TRITIUM-IN-AIR MEASUREMENTS BY PULSE-SHAPE DISCRIMINATION METHODS

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Introduction

The simplest method of monitoring ^{3}H is passing it through an ionisation chamber. However, the sensitivities obtained are far off the values required by regulations in many countries. (Table 1).

Section	Exposure Group	Concentration limit in Bq m^{-3}	Concentration limit in Ci/m^3
§ 52 (1) 1	Category A in controlled areas	1.8×10^{5}	5×10^{-6}
§ 52 (1) 2	Category B in controlled areas	5.9×10^{4}	1.6×10^{-6}
§ 52 (1) 3	Non-occupational exposure in monitored operating areas	5.9×10^{3}	1.6×10^{-7}
§ 52 (1) 4	Non-occupational exposure in monitored areas outside plants	3.7×10^{2}	1×10^{-8}
§ 46 (3)	General national territory (emission concentration)	3.7×10^{2}	1×10^{-8}

Table 1: Concentration Limits for airborne ^{3}H (German Radiation Protection Regulations)

Furthermore, in ionisation chambers it is very difficult to discriminate the signal due to ^{3}H from the effect of external gamma-radiation and higher energy gaseous radionuclides.

Ehret, Kiefer and Maushart (1) successfully introduced proportional counter tubes with volumes of several l for ^{3}H-monitoring.

The price for obtaining excellent sensitivity, stability and good discrimination against ambient gamma emitters is the necessity to continuously add counting gas to the sample air. As a consequence of the detector design, with separate sample and shield volumes, about 75% of the counting gas/air mixture is always in the shield or dead volume.

One of the objects of the present work was to use the entire detector volume as sample counter, therefore reducing counting gas consumption and/or increase sensitivity (2).

Principle

The pulse rise-time in a proportional counter tube is dependent upon the different drift times of the secondary electrons generated in the ionisation process as they travel to the counting wire. The shorter the range of the beta particle, the smaller is the average fluctuation of the arrival time at the counting wire, thus leading to shorter rise-times. Rise-time discrimination therefore allows to differentiate between radionuclides with different particle range.

Detector Design

Two different detectors are used:
1. Cylindrical design with 2 concentric counting volumes, each with a cylindrical array of counting wires, separated by ground wires, with total volume 3.0 l.
2. Rectangular design with a single plane of counting wires, volume 0.5 l.

Electronics

All counting wires are operated in parallel. Pulses are amplified by a fast (rise-time approx. 10 ns) charge-sensitive preamplifier followed by a voltage amplifier, then passed through a double delay-line pulse shaping network with zero-crossing discriminator. This allows to obtain pulses the width of which is a measure of the pulse-rise time. A pulse-width discriminator sorts all pulses into two channels (see also Fig. 2), channel A representing tritium-particles, and channel B representing background, gamma-radiation or radioactive noble gases.

Operation

For better understanding of the nature of the process, the pulses of the detector have been fed into a rise-time/amplitude converter, followed by a standard multichannel pulse-height analyzer.

Fig. 1 shows the rise-time spectra for a relatively high concentration of ^{3}H (16000 cpm), so that background contribution (1050 cpm) is hardly noticeable. A relatively narrow peak is clearly recognized.

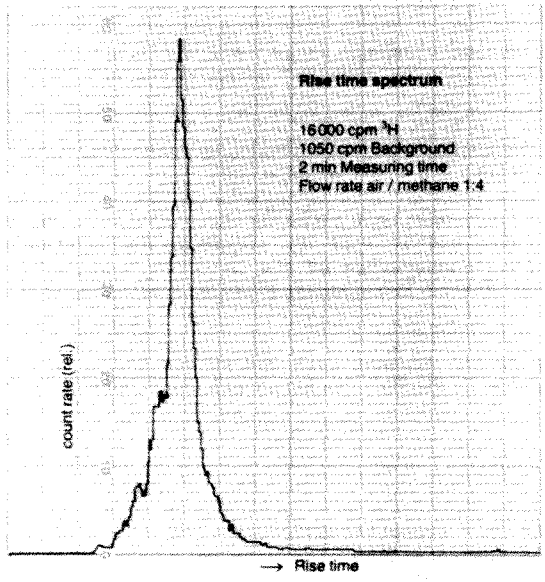

Fig. 1 Rise-time spectrum for ^{3}H in air/methane mixture.

Fig. 2 shows corresponding results for a smaller ^{3}H-concentration (300 cpm). The background contribution with its much longer rise-times is now clearly recognizeable.

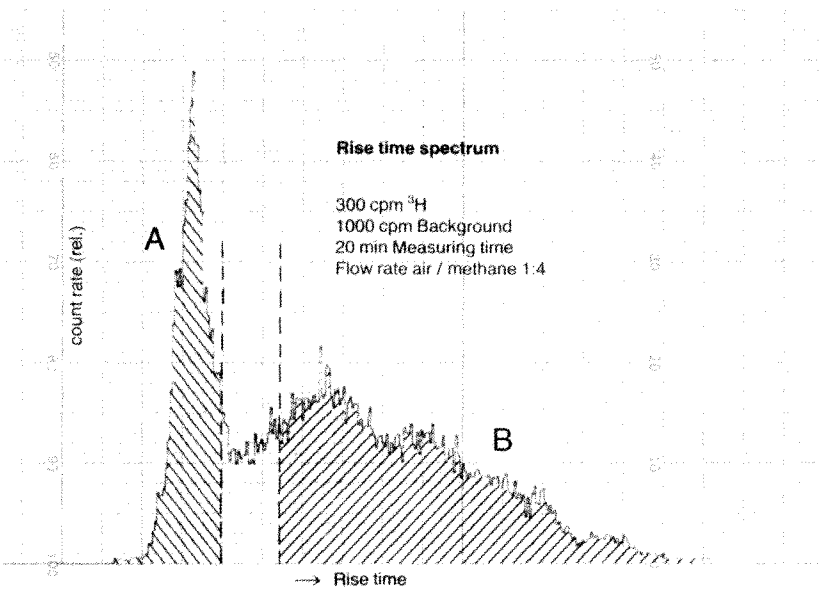

Fig. 2 Rise-time spectrum for ^{3}H and background (see text).

Rise-time scales have not been calibrated absolutely since the method is based upon the difference of relative rise-times only. For ^{3}H, rise-times for a methane/air mixture are below 20 ns, while the majority of background pulses shows rise-times around 100 ns. Using P10 gas and air, rise-times appear to be at least 5 times larger, for both tritium and background pulses.

Fig. 2 also explains the function of the rise-time discriminator. Channel A is set to enclose essentially the rise-time "peak" caused by ^{3}H-particles. Channel B covers the broad spectrum of long-range ^{3}H particles. It can be used to measure radioactive noble gases independent from ^{3}H, or to establish a monitoring channel for either noble gases or ambient radiation, in order to establish a spill-over factor into the ^{3}H-channel.

Results

Table 2 shows operating data and results, while table 3 shows detection limits as a function of measuring time.

Detector Volume	3.0 l	0.5 l	
Flow rate air/methane	1/3	0.25/0.75	l min^{-1}
Air sample volume inside detector	750	125	ml
Efficiency for ^{3}H	60	50	%
Background rate	0.6-1.5	0.2-0.4	s^{-1}
Spill-over (^{137}Cs gamma radiation → ^{3}H-channel)	4-5	4-5	%

Table 2 Results with 3.0 and 0.5 l detectors

	3 l - Detector		0.5 l - Detector	
Measuring Time	kBq·m^{-3}	Ci/m^3	kBq·m^{-3}	Ci/m^3
30 s	0.920	2.5×10^{-8}	4.8	1.3×10^{-7}
1 min	0.650	1.75×10^{-8}	3.4	9.2×10^{-8}
10 min	0.205	5.5×10^{-9}	1.1	1.0×10^{-8}
1 h	0.084	2.3×10^{-9}	0.44	1.2×10^{-8}
24 h	0.017	0.46×10^{-9}	0.09	2.4×10^{-9}

Table 3 Detection limits (3σ error) as function of measuring time. Values given apply for operation with methane, for P10 the detection limits are higher by a factor of 2.2.

Literature

1. Ehret, Kiefer und Maushart, "Fortschritte bei der kontinuierlichen Tritiumüberwachung in Luft", Direct-Information 2/63, G. Braun-Verlag, Karlsruhe
R. Maushart, "Tritiummessungen im Strahlenschutz", G-I-T p. 845 (1967).

2. German Patent No. 2500 510, "Verfahren zur Selektierung der Kernstrahlung bestimmter gasförmiger, in einem Trägergas in ein Zählrohr gebrachter Radionuklide, unter Diskriminierung nach der Impulsform sowie Anwendung dieses Verfahrens und Verwendung eines Durchflußzählrohres hierzu."