THE SINGLE SPHERE ALBEDO TECHNIQUE: A REFERENCE INSTRUMENT FOR DOSEMETER CALIBRATION AND ANALYSIS OF STRAY NEUTRON FIELDS

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1. INTRODUCTION

In neutron monitoring there is the need for a standardized technique which may be applied in stray neutron fields in order to establish reference data mainly for the field calibration of neutron dosemeters and to replace the more sophisticated multisphere technique. The single sphere albedo technique originally applied for the calibration of albedo neutron dosemeters [1-3] makes use of thermal neutron detectors in the center of a 30 cm polyethylene sphere and behind boron-plastic shields on the surface of the sphere. Based on well established response functions of four neutron detectors and an on-line computer assisted evaluation technique, the system allows for the estimation of actual field data, i.e. neutron fluence, absorbed dose, dose equivalent as well as the corresponding factors d_{eff}, h_{eff} and Q_{eff} [4,5].

2. TECHNIQUE

The single sphere albedo technique reduces the energy dependence of the 30 cm sphere by using for instance the read-out of TLD600/

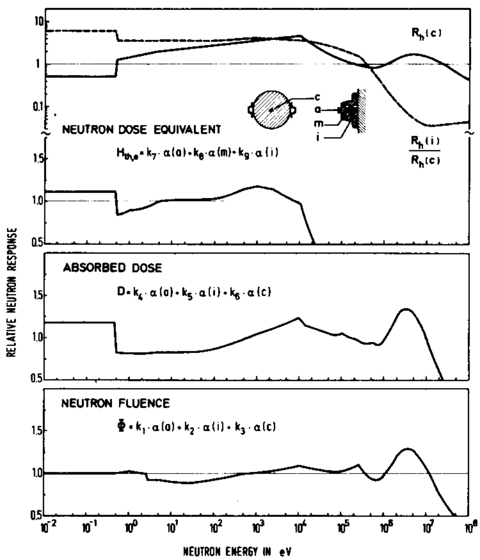


Fig. 1: Dose equivalent response function R_h of the 30 cm sphere detector c and linear combinations using the energy response of the detectors c, m, a, i and the constants k_1 to k_9 for the estimation of neutron fluence and absorbed dose

TLD700 detector pairs in the center of the sphere c and in three positions m, a, i of the boron-plastic encapsulation of the Karlsruhe albedo dosemeter. The detector system enables one to calculate at first the dose contributions of thermal and epithermal neutrons using the readings of detector m and a in front and behind the boron absorber and thus the reading contributions of fast neutrons. With respect to fast neutrons the reading ratio of albedo detector i and sphere detector c is used to establish an energy parameter E_o. The apparent dose contributions of the sphere detector c separated for thermal, epithermal and fast neutrons are then corrected for energy dependence. This technique has been standardized for an application in multi-directional fields by using the reading sum of two dosemeters positioned diametrically at the sphere.

Using experimental and recently calculated fluence response functions $R_\Phi(k)$ of the detectors a, m, i and c, it can be shown in Fig. 1 that the adequate superposition of the detector reading $\alpha(k)$ allows to estimate neutron fluence and absorbed dose practically independent of neutron energy within +30 %/-20 % and the dose equivalent of thermal and epithermal neutrons within ±20 %.

3. STANDARDIZED EVALUATION TECHNIQUE

The on-line computer program described in Table 1 estimates at first the neutron dose reading taking into account the individual response of the detector, the zero dose reading and the separation of the gamma contribution, and corrects then for angular response using the reading ratio of diametrically opposite detectors at the sphere. By splitting up the four detector readings $\alpha(k)$ with k = a, m, i, c in three energy groups of thermal, epithermal and fast neutrons, the set of simultaneous equations are solved. After estimation of the neutron fluence contributions Φ_{th} and Φ_e for thermal and epithermal neutrons, the readings $\alpha_f(k)$ for fast neutrons are derived and the energy parameter E_o reduces the energy dependence of $\alpha_f(c)$ for the estimation of H.

$$\Phi = k_1 \cdot \alpha(a) + k_2 \cdot \alpha(i) + k_3 \cdot \alpha(c) \qquad (1)$$

$$D = k_4 \cdot \alpha(a) + k_5 \cdot \alpha(i) + k_6 \cdot \alpha(c) \qquad (2)$$

$$H_{th,e} = k_7 \cdot \alpha(a) + k_8 \cdot \alpha(m) + k_9 \cdot \alpha(i) \qquad (3)$$

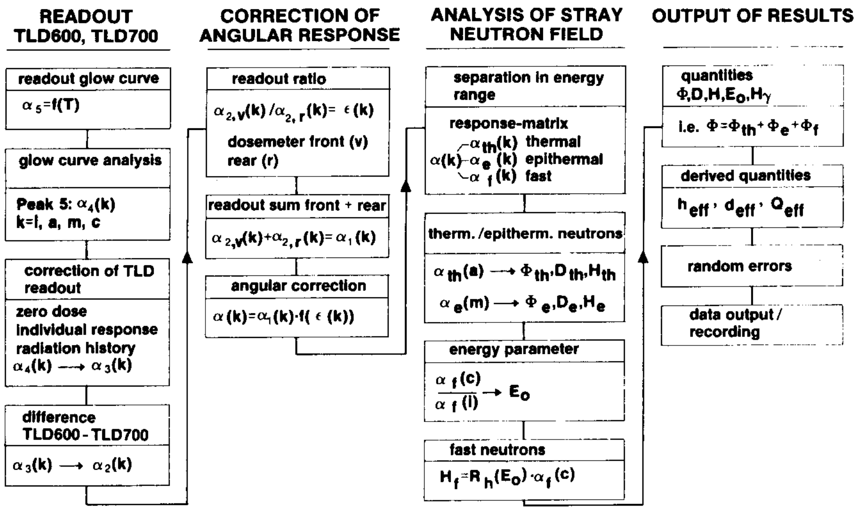
$$H = h_{th} \cdot \Phi_{th} + h_e \cdot \Phi_e + R_{h,E_o} \cdot \alpha_f(c) \qquad (4)$$

$$= k_7 \cdot \alpha(a) + k_8 \cdot \alpha(m) + k_9 \cdot \alpha(i) + R_{\alpha,E_o} \cdot \alpha_f(c) \qquad (5)$$

with the detector readings $\alpha(k)$ and k = a, m, i, c, the constants k_1 to k_9 found by least square fits and the fluence-to-dose conversion factors d and h given by ICRP 21.

From H, D and Φ the following actual field data can be computed

- the neutron fluence-to-dose equivalent conversion factor $h = H/\Phi$
- the neutron fluence-to-absorbed dose conversion factor $d = D/\Phi$
- the effective quality factor $Q_{eff} = H/D$.



Tab. 1: On-line computer assisted evaluation of TLD detectors using the single sphere albedo technique

4. APPLICATION

With respect to a qualitative interpretation of the stray neutron field, the energy parameter E_O established for neutron energies > 10 keV has been found to be comparable with the mean neutron energy. Values between 50 keV $\leqq E_O \leqq$ 120 keV have been found behind shieldings at reactors and medical linacs (Fig. 2). Experimental field data derived with the single sphere albedo technique have been found to be highly consistant for the various intercomparison experiments at the HPRR in Oak Ridge [6] and agree with calculated data taking into account the neutron spectrum and the detector response functions. The maximum scatter of 14 measurements for each neutron spectrum was within ± 15 %. Because of energy dependence detector i indicates any change of the neutron spectrum in the energy range of intermediate neutrons. The comparison of calculated and measured data shows an excellent agreement for the bare reactor spectrum but small deviations for the shielded reactor spectra.

5. CONCLUSION

Compared to other detector systems based on the reading of four detectors, the main advantages of the single sphere albedo technique is the use of only one sphere, one detector type, one irradiation, one calibration, and the simultaneous measurement of all detectors. After establishing more reliable response functions and a computer assisted evaluation, this technique seems to be most consistant to estimate actual values of Φ, D, H and the corresponding conversion

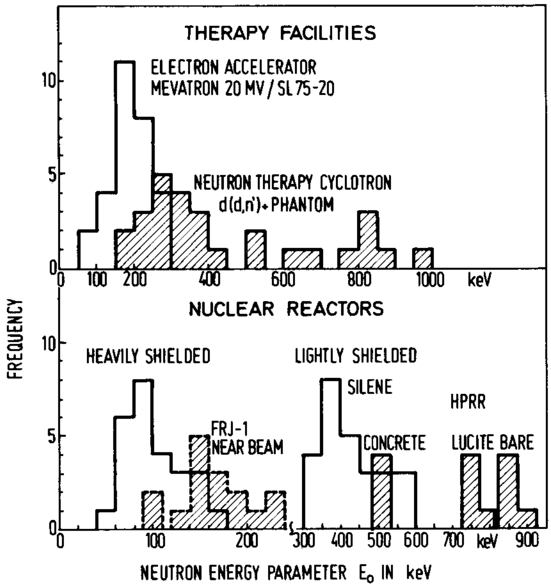


Fig. 2: Frequence distribution of the energy parameter E_O found at reactors and accelerators

factors d_{eff}, h_{eff}, Q_{eff} in the stray neutron field at the location of interest. The technique is more or less independent of any change of the fluence-to-dose conversion factors by applying a new linear fit of the response functions as described in Fig. 1. Because the neutron energy response functions of the TLD600/TLD700 detectors are well established only gamma calibrations are routinely applied. Instead of TLD's, active detectors which simulate the albedo dosemeter type of interest [7] in future will improve this technique for quick field calibrations of albedo dosemeters.

6. REFERENCES

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