

SUPERHEATED DROP, "BUBBLE", NEUTRON DOSIMETER PERFORMANCE IN A WORK ENVIRONMENT

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Abstract

Bubble dosimeters offer a unique combination of sensitivity, immediate results, and dose equivalent response, but their use has been limited by temperature and vibration. To determine their practicality, we simulated a large operation in an air conditioned radiation work environment. We tested 120 devices of three types. The batch homogeneity and reproducibility were about 20%, and the lower limit of detection was about 10 μ Sv (1 mrem). The dose equivalent indicated by bubble dosimeters agreed with remmeters and spectrometers more closely than did the dose indicated by conventional dosimeters.

I. Introduction

The Question

Can bubble dosimeters be used in the numbers that a large operation may require and give reliable results in a work environment? They offer a unique combination of sensitivity, immediate results, and dose equivalent response [1], but fail when stressed by temperature, pressure, and vibration [2], [3].

Bubble Technology Inc. [4]

BD-100R: The superheated drops are retained in a polymer (Figure 1.) and counted either by eye or a video system. Bubbles can be re-compressed for re-use by applying external pressure.

BDS-SPECTROMETER: A set of thirty six tubes containing six different compositions with neutron energy thresholds nominally from 10 to 10,000 keV.

Apfel Enterprises Inc. [5]

Active Personnel Neutron Dosimeter (APND): The saturated drops are contained in a liquid, and the sounds of vaporization are counted [6]. An anticoincidence circuit inhibits counting when the noise transducer detects sound or vibration. See Figure 2. Replaceable cartridges (SDD) are available with different neutron energy thresholds. Cartridges of two thresholds in The Area/Spectrum Monitor (A/SM) aid in estimating energy dependent errors in albedo neutron dosimeters [7].

Pen Type: The drops and matrix are in a small syringe, and the dose is read from the displacement. This prototype device, produced for NAVSWC, led to a displacement device using the standard APFEL™ cartridge.

Fig. 1

BTI™ Polymer Matrix

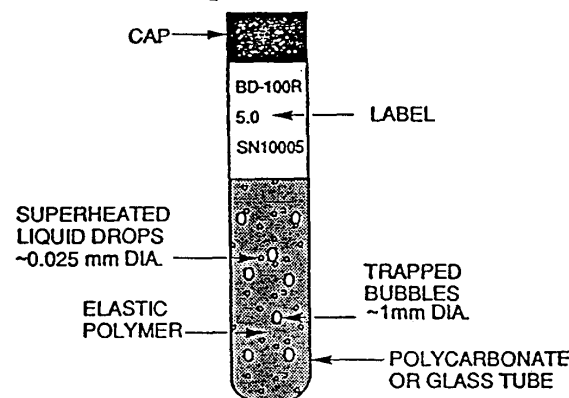
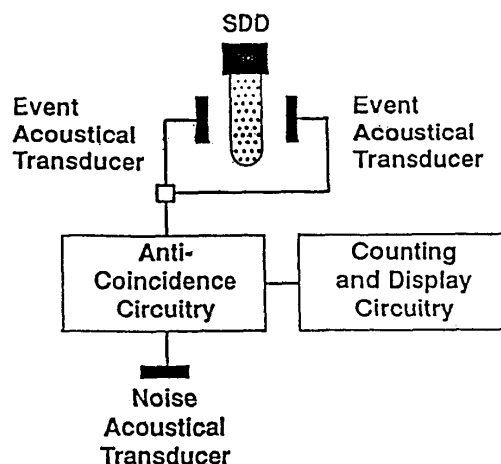


Fig. 2

APFEL™ Liquid Matrix



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Advantages and Disadvantages

Users like Bubble dosimeters because their response is immediately visible, or audible, and because it is proportional to the dose equivalent over a broad range of neutron energy. Since the characteristics are controlled by the formulation, various sensitivities, energy thresholds, and even types of radiation may be measured. The sensitivity is high compared to personnel dosimeters, but lower than active counters. The cost is high for routine dosimetry, but low for investigations.

Temperature

Efficiency varies with temperature at about 5%/°C over a usable range of 10 to 35°C. Each vendor has a method of temperature compensation now being tested.

Dynamic Range

The range from the lower limit of detection to saturation is set by the minimum # of bubbles (25) that may be read to $\pm 20\%$, and the maximum number of bubbles that may be counted. In the polymer system, the maximum is set by the resolution of the reading device. In the liquid system it is set by the number of bubbles initially present. Table I lists typical values.

Table I

System	Reader	Dynamic Range
Polymer	Eye	4
Polymer	Video	10
Polymer	AI, 3 Dimensional (Artificial Intelligence)	40
Liquid	Linear to -20%	240
Liquid	With Correction (50% of drops consumed)	600

II. Test Protocol

Tests

We followed the International Organization for Standardization (ISO) procedure [8] for testing personnel dosimeters, and compared bubble dosimeters with conventional detectors. Extra bubble dosimeters were given to radiation protection personnel to obtain comments on practical use.

The Environment

Normal work, which continued throughout the test, fortunately did not include sufficient noise to shut down the APFEL™ counters. The area was temperature controlled, and the neutron field as measured by neutron remmeters and Bonner multi-sphere spectrometers was uniform in intensity and energy. The fluence spectrum peaked at about an MeV, and decreased

with energy by a decade from the peak to one eV. The thermal fluence was about equal to the peak fluence.

Procedure

BTI™ BD-100R and BDS-SPECTROMETER: Thirty BD-100R tubes and 2 spectrometer sets (six tubes of each threshold) were cleared, read, exposed, and read three times, with a total exposure time of 50 hours.

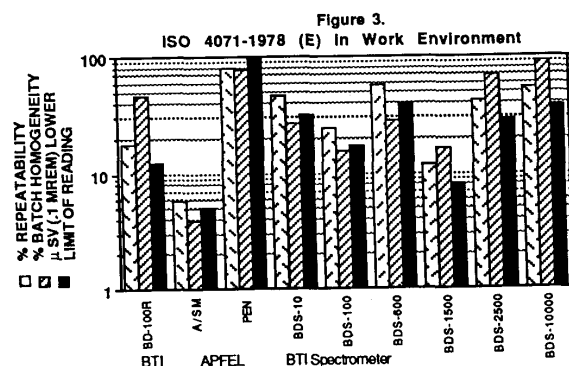
APFEL™: Five monitors using the standard cartridge and six prototype pen devices were exposed continuously for eighty hours, and read nine times during the exposure.

Comparison Detectors: We compared the bubble systems response with: Snoopy remmeters and an area monitor based on the remmeter (TLD Monitor) [9], LiF thermoluminescent albedo neutron dosimeters (TLD phantom), Columbia resin-39 neutron track dosimeters (CR-39), and; Bonner multi-sphere (BMS), Nuclear Enterprises (NE213), and tissue equivalent proportional counter (TEPC) spectrometers.

III. Results

ISO Tests

Figure 3. displays the result of three tests [8].



Reproducibility (Repeatability): The standard deviation (SD) divided by the mean of repeated tests should be less than 20%.

The acceptable devices are: the BD-100R @ 18%, the BDS 1500 @ 12%, and the APND and A/SM Monitors @ 6%. The BDS 100 keV is marginal at 24%.

Other BDS tubes exceeded 40%. The dose rates were too low to test the APFEL™ Pen and BDS 10,000 keV.

Batch Uniformity: This is the probable error in using a single efficiency for a batch of detectors.

The BD-100R, at 46%, requires individual calibration. The acceptable devices are:

The BDS-100 @ 15%, the BDS 1500 @ 12%, and the APND and A/SM @ 4%.

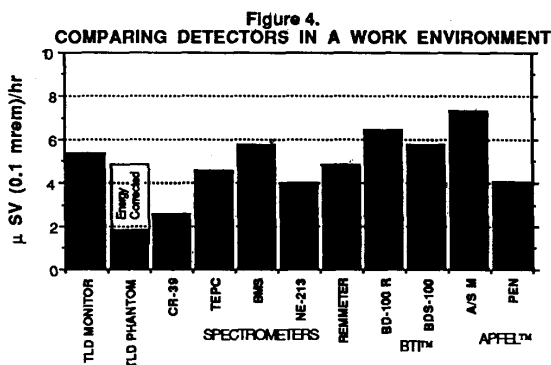
Lower Limit of Detection (LLD): The LLD equals 1.96 times the SD divided by the square root of the number of detectors in the test. Dose equivalents of 5 to 20 μSv (0.5 to 2 mrem) are detectable; see Table II.

TABLE II

Dosimeter	LLD μSv (tenths of mrem)
BD-100R	12
BDS-100	17
BDS-1500	12
APND & A/SM	5

Comparison with other Devices

Figure 4. displays the mean dose equivalent rate for each type of detector. All rates measured by dose equivalent devices (APND, A/S Monitor, Pen, BD-100R, BDS-100, TLD Monitor, remmeter, BMS, TEPC, and NE-213) were between 4 and 7 μSv (0.4 and 0.7 mrem)/Hr. This agreement is better than one would expect, since each is calibrated in a different way. NE 213 and the TEPC were on the low end, since the spectrum is rich in low energy neutrons which they do not measure. CR-39 reads low for the same reason. The TLD Phantom albedo dosimeters read low because they are calibrated with D_2O moderated Cf^{252} . The energy correction for this spectrum raises their reading to 5 $\mu\text{Sv}/\text{Hr}$.



IV. CONCLUSIONS

Bubble dosimeters met ISO [8] standards in an operational environment. They measured the neutron dose equivalent more correctly than did common personnel dosimeters.

APFEL™ The Active Personnel Neutron Dosimeter and Area/Spectrum Monitors were the more precise and sensitive devices in the test, but since they incorporate an anti-coincidence circuit to eliminate acoustical noise, a dead time counter will be required before they can be used for personnel protection.

BTI™ The BD-100R meets the 20% criteria, provided that each tube is individually calibrated. Of the BDS spectrometer set, only the 100 and 1500 keV compositions gave consistent results. They are candidates for energy correction of the albedo dosimeter [10].

Results agreed more closely with: a tissue equivalent proportional counter, Bonner multi-sphere and NE213™ neutron spectrometers, remmeters and a Dose Equivalent TLD Area Monitor than did measurements with LiF albedo TLD and CR-39 neutron track dosimeters.

V. References

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