

Importance of properly sizing valves

It is important to properly size a valve. There are undesirable affects in both undersizing and oversizing.

Undersizing may result in:

- 1) inability to pass desired flow requirements
- 2) flashing of liquids to vapours on the outlet size of the valve
- 3) lowering the outlet pressure
- 4) creating a substantial pressure loss in a piping system

Oversizing may result in:

- 1) unnecessary cost in oversized equipment
- 2) variable flow through the valve or erratic control of the flow
- 3) shorter life of some valve designs through oscillating of internal parts caused by lack of flow to maintain required internal pressure differentials
- 4) erratic operation of some designs such as failure to shift position due to lack of required flow in 3- and 4-way valves
- 5) erosion or wire drawing of seats in some designs because they operate at nearly closed position

Definition of Kv

The flow coefficient Kv in cubic metres per hour or litres per minute is a special volumetric flow rate (capacity) through a valve at a specified travel and at the following conditions:

- the static pressure loss (Δp_{Kv}) across the valve is 10^5 Pa (1 bar)
- the fluid is water within a temperature range of 278 K to 313 K (5°C to 40°C)
- the unit of the volumetric flow rate is the cubic metre per hour or liters per minute

The value of Kv can be obtained from test results with the help of the following equation:

$$Kv = Q \sqrt{\frac{\Delta p_{Kv} \cdot \rho}{\Delta p \cdot \rho_w}}$$

where:

- Q is the measured volumetric flow rate in cubic metres per hour or liters per minute
- Δp_{Kv} is the static pressure loss of 10^5 Pa (see above)
- Δp is the measured static pressure loss across the valve in pascals
- ρ is the density of the fluid in kilograms per cubic metre
- ρ_w is the density of water (see above) in kilograms per cubic metre (according to IEC 534)

Conditions to be known

In general, we must obtain as many of the conditions surrounding the application as possible.

Flow required in cubic metres per hour (m^3/h) as used for liquids, Normal Cubic Metre per hour (nm^3/h) as used for gases, or Kilogram per hour (kg/h) as used for steam. This can be obtained by merely asking the customer's requirements or from nameplates on pumping equipment, boiler room charts or calculations.

Inlet Pressure (p_1) - This is usually known by knowing the source of the supply or readily obtained by placing a gauge near the valve inlet.

Outlet Pressure (p_2) - This can be obtained by gauge observations but usually is tied in with specifications regarding allowable system pressure drop. If we know the inlet pressure and the pressure drop, we, of course, know the outlet pressure.

Pressure Drop (Δp) - In large or complicated systems, it is desirable to keep the pressure drop across a valve to a minimum and often the customer will have definite specifications concerning the factor. Of course, if the valve is discharging to atmosphere, the pressure drop is equal to the inlet pressure when dealing with liquids. With gases and steam, although the valve may be discharging to atmosphere, when sizing a valve, only 50 percent of the inlet pressure can be used for the pressure drop used in the formulas (commonly called critical pressure drop). In all other cases the pressure drop is, the difference between inlet and outlet pressures.

Note: It often is difficult to understand the meaning of the term "minimum operating pressure differential" (see page V1210). Certain pilot operated valves operate by differential pressures created internally by "pilot" and "bleed" arrangements. This differential is measured as the difference between inlet and outlet conditions on all valve construction. If pressure conditions are not known, but only flow information, we can use the graphs or formulas to solve the resulting pressure drop. If the drop is less than assigned minimum differential, the valve is oversized. In these situations, offer a valve with a lower min. operating pressure differential, or go to a smaller sized valve with a closer Kv.

The formulas necessary to determine the Kv are quite complicated and for that reason ASCO/JOUCOMATIC has developed a series of flow graphs which reduce that problem to one of a simple multiplication or division.

All flow calculation work of a medium has been simplified to a basic formula:

$$Kv = \frac{\text{Flow required: } Q}{\text{Graph factors: } F_{gm}, F_{sg}, F_{gl}}$$

The graph factors F_{gm} , F_{sg} , F_{gl} can be easily picked out by aligning known pressure conditions on the graphs I to X on the following pages (for calculations see next page).

The tables below can be used to estimate a Kv if the orifice size is known or relate the approximate orifice size if the Kv is known. The chart is based on the ASCO/JOUCOMATIC design of in-line globe type valves. The flow charts must be used for precise sizing and converting Kv factors to actual flow terms and the catalogue sheet must be consulted for the actual Kv of a particular valve.

Approx. orifice size (mm)	approx. Kv		Approx. orifice size (mm)	approx. Kv	
	(m^3/h)	(l/min)		(m^3/h)	(l/min)
0.8	0,02	0,33	13	3	50,0
1.2	0,05	0,83	16	4	66,7
			18	4,5	75,0
1.6	0,08	1,33	19	6,5	108
			25	11	183
2.4	0,17	2,83	32	15	250
			38	22	366
3.2	0,26	4,33	51	41	683
			64	51	850
4.8	0,45	7,50	76	86	1433
			80	99	1650
6.4	0,60	10,0	100	150	2500
			125	264	4400
8	1,5	25,0	150	383	6375
			9	1,7	28,3

SAMPLE PROBLEMS
LIQUIDS (tables I and III)

To find Kv: What Kv is required to pass 22 litres of oil per minute with a specific gravity of 0,9 and a pressure drop of 1,5 bar?

The viscosity is less than 9° Engler.

Solution: The formula is:

$$Kv \text{ (m}^3\text{/h)} = \frac{Q \text{ (m}^3\text{/h)}}{F_{gm} \cdot F_{sg}}$$

$$Kv \text{ (l/min)} = \frac{Q \text{ (m}^3\text{/h)}}{F_{gl} \cdot F_{sg}}$$

To find Fg, use the Liquid Flow Graph.

The Fgm factor is that which corresponds to a pressure drop of 1,5 bar and equals 1,25.

The Fgl factor is 0,075.

The Fsg factor can be obtained from the Fsg chart and is that which corresponds to 0,09 specific gravity and equals 1,05.

Insert values into formula :

$$Kv = \frac{60.22 \cdot 10^{-3}}{1,25 \cdot 1,05} = 1 \text{ m}^3\text{/h}$$

$$Kv = \frac{60.22 \cdot 10^{-3}}{0,075 \cdot 1,05} = 16,7 \text{ l/min}$$

AIR AND GASES (tables I and IV - VII)

To find Kv: A valve is required to pass 14 Nm³/h at an inlet pressure of 4 bar and a pressure drop (Δp) of 0,5 bar. Find the Kv if the medium is carbon dioxide.

Solution: Refer to the 1-10 bar graph. The formula used is:

$$Kv \text{ (Nm}^3\text{/h)} = \frac{Q \text{ (Nm}^3\text{/h)}}{F_{gm} \cdot F_{sg}}$$

$$Kv \text{ (NI/min)} = \frac{Q \text{ (Nm}^3\text{/h)}}{F_{gl} \cdot F_{sg}}$$

Locate Fgm at the intersection of 4 bar inlet pressure and 0,5 bar pressure drop Δp (along curve). Read down to Fgm = 43,5.

Fgl factor is 2,61

Locate Fsg corresponding to specific gravity of carbon dioxide (= 1,5) on Fsg Chart. Fsg = 0,81.

Insert values into formula :

$$Kv = \frac{Q \text{ (Nm}^3\text{/h)}}{F_{gm} \cdot F_{sg}} = \frac{14}{43,5 \cdot 0,81} = 0,4 \text{ Nm}^3\text{/h}$$

$$Kv = \frac{Q \text{ (Nm}^3\text{/h)}}{F_{gl} \cdot F_{sg}} = \frac{14}{2,61 \cdot 0,81} = 6,62 \text{ NI/min}$$

STEAM (tables VIII - X)

To find Kv: A valve is required to pass 25 kg/h of saturated steam at an inlet pressure of 1 bar and a Δp of 0,2 bar. What is the Kv?

Solution: Refer to the appropriate Steam Graph. Use the formula:

$$Kv \text{ (m}^3\text{/h)} = \frac{Q \text{ (kg/h)}}{F_{gm}}$$

$$Kv \text{ (l/min)} = \frac{Q \text{ (kg/h)}}{F_{gl}}$$

Locate Fg on graph corresponding to 1 bar inlet pressure and a Δp of 0,2 bar (along curve).

Fgm = 13,8 and the Fgl = 0,83

Insert values into formula :

$$Kv = \frac{Q \text{ (kg/h)}}{F_{gm}} = \frac{25}{13,8} = 1,8 \text{ m}^3\text{/h}$$

$$Kv = \frac{Q \text{ (kg/h)}}{F_{gl}} = \frac{25}{0,83} = 30 \text{ l/min}$$

Formula for liquids

$$Q \text{ (m}^3\text{/h)} = Kv \sqrt{\frac{\Delta p}{S.G.}}$$

$$Q \text{ (dm}^3\text{/min)} = Kv_1 \sqrt{\frac{\Delta p}{S.G.}}$$

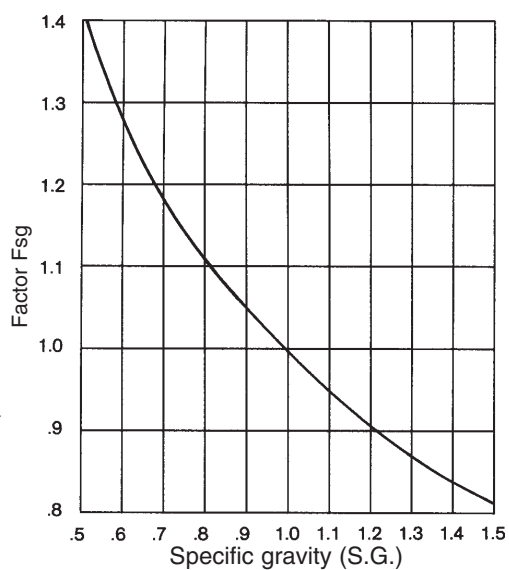
Formula for gases (with temperature correction)

$$Q \text{ (Nm}^3\text{/h)} = Kv \cdot 18,9 \sqrt{\frac{\Delta p (2P_1 - \Delta p)}{(S.G.)} \cdot \frac{293}{(273 + t_2)}}$$

$$Q \text{ (Ndm}^3\text{/h)} = Kv \cdot 18,9 \sqrt{\frac{\Delta p (2P_1 - \Delta p)}{(S.G.)} \cdot \frac{293}{(273 + t_2)}}$$

S.G. : specific gravity related to water for liquids and to air for gases
 t₂ : fluid temperature (in °C)

Table I : Calculation factor Fsg

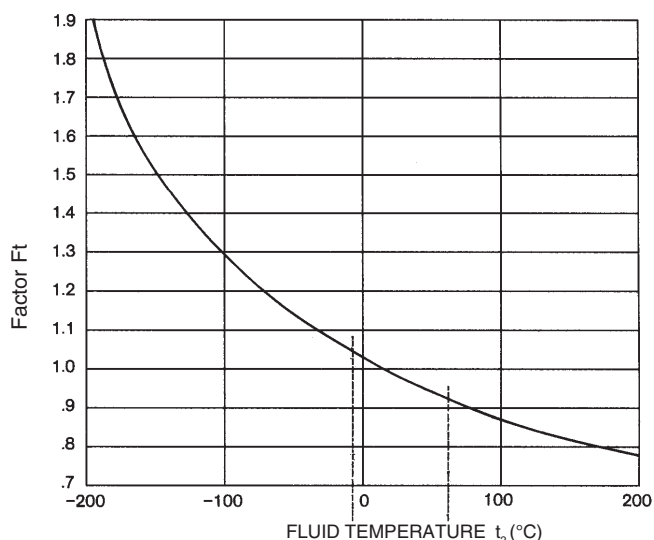


OTHER GRAVITIES

$$Fsg = \frac{1}{\text{S.G.}}$$

specific gravity (for 1 bar absolute and 15°C)

Table II : Calculation factor Ft for temperature correction



OTHER TEMPERATURES

$$Ft = \sqrt{\frac{293}{273 + t_2}}$$

The correction for temperature in the range of -7°C to 65°C is very small and, therefore, can be ignored in ordinary applications

Table III : Flow calculation Fgm and Fgl for liquids

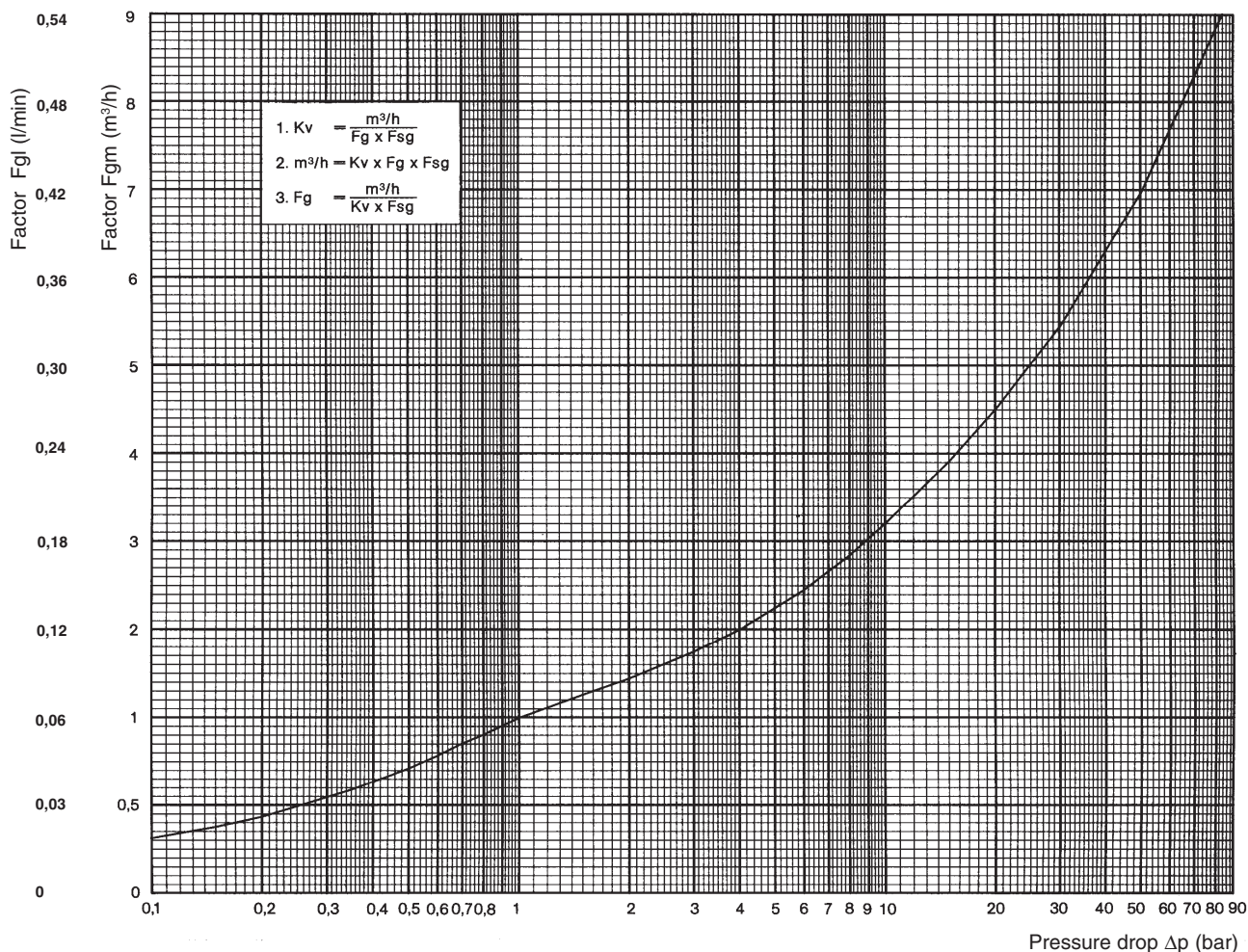


Table IV : Flow calculation Fgm and Fgl for air/gas

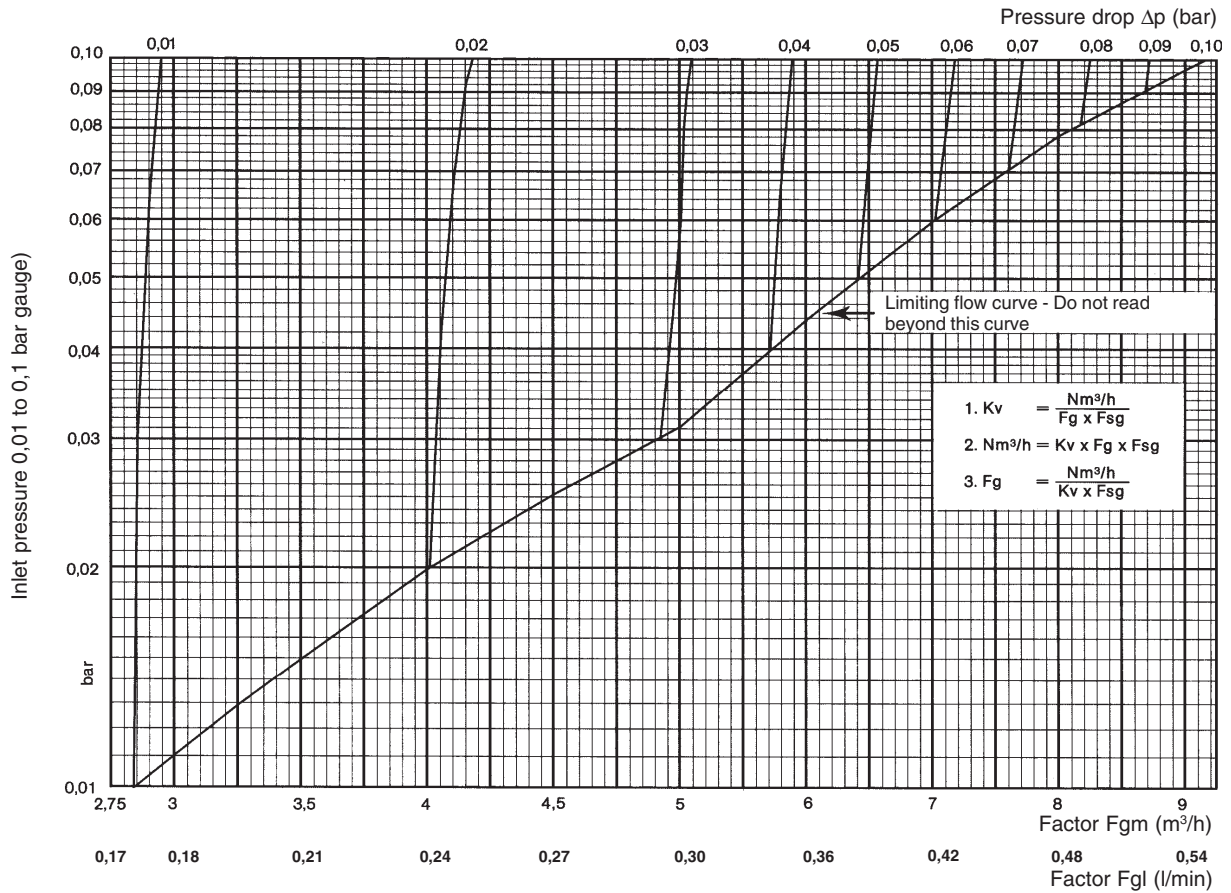


Table V : Flow calculation Fgm and Fgl for air/gas

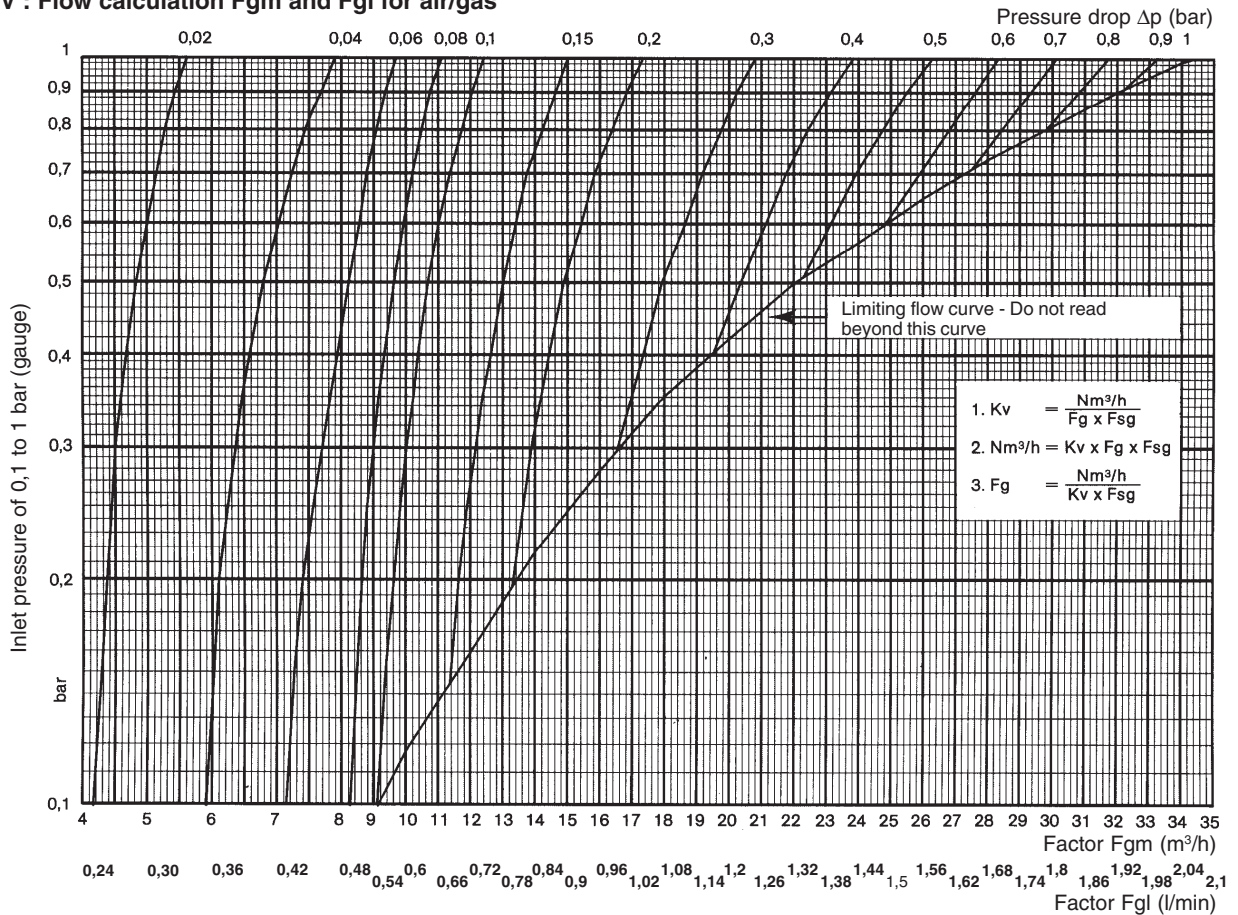


Table VI : Flow calculation Fgm and Fgl for air/gas

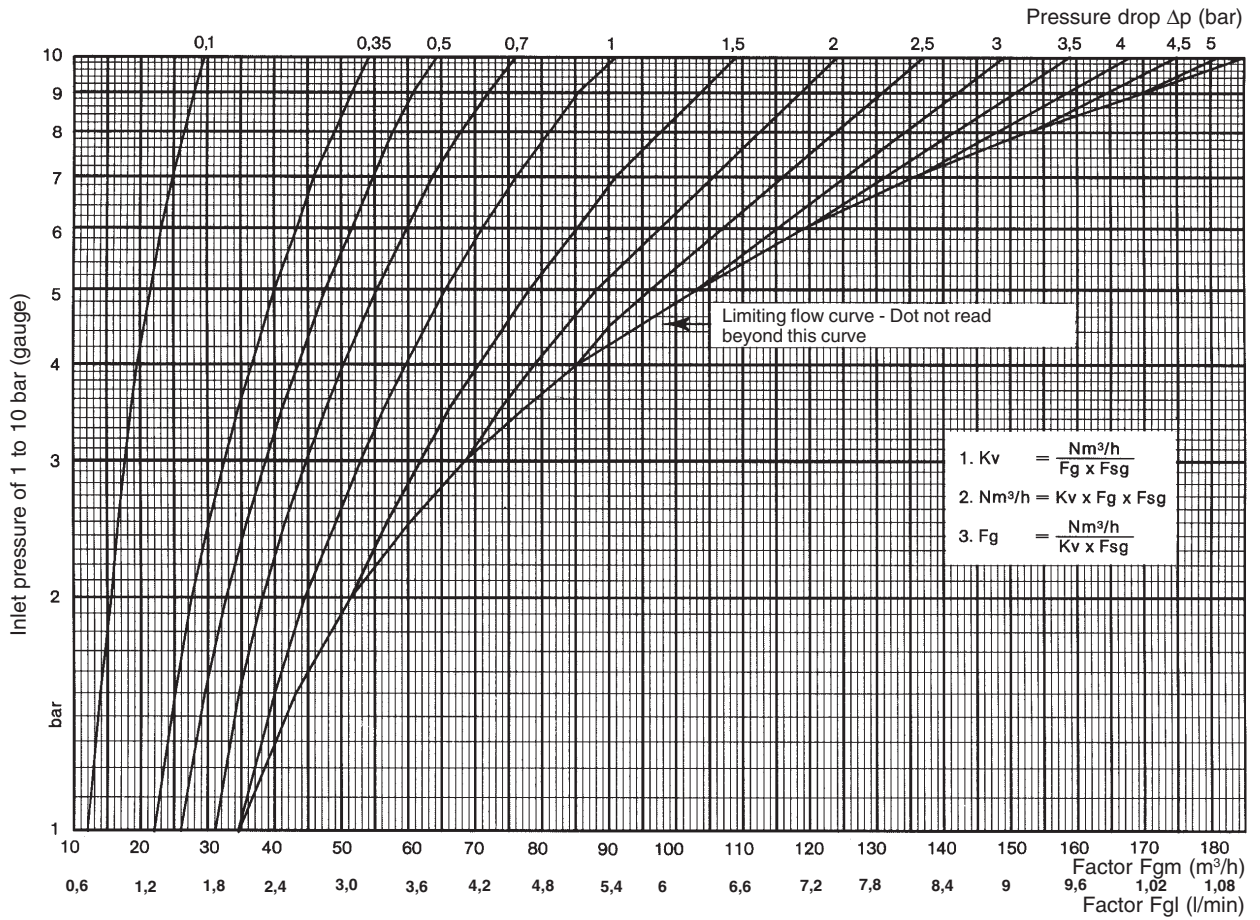


Table VII : Flow calculation Fgm and Fgl for air/gas

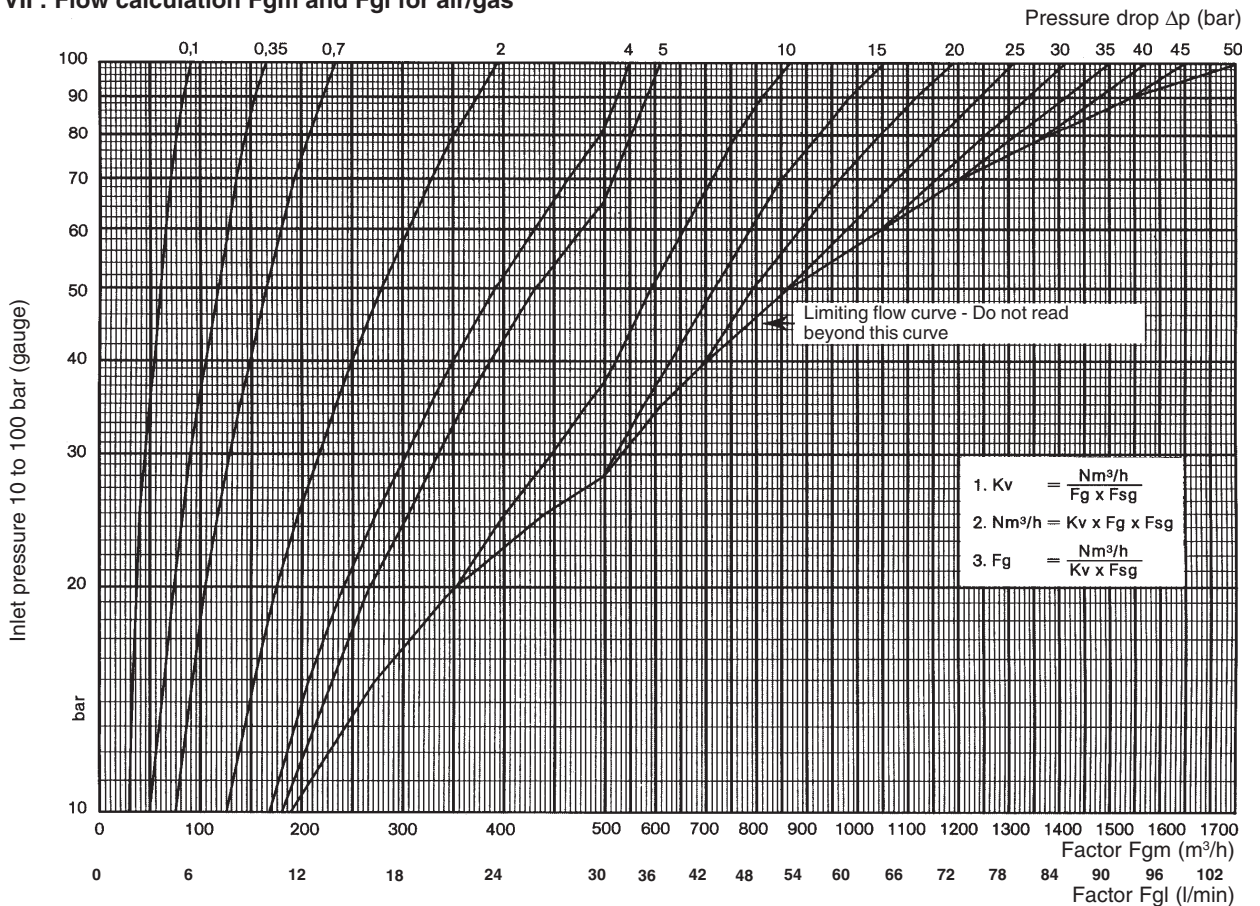


Table VIII : Flow calculation Fgm and Fgl for steam

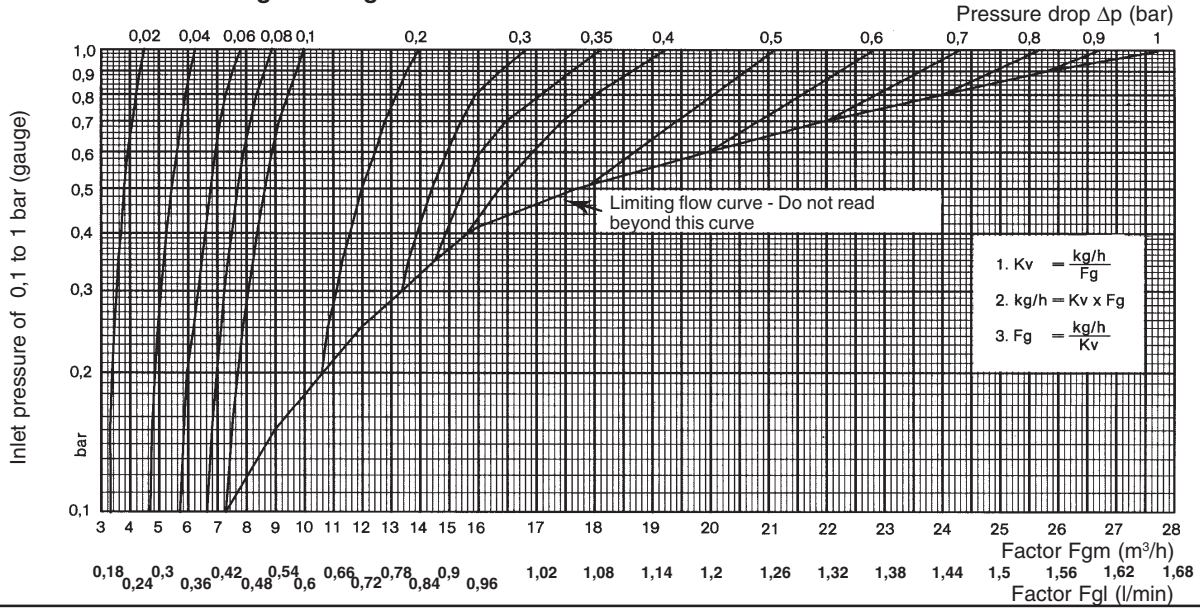


Table IX : Flow calculation Fgm and Fgl for steam

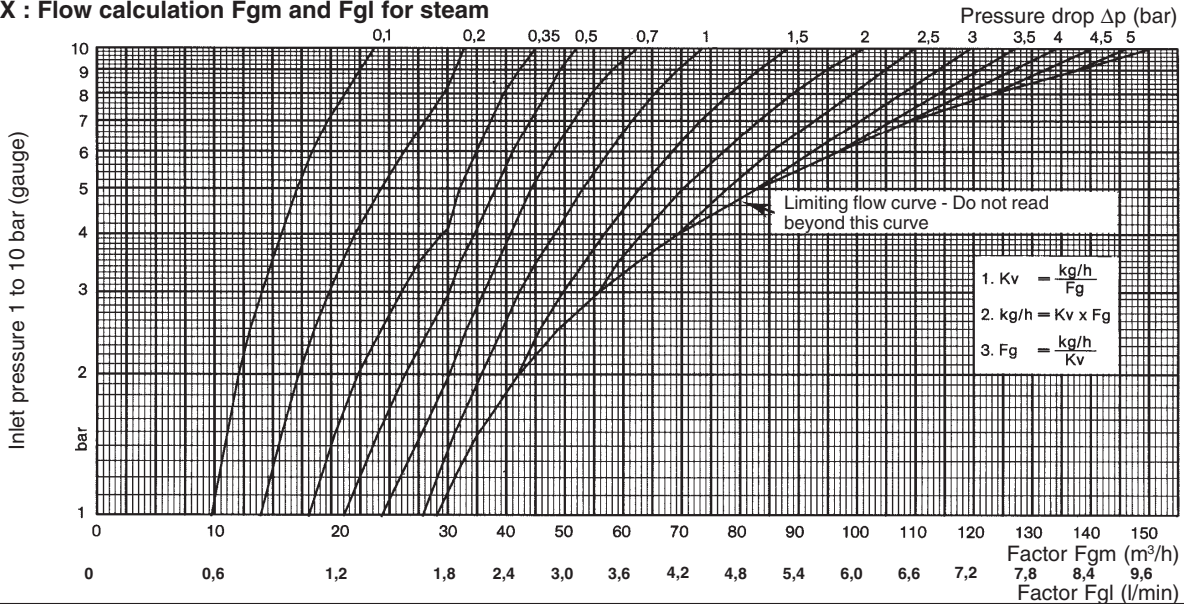
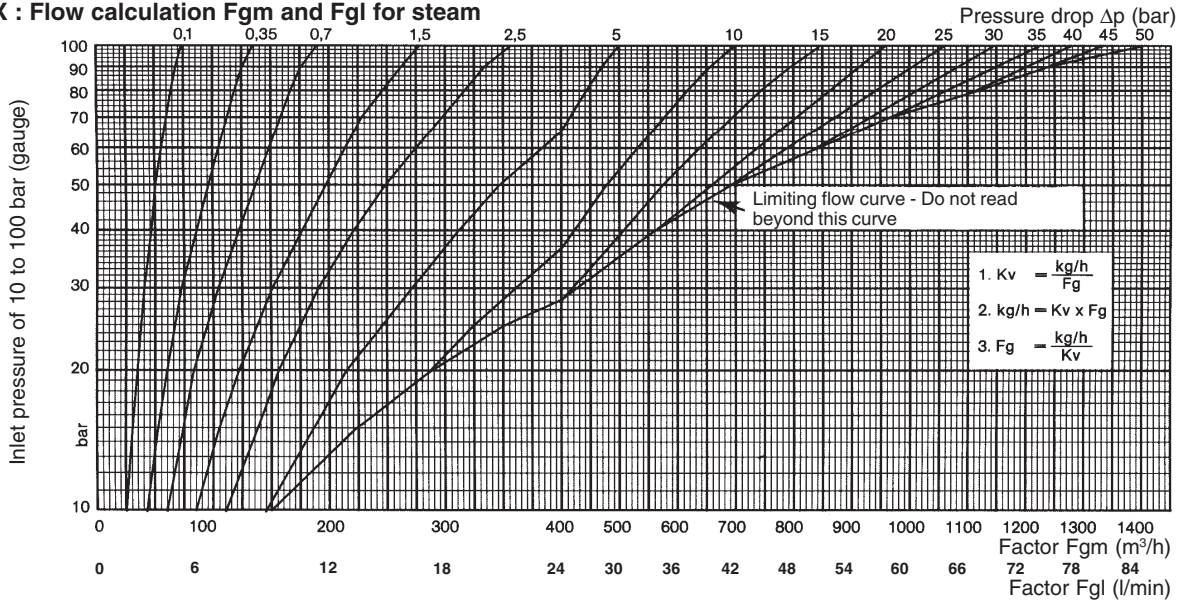


Table X : Flow calculation Fgm and Fgl for steam



ADDITIONAL FLOW FORMULAS AND PHYSICAL DATA
Definition of Kv- (or Cv-) coefficient

Valve flow coefficient Kv (or Cv) is the flow of water (specific gravity = 1),

 expressed in units volume "A" per time unit "B", that will pass through a valve with a pressure drop equal to pressure unit "C".
(See table below)

Kv- and Cv-conversion table

volume "A"	units		symbol	conversion formulas
	time "B"	press. "C"		
litre	min.	bar	Kvl	16,7 Kv = 17,3 Cve = 14,4 Cv
cubic metre	hour	bar	Kv	0,06 Kvl = 1,04 Cve = 0,865 Cv
imp. gallon	min.	psi	Cve	0,058 Kvl = 0,963 Kv = 0,833 Cv
U.S. gallon	min.	psi	Cv	0,069 Kvl = 1,16 Kv = 1,2 Cve

Flow calculation

General: Pressure drop values for which no curves are shown, may be determined by interpolation in the graphs. However, more accurate results can be obtained for the calculation of the required values by using the following equations (on which the flow graphs are based):

p_1 = absolute inlet pressure (bar) = gauge pressure plus atmospheric pressure of 1,013 bar

p_2 = absolute outlet pressure (bar) = gauge pressure plus atmospheric pressure of 1,013 bar

Δp = $p_1 - p_2$ = pressure drop across the valve (bar)

t = °C

Note: In most systems it is desirable to keep the pressure drop to a minimum. If necessary - in case of liquids - the pressure drop may equal the total inlet (gauge) pressure. This also applies to air, gases and steam up to 1,013 bar inlet (gauge) pressure but for these media never use a Δp greater than 50% of the absolute inlet pressure because excessive pressure drops will cause an irregular flow. If Δp is not specified and this information is needed to size the valve, a rule of thumb is to take 10% of the inlet pressure as pressure drop.

Liquids

$$F_{gm} = \sqrt{\Delta p} \quad (\text{m}^3/\text{h})$$

et

$$F_{gl} = 0,06 \sqrt{\Delta p} \quad (\text{l}/\text{min})$$

Example: for $\Delta p = 1,7$ bar will be found $F_{gm} = 1,3$ (m³/h) and $F_{gl} = 0,08$ (l/min)

Note: if the medium viscosity is higher than 300 SSU (approx. 9°E), the determined Kv-value must be adjusted. Consult your ASCO/JOUCOMATIC supplier.

Air and Gases

$$F_{gm} = 18,9 \sqrt{\Delta p (2p_1 - \Delta p)} \quad (\text{m}^3/\text{h})$$

$$F_{gl} = 1,13 \sqrt{\Delta p (2p_1 - \Delta p)} \quad (\text{l}/\text{min})$$

Example: $\Delta p = 0,4$ bar; $p_1 = 3$ bar gauge or 4,013 bar absolute.

Calculation:

$$F_{gm} = 18,9 \sqrt{0,4(8,026 - 0,4)} = 33 \quad \text{m}^3/\text{h}$$

$$F_{gl} = 1,13 \sqrt{0,4(8,026 - 0,4)} = 1,97 \quad \text{l}/\text{min}$$

Note: The gas equations only apply accurately to a medium temperature of 20°C (for the purpose of this catalogue the standard cubic meter nm³ has been defined at 20°C and 1,013 bar absolute or 760 mm mercury).

At a different temperature (= t_2 °C) the determined Kv₁-value must be adjusted by the following correction factor.

$$F_t = \sqrt{\frac{293}{273 + t_2}}$$

Specific gravity of various liquids at 20°C (related to water at 4°C)

Alcohol, Ethyl	0,79
Bezene	0,88
Carbon-tetrachloride	1,589
Castor Oil	0,95
Fuel Oil no. 1	0,83
Fuel Oil no. 2	0,84
Fuel Oil no. 3	0,89
Fuel Oil no. 4	0,91
Fuel Oil no. 5	0,95
Fuel Oil no. 6	0,99
Gasoline (petrol)	0,75 to 0,78
Glycerine	1,26
Linseed Oil	0,94
Olive Oil	0,98
Turpentine	0,862
Water	1,000

The actual flow factor is: $Kv_2 = \frac{Kv_1}{F_t}$

Steam and vapours (e.g. refrigerants)

For steam:

$$F_{gm} = 15,83 \sqrt{\Delta p(2P_1 - \Delta P)} \quad (\text{m}^3/\text{h})$$

$$F_{gl} = 0,95 \sqrt{\Delta p(2P_1 - \Delta P)} \quad (\text{l}/\text{min})$$

Example : $\Delta P = 7$ bar,
 $P_1 = 40$ bar or 41,013 bar abs.

Calculation :

$$F_{gm} = 15,83 \sqrt{7(82,026 - 7)} = 363 \quad \text{m}^3/\text{h}$$

$$F_{gl} = 0,95 \sqrt{7(82,026 - 7)} = 21,8 \quad \text{l}/\text{min}$$

Note 1: The steam formulas apply to saturated steam. For superheated steam a correction factor is required. Consult your ASCO/JOUCOMATIC supplier.

Note 2: For vapours (e.g. Freon) various other factors have to be considered.

Specific gravity of various gases (at 20°C and atm. pressure and related to air)

Acetylene	0,91
Air	1,000
Ammonia	0,596
Butane	2,067
Carbon-dioxide	1,53
Chloride	2,486
Ethane	1,05
Ethyl-chloride	2,26
Helium	0,138
Methane	0,554
Methyl-chloride	1,785
Nitrogen	0,971
Oxygen	1,105
Propane	1,56
Sulphur-dioxide	2,264

