BUBBLE DETECTORS IN INDIVIDUAL NEUTRON DOSIMETRY

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INTRODUCTION

Bubble detectors would be able to fulfill requirements following from the ICRP 60 recommendations as far as individual neutron dosimeter is concerned. Particularly, the lowest limit of detection seems to be decreased down to about 10 μSv or even lower. At the moment, there are two types of such detectors commercially available: bubble damage neutron detectors (1) (BDNDs - Bubble Technology Industries, Chalk River), and superheated drop detectors (2) (SDDs - Apfel Enterpr., New Haven). Both these types have been tested in our studies from the point of view of personal dosimetry. Particular attention is devoted to their energetical dependences and their responses in the fields in which they should be used to determine occupational exposures.

EXPERIMENTAL CONDITIONS

BUBBLE DETECTORS TESTED

BDNDs' tested had issued from two deliveries. The first one was constituted from the type BD 100R (threshold neutron energy 100 keV) of two different sensitivities to AmBe neutrons (0.8 and 2.2 bubbles per 1 μSv of H*(10)). The second delivery constituted again of BD 100R (1.0 bubble per 1 μSv), not compensated for the temperature, and temperature compensated PND of the same nominal sensitivity and similar energy dependence.

SDDs' tested had issued from the single delivery. It consisted of AMS reader and sets of detectors with three different energy thresholds: 100 keV (SDD 100), 1 MeV (SDD 1000) and 6 MeV (SDD 6000). The sensitivity of all of them ought to be about 3.3 bubbles (counts) per 1 μSv of H*(10) from neutrons with energies above the threshold.

NEUTRON FIELDS USED FOR TESTING

The response of bubble detectors has been studied in neutron beams and fields characterized in Table 1.

Table 1. Neutron fields used for testing.

Neutron field	$\bar{E}_N$ [MeV]	H*(10) [1) [Sv.cm^2]	Neutron field	$\bar{E}_N$ [MeV]	H*(10) [Sv.cm^2]
SIGMA (3)	0.070	2.29 -11	PuBe	4.2	3.80 -10
CANEL+ (H_2O) (4)	0.096	3.47 -11	AmBe	4.4	3.80 -10
CANEL+ (4)	0.185	7.26 -11	JINR - soft (5)	0.25	2.90 -11
$^{252}Cf/D_2O/Cd$	0.54	9.10 -11	CERN - iron (6)	1.9	1.60 -10
AmF	1.5	3.40 -10	JINR - hard (5)	12.5	1.05 -10
^{252}Cf	2.1	3.40 -10	CERN - concrete (6)	49.8	2.80 -10

1) ICRP 21 conversion factors

RESULTS OBTAINED

Multiple irradiation of several pieces of BDNDs′ (type PND) has been realized with neutrons of an AmBe source. The standard deviation of a single reading was found to be close to √N/N, where N is the number of bubbles. The precision about ± 30% is hence achieved when total number of bubbles is above 10.

The relative responses of BDNDs′ studied in different neutron fields are presented in Table 2.

Table 2. Relative responses of BNDDs′ (BD 100R and PND - 2nd delivery) to neutrons.

Neutron source	Relative response	
	BD 100R	PND
SIGMA	0.52 ± 0.04	0.54 ± 0.04
CANEL+ (H_2O)	1.13 ± 0.09	1.06 ± 0.08
CANEL+	1.22 ± 0.09	1.06 ± 0.08
AmF	1.10 ± 0.08	1.16 ± 0.08
^{152}Cf	1.34 ± 0.14	1.38 ± 0.15
AmBe	1.00[1)]	0.94 ± 0.07
PuBe	1.05 ± 0.07	1.03 ± 0.07
JINR - soft	-	1.13 ± 0.13
CERN - iron	1.28 ± 0.13	1.17 ± 0.10
JINR - hard	-	0.70 ± 0.07
CERN - concrete	0.63 ± 0.04	0.62 ± 0.04

[1)] Taken as a reference

One can see there that, with the exception of thermal neutron source SIGMA (50% of H*(10) from thermal neutrons) and high energy reference fields the relative response of both BDNDs′ is not too far from 1.0. However, it should be mentioned that the results obtained with BD 100R of the 1st delivery have been slightly different, generally about (19±5)% lower for sources CANEL+ (H_2O), CANEL+, AmF, ^{252}Cf and CERN-iron, i.e. closer to 1.00 as compared with results presented in Table 2. It could be connected with slightly different energy dependence, the BD 100R from the 2nd delivery being relatively more sensitive to neutrons with energies from 0.1 to 1-2 MeV.

The relative responses of SDDs′ studied in different neutron fields are presented in Table 3.

Table 3. Relative responses of SDDs to neutrons.

Neutron source	Relative response of SDD with the threshold, [MeV]		
	0.1	1.0	6.0
SIGMA	0.60 ± 0.05	0.12 ± 0.01	0.010 ± 0.003
CANEL+ (H_2O)	0.23 ± 0.03	0.025 ± 0.005	0.0054 ± 0.0010
CANEL+	0.48 ± 0.05	0.006 ± 0.002	0.0028 ± 0.0005
AmF	0.66 ± 0.05	0.081 ± 0.010	0.028 ± 0.005
^{252}Cf	1.03 ± 0.06	0.17 ± 0.02	0.090 ± 0.010
PuBe	0.90 ± 0.08	0.35 ± 0.03	0.16 ± 0.02
AmBe	1.00[1)]	0.38 ± 0.02	0.16 ± 0.02
CERN - iron	0.70 ± 0.10	0.17 ± 0.02	0.09 ± 0.02
CERN - concrete	0.50 ± 0.05	-	-

[1)] Taken as a reference value

One can see there that:

- the drop down in the relative responses for neutrons with energies going down below 1 MeV to 100 keV is faster for SDD 100 as compared with BD 100R or PND;
- the comparison of responses of SDD 100 with SDD 1000 (or 6000) permits clearly to distinguish fission from more energetic neutrons;

the relative response of SDD to high energy neutrons (CERN - concrete) is also, as for BDNDs, lower.

There are two types of occupational exposures for which the use of bubble detectors could be particularly fruitfull:

- degraded spectra of fission neutrons behind the shielding of power and/or research reactors;
- neutron fields behind the thick shielding of primary high energy particles (high energy accelerators, cosmic radiation in the Earths atmosphere.

In both cases, bubble detectors can be used as an individual dosimeter. At reactors, BDNDs with threshold 100 keV can be used even without important corrections on the actual neutron spectrum. As far as SDDs and both types using in high energy neutron fields are concerned, it seems to be appropriate to multiply their readings by a factor of about two to compensate for their energetical dependence.

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