# DETERMINATION OF AMBIENT DOSE EQUIVALENT IN MIXED RADIATION FIELDS BY MEANS OF RECOMBINATION CHAMBER

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## ABSTRACT

The response of the REM2 recombination chamber to $H^*(10)$ was determined for some photon and neutron radiation fields (X-rays with effective energy 111 keV, gamma radiation of $^{137}Cs$ and $^{60}Co$ sources, the radiation of isotopic neutron sources $^{241}Am$-Be and $^{252}Cf$, monoenergetic neutrons in energy range from thermal to 19 MeV). For mixed gamma-neutron radiation with broad neutron energy spectrum the response of the chamber to $H^*(10)$ is constant within 20%, so the chamber can be used as a good detector for monitoring of the ambient dose equivalent.

## INTRODUCTION

The recombination chamber it is a high-pressure ionization chamber operated in non-saturated mode. In this mode the initial recombination of ions is significant, so the sensitivity of the chamber depends on LET of incident radiation and provides information about the quality of this radiation. Therefore the chamber can be used for determination of the dose equivalent.

Recently, the ambient dose equivalent $H^*(10)$ is recommended as an operational radiation protection quantity for external radiation. The aim of this work was to estimate, whether the recombination chamber can be used for determination of this quantity in mixed neutron - gamma fields.

## INSTRUMENT

For present investigation the REM2 recombination chamber was chosen. The chamber was manufactured in Poland by POLON. Now it is no longer commercially available, but it is still routinely used in some laboratories over the world for monitoring of the dose equivalent. REM2 is a parallel-plate ionization chamber with 25 tissue-equivalent plates, the volume of 2 $dm^3$, the mass of 6 kg and the effective wall thickness of about 2 $g/cm^2$. The chamber is filled with methane and nitrogen (4%) at pressure of about 1 MPa. The chamber was operated in differential mode [1]. In this mode the collecting voltage in one half of the chamber is high and the ionization current is close to saturation. In the second half of the chamber the collecting voltage has a lower value, specially chosen so that the ionization current depends on the initial recombination of ions. The signal from the chamber is equal to the difference between this two currents and is proportional to the dose equivalent rate. For the purpose of this work the response of the chamber was defined as the ratio of the signal to $H^*(10)$.

## METHOD

Response of the chamber to $H^*(10)$ was experimentally determined in three photon and two neutron fields: X-rays with effective energy 111 keV, gamma radiation of $^{137}Cs$ and $^{60}Co$ sources, the radiation of isotopic neutron sources $^{241}Am$-Be and $^{252}Cf$. The radiation fields were established in calibration room at the Radiation Protection Department of IAE Swierk. Exposure for photons and fluence for neutrons were well defined for all irradiation conditions. Ambient dose equivalent for photons was calculated by multiplying the exposure with the conversion factors for monoenergetic photons, given in the ICRP Publication 51 [2]. For isotopic neutron sources the conversion factors given by Bartlett were used [3].

The current of the ionization chamber was measured with a Keithley 642 electrometer connected to an automated system for the experiment control and data acquisition. Response of the chamber for some monoenergetic neutrons, over a neutron energy range from thermal to 19 MeV, was estimated on the basis of experimental results by Höfert and Raffnsoe [4]. Since the results had been expressed by authors in terms of MADE (according to ICRP 21 [5]), so the recalculation to the $H^*(10)$ was made. The conversion factors given in ICRP Publication 51 [2] and spline interpolation between given points were used for the recalculation.

## PHOTON AND NEUTRON RESPONSES

Experimental results for photons and for neutrons from isotopic sources are given in Table 1. The relative response quoted in the Table is defined as the ratio of the chamber response for the radiation considered to the response for $^{137}Cs$.

TABLE 1. Response of the REM2 recombination chamber to $H^*(10)$ for photons and for isotopic sources of neutrons.

| Photon source | Neutron source | Correct. to photon emission | Effective energy $E_\gamma$ (keV) | Response to $H^*(10)$ ($\mu C \cdot Sv^{-1}$) | Relative response $R/R_{Cs}$ |
|---|---|---|---|---|---|
| X-rays | | | 111 | 10.12 | 0.992 |
| $^{137}Cs$ | | | 662 | 10.2 | 1.000 |
| $^{60}Co$ | | | 1250 | 10.51 | 1.03 |
| | $^{241}Am$-Be | no | | 10.2 | 1.0 |
| | $^{252}Cf$ | no | | 11.0 | 1.08 |
| | $^{252}Cf$ | yes | | 11.08 | 1.086 |

Uncertainties of the relative response values are of about 4% for photons and of about 8% for neutrons. This include the uncertainties of the exposure or fluence determination and stochastic uncertainty (expressed as one standard deviation) of measured ionization currents. Conversion factors are taken without uncertainties, however it should be noted that for neutrons this uncertainties may be as great as 10%.

It can be seen that for photons of energies considered the differences in responses of the chamber are very small. The second practically important fact is, that the response for $^{241}$Am-Be neutron source is the same as for $^{137}$Cs photon source. It was the reason, why the correction of response for photon emission was not needed in case of $^{241}$Am-Be source.

The values of the response for monoenergetic neutrons, related to the response for $^{241}$Am-Be source, are given in Table 2 and in Fig. 1. As it was mentioned above, the values were obtained by recalculation of earlier published results [4]. No assessment of uncertainties has been made for this case; the results are not considered to be unequivocal, but they can help to asses the applicability of the recombination chamber as an instrument for the ambient dose equivalent determination.

TABLE 2. Relative response of the REM2 chamber to $H^*(10)$ for neutrons (recalculated from data given in [4]).

| Neutron source or energy (MeV) | Relative response $R/R_{Am-Be}$ |
|---|---|
| Thermal | 1.15 |
| 0.0245 | 2.46 |
| 0.1 | 1.19 |
| 0.25 | 1.19 |
| 0.57 | 0.94 |
| 1.0 | 1.14 |
| 2.5 | 1.22 |
| 5.0 | 0.89 |
| 15.5 | 0.53 |
| 19.0 | 0.64 |
| $^{252}$Cf | 1.096 |

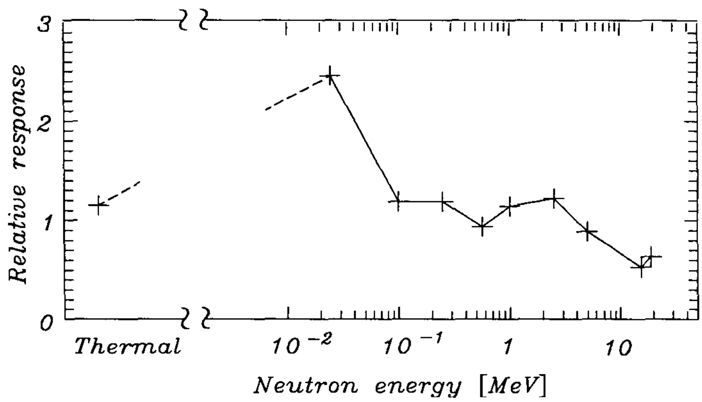


Fig.1 Relative response of the REM2 chamber to $H^*(10)$ versus neutron energy (related to $^{241}$Am-Be source).

## DISCUSSION AND CONCLUSIONS

As it was expected from general considerations, only minor differences in the response of the chamber were found for the photon radiations investigated. The experimental results are too poor to exclude that somewhat larger differences may appear for photons of other energies. Even though, this should not have any significant influence on the determination of $H^*(10)$ for mixed radiation fields, because the photon contribution to the dose equivalent is usually low.

A serious advantage of the chamber is the almost equal response for gamma radiation and for neutrons of $^{241}$Am-Be source. Therefore, for determination of $H^*(10)$ in mixed neutron-gamma fields, the chamber may be calibrated either with $^{241}$Am-Be source, or with $^{137}$Cs source.

There is a number of factors which cause that the sensitivity of the commonly used T.E. chambers is lower for neutrons than for photons. In the REM2 chamber influence of these factors is compensated by an excess of the hydrogen content in the filling gas with respect to the T.E.-gas.

The usefulness of the recombination chamber in monitoring of the $H^*(10)$ depends primarily on the neutron energy dependence of the chamber response. Such a dependence for the REM2 chamber is given in Fig.1. It can be seen, that with respect to calibration with $^{241}$Am-Be source, there is an overestimation of the $H^*(10)$ for neutron energies lower than 5 MeV and underestimation for higher energies. The overestimation for lower neutron energies, caused by the excess of hydrogen, does not exceed 20%, except of the 24.5 keV neutrons, where the relative response of almost 2.5 was observed. We are not able to find any explanation for so high overestimation at this neutron energy. With increasing energy of neutrons the effectiveness of the compensation decreases and $H^*(10)$ becomes to be underestimated down to the value of 0.53 for neutrons of energy 15.5 MeV. Taking into account the operating principle of the recombination chamber and the differences of the chamber construction comparing to the ICRU sphere, we expect that the relative response of the chamber will not decrease more, even for high energy neutrons. However this prediction needs further investigations.

For a broad neutron energy spectrum, which is the usual case in radiation protection practice, one can expect that the relative response of the chamber is sufficiently constant. Therefore a large recombination chamber, like the REM2, may be considered as a good detector of the ambient dose equivalent of mixed radiation in vicinity of isotopic sources and nuclear installations.

## REFERENCES

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