Safety valves, general design and function

- Protect pressure vessels against overpressure
- By exceeding set pressure valve opens and discharges fluid
- Usually spring loaded, manual opening optionally
- Automatically re-closing when closing pressure reached
- Equipment part with safety function according to PED 2014/68/EU

Cryogenic safety valves in addition focus on heat load, repeated actuating and fluid recovery

Cryogenic safety valves for ITER, specific requirements

- Helium 8…10 K
- Seat tightness 1*10^{-2} mbar*l/s
- Response at 20 bar, independent from back pressure
- Safety mode and On/Off mode
  - (pneumatic actuator, controlled with piezo-valve)
- Redundant limit switches for close and open position
- Radiation dose 100 Gy
- Magnetic field 100 mT
- Earthquake-proof
- Delivery of more than 100 safety valves DN20 and DN40

Type tests

ITER specific cold tests at WEKA

Test setup
- Valve immersed in 77 K LN2 Dewar (cold seat)
- Helium supply @ 200 bar / 300 K for pressure vessels
- Two pressure vessels at valve inlet and outlet (back pressure)
- Mechanical displacement equipment on valve body
- Bubble test vessel for seat tightness test after reclosing
- Recording of pressure values, valve stroke and signals of limit switches with LabVIEW

Tests performed with one DN20 and one DN40 safety valve:
- Opening pressure 20 bar g with 1 bar a back pressure (10 times)
- Opening pressure 20 bar g with 10 bar a back pressure (10 times)
- Seat tightness test @ 5 bar g
- Opening pressure 20 bar g with 1 bar a back pressure and mechanical displacement on valve body
- Functional behavior of piezo-valve and pneumatic actuator with piezo valve being exposed to magnetic field in 6 different orientations
- Functional behavior of the 4 end switches

Test results for both DN20 and DN40:
- All opening tests with and without back pressure, with and without mechanical displacement were successful
- Opening pressure @ 20 bar g +/- 0.5 bar
- Seat leakage rate < 10^{-2} mbar*l/s
- Piezo-valve and pneumatic actuator work reliable, also when exposed to magnetic field
- Limit switches work reliable

Type tests at external laboratory with notified body

- Executed by TÜV Süd according to ISO 4126-1
- Mandatory for CE-marking and using in ITER
- Strict qualification procedure
- Measurements in laboratory of IMI Bopp & Reuther (airflow, set/opening/closing pressure)
- Design review, dimensional inspection
- Extensive documentation to submit (descriptions, calculations, instructions, risk assessment, …)

Serial tests with each valve performed at room temperature:
- Seat tightness test
- Tightness to vacuum (welding seams)
- Tightness to ambient (welding seams and o-rings)
- Pressure proof test (third party approval)
- Measurement of set pressure (third party approval)
- Functional tests

Test results, serial products

<table>
<thead>
<tr>
<th>ITER specification</th>
<th>Actual DN20/40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass flow (He, 10 K, p1/2 21 bar g / 9 bar g)</td>
<td>&gt; 1 / 6.5 kg/s</td>
</tr>
<tr>
<td>Seat leak rate (5 bar, 80 K)</td>
<td>&lt; 1<em>10^{-2} mbar</em>l/s</td>
</tr>
<tr>
<td>Set-, opening-, closing pressure</td>
<td>passed</td>
</tr>
<tr>
<td>Back pressure (0 bar … 9 bar)</td>
<td>independent</td>
</tr>
<tr>
<td>Heat load at 4.3 K</td>
<td>0.3 W / 1.2 W</td>
</tr>
<tr>
<td>Coefficient of discharge, certified</td>
<td>0.77 / 0.79</td>
</tr>
<tr>
<td>Radiation, magnetic field, seismic load</td>
<td>passed</td>
</tr>
</tbody>
</table>

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