Reference material for Safety Relief Valves

Applicable code and calculating formula for certified capacity

For steam, air and gas

Note : ([1]) As per your request, we can calculate by JIS B 8210-2009.

Code and Regulation	Formula	Symbol
Boiler construction code Pressure vessel construction code JIS B 8210-1994 Spring loaded safety valves for steam and gas services ([1])	Steam $Qm=5.246CKd'A(P+0.1)\times0.9$	Qm : Certified capacity kg/h C : Coefficient determined by steam property (Refer to Table 1). In case relieving steam is less than 0.4MPa with saturated temperature C=1 Kd' : Relieving coefficient For full bore type : 0.864 For lift type : 0.981 when L=D/40 : 0.847 when L=D/25 L : Lift mm D : Seat opening diameter mm A : Discharge area mm^2 For full bore type : $A=\pi d^2/4$ (Throat area) For lift type (Flat seat) : $A=\pi DL$ (Conic seat) : $A=\pi DL\sin\theta$ d : Throat diameter mm θ : Angle of seat to shaft P : Relieving pressure MPa·G At boiler construction code and JIS B 8210 Set press.×1.03 for Set press. >0.1MPa Set press.+0.02MPa for Set press. ≦0.1MPa At pressure vessel construction code Set press.×1.1 or Set Press+0.02MPa whichever is larger Remark : As for d, A, D and L of type RPN6B, please refer to table 4.
Pressure vessel construction code JIS B 8210-1994 Spring loaded safety valves for steam and gas services ([1])	Gas $Qm=C'Kd'AP_1\sqrt{\frac{M}{ZT}}\times0.9$	Qm : Certified capacity kg /h P_1 : Absolute relieving pressure MPa abs Set press.×1.1 or Set Press+0.02MPa whichever is larger C' : Coefficient in Figure 1 depending on k and P_2/P_1 C'=24 at k is unknown (k=1.0) k : Adiabatic index P_2=Absolute back pressure MPa abs Kd' : Relieving coefficient For full bore type : 0.864 For lift type : 0.981 when L=D/40 : 0.847 when L=D/25 L : Lift mm D : Seat opening diameter mm A : Discharge area mm^2 For full bore type : $A=\pi d^2/4$ (Throat area) For lift type (Flat seat) : $A=\pi DL$ (Conic seat) : $A=\pi DL\sin\theta$ d : Throat diameter mm θ : Angle of seat to shaft M : Molecular weight of gas Z : Compression factor (Refer to Figure 2) T : Absolute temperature of gas at relieving pressure K
High pressure gas safety act	Gas 1) In case P_2/P_1 corresponding to adiabatic index k is not more than the value of Table 2 $W=CKP_1A\sqrt{\frac{M}{ZT}}$ 2) In case P_2/P_1 corresponding to adiabatic index k is more than the value of Table 2 $W=5580KP_1A\sqrt{\frac{k}{k-1}\left\{\left(\frac{P_2}{P_1}\right)^{\frac{2}{k}}-\left(\frac{P_2}{P_1}\right)^{\frac{k+1}{k}}\right\}}\cdot\sqrt{\frac{M}{ZT}}$	k : Adiabatic index P_1 : Absolute relieving pressure (Set press.+accumulation press.+0.1) MPa abs Accumulation pressure Compressed gas : 10% of set press. Liquefied gas : 20% of set press. P_2 : Absolute back pressure MPa abs A : Discharge area cm^2 For full bore type : $A=0.01\pi d^2/4$ (Throat area) For lift type (Flat seat) : $A=0.01\pi DL$ D : Seat opening diameter mm L : Lift mm d : Throat diameter mm W : Relieving capacity kg /h C : Coefficient in Table 2 depending on k (In case k is unknown, C=2380) K : Relieving coefficient For full bore type : 0.777 For lift type (flat seat) : 0.875 M : Molecular weight of gas T : Absolute temperature of gas at relieving pressure K(: ℃+273)

Applicable code and calculating formula for certified capacity

For liquid

Code and Regulation	Formula	Symbol
General use	$W=161AK\sqrt{(P_1-P_2)G}\times Kp$ Correction should be done at viscosity over 20mm²/s	W : Relieving capacity kg /h A : Discharge area mm² For full bore type : $A=\pi d^2/4$ (Throat area) For lift type (Flat seat) : $A=\pi DL$ (Conic seat) : $A=\pi DL\sin\theta$ d : Throat dia mm D : Seat opening diameter mm L : Lift mm θ : Angle of seat to shaft K : Flow coefficient For both full bore and lift type : 0.6 P_1 : Relieving pressure Set press.×1.25 or Set Press+0.02 which is larger P_2 : Back pressure MPa G : Specific gravity (Water : 1) Kp : Accumulation pressure correction factor In case accumulation pressure is 25% of set pressure, Kp = 1 (but minimum 0.02MPa). Refer to Figure 3.
Hot-water relief valve of Boiler construction code and Pressure vessel construction code	① When obtain from relieving capacity $S=\frac{W}{87.7\sqrt{(P_1+0.1)\kappa\gamma_1}}\times\frac{1}{Kp}$ ····· (1) ② When obtain from pressure vessel thermal input or boiler thermal output $S=\frac{Q\varepsilon}{87.7C\sqrt{(P_1+0.1)\kappa\gamma_1}}\times\frac{1}{Kp}$ ····· (2)	S : Discharge area mm² W : Relieving capacity kg/h κ : Correction factor (Refer to Figure 4) where △t : Differential between sat. temp. corresponding to P1 and inlet hot-water temp. (℃) P_1 : Relieving pressure MPa Set press.×1.1 or Set Press+0.034 whichever is larger γ_1 : Inlet hot-water specific gravity (kg / ℓ) (Refer to Table 5) Q : Pressure vessel thermal input or boiler thermal output kJ/h ε : Expansion coefficient of water (Refer to table 3) C : Specific heat of water (kJ/ kg℃) (Refer to table 3) Kp : Same as above.

Table 1. Coefficient C according to steam property

Absolute pressure MPa	Temperature (℃)																
	Saturated temperature	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500
0.5	1.005	0.996	0.972	0.951	0.931	0.913	0.896	0.879	0.864	0.849	0.835	0.822					
1.0	0.987	0.981	0.983	0.960	0.938	0.919	0.901	0.884	0.868	0.853	0.838	0.825					
1.5	0.977	0.976	0.970	0.972	0.947	0.925	0.906	0.888	0.872	0.856	0.841	0.828					
2.0	0.972		0.967	0.964	0.955	0.932	0.912	0.893	0.876	0.860	0.845	0.830	0.817	0.804	0.792	0.780	0.768
2.5	0.969			0.961	0.961	0.937	0.918	0.898	0.880	0.863	0.848	0.833	0.819	0.806	0.793	0.782	0.770
3.0	0.967			0.962	0.957	0.949	0.924	0.903	0.885	0.867	0.851	0.836	0.822	0.808	0.795	0.783	0.774
4.0	0.965				0.958	0.954	0.934	0.915	0.894	0.875	0.857	0.841	0.826	0.813	0.799	0.787	0.775
5.0	0.966					0.955	0.953	0.927	0.904	0.884	0.865	0.848	0.832	0.817	0.803	0.790	0.778
6.0	0.968					0.962	0.953	0.941	0.911	0.891	0.872	0.854	0.838	0.822	0.808	0.794	0.781
7.0	0.971						0.958	0.954	0.924	0.901	0.881	0.861	0.844	0.827	0.812	0.798	0.785
8.0	0.975						0.967	0.956	0.937	0.912	0.888	0.868	0.850	0.833	0.817	0.802	0.789
9.0	0.980							0.962	0.957	0.926	0.897	0.876	0.856	0.838	0.822	0.807	0.792
10.0	0.986							0.971	0.961	0.936	0.909	0.883	0.863	0.844	0.827	0.811	0.796

Remarks 1. Intermediate values of pressures and temperature in this table are calculated by proportional method.
2. Absolute pressure is placed by relieving pressure.

Table 2. Coefficient C according to k

k	C	P_2/P_1	k	C	P_2/P_1	k	C	P_2/P_1	k	C	P_2/P_1
1.00	2380	0.606	1.20	2550	0.563	1.40	2700	0.528	1.60	2820	0.496
1.02	2410	0.602	1.22	2570	0.559	1.42	2710	0.525	1.62	2830	0.493
1.04	2420	0.597	1.24	2590	0.556	1.44	2720	0.522	1.64	2850	0.490
1.06	2440	0.593	1.26	2600	0.552	1.46	2730	0.518	1.66	2860	0.488
1.08	2460	0.588	1.28	2620	0.549	1.48	2750	0.515	1.68	2870	0.485
1.10	2480	0.584	1.30	2630	0.545	1.50	2760	0.512	1.70	2880	0.482
1.12	2490	0.580	1.32	2650	0.542	1.52	2770	0.509	1.80	2940	0.468
1.14	2500	0.576	1.34	2660	0.538	1.54	2790	0.505	1.90	2980	0.456
1.16	2520	0.571	1.36	2680	0.535	1.56	2800	0.502	2.00	3030	0.444
1.18	2540	0.567	1.38	2690	0.531	1.58	2810	0.499	2.20	3130	0.422

Remark : In case k takes middle value, obtain P_2/P_1 with interpolation and below 4 places and disregards below decimal point for C.

Applicable code and calculating formula for certified capacity

Figure 1. Coefficient C' depending on k and P_2 / P_1

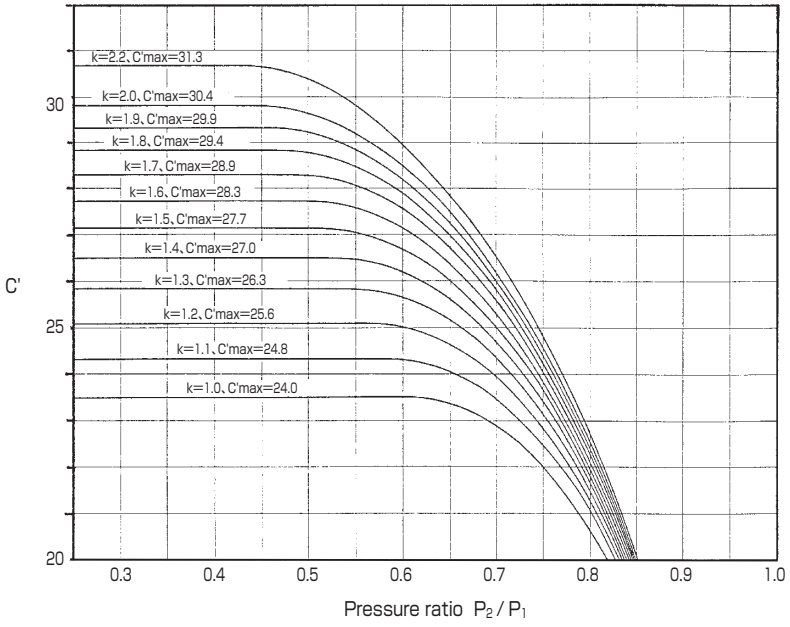


Table 3. Specific heat and expansion coefficient of hot water

Temperature ℃	Specific heat kJ/kg℃	Expansion coefficient ε ℓ /℃
40	4.179	0.00039
50	4.181	0.00046
60	4.185	0.00053
70	4.190	0.00060
80	4.197	0.00066
90	4.205	0.00072
100	4.216	0.00079
110	4.229	0.00085
120	4.245	0.00090
130	4.263	0.00097
140	4.285	0.00103
150	4.310	0.00110
160	4.339	0.00118
170	4.371	0.00126
180	4.408	0.00134
190	4.449	0.00145
200	4.497	0.00155
210	4.551	0.00165
220	4.613	0.00179

Remark : Intermediate values of pressures and temperatures in this table are calculated by proportional method.

Figure 2. Compression factor

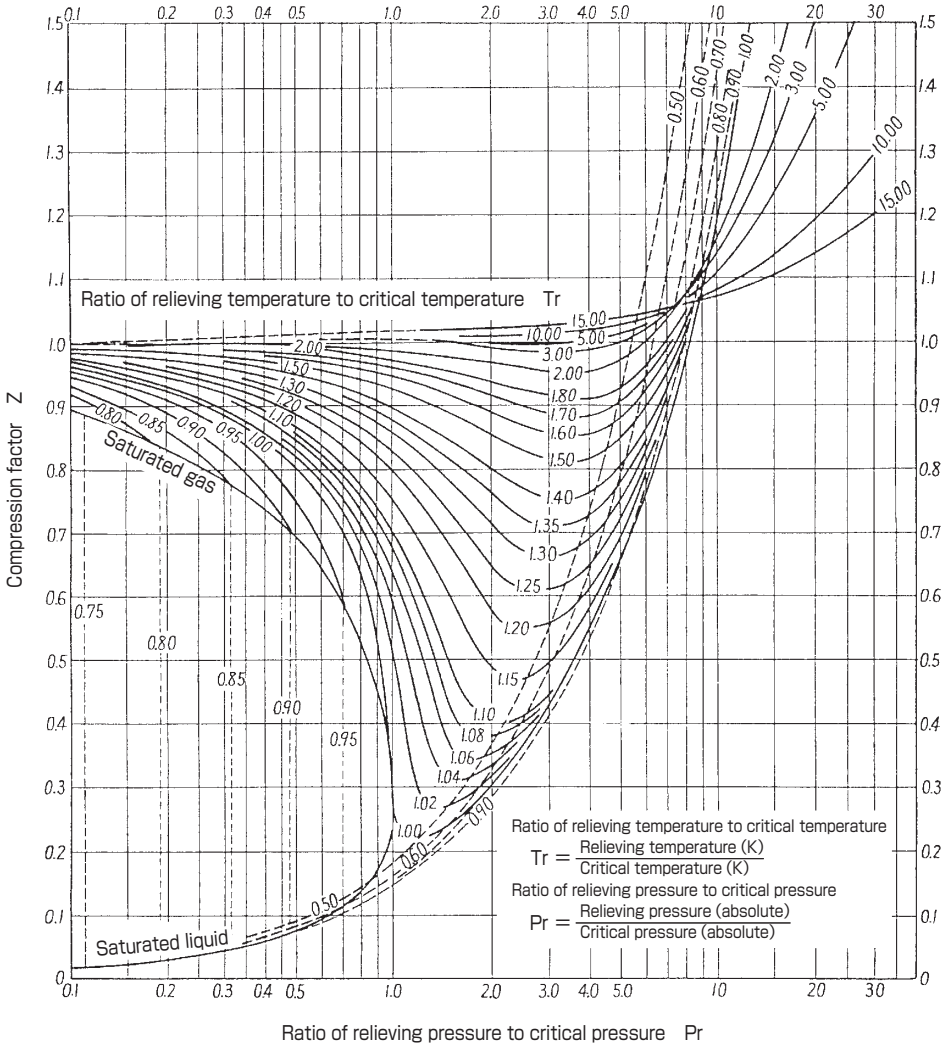


Table 4. Type RPN6B orifice size

orifice	Throat diameter d (mm)	Discharge area A (mm^2)	Seat opening diameter D (mm)	Lift L (mm)
E	12.7	126.6	15.0	2.9
F	15.9	198.5	23.5	2.9
G	20.4	326.8	23.5	4.7
H	25.4	506.7	29.3	5.8
J	32.6	834.6	37.5	7.5
K	38.9	1188	44.8	8.9
L	48.5	1847	55.8	11.1
M	54.4	2324	68.8	11.4
N	59.8	2808	68.8	13.7
P	72.4	4116.8	83.3	16.6
Q	95.3	7133	109.6	21.8
R	114.7	10330	132	26.2
T	146.2	16780	170	33.5

Applicable code and calculating formula for certified capacity

Table 5. Hot-water specific gravity γ_1 kg/ℓ

Temperature ℃ \ Absolute pressure MPa・A	0.1	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.5
40	0.992	0.992	0.992	0.993	0.993	0.993	0.993	0.993	0.993	0.993	0.993	0.993	0.993
50	0.988	0.988	0.988	0.988	0.988	0.988	0.989	0.989	0.989	0.989	0.989	0.989	0.989
60	0.983	0.983	0.983	0.983	0.983	0.984	0.984	0.984	0.984	0.984	0.984	0.984	0.984
70	0.978	0.978	0.978	0.978	0.978	0.978	0.978	0.978	0.978	0.978	0.979	0.979	0.979
80	0.972	0.972	0.972	0.972	0.972	0.972	0.972	0.972	0.972	0.972	0.973	0.973	0.973
90	0.965	0.965	0.965	0.965	0.965	0.966	0.966	0.966	0.966	0.966	0.966	0.966	0.966
100		0.958	0.958	0.958	0.958	0.959	0.959	0.959	0.959	0.959	0.959	0.959	0.959
110		0.951	0.951	0.951	0.951	0.951	0.951	0.951	0.951	0.951	0.952	0.952	0.952
120		0.943	0.943	0.943	0.943	0.943	0.943	0.943	0.944	0.944	0.944	0.944	0.944
130			0.935	0.935	0.935	0.935	0.935	0.935	0.935	0.935	0.935	0.936	0.936
140			0.926	0.926	0.926	0.926	0.926	0.926	0.927	0.927	0.927	0.927	0.927
150				0.917	0.917	0.917	0.917	0.917	0.917	0.918	0.918	0.918	0.918
160					0.907	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908
170					0.897	0.897	0.898	0.898	0.898	0.898	0.898	0.898	0.898
180							0.887	0.887	0.887	0.887	0.888	0.888	0.888
190								0.876	0.876	0.876	0.877	0.877	0.877
200									0.865	0.865	0.865	0.865	0.865
210											0.853	0.853	0.853
220													0.841

Remark : Intermediate values of pressures and temperatures in this table are calculated by proportional method.

Figure 3. Accumulation pressure correction factor Kp

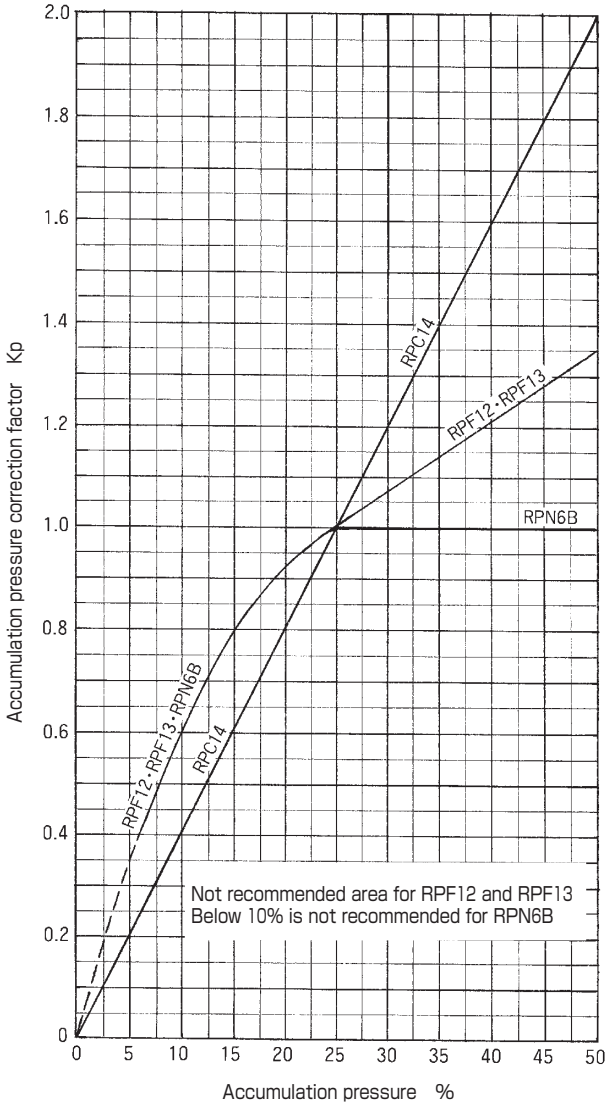
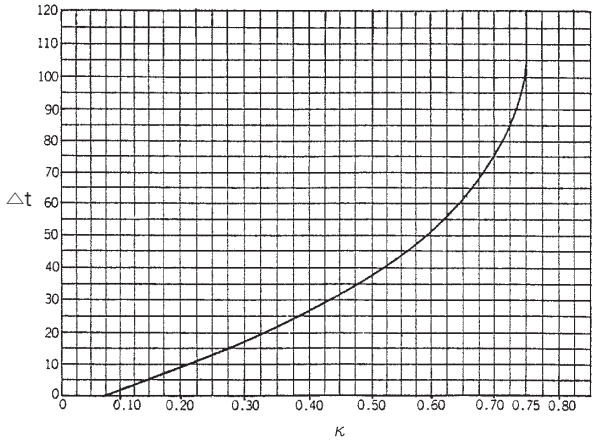


Figure 4. Correction factor κ depending on △ t℃

(In case of Boiler construction code and Pressure vessel construction code)



Performance

●Tolerance of opening pressure

○ Setting by popping pressure (Comply with JIS B8210)
(For steam and gas) (MPa)

Set pressure	Tolerance
Less than 0.5	±0.014
0.5 to lower than 2.3	±3%×set pressure
2.3 to lower than 7.0	±0.07
7.0 and over	±1%×set pressure

●Setting by start-to-discharge pressure

(For gas and liquid) (MPa)

Set pressure	Tolerance
Lower than 0.5	±0.025
0.5 and over	±5%×set pressure

●Blow down pressure

○ Blow down pressure of safety valve and safety relief valve for steam
(Setting by popping pressure) (MPa)

Set pressure	Blow down pressure
0.3 or lower	0.03 and below
over 0.3	10% of set pressure and below

○ Blow down pressure of safety relief and relief valve for liquid
(Setting by start-to-discharge pressure) (MPa)

Set pressure	Blow down pressure
0.2 or lower	0.03 and below
over 0.2	15% of set pressure and below

○ Blow down of safety and safety relief valve for gas
(Setting by popping pressure or start-to-discharge pressure) (MPa)

Set pressure	Blow down pressure	
	Metal seat valve	Soft seat valve
0.2 or lower	0.03 and below	0.05 and below
over 0.2	15% of set pressure and below	25% of set pressure and below

●Allowable over pressure (%)

Application		Allowable over pressure
Boiler construction code	Steam	3 (1)
	Hot water	10 (but min. 0.034MPa)
Pressure vessel construction code	Steam, gas	10 (but min. 0.02MPa)
	Hot water	10 (but min. 0.034MPa)
High pressure gas safety act	Compressed gas	10
	Liquefied gas	20
Water, oil, other liquid		25 (but min. 0.02MPa)

Note (1) : 0.02MPa and below at 0.1MPa and lower of popping pressure.

Terms

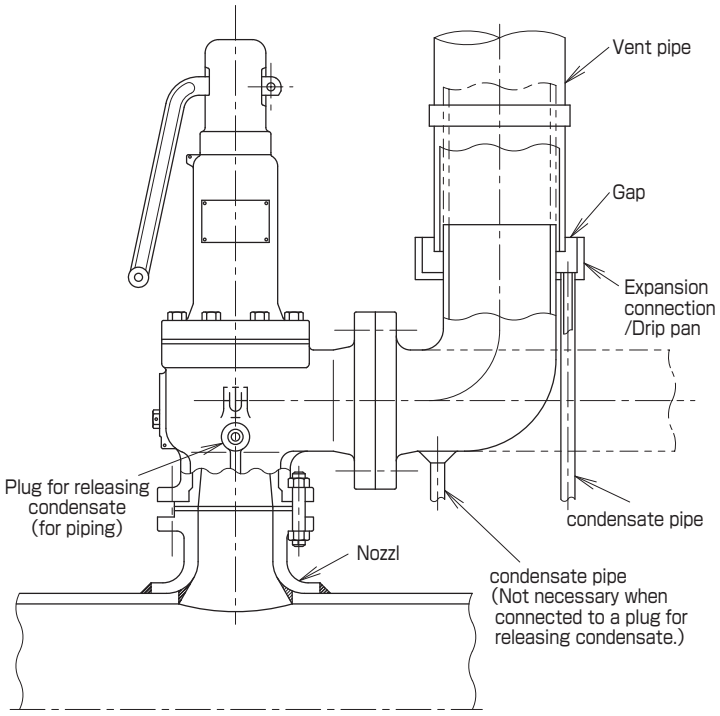
1. **Safety valve**
Spring loaded safety valve for steam or gas which is used for steam boiler or pressure vessel. Valve has a popping characteristic.
2. **Safety relief valve**
Spring loaded safety relief valve for steam, gas or liquid which is used for pressure vessel or piping line. Valve has a popping characteristic or a feature to increase lift relatively to pressure.
3. **Relief valve**
Relief valve to release excess pressure for liquid. Valve has a characteristic to increase lift relatively to pressure.
4. **Set pressure**
Popping pressure for safety and safety relief valve which is specified as set pressure by customer. Start-to-discharge pressure for safety relief and relief valve which is specified as set pressure by customer. Set pressure is written on name plate.
5. **Start-to-discharge pressure**
Start-to-discharge pressure which is sensed small flow (2) at outlet. In case of popping pressure as a set pressure, start-to-discharge pressure which is sensing small flow (2) before popping.
Note (2) : Seat leakage is out of "small flow".
6. **Popping pressure**
Inlet pressure for safety valve and safety relief valve when fluid is discharged by popping.
7. **Closing pressure, reseating pressure**
The inlet pressure when valve reseated after blow and no flow (3) at outlet.
Note (3) : Seat leakage is out of "flow".
8. **Reseating pressure**
Inlet pressure at no seat leakage after closing.
9. **Blow down**
(a) Difference between popping pressure and closing pressure for safety and safety relief valve which is set by popping pressure. But in case of request no seat leakage, it is difference between popping pressure and seal pressure.
(b) Difference between start-to-discharge pressure and closing pressure for safety relief and relief valve which is set by start-to-discharge pressure. But in case of request no seat leakage, it is difference between start-to-discharge pressure and reseating pressure.
10. **Over pressure**
Pressure which is increased from set pressure at operating condition for safety, safety relief and relief valve. It is expressed by percent of set pressure or MPa.
11. **Back pressure**
Outlet pressure of valve. There are following two cases.
(a) Built-up back pressure : Pressure arisen by friction loss of discharge flow.
(b) Existing back pressure : Pressure existed at outlet of valve before blowing off.
12. **Lift**
Valve shaft movement from closed position to opening position.
13. **Seat diameter**
Inside diameter of seat circle contacted with disc.
14. **Throat diameter**
Narrowest diameter of nozzle between fluid inlet to seat.
15. **Effective discharge area**
Minimum area of fluid pass between valve seat and throat.
16. **Compression factor**
Correction factor depending on characteristics difference between ideal gas and real gas.
17. **Relieving coefficient**
Ratio of actual capacity to ideal capacity.
18. **Lift type safety valve, safety relief valve and relief valve**
Safety valve, safety relief valve and relief valve which lift is over 1/40 and lower than 1/4 of valve seat, and seat flow area is smallest in the flow area.
19. **Full bore type safety valve, safety relief valve**
Safety valve and safety relief valve which seat flow area is bigger than the throat area.

Notes for installation and maintenance of safety relief valve

1. Nozzle to install safety relief valve

1.1 The nozzle to install safety relief valve and vent pipe should have sufficent strength to endure internal pressure and contrary force due to discharge.

1.2 The pressure drop of the nozzle should be less than 3% of discharge pressure. A large pressure drop will be the cause of unstable operation.



2. Vent pipe

2.1 Installation of an expansion connection/drip pan is recommended to separate from a vent pipe.
Where there are chain double-dashed lines in the figure, this denotes that supports will be required to endure the weight of the pipe as well as the contrary force due to dischange.
The weight of the pipe could cause valve body distortion and seat leakage.

2.2 When vent pipe is connected to closed vessel or fixed to a building frame, please ensure that the force of expansion and contraction of the pipe does not apply force to the valve.
It will be cause of body damage as well as seat leakage.

2.3 Eeach valve should have vent pipe. If the vent pipe have to be joined, each junction angle should not be over 45°. Where the fulid from the separate pipes join one pipe the area into which the fluid flows should be bigger than the total area of the separate pipes.

2.4 When an expansion connection/drip pan is used, the flow area in the vent pipe should be more than 2.5 times larger than the flow area in the expansion connection/drip pan. Otherwise friction in the vent pipe will result in steam escaping from the gap between the expansion connection/drip pan and the vent pipe and cause serious injury.

3. Condensate piping

In the case of safety relief valves for steam, condensate piping should be installed. Condensate will cause seat distortion and leakage, due to thermal stress. Condensate piping should be provided to each valve individually.

4. Installation area

In the case of indoor installation, discharge flow should be lead outdoors.

5. Back pressure

Built-up back pressure of safety valves in this catarog should be less than 10% of opening pressure.

Maintenance

We recommend that periodical maintenace is done once a year or more.

Warning	①The nozzle for the safety valve and support for vent pipe should be of sufficient strength. Breakage of the nozzle may be the cause of personal injury or physical damage. ②The outlet of the safety valve or vent pipe should be located where discharge flow cannot cause serious injury or damage.