Basics of Helium Leak Detection

with Pfeiffer Vacuum
What are the reasons for Leak Detection?

- Environmental protection and their constraints or legal standards
- Industrial norms and partially detailed specifications of the customers
- Optimization of the process
- Quality Management
The denseness requirements are in general quantized by the maximum allowable leak rate.

Types:

- Pressure increase in a vacuum - reservoir
  
  \[ P_o > P_i \]

- Pressure decrease in a pressure - tank
  
  \[ P_o < P_i \]
Leak rate

Definition

The leak rate value is 1 mbar l/s if in a vacuum - reservoir with a volume of 1 Litre the pressure rises in 1 Second about 1 mbar or in a pressure - reservoir it drops about 1 mbar.

Unit

- [mbar × l/s]
- SI – Units: [Pa × m³/s]
- Fluid Technology: [sccm; sccs]
- Climate Technology: [g/a; oz/y]
Example: leak rate in mbar l/s

- The wheel of a bicycle allows in 175 days a maximum pressure drop of 1000 mbar without pumping up!

- Volume = approximately 1.5 Liter
- 175 days = approximately $1.5 \times 10^7$ Seconds

- What is the maximum acceptable Leak rate?
Example: leak rate in mbar l/s

Result:

- Unit: mbar l s\(^{-1}\)
- \(q_L = \frac{V \cdot (p_2 - p_1)}{t}\)
  - \([q_L]\) = mbar l s\(^{-1}\) – Leak rate
  - \([V]\) = l - Volume Test object (piece?)
  - \([p_1]\) = mbar – pressure at the start of the measurement
  - \([p_2]\) = mbar - pressure at the end of the measurement

\[
Q_L = \frac{mbar \cdot l}{s} = \frac{1000 \cdot 1,5}{1,5 \cdot 10^7} = 1,0 \cdot 10^{-4} \text{ mbar \cdot l / s}
\]
Example: leak rate in mbar l/s

- Testing of Car tires
- Testing method: manual underwater – sight check (Bubble test)
- Test conditions: testing – pressure and – temperature constant
- Volume: approximately 40 Litres
- Ascension of several air – bubbles
- Ø oft air - bubbles: 2,26 mm

<table>
<thead>
<tr>
<th>Bubbles / time - period</th>
<th>1 Bubble / Minute</th>
<th>1 Bubble / Second</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leak rate</td>
<td>$6,0 \times 10^{-03}$ cm³/min</td>
<td>$0,3636$ cm³/min</td>
</tr>
<tr>
<td></td>
<td>$1,0 \times 10^{-04}$ mbar l/s</td>
<td>$6,0 \times 10^{-02}$ mbar l/s</td>
</tr>
</tbody>
</table>
Example: leak rate in mbar l/s

- Ø of a Bubble per minute = 2.26 mm
- \( q_L = \frac{\Delta V}{\Delta t} \) with \( p = \text{const.} \)

\[
\Delta V = \frac{4}{3} \cdot \pi \cdot r^3 = \frac{4 \cdot \pi \cdot (1,13 \text{ mm})^3}{3} = 6.06 \text{ mm}^3
\]

- \( q_L = 6.06 \text{ mm}^3/\text{min} \text{ or } 6.0 \times 10^{-03} \text{ cm}^3/\text{min} \)
- Because 60 cm³/min is nearly similar to 1 mbar l/s it follows, that
- \( q_L = 1.0 \times 10^{-04} \text{ mbar l/s} \)
## Equivalent leak rates

<table>
<thead>
<tr>
<th>Definition</th>
<th>kg air/h</th>
<th>mbar l/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water tight</td>
<td>$10^{-05}$</td>
<td>$10^{-02}$</td>
</tr>
<tr>
<td>Vapour tight (sweat)</td>
<td>$10^{-06}$</td>
<td>$10^{-03}$</td>
</tr>
<tr>
<td>Bacteria tight</td>
<td>$10^{-07}$</td>
<td>$10^{-04}$</td>
</tr>
<tr>
<td>Fuel – and Oil tight</td>
<td>$10^{-08}$</td>
<td>$10^{-05}$</td>
</tr>
<tr>
<td>Virus tight</td>
<td>$10^{-09}$</td>
<td>$10^{-06}$</td>
</tr>
<tr>
<td>Gas tight</td>
<td>$10^{-10}$</td>
<td>$10^{-07}$</td>
</tr>
<tr>
<td>Technically tight</td>
<td>$10^{-13}$</td>
<td>$10^{-10}$</td>
</tr>
</tbody>
</table>

Conversion: 1 mbar l/s = $4.3 \times 10^{-03}$ kg/h air at 20° C and the same test pressure.
## Conversion table of leak rates

<table>
<thead>
<tr>
<th></th>
<th>mbar l/s</th>
<th>kg/h (air, 20°C)</th>
<th>kg/h (air, 0°C)</th>
<th>cm³/h (NTP)</th>
<th>cm³/s (NTP)</th>
<th>Torr l/s</th>
<th>g/a (R12, 20°C)</th>
<th>Pa m³/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>mbar l/s</td>
<td>1</td>
<td>4,28 * 10⁻³</td>
<td>4,59 * 10⁻³</td>
<td>3554</td>
<td>0,987</td>
<td>0,75</td>
<td>1,56 * 10⁵</td>
<td>1,00 * 10⁵</td>
</tr>
<tr>
<td>kg/h (air, 20°C)</td>
<td>234</td>
<td>1</td>
<td>1,073</td>
<td>8,31 * 10⁵</td>
<td>231</td>
<td>175</td>
<td>23,4 * 10⁶</td>
<td></td>
</tr>
<tr>
<td>kg/h (air, 0°C)</td>
<td>218</td>
<td>0,932</td>
<td>1</td>
<td>7,74 * 10</td>
<td>215</td>
<td>163</td>
<td>21,8 * 10³</td>
<td></td>
</tr>
<tr>
<td>cm³/h (NTP)</td>
<td>2,81 * 10⁻⁴</td>
<td>1,20 * 10⁻⁶</td>
<td>1,29 * 10⁻⁶</td>
<td>1</td>
<td>2,78 * 10⁻⁴</td>
<td>2,11 * 10⁻⁴</td>
<td>44</td>
<td>28,10</td>
</tr>
<tr>
<td>cm³/s (NTP)</td>
<td>1,013</td>
<td>4,33 * 10⁻³</td>
<td>4,65 * 10⁻³</td>
<td>3600</td>
<td>1</td>
<td>0,760</td>
<td>1,58 * 10⁵</td>
<td>1,01 * 10⁵</td>
</tr>
<tr>
<td>Torr l/s</td>
<td>1,33</td>
<td>5,70 * 10⁻³</td>
<td>6,12 * 10⁻³</td>
<td>4737</td>
<td>1,32</td>
<td>1</td>
<td>2,08 * 10⁵</td>
<td>1,33 * 10⁵</td>
</tr>
<tr>
<td>g/a (R12, 20°C)</td>
<td>6,39 * 10⁻⁶</td>
<td>2,27 * 10⁻²</td>
<td>6,31 * 10⁻⁶</td>
<td>4,80 * 10⁻⁶</td>
<td>1</td>
<td></td>
<td>6,41 * 10⁻¹</td>
<td></td>
</tr>
<tr>
<td>Pa m³/s</td>
<td>10</td>
<td>4,28 * 10⁻²</td>
<td>4,59 * 10⁻²</td>
<td>35,54 * 10³</td>
<td>9,87</td>
<td>7,50</td>
<td>1,56</td>
<td>1</td>
</tr>
</tbody>
</table>

NTP = 1 cm³ under normal conditions (T = 273,15 K, p = 1013,25 mbar)
## Testing methods

<table>
<thead>
<tr>
<th>Methods</th>
<th>detectable Leak rate</th>
<th>principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure drop</td>
<td>$10^{-02}$ mbar l/s</td>
<td>Overpressure</td>
</tr>
<tr>
<td>Pressure rise</td>
<td>$10^{-04}$ mbar l/s</td>
<td>Vacuum</td>
</tr>
<tr>
<td>Bubble Test</td>
<td>$10^{-04}$ mbar l/s</td>
<td>number of Bubbles with defined $\phi$</td>
</tr>
<tr>
<td>He – Sniffing</td>
<td>$10^{-06}$ mbar l/s</td>
<td>change of Helium concentration</td>
</tr>
<tr>
<td>He – Integral</td>
<td>$10^{-10}$ mbar l/s</td>
<td>change of integral Leak rate</td>
</tr>
</tbody>
</table>

Other Methods
Why Helium?

- Low concentration in the normal atmosphere (≈ 5ppm)
- Small molecule - mass 4
- Easy to detect with standard mass spectrometer
- Fast spreading in atmospheric – and vacuum surrounding
- Does not undergo chemical reactions, does not stick to surfaces
- Not poisonous
Overpressure leak detection

Local

Integral
Local leak detection

Sample under vacuum
Leak detection integral

Sample under **pressure**
Chamber under **vacuum**

Sample under **vacuum**
Chamber under **testgas**
Why testing in vacuum?

- Suppress of the helium background in the atmosphere
- Faster spreading of the test gas
- Effect: fast and reproducible measurement results
HLT 260
One device for a lot of applications

- LCD Displays
- Industry
- Automotive
- Semiconductor technology
- IC’s
- Medicine
- Aviation
Advantages of the HLT 260
Advantages of the HLT 260

- **Simple, user-friendly operation**
  - Only Start/Stop and Zero are required for standard operation

- **Vacuum mode**
  - Smallest detectable leak rate: $5 \times 10^{-12}$ mbar $\times$ l/s
  - Leak testing is possible at 18 mbar inlet pressure $\Rightarrow$ short Test cycles
  - Helium pumping speed at the inlet 2.1 l/s $\Rightarrow$ very fast recovery time

- **Sniffer mode**
  - Smallest detectable leak rate: $5 \times 10^{-08}$ mbar $\times$ l/s
  - 5 m$^3$/h rotary vane pump for roughing $\Rightarrow$ faster Leak test
  - Completely oil free leak test with a diaphragm pump possible
Advantages of the HLT 260

- ISO 9001 compatible
  - Product identification via Barcode reader

- Product documentation
  - Printout protocol

- Integrated total-pressure measurements

- Metal housing
Advantages of the HLT 260

- Helpful Accessories
  - Different sniffer probes
  - Flexible Sniffer tips
  - Cart
  - Calibrated sniffer test leaks
  - Barcode Reader, Signal – Lamp