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REPLACEMENT TISSUE-EQUIVALENT PROPORTIONAL COUNTER FOR THE INTERNATIONAL SPACE STATION

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The tissue-equivalent proportional counter (TEPC)-based dosemeters used on the International Space Station have exceeded their planned useful lives, and are scheduled to be replaced with the new units taking advantage of improved technology. The original TEPC detectors used cylindrical geometry with field tubes to achieve good energy resolution and minimum sensitivity to noise created by vibration. The inside diameter of these detectors is 5.1 cm. The new detectors developed for this application produce the resolution and vibration resistance of the cylindrical detector with the isotropic response and compact size of a spherical detector. The cathode structure consists of conductive tissue-equivalent plastic A-150 layers separated by thin polyethylene layers perpendicular to the anode. Each conductive layer is held at the electrical potential needed to produce uniform electric field strength along the anode wire, and thus the same gas gain for electrons produced in different portions of the spherical volume. The new design contains the whole preamplifier inside the vacuum chamber to reduce electronic noise. Also the vacuum chamber has a novel design with a 0.020-inch-thick aluminium wall to allow a total wall thickness of 0.5 g cm^{-2}, which is typical of the shielding provided by a space suit. This feature will allow measuring the dose on the astronauts' skin due to low-energy electrons and protons produced during solar events. The vacuum chamber has a new bayonet clamping system that reduces the total detector weight to less than half that of the old TEPC.

CURRENT INTERNATIONAL SPACE STATION ACTIVE DOSEMETER

The tissue-equivalent proportional counters (TEPCs) used on the International Space Station (ISS) have exceeded their planned useful lives, and are scheduled to be replace with the new units taking advantage of improved technology. ISS has one TEPC on board; this is a cylindrical detector of 5.08-cm diameter by 5.08-cm long that represents a 2-μm diameter volume of human tissue, when filled with the propane gas at 15 Torr. The TEPC spectrometer has a dual multichannel analyzer design with 1024 channels of low-gain data, and 256 channels of high-gain data. This can operate with 120 or 28 V power and use RS-232 and 1553 communications ports(1).

DESIRED IMPROVEMENTS

Critical features that are present in current instrument and must be maintained in the new version are robust, resistant to vibration-induced noise, and minimum weight and volume (avoid cables between detectors and electronics). Improvements should include isotropic response, a wider dose rate range and lower electronic noise to provide response to a wider range of lineal energy values.

Isotropic response

There are many considerations to take into account in the design of proportional counters; one of them is the detector geometry. The radiation environment in space is nearly isotropic, but differences in shielding on the walls of the ISS lead to non-isotropic radiation within. Spherical detectors are preferred for many applications because of their relatively simple chord length distribution and isotropic response, but Rossi style detectors are very sensitive to vibration.

The main challenge in designing a spherical detector is to create a uniform electric field along the axis of the detector. Because the distance between the spherical shell and the anode wire placed along the diameter of the sphere is not constant, the electric field will be stronger and the gas gain will be higher near the ends of the anode. There are several techniques that can be used to correct this problem. The approach used here is to divide the cathode (spherical shell) into several rings with different thicknesses, and adjust the potential difference between each ring and the anode to produce an electric field that it is nearly constant along the length of the anode. This choice in design has an important advantage over using a grid around the anode because it produces considerably less microphonic noise. This approach was used for a grid-walled detector many years ago(2), but it requires the development of new plastic moulding and lamination techniques to produce a successful solid-walled detector.

Wider dose rate range

In order to record the maximum dose rate expected during a solar particle event while maintaining sensitivity to low-dose rates, two detectors with inside diameters of 3.7 cm and 1.25 cm were used. Each detector is housed in an individual vacuum chamber with gas pressure to simulate 2-μm site size. In order to minimise electronic noise, the entire charge-sensitive preamplifier is located inside the vacuum chamber.

Range of incident particle energies

The new detector system should be able to measure the dose due to particles ranging from protons to iron ions, which are the main sources of dose for astronauts working on extra vehicular activity. The dosemeters located outside the space station will have a total wall thickness of $\sim$0.5 g cm^{-2}, including the TE wall, vacuum chamber and electromagnetic interference shield. This small wall thickness could not be achieved using the stainless steel chamber we have used previously; so aluminium vacuum chambers with 0.5-mm wall thickness are being tested. Special surface treatment[(3)] (Almeco 18 is not longer manufactured but has been replaced by Ridoline 18) developed for preparing aluminium components for high vacuum use, was used to minimise the outgassing of the aluminium vacuum chamber. Figure 1 shows the desired final configuration for use at various locations inside ISS, and also a second version for use at a fixed location outside.

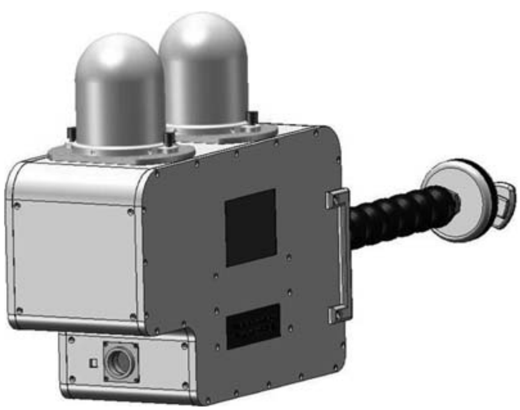

Figure 1. Desired final configuration.

DESIGN PREDECESSOR

Previous work[(4)] showed that dividing the cathode into nine rings, spaced for 5 % increments in applied voltage, provided slightly better resolution than a Rossi detector. TE A-150 plastic rings are moulded individually, and then welded into complete hemispheres using a low-density polyethylene that provides electrical isolation between rings. Initial prototypes developed at Texas A&M are adapted to meet mechanical and electronics parts' specifications for flight hardware at Johnson Space Center (JSC).

NEW DESIGN FOR THE ISS

The new design uses two detectors: the 3.7-cm diameter detector is divided into 11 rings with 5 % voltage increments, and the 1.25-cm diameter detector is divided into 9 rings. Each detector is housed in an individual chamber filled with propane at pressure to simulate 2-μm site size. The whole charge sensitive preamplifier is inside the vacuum chamber to reduce electronic noise.

The outer shield and vacuum chamber are made of aluminium; they have a novel design with a 0.020-inch wall thickness. The vacuum chamber's base, with electrical feedthroughs, is made of stainless steel and has a new bayonet system to compress an indium wire seal that reduces the total detector weight in less than half of the old TEPC. The vacuum chamber and outer shield have a dome shape on top to

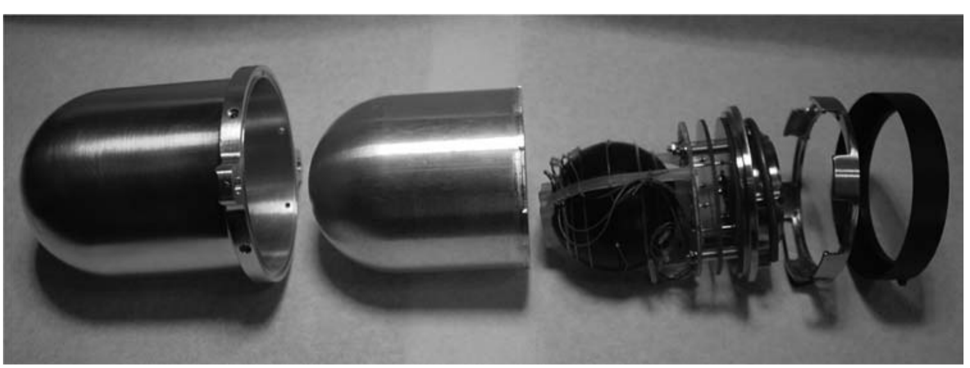

Figure 2. TEPC (3.8 cm) from left to right: outer shield, vacuum chamber, detector, preamplifier, base, bayonet and insulator.

minimise volume and weight. Detectors will be calibrated using the proton drop point, eliminating the need for an internal calibration source.

A-150 issues

Meeting flight hardware specifications requires only minor changes in things such as plastic screws and electronic components, but it also involves specialised knowledge and a great deal of paperwork. Due to the lack of certification, the A-150 plastic[(5)] used for the design predecessor could not be used for the new design. A new batch of A-150 was obtained with the appropriated documentations for quality assurance.

The shift in the mechanical properties of the TE plastic currently produced, relative to the early A-150 used to build the first prototype, required significant changes in the plastic moulding procedures. Many people have observed that each new batch of A-150 seems to be harder, more brittle and more difficult to release from the mould than the previous batch. This is apparently due to changing properties of commercially available nylon. We have recently learned that some soft, low-melting-point nylon is still made, but is sold under a different name. In the future, it may be possible to make A-150 with mechanical properties similar to those of the original version.

Figure 2 shows the whole assembly of the 3.8 cm A-150 tissue-equivalent plastic sphere detector with the preamplifier, stainless steel base, aluminium vacuum chamber, aluminium outer shield, stainless steel bayonet and Delrin® insulator. The small diameter detector utilises a shorter vacuum chamber of the same diameter as the 3.8-cm diameter detector, in order to take advantage of a single preamplifier and vacuum chamber design, as shown in Figure 3.

Figure 3. TEPC (1.25 cm). Caliper set to 5 cm.

ACTUAL STATUS

The detectors were tested with an Americium–Beryllium neutron source. Figure 4 shows the typical Microdosimetry representation of the 3.8-cm detector operating at 800 V. The first peak represents the gamma events, the second peak the proton events and a very small third peak that could be associated with heavy ions. The proton drop point is located on 150 keV per μm. Prototype detectors are also being tested for response to simulated cosmic ray particles at NASA Space Radiation Laboratory (NSRL) at

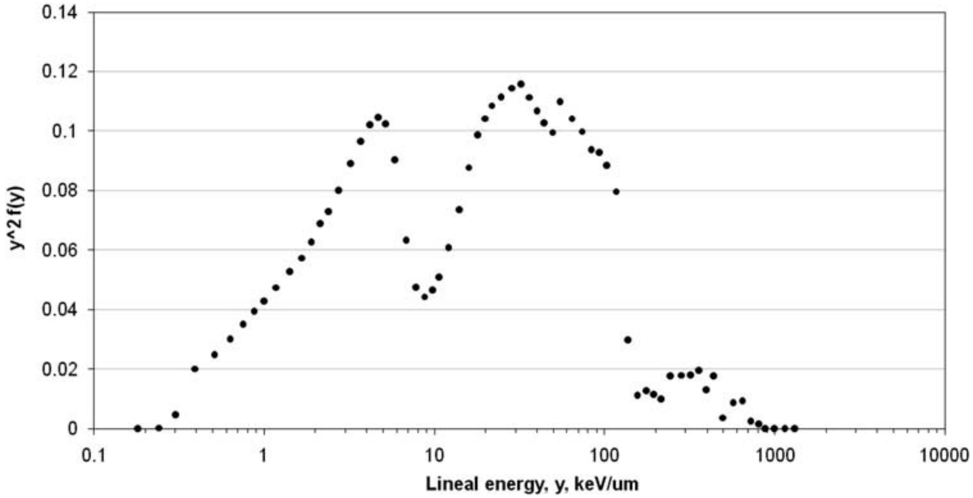

Figure 4. Typical microdosimetry representation.

Brookhaven National Laboratory and at the Heavy Ion Medical Accelerator in Chiba (HIMAC), Japan.

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