

Instruction

Designing and selecting pressure regulating valves is not a secret science mastered only by a handful of experts. The procedure described below allows the user to select a suitable valve for a particular application with relatively little effort. The calculations based on the so-called K_v value method have been considerably simplified compared with the very accurate calculations given in IEC 534; they produce, however, results which for our purposes are sufficiently accurate.

The K_v value is the flow coefficient which corresponds to a water flow rate -given in m^3/h - at a differential pressure of 1 bar and a water temperature between 5 and 30 °C.

The American system uses the flow coefficient C_v which corresponds to a water flow rate -given in USgal/min- at a pressure difference of 1 psi and a water temperature of 60 °F. The relationship between K_v and C_v is:

$$K_v = 0,86 \times C_v$$

The K_{vs} value quoted in technical documentation is the K_v value at nominal valve lift for a specific series of valves. The K_{vs} value allows the maximum throughput to be calculated for a valve.

The methods of calculating the K_v value described here have been, as mentioned above, considerably simplified. Many factors have been excluded from the calculation. By treating steam as an ideal gas and excluding the specific volume, a maximum error of 5% may result which, however, in view of the allowances used, is acceptable.

The calculations are simple; a knowledge of basic arithmetic and finding roots is sufficient. Tables or diagrams are not absolutely necessary but can be helpful if available.

The operating pressures and setting ranges specified in our design examples are given as pressures above atmospheric [barg = bar], as is customary. The calculations, on the other hand, are based on absolute pressures [bara]. For instance, if an outlet pressure of 7 bar is specified an absolute pressure of $7 + 1 = 8$ bara must be used in the calculation.

Flow rate and density should be specified for liquids in their operating state and for gases in their standard state (0°C, 1013 mbar).

Pressure Regulators for Liquids

Calculation of the K_v -value

To design or select a valve you should first calculate the K_v value from the operating data at which the valve is to operate

$$K_v = Q \sqrt{\frac{\rho}{1000 \cdot \Delta p}}$$

K_v	Flow Coefficient	m^3/h
Q	Volume Flow	m^3
ρ	Density	kg/m^3
p_1	Inlet Pressure (abs.)	bar
p_2	Outlet Pressure (abs.)	bar
Δp	Differential Pressure ($p_1 - p_2$)	bar

Example:

We are looking for a pressure reducing valve for 2-7 m^3/h of methanol having a density of 790 kg/m^3 ; the inlet pressure varies between 9 and 12 bar and the outlet pressure is to be maintained at 4 bar.

In our calculation we use the maximum flow rate and the minimum pressure drop

$$K_v = 7 \sqrt{\frac{790}{1000 \cdot 5}} = 2,78 \text{ m}^3/h$$

To the K_v - value calculated from the operating data we add an allowance of 30 % and thus obtain the minimum K_{vs} - value which the valve should have

$$K_{vs} \text{ value} \geq 1.3 \times K_v \text{ value} = 1.3 \times 2.78 = 3.61 \text{ m}^3/h$$

Calculating the nominal diameter

To keep pressure drop and noise within acceptable limits, certain flow velocities in the pipelines should not be exceeded e.g.

» suction side of centrifugal pumps	2 m/s
» suction side of reciprocating pumps	1 m/s
» delivery side of pumps	5 m/s
» local drinking water supplies	1 m/s
» water or fuel trunk pipelines	3 m/s
» high-viscosity liquids	1 m/s

Pipeline diameter can be calculated as follows

$$d = 18,8 \sqrt{\frac{Q}{w}}$$

d	Pipeline Diameter	mm
Q	Volume Flow	m^3/h
w	Flow Velocity	m/s

If in our Example we permit a maximum flow velocity of 2 m/s, the required pipeline diameter will be

$$d = 18,8 \sqrt{\frac{7}{2}} = 35,2$$

In this case we would select a pipe of 40 mm nominal diameter (DN 40).

For a given pipeline diameter the flow velocity can be calculated as follows

$$w = 354 \frac{Q}{d^2}$$

In our example the flow velocity for a DN 40 pipeline and a flow rate of 7 m^3/h would be

$$w = 354 \frac{7}{40^2} = 1,55 \text{ m/s}$$

For certain operating conditions a control valve may be selected whose nominal diameter is one or two sizes smaller than the nominal pipeline diameter; this applies especially to valves with sense line.

Selecting a suitable valve

Our selection tables and data sheets contain all the technical data needed to select MANKENBERG valves.

The K_{vs} value of the selected valve should be equal to the calculated K_v value plus the required allowance. Most valves operate most efficiently within 10 to 70 % of their K_{vs} values; small non-balanced valves such as our pressure reducers DM 502, 505, 506, 510, 762 and 765, will operate satisfactorily even at minimum flow rates.

You should select a setting range which places the required control pressure at the top end. If, for instance, the pressure to be controlled is 2.3 bar, you should select the 0.8-2.5 bar range rather than the 2-5 bar range, as with the latter the control errors would be considerably greater. If in special cases the standard setting range is not wide enough, a lower setting range may be selected provided the valve operates at low capacity and the control accuracy is of minor importance. Under such conditions, for instance, a pressure reducer featuring a setting range of 0.8-2.5 bar may still operate satisfactorily at 0.5 bar.

You should select the materials in accordance with the operating requirements by using the material resistance table.

Let us return to our example:

Based on the operating data we had calculated a minimum K_{vs} value of 3.61 m^3/h . According to our selection table several valve types meet this requirement. In view of the properties of the fluid to be handled we select pressure reducer DM 652, DN 25, K_{vs} value 6 m^3/h , setting range 2-5 bar, spring cap with leakage line connection. In its standard version this valve is manufactured from materials which are compatible with methanol. Additional features are high control accuracy, low weight, good surface quality and a price which is remarkably low for a stainless steel valve.

Here is another example:

We are looking for an overflow valve (back pressure regulator) capable of discharging 250 m^3/h of drinking water into an open reservoir at a pressure of 10 bar. First we calculate the K_v value corresponding to the operating data. Although the pressure drop ($p_1 - p_2$) is 10 bar, we shall use for our calculation a pressure drop of only $0.6 \times p_1$ [bara] = 6.6 bar because of the evaporation which occurs across the valve.

Thus:

$$K_v = 250 \sqrt{\frac{1000}{1000 \cdot 6,6}} = 97,3 \text{ m}^3/h$$

Hence the K_{vs} value of the valve should be at least

$$K_{vs} \text{ value} = 1.3 \times K_v \text{ value} = 1.3 \times 97.3 = 126.5 \text{ m}^3/h$$

We select the pilot operated overflow valve UV 824, DN 200, K_{vs} value 180 m^3/h , setting range 4-12 bar, a relatively economical, lightweight and very accurate control valve made from steel or better stainless steel.

Let us give another example:

We are looking for a CIP pressure reducing valve capable of reducing the pressure of demineralized water from 2-4 bar to 0.7 bar at a rate of 1-3 l/min . The pipeline has a nominal diameter of 25 mm and Tri Clamp connection.

Based on the operating data we again calculate the K_v value as follows:

$$K_v = 0.003 \times 60 \sqrt{\frac{1000}{1000 \cdot 1.3}} = 0.16 \text{ m}^3/h$$

Hence the K_{vs} value of the valve should be at least

$$K_{vs} \text{ value} = 1.3 \times K_v \text{ value} = 1.3 \times 0.16 = 0.21 \text{ m}^3/h$$

We select the pressure reducer DM 152, DN 25, K_{vs} value 3.5 m³/h, setting range 0.8-2.5 bar, an angled stainless steel valve which can be polished. We have selected this valve, although its K_{vs} value is relatively high and the required outlet pressure is outside the specified setting range, because extensive bench testing has shown that this valve is ideal for the above-mentioned operating conditions.

We have used this example to demonstrate that in special cases valves can be used outside the parameter ranges specified in the catalogue provided that the user has a good knowledge of the operating characteristics of the valve.

Pressure Regulators for Gas

Calculation of the K_v value

The selection of a valve first of all that the K_v value is determined from the operating data under which the valve is to operate. For subcritical pressure drops, i.e. if

$$\Delta p < \frac{p_1}{2}$$

use formula

$$K_V = \frac{Q_N}{514} \sqrt{\frac{\rho_N(t_1 + 273)}{\Delta p \times p_2}}$$

or for supercritical pressure drops, i.e. if

$$\Delta p > \frac{p_1}{2}$$

use formular

$$K_V = \frac{Q_N}{257 \times p_1} \sqrt{\rho_N(t_1 + 273)}$$

K_v	Flow Coefficient	m ³ /h
Q_N	Volume Flow	m ³ /h
Q_1	Volume Flow Upstream of the Valve	m ³ /h
Q_2	Volume Flow Downstream of the Valve	m ³ /h
ρ_N	Density	kg/m ³
Δp	Differential Pressure ($p_1 - p_2$)	bar
p_1	Inlet Pressure (abs.)	bar
p_2	Outlet Pressure (abs.)	bar
t_1	Temperature at Inlet	°C
t_2	Temperature at Outlet	°C
w_1	Velocity inside Pipeline before the Valve	m/s
w_2	Velocity inside Pipeline behind the Valve	m/s
d_1	Nominal Diameter before the Valve	mm
d_2	Nominal Diameter behind the Valve	mm

We are looking for a stainless steel pressure reducing valve for Q_N max. 1200 m³/h CO₂, operating temperature 20 °C, density 2 kg/m³, inlet pressure 10-12 bar above atmospheric, controlled outlet pressure 7 bar above atmospheric.

The pressure drop is subcritical, as

$$\Delta p < \frac{p_1}{2} \quad \text{namely } 3 < \frac{11}{2}$$

Hence

$$K_V = \frac{1200}{514} \sqrt{\frac{2(20 + 273)}{3 \times 8}} = 11,54 \text{ m}^3/\text{h}$$

To the K_v value calculated from the operating data we add an allowance of 30 % and thus obtain the minimum K_v value which the valve to be selected should have.

$$K_{vs} \text{ value} \geq 1.3 \quad K_v \text{ value} = 1.3 \times 11.54 = 15 \text{ m}^3/\text{h}$$

Calculating the Nominal Diameter

To keep pressure drop and noise within acceptable limits, certain flow velocities in the pipelines should not be exceeded.

» up to 10 mbar	2 m/s
» up to 100 mbar	4 m/s
» up to 1 bar	10 m/s
» up to 10 bar	20 m/s
» above 10 bar	40 m/s

If no values have been specified we recommend the following: These rough guidelines apply to pipe diameters from DN 80 up. For smaller diameters lower flow velocities should be used. To calculate the flow velocity we need the flow rate figure under operating conditions. This may be calculated as follows:

$$Q = \frac{Q_N(273 + t)}{p \times 273}$$

Accordingly in our example the flow rates upstream and downstream of the valve are as follows:

$$Q_1 = \frac{1200(273 + 20)}{11 \times 273} = 117,1 \text{ m}^3/\text{h} \quad Q_2 = \frac{1200(273 + 20)}{8 \times 273} = 161 \text{ m}^3/\text{h}$$

The pipeline diameter can be calculated as follows:

$$d = 18,8 \sqrt{\frac{Q}{w}}$$

If in our example maximum flow velocities of 20 m/s upstream and 15 m/s downstream of the valve have been specified, the following pipeline diameters will be required

$$d_1 = 18,8 \sqrt{\frac{117,1}{20}} = 45,5 \text{ mm} \quad d_2 = 18,8 \sqrt{\frac{161}{15}} = 59,6 \text{ mm}$$

Consequently we would recommend a DN 50 pipeline upstream and a DN 65 pipeline downstream of the valve.

For a given nominal diameter the flow velocity can be calculated as follows

$$w = 354 \frac{Q}{d^2}$$

In our example we would thus obtain the following flow velocities

$$w_1 = 354 \frac{117,1}{50^2} = 16,6 \text{ m/s} \quad w_2 = 354 \frac{161}{65^2} = 13,5 \text{ m/s}$$

For certain operating conditions a control valve may be selected whose nominal diameter is one or two sizes smaller than the nominal pipeline diameter. Downstream of the valve the pipeline diameter may be increased by one or two sizes depending on the flow velocity; this applies especially to valves with sense line.

Selecting a suitable valve

Our selection tables and data sheets contain all the technical data needed to select MANKENBERG valves.

The K_{vs} value of the selected valve should be equal to the calculated K_v value plus the required allowance. Most valves operate most efficiently within 10 to 70 % of their K_{vs} values; small non-balanced valves such as our pressure reducers DM 502, 505, 506, 510, 762 and 765, will operate satisfactorily even at minimum flow rates.

You should select a setting range which places the required control pressure at the top end. If, for instance, the pressure to be controlled is 2.3 bar, you should select the 0.8-2.5 bar range rather than the 2-5 bar range, as with the latter the control errors would be considerably greater. If in special cases the standard setting range is not wide enough, a lower setting range may be selected provided the valve operates at low capacity and the control accuracy is of minor importance. Under such conditions, for instance, a pressure reducer featuring a setting range of 0.8-2.5 bar may still operate satisfactorily at 0.5 bar.

You should select the materials in accordance with the operating requirements by using the material resistance table.

If toxic or flammable fluids are to be handled a sealed spring cover – possibly with sealed setting screw - should be used and a leakage line connection (threaded connection at spring cover) provided so that any fluid leaking as a result of a defective control mechanism can be drained safely.

Let us return to our example:

Based on the operating data we had calculated a minimum K_{vs} value of 15 m³/h. According to our selection table several valve types meet this requirement. We select pressure reducer DM 652, DN 50, K_{vs} value 18 m³/h, setting range 4-8 bar. In its standard version this valve is manufactured from materials which are suitable for the application. Additional features are high control accuracy, low weight, good surface quality and a price which is remarkably low for a stainless steel valve.

Pressure Regulators for Steam

Calculation of the K_v value

The selection of a valve requires first of all that the K_v value is determined from the operating data under which the valve is to operate. As in most cases a table or diagram giving the specific volume of steam is not available, the formulae given below, which treat steam as an ideal gas, can be used to arrive at a sufficiently accurate result.

For subcritical pressure drops i.e. if

$$\Delta p < \frac{p_1}{2}$$

use formula

$$K_v = \frac{G}{461} \sqrt{\frac{t_1 + 273}{\Delta p \times p_2}}$$

or for supercritical pressure drops, i.e. if

$$\Delta p > \frac{p_1}{2}$$

use formula

$$K_v = \frac{G}{230 \times p_1} \sqrt{t_1 + 273}$$

The temperature of steam in its saturated state (saturated steam) may be roughly calculated using the formula

$$t_s \approx \sqrt[4]{p_1} \times 100$$

Let us take another example:

We are looking for an overflow valve capable of discharging 2000 m³/h of 60°C warm air to atmosphere at 4 bar.

The pressure drop is supercritical because

$$\Delta p > \frac{p_1}{2} \text{ namely } 4 > \frac{5}{2}$$

Hence

$$K_v = \frac{2000}{257 \times 5} \sqrt{1.293 \times (60 + 273)} = 32.3 \text{ m}^3/\text{h}$$

To the K_v value calculated from the operating data we add an allowance of 30 % and thus obtain the minimum K_{vs} value which the valve should have.

$$K_{vs} \text{ value} \geq 1.3 \times K_v \text{ value} = 1.3 \times 32.3 = 42 \text{ m}^3/\text{h}$$

The flow rate under operating conditions is

$$Q_1 = \frac{2000(273 + 60)}{5 \times 273} = 488 \text{ m}^3/\text{h}$$

and accordingly, given a maximum permitted flow velocity of 20 m/s, the minimum pipeline diameter is

$$d_1 = 18.8 \sqrt{\frac{488}{20}} = 93 \text{ mm}$$

On the basis of the calculated data and taking into account the properties of the medium, we select the MANKENBERG overflow valve UV 4.1, DN 100, K_{vs} value 100 m³/h, setting range 2-5 bar; a relatively economical and accurate valve very suitable for the application.

K_v	Flow Coefficient	m ³ /h
G	Mass Flow	kg/h
Q_1	Volume Flow Upstream of the Valve	m ³ /h
Q_2	Volume Flow Downstream of the Valve	m ³ /h
Δp	Differential Pressure ($p_1 - p_2$)	bar
p_1	Inlet Pressure (abs.)	bar
p_2	Outlet Pressure (abs.)	bar
t_1	Temperature at Inlet	°C
t_2	Temperature of Saturated Steam	°C
w_1	Velocity Inside of the Pipeline before the valve	m/s
w_2	Velocity Inside of the Pipeline behind the valve	m/s
d_1	Nominal Diameter before the Valve	mm
d_2	Nominal Diameter behind the Valve	mm

Example:

We are looking for a stainless steel pressure reducing valve capable of reducing the pressure of 1100 kg/h of saturated steam from 7 to 4 bar. The pressure drop is subcritical because

$$\Delta p < \frac{p_1}{2} \text{ namely } 3 < \frac{8}{2}$$

As we do not know either the specific volume nor the temperature, we use the formula

$$K_v = \frac{G}{461} \sqrt{\frac{t_1 + 273}{\Delta p \times p_2}}$$

Having calculated the temperature

$$t_s \approx \sqrt[4]{p_1} \times 100 = \sqrt[4]{8} \times 100 = 168 \text{ °C}$$

we calculate

$$K_v = \frac{1100}{461} \sqrt{\frac{168+273}{3 \times 5}} = 12,9 \text{ m}^3/\text{h}$$

To the K_{vs} value calculated from the operating data we add an allowance of 30 % and thus obtain the minimum K_{vs} value which the valve to be selected should have

$$K_{vs} \text{ value} \geq 1.3 \times K_v \text{ value} = 1.3 \times 12.9 = 16.8 \text{ m}^3/\text{h}$$

Calculating the nominal diameter

To keep pressure drop and noise within acceptable limits, certain flow velocities in the pipelines should not be exceeded. If no values have been specified we recommend the following:

» Exhaust steam	25 m/s
» Saturated steam	40 m/s
» Super heated steam	60 m/s

These rough guidelines apply to pipe diameters from DN 80 up. For smaller diameters lower flow velocities should be used. As in most cases the specific volume is not known, we use the following sufficiently accurate formula to calculate the volume:

$$Q = \frac{G \times (t + 273)}{p \times 219}$$

Accordingly in our example the flow rates upstream and downstream of the valve are as follows

$$Q_1 = \frac{1100(168+273)}{8 \times 219} = 277 \text{ m}^3/\text{h} \quad Q_2 = \frac{1100(168+273)}{5 \times 219} = 443 \text{ m}^3/\text{h}$$

Pipeline diameter can be calculated using following formula

$$d = 18,8 \sqrt{\frac{Q}{w}}$$

If in our example a maximum flow velocity of 25 m/s before the valve and of 15 m/s behind the valve has been specified, the required pipeline diameters will be as follows:

$$d_1 = 18,8 \sqrt{\frac{277}{25}} = 63 \text{ mm} \quad d_2 = 18,8 \sqrt{\frac{443}{15}} = 79 \text{ mm}$$

We would therefore recommend pipes DN 65 upstream and pipes DN 80 downstream of the valve.

For a given nominal diameter the flow velocity can be calculated as follows:

$$w = 354 \frac{Q}{d^2}$$

In our example the flow velocities in the pipeline would be

$$w_1 = 354 \frac{277}{65^2} = 23 \text{ m/s} \quad w_2 = 354 \frac{443}{80^2} = 24 \text{ m/s}$$

For certain operating conditions a control valve may be selected whose nominal diameter is one or two sizes smaller than the nominal pipeline diameter. Downstream of the valve the pipeline diameter may be increased by one or two sizes depending on the flow velocity; this applies especially to valves designed for sense line operation.

Selecting a suitable valve

Our selection tables and data sheets contain all the technical data needed to select MANKENBERG valves. The K_{vs} value of the selected valve should be equal to the calculated K_v value plus the required allowance. Most valves operate most efficiently within 10 to 70 % of their K_{vs} values; small non-balanced valves such as our pressure reducers DM 152, 505 and 701, will operate satisfactorily even at minimum flow rates.

You should select a setting range which places the required control pressure at the top end. If, for instance, the pressure to be controlled is 2.3 bar, you should select the 0.8-2.5 bar range rather than the 2-5 bar range, as with the latter the control errors would be considerably greater. In special cases the standard setting range is not wide enough, a lower setting range may be selected provided the valve operates at low capacity and the control accuracy is of minor importance. Under such conditions, for instance, a pressure reducer featuring a setting range of 0.8-2.5 bar may still operate satisfactorily at 0.5 bar.

You should select the materials in accordance with the operating requirements by using the material resistance table.

Let us return to our example:

Based on the operating data we had calculated a minimum K_{vs} value of 16.8 m³/h. According to our selection table several valve types meet this requirement. We select pressure reducer type 652, DN 50, K_{vs} value 18 m³/h, setting range 2-5 bar. In its standard version this valve is manufactured from materials which are suitable for the application. Additional features are high control accuracy, low weight, good surface quality and a price which is remarkably low for a stainless steel valve.

Here is another example:

We are looking for a pressure reducing valve capable of reducing the pressure of 8 t/h of 460°C superheated steam from 100 bar to 20 bar for the purpose of soot blowing.

The pressure drop is supercritical because

$$\Delta p > \frac{p_1}{2} \text{ namely } 80 > \frac{101}{2}$$

As we do not know the specific volume at the moment, we calculate

$$K_v = \frac{8000}{230 \times 101} \sqrt{460+273} = 9,33 \text{ m}^3/\text{h}$$

To the K_v value calculated from the operating data we add an allowance of 30 % and thus obtain the minimum K_{vs} -value which the valve to be selected should have.

$$K_{vs} \text{ value} \geq 1.3 \times K_v \text{ value} = 1.3 \times 9.33 = 12.1 \text{ m}^3/\text{h}$$

Under operating conditions the volume flow rates are

$$Q_1 = \frac{8000(460+273)}{101 \times 219} = 265 \text{ m}^3/\text{h} \quad Q_2 = \frac{8000(460+273)}{21 \times 219} = 1275 \text{ m}^3/\text{h}$$

Pipeline diameter can be calculated using following formula:

$$d = 18,8 \sqrt{\frac{Q}{w}}$$

If in our example a maximum permitted flow velocity of 50 m/s has been specified, the required pipeline diameter will be as follows:

$$d_1 = 18,8 \sqrt{\frac{265}{50}} = 43,3 \text{ mm} \quad d_2 = 18,8 \sqrt{\frac{1275}{50}} = 94,5 \text{ mm}$$

Consequently we would recommend a DN 50 pipeline up-stream and a DN 100 pipeline downstream of the valve.

Using the calculated data and taking into account the special operating conditions, we select the twin seat pressure reducer type 401 ZK, DN 50/80, K_{vs} value 16 m³/h, setting range 15-25 bar, complete with adjustable damper unit and stellited cones - a design which has proved reliable in many soot blowing systems.