Leakage testing of sealed sources

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1 Introduction

- BAM, as the competent authority in Germany for special form radioactive material approvals and for type testing of sealed sources, has comprehensive knowledge, experience and equipment for leakage testing of sealed sources.
- BAM uses exclusively leakage test methods by non radioactive means, based on a relationship between volumetric leakage rate and loss of radioactive material according to the International Standard ISO 9978
- BAM has to assess the boundary conditions and limiting values for applicability of test methods for different source designs
- BAM started a research programme for leakage testing of sources with a very small void and/or very small leak capillaries.

2 Leakage test methods used by BAM

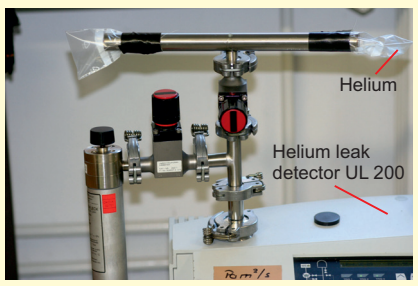
General remarks:
- various source designs require different test methods
- limiting valves for leaktightness of sealed sources
  - 0.2 kBq activity release after tests according ISO 2919, after manufacturing and in use
  - 2 kBq activity release after tests according to the IAEA regulations TS-R-1 for special form radioactive material
- 2 kBq is equivalent to 1 x 10^{-7} Pa*m³/s (for non leachable solid content) and 1 x 10^{-5} Pa*m³/s (for leachable solid content, liqiued or gases) [IAEA Advisory Material TS-G-1.1, Para 603.3]


Various sealed sources designs

Helium test


Dummy of a Caesium Cs-137 source prepared with a test adapter

- The object is evacuated and connected to the dedector, the suspect areas are covered by a suitable, gas -tight enclosure filled with Helium.



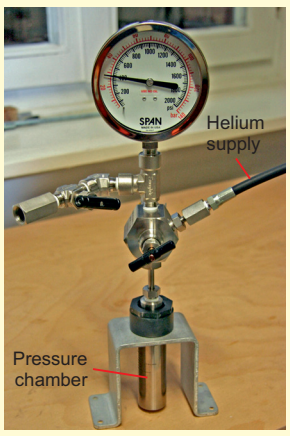
Leakage test of the weld seams on both sides of the rod source

Vacuum bubble test

- Sealed source is to submerge completely in a evacuated fluid (ethylen glycol, isopropylalcohol).
- After reducing absolut pressure in the chamber to between 15 and 25 kPa bubble emanating is to abserve for at least 1 min.

Test equipment with vacuum chamber

Helium pressurization test



Helium pressurization test equipment

- Sealed source is placed in the pressure chamber.
- Chamber is pressurized to a given Helium pressure p for a given time t.
- The cleaned sealed source is transfered to a vacuum chamber for Helium leakage rate measurement.

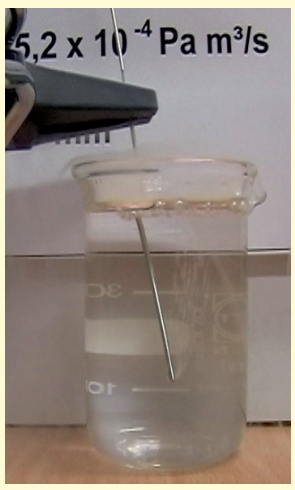
Equation applies for display leakage rate:

$$q_R=(q_L^* p/p_0)*(1-e^{(-q_L*t/(p_0*V))})*e^{(-q_L*T/(p_0*V))}$$

Equation for determining the Standard Helium leakage rate:

$$q_L= (q_1*p_0)/p*e^{(((\ln q_1/(q_2))/((T_2-T_1))*T_1)}$$

Liquid nitrogen bubble test

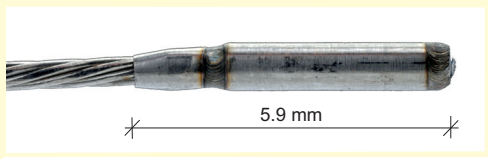


- Sealed source is to immerse in liquid nitrogen for a period of 5 min (ISO 9978).
- After transfer into the test fluid (i.e. methanol, ethylen glycol, isopropylalcohol) bubble emanating is to observe for at least 1 min.
- The detection value is 1.0 x 10^{-6} Pa*m³/s.

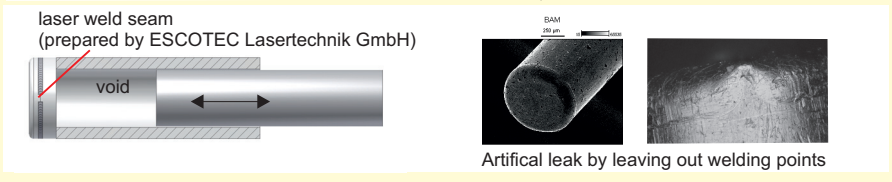
Bubble stream induced by a leak specified by a Standard He-Leakage rate of 5.2 x 10^{-4} Pa*m³s^{-1}

3 BAM research programme on small voids and small capillaries

Objectives:
- Applicability of volumetric leak lest methods for smaller voids than specified in Table 1
- Boundary conditions for keeping the detection values specified in Table 2



Design of a Ir-129 source for medical use, free volume inside is 0.5 mm³



Artifical leak by leaving out welding points

Design of the test capsule void is varied from 0.5 to 80 mm³ and leak size values are varied from by 10^{-4} Pa*m³/s to 10^{-7} Pa*m³/s

Table 1: Minimum void as a precondition for volumetric leakage test methods [according to IAEA Advisory Material TS-G-1.1]

Leak test method	**Minimum void in capsule [mm³]**
Vacuum bubble test	
- Glycol or isopropyl alcohol	10
- Water	40
- Pressurized bubble with isopropyl alcohol	10
Liquid nitrogen bubble	2
Helium pressurization	10

Table 2: Detection and limiting values [according to ISO 9978]

	Standard Helium leakage rate [Pa*m³*s^{-1}]		
	Detection Value	Limiting value	
		Non leachable content	Leachable or gaseous content
Helium test	10^{-8} - 10^{-10}	10^{-6}	10^{-8}
He pressurization test	10^{-6} - 10^{-8}	10^{-6}	10^{-8}
Vacuum bubble test	10^{-6}	10^{-6}	unsuitable
Liquid nitrogen bubbletest	10^{-8}	10^{-6}	10^{-8}

First results:
- He pressurize test for leaks > 1x10^{-4} Pa*m³/s is not suitable due to fast escape of Helium.
- For immersion in liquid nitrogen a period of 5 min is to short for source design with leak sizes < 1 x 10^{-4} Pa*m³/s and voids < 10 mm³; significant longer periods up to 90 min could be necessary for bubble emanating.
- Vacuum bubble test and liquid nitrogen bubble test are applicable also for source designs with smaller voids than specified in Table 2.

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