USE OF BUBBLE DETECTORS FOR THE DOSIMETRY OF COLD NEUTRONS

D. Delacroix, L. Bourgois, V. Juhasz, J.E. Noye, J.Daude

Service de Protection contre les Rayonnements, Commissariat à l' Energie Atomique, UGSP/SPR - CEA, Saclay
91191 Gif sur Yvette - France.

INTRODUCTION

Several different types of detector are presently used for health physics oriented neutron detection and measurements. These detectors are based on a wide variety of different principles, ranging from activation reactions induced by neutron radiation in materials, nuclear reactions in gas counters, as well as on the use of photographic emulsions or solid state track detectors.

Several years ago Apfel (1-2) and Ing (3) developed a new type of detector, bubble detectors, which have ever since raised considerable interest among radiation protection specialists. These neutron detectors are insensitive to X and γ radiations and are extremely useful for mixed photon + neutron field measurements.

The present article describes studies performed in Orphée, a nuclear reactor, located in the Saclay Nuclear Research Center, providing different wavelength ($\lambda < 20$ Å) cold neutron beams. We have thus determined the response of « thermal neutron » bubble detectors from 3 to 15 Å (i.e. corresponding to energies in the 9 meV to 0.36 meV range) and compared the results obtained with those determined using Li-6F.

Images obtained with a scanner reveal that the heterogeneity in the distribution of bubbles in the detection medium is a function of λ.

1) REMINDER OF PRINCIPLES

Bubble detectors are based on a principle similar to the one used for the bubble chambers employed in high energy physics. Bubble detectors consist of a gel or transparent polymer in which micro droplets of freon have been dispersed. In the absence of radiation these droplets are thermodynamically stable and capable of remaining in a metastable state over a period of several months. When exposed to a neutron field, charged secondary particles induce these droplets to undergo a liquid-to-gaseous phase change. Bubbles can be seen with the naked eye. The dosemeter composition is such as to assure proportionality between the number of bubbles and the dose equivalent (ref. NCRP 38). Dosemeters commercialized by Bubble Technology Industries cover a range of sensitivities (0.03 to 3 bubbles/µSv) together with different energy ranges (thermal energies, energies in the 200 keV to 15 MeV range etc.).

2) MATERIALS AND METHODS

Measurements were performed with BDT (thermal) type bubble detectors from Bubble Technology Industries with sensitivities in the 1.5 to 3 bubbles.μSv^{-1} range for thermal neutrons (sensitivity given by the manufacturer for a temperature of 20 °C).

The experimental equipment used is shown in Figure 1. In order to ensure measurement reproducibility, the detector is housed in a support located at a distance of one centimeter from the beam window (3 cm in diameter). The position of the detector with respect to the beam was checked with a Polaroid photograph. In this way, a corrective factor was determined to take into account the fact that the detector is not completely exposed to the beam. Exposure times, varying between 30 and 90 seconds were measured with a chronometer.

Prior to the positioning of the bubble detector in the beam, flux measurements were performed with an RTC make 4.74 mm diameter CFUF.32.S type fission chamber. Chamber measurements were corrected to take the variations in response as a function of neutron wavelength into consideration.

Measurements were also performed using simultaneously exposed Li-6F (sensitive to both neutrons and photons) and Li-7F (only sensitive to photons) detectors. The dose equivalent due solely to neutrons is obtained by subtraction.

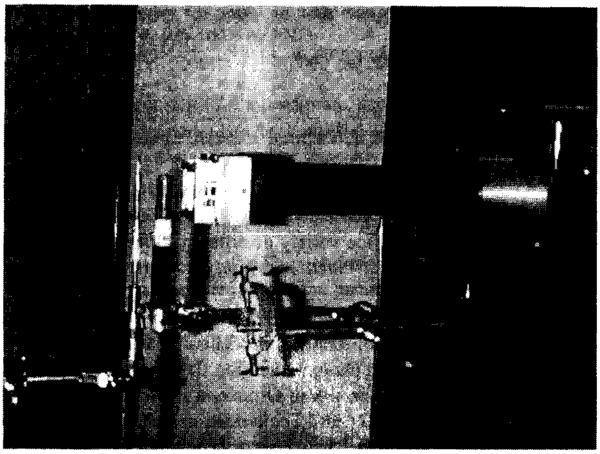

Fig. 1 : Bubble detector and fission chamber in the cold neutron beam

It should be noted that « equivalent thermal neutrons » units are employed for both LiF and bubble detector measurements. It is assumed that bubble-dose equivalent conversion factors or digital - dose equivalent factors remain constant for $\lambda > 1.8$ Å values.

3) RESULTS AND DISCUSSIONS

Figure 2 indicates that bubble detector and thermoluminescent detector responses slightly increase with λ. Extrapolation of the experimental curve to the theoretical « thermal wavelength » (1.8 Å) is in good agreement with the « thermal » point calculated for reference NCRP 38 (4) and shown in Figure 2.

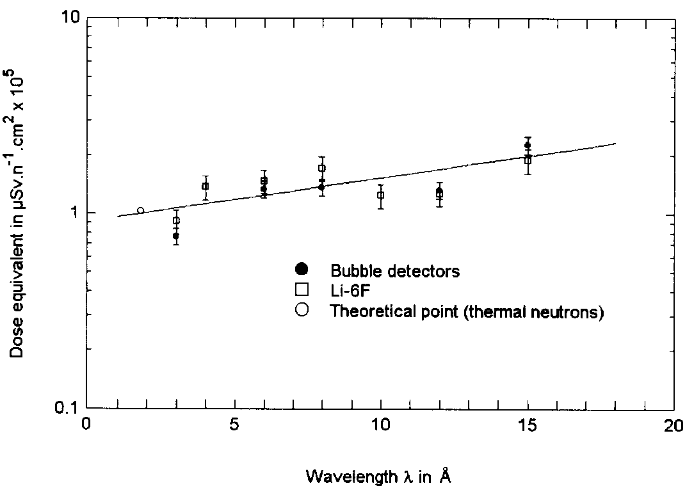

Fig. 2 : Response of Bubble detectors and Li-6F for cold neutrons

Attention is drawn to the fact that dose equivalent (in thermal equivalent units) is practically independent of λ (to within ± 30%), thus enabling bubble detectors to be used as fluence meters. Besides being easy to use in comparison with fission chambers, these detectors also present the advantage of providing a direct readout in terms of bubbles-$n.cm^{-2}$ and do not necessitate the use of any λ dependent correction factor.

Finally, images obtained with a scanner for 3, 5, 10 and 15 Å radiations reveal an increasing bubble distribution heterogeneity with λ (see Figure 3).

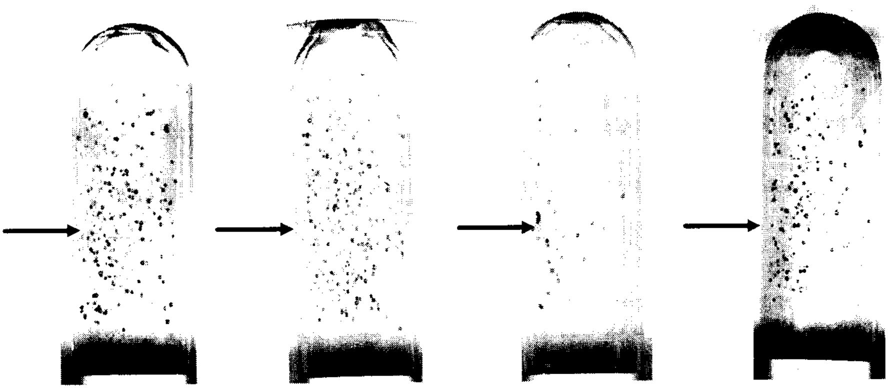

Fig. 3 : Bubble detectors irradied by different wavelength neutrons (3, 5, 10 and 15 Å) (⟶ beam direction)

4) CONCLUSIONS

Radiation protection requirements can be satisfied with the sensitivities and operational energy ranges covered by bubble dosemeters. The responses of bubble detectors have been validated by different laboratories (5,6,7). This preliminary study shows that the « thermal neutron dose equivalent or fluence » responses of these dosemeters to cold neutrons with energies in the 9 meV to 0.4 meV range are practically energy independent (to within ± 30%); furthermore the responses of Li-6F and bubble dosemeters have been shown to be very similar. Radiation protection specialists thus have at their disposal a new easy-to-use tool with a satisfactory response for fluence or dose equivalent estimations in or in the vicinity of cold neutron beams.

5) REFERENCES

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