Design of Safety Valves
Design standard: ASME VIII / API 520

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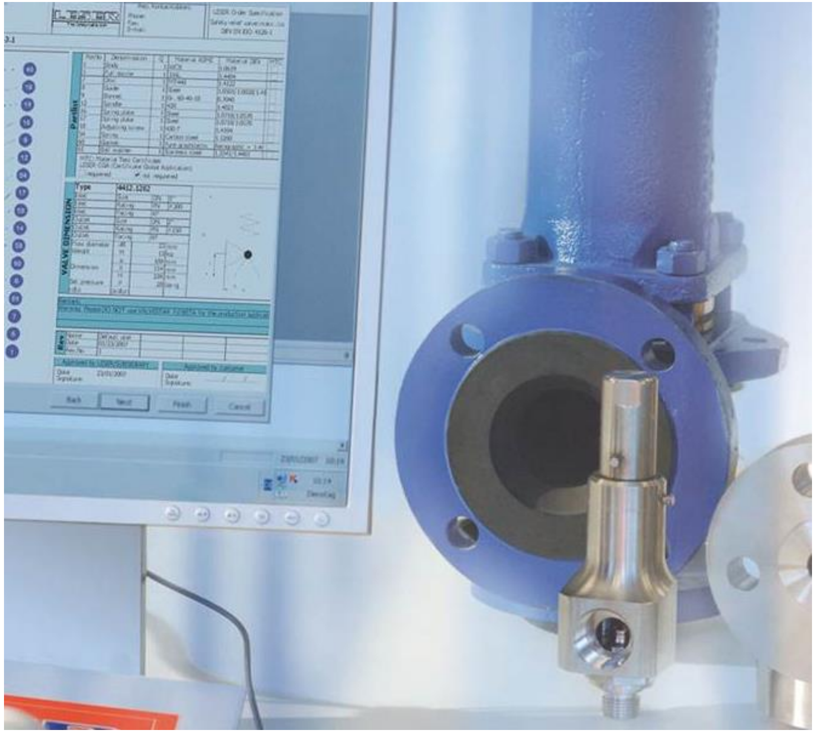
Objectives of this Presentation. Design of Safety Valves: ASME VIII / API 520.

The objective of the presentation is to show the **design of safety valves** in compliance with ASME VIII / API 520

- **Standard specifications for the design** of safety valves
- **Formulas for the design** of safety valves
- **Factors Influencing the stability** in operation



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National and international standards. For calculation of safety valves.

Calculation levels for safety valves

ISO 4126-1	AD 2000 – Merkblatt A2	API 520	ASME VIII

Calculation levels of inlet pressure loss and back pressure

ISO 4126-9 Chapter 7 + 9	AD 2000 – Merkblatt A2 Chapter 6

National and international standards. For calculation of safety valves.

Size determination

- **ISO 4126-1** must be applied in the **European region** for size determination of safety valves
- TRBS is not yet available for specification of the safety valve

Inlet pressure loss

- There is no effect on the capacity and function up to a pressure loss of 3%
- Pressure losses >3% must be taken into account in the capacity calculation. The operation may be affected.

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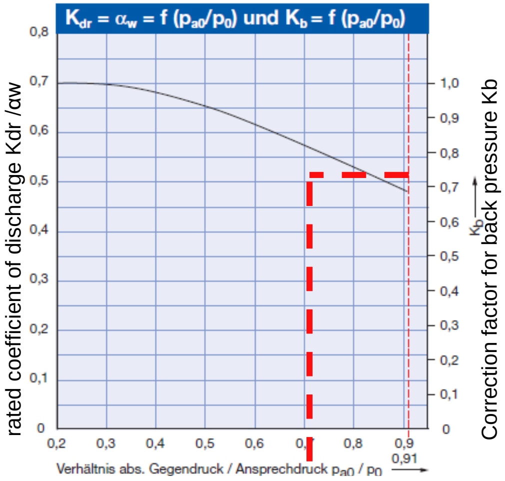
What impact does this have on the user?

Back pressure



Ratio back pressure / set pressure p_{ao}/ p_o

- Effect on the capacity taking the p_{ao}/p_o curve into consideration
- This ratio is observed for absolute pressures.

- Capacity minimisation must also be taken into consideration for low set pressures.
- p = 03 bar g (set pressure)
- p_{ao} = 1.013 bar a (ambient pressure)
- p_o = (0.3 barg + 0.1 barg + 1.013 bar a) (pressure in the system to be secured)
- p_{ao} / p_0 = 1.013 bar a / (0.3 barg + 0.1 bar g + 1.013 bar a) = 0.72
- >> K_b = 0.81

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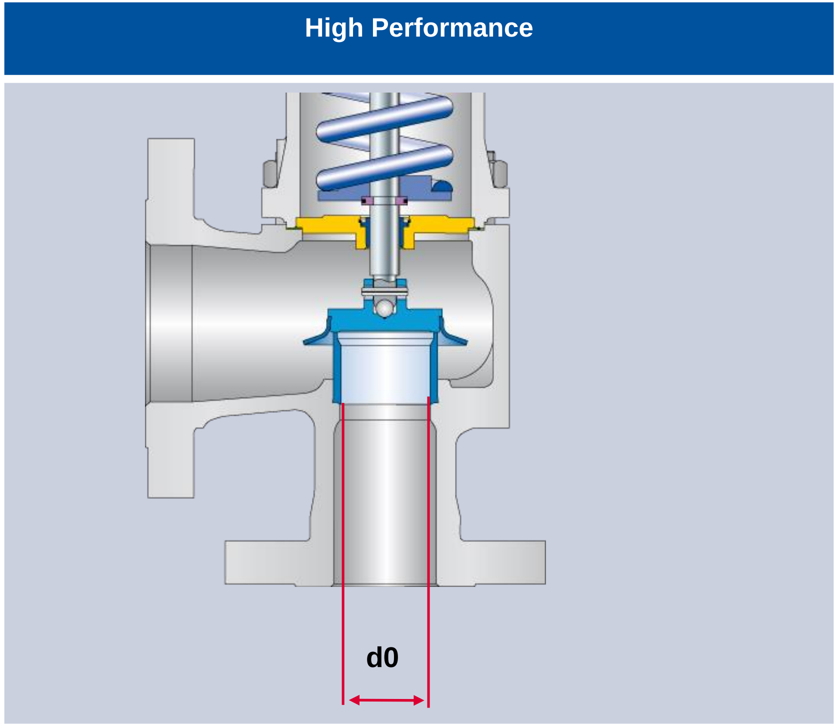
What parameters are important for the design and how are they related?



- **Coefficient of discharge α_w:**
  the rated coefficient of discharge from component testing (often also referred to as α_d)
- **Orifice area A_0:**
  actual orifice area
- **Substance information**
  medium-dependent substance data
- **Operating data:**
  state parameters like pressure and temperature

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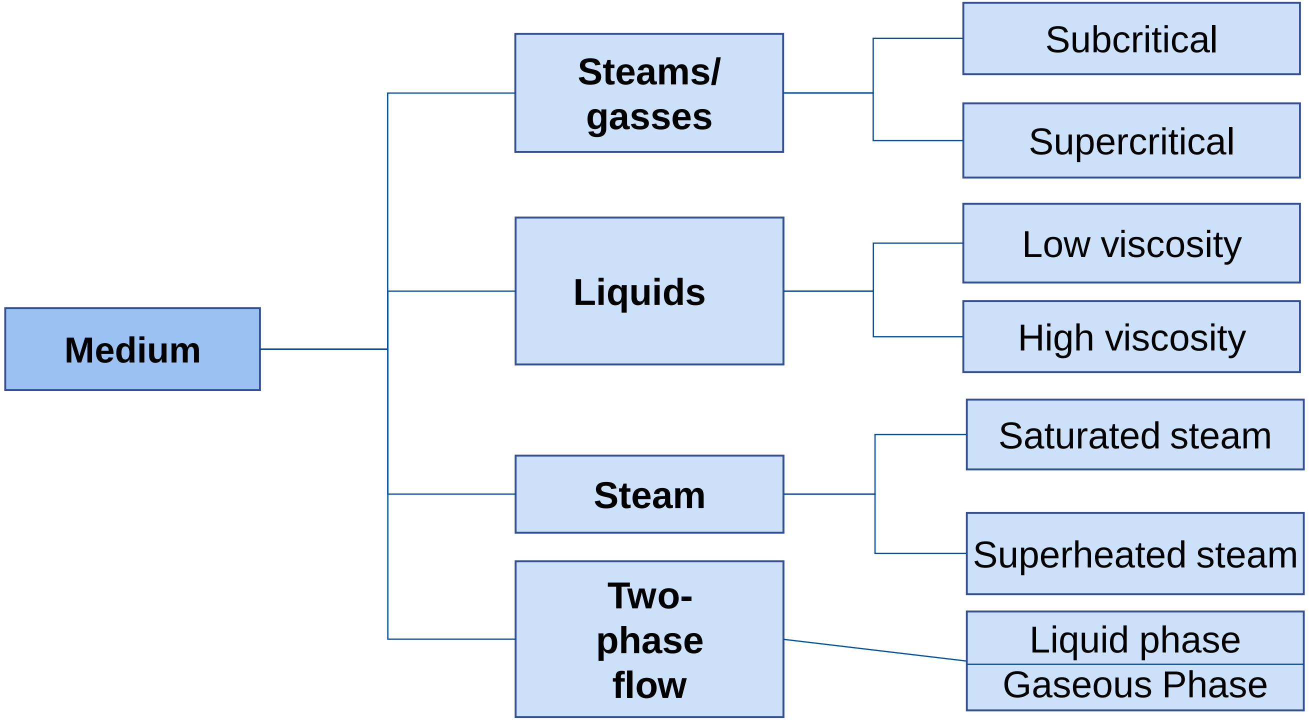
Coefficient of discharge and rated coefficient of discharge.

	German Code	American Code
	VdTÜV Merkblatt SV 100, § 3.3.1	**ASME-Code Sec.VIII, Div. 1, UG-131 (e)**
Coefficient of discharge	$\alpha = \frac{q_{measured}}{q_{theoretical}}$	$K_d = \frac{q_{measured}}{q_{theoretical}}$
Rated coefficient of discharge	$\alpha_w = 0.9 \times \alpha$	$K = 0.9 \times K_d$

$q_{measured}$ = actual measured q_m
$q_{theoretical}$ = calculated q_m

α or K_d = coefficient of discharge
α_d or K = rated coefficient of discharge
0.9 = correction factor

Differentiation of media.



Coefficient of discharge and rated coefficient of discharge.

		Gasses / steams	Liquids	Saturated steam	Superheated team
Set pressure p_{set}	psig	x	x	x	x
Back pressure p_a	psig	x	x	x	x
Temperature T	[°C]	x			x
Mass flow* q_m	[kg/h]	x	x	x	x
Volumetric flow rate* q_v (while operating)	[m³/h]	x	x	x	x
Volumetric flow rate* q_v	[Nm³/h]	x			
Overpressure c	[%]	x	x	x	x
Real gas factor Z	[-]	x			
Molar mass M	[kg/kmol]	x			
Isentropic exponent k	[-]	x			
Density ρ	[kg/m³]		x		
Kinematic viscosity ν	[m²/s]		x		

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Design for gasses/steam as per ASME VIII.

Code	$A = \dfrac{W}{C \cdot K \cdot P} \cdot \sqrt{\dfrac{Z \cdot T}{M}}$
$\sqrt{\dfrac{Z \cdot T}{M}} \cdot \dfrac{}{C}$	Medium data – components
$\dfrac{W}{P}$	Process data – components
$\dfrac{1}{K}$	Flow coefficient – components

Design for gasses/steam as per API 520 vs. ASME VIII.

API

$$A = \frac{W}{C \cdot K_d \cdot P_1 \cdot K_b \cdot K_c} \cdot \sqrt{\frac{T \cdot Z}{M}}$$

ASME

$$A = \frac{W}{C \cdot K \cdot P_1} \cdot \sqrt{\frac{T \cdot Z}{M}}$$

ASME/API

$$A_{ASME} \times K \geq A_{API} \times K_d$$

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ASME VIII

$$A = \frac{W}{C \cdot K \cdot P_1} \cdot \sqrt{\frac{T \cdot Z}{M}}$$

ASME VIII	
▪ Actual orifice area	**A [inch²]**
▪ Mass flow	**W [lb/h]**
▪ Functional isentropic exponent	**C [-]**
▪ Rated coefficient of discharge	**K**
▪ Relieving pressure	**P_1 [psi g]**
▪ Temperature	**T [°F]**
▪ Molar mass	**M [kg/kmol]**
▪ Real gas factor	**Z [-]**

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Orifices as per API RP 526 and ASME VIII (Steams and Gasses).

(Type 526, orifice and discharge coefficient K individual for LESER types)

Designation	API Effective Orifice Area [sq in]	API Coefficient of discharge Kd	ASME Actual Orifice Area [sq in]	ASME coefficient of discharge K
D	**0.110**	**0.975**	**0.239**	**x 0.801**
E	**0.196**		**0.239**	
F	**0.307**		**0.394**	
G	**0.503**		**0.616**	
H	**0.785**		**0.975**	
J	**1.287**		**1.58**	
K	**1.838**		**2.25**	
L	**2.853**		**3.48**	
M	**3.60**		**4.43**	
N	**4.34**		**5.30**	
P	**6.38**		**7.79**	
Q	**11.05**		**13.55**	
R	**16.00**		**19.48**	
T	**26.00**		**31.75**	

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Design for steam as per API 520 vs. ASME VIII.

API

$$A = \frac{W}{51.5 \cdot P_1 \cdot K_d \cdot K_b \cdot K_c \cdot K_N \cdot K_{SH}}$$

ASME

$$A = \frac{W}{51.5 \cdot K \cdot p_0 \cdot K_N \cdot K_{SH}}$$

ASME/API

$$A_{ASME} \times K \geq A_{API} \times K_d$$

Design for saturated steam as per ASME VIII.

ASME VIII

$$A = \frac{W}{51.5 \cdot K \cdot p_0 \cdot K_N \cdot K_{SH}}$$

ASME VIII	
Actual orifice area	**A [in²]**
Pressure in pressure chamber	**p_0 [bar abs]**
Mass flow	**W [lb/h]**
Rated coefficient of discharge	**K**
Napier correction factor	**K_N**
Superheated steam correction factor	**K_{SH}**

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Orifices as per API RP 526 and ASME VIII (Saturated Steam).

(Type 526, orifice and discharge coefficient K individual for LESER types)

Designation	API Effective Orifice Area [sq in]	API Coefficient of discharge Kd	ASME Actual Orifice Area [sq in]	ASME coefficient of discharge K
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API sizing vs. ASME VIII sizing. (Liquids).

API

$$A = \frac{W}{38 \cdot K_d \cdot K_W \cdot K_c \cdot K_V} \cdot \sqrt{\frac{\quad}{p1 - p2}}$$

ASME

$$A = \frac{W}{2407 \cdot K \cdot \sqrt{(p_0 - p_{a0}) \cdot w}}$$

ASME/API

$$A_{ASME} \, x \, K \geq A_{API} \, x \, K_d$$

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Design equation for liquids as per API 520.

API

$$A = \frac{W}{38 \cdot K_d \cdot K_W \cdot K_c \cdot K_V} \cdot \sqrt{\frac{G}{p1 - p2}}$$

API	
Actual orifice area	**A [in²]**
Pressure in pressure chamber	**p_1 [psi a]**
Back pressure	**p_2 [psi g]**
Mass flow	**Q [US gpm]**
Specific density	**G**
Rated coefficient of discharge	**K_d**
Correction factor for bellows	**K_w**
Correction factor for bursting disc	**K_c**
Correction factor for viscosity	**K_v**

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Orifices as per API RP 526 and ASME VIII (Saturated Steam).

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Designation	API Effective Orifice Area [sq in]	API coefficient of discharge Kd	ASME Actual Orifice Area [sq in]	ASME coefficient of discharge K
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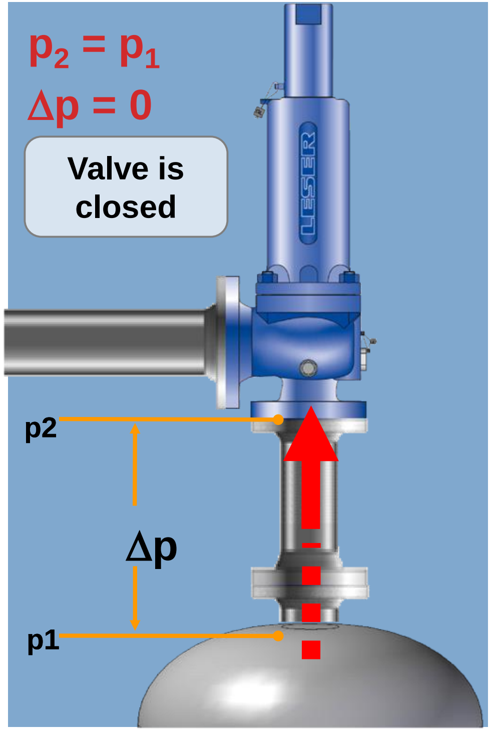
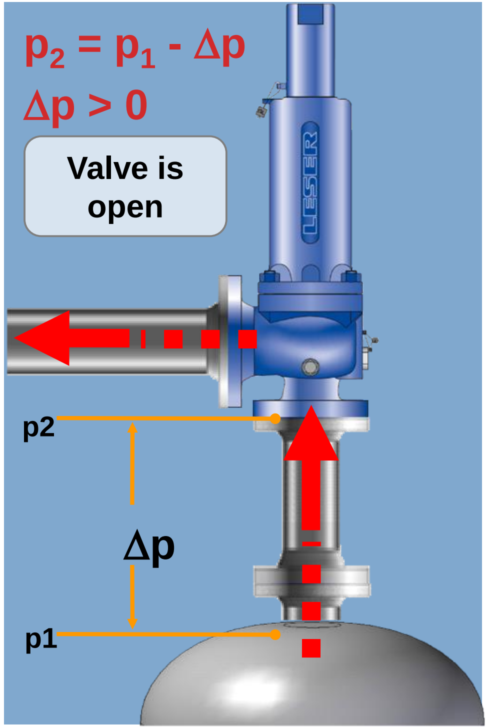
Inlet pressure loss. Influencing factors.





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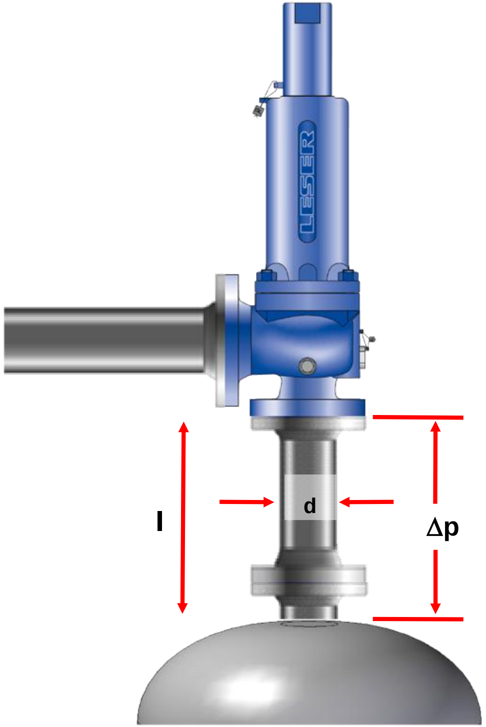
Inlet pressure loss. Standards and bodes.

- (Type 526, orifice aA maximum pressure loss of 3% between the vessel and the safety valve is permissible for the most common international standards and codes.
- **API 520 Part II (08.2003), 4.2.2**
  “When a pressure relief valve is installed an a line directly connected to a vessel, the total non-recoverable pressure loss between the protected equipment and the pressure relief valve should not exceed 3 percent except as permitted in 4.2.3 for pilot-operated pressure relief valve.”

Calculation. (Only calculated as per AD and ISO).



$$\Delta p = (\lambda \cdot l/d + \Sigma\zeta) \cdot \rho/2 \cdot w^2$$

Flow resistance: $(\lambda \cdot l/d + \Sigma\zeta)$

Flow rate: $\rho/2 \cdot w^2$

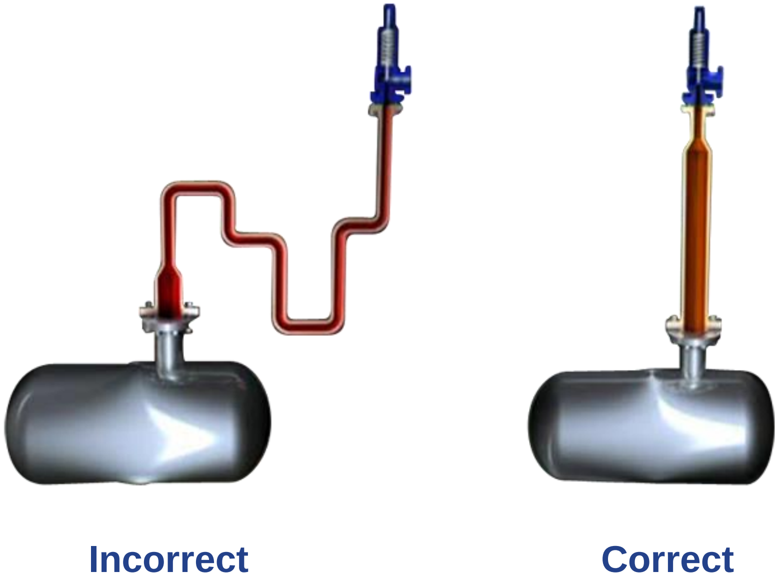
λ = Pipe friction coefficient (pipeline)
l/d = Length and diameter of a pipe
ζ = Friction coefficient (components)
ρ = Density
w = Speed

Inlet pressure loss.

The following **measures prevent malfunctions** that are caused by an inadmissible **inlet pressure loss**:

- **Reduction of the flow rate through**
  - increasing the pipe diameter
  - reducing the mass flow through a smaller valve
  - reducing the mass flow through a lift stopper
  - reducing the mass flow through an O-ring-damper

- **Reduction of the flow rate through**
  - shorter inlet pipeline
  - low-resistance connection to the vessel



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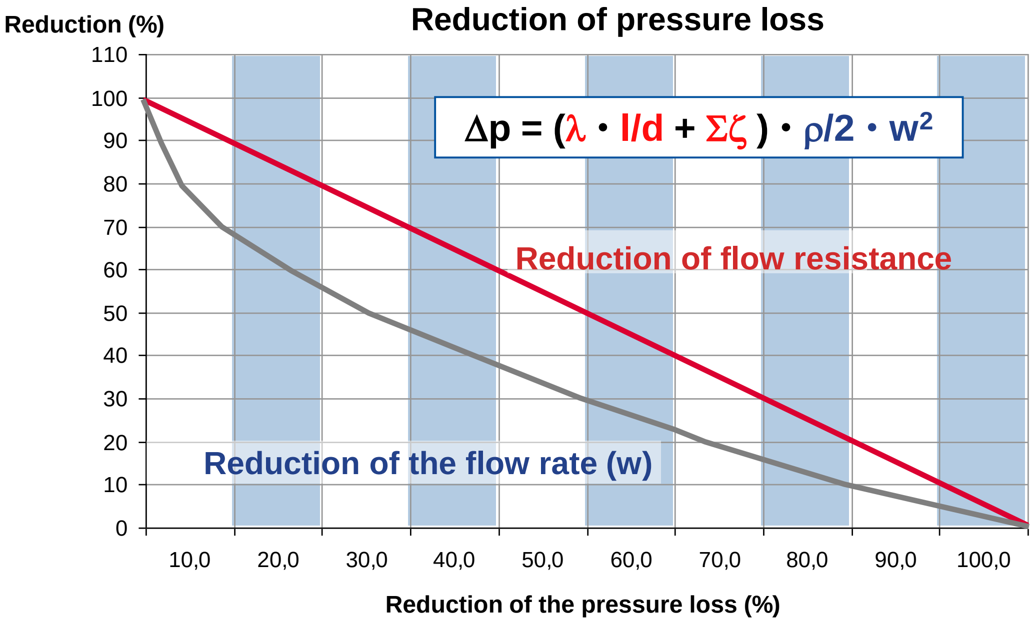
Inlet pressure loss. (Only calculated as per AD and ISO).

Reduction of the flow rate is **more effective** than **reduction of the flow resistance**



Back pressure. Definition.

Back pressure

- **Built-up back pressure**
- **External back pressure**
  - **Constant**
  - **Variable**

Exists only in the outlet **while** the **safety valve blows off.** It is dependent on the flow loss in the discharge line.

Exists permanently in the outlet system The external back pressure is dependent on the blow-off of the safety valve

Back pressure = built-up back pressure – external pressure

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Back pressure – stability. Setting.

The following **measures prevent malfunctions resulting from the back pressure**:

- **Constant back pressure**
  - settings to differential set pressure (CDTP)
  - use of stainless steel bellows
- **Variable back pressure**
  - use of stainless steel bellows

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Design of Safety Valves
Thank you for your attention.