove, tongue etc.).



L = bolt hole diameter
K = pitch circle diameter
D = outside diameter

Fig. 142 This diagram shows only the general arrangement of the bolt holes. For the exact number of bolt holes, see Figs. 143 and 144.

DN	PN 6				PN 10				PN 16				PN 25			
	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts
	D	K	L		D	K	L		D	K	L		D	K	L	
	[mm]	[mm]	[mm]		[mm]	[mm]	[mm]		[mm]	[mm]	[mm]		[mm]	[mm]	[mm]	
10	75	50	11	4	See PN 40				See PN 40				See PN 40			
15	80	55	11	4	See PN 40				See PN 40				See PN 40			
20	90	65	11	4	See PN 40				See PN 40				See PN 40			
25	100	75	11	4	See PN 40				See PN 40				See PN 40			
32	120	90	14	4	See PN 40				See PN 40				See PN 40			
40	130	100	14	4	See PN 40				See PN 40				See PN 40			
50	140	110	14	4	See PN 40				165	125	18	4	See PN 40			
65	160	130	14	4	See PN 40				185	145	18	8[a)]	See PN 40			
80	190	150	18	4	See PN 40				200	160	18	8	See PN 40			
100	210	170	18	4	See PN 40				220	180	18	8	See PN 40			
125	240	200	18	8	See PN 40				250	210	18	8	See PN 40			
150	265	225	18	8	See PN 40				285	240	22	8	See PN 40			
200	320	280	18	8	340	295	22	8	340	295	22	12	360	310	26	12
250	375	335	18	12	395	350	22	12	405	355	26	12	425	370	30	12
300	440	395	22	12	445	400	22	12	460	410	26	12	485	430	30	16
350	490	445	22	12	505	460	22	16	520	470	26	16	555	490	33	16
400	540	495	22	16	565	515	26	16	580	525	30	16	620	550	36	16
450	595	550	22	16	615	565	26	20	640	585	30	20	670	600	36	20
500	645	600	22	20	670	620	26	20	715	650	33	20	730	660	36	20
600	755	705	26	20	780	725	30	20	840	770	36	20	845	770	39	20

Fig. 143a Connection dimensions for steel flanges (DIN EN 1092-1 - selection)
a) Flanges with 4 holes may be delivered if so agreed by manufacturer and customer.

DN	PN 40				PN 63				PN 100			
	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts
	D	K	L		D	K	L		D	K	L	
	[mm]	[mm]	[mm]		[mm]	[mm]	[mm]		[mm]	[mm]	[mm]	
10	90	60	14	4	See PN 100				100	70	14	4
15	95	65	14	4	See PN 100				105	75	14	4
20	105	75	14	4	See PN 100				130	90	18	4
25	115	85	14	4	See PN 100				140	100	18	4
32	140	100	18	4	See PN 100				155	110	22	4
40	150	110	18	4	See PN 100				170	125	22	4
50	165	125	18	4	180	135	22	4	195	145	26	4
65	185	145	18	8	205	160	22	8	220	170	26	8
80	200	160	18	8	215	170	22	8	230	180	26	8
100	235	190	22	8	250	200	26	8	265	210	30	8
125	270	220	26	8	295	240	30	8	315	250	33	8
150	300	250	26	8	345	280	33	8	355	290	33	12
200	375	320	30	12	415	345	36	12	430	360	36	12
250	450	385	33	12	470	400	36	12	505	430	39	12
300	515	450	33	16	530	460	36	16	585	500	42	16
350	580	510	36	16	600	525	39	16	655	560	48	16
400	660	585	39	16	670	585	42	16	715	620	48	16
450	685	610	39	20	–	–	–	–	–	–	–	–
500	755	670	42	20	800	705	48	20	870	760	56	20
600	890	795	48	20	930	820	56	20	–	–	–	–

Fig. 143b Connection dimensions for steel flanges (contd)
(DIN EN 1092-1 - selection)

DN	PN 6				PN 10				PN 16				PN 25			
	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameterr	Bolt hole diameter	Number of bolts
	D	K	L		D	K	L		D	K	L		D	K	L	
	[mm]	[mm]	[mm]		[mm]	[mm]	[mm]		[mm]	[mm]	[mm]		[mm]	[mm]	[mm]	
10	75	50	11	4	See PN 16				s. PN 40				s. PN 40			
15	80	55	11	4	See PN 16				See PN 40				See PN 40			
20	90	65	11	4	See PN 16				See PN 40				See PN 40			
25	100	75	11	4	See PN 16				See PN 40				See PN 40			
32	120	90	14	4	See PN 16				See PN 40				See PN 40			
40	130	100	14	4	See PN 16				See PN 40				See PN 40			
50	140	110	14	4	See PN 16				See PN 40				See PN 40			
60	150	120	14	4	See PN 16				175	135	19	4	See PN 40			
65	160	130	14	4	See PN 16				185	145	19	4[a)]	See PN 40			
80	190	150	19	4	See PN 16				200	160	19	8	See PN 40			
100	210	170	19	4	See PN 16				220	180	19	8	See PN 40			
125	240	200	19	8	See PN 16				250	210	19	8	270	220	28	8
150	265	225	19	8	See PN 16				285	240	23	8	300	250	28	8
200	320	280	19	8	340	295	23	8	340	295	23	12	360	310	28	12
250	375	335	19	12	395[b)]	350	23	12	405[b)]	355	28	12	425	370	31	12
300	440	395	23	12	445[b)]	400	23	12	460[b)]	410	28	12	485	430	31	16
350	490	445	23	12	505	460	23	16	520	470	28	16	555	490	34	16
400	540	495	23	16	565	515	28	16	580	525	31	16	620	550	37	16
450	595	550	23	16	615	565	28	20	640	585	31	20	670	600	37	20
500	645	600	23	20	670	620	28	20	715	650	34	20	730	660	37	20
600	755	705	28	20	780	725	31	20	840	770	37	20	845	770	41	20

Fig. 144a Connection dimensions for cast iron flanges (DIN EN 1092-2 - selection)

a) Flanges with 8 holes may be delivered if so agreed by manufacturer and customer.

b)) For pipes and fittings of ductile cast iron, the outside diameter of DN 250/300 flanges must be as follows:
D = 400 mm for DN 250
D = 455 mm for DN 300

DN	PN 40				PN 63			
	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts
	D [mm]	K [mm]	L [mm]		D [mm]	K [mm]	L [mm]	
10	90	60	14	4	–			
15	95	65	14	4	–			
20	105	75	14	4	–			
25	115	85	14	4	–			
32	140	100	19	4	–			
40	150	110	19	4	170	125	23	4
50	165	125	19	4	180	135	23	4
60	175	135	19	8	190	145	23	8
65	185	145	19	8	205	160	23	8
80	200	160	19	8	215	170	23	8
100	235	190	23	8	250	200	28	8
125	270	220	28	8	295	240	31	8
150	300	250	28	8	345	280	34	8
200	375	320	31	12	415	345	37	12
250	450	385	34	12	470	400	37	12
300	515	450	34	16	530	460	37	16
350	580	510	37	16	600	525	41	16
400	660	585	41	16	670	585	44	16
450	685	610	41	20	–			
500	755	670	44	20	–			
600	890	795	50	20	–			

Fig. 144b Connection dimensions for cast iron flanges (contd)
(DIN EN 1092-2 - selection)

8.1.5 Flange sealing surfaces

For flange joints, a variety of sealing types are in general use, together with the corresponding forms of different sealing surfaces at the flanges. In addition, various degrees of roughness are required for the sealing surfaces. The sealing surfaces for steel flanges currently prescribed by DIN EN 1092-1 and for cast iron flanges by DIN EN 1092-2 are given below.

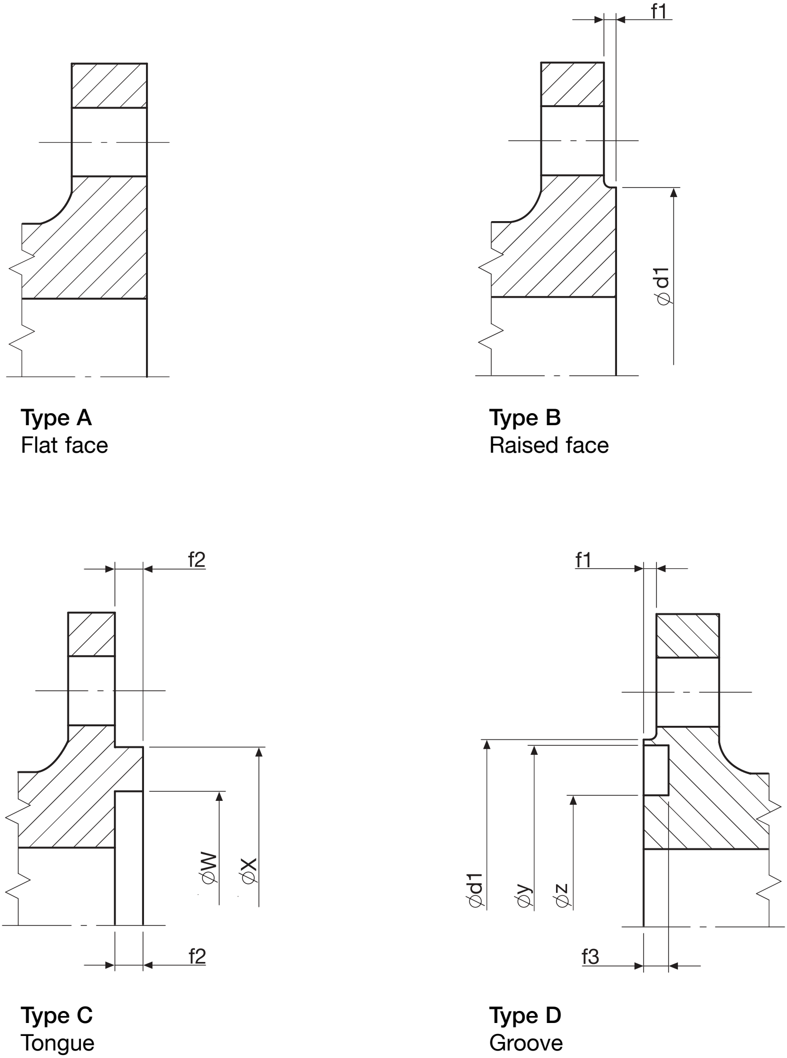
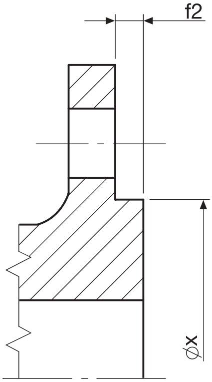
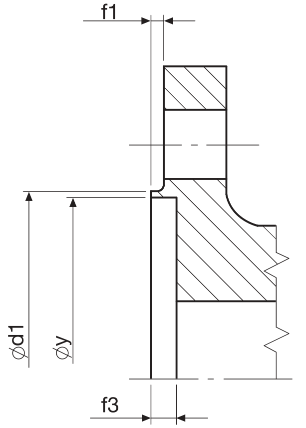


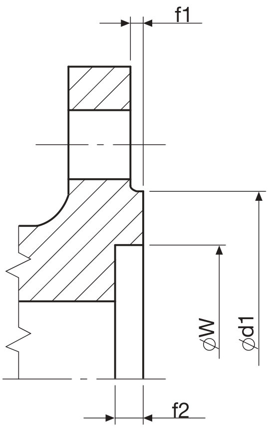
Fig. 145a Types of sealing surfaces



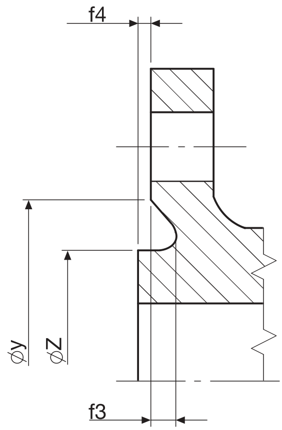
Type E
Male face



Type F
Female face



Type G
O-ring recess



Type H
O-ring groove

Fig. 145b Types of sealing surfaces

DN	d1 PN 6	d1 PN10	d1 PN16	d1 PN25	d1 PN40	d1 PN 63	d1 PN 100	w	x	y	z	f1	f2	f3	f4
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
10	35	See PN 100					40	24	34	35	23				
15	40	See PN 100					45	29	39	40	28				
20	50	See PN 100					58	36	50	51	35				
25	60	See PN 100					68	43	57	58	42				
32	70	See PN 100					78	51	65	66	50		4.5	4.0	2.0
40	80	See PN 100					88	61	75	76	60				
50	90	See PN 100					102	73	87	88	72				
65	110	See PN 100					122	95	109	110	94				
80	128	See PN 100					138	106	120	121	105				
100	148	158	158	162	162	162	162	129	149	150	128	2.0			
125	178	188	188	188	188	188	188	155	175	176	154				
150	202	212	212	218	218	218	218	183	203	204	182		5.0	4.5	2.5
200	258	268	268	278	285	285	285	239	259	260	238				
250	312	320	320	335	345	345	345	292	312	313	291				
300	365	370	378	395	410	410	410	343	363	364	342				
350	415	430	438	450	465	465	465	395	421	422	394				
400	465	482	490	505	535	535	535	447	473	474	446				
450	520	532	550	555	560	560	560	497	523	524	496		5.5	5.0	3.0
500	570	585	610	615	615	615	615	549	575	576	548				
600	670	685	725	720	735	735	–	649	675	676	648				

Fig. 146 Dimensions of sealing surfaces for steel flanges
(DIN EN 1092-1 - selection)
Sealing surfaces of type A, B, C, D, E, F, G and H

DN	d1						f1
	PN 6	PN10	PN16	PN25	PN40	PN 63	
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
10	33	41	41	41	41	–	2
15	38	46	46	46	46	–	2
20	48	56	56	56	56	–	2
25	58	65	65	65	65	–	3
32	69	76	76	76	76	–	3
40	78	84	84	84	84	84	3
50	88	99	99	99	99	99	3
60	98	108	108	108	108	108	3
65	108	118	118	118	118	118	3
80	124	132	132	132	132	132	3
100	144	156	156	156	156	156	3
125	174	184	184	184	184	184	3
150	199	211	211	211	211	211	3
200	254	266	266	274	284	284	3
250	309	316	319	330	345	345	3
300	363	370	370	389	409	409	4
350	413	429	429	448	465	465	4
400	463	480	480	503	535	535	4
450	518	530	548	548	560	–	4
500	568	582	609	609	615	–	4
600	667	682	720	720	735	–	5

Fig. 147 Dimensions of sealing surfaces for cast iron flanges
(DIN EN 1092-2 - selection)
Sealing surfaces of type A and B

8.1.5.2 Sealing surface roughness

The sealing surfaces according to the current standards DIN EN 1092-1 and DIN EN 1092-2 deviate, with regard to both designation and roughness, from the sealing surface specifications given in the DIN standards previously applicable; see the tables below.

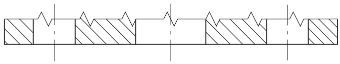
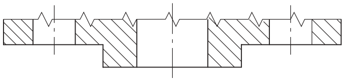
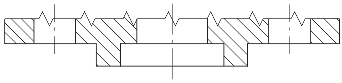
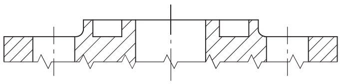
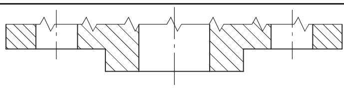
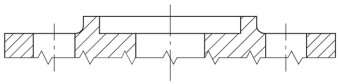
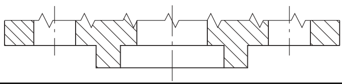
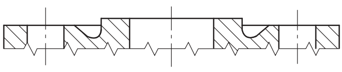
Current sealing surfaces as per DIN EN 1092-1			Former sealing surfaces as per DIN 2...	
Designation	Roughness Ra [µm]	Schematic view	Designation	Roughness Ra [µm]
Flat sealing surface (without raised face)				
Type A	12.5 - 6.3		Type B	25 - 12.5
Raised face				
Type B1 (<= PN 40)	12.5 - 6.3 *)		Type C (<= PN 40)	25 - 12.5
			Type D	6.3 - 3.2
Type B2 (PN 63 - PN 100)	3.2 - 1.6		Type E (>= PN 63)	3.2 - 1.6
Tongue. groove				
Type C	3.2 - 1.6		Type F	6.3 - 3.2
Type D	3.2 - 1.6		Type N	6.3 - 3.2
Male/female face				
Type E	12.5 - 6.3 *)		Type V13	25 -12.5
Type F	12.5 - 6.3 *)		Type R13	25 - 12.5
O-ring recess. O-ring groove				
Type G	3.2 - 1.6		Type R14	25 - 12.5
Type H	3.2 - 1.6		Type R14	25 - 12.5

Fig. 148 Roughnesses for steel flanges
*) prescribed groove

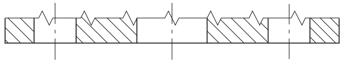
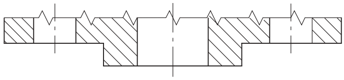
Current sealing surfaces as per DIN EN 1092-2			Former sealing surfaces as per DIN 2...	
Designation	Roughness Ra [µm]	Schematic view	Designation	Roughness Ra [µm]
Flat sealing surface (without raised face)				
Type A	12.5 - 6.3		Type B	25 - 12.5
Raised face				
Type B	12.5 - 6.3		Type C	25 - 12.5

Fig. 149 Roughnesses for cast iron flanges

8.1.6 Flange bolts and nuts

Suitable materials for bolts, threaded bolts (studs) and nuts are specified in DIN EN 1515-1 for PN flanges to the DIN EN 1092 series of standards and for Class flanges to the DIN EN 1759 series of standards. The combination of bolts/threaded bolts with the various materials of the PN steel flanges as per DIN EN 1092-1 is given in DIN EN 1515-2. However, this standard does not specify the flange materials themselves, but rather the material groups to which the flange materials are assigned.
The following table lists the materials for bolts , threaded bolts and nuts, together with their possible application in conjunction with selected material groups for PN steel flanges.

A distinction is made between three strength levels as follows (for further details, see DIN EN 1515-2):

- Low strength bolting: the bolts may only be used for low-stress applications or overdimensioned flange joints. There must be adequate experience for the intended application, or an analysis must be performed.

= Normal strength bolting: the bolts can be used for all applications in the pressure/temperature rating range, insofar as there are no other restrictions to the contrary.

+ High strength bolting: the bolts can be used for all applications in the pressure/temperature rating range. During installation, however, care must be taken to ensure that the flanges are not overstressed (e.g. by checking the tightening torque).

Apart from pressure and temperature, all other operating conditions - e.g. the medium - must be taken into account.
Bolt materials 4.6 and 6.8 may not be used for applications falling under the Pressure Equipment Directive 97/23/EC.

Fig. 150 **See opposite page**

				PN flanges: flange material groups and flange materials that can be combined (selection)													
				forged	1.0038	1.0460	1.5415	1.7335	1.7383	1.4922	1.4307	1.4301	1.4541	–	1.4404	1.4401	1.4571
				cast	-	1.0619	1.5419	1.7357	1.7379	1.4931	1.4309	1.4308	–	1.4552	1.4409	1.4408	–
				hot-rolled	1.0038	1.0425	1.5415	1.7335	–	–	1.4306	1.4301	1.4541	1.4550	1.4404	1.4401	1.4571
PN	Class	Temperature range	Bolts/ threaded bolts	Nuts													
up to	up to	°C	Mat. No./ strength class	Mat. No./ strength class	1E1	3E0	4E0	5E0	6E0	9E0	10E0	11E0	12E0	12E0	13E0	14E0	15E0
40	300	-10 - 120	4.6	5	-	-	-	-	-	-	-	-	-	-	=	-	-
40	300	-10 - 300	5.6	5	=	=	-	-	-	-	+	=	=	=	=	=	=
63	-	-10 - 120	5.6	5	=	=	-	-	-	-	=	=	=	=	=	=	=
40	300	-10 - 300	6.8	6	=	=	=	=	=	=	=	=	=	=	=	=	=
63	-	-10 - 120	6.8	6	=	=	=	=	=	=	=	=	=	=	=	=	=
40	300	-10 - 300	8.8	8	+	+	=	=	=	=	+	+	+	+	+	+	+
63	-	-10 - 120	8.8	8	+	+	=	=	=	=	+	+	+	+	+	+	+
100	2500	-10 - 450	1.7218	1.1181	=	=	=	=	=	=	=	=	=	=	=	=	=
100	2500	-10 - 450	1.7225	1.1191	+	+	=	=	=	=	+	+	+	+	+	+	+
100	2500	-60 - 400	1.7218	A2-50	=	=	=	=	=	=	=	=	=	=	=	=	=
100	2500	-60 - 400	1.7218	A2-70	=	=	=	=	=	=	=	=	=	=	=	=	=
100	2500	-100 - 450	1.7225	1.7225	+	+	=	=	=	=	+	+	+	+	+	+	+
100	2500	-40 - 300	1.6580	1.7225	+	+	+	+	+	+	+	+	+	+	+	+	+
100	2500	-10 - 500	1.7233	1.7225	+	+	+	=	=	=	+	+	+	+	+	+	+
100	2500	-10 - 500	1.7711	1.7225	+	+	+	=	=	=	+	+	+	+	+	+	+
100	2500	-10 - 540	1.7709	1.7709	=	=	=	=	=	=	+	+	+	+	+	+	+
100	2500	-10 - 600	1.7729	1.7729	+	+	+	=	=	=	+	+	+	+	+	+	+
100	2500	-200 - 550	1.4980	1.4980	+	=	=	=	=	=	+	+	+	+	+	+	+
100	2500	-10 - 550	1.4986	1.4986	=	=	=	=	=	=	=	=	=	=	=	=	=
40	300	-200 - 400	A4-50	A4-50	-	-	-	-	-	-	-	-	-	-	-	-	-
100	600	-200 - 400	A4-70	A4-70	=	=	=	=	=	=	=	=	=	=	=	=	=
40	300	-200 - 400	A2-50	A2-50	-	-	-	-	-	-	-	-	-	-	-	-	-
100	600	-200 - 400	A2-70	A2-70	=	=	=	=	=	=	=	=	=	=	=	=	=
40	300	-200 - 550	1.4401	1.4401	-	-	-	-	-	-	-	-	-	-	-	-	-
100	600	-200 - 200	1.4401 (AT+C)	1.4401	=	=	=	=	=	-	=	=	=	=	=	=	=
40	300	-200 - 550	1.4301	1.4301	-	-	-	-	-	-	-	-	-	-	-	-	-
100	600	-200 - 200	1.4301 (AT+C)	1.4301	=	=	=	=	=	-	=	=	=	=	=	=	=

8.2 ASME Flanges, Pipes

8.2.1 Steel pipes

ASME B36.10M specifies the diameters and masses per unit length for seamless and welded steel pipes. The following table presents a selection of steel pipes, namely for schedules 40-160 and the identifications that are also in common use: STD (Standard), XS (Extra Strong) and XXS (Double Extra Strong).

NPS	Outside dia-meter	Identification STD			Identification XS			Identification XXS			Schedule 40			Schedule 60		
		Wall thickness		Mass	Wall thickness		Mass	Wall thickness		Mass	Wall thickness		Mass	Wall thickness		Mass
	[mm]	[in]	[mm]	[kg/m]	[in]	[mm]	[kg/m]	[in]	[mm]	[kg/m]	[in]	[mm]	[kg/m]	[in]	[mm]	[kg/m]
1/8	10.3	0.068	1.7	0.37	0.095	2.4	0.47		–		0.068	1.7	0.37		–	
1/4	13.7	0.088	2.2	0.63	0.119	3.0	0.80		–		0.088	2.2	0.63		–	
3/8	17.1	0.091	2.3	0.84	0.126	3.2	1.10		–		0.091	2.3	0.84		–	
1/2	21.3	0.109	2.7	1.27	0.147	3.7	1.62	0.294	7.4	2.55	0.109	2.7	1.27		–	
3/4	26.7	0.113	2.8	1.69	0.154	3.9	2.20	0.308	7.8	3.64	0.113	2.8	1.69		–	
1	33.4	0.133	3.3	2.50	0.179	4.5	3.24	0.358	9.0	5.45	0.133	3.3	2.50		–	
1 1/4	42.2	0.140	3.5	3.39	0.191	4.8	4.47	0.382	9.7	7.77	0.140	3.5	3.39		–	
1 1/2	48.3	0.145	3.6	4.05	0.200	5.0	5.41	0.400	10.1	9.55	0.145	3.6	4.05		–	
2	60.3	0.154	3.9	5.44	0.218	5.5	7.48	0.436	11.0	13.44	0.154	3.9	5.44		–	
2 1/2	73.0	0.203	5.1	8.63	0.276	7.0	11.41	0.552	14.0	20.39	0.203	5.1	8.63		–	
3	88.9	0.216	5.4	11.29	0.300	7.6	15.27	0.600	15.2	27.68	0.216	5.4	11.29		–	
3 1/2	101.6	0.226	5.7	13.57	0.318	8.0	18.64		–		0.226	5.7	13.57		–	
4	114.3	0.237	6.0	16.08	0.337	8.5	22.32	0.674	17.1	41.03	0.237	6.0	16.08		–	
5	141.3	0.258	6.5	21.77	0.375	9.5	30.97	0.750	19.0	57.43	0.258	6.5	21.77		–	
6	168.3	0.280	7.1	28.26	0.432	10.9	42.56	0.864	21.9	79.22	0.280	7.1	28.26		–	
8	219.1	0.322	8.1	42.55	0.500	12.7	64.64	0.875	22.2	107.93	0.322	8.1	42.55	0.406	10.3	53.09
10	273.0	0.365	9.2	60.29	0.500	12.7	81.53	1.000	25.4	155.1	0.365	9.2	60.29	0.500	12.7	81.53
12	323.8	0.375	9.5	73.86	0.500	12.7	97.44	1.000	25.4	186.92	0.406	10.3	79.71	0.562	14.2	108.93
14	355.6	0.375	9.5	81.33	0.500	12.7	107.40		–		0.438	11.1	94.55	0.594	15.0	126.72
16	406.4	0.375	9.5	93.27	0.500	12.7	123.31		–		0.500	12.7	123.31	0.656	16.6	160.13
18	457	0.375	9.5	105.17	0.500	12.7	139.16		–		0.562	14.27	155.81	0.750	19.0	205.75
20	508	0.375	9.5	117.15	0.500	12.7	155.13		–		0.594	15.0	183.43	0.812	20.6	247.84
22	559	0.375	9.5	129.14	0.500	12.7	171.10		–			–		0.875	22.2	294.27
24	610	0.375	9.5	141.12	0.500	12.7	187.07		–		0.688	17.4	255.43	0.969	24.6	355.28

Fig. 151a Dimensions and mass per unit length
(ASME B36.10M - selection)

NPS	Outside dia-meter	Schedule 80			Schedule 100			Schedule 120			Schedule 140			Schedule 160		
		Wall thickness		Mass	Wall thickness		Mass	Wall thickness		Mass	Wall thickness		Mass	Wall thickness		Mass
	[mm]	[in]	[mm]	[kg/m]	[in]	[mm]	[kg/m]	[in]	[mm]	[kg/m]	[in]	[mm]	[kg/m]	[in]	[mm]	[kg/m]
1/8	10.3	0.095	2.4	0.47	–			–			–			–		
1/4	13.7	0.119	3.0	0.80	–			–			–			–		
3/8	17.1	0.126	3.2	1.10	–			–			–			–		
1/2	21.3	0.147	3.7	1.62	–			–			–			0.188	4.7	1.95
3/4	26.7	0.154	3.9	2.20	–			–			–			0.219	5.5	2.90
1	33.4	0.179	4.5	3.24	–			–			–			0.250	6.3	4.24
1 1/4	42.2	0.191	4.8	4.47	–			–			–			0.250	6.3	5.61
1 1/2	48.3	0.200	5.0	5.41	–			–			–			0.281	7.1	7.25
2	60.3	0.218	5.5	7.48	–			–			–			0.344	8.7	11.11
2 1/2	73.0	0.276	7.0	11.41	–			–			–			0.375	9.5	14.92
3	88.9	0.300	7.6	15.27	–			–			–			0.438	11.1	21.35
3 1/2	101.6	0.318	8.0	18.64	–			–			–			–		
4	114.3	0.337	8.5	22.32	–			0.438	11.1	28.32	–			0.531	13.4	33.54
5	141.3	0.375	9.5	30.97	–			0.500	12.7	40.28	–			0.625	15.8	49.12
6	168.3	0.432	10.9	42.56	–			0.562	14.2	54.21	–			0.719	18.2	67.57
8	219.1	0.500	12.7	64.64	0.594	15.0	75.92	0.719	18.2	90.44	0.812	20.6	100.93	0.906	23.0	111.27
10	273.0	0.594	15.0	95.98	0.719	18.2	114.71	0.844	21.4	133.01	1.000	25.4	155.10	1.125	28.5	172.27
12	323.8	0.688	17.4	132.05	0.844	21.4	159.87	1.000	25.4	186.92	1.125	28.5	208.08	1.312	33.3	238.69
14	355.6	0.750	19.0	158.11	0.938	23.8	194.98	1.094	27.7	224.66	1.250	31.7	253.58	1.406	35.7	281.72
16	406.4	0.844	21.4	203.54	1.031	26.1	245.57	1.219	30.9	286.66	1.438	36.5	333.21	1.594	40.4	365.38
18	457	0.938	23.8	254.57	1.156	29.3	309.64	1.375	34.9	363.58	1.562	39.6	408.28	1.781	45.2	459.39
20	508	1.031	26.1	311.19	1.281	32.5	381.55	1.500	38.1	441.52	1.750	44.4	508.15	1.969	50.1	564.85
22	559	1.125	28.5	373.85	1.375	34.9	451.45	1.625	41.2	527.05	1.875	47.6	600.67	2.125	53.9	672.30
24	610	1.219	30.9	442.11	1.531	38.8	547.74	1.812	46.0	640.07	2.062	52.37	720.19	2.344	59.5	808.27

Fig. 151b Dimensions and mass per unit length (contd)
(ASME B36.10M - selection)

8.2.2 Flange types

The various types of steel flanges are standardized in ASME B16.5 for NPS ½ - NPS 24. ASME B16.47 applies for NPS 26 - NPS 60. See ASME B16.1 for grey cast iron flanges.

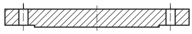
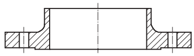
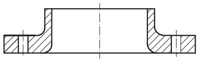
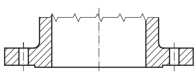
Designation	Schematic view	Class	NPS 1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	5	6	8	10	12	14	16	18	20	24
Blind		150	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		300	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		400	See Class 600									X	X	X	X	X	X	X	X	X	X	X
		600	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		900	See Class 1500							X	–	X	X	X	X	X	X	X	X	X	X	X
		1500	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X
		2500	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	–	–	–	–	–
Welding neck		150	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		300	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		400	See Class 600									X	X	X	X	X	X	X	X	X	X	X
		600	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		900	See Class 1500							X	–	X	X	X	X	X	X	X	X	X	X	X
		1500	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X
		2500	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	–	–	–	–	–
Slip-on welding		150	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		300	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		400	See Class 600									X	X	X	X	X	X	X	X	X	X	X
		600	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		900	See Class 1500							X	–	X	X	X	X	X	X	X	X	X	X	X
		1500	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X
		2500	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Socket welding		150	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		300	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		400	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		600	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		900	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		1500	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X
		2500	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lapped		150	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		300	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		400	See Class 600									X	X	X	X	X	X	X	X	X	X	X
		600	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		900	See Class 1500							X	–	X	X	X	X	X	X	X	X	X	X	X
		1500	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X
		2500	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	–	–	–	–	–
Threaded		150	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		300	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		400	See Class 600									X	X	X	X	X	X	X	X	X	X	X
		600	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		900	See Class 1500							X	–	X	X	X	X	X	X	X	X	X	X	X
		1500	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X
		2500	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	–	–	–	–	–
Flanged fitting		150	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		300	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		400	See Class 600									X	X	X	X	X	X	X	X	X	X	X
		600	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		900	See Class 1500							X	–	X	X	X	X	X	X	X	X	X	X	X
		1500	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X
		2500	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	–	–	–	–	–

Fig. 152a Steel flanges, overview of types
(ASME B16.5 - selection)

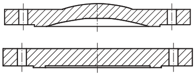
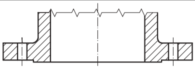
Designation	Schematic view	Class	NPS																					
			1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	5	6	8	10	12	14	16	18	20	24
Blind		25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		125	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		250	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Threaded		25	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X
		125	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		250	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Flanged fitting		25	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X
		125	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		250	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Fig. 152b Grey cast iron flanges, overview of types
(ASME B16.5 - selection))

8.2.3 Flange materials and pressure/temperature rating

Steel materials for flanges and their admissible working pressure and temperatures (p/T Rating) are specified in ASME B16.5, whilst ASME B16.1 contains the corresponding data for grey cast iron flanges.
Some of the operating data given in the tables below are subject to certain conditions; see the relevant standards.

Class	Materials		Material	Admissible pressure *p* in [bar] for temperature *t* in [°C]					Admissible pressure *p* in [bar] for temperature *t* in [°C]											
	forged	cast	group	20	100	200	250	300	350	400	425	450	475	500	510	520	530	540	550	600
150	A105	A216 Gr. WCB	1.1	19.7	17.7	14.0	12.1	10.2	8.4	6.5	5.6	4.6	3.7	2.8	2.4	2.0	1.7			
	A182 Gr. F1	A217 Gr. WC1	1.5	18.3	17.7	14.0	12.1	10.2	8.4	6.5	5.6	4.6	3.7	2.8	2.4	2.0	1.7			
	A182 Gr. F12 Cl.2	A217 Gr. WC6	1.9	20	17.7	14.0	12.1	10.2	8.4	6.5	5.6	4.6	3.7	2.8	2.4	2.0	1.7	1.4	1.4	1.4
	A182 Gr. F22 Cl.3	A217 Gr. WC9	1.10	20	17.7	14.0	12.1	10.2	8.4	6.5	5.6	4.6	3.7	2.8	2.4	2.0	1.7	1.4	1.4	1.4
300	A105	A216 Gr. WCB	1.1	51.0	46.4	43.9	41.8	38.9	36.9	34.6	28.7	20.2	13.5	8.9	7.2	5.9	4.5			
	A182 Gr. F1	A217 Gr. WC1	1.5	47.9	46.7	44.2	43.0	42.0	40.3	36.5	35.2	33.7	31.7	23.5	19.3	16.5	13.6			
	A182 Gr. F12 Cl.2	A217 Gr. WC6	1.9	51.7	51.5	48.1	46.2	42.9	40.3	36.5	35.2	33.7	31.7	25.3	22.1	19.5	16.9	14.4	12.7	6.0
	A182 Gr. F22 Cl.3	A217 Gr. WC9	1.10	51.7	51.5	48.7	46.3	42.9	40.3	36.5	35.2	33.7	31.7	27.7	25.9	23.0	20.1	17.5	15.3	6.9
400	A105	A216 Gr. WCB	1.1	68.3	61.8	58.4	55.7	51.7	49.2	45.9	38.4	26.6	18.1	11.9	9.7	7.9	6.2			
	A182 Gr. F1	A217 Gr. WC1	1.5	63.8	62.1	59.0	57.5	56.0	53.6	48.9	46.6	45.1	42.3	31.4	25.9	22.0	18.2			
	A182 Gr. F12 Cl.2	A217 Gr. WC6	1.9	68.9	68.7	64.0	61.5	57.0	53.6	48.9	46.7	45.1	42.3	33.6	29.3	26.0	22.6	19.4	17.0	8.1
	A182 Gr. F22 Cl.3	A217 Gr. WC9	1.10	68.9	68.7	65.0	61.7	57.0	53.6	48.9	46.7	45.1	42.3	37.2	34.8	30.8	26.9	23.2	20.4	9.1
	A182 Gr. F91	A217 Gr. C12A	1.15	68.9	68.7	65.0	61.7	57.0	53.6	48.9	46.7	45.1	42.3	37.6	35.5	34.8	34.0	33.4	33.3	25.8
600	A105	A216 Gr. WCB	1.1	102.0	92.8	87.8	83.6	77.5	74.0	69.1	57.6	40.1	27.2	17.6	14.1	11.7	9.2			
	A182 Gr. F1	A217 Gr. WC1	1.5	95.8	93.3	88.4	86.3	84.1	80.4	73.3	70.2	67.7	63.4	47.0	38.6	32.9	27.2			
	A182 Gr. F12 Cl.2	A217 Gr. WC6	1.9	103.4	103.0	95.8	92.4	85.7	80.4	73.3	70.2	67.7	63.4	50.6	44.1	38.9	33.7	28.9	25.4	12.0
	A182 Gr. F22 Cl.3	A217 Gr. WC9	1.10	103.4	103.0	97.5	92.7	85.7	80.4	73.3	70.2	67.7	63.4	55.7	52.1	46.2	40.4	34.9	30.7	13.8
	A182 Gr. F91	A217 Gr. C12A	1.15	103.4	103.0	97.5	92.7	85.7	80.4	73.3	70.2	67.7	63.4	56.5	53.4	52.2	51.0	50.0	49.8	39.1
900	A105	A216 Gr. WCB	1.1	153.1	139.2	131.4	125.1	116.1	110.8	103.4	86.3	60.2	40.7	26.5	21.4	17.5	13.7			
	A182 Gr. F1	A217 Gr. WC1	1.5	143.8	139.6	132.6	129.3	126.1	120.7	109.8	105.4	101.4	95.1	70.8	58.3	49.6	40.9			
	A182 Gr. F12 Cl.2	A217 Gr. WC6	1.9	155.1	154.4	143.9	138.6	128.6	120.7	109.8	105.4	101.4	95.1	75.6	65.8	58.3	50.7	43.6	38.1	18.3
	A182 Gr. F22 Cl.3	A217 Gr. WC9	1.10	155.1	154.6	146.2	139.0	128.6	120.7	109.8	105.4	101.4	95.1	83.4	77.9	69.2	60.5	52.4	46.0	20.7
	A182 Gr. F91	A217 Gr. C12A	1.15	155.1	154.6	146.2	139.0	128.6	120.7	109.8	105.4	101.4	95.1	84.7	80.0	78.2	76.5	75.1	74.8	58.5
1500	A105	A216 Gr. WCB	1.1	255.5	231.9	219.2	208.7	193.6	184.8	172.5	143.9	103.9	67.9	44.1	35.5	29.2	22.8			
	A182 Gr. F1	A217 Gr. WC1	1.5	239.2	233.0	221.0	215.3	210.1	201.1	183.1	175.6	169.0	158.2	117.7	96.9	82.5	68.1			
	A182 Gr. F12 Cl.2	A217 Gr. WC6	1.9	258.6	257.4	239.7	231.0	214.4	201.1	183.1	175.6	169.0	158.2	126.1	110.0	97.2	84.4	72.5	63.5	30.3
	A182 Gr. F22 Cl.3	A217 Gr. WC9	1.10	258.6	257.6	244.0	231.8	214.4	201.1	183.1	175.6	169.0	158.2	138.9	130.0	115.6	101.2	87.6	76.9	34.5
	A182 Gr. F91	A217 Gr. C12A	1.15	258.6	257.6	244.0	231.8	214.4	201.1	183.1	175.6	169.0	158.2	140.9	133.1	130.3	127.6	125.4	124.9	97.6
2500	A105	A216 Gr. WCB	1.1	425.4	386.5	365.1	347.6	322.7	308.0	287.5	239.7	167.0	112.9	73.4	59.3	48.6	37.9			
	A182 Gr. F1	A217 Gr. WC1	1.5	398.9	388.4	368.1	359.0	350.2	335.3	304.9	292.5	281.8	263.9	196.4	161.7	137.5	113.3			
	A182 Gr. F12 Cl.2	A217 Gr. WC6	1.9	430.9	429.0	399.5	384.9	357.1	335.3	304.9	292.5	281.8	263.9	210.1	183.1	161.8	140.6	120.8	105.9	50.4
	A182 Gr. F22 Cl.3	A217 Gr. WC9	1.10	430.9	429.4	406.5	386.2	357.1	335.3	304.9	292.5	281.8	263.9	231.7	216.8	192.6	168.4	145.7	127.9	57.4
	A182 Gr. F91	A217 Gr. C12A	1.15	430.9	429.4	406.5	386.2	357.1	335.3	304.9	292.5	281.8	263.9	235.0	222.0	217.3	212.6	208.7	208.0	162.5

Fig. 153 Operating data for ferritic steel materials
(ASME B16.5 - selection)

FLOWSERVE GESTRA

Class	Materials forged	Materials cast	Material group	Admissible pressure *p* in [bar] for temperature *t* in [°C]: 20	100	200	250	300	350	400	425	450	475	500	510	520	530	540	550	600
150	A 182 Gr. F304 / F304H	A 351 Gr. CF3 / CF8	2.1	19.0	15.7	13.2	12.0	10.2	8.4	6.5	5.6	4.6	3.7	2.8	2.4	2.0	1.7			
	A 182 Gr. F316 / F316H	A 351 Gr. CF3M / CF8M	2.2	19.0	16.0	13.6	12.0	10.2	8.4	6.5	5.6	4.6	3.7	2.8	2.4	2.0	1.7			
	A 182 Gr. F304L / F316L	–	2.3	15.9	13.3	11.1	10.2	9.7	8.4	6.5	5.6	4.6								
	A 182 Gr. F321 / F321H	–	2.4	19.0	16.8	14.0	12.1	10.2	8.4	6.5	5.6	4.6	3.7	2.8	2.4	2.0	1.7			
	A 182 Gr. F347/347H/348/348H	A 351 Gr. CF8C	2.5	19.0	17.4	14.0	12.1	10.2	8.4	6.5	5.6	4.6	3.7	2.8	2.4	2.0	1.7			
300	A 182 Gr. F304 / F304H	A 351 Gr. CF3 / CF8	2.1	49.6	40.9	34.4	32.4	30.6	29.6	28.6	28.0	27.3	27.0	26.4	26.2	24.7	23.2	22.0	21.8	16.7
	A 182 Gr. F316 / F316H	A 351 Gr. CF3M / CF8M	2.2	49.6	42.3	35.8	33.5	31.6	30.4	29.3	29.0	29.0	28.7	27.3	26.5	25.7	24.8	24.1	24.0	19.9
	A 182 Gr. F304L / F316L	–	2.3	41.4	34.4	28.8	26.6	25.2	24.0	23.1	22.8	22.2								
	A 182 Gr. F321 / F321H	–	2.4	49.6	44.1	38.2	35.9	34.0	32.8	31.7	31.1	30.7	30.4	27.9	26.5	25.8	25.1	24.3	23.3	18.0
	A 182 Gr. F347/347H/348/348H	A 351 Gr. CF8C	2.5	49.6	45.1	39.9	37.7	36.0	34.7	33.8	33.5	33.4	31.7	28.2	26.5	26.0	25.6	25.1	25.0	21.6
400	A 182 Gr. F304 / F304H	A 351 Gr. CF3 / CF8	2.1	66.2	54.5	45.8	43.2	40.8	39.5	38.2	37.3	36.7	36.0	35.4	35.2	33.2	31.2	29.5	29.0	22.5
	A 182 Gr. F316 / F316H	A 351 Gr. CF3M / CF8M	2.2	66.2	56.2	47.6	44.4	42.0	40.5	39.3	39.0	38.4	38.3	36.5	35.5	34.3	33.0	32.0	31.9	26.4
	A 182 Gr. F304L / F316L	–	2.3	55.2	46.0	38.2	35.7	33.7	32.2	31.0	30.4	29.8								
	A 182 Gr. F321 / F321H	–	2.4	66.2	58.8	51.0	47.8	45.5	43.5	42.0	41.4	41.1	40.8	37.4	35.5	34.5	33.5	32.4	30.9	24.1
	A 182 Gr. F347/347H/348/348H	A 351 Gr. CF8C	2.5	66.2	60.2	53.0	50.2	47.9	46.0	45.1	44.8	44.5	42.2	37.6	35.5	34.8	34.0	33.4	33.3	28.6
600	A 182 Gr. F304 / F304H	A 351 Gr. CF3 / CF8	2.1	99.3	81.7	69.1	64.9	61.4	59.1	57.2	55.6	54.6	54.0	53.1	52.7	49.6	46.5	44.0	43.4	33.6
	A 182 Gr. F316 / F316H	A 351 Gr. CF3M / CF8M	2.2	99.3	84.5	71.2	66.7	63.1	61.0	58.9	58.3	57.7	57.3	54.8	53.4	51.6	49.7	48.2	47.8	39.8
	A 182 Gr. F304L / F316L	–	2.3	82.7	69.1	57.4	53.5	50.5	48.0	46.2	45.5	44.6								
	A 182 Gr. F321 / F321H	–	2.4	99.3	88.1	76.7	71.9	68.3	65.4	63.0	62.1	61.8	61.2	56.2	53.4	51.9	50.5	48.8	46.6	36.4
	A 182 Gr. F347/347H/348/348H	A 351 Gr. CF8C	2.5	99.3	90.3	79.4	75.3	71.7	69.3	67.9	67.3	66.9	63.3	56.5	53.4	52.2	51.0	50.0	49.8	42.9
900	A 182 Gr. F304 / F304H	A 351 Gr. CF3 / CF8	2.1	148.9	122.6	103.4	97.4	62.0	88.7	85.7	83.6	82.3	80.8	79.4	78.9	74.5	70.0	66.3	65.3	50.2
	A 182 Gr. F316 / F316H	A 351 Gr. CF3M / CF8M	2.2	148.9	126.8	107.0	100.2	95.0	91.3	88.2	87.3	86.6	86.0	82.1	80.0	77.2	74.5	72.3	71.8	59.7
	A 182 Gr. F304L / F316L	–	2.3	124.1	103.5	86.2	80.1	75.7	72.1	69.6	68.0	66.8								
	A 182 Gr. F321 / F321H	–	2.4	148.9	132.2	114.8	107.9	102.3	98.3	94.7	93.5	92.6	91.6	84.1	80.0	77.7	75.5	73.1	69.8	54.5
	A 182 Gr. F347/347H/348/348H	A 351 Gr. CF8C	2.5	148.9	135.4	119.3	112.9	107.7	103.7	101.7	100.7	100.4	95.0	84.7	80.0	78.2	76.5	75.1	74.8	64.2
1500	A 182 Gr. F304 / F304H	A 351 Gr. CF3 / CF8	2.1	248.2	204.4	172.5	162.6	153.4	147.8	142.9	139.2	136.9	134.7	132.6	131.7	124.1	116.5	110.3	108.8	83.8
	A 182 Gr. F316 / F316H	A 351 Gr. CF3M / CF8M	2.2	248.2	210.9	178.4	167.0	158.1	152.2	147.1	145.6	144.3	143.3	136.7	133.1	128.6	124.1	120.5	119.7	99.5
	A 182 Gr. F304L / F316L	–	2.3	206.8	172.3	143.5	133.6	126.2	120.1	115.7	113.6	111.4								
	A 182 Gr. F321 / F321H	–	2.4	248.2	220.6	191.5	179.6	170.5	163.8	157.8	155.6	154.0	152.7	140.0	133.1	129.5	125.9	121.9	116.4	90.9
	A 182 Gr. F347/347H/348/348H	A 351 Gr. CF8C	2.5	248.2	225.6	199.0	188.3	179.7	172.9	169.5	168.0	167.3	158.0	140.9	133.1	130.3	127.6	125.4	124.9	107.0
2500	A 182 Gr. F304 / F304H	A 351 Gr. CF3 / CF8	2.1	413.7	340.6	287.4	270.7	255.6	246.2	238.3	232.1	228.2	224.5	220.7	219.3	206.7	194.2	183.9	181.2	139.8
	A 182 Gr. F316 / F316H	A 351 Gr. CF3M / CF8M	2.2	413.7	351.6	297.2	278.1	263.5	253.8	245.3	242.9	240.4	238.9	228.0	222.0	214.4	206.9	200.7	199.5	166.0
	A 182 Gr. F304L / F316L	–	2.3	344.7	287.3	239.1	222.5	210.3	200.3	192.9	189.2	185.4								
	A 182 Gr. F321 / F321H	–	2.4	413.7	367.5	319.1	299.3	284.3	272.8	263.2	259.5	256.9	254.4	233.4	222.0	215.8	209.6	202.8	193.7	151.3
	A 182 Gr. F347/347H/348/348H	A 351 Gr. CF8C	2.5	413.7	376.1	331.4	313.7	299.3	288.3	282.6	280.1	278.8	263.5	235.0	222.0	217.3	212.6	208.7	208.0	178.5

Fig. 154 Operating data for austenitic and austenitic-ferritic steel materials
(ASME B16.5 - selection)

FLOWSERVE GESTRA

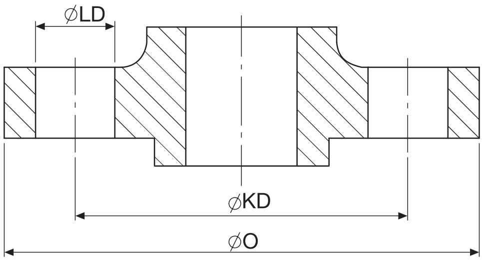
Class	Material	Admissible pressure *p* in [bar] for temperature *t* in [°C]									
		20	**65**	**75**	**100**	**120**	**135**	**150**	**175**	**200**	**230**
25	A 126 Cl.A	3.1	3.1	3.0	2.6	2.1	1.7				
125	A 126 Cl.A	12.0	12.0	11.8	11.0	10.3	10.0	9.6	8.7		
	A 126 Cl.B	13.8	13.8	13.5	12.7	12.1	11.7	11.3	10.4	9.8	8.6
250	A 126 Cl.A	27.5	27.5	26.8	25.0	23.5	22.4	21.3	19.5	17.7	
	A 126 Cl.B	34.4	34.4	33.5	31.0	28.7	27.0	25.7	23.4	20.7	17.4

Fig. 155 Operating data for grey cast iron materials
(ASME B16.1 - selection for NPS 1-12")

8.2.4 Flange connection dimensions

The dimensions for steel flanges up to Class 2500 are specified in ASME B16.5, and for grey cast iron flanges to Class 250 in ASME B16.1.

For selected Class and NPS ranges, the principal connection dimensions of the flanges are given in the tables below. Unless specified otherwise, the data apply for all flange types (welding neck flanges, flanged fittings etc.) and all sealing surface variants (raised face, groove, tongue etc.).



LD = bolt hole diameter
KD = pitch circle diameter
O = outside diameter

Fig. 156

NPS	Class 150				Class 300				Class 400				Class 600			
	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts
	O	KD	LD		O	KD	LD		O	KD	LD		O	KD	LD	
	[mm]	[mm]	[mm]		[mm]	[mm]	[mm]		[mm]	[mm]	[mm]		[mm]	[mm]	[mm]	
1/2	90	60.3	15.7	4	95	66.7	15.7	4	See Class 600				95	66.7	15.7	4
3/4	100	69.9	15.7	4	115	82.6	19.0	4	See Class 600				115	82.6	19.0	4
1	110	79.4	15.7	4	125	88.9	19.0	4	See Class 600				125	88.9	19.0	4
1 1/4	115	88.9	15.7	4	135	98.4	19.0	4	See Class 600				135	98.4	19.0	4
1 1/2	125	98.4	15.7	4	155	114.3	22.3	4	See Class 600				155	114.3	22.3	4
2	150	120.7	19.0	4	165	127.0	19.0	8	See Class 600				165	127.0	19.0	8
2 1/2	180	139.7	19.0	4	190	149.2	22.3	8	See Class 600				190	149.2	22.3	8
3	190	152.4	19.0	4	210	168.3	22.3	8	See Class 600				210	168.3	22.3	8
3 1/2	215	177.8	19.0	8	230	184.2	22.3	8	See Class 600				230	184.2	25.4	8
4	230	190.5	19.0	8	255	200.0	22.3	8	255	200.0	25.4	8	275	215.9	25.4	8
5	255	215.9	22.3	8	280	235.0	22.3	8	280	235.0	25.4	8	330	266.7	28.4	8
6	280	241.3	22.3	8	320	269.9	22.3	12	320	269.9	25.4	12	355	292.1	28.4	12
8	345	298.5	22.3	8	380	330.2	25.4	12	380	330.0	28.4	12	420	349.2	31.7	12
10	405	362.0	25.4	12	445	387.4	28.4	16	445	387.4	31.7	16	510	431.8	35.0	16
12	485	431.8	25.4	12	520	450.8	31.7	16	520	450.8	35.0	16	560	489.0	35.0	20
14	535	476.3	28.4	12	585	514.4	31.7	20	585	514.4	35.0	20	605	527.0	38.1	20
16	595	539.8	28.4	16	650	571.5	35.0	20	650	571.5	38.1	20	685	603.2	41.1	20
18	635	577.9	31.7	16	710	628.6	35.0	24	710	628.6	38.1	24	745	654.0	44.4	20
20	700	635.0	31.7	20	775	685.8	35.0	24	775	685.8	41.1	24	815	723.9	44.4	24
24	815	749.3	35.0	20	915	812.8	41.1	24	915	812.8	47.7	24	940	838.2	50.8	24

Fig. 157a Connection dimensions for steel flanges (millimetres)
(ASME B16.5 - selection)

NPS	Class 900				Class 1500				Class 2500			
	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts
	O	KD	LD		O	KD	LD		O	KD	LD	
	[mm]	[mm]	[mm]		[mm]	[mm]	[mm]		[mm]	[mm]	[mm]	
1/2	See Class 1500				120	82.6	22.3	4	135	88.9	22.3	4
3/4	See Class 1500				130	88.9	22.3	4	140	95.2	22.3	4
1	See Class 1500				150	101.6	25.4	4	160	108.0	25.4	4
1 1/4	See Class 1500				160	111.1	25.4	4	185	130.2	28.4	4
1 1/2	See Class 1500				180	123.8	28.4	4	205	146.0	31.7	4
2	See Class 1500				215	165.1	25.4	8	235	171.4	28.4	8
2 1/2	See Class 1500				245	190.5	28.4	8	265	196.8	31.7	8
3	240	190.5	25.4	8	265	203.2	31.7	8	305	228.6	35.0	8
3 1/2	–	–	–	–	–	–	–	–	–	–	–	–
4	290	235.0	31.7	8	310	241.3	35.0	8	355	273.0	41.1	8
5	350	279.4	35.0	8	375	292.1	41.1	8	420	323.8	47.7	8
6	380	317.5	31.7	12	395	317.5	38.1	12	485	368.3	53.8	8
8	470	393.7	38.1	12	485	393.7	44.4	12	550	438.2	53.8	12
10	545	469.9	38.1	16	585	482.6	50.8	12	675	539.8	66.5	12
12	610	533.4	38.1	20	675	571.5	53.8	16	760	619.1	73.1	12
14	640	558.8	41.1	20	750	635.0	60.4	16	–	–	–	–
16	705	616.0	44.4	20	825	704.8	66.5	16	–	–	–	–
18	785	685.8	50.8	20	915	774.7	73.1	16	–	–	–	–
20	855	749.3	53.8	20	985	831.8	79.2	16	–	–	–	–
24	1040	901.7	66.5	20	1170	990.6	91.9	16	–	–	–	–

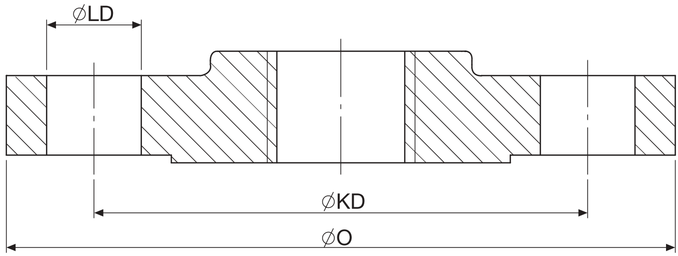
Fig. 157b Connection dimensions for steel flanges (millimetres) (contd)
(ASME B16.5 - selection)

NPS	Class 150				Class 300				Class 400				Class 600			
	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts
	O	KD	LD		O	KD	LD		O	KD	LD		O	KD	LD	
	[in]	[in]	[in]		[in]	[in]	[in]		[in]	[in]	[in]		[in]	[in]	[in]	
1/2	3.50	2.38	0.62	4	3.75	2.62	0.62	4	See Class 600				3.75	2.62	0.62	4
3/4	3.88	2.75	0.62	4	4.62	3.25	0.75	4	See Class 600				4.62	3.25	0.75	4
1	4.25	3.12	0.62	4	4.88	3.50	0.75	4	See Class 600				4.88	3.50	0.75	4
1 1/4	4.62	3.50	0.62	4	5.25	3.88	0.75	4	See Class 600				5.25	3.88	0.75	4
1 1/2	5.00	3.88	0.62	4	6.12	4.50	0.88	4	See Class 600				6.12	4.50	0.88	4
2	6.00	4.75	0.75	4	6.50	5.00	0.75	8	See Class 600				6.50	5.00	0.75	8
2 1/2	7.00	5.50	0.75	4	7.50	5.88	0.88	8	See Class 600				7.50	5.88	0.88	8
3	7.50	6.00	0.75	4	8.25	6.62	0.88	8	See Class 600				8.25	6.62	0.88	8
3 1/2	8.50	7.00	0.75	8	9.00	7.25	0.88	8	See Class 600				9.00	7.25	1.00	8
4	9.00	7.50	0.75	8	10.00	7.88	0.88	8	10.00	7.88	1.00	8	10.75	8.50	1.00	8
5	10.00	8.50	0.88	8	11.00	9.25	0.88	8	11.00	9.25	1.00	8	13.00	10.50	1.12	8
6	11.00	9.50	0.88	8	12.50	10.62	0.88	12	12.50	10.62	1.00	12	14.00	11.50	1.12	12
8	13.50	11.75	0.88	8	15.00	13.00	1.00	12	15.00	13.00	1.12	12	16.50	13.75	1.25	12
10	16.00	14.25	1.00	12	17.50	15.25	1.12	16	17.50	15.25	1.25	16	20.00	17.00	1.38	16
12	19.00	17.00	1.00	12	20.50	17.75	1.25	16	20.50	17.75	1.38	16	22.00	19.25	1.38	20
14	21.00	18.75	1.12	12	23.00	20.25	1.25	20	23.00	20.25	1.38	20	23.75	20.75	1.50	20
16	23.50	21.25	1.12	16	25.50	22.50	1.38	20	25.50	22.50	1.50	20	27.00	23.75	1.62	20
18	25.00	22.75	1.25	16	28.00	24.75	1.38	24	28.00	24.75	1.50	24	29.25	25.75	1.75	20
20	27.50	25.00	1.25	20	30.50	27.00	1.38	24	30.50	27.00	1.62	24	32.00	28.50	1.75	24
24	32.00	29.50	1.38	20	36.00	32.00	1.62	24	36.00	32.00	1.88	24	37.00	33.00	2.00	24

Fig. 158a Connection dimensions for steel flanges (inches)
(ASME B16.5 - selection)

NPS	Class 900				Class 1500				Class 2500			
	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts
	O	KD	LD		O	KD	LD		O	KD	LD	
	[in]	[in]	[in]		[in]	[in]	[in]		[in]	[in]	[in]	
1/2	See Class 1500				4.75	3.25	0.88	4	5.25	3.50	0.88	4
3/4	See Class 1500				5.12	3.50	0.88	4	5.50	3.75	0.88	4
1	See Class 1500				5.88	4.00	1.00	4	6.25	4.25	1.00	4
1 1/4	See Class 1500				6.25	4.38	1.00	4	7.25	5.12	1.12	4
1 1/2	See Class 1500				7.00	4.88	1.12	4	8.00	5.75	1.25	4
2	See Class 1500				8.50	6.50	1.00	8	9.25	6.75	1.12	8
2 1/2	See Class 1500				9.62	7.50	1.12	8	10.50	7.75	1.25	8
3	9.50	7.50	1.00	8	10.50	8.00	1.25	8	12.00	9.00	1.38	8
3 1/2	–	–	–	–	–	–	–	–	–	–	–	–
4	11.50	9.25	1.25	8	12.25	9.50	1.38	8	14.00	10.75	1.62	8
5	13.75	11.00	1.38	8	14.75	11.50	1.62	8	16.50	12.75	1.88	8
6	15.00	12.50	1.25	12	15.50	12.50	1.50	12	19.00	14.50	2.12	8
8	18.50	15.50	1.50	12	19.00	15.50	1.75	12	21.75	17.25	2.12	12
10	21.50	18.50	1.50	16	23.00	19.00	2.00	12	26.50	21.25	2.62	12
12	24.00	21.00	1.50	20	26.50	22.50	2.12	16	30.00	24.38	2.88	12
14	25.25	22.00	1.62	20	29.50	25.00	2.38	16	–	–	–	–
16	27.75	24.25	1.75	20	32.50	27.75	2.62	16	–	–	–	–
18	31.00	27.00	2.00	20	36.00	30.50	2.88	16	–	–	–	–
20	33.75	29.50	2.12	20	38.75	32.75	3.12	16	–	–	–	–
24	41.00	35.50	2.62	20	46.00	39.00	3.62	16	–	–	–	–

Fig. 158b Connection dimensions for steel flanges (inches) (contd)
(ASME B16.5 - selection)



LD = bolt hole diameter
KD = pitch circle diameter
O = outside diameter

Fig. 159

NPS	Class 25				Class 125				Class 250			
	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts	Outside diameter	Pitch circle diameter	Bolt hole diameter	Number of bolts
	O	KD	LD		O	KD	LD		O	KD	LD	
	[mm]	[mm]	[mm]		[mm]	[mm]	[mm]		[mm]	[mm]	[mm]	
1/2	–	–	–	–	–	–	–	–	–	–	–	–
3/4	–	–	–	–	–	–	–	–	–	–	–	–
1	–	–	–	–	107.9	79.2	15.7	4	23.9	88.9	19.0	4
1 1/4	–	–	–	–	117.3	88.9	15.7	4	133.3	98.5	19.0	4
1 1/2	–	–	–	–	127.0	98.5	15.7	4	155.8	114.3	22.3	4
2	–	–	–	–	152.4	120.6	19.0	4	165.1	127	19.0	8
2 1/2	–	–	–	–	177.8	139.7	19.0	4	190.5	149.3	22.3	8
3	–	–	–	–	190.5	152.4	19.0	4	209.5	168.1	22.3	8
3 1/2	–	–	–	–	215.9	177.8	19.0	8	228.6	184.1	22.3	8
4	228.6	190.5	19.0	8	228.6	190.5	19.0	8	254.0	200.1	22.3	8
5	254.0	215.9	19.0	8	254.0	215.9	22.3	8	279.4	234.9	22.3	8
6	279.4	241.3	19.0	8	279.4	241.3	22.3	8	317.5	269.7	22.3	12
8	342.9	298.4	19.0	8	342.9	298.4	22.3	8	381.0	330.2	25.4	12
10	406.4	361.9	19.0	12	406.4	361.9	25.4	12	444.5	387.3	28.4	16
12	482.6	431.8	19.0	12	482.6	431.8	25.4	12	520.7	450.8	31.7	16
14	533.4	476.2	22.3	12	533.4	476.2	28.4	12	584.2	514.3	31.7	20
16	596.9	539.7	22.3	16	596.9	539.7	28.4	16	647.7	571.5	35.0	20
18	635.0	577.8	22.3	16	635.0	577.8	31.7	16	711.2	628.6	35.0	24
20	698.5	635.0	22.3	20	698.5	635	31.7	20	774.7	685.8	35.0	24
24	812.8	749.3	22.3	20	812.8	749.3	35.0	20	914.4	812.8	41.1	24

Fig. 160 **Connection dimensions for grey cast iron flanges** (millimetres)
(ASME B16.1 - selection)

NPS	Class 25				Class 125				Class 250			
	Outside diameter O [in]	Pitch circle diameter KD [in]	Bolt hole diameter LD [in]	Number of bolts	Outside diameter O [in]	Pitch circle diameter KD [in]	Bolt hole diameter LD [in]	Number of bolts	Outside diameter O [in]	Pitch circle diameter KD [in]	Bolt hole diameter LD [in]	Number of bolts
1/2	–	–	–	–	–	–	–	–	–	–	–	–
3/4	–	–	–	–	–	–	–	–	–	–	–	–
1	–	–	–	–	4.25	3.12	0.62	4	4.88	3.50	0.75	4
1 1/4	–	–	–	–	4.62	3.50	0.62	4	5.25	3.88	0.75	4
1 1/2	–	–	–	–	5.00	3.88	0.62	4	6.12	4.50	0.88	4
2	–	–	–	–	6.00	4.75	0.75	4	6.50	5.00	0.75	8
2 1/2	–	–	–	–	7.00	5.50	0.75	4	7.50	5.88	0.88	8
3	–	–	–	–	7.50	6.00	0.75	4	8.25	6.62	0.88	8
3 1/2	–	–	–	–	8.50	7.00	0.75	8	9.00	7.25	0.88	8
4	9.00	7.50	0.75	8	9.00	7.50	0.75	8	10.00	7.88	0.88	8
5	10.00	8.50	0.75	8	10.00	8.50	0.88	8	11.00	9.25	0.88	8
6	11.00	9.50	0.75	8	11.00	9.50	0.88	8	12.50	10.62	0.88	12
8	13.50	11.75	0.75	8	13.50	11.75	0.88	8	15.00	13.00	1.00	12
10	16.00	14.25	0.75	12	16.00	14.25	1.00	12	17.50	15.25	1.12	16
12	19.00	17.00	0.75	12	19.00	17.00	1.00	12	20.50	17.75	1.25	16
14	21.00	18.75	0.88	12	21.00	18.75	1.12	12	23.00	20.25	1.25	20
16	23.50	21.25	0.88	16	23.50	21.25	1.12	16	25.50	22.50	1.38	20
18	25.00	22.75	0.88	16	25.00	22.75	1.25	16	28.00	24.75	1.38	24
20	27.50	25.00	0.88	20	27.50	25.00	1.25	20	30.50	27.00	1.38	24
24	32.00	29.50	0.88	20	32.00	29.50	1.38	20	36.00	32.00	1.62	24

Fig. 161 Connection dimensions for grey cast iron flanges (inches)
(ASME B16.1 - selection)

8.2.5 Flange sealing surfaces

For flange joints, a variety of sealing types are in general use, together with the corresponding forms of different sealing surfaces at the flanges. In addition, various degrees of roughness are required for the sealing surfaces. The sealing surfaces for steel flanges currently prescribed by ASME B16.5 and for grey cast iron flanges by ASME B16.1 are given below.

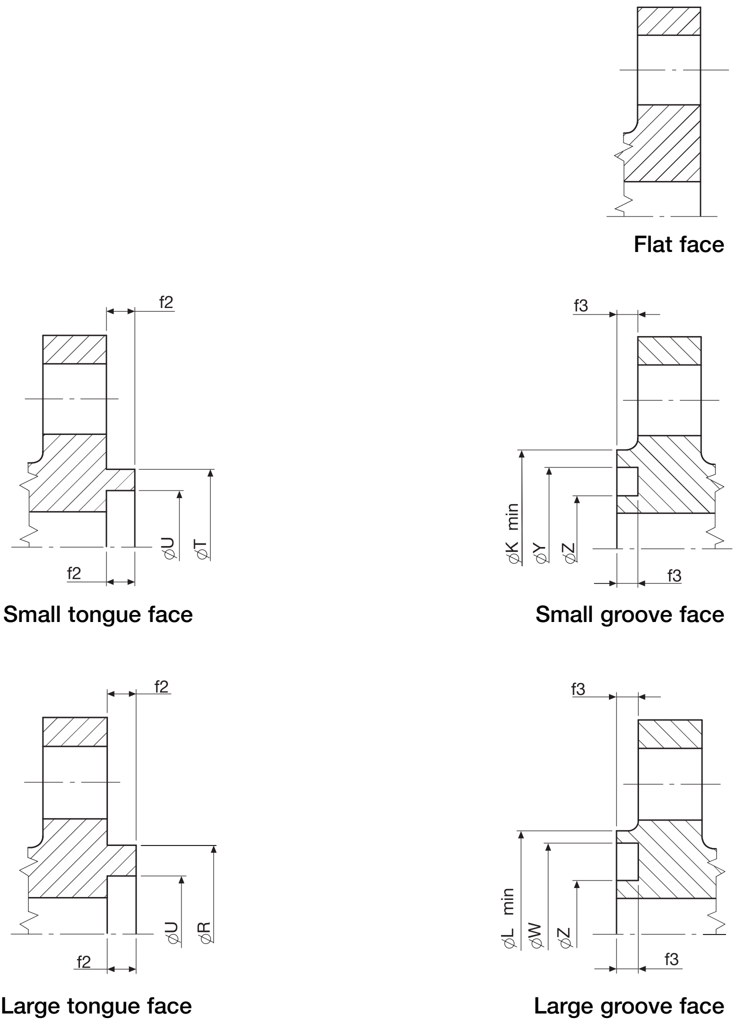


Fig. 162a Dimensions of sealing surfaces

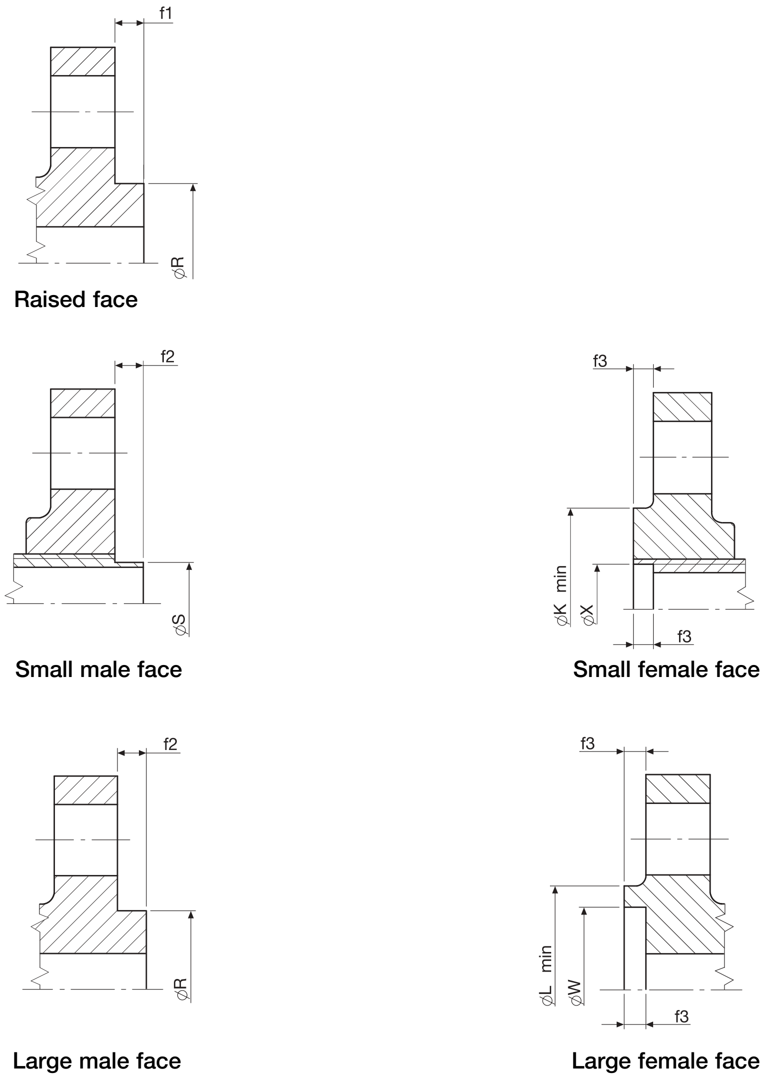


Fig. 162b Dimensions of sealing surfaces (contd)

										CL 150 - CL 300	CL 400 - CL 2500		
NPS	R	K	L	S	T	U	W	X	Y	Z	f1	f1	f2	f3
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
1/2	34.9	44	46	18.3	35.1	25.4	36.5	19.9	36.5	23.8	1.52	6.35	6.35	4.82
3/4	42.9	52	54	23.8	42.9	33.3	44.4	25.4	44.4	31.8	1.52	6.35	6.35	4.82
1	50.8	57	62	30.2	47.8	38.1	52.4	31.8	49.2	36.5	1.52	6.35	6.35	4.82
1 1/4	63.5	67	75	38.1	57.2	47.6	65.1	39.7	58.7	46.0	1.52	6.35	6.35	4.82
1 1/2	73.0	73	84	44.4	63.5	54.0	74.6	46.0	65.1	52.4	1.52	6.35	6.35	4.82
2	92.1	92	103	57.2	82.6	73.0	93.7	58.8	84.1	71.4	1.52	6.35	6.35	4.82
2 1/2	104.8	105	116	68.3	95.2	85.7	106.4	69.8	96.8	84.1	1.52	6.35	6.35	4.82
3	127.0	127	138	84.1	117.5	108.0	128.6	85.7	119.1	106.4	1.52	6.35	6.35	4.82
3 1/2	139.7	140	151	96.8	130.2	120.6	141.3	98.4	131.8	119.1	1.52	6.35	6.35	4.82
4	157.2	157	168	109.5	144.5	131.8	158.8	111.1	146.0	130.2	1.52	6.35	6.35	4.82
5	185.7	186	197	136.5	173.0	160.3	187.3	138.1	174.6	158.8	1.52	6.35	6.35	4.82
6	215.9	216	227	161.9	203.2	190.5	217.5	163.5	204.8	188.9	1.52	6.35	6.35	4.82
8	269.9	270	281	212.7	254.0	238.1	271.5	214.3	255.6	236.5	1.52	6.35	6.35	4.82
10	323.8	324	335	266.7	304.8	285.8	325.4	268.3	306.4	284.2	1.52	6.35	6.35	4.82
12	381.0	381	392	317.5	362.0	342.9	382.6	319.1	363.5	341.3	1.52	6.35	6.35	4.82
14	412.8	413	424	349.2	393.7	374.6	414.3	350.8	395.3	373.1	1.52	6.35	6.35	4.82
16	469.9	470	481	400.0	447.5	425.4	471.5	401.6	449.3	423.9	1.52	6.35	6.35	4.82
18	533.4	533	544	450.8	511.2	489.0	535.0	452.4	512.8	487.4	1.52	6.35	6.35	4.82
20	584.2	584	595	501.6	558.8	533.4	585.8	503.2	560.4	531.8	1.52	6.35	6.35	4.82
24	692.2	692	703	603.2	666.8	641.4	693.7	604.8	668.3	639.8	1.52	6.35	6.35	4.82

Fig. 163 Dimensions of sealing surfaces for steel flanges (millimetres), without ring joint
(ASME B16.5 - selection)

										CL 150 - CL 300	CL 400 - CL 2500		
NPS	R	K	L	S	T	U	W	X	Y	Z	f1	f1	f2	f3
	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]
1/2	1.38	1.75	1.81	0.72	1.38	1.00	1.44	0.78	1.44	0.94	0.06	0.25	0.25	0.19
3/4	1.69	2.06	2.12	0.94	1.69	1.31	1.75	1.00	1.75	1.25	0.06	0.25	0.25	0.19
1	2.00	2.25	2.44	1.19	1.88	1.50	2.06	1.25	1.94	1.44	0.06	0.25	0.25	0.19
1 1/4	2.50	2.62	2.94	1.50	2.25	1.88	2.56	1.56	2.31	1.81	0.06	0.25	0.25	0.19
1 1/2	2.88	2.88	3.31	1.75	2.50	2.12	2.94	1.81	2.56	2.06	0.06	0.25	0.25	0.19
2	3.62	3.62	4.06	2.25	3.25	2.88	3.69	2.31	3.31	2.81	0.06	0.25	0.25	0.19
2 1/2	4.12	4.12	4.56	2.69	3.75	3.38	4.19	2.75	3.81	3.31	0.06	0.25	0.25	0.19
3	5.00	5.00	5.44	3.31	4.62	4.25	5.06	3.38	4.69	4.19	0.06	0.25	0.25	0.19
3 1/2	5.50	5.50	5.94	3.81	5.12	4.75	5.56	3.88	5.19	4.69	0.06	0.25	0.25	0.19
4	6.19	6.19	6.62	4.31	5.69	5.19	6.25	4.38	5.75	5.12	0.06	0.25	0.25	0.19
5	7.31	7.31	7.75	5.38	6.81	6.31	7.38	5.44	6.88	6.25	0.06	0.25	0.25	0.19
6	8.50	8.50	8.94	6.38	8.00	7.50	8.56	6.44	8.06	7.44	0.06	0.25	0.25	0.19
8	10.62	10.62	11.06	8.38	10.00	9.38	10.69	8.44	10.06	9.31	0.06	0.25	0.25	0.19
10	12.75	12.75	13.19	10.50	12.00	11.25	12.81	10.56	12.06	11.19	0.06	0.25	0.25	0.19
12	15.00	15.00	15.44	12.50	14.25	13.50	15.06	12.56	14.31	13.44	0.06	0.25	0.25	0.19
14	16.25	16.25	16.69	13.75	15.50	14.75	16.31	13.81	15.56	14.69	0.06	0.25	0.25	0.19
16	18.50	18.50	18.94	15.75	17.62	16.75	18.56	15.81	17.69	16.69	0.06	0.25	0.25	0.19
18	21.00	21.00	21.44	17.75	20.12	19.25	21.06	17.81	20.19	19.19	0.06	0.25	0.25	0.19
20	23.00	23.00	23.44	19.75	22.00	21.00	23.06	19.81	22.06	20.94	0.06	0.25	0.25	0.19
24	27.25	27.25	27.69	23.75	26.25	25.25	27.31	23.81	26.31	25.19	0.06	0.25	0.25	0.19

Fig. 164 Dimensions of sealing surfaces for steel flanges (inches), without ring joint (ASME B16.5 - selection)

NPS	R	f1	R	f1
	[mm]	[mm]	[in]	[in]
1/2	–	–	–	–
3/4	–	–	–	–
1	68.32	1.52	2.69	0.06
1 1/4	77.72	1.52	3.06	0.06
1 1/2	90.42	1.52	3.56	0.06
2	106.42	1.52	4.19	0.06
2 1/2	125.47	1.52	4.94	0.06
3	144.52	1.52	5.69	0.06
3 1/2	160.27	1.52	6.31	0.06
4	176.27	1.52	6.94	0.06
5	211.07	1.52	8.31	0.06
6	246.12	1.52	9.69	0.06
8	303.27	1.52	11.94	0.06
10	357.12	1.52	14.06	0.06
12	417.57	1.52	16.44	0.06
14	481.07	1.52	18.94	0.06
16	534.92	1.52	21.06	0.06
18	592.07	1.52	23.31	0.06
20	649.22	1.52	25.56	0.06
24	769.87	1.52	30.31	0.06

Fig. 165 Dimensions of sealing surfaces for grey cast iron flanges, Class 250
(ASME B16.1 - selection)
(Class 125 and 125 flanges are always with flat face, i.e. no raised face)

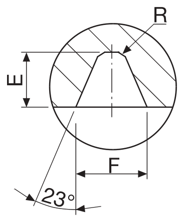


Fig. 166

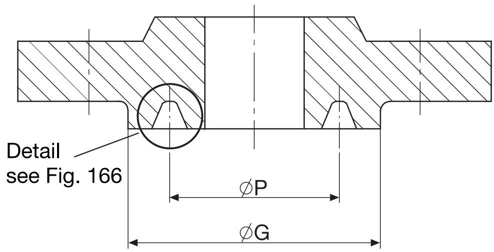


Fig. 167 **Caution!** Select diameter G according to ANSI B16.5 (in deviation from RF)

Class							Size								
150	300	400 a)	600	900 b)	1500	2500	No.	P	E	F	R	P	E	F	R
NPS								[mm]	[mm]	[mm]	[mm]	[in]	[in]	[in]	[in]
–	½	–	½	–	–	–	R11	34.14	5.54	7.14	0.8	1.344	0.219	0.281	0.03
–	–	–	–	–	½	–	R12	39.67	6.35	8.74	0.8	1.562	0.250	0.344	0.03
–	¾	–	¾	–	–	½	R13	42.88	6.35	8.74	0.8	1.688	0.250	0.344	0.03
–	–	–	–	–	¾	–	R14	44.45	6.35	8.74	0.8	1.750	0.250	0.344	0.03
1	–	–	–	–	–	–	R15	47.63	6.35	8.74	0.8	1.875	0.250	0.344	0.03
–	1	–	1	–	1	¾	R16	50.80	6.35	8.74	0.8	2.000	0.250	0.344	0.03
1 ¼	–	–	–	–	–	–	R17	57.15	6.35	8.74	0.8	2.250	0.250	0.344	0.03
–	1 ¼	–	1 ¼	–	1 ¼	1	R18	60.33	6.35	8.74	0.8	2.375	0.250	0.344	0.03
1 ½	–	–	–	–	–	–	R19	65.07	6.35	8.74	0.8	2.562	0.250	0.344	0.03
–	1 ½	–	1 ½	–	1 ½	–	R20	68.27	6.35	8.74	0.8	2.688	0.250	0.344	0.03
–	–	–	–	–	–	1 ¼	R21	72.23	7.92	11.91	0.8	2.844	0.312	0.469	0.03
2	–	–	–	–	–	–	R22	82.55	6.35	8.74	0.8	3.250	0.250	0.344	0.03
–	2	–	2	–	–	1 ½	R23	82.55	7.92	11.91	0.8	3.250	0.312	0.469	0.03
–	–	–	–	–	2	–	R24	95.25	7.92	11.91	0.8	3.750	0.312	0.469	0.03
2 ½	–	–	–	–	–	–	R25	101.60	6.35	8.74	0.8	4.000	0.250	0.344	0.03
–	2 ½	–	2 ½	–	–	2	R26	101.60	7.92	11.91	0.8	4.000	0.312	0.469	0.03
–	–	–	–	–	2 ½	–	R27	107.95	7.92	11.91	0.8	4.250	0.312	0.469	0.03
–	–	–	–	–	–	2 ½	R28	111.13	9.52	13.49	0.8	4.375	0.375	0.531	0.06
3	–	–	–	–	–	–	R29	114.30	6.35	8.74	0.8	4.500	0.250	0.344	0.03
–	c)	–	c)	–	–	–	R30	117.48	7.92	11.91	0.8	4.625	0.312	0.469	0.03
–	3 c)	–	3 c)	3	–	–	R31	123.83	7.92	11.91	0.8	4.875	0.312	0.469	0.03
–	–	–	–	–	–	3	R32	127.00	9.53	13.49	1.5	5.000	0.375	0.531	0.06
3 ½	–	–	–	–	–	–	R33	131.78	6.35	8.74	0.8	5.188	0.250	0.344	0.03
–	3 ½	–	3 ½	–	–	–	R34	131.78	7.92	11.91	0.8	5.188	0.312	0.469	0.03
–	–	–	–	–	3	–	R35	136.53	7.92	11.91	0.8	5.375	0.312	0.469	0.03
4	–	–	–	–	–	–	R36	149.23	6.35	8.74	0.8	5.875	0.250	0.344	0.03
–	4	4	4	4	–	–	R37	149.23	7.92	11.91	0.8	5.875	0.312	0.469	0.03
–	–	–	–	–	–	4	R38	157.18	11.13	16.66	1.5	6.188	0.438	0.656	0.06
–	–	–	–	–	4	–	R39	161.93	7.92	11.91	0.8	6.375	0.312	0.469	0.03
5	–	–	–	–	–	–	R40	171.45	6.35	8.74	0.8	6.750	0.250	0.344	0.03
–	5	5	5	5	–	–	R41	180.98	7.92	11.91	0.8	7.125	0.312	0.469	0.03
–	–	–	–	–	–	5	R42	190.50	12.70	19.84	1.5	7.500	0.500	0.781	0.06
6	–	–	–	–	–	–	R43	193.68	6.35	8.74	0.8	7.625	0.250	0.344	0.03
–	–	–	–	–	5	–	R44	193.68	7.92	11.91	0.8	7.625	0.312	0.469	0.03
–	6	6	6	6	–	–	R45	211.12	7.92	11.91	0.8	8.312	0.312	0.469	0.03

Fig. 168a Dimensions of sealing surfaces for steel flanges with ring joint
(ASME B16.5 - selection)

a) Nominal sizes from ½ in to 3½ in: use data for 600 psi.
b) Nominal sizes from ½ in to 2½ in: use data for 1500 psi.
c) For connections with lapped flanges, ring/groove number R30 is used instead of R31.

Class							Groove								
150	300	400 a)	600	900 b)	1500	2500	No.	P	E	F	R	P	E	F	R
NPS								[mm]	[mm]	[mm]	[mm]	[in]	[in]	[in]	[in]
–	–	–	–	–	6	–	R46	211.14	9.53	13.49	1.5	8.312	0.375	0.531	0.06
–	–	–	–	–	–	6	R47	228.60	12.70	19.84	1.5	9.000	0.500	0.781	0.06
8	–	–	–	–	–	–	R48	247.65	6.35	8.74	0.8	9.750	0.250	0.344	0.03
–	8	8	8	8	–	–	R49	269.88	7.92	11.91	0.8	10.625	0.312	0.469	0.03
–	–	–	–	–	8	–	R50	269.88	11.13	16.66	1.5	10.625	0.438	0.656	0.06
–	–	–	–	–	–	8	R51	279.40	14.27	23.01	1.5	11.000	0.562	0.906	0.06
10	–	–	–	–	–	–	R52	304.80	6.35	8.74	0.8	12.000	0.250	0.344	0.03
–	10	10	10	10	–	–	R53	323.85	7.92	11.91	0.8	12.750	0.312	0.469	0.03
–	–	–	–	–	10	–	R54	323.85	11.13	16.66	1.5	12.750	0.438	0.656	0.06
–	–	–	–	–	–	10	R55	342.90	17.48	30.18	2.4	13.500	0.688	1.188	0.09
12	–	–	–	–	–	–	R56	381.00	6.35	8.74	0.8	15.000	0.250	0.344	0.03
–	12	12	12	12	–	–	R57	381.00	7.92	11.91	0.8	15.000	0.312	0.469	0.03
–	–	–	–	–	12	–	R58	381.00	14.27	23.01	1.5	15.000	0.562	0.906	0.06
14	–	–	–	–	–	–	R59	396.88	6.35	8.74	0.8	15.625	0.250	0.344	0.03
–	–	–	–	–	–	12	R60	406.40	17.48	33.32	2.4	16.000	0.688	1.312	0.09
–	14	14	14	–	–	–	R61	419.10	7.92	11.91	0.8	16.500	0.312	0.469	0.03
–	–	–	–	14	–	–	R62	419.10	11.13	16.66	1.5	16.500	0.438	0.656	0.06
–	–	–	–	–	14	–	R63	419.10	15.88	26.97	2.4	16.500	0.625	1.062	0.09
16	–	–	–	–	–	–	R64	454.03	6.35	8.74	0.8	17.875	0.250	0.344	0.03
–	16	16	16	–	–	–	R65	469.90	7.92	11.91	0.8	18.500	0.312	0.469	0.03
–	–	–	–	16	–	–	R66	469.90	11.13	16.66	1.5	18.500	0.438	0.656	0.06
–	–	–	–	–	16	–	R67	469.90	17.48	30.18	2.4	18.500	0.688	1.188	0.09
18	–	–	–	–	–	–	R68	517.53	6.35	8.74	0.8	20.375	0.250	0.344	0.03
–	18	18	18	–	–	–	R69	533.40	7.92	11.91	0.8	21.000	0.312	0.469	0.03
–	–	–	–	18	–	–	R70	533.40	12.70	19.84	1.5	21.000	0.500	0.781	0.06
–	–	–	–	–	18	–	R71	533.40	17.48	30.18	2.4	21.000	0.688	1.188	0.09
20	–	–	–	–	–	–	R72	558.80	6.35	8.74	0.8	22.000	0.250	0.344	0.03
–	20	20	20	–	–	–	R73	584.20	9.53	13.49	1.5	23.000	0.375	0.531	0.06
–	–	–	–	20	–	–	R74	584.20	12.70	19.84	1.5	23.000	0.500	0.781	0.06
–	–	–	–	–	20	–	R75	584.20	17.48	33.32	2.4	23.000	0.688	1.312	0.09
24	–	–	–	–	–	–	R76	673.10	6.35	8.74	0.8	26.500	0.250	0.344	0.03
–	24	24	24	–	–	–	R77	692.15	11.18	16.66	1.5	27.250	0.438	0.656	0.06
–	–	–	–	24	–	–	R78	692.15	15.88	26.97	2.4	27.250	0.625	1.062	0.09
–	–	–	–	–	24	–	R79	692.15	20.62	36.53	2.4	27.250	0.812	1.438	0.09

Fig. 168b Dimensions of sealing surfaces for steel flanges with ring joint (contd) (ASME B16.5 - selection)

a) Nominal sizes from ½ in to 3½ in: use data for 600 psi.
b) Nominal sizes from ½ in to 2½ in: use data for 1500 psi.
c) For connections with lapped flanges, ring/groove number R30 is used instead of R31.

8.2.5.1 Sealing surface roughness

The sealing surface roughnesses for steel flanges currently prescribed by ASME B16.5 and for grey cast iron flanges by ASME B16.1 are given below.

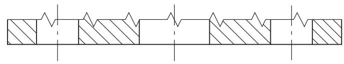
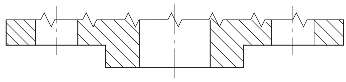
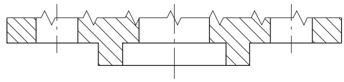
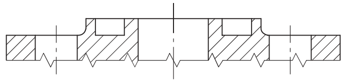
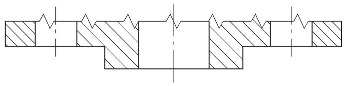
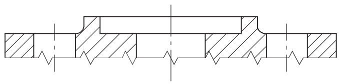
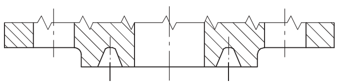
Designation	Roughness Ra[µm]	Schematic view
Flat sealing surface (without raised face)		
Flat face	6.3 - 3.2	
Raised face		
Raised face	6.3 - 3.2 *)	
Tongue, groove		
Large tongue face	3.2 - 1.6	
Small tongue face	3.2 - 1.6	
Large groove face	3.2 - 1.6	
Small groove face	3.2 - 1.6	
Male/female face		
Large male face	6.3 - 3.2 *)	
Small male face	3.2 - 1.6 *)	
Large female face	6.3 - 3.2 *)	
Small female face	3.2 - 1.6 *)	
Ring groove, trapezoidal		
Ring joint face	1.6 - 0.8	

Fig. 169 Roughnesses for steel flanges
(ASME B16.5 - selection)
*) Prescribed groove

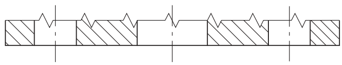
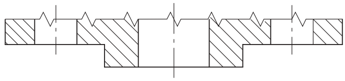
Designation	Roughness Ra[µm]	Schematic view
Smooth sealing surface (without raised face)		
Flat face	12,5 - 6,3 *)	
Raised face		
Raised face	12,5 - 6,3 *)	

Fig. 170 Roughnesses for cast iron flanges
(ASME B16.5 - selection)
*) Prescribed groove

8.2.6 Flange bolts and nuts

Suitable materials for bolts, threaded bolts (studs) and nuts (fasteners) for Class flanges are specified in ASME B16.5.
The table below lists a selection of materials that are suitable for fasteners to be used with steel flanges.

A distinction is made between three strength levels as follows (for further details, see ASME B16.5):

- Low strength bolting: Fasteners may be used for all the flange materials given in ASME B16.5, but only for Class 150 and Class 300. Moreover, this applies only in conjunction with flange gaskets as per ASME B16.5, Annex E, Fig. E1, gasket group Ia.
- Intermediate strength bolting: Fasteners may be used for all the flange materials and gaskets given in ASME B16.5. However, it must be shown that the gasket is sufficiently compressed and that a tight connection is ensured under the envisaged operating conditions.
- High strength bolting: Fasteners may be used for all the flange materials and gaskets given in ASME B16.5.

Class up to	Bolts / threaded bolts ASTM material	Nuts ASTM material	Low strength	Intermediate strength	High strength	Elevated temperature	Low temperature
300	A193 B8 Class 1	A194 8	X			X	
300	A193 B8A	A194 8A	X			X	
300	A193 B8C Class 1	A194 8C	X			X	
300	A193 B8CA	A194 8CA	X			X	
300	A193 B8M Class 1	A194 8M	X			X	
300	A193 B8MA	A194 8MA	X			X	
300	A193 B8T Class 1	A194 8T	X			X	
300	A193 B8TA	A194 8TA	X			X	
300	A320 B8 Class 1	A194 8	X				X
300	A320 B8C Class 1	A194 8C	X				X
300	A320 B8M Class 1	A194 8M	X				X
300	A320 B8T Class 1	A194 8T	X				X
2500	A193 B16	A194 8M (*)			X	X	
2500	A193 B7	A194 2H (*)			X	X	
2500	A193 B8 Class 2	A194 8		X		X	
2500	A193 B8C Class 2	A194 8C		X		X	
2500	A193 B8M Class 2	A194 8M		X		X	
2500	A193 B8T Class 2	A194 8T		X		X	
2500	A453 651	A453 651		X		X	
2500	A453 660	A453 660		X		X	
2500	A320 B8 Class 2	A194 8		X			X
2500	A320 B8C Class 2	A194 8C		X			X
2500	A320 B8F Class 2	A194 8F		X			X
2500	A320 B8M Class 2	A194 8M		X			X
2500	A320 B8T Class 2	A194 8T		X			X
2500	A320 L43	A194 4 / A194 7			X		X
2500	A320 L7	A194 4 / A194 7			X		X
2500	A320 L7A	A194 4 / A194 7			X		X
2500	A320 L7B	A194 4 / A194 7			X		X
2500	A320 L7C	A194 4 / A194 7			X		X

Fig. 171
(*) Nuts according to API Standard 602

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9 Standards

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GESTRA Steam Systems

Valves

Industrial Electronics, Automation

Special Equipment
and Vessels for Heat Recovery

Services

9 Standards

9.1 List of Standards with Keywords

Standard	Keywords
	EU Directives, ordinances
87/404/EC	EU Directive “Pressure Vessels, Simple”
97/23/EC	EU Directive “Pressure Equipment” (PED)
1999/36/EC	EU Directive “Pressure Equipment, Transportable” (TPED)
89/336/EC	EU Directive “Electromagnetic Compatibility” (EMC)
1999/92/EC	EU Directive “Explosion Protection, Worker Protection” (ATEX)
94/9/EC	EU Directive “Explosion Protection, Manufacturers” (ATEX)
98/37/EC	EU Directive “Machinery” (MD)
73/23/EC	EU Directive “Low Voltage Equipment” (LVD)
96/98/EC	EU Directive “Marine Equipment” (MED)
BetrSichV	Ordinance “Safety of Plants Requiring Supervision”
	Valves and fittings
DIN 3230-6	Valves for combustible liquids, technical conditions of supply
DIN 3230-5	Valves for gas lines, technical conditions of supply
DIN 3230-4	Valves for drinking water, technical conditions of supply
DIN EN 12569	Valves: requirements and tests for the chemical and petrochemical industry
DIN EN 736-2	Valves: definition of valve components
DIN EN 736-3	Valves: definition of terms
DIN EN 12570	Valves: design of actuating elements
DIN EN 736-1	Valves: definition of basic types
ASME B16.25	Valve connections: butt-weld ends
DIN EN 12627	Valve connections: butt-weld ends
DIN 3239-1	Valve connections: butt-weld end *(no longer valid, but still in use)*
DIN 2559-2	Valve connections: butt-weld ends, fitting diameter
DIN EN 12760	Valve connections: socket-weld ends
DIN EN 12982	Valves, overall lengths: butt-weld ends
DIN EN 558-2	Valves, overall lengths: class-designated, flanged end
DIN 3202-4	Valves, overall lengths: female thread connection
DIN EN 558-1	Valves, overall lengths: PN-designated, flanged end
DIN 3202-5	Valves, overall lengths: compression couplings
AD 2000 A4	Valve body
ASME B16.34	Valve body
DIN EN 12516-3	Valve body: strength, experimental verification
DIN 3840	Valve body: strength calculation
DIN EN 19	Valve marking
ISO 5209	Valve marking
MSS SP-25	Valve marking
VDMA 24421	Valve testing
DIN EN 12266-1	Valve testing: pressure test

Standard	Keywords
MSS SP-61	Valve testing: pressure test
API Std 598	Valve testing: testing and inspection
ISO 5208	Valve testing: testing and inspection
DIN EN 12266-2	Valve testing: test procedure, acceptance criteria
DIN EN 1503-3	Valve materials: cast iron
DIN EN 1503-4	Valve materials: copper alloys
DIN EN 1503-1	Valve materials: steels defined in European standards
DIN EN 1503-2	Valve materials: steels not defined in European standards
	Steam traps
DIN EN 26704	Steam traps: classification of types
DIN 3548-1	Steam traps: overall lengths, materials, p/T rating
ISO 6552	Steam traps: definition of terms
DIN EN 26554	Steam traps, overall lengths: flanged ends
ANSI/FCI 69-1	Steam traps, body: strength analysis
ANSI/FCI 69-1	Steam traps, marking
DIN ISO 6553	Steam traps, marking
DIN EN 26948	Steam traps, testing
	Other pressure equipment
DIN EN 13445-1	Pressure vessels, unfired: general
DIN EN 13445-6	Pressure vessels, unfired: requirements for cast iron with spheroidal graphite
DIN EN 13445-4	Pressure vessels, unfired: manufacture
DIN EN 13445-5	Pressure vessels, unfired: inspection and testings
DIN EN 13445-3	Pressure vessels, unfired: design, calculation
DIN EN 13445-2	Pressure vessels, unfired: materials
DIN EN 764-3	Pressure equipment: definition of parties involved
DIN EN 764-2	Pressure equipment: sizes, symbols, units
DIN EN 764-7	Pressure equipment: safety arrangements
DIN EN 764-1	Pressure equipment: terminology, pressure, temperature, volume, nominal size
DIN EN 764-4	Pressure equipment: terms of delivery for materials
DIN EN 764-5	Pressure equipment: Material test certificates
	Flanges
ASME B16.21	Class-designated flange gaskets: flat gaskets, non-metallic
DIN EN 12560-1	Class-designated flange gaskets: flat gaskets, non-metallic
DIN EN 12560-4	Class-designated flange gaskets: metallic gaskets
DIN EN 12560-7	Class-designated flange gaskets: metal-coated gaskets
DIN EN 12560-5	Class-designated flange gaskets: ring-joint gaskets
ASME B16.20	Class-designated flange gaskets: ring-joint, spiral-wound, jacketed
DIN EN 12560-2	Class-designated flange gaskets: spiral-wound gaskets
DIN EN 12560-3	Class-designated flange gaskets: soft gaskets with PTFE envelope

Standard	Keywords
DIN EN 1759-4	Class-designated flanges: aluminium alloys
MSS SP-6	Class-designated flanges: processing of sealing surfaces
ASME B16.1	Class-designated flanges: cast iron
ASME B16.24	Class-designated flanges: copper alloys
DIN EN 1759-3	Class-designated flanges: copper alloys
MSS SP-9	Class-designated flanges: screw seating areas
DIN EN 1759-1	Class-designated flanges: steel
MSS SP-44	Class-designated flanges: steel
ASME B16.5	Class-designated flanges: steel, NPS 1/2 - 24
ASME B16.47	Class-designated flanges: steel, NPS 26 - 60
DIN EN 1515-1	Flange bolts and nuts: material selection
DIN EN 1515-2	Flange bolts: allocation to material classes
DIN 2696	PN flange gaskets: lens-shaped gaskets
DIN EN 1514-1	PN flange gaskets: flat gaskets, non-metallic
DIN 2697	PN flange gaskets: grooved gaskets
DIN 2695	PN flange gaskets: welded diaphragm gaskets
DIN EN 1514-4	PN flange gaskets: metallic gaskets
DIN 2693	PN flange gaskets: O-ring gaskets for male flanges
DIN EN 1514-2	PN flange gaskets: spiral-wound gaskets
DIN EN 1514-3	PN flange gaskets: soft gaskets with PTFE envelope
DIN 2500	PN flanges: general information, survey
DIN EN 1092-4	PN flanges: aluminium alloys
DIN 2501-1	PN flanges: connection dimensions
DIN 2526	PN flanges: forms of sealing surfaces
DIN 2558	PN flanges: screwed flanges, oval
DIN EN 1092-2	PN flanges: cast iron
DIN EN 1092-3	PN flanges: copper alloys
DIN 2512	PN flanges: tongue and groove, PN 160
DIN EN 1092-1	PN flanges: steel
DIN 2548	PN flanges: cast steel, PN 160
DIN 2549	PN flanges: cast steel, PN 250
DIN 2550	PN flanges: cast steel, PN 320
DIN 2551	PN flanges: cast steel, PN 400
DIN 2638	PN flanges: weld-neck flanges, PN 160
DIN 2628	PN flanges: weld-neck flanges, PN 250
DIN 2629	PN flanges: weld-neck flanges, PN 320
DIN 2627	PN flanges: weld-neck flanges, PN 400

Standard	Keywords
	Pipework
DIN EN 10241	Fittings: steel
ASME B16.11	Fittings: forged steel
DIN EN 10242	Fittings: malleable cast iron
VdTüV MB 1065	Pipework
DIN 2429-1	Pipework: general
DIN EN 13480-1	Pipework: general
DIN 2403	Pipework: colour coding to identify the medium
DIN 2404	Pipework: colour coding of heating pipes
DIN EN 13480-4	Pipework: manufacturing, laying
DIN 2429-2	Pipework: functional presentation
DIN EN 13480-3	Pipework: design, calculation
API Spec. 6D	Pipework: pipelines
DIN EN 13480-5	Pipework: testing
DIN EN 13480-2	Pipework: materials
DIN EN ISO 9692-2	Weld seams: joint types
DIN 2559-1	Weld seams: types of joints for steel pipes
DIN EN 10217-2	Steel pipes: elevated temperature, electrically welded
DIN EN 10216-2	Steel pipes: elevated temperature, seamless
DIN EN 10217-5	Steel pipes: elevated temperature, submerged-arc welded
DIN EN 10217-3	Steel pipes: fine-grained structural steels, welded
DIN EN 10216-3	Steel pipes: fine-grained structural steels, seamless
DIN EN 10220	Steel pipes: dimensions and sizes
DIN 2440	Steel pipes: medium-heavy type
ASME B36.10M	Steel pipes: seamless/welded, hot-rolled
DIN EN 10305-2	Steel pipes: precision, welded, cold drawn
DIN EN 10305-3	Steel pipes: precision, welded, rolled to size
DIN EN 10305-1	Steel pipes: precision, seamless, cold drawn
DIN EN 10217-1	Steel pipes: room temperature, welded
DIN EN 10216-1	Steel pipes: room temperature, seamless
DIN 2441	Steel pipes: heavy type
DIN EN 10217-4	Steel pipes: low-temperature, arc/welded
DIN EN 10216-4	Steel pipes: low-temperature, seamless
DIN EN 10217-6	Steel pipes: low-temperature, submerged-arc welded
	Tank cars
DIN EN 12561-1	Tank cars: marking of hazardous goods
DIN EN 12561-6	Tank cars: manholes
DIN EN 12561-4	Tank cars: top filling and emptying, liquids
DIN EN 12561-5	Tank cars: top filling, bottom emptying, liquids
DIN EN 12561-3	Tank cars: bottom filling and emptying, pressurized gases
DIN EN 12561-2	Tank cars: bottom emptying, liquids

Standard	Keywords
	Miscellaneous
DIN EN ISO 6708	Definition: DN
DIN 1301-1	Definition: units, names and symbols
DIN 1304-1	Definition: letter symbols
DIN EN 1333	Definition: PN
DIN EN 50014	Explosion protection: electrical equipment (ATEX)
DIN EN 13463-1	Explosion protection: non-electrical equipment (ATEX)
DIN 55928-9	Corrosion protection through coatings: coating materials
DIN 55928-8	Corrosion protection through coatings: thin-walled components
DIN 53210	Corrosion protection: coatings, designation of the degree of rusting
DIN EN ISO 12944-4	Corrosion protection: coating systems, preparatory treatment
DIN EN ISO 1302	Surface texture: indication in documentation
DIN EN 10204	Test certificates, acceptance certificates, types
DIN 3852-1	Plug screws
DIN 910	Plug screws
DIN 5586	Plug screws with venting
DIN 7603	Plug screws, sealing rings
DIN 3869	Plug screws, sealing rings: profile gaskets
DIN 2481	Thermal power plants: symbols

9.2 Abbreviations

AD	German Authority for Pressure Vessel Regulations
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	The American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
AWWA	American Society for Testing and Materials
BG	German employer's liability insurance association
BS	British Standard
BSI	British Standards Institute
CEN	European Committee for Standardization *(Comité Européen de Normalisation)*
DIN	German Institute for Standardization
DVGW	German Technical and Scientific Association for Gas and Water
DVS	German Welding Society
EN	European Standard
GGVSE	Ordinance on the Transport of Dangerous Goods on Seagoing Vessels (Germany)
IEC	International Electrotechnical Commission
IMO	International Maritime Organization
ISA	Instrument Society of America
ISO	International Organization for Standardization
JIS	Japanese Industrial Standard
KTA	Nuclear Safety Standards Commission
LN	German standard for aviation and spaceflight
MSS	Manufacturers' Standardization Society of the Valve and Fittings Industry
NF	French Standard *(Norme Francaise)*
RID	Regulations governing the International Carriage of Dangerous Goods by Rail *(Reglemente Internationale Marchandises Dangereuses)*
SIS	Swedish Standards Institute *(Standardiseringskommissionen i Sverige)*
TRAC	Technical Rules for Acetylene and Calcium Carbide Stores
TRB	Technical Rules for Pressure Vessels
TRbF	Technical Rules for Combustible Liquids
TRD	Technical Rules for Steam Boilers
TRG	Technical Rules for Compressed Gases
TRgA	Technical Rule for Hazardous Agents
TRGL	Technical Rules for High-Pressure Gas Lines
TRT	Technical Guidelines for Tanks
UIC	Internation Union of Railways *(Union Internationale des Chemins de Fer)*
UVV	Accident prevention regulations of the employer's liability insurance associations
VDE	Association for Electrical, Electronic and Information Technologies
VDI	Association of German Engineers
VDMA	German Machinery and Plant Manufacturers' Association
VdTÜV	German Technical Supervisory Association

9.3 Sources

Title	Publisher	Obtainable from	or
AD Bulletins	Verband der Technischen Überwachungsvereine e.V. Kurfürstenstrasse 56 D-45138 Essen	Beuth Verlag GmbH Burggrafenstrasse 6 D-10787 Berlin	
DIN German standards	DIN Deutsches Institut für Normung e.V. Burggrafenstrasse 6 D-10787 Berlin	Beuth Verlag GmbH Burggrafenstrasse 6 D-10787 Berlin	
DVGW Gas and water code	DVGW Deutsche Vereinigung des Gas- und Wasserfaches e.V. Josef-Wirmer-Strasse 1-3 D-53123 Bonn	DVGW e.V. Josef-Wirmer-Strasse 1-3 D-53123 Bonn	
DVS Guidelines and bulletins	DVS Deutscher Verband für Schweissen und verwandte Verfahren e.V. Aachener Strasse 172 D-40223 Düsseldorf	DVS-Verlag GmbH Postfach 10 19 65 D-40010 Düsseldorf	
KTA Technical safety rules	KTA-Geschäftsstelle beim Bundesamt für Strahlenschutz Postfach 10 01 49 D-38201 Salzgitter	Carl Heymanns Verlag KG. Luxemburger Strasse 449 D-50939 Köln	
TRB Technical Rules for Pressure Vessels	Berufsgenossenschaftliche Zentrale für Sicherheit und Gesundheit (BGZ) Alte Heerstrasse 111 D-53757 St. Augustin	Beuth Verlag GmbH Burggrafenstrasse 6 D-10787 Berlin	Carl Heymanns Verlag KG. Luxemburger Strasse 449 D-50939 Köln
TRG Technical Rules for Compressed Gases	Verband der Technischen Überwachungsvereine e.V. Kurfürstenstrasse 56 D-45138 Essen	Beuth Verlag GmbH Burggrafenstrasse 6 D-10787 Berlin	TÜV-Verlag GmbH Unternehmesgruppe Rheinland Berlin Brandenburg Am Grauen Stein D-51105 Köln
TRbF Technical Rules for Combustible Liquids	Verband der Technischen Überwachungsvereine e.V. Kurfürstenstrasse 56 D-45138 Essen	Beuth Verlag GmbH Burggrafenstrasse 6 D-10787 Berlin	Carl Heymanns Verlag KG. Luxemburger Strasse 449 D-50939 Köln
TRD Technical Rules for Steam Boilers	Verband der Technischen Überwachungsvereine e.V. Kurfürstenstrasse 56 D-45138 Essen	Beuth Verlag GmbH Burggrafenstrasse 6 D-10787 Berlin	Carl Heymanns Verlag KG. Luxemburger Strasse 449 D-50939 Köln
TRGL Technical Rules for High-Pressure Gas Lines	Verband der Technischen Überwachungsvereine e.V. Kurfürstenstrasse 56 D-45138 Essen	Beuth Verlag GmbH Burggrafenstrasse 6 D-10787 Berlin	Carl Heymanns Verlag KG. Luxemburger Strasse 449 D-50939 Köln

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