Design of Safety Valves
Design standard: DIN EN ISO 4126-1
The objective of the presentation is to show the design of safety valves in compliance with ISO 4126-1.

- **Standard specifications for the design** of safety valves
- **Formulas for the design** of safety valves
- **Factors Influencing the stability** in operation
National and international standards. For calculation of safety valves.


Calculation levels of 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
What impact does this have on the user?


- **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

- 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.
What impact does this have on the user?


**Back pressure**

- 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.
- $p = 0.3$ 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)
- $p_{ao} / p_o = 1.013$ bar a $/ (0.3$ barg $+ 0.1$ bar g $+ 1.013$ bar a) $= 0.72$
- $>> K_b = 0.81$
What parameters are important for the design, and how are they related?


- **Coefficient of discharge $\alpha_w$**: 
  \((k_{dr} \text{ acc. to ISO 4126-1})\) 
  the rated coefficient of discharge from component testing (often also referred to as $\alpha_d$)

- **Orifice area $A_0$**: 
  actual orifice area

- **Substance information**
  medium-dependent substance data

- **Operating data**:
  state parameters like pressure and temperature
Coefficient of discharge and rated coefficient of discharge.

<table>
<thead>
<tr>
<th>German Code</th>
<th>American Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>VdTÜV Merkblatt SV 100, § 3.3.1</td>
<td>ASME-Code Sec.VIII, Div. 1, UG-131 (e)</td>
</tr>
<tr>
<td>( \alpha = \frac{q_{\text{measured}}}{q_{\text{theoretical}}} )</td>
<td>( K_d = \frac{q_{\text{measured}}}{q_{\text{theoretical}}} )</td>
</tr>
<tr>
<td>( \alpha_w = 0.9 \times \alpha )</td>
<td>( K = 0.9 \times K_d )</td>
</tr>
</tbody>
</table>

- \( q_{\text{measured}} \) = actual measured \( q_m \)
- \( q_{\text{theoretical}} \) = calculated \( q_m \)
- \( \alpha \) or \( K_d \) = coefficient of discharge
- \( \alpha_d \) or \( K \) = rated coefficient of discharge
- 0.9 = correction factor
Differentiation of media.


Medium

- Steams/gasses
  - Subcritical
  - Supercritical

- Liquids
  - Low viscosity
  - High viscosity

- Steam
  - Saturated steam
  - Superheated steam

- Two-phase flow
  - Liquid phase
  - Gaseous Phase
### Required data on materials.

1. **Objectives**
2. **Codes and standards**
3. **Design**
4. **Inlet pressure loss**
5. **Back pressure**

<table>
<thead>
<tr>
<th></th>
<th>Gasses / steams</th>
<th>Liquids</th>
<th>Saturated steam</th>
<th>Superheated team</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Set pressure</strong> $p_{set}$</td>
<td>psig</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Back pressure</strong> $p_a$</td>
<td>psig</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Temperature</strong> $T$</td>
<td>[°C]</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td><strong>Mass flow</strong> $q_m$</td>
<td>[kg/h]</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Volumetric flow rate</strong> $q_v$ (while operating)</td>
<td>[m³/h]</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Volumetric flow rate</strong> $q_v$</td>
<td>[Nm³/h]</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Overpressure</strong> $c$</td>
<td>[%]</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Real gas factor</strong> $Z$</td>
<td>[-]</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Molar mass</strong> $M$</td>
<td>[kg/kmol]</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Isentropic exponent</strong> $k$</td>
<td>[-]</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Density</strong> $\rho$</td>
<td>[kg/m³]</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Kinematic viscosity</strong> $\nu$</td>
<td>[m²/s]</td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Design for gasses / steam as per DIN EN ISO 4126-1.


ISO 4126-1

\[ A = \frac{Q_m}{C \cdot K_{dr} \cdot p_0} \cdot \sqrt{\frac{Z \cdot T}{M}} \]

ISO 4126-1

- Actual orifice area
- Mass flow
- Functional isentropic exponent
- Rated coefficient of discharge
- Set pressure
- Temperature
- Molar mass
- Real gas factor

<table>
<thead>
<tr>
<th>A [mm²]</th>
<th>Q_m [kg/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>C [-]</td>
<td>K_{dr}</td>
</tr>
<tr>
<td>p_0 [bar abs]</td>
<td>T [K]</td>
</tr>
<tr>
<td>M [kg/kmol]</td>
<td>Z [-]</td>
</tr>
</tbody>
</table>
ISO 4126-1

\[ A = \frac{Q_m}{C \cdot K_{dr} \cdot 0.2883} \cdot \sqrt{\frac{v}{p_0}} \]

### ISO 4126-1

- Actual orifice area
- Set pressure
- Functional isentropic exponent
- Mass flow
- Specific volume
- Rated coefficient of discharge

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual area</td>
<td>A</td>
<td>[mm²]</td>
</tr>
<tr>
<td>Set pressure</td>
<td>( p_0 )</td>
<td>[bar abs]</td>
</tr>
<tr>
<td>Functional isentropic exponent</td>
<td>( C )</td>
<td></td>
</tr>
<tr>
<td>Mass flow</td>
<td>( Q_m )</td>
<td>[kg/h]</td>
</tr>
<tr>
<td>Specific volume</td>
<td>( v )</td>
<td>[m³/kg]</td>
</tr>
<tr>
<td>Rated coefficient of discharge</td>
<td>( K_{dr} )</td>
<td>[m³/kg]</td>
</tr>
</tbody>
</table>
Design for saturated steam as per DIN EN ISO 4126-1.


ISO 4126-1

\[ A = \sqrt{\frac{V}{p_0 - p_b}} \cdot \frac{Q_m}{1.61 \cdot K_{dr} \cdot K_v} \]

ISO 4126-1

- Actual orifice area
- Set pressure
- Back pressure
- Mass flow
- Specific volume
- Rated coefficient of discharge
- Viscosity correction factor

<table>
<thead>
<tr>
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</tr>
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<tbody>
<tr>
<td>A</td>
<td>[mm²]</td>
</tr>
<tr>
<td>p_o</td>
<td>[bar abs]</td>
</tr>
<tr>
<td>p_b</td>
<td>[barü]</td>
</tr>
<tr>
<td>Q_m</td>
<td>[kg/h]</td>
</tr>
<tr>
<td>v</td>
<td>[m³/kg]</td>
</tr>
<tr>
<td>K_{dr}</td>
<td></td>
</tr>
<tr>
<td>K_v</td>
<td></td>
</tr>
</tbody>
</table>
Inlet pressure loss. Influencing Factors.


\[ p_2 = p_1 \]
\[ \Delta p = 0 \]

Valve is closed

\[ p_2 = p_1 - \Delta p \]
\[ \Delta p > 0 \]

Valve is open
Inlet pressure loss. Standards and Codes.


- A **maximum pressure loss of 3%** from the vessel to the safety valve is permissible for the most common international standards and codes.

- **ISO 4126-9 Chapter 6.2**
  Unless otherwise specified by national codes or regulations, the inlet line shall be so designed that the total pressure drop to the valve inlet does not exceed 3 % of the set pressure of the safety device,…
1. Objectives
2. Codes and standards
3. Design
4. Inlet pressure loss
5. Back pressure

Calculation.

\[ \Delta p = \left( \lambda \cdot \frac{l}{d} + \sum \zeta \right) \cdot \frac{\rho}{2} \cdot w^2 \]

Flow resistance \quad Flow rate

\( \lambda \) = Pipe friction coefficient (pipeline)
\( \frac{l}{d} \) = Length and diameter of a pipe
\( \zeta \) = Friction coefficient (components)
\( \rho \) = Density
\( w \) = Speed
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
Inlet pressure loss.

1. Objectives  
2. Codes and standards  
3. Design  
4. Inlet pressure loss  
5. Back pressure

- Reduction of the flow rate through
  - shorter inlet pipeline
  - low-resistance connection to the vessel
Reduction of the flow rate is more effective than reduction of the flow resistance

\[ \Delta p = (\lambda \cdot \frac{l}{d} + \sum \zeta) \cdot \frac{\rho}{2} \cdot w^2 \]

Reduction of the flow rate (w)

Reduction of the pressure loss (%)

Reduction of flow resistance

Reduction (\%)
Back pressure. Definition


#### Back pressure

- **Built-up 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.

- **External back pressure**
  - 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
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
Design of Safety Valves
Thank you for your attention.