In-Process Leakage Testing of R744 Components

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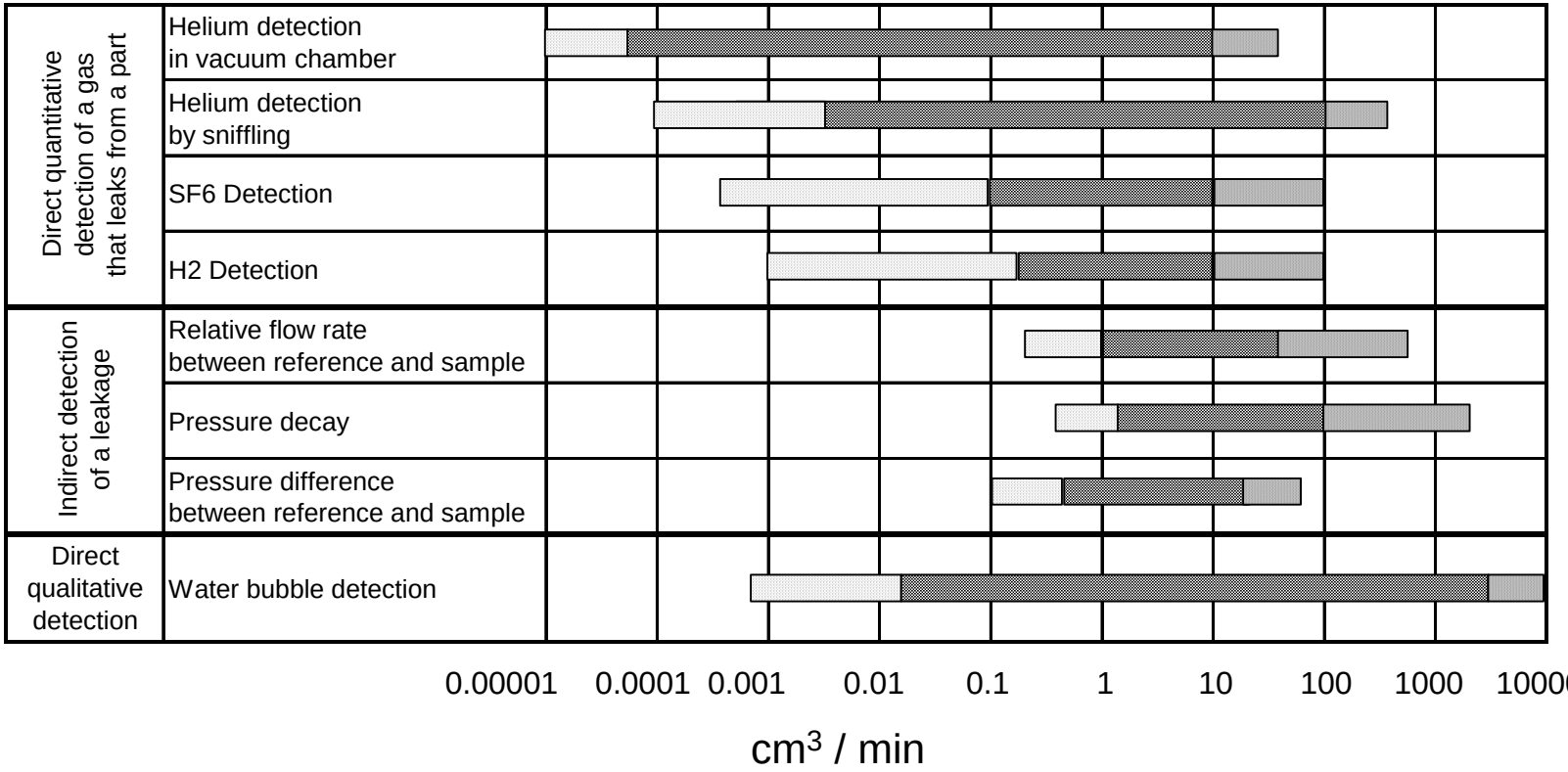
In-Process Leakage Testing of R744 Components

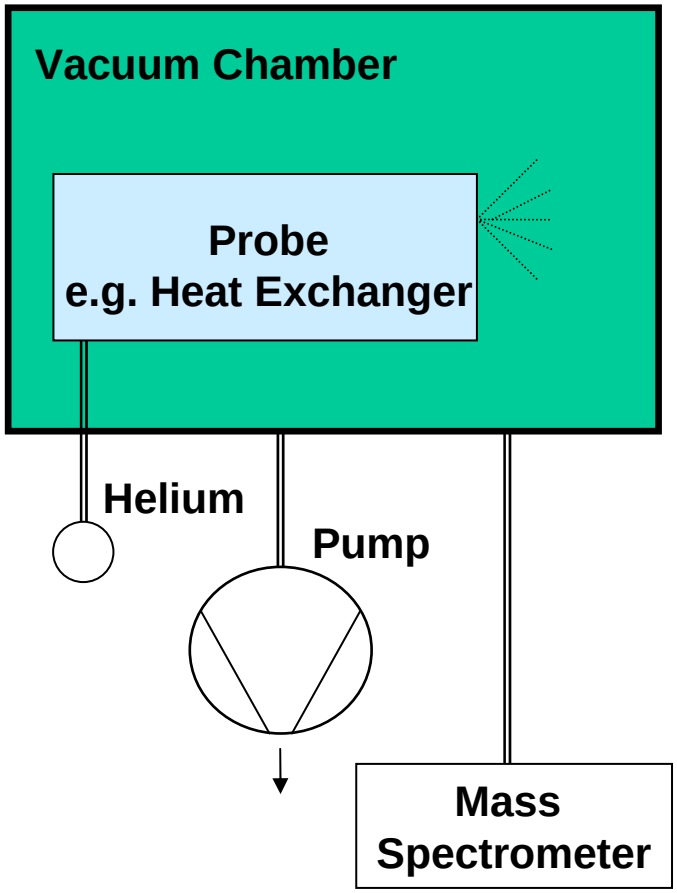
- Methods for In-Process Leakage Testing
  - Overview of Test Methods
  - Test Agents (He, Air, CO2)
  - Test conditions (pressure and detection limit)
- Feasible leakage rate limit
- Recommendation of In-Process Leakage Testing of R744 Components

Methods of Leakage Test



Methods of Leakage Test

Helium detection in vacuum chamber



Properties of Helium

- Non toxic
- Not flammable
- Does not condens
- Inert
- Temperature stabil
- Negligible concentration in air (5ppm)

Detection Method

- High resolution with mass spectrometer
- In-Line automatization is possible

Methods of Leakage Test

Other test agents

CO_2 high natural concentration in air (about 340 ppm)
fluctuation (breath, exhaust,...)
→ Interference from enviroment is considerable

Air Small drift of temperature results in a non-negligible change of a „virtual“ leackage rate

Example:
Drift of ambient temperature: 0,1 K/min
→ „virtual“ leackage rate: **19 cm^3/min**

for comparison: 5g/a R134a at 40 bar (condensers)
→ limit : **0,002 cm^3/min**

→ **Helium is the right test agent for leakage testing**

Feasible leakage rate limit

Mean operating pressure $\mathbf{p_m}$ (example gascooler)

a) Rough estimation

Non operating pressure	55 bar
ambient temperature	20°C
max. high pressure	130 bar
anual mileage	20,000 km
mean speed	35 km/h
AC on	50% of vehicle operation

→ **p_m = 57.5 bar**

b) Conservative estimation

→ **p_m = 65 bar**

Specified pressure for leakage rate determination

Feasible leakage rate limit

Deduction of leackage rate

Current parameters for development

- Target of 1 g/a R744 at mean operating pressure (p_m= 65 bar)

Leackage Rate

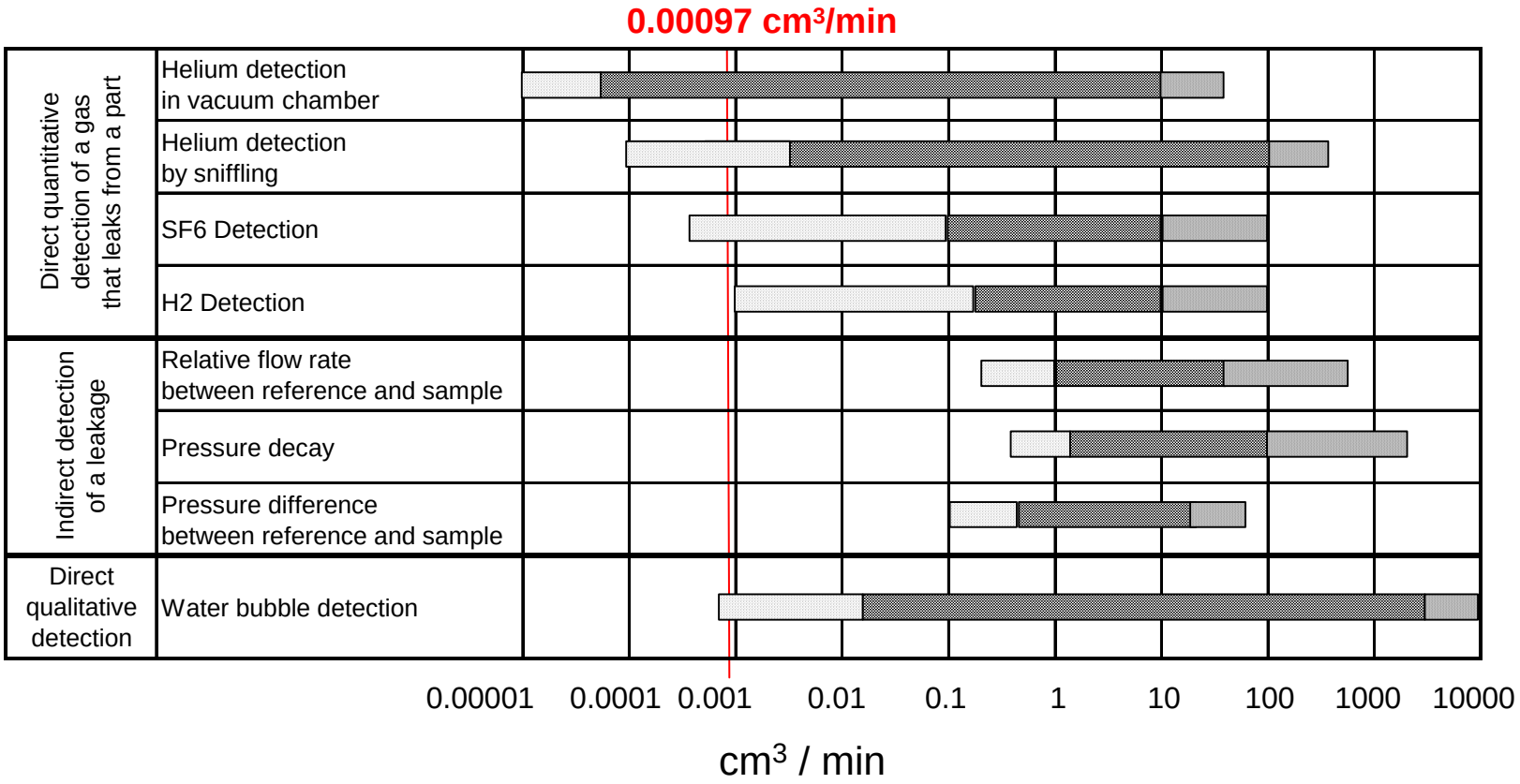
- Molar Mass of R744 = 44 g/mol
- 44 g / 22400 cm^3 = 1 g / X cm^3
- X = 509.1 cm^3 → Leakage Rate = 9.7 x 10^{-4} cm^3/min

Required detectable leakage rate q:

q = 0.00097 cm^3/min

Feasible leakage rate limit

Test Method



Constrained Range of Operation. Needs additional control of ambience.
Regular Range of Operation
Limited range of Operation

Feasible leakage rate limit

In-Process Leakage Rate: 190 bar and Helium

Agent	R744	→	Helium
Pressure In-Process test	65 bar	→	190 bar

The volume rate (of the leak) is proportional to the square of the pressure difference to the ambient and inverse proportional to the viscosity

Leak to be detected 0.97 x 10^{-3} cm^3/min → **6.2 x 10^{-3} cm^3/min**

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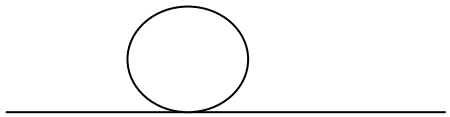
Feasibel leakage rate limit

Localisation of defects

- Defective part (leaker) needs to be root caused immediately, i.e. the location of the leak has to be detected.
- State of the art: visual check for gas bubbles
- R134a: moderate pressure
- Manual Process: bubble frequency < 30 s



Feasibel leakage rate limit

Localisation of defects

Test duration: Target < 30 seconds

		Pressure = 65 bar			
Leakage limit in g (R744) / year	Leakage limit in ccm/min	1 Bubble **1 mm** ∅ departs after Seconds	1 Bubble **2 mm** ∅ departs after Seconds	1 Bubble **3 mm** ∅ departs after Seconds	1 Bubble **5 mm** ∅ departs after Seconds
1 g / a	0.0007 ccm/min	**42**	335	1129	5227
2 g / a	0.0015 ccm/min	**21**	167	565	2613
3 g / a	0.0023 ccm/min	**14**	112	376	1742
4 g / a	0.0030 ccm/min	**10**	84	282	1307
6 g / a	0.0045 ccm/min	**7**	56	188	871
8 g / a	0.0060 ccm/min	**5**	42	141	653
10 g / a	0.0075 ccm/min	**4**	33	113	523

Feasibel leakage rate limit

Localisation of defects

Test duration: Target < 30 seconds

		Pressure = 190 bar			
Leakage limit in g (R744) / year	Leakage limit in ccm/min	1 Bubble **1 mm ∅** departs after Seconds	1 Bubble **2 mm ∅** departs after Seconds	1 Bubble **3 mm ∅** departs after Seconds	1 Bubble **5 mm ∅** departs after Seconds
1 g / a	0.0064 ccm/min	**4.9**	39	132	612
2 g / a	0.0128 ccm/min	**2.4**	**20**	66	306
3 g / a	0.0193 ccm/min	**1.6**	**13**	44	204
4 g / a	0.0257 ccm/min	**1.2**	**10**	33	153
6 g / a	0.0385 ccm/min	**0.82**	**7**	**22**	102
8 g / a	0.0513 ccm/min	**0.61**	**4.9**	**17**	76
10 g / a	0.0642 ccm/min	**0.49**	**3.9**	**13**	61

Visual test at 190 bar to be investigated (Safety)
Limit = 3 g/a to detect bubbles

In-Process Leakage Testing of R744 Components

Summary

Results

- He-Leak Test for R744-Heat Exchangers is mandatory
- A leakage rate of 1 g/a does not allow a visual inspection of a leaker at suitable pressures

Recommendations

- Leakage rate of 3 g/a for in-process tests
- Helium test pressure 190 bar

Open Items

- Development of a visual leak detection at high pressure
- Fittings for in-process testing (seal, sealing surface)