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	Task 1: Design, Fabrication, and Testing Mod1 prototype detector The purpose of this task was to design, build, and assemble a prototype Tissue Equivalent Proportional Counters (TEPC) that would satisfy the basic specifications outlined by NASA for a dosimeter for astronauts during lunar EVAs. The spherical TEPC is based on a single-wire anode with recessed guard ring insulators to shape the electric field near the poles. The diameter of the gas cavity is 18mm and the wall thickness is 3mm for a total diameter of 24mm (~ 1 inch). Aluminum vacuum chambers with a shell thickness of 0.5mm were designed and gold plated to maintain electrical conductivity. A system using a high sensitivity mass spectrometer was assembled to measure vacuum leaks for the assembled detectors with high special specificity.		

Task Description:

We have been using a version of the software package. LORENTZ 3D™ to model the electric field inside a spherical detector with a linear collector. This uses special modeling techniques based on the Boundary Element Method make the solution of these very challenging problems a simple matter. The geometry of the problem can be created with the geometric modeler built into the electric field solvers or can be imported from any of the major CAD vendors. More importantly, the geometry can be changed parametrically to optimize a design for robustness, weight, size and, of course, cost.

We have fabricated four versions of the TEPC and Vacuum Chamber. Two versions were with spherical detector and single wire anode operated with the wall at high voltage and the anode at ground. One version was with spherical detector and single wire anode operated with the wall at ground and the anode at high voltage. Another detector was a new hybrid design with a parallel wire grid surrounding the anode. The objective of this design was to form a virtual cylindrical geometry around the anode with that would improve the spatial resolution of the TEPC without distorting the signals required for microdosimetry applications. The detectors were exposed to high energy charged particle beams at the HIMAC synchrotron in Chiba Japan. This included the following ions and energies: 56Fe (380 MeV/amu), 18Ar (300 MeV/amu), 12C (200 MeV/amu), and 1H (230 MeV/amu). Measurements were taken at several angles of incidence to determine the angular response of the detector. These results were compared with similar measurements using a commercial TEPC with a Rossi design that has a helical grid surrounding the anode to provide a uniform angular response.

We have begun the design of Mod 3 system based on the results of the experimental investigations with Mod 2. A new vacuum chamber has been successfully machined using Al with a wall thickness of 0.5mm. Improvements to the insulation materials for all detectors have been implemented and a second version of the multiwire grid has been designed and is being fabricated.

Task 2: Modeling Detector Response

The objective of this task is to determine the response of the TEPC under ambient conditions and during SPE events on the lunar surface. Computations using the Monte Carlo Code PHITS have been made to determine the energy deposition in the TEPC using protons with an energy spectrum from a SPE in October 2003. These data were compared with the dose that would be delivered to the skin beneath a space suit with an areal density of 0.4 g/cm2. It is clear that a stainless steel vacuum chamber in Mod 1 needs to be replaced with lighter and thinner materials. These results will be important in determining what additional modifications will be necessary to achieve the design goal for real time measurements to the skin and BFO.

Task 3: Modeling the Variance-Covariance Method

The original proposal for the EVA dosimeter was based on the concept of having two independent proportional counters that would be used to obtain estimates of dose, D, and a quality factor, Q, based on estimating using the variance-covariance method. It was recognized that because of size limitations, the proportional counters would have to be located too close to one another to satisfy the condition that a single particle could not intercept both detectors. The additional constraint that one of the detectors must measure the dose at the skin surface and the other at a depth corresponding to the blood forming organs, makes the original variance-covariance method with paired detectors impractical.

We are developing a method based on using one detector in a variance-covariance scheme. The concepts are based on collecting the charge, zi, in a single TEPC for n successive time intervals. The method proposed by Borak at CSU separates the data set into two groups of n/2 entries of values for zi based on odd and even indices. The n/2 pairs of data (odd and even) are used to obtain the covariance and each of the two sets of n/2 values (odd or even) to estimate a variance. Monte Carlo codes have been written to test the algorithmic using microdosimetric spectra obtained from measurements in Task 1. The results will be used to optimize the design of the electronics for the variance-covariance method to obtain radiation quality factors.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:

This type of dosimeter has additional applications for first responders to nuclear accidents or terrorist events. It can also provide real time dosimetry during commercial space flight, diagnostic and therapeutic medical procedures such as proton and carbon ion radiation therapy, and surveillance activities associated with homeland security and nuclear non proliferation. It can also serve an a area monitor with live-time capabilities that provide dose rate as well as estimates of quality factors for radiation workers as well as the general public.

Task 1: Design, Fabrication, and Testing Mod1 prototype detector
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*The single wire detectors operating with the anode a ground potential could detect protons above background noise.

*The single wire detectors operating with the anode a ground potential underestimated the frequency mean lineal energy (Dose) by about 50%. This may be due to extracameral effects generated from particles passing through the vacuum chamber but not through the TEPC.

*A detector with parallel-wire grid correctly measured the frequency mean lineal energy (Dose) and dose meal lineal energy (Quality factor) for the C, Ar, and Fe beams.

*The single wire detector operating with the anode at high voltage had an angular dependence that varied by more than

Task Progress:	50%. *The multiwire detector showed an angular dependence that varied less than 10%. Task 2: Modeling Detector Response Computations using the Monte Carlo Code PHITS have been made to determine the energy deposition in the TEPC using protons with an energy spectrum from a SPE in October 2003. * The TEPC should be capable of measuring the dose and dose rate from protons with energies sufficient to penetrate either the space suit for EVA applications. Task 3: Modeling the Variance-Covariance Method We are developing a method based on using one detector in a Variance/Covariance scheme proposed by Dr. Borak. Monte Carlo codes have been written to test the algorithmic using microdosimetric data from measurements in Task 1. *More than 100 sequential time intervals are necessary for convergence of the dose mean lineal energy used for estimated of quality factors. *Timing intervals that have a significant number of intervals without an energy deposition event should be registered as zero energy deposition. But because of noise, they could be assigned as events with very low LET. This would not influence dose but could cause an underestimate of Quality Factor.
Bibliography Type:	Description: (Last Updated: 03/20/2019)
Significant Media Coverage	Gorwyn A. "Thomas Borak designs radiation alarm for astronauts and everyone. Interview and podcast of Thomas Borak by EarthSky." EarthSky, February 22, 2010. Check this site for download options: http://eq.uen.org/emedia/items/fe482333-180a-c85b-7554-0b97e92ec432/1/ , Feb-2010