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APPENDIX D

DOSIMETRY ON STS-42 WITH THE RME APD

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Introduction

Beginning with the STS-42 mission, this laboratory began participating in instrument comparison studies in which space radiation was measured contiguously by passive and active methods. The active instrument was the RME-III microdosimeter. This instrument measures 4-channel LET spectra and employs a tissue-equivalent proportional counter. It is sensitive to the full LET range of ionizing radiation present.

Our Area Passive Dosimeter, the RME APD, contained arrays of PNTDs and TLDs. The PNTDs measure LET spectra ($LET_\infty \cdot H_2O \geq 5$ keV μm^{-1}), while the TLDs measure total absorbed dose. The object of this experiment is to compare the active and passive measurements on the basis of LET spectra, total absorbed dose and dose equivalent.

The STS-42 mission was launched on January 22, 1992, with a flight duration of 8.052 days. The orbit had an inclination of 57°and an altitude of 302 km. The Shuttle in this orbit is expected to encounter radiation levels dominated by GCRs with a lesser contribution from trapped protons in the lower region of the SAA.

Experiment

The RME APD consisted of an acrylic box (9.8 x 9.8 x 5.2 cm in outer dimensions) containing ten stacks of PNTDs which were oriented in seven directional angles and also four sets of TLDs which were positioned at the sides of the box. There were also four sets of TLDs from Johnson Space Center at the sides of the box. The RME APD is sketched in Figures 1 and 2.

The placement and angular orientation of the PNTD stacks is intended to compensate for the angular sensitivity of these detectors, which have maximum response to particles incident normal to the surface. The response is characterized by a cutoff angle of incidence, δ_c(LET). The solid angle of acceptance decreases with decreasing LET and goes to zero below ~5 keV μm^{-1}. In the RME APD

six stacks are adjacent to the box walls while the remaining four are perpendicular to the axes of the box corners.

After the return of the APD the TLDs were read out with a Harshaw Model 4000 reader. The PNTDs were processed to delineate the latent tracks and then read out with a semi-automated digitizer system. This consists of locating the tracks on the surfaces, rejecting background features and measuring the major and minor axes of the elliptical track openings. Tracks were accepted in two categories, for "Short Range" and "Long Range" particles. The short range particles left track pairs on the adjacent surfaces of a CR-39 doublet. A long range particle also left tracks at both of the outer surfaces of the doublet, showing that it had penetrated at least 1200 μm of CR-39 material.

The TLD signals were converted to absorbed doses by the use of ^{137}Cs standard source calibrations. The PNTD track parameter files were converted to LET spectra using calibrations performed with accelerated ion beams of various LETs. Doses and dose equivalents for high LET particles ($\geq$5 keV μm^{-1}) were then found from the LET spectra.

Measurements

The TLD measurements are given in Table 1. Some of the individual TLD measurements were lost due to a reader malfunction but there was sufficient data to yield a good average for the APD box.

The PNTD measurements of seven categories of LET flux spectra are shown in Figure 3. The seven categories represent the different angular alignments of PNTDs present in the APD box. The X, Y and Z directions are represented by averages of pairs of PNTD stacks (at opposite sides of the box). The remaining four are single stacks. There is approximately a factor of 2 between minimum and maximum values of integral flux with the X direction being the highest. The spread in values represent differences in directional shielding and averaged incident directional fluxes. The Shuttle did not maintain a particular orientation with respect to the Earth so the directions of maximum intensity of incident radiation varied. In the high LET region (>200 keV/μm) there is a large spread in the measurements but the statistical accuracy is poor (only a few tracks were found).

The flux, dose rate and dose equivalent rate spectra for three APD configurations are given in Figures 4, 5 and 6. The RME APD includes all ten of the PNTD stacks. The USF APD includes six of the stacks (+x, -x, +y, -y, +z, -z). The Basic APD includes only three of the stacks (+x, +y, +z) and is the simple orthogonal configuration flown on most Shuttle flights as part of the mission dosimetry effort. The integral quantities for these curves are given in Table 2. Similar data for the seven directions are given in Table 3. The three APD configurations have differences up to 17% in flux, 16% in dose rate and 18% in dose equivalent rate, with the Basic APDs being highest.

Discussion

The comparison of the three data sets revealed a significant advantage in using PNTD stacks oriented in seven directions, rather than three directions, to measure the averaged 4π radiation fluxes in space. There was also a smaller difference between six-stack and three-stack measurements in three directions (7%) which may have been due to attenuation through the APD box or to improved sampling of the radiation, using larger detector areas.

The TLDs do not measure high LET absorbed dose with 100% efficiency. For the orbit of STS-42, the average efficiency of dose from particles with LET >5 keV/μm is about 50%. Total dose rate is therefore

$$D_T = (D_{TLD} - D_{PNTD}) + 2\ D_{PNTD}$$

or

$$D_T = D_{TLD} + D_{PNTD}$$

It is of interest to compare total dose rate (11.5 mrad/d) with PNTD dose rate (0.983 x 2 = 1.97 mrad/d). This demonstrates that more than 80% of the dose is due to radiation with $LET_\infty \cdot H_2O$ <5 keV/μm, mainly from higher energy protons (E_p >10 MeV). The doses measured on STS-42 can be given as follows:

D_{TLD} = 10.5 mrad d^{-1}

D for $LET_{\infty} \cdot H_2O$ <5 keV μm^{-1} = 9.52 mrad d^{-1}

D for $LET_{\infty} \cdot H_2O$ >5 keV μm^{-1} = 1.97 mrad d^{-1}

D_T = 11.5 mrad d^{-1}

Dose equivalent rate for $LET_{\infty} \cdot H_2O$ >5 keV μm^{-1} = 8.15 mrem d^{-1}

Total dose equivalent rate = 17.7 mrem d^{-1}

Average Quality Factor = 1.54