$$P_w = \frac{1}{2} \rho \vartheta^2$$ EQ. 4.25

where:

ρ = Density of air
= 1.2 kg/m^3 (at 1.013 bar and 20°C)
ϑ = Wind velocity, m/sec.

Once the uniform wind force, Fw, is determined, the restraints loads can be calculated by the method previously proposed for the uniform weight loads. Since the wind loading is modeled as a static horizontal uniform load, which may act in any direction (depending upon the local conditions) and at any time, the design engineer should consider the following:

- In how many directions should the piping system be analyzed for wind loading?
- Should the wind act on the piping system when it is in-operation (hot) or out-of-operation (cold)?

4.2.2 RELIEF VALVE DISCHARGE

When a relief valve discharges, the fluid initiates a jet force. This force must be resisted by pipe supports if the pipe is not capable of resisting the load internally.
The magnitude of the jet force is usually provided by the valve manufacturer. If this value is not known, it may be calculated fairly easily for those cases where the valve vents to the atmosphere. If the fluid discharges through a closed system, transient flow conditions may be developed which make the valve discharge force difficult to calculate.
For a relief valve venting to the atmosphere, the discharge force as shown in figure 4.10 and 4.11 can be estimated as follows:

$$F = DLF\,(m\vartheta + PA)$$ EQ. 4.26

where:

F = discharge force, N
DLF = dynamic load factor. For a safe design use a value of 2.0. This may be overly conservative especially at low set pressures and where sonic flow through the valve outlet is unlikely.
m = mass flow rate through the valve x 1.1, Kg/sec.
Where 1.1 is a safety factor accounting for the flow rate just after the valve has opened and it is flowing its maximum capacity at overpressure conditions.

ϑ = fluid exit velocity , m/sec.
$\leq$ sonic velocity (ϑ_s)
P = static gauge pressure at exit, MPa (= N/mm²)
A = discharge flow area, mm².

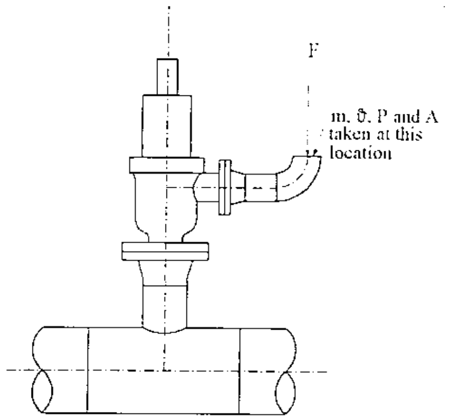


Figure 4.10

Since the static pressure P and velocity ϑ at the exit of the discharge pipe are not known for the engineer when designing the discharge header, they can be estimated (approximately) by the procedure explained later in section 4.2.2.1.
The maximum velocity of a compressible fluid in pipe is limited by the velocity of propagation of a pressure wave which travels at the speed of sound in the fluid.
When the pressure drop in the downstream of the relief valve is sufficiently high, the exit velocity will reach the velocity of sound.
Further decrease in the downstream pressure will not be felt upstream because the pressure wave can not travel at a velocity higher than the sonic speed.
The maximum discharge will be obtained at the sonic speed, and any "Surplus" pressure drop in the downstream after the maximum discharge has already been reached will take place beyond the exit of the discharge pipe. This pressure will be lost in shock waves and turbulence of the jetting fluid.

Physical Properties of Gases

(Approximate values at 20°C and 1.01325 bar)

c_p = specific heat at constant pressure
c_v = specific heat at constant volume

Name of Gas	Chemical Formula or Symbol	Approx. Molecular Weight	Density kg/m³	Specific Gravity Relative to Air	Individual Gas Constant J/kg K	Specific Heat at Room Temperature J/kg K		Heat Capacity per Cubic Metre J/m³ K		c_p/c_v =
		M	ρ	S_g	R	c_p	c_v	c_p	c_v	
Acetylene (ethyne)	C_2H_2	26.0	1.0925	0.907	320	1465	1127	1601	1231	1.30
Air	—	29.0	1.2045	1.000	287	1009	721	1215	868	1.40
Ammonia	NH_3	17.0	0.7179	0.596	490	2190	1659	1572	1191	1.32
Argon	A	39.9	1.6610	1.379	208	519	311	862	517	1.67
n-Butane	C_4H_{10}	58.1	2.4897	2.067	143	1654	1490	4118	3710	1.11
Carbon dioxide	CO_2	44.0	1.8417	1.529	189	858	660	1580	1216	1.30
Carbon monoxide	CO	28.0	1.1648	0.967	297	1017	726	1185	846	1.40
Chlorine	Cl_2	70.9	2.9944	2.486	117	481	362	1440	1084	1.33
Ethane	C_2H_6	30.0	1.2635	1.049	277	1616	1325	2042	1674	1.22
Ethylene	C_2H_4	28.0	1.1744	0.975	296	1675	1373	1967	1612	1.22
Helium	He	4.0	0.1663	0.1381	2078	5234	3153	870	524	1.66
Hydrogen Chloride	HCl	36.5	1.5273	1.268	228	800	567	1222	866	1.41
Hydrogen	H_2	2.0	0.0837	0.0695	4126	14319	10155	1199	850	1.41
Hydrogen sulphide	H_2S	34.1	1.4334	1.190	243	1017	782	1458	1121	1.30
Methane	CH_4	16.0	0.6673	0.554	519	2483	1881	1657	1255	1.32
Methyl Chloride	CH_3Cl	50.5	2.1500	1.785	165	1005	838	2161	1800	1.20
Natural gas (a)	—	19.5	0.8034	0.667	426	2345	1846	1884	1483	1.27
Nitric Oxide	NO	30.0	1.2491	1.037	277	967	691	1208	863	1.40
Nitrogen	N_2	28.0	1.1648	0.967	297	1034	733	1204	854	1.41
Nitrous oxide	N_2O	44.0	1.8429	1.530	189	925	706	1705	1301	1.31
Oxygen	O_2	32.0	1.3310	1.105	260	909	649	1210	864	1.40
Propane	C_3H_8	44.1	1.8814	1.562	188	1645	1430	3095	2690	1.15
Propane propylene	C_3H_6	42.1	1.7477	1.451	198	1499	1315	2620	2298	1.14
Sulphur dioxide	SO_2	64.1	2.7270	2.264	129	645	512	1759	1396	1.26

(a) Representative values; exact characteristics require knowledge of exact constitutents.

Notes. To obtain density values at 15°C, 1.01325 bar, multiply table values by 1.0174.

Where the Kelvin (K) appears in the above table it may be replaced by the degree Celsius (°C) i.e. kJ/kg K may be written kJ/kg°C.

Values of Molecular Weight, Specific Gravity, Individual Gas Constant and Specific Heat abstracted from or based on Table 24 in Mark's "Standard Handbook for Mechanical Engineers", Seventh Edition, 1966 – approximate values adapted from a number of sources.[22]

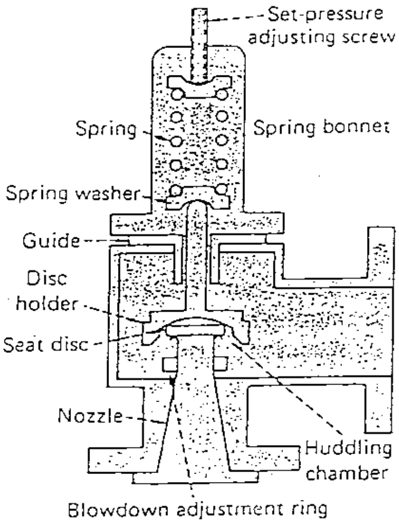
Values of Densities obtained by multiplying density of dry air at 20°C, 1.01325 bar, by specific gravity of gas, i.e. 1.2045 x S_g. Density of air, from "Thermodynamic and Transport Properties of Fluids", Y. R. Mayhew and G. F. C. Rogers, 1972.[14]

Figure 4.11

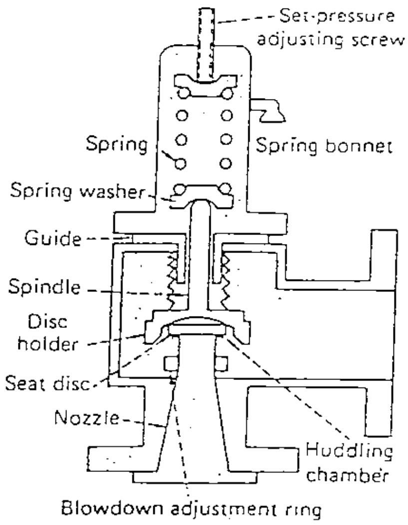
When back pressure exists, it will be a very significant factor in many pressure-relief-valve applications. Unfortunately, it is sometimes neglected by designers who are unfamiliar with its effects on pressure-relief-valve operation. Back pressure is the pressure that exists on the outlet side (downstream) of the valve.
Back pressure that exists prior to the opening of the valve is called "superimposed" back pressure. In conventional, unbalanced, direct spring-loaded pressure relief valves (PRV's), superimposed back pressure changes set pressure on a one to one basis.
Back pressure created by flow through the valve into downstream piping is called "built-up" back pressure.
Built-up back pressure acting on conventional spring loaded PRV's often reduces relieving capacity, causes chatter, or does both.
Normally, conventional valves can not remain fully open and allow flow properly with much more than 10% built-up back pressure. A solution to this is to redesign the configuration of the discharge piping (shorter and larger diameter) or to use balanced valves or pilot-operated valves. (see figure 4.13)
Proper selection of a PRV for use where back pressure can occur is very important. To obtain the required relief capacity and ensure stable chatter-free operation, PRV's generally best suited for this service, in order of preference are:

1. Pilot-operated safety relief valves or balanced spring-loaded valves (bellows or balanced piston type), dependent upon application.
2. Conventional spring-loaded valves.

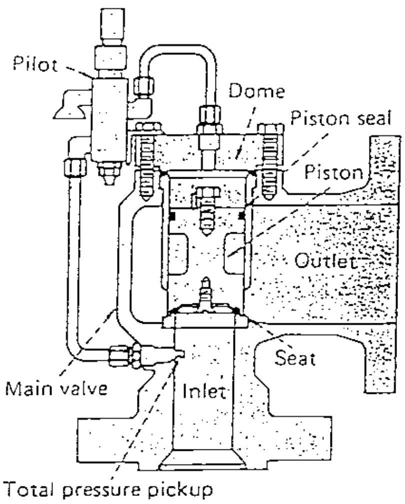
As a rule, conventional valves should not be vented into either closed headers or long discharge pipes. Discharge pipes configurations, including the common long-radius elbow, may create even greater back pressure problems.
Built-up back pressure calculations in discharge piping design usually start at the exit and are worked out backward toward the relief valve.
The calculated built-up back pressure 'P_0' at the valve outlet must be less than the maximum allowable back pressure per type of valve.
$P_0 = P \div \Delta P$, where ΔP is the pressuredrop in the discharge pipe. Calculations of ΔP is beyond the scope of this course.
The percentage of the built-up back pressure to the valve's set pressure: $(P_0 : P_s) \times 100$, will determine the suitability of the valve's type for the intended service.
Figure 4.14 shows typical capacity versus back pressures for the different types of pressure relief valves.
If the built-up back pressure is too high, then make the necessary modification to the configuration of the discharge system (larger diameter and/or shorter length) or select another type of valve.
Check also the stresses in the discharge pipe, the inlet pipe and the loads on the adjacent supports.



a) Conventional direct-spring operated



b) Balanced bellows direct-spring operated



c) Pilot-operated

Figure 4.13 Different types of pressure relief valves

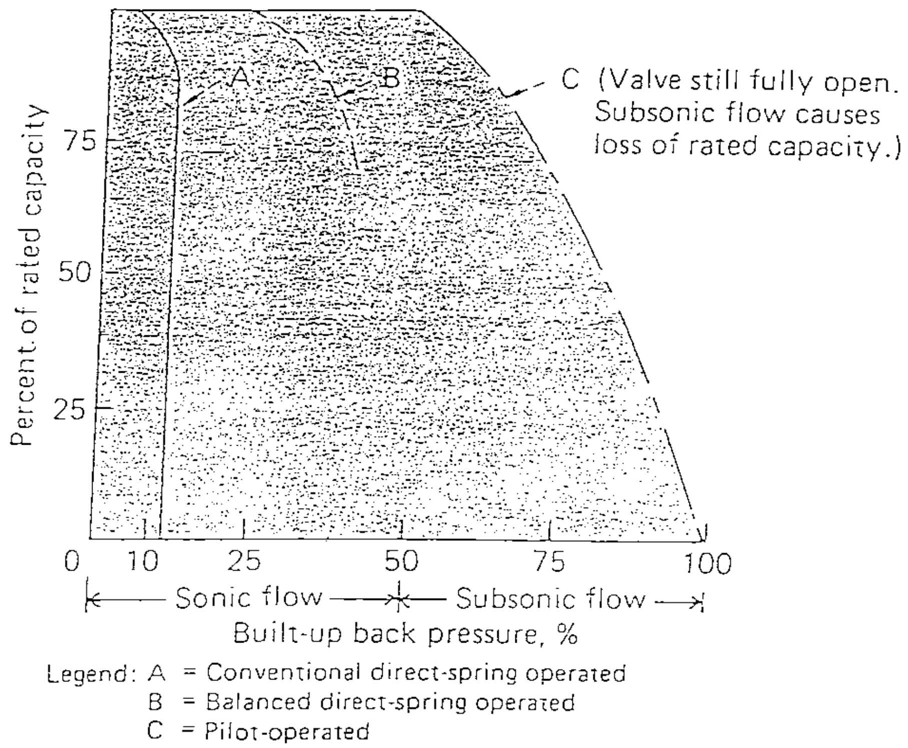


Figure 4.14 Typical back pressure vs. capacity, at 10% overpressure, for different types of pressure relief valves.

4.2.2.1 Determination of the pressure and velocity at the exit of the discharge pipe

<u>Gasflow</u>

Step-1: Assume the exit pressure is atmospheric

$P = 1.013$ bara

Step-2: Calculate the Mach number M_a:

$$M_a = \frac{4m}{\pi D^2 \times 1.013 \times 10^5} \left[\frac{zRT}{k} \right]^{\frac{1}{2}} \qquad \text{EQ. 4.27}$$

where:
- M_a = the Mach no., defined as the ratio of the actual velocity and the sonic velocity
- D = inside diameter discharge pipe, m
- Z = compressibility factor
- R = individual gas constant, j/kg.k
  = R_0/M
- R_0 = universal gas constant = 8314 j/kg.mol.k
- M = molecular weight
- k = ratio of specific heats (c_p/c_v)
- T = absolute temperature at inlet of valve, in Kelvins (= 273 + t)
- t = inlet temperature, ^{0}C

Step-3: If $M_a \leq 1.0$ then the assumed exit pressure in step-1 was correct.
Thus: $P = 1.013$ bara.

If $M_a > 1.0$ then the assumed exit pressure was incorrect.
The correct exit pressure will be: $P = M_a \times 1.013$ bara.

Step-4: Calculate valve relieving pressure P_r

$P_r = P_s$ + overpressure + 1.013

where:
- P_r = relieving pressure, bara
- P_s = set pressure, barg

For 10% overpressure:
$P_r = P_s \times 1.1 + 1.013$

Step-5: Calculate the approximate exit temperature T_e

$$T_e = T - \frac{1}{2}(P_r - P)$$

where: T_e and T in Kelvin
P_r and P in bara

Step-6: Calculate the sonic velocity ϑ_s :

$$\vartheta_s = \left[kRT_e\right]^{\frac{1}{2}} \text{ m/s} \qquad \text{EQ. 4.28}$$

Step-7: Calculate the exit velocity ϑ

If $M_a \leq 1.0$ then $\vartheta = M_a \times \vartheta_s$
If $M_a > 1.0$ then $\vartheta = \vartheta_s$

<u>Steamflow</u> (Ref.: ANSI/ASME B31.1 Power Piping Code, Appendix II)

Step-1: Calculate the exit pressure P

$$P = \frac{4m}{\pi D^2 . 10^5}\left(\frac{b-1}{b}\right)\left[\frac{1995.10^{12}(h-a)}{2b-1}\right]^{\frac{1}{2}} \qquad \text{EQ. 4.29}$$

where: P = pressure at exit of discharge pipe, bara
D = inside diameter discharge pipe, mm
h = specific enthalpy (total heat) at the valve inlet (at absolute set pressure and inlet temperature), kj/kg To be obtained from appendix 4
a and b are listed in table 4.3

Table 4.3

Steam condition	a kj/kg	b dimensionless
Saturated, wet (< 90% Quality)	677	11
Saturated, dry (≥ 90% Quality)	1914	4.33
Superheated	1933	4.33

Step-2: Calculate the exit velocity ϑ

$$\vartheta = \left[\frac{2.10^3(h-a)}{2b-1}\right]^{\frac{1}{2}} \qquad \text{EQ. 4.30}$$

Example 4.3:

Calculate the discharge force of a relief valve venting to atmosphere.

Given data:

medium	:	natural gas
inlet temprature	:	15^0 C
mass flow rate	:	0.75 kg/s
set pressure	:	14.5 barg
overpressure	:	10%
discharge pipe	:	3" sch.40

Solution:

First calculate the pressure and velocity at the exit of discharge pipe in accordance with section 4.2.2.1, then substitute in EQ. 4.26 to obtain the discharge reaction force.

Step-1: Assume P = 1.013 bara

Step-2:

$$M_a = \frac{4m}{\pi D^2 \times 1.013 \times 10^5}\left[\frac{zRT}{k}\right]^{\frac{1}{2}}$$

where:

m =	1.1 x 0.75 kg/s	
D =	77.9×10^{-3} m	(from appendix 3)
Z =	1.0	(if unknown)
R =	426 j/kg.k	(from fig. 4.12 if unknown)
k =	1.27	(from fig. 4.12 if unknown)
T =	273 + 15 = 288 K	

Substituting in M_a equation gives $M_a = 0.53$

Step-3: $M_a < 1.0$ then P = 1.013 bara

Step-4: $P_r = P_s \times 1.1 + 1.013 = 14.5 \times 1.1 + 1.013 = 16.96$ bara

Step-5: $T_e = T - ½(P_r - P) = 288 - ½(16.96 - 1.013) = 280$ K

Step-6: $\vartheta_s = [\,kRT_e\,]^{½} = [\,1.27 \times 426 \times 280\,]^{½} = 389.2$ m/s

Step-7: M_a < 1.0 then $\vartheta = M_a \times \vartheta_s$ = 0.53 x 389.2 = 206.7 m/s

Substitute in EQ. 4.26 to calculate the discharge reaction force.
(note: P = 1.013 bara = 0.0 barg = 0.0 Mpa)

F = 2 (1.1 x 0.75 x 206.7 + 0.0) = 341 N

Example 4.4

Calculate the discharge reaction force of a relief valve venting to atmosphere through dual outlets.

Given data:	medium	: natural gas
	inlet temprature	: 43^0 C
	mass flow rate	: 201.4 kg/s
	set pressure	: 70 barg
	overpressure	: 10%
	compressibility factor	: 0.98
	molecular weight	: 18.63
	ratio of specific heats	: 1.3
	size discharge pipes	: 8" sch.40

Solution

Step-1: Assume P = 1.013 bara

Step-2: $$M_a = \frac{4(\frac{1}{2}m)}{\pi D^2 \times 1.013 \times 10^5}\left[\frac{zRT}{k}\right]^{\frac{1}{2}}$$

Note: For dual outlets the massflow per discharge pipe is ½m.

where:
m = 1.1 x 201.4 kg/s
D = 202.7 x 10^{-3} m
Z = 0.98

$$R = \frac{R_0}{M} = \frac{8314}{18.63} = 446.3 \text{ j/kg.k}$$

k = 1.3
T = 273 + 43 = 316 K

Substituting in M_a equation gives M_a = 11.05

Step-3: M_a > 1.0 then P = M_a x 1.013 = 11.19 bara

Step-4: $P_r = P_s \times 1.1 + 1.013 = 70 \times 1.1 + 1.013 = 78.01$ bara

Step-5: $T_e = T - ½(P_r - P) = 316 - ½(78.01 - 11.19) = 282.6$ K

Step-6: $\vartheta_s = [\,kRT_e\,]^{½} = [\,1.3 \times 446.3 \times 282.6\,]^{½} = 405$ m/s

Step 7: $M_a > 1.0$ then $\vartheta = \vartheta_s = 405$ m/s

Substitute with P and ϑ in EQ. 4.26 to calculate the reaction force per outlet:

$$F = 2\left[1.1 \times \frac{1}{2} \times 201.4 \times 405 + \left(\frac{11.19 - 1.013}{10}\right) \times \frac{\pi}{4}(202.7)^2\right] = 155.4 \quad kN$$

Example 4.5

Calculate the discharge force of a relief valve venting to atmosphere.

Given data:		
	medium	: superheated steam
	inlet temprature	: 538^0 C
	mass flow rate	: 48 kg/s
	set pressure	: 63 barg
	size discharge pipe	: 8" sch.40

Solution

Step-1: Calculate pressure at exit of discharge pipe.

$$P = \frac{4m}{\pi D^2 .10^5}\left(\frac{b-1}{b}\right)\left[\frac{1995.10^{12}(h-a)}{2b-1}\right]^{\frac{1}{2}}$$

where: m = 1.1 x 48 kg/s

h = 3507 ? kj/kg (from appendix 4) at 64 bara and 538 ^{0}C

a = 1933 kj/kg

b = 4.33

D = 202.7 mm (from appendix 3)

Substituting in P equation gives P = 8.06 bara.

Step-2: Calculate velocity at exit of discharge pipe:

$$\vartheta = \left[\frac{2 \times 10^3(3507 - 1933)}{2 \times 4.33 - 1}\right]^{\frac{1}{2}} = 641 \quad m/s$$

substitute in EQ. 4.26 to calculate the discharge reaction force:

$$F = 2\left[1.1 \times 48 \times 641 + \left(\frac{8.06 - 1.013}{10}\right) \times \frac{\pi}{4}(202.7)^2\right] = 113.1 \quad kN$$

Example 4.6

Calculate the discharge force of a relief valve to atmosphere.

Given data:	medium	: saturated dry steam
	mass flow rate	: 1.35 kg/s
	set pressure	: 11 barg
	size discharge pipe	: 2" sch.40

Solution

Saturated steam at any pressure has always a definite temperature (saturation) and a definite specific enthalphy (total heat).

From appendix 4: For steam at 12 bara the specific enthalphy (total heat) is 2782.7 kj/kg.

Step-1: Calculate the exit pressure P.

$$P = \frac{4m}{\pi D^2 . 10^5}\left(\frac{b-1}{b}\right)\left[\frac{1995.10^{12}(h-a)}{2b-1}\right]^{\frac{1}{2}}$$

where:

$m = 1.1 \times 1.35$ kg/s

$h = 2782.7$ kj/kg

$a = 1914$ kj/kg

$b = 4.33$

$D = 52.5$ mm

Substituting in P equation gives P = 2.51 bara.

Step-2: Calculate the exit velocity ϑ

$$\vartheta = \left[\frac{2 \times 10^3(2782.7 - 1914)}{2 \times 4.33 - 1}\right]^{\frac{1}{2}} = 476 \quad m/s$$

substitute in EQ. 4.26 to calculate the discharge reaction force:

$$F = 2\left[1.1 \times 1.35 \times 476 + \left(\frac{2.51 - 1.013}{10}\right) \times \frac{\pi}{4}(52.5)^2\right] = 2063 \quad N$$

stoom

Tabel 1.11 Gegevens homogene series aromacomponenten (25 °C)

stof	normaal kookpunt [°C]	damp-druk [Pa]	activiteits-coëfficiënt γ_i^∞	relatieve vluchtigheid berekend	relatieve vluchtigheid experimenteel
butanol	117,4	1 133	43	15	16
hexanol	155,5	160	680	34	30
octanol	194,5	24	11 000	85	43
aceton	56,2	30 660	7,8	75	70
butan-2-on	79,6	12 000	27	100	82
pentan-2-on	102	4 930	100	160	110
heptan-2-on	151,5	640	1 600	330	260
octan-2-on	172,9	250	6 600	530	330
nonan-2-on	195	100	27 000	870	650
undecan-2-on	228	25	460 000	3 700	1 100
acetaldehyde	21	121 300	4,2	160	120
propanal	48	38 650	16	190	130
butanal	75	12 000	61	240	200
pentanal	103	5 000	250	400	260
hexanal	131	1 600	1 000	500	310
heptanal	153	625	4 200	820	610
octanal	177	225	17 000	1 200	910
nonanal	191	119	71 000	2 700	1 300
methyl acetaat	57,5	22 500	24	240	200
methyl propionaat	79,7	9 330	95	380	310
methyl butyraat	102,3	3 330	390	560	370
methyl pentanoaat	130	973	1 300	560	560
methyl hexanoaat	150	387	7 100	1 200	650
methyl octanoaat	193	49	13 000	2 800	1 000

APPENDIX 4

Tabel 1.12a Gegevens verzadigde stoom

absolute druk [MPa]	tempe-ratuur [°C]	soortelijk volume stoom [m³/kg]	dicht-heid [kg/m³]	soort. enthalpie water [kJ/kg]	verdam-pings warmte [kJ/kg]	soort. enthalpie stoom [kJ/kg]	soortelijk volume water [dm³/kg]
0,001	7,0	129,2	0,0077	29	2484	2513	–
0,002	17,5	67,0	0,0149	73	2459	2533	–
0,003	24,1	45,7	0,0219	101	2444	2545	–
0,004	29,0	34,8	0,0287	121	2433	2554	–
0,005	32,9	28,2	0,0355	138	2423	2561	–
0,006	39,0	20,5	0,0488	163	2409	2572	–
0,01	45,8	14,7	0,068	192	2392	2584	–
0,02	60,1	7,7	0,130	251	2358	2609	–
0,03	69,1	5,2	0,193	289	2335	2624	–
0,05	81,4	3,2	0,312	340	2305	2645	–
0,07	90,0	2,4	0,416	377	2282	2659	–
0,1	99,6	1,69	0,591	417	2257	2674	1,044
0,2	120,2	0,89	1,12	505	2200	2705	1,061
0,3	133,5	0,61	1,64	561	2162	2723	1,074
0,4	143,6	0,46	2,18	604	2132	2737	1,084
0,5	151,8	0,37	2,70	640	2107	2747	1,093
0,7	165,0	0,27	3,71	697	2065	2762	1,108
1	179,9	0,19	5,24	762	2015	2777	1,128
2	212,4	0,100	10,1	908	1893	2801	1,177
3	233,8	0,067	14,7	1008	1798	2806	1,217
4	250,3	0,050	20,0	1087	1715	2802	1,252
5	264,0	0,039	25,6	1154	1641	2795	1,286
6	275,6	0,032	31,3	1213	1571	2784	1,319
8	295,0	0,023	43,5	1316	1440	2756	1,384
10	311,0	0,018	54,2	1407	1318	2726	1,451
12	324,6	0,0143	70,0	1490	1197	2687	1,525
14	336,6	0,0115	93,0	1570	1067	2637	1,610
16	347,3	0,0093	108,0	1649	932	2581	1,713
18	357,0	0,0075	133,0	1733	778	2511	1,85
20	365,7	0,0059	169,0	1827	590	2417	2,06
22	373,7	0,0039	256,0	2010	208	2218	2,64
22,13	374,2	0,0032	313,0	2099	0	2099	3,20

Stoom

APPENDIX 4

Tabel 1.12b Soortelijke enthalpie oververhitte stoom [kJ/kg]

stoom-druk [MPa]	verzadigings temp. [°C]	temperatuur [°C] 200	250	300	400	500	600	700	800
0,1	99,6	2875	2974	3074	3277	3487	3704	3927	4158
0,2	120,2	2870	2970	3071	3276	3486	3703	3927	4158
0,3	133,5	2866	2967	3068	3274	3485	3702	3926	4157
0,4	143,6	2861	2964	3066	3272	3484	3701	3926	4156
0,5	151,8	2857	2966	3063	3271	3483	3700	3925	4156
0,7	165,0	2847	2954	3058	3268	3481	3699	3924	4155
1,0	179,9	2831	2943	3051	3263	3479	3697	3922	4154
2,0	212,4	–	2906	3024	3246	3466	3689	3916	4149
3,0	233,8	–	2859	2995	3230	3455	3681	3910	4144
4,0	250,3	–	–	2963	3213	3444	3673	3904	4140
5,0	264,0	–	–	2927	3195	3433	3665	3898	4135
6,0	275,6	–	–	2886	3177	3421	3657	3892	4130
8,0	295,0	–	–	2784	3139	3398	3641	3880	4121
10	311,0	–	–	–	3098	3375	3625	3868	4112
12	324,6	–	–	–	3053	3351	3608	3856	4103
14	336,6	–	–	–	3002	3326	3592	3844	4093
16	347,3	–	–	–	2946	3300	3576	3832	4084
18	357,0	–	–	–	2884	3274	3559	3820	4074
20	365,7	–	–	–	2815	3246	3542	3809	4066
22	373,7	–	–	–	2738	3217	3525	3796	4057
23	–	–	–	–	2692	3202	3516	3790	4052
24	–	–	–	–	2640	3187	3508	3784	4048
25	–	–	–	–	2579	3172	3499	3778	4043
26	–	–	–	–	2509	3156	3490	3772	4038
28	–	–	–	–	2321	3123	3472	3760	4030
30	–	–	–	–	2151	3089	3454	3748	4021
35	–	–	–	–	1988	3002	3408	3717	3998
40	–	–	–	–	1928	2911	3360	3686	3976
45	–	–	–	–	1895	2819	3311	3654	3953
50	–	–	–	–	1870	2731	3263	3623	3931

Tabel 1.12c Soortelijk volume oververhitte stoom [m³/kg]

stoomdruk [MPa]	oververhittingstemperatuur [°C] 200	250	300	400	500	600
0,1	2,17	2,4	2,6	3,1	3,6	4,12
0,2	1,08	1,20	1,31	1,55	1,78	2,01
0,3	0,72	0,80	0,9	1,–	1,2	1,3
0,4	0,54	0,6	0,65	0,77	0,89	1,01
0,5	0,43	0,47	0,52	0,62	0,71	0,9
1,0	0,21	0,23	0,26	0,31	0,35	0,4
1,5	0,13	0,15	0,17	0,2	0,24	0,27
2,0		0,11	0,13	0,15	0,18	0,2
2,5		0,9	0,1	0,12	0,14	0,16
3,0		0,07	0,8	0,1	0,12	0,13
4,0			0,06	0,07	0,09	0,1
5,0			0,045	0,06	0,07	0,08
6,0			0,04	0,05	0,06	0,07
8,0			0,02	0,03	0,04	0,05
10,0				0,025	0,03	0,04
12,5				0,02	0,025	0,03
15,0				0,016	0,02	0,025
17,5				0,012	0,017	0,02
20,0				0,01	0,015	0,018

Tabel 1.13 Warmte-overdrachtscoëfficiënten α [W/(m² · K)]

	α
gas (vrije convectie)	5–15
gas (gedwongen convectie)	10–100
vloeistof (vrije convectie)	50–1000
vloeistof (gedwongen convectie)	500–3000
water in rust	350–580
water (geforceerde stroming)	580–2300
condenserend water	11 600
condenserend ammoniak	9 300
condenserend R_{12}, R_{22}	2 300