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NASA CR- 132475

(NASA-CR-132475) STUDY OF BLOOD FORMING ORGAN DOSE AS A FUNCTION OF PROTON ENVIRONMENT Final Technical Report (Old Dominion Univ. Research Foundation) 7 p HC $4.00 CSCL 06P G3/04

N74-28561

Unclas 43733

STUDY OF BLOOD FORMING ORGAN DOSE AS A FUNCTION OF PROTON ENVIRONMENT

FINAL TECHNICAL REPORT

By

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Prepared for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Langley Research Center
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Under
Master Contract Agreement NAS1-9434
Task Order No. 47

Submitted by the
Old Dominion University Research Foundation
P.O. Box 6173
Norfolk, Virginia 23508

June 1974

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OF PROTON ENVIRONMENT

By G.S. Khandelwal[1]

The work under task order NAS1-9434-47 began in February 1972. The following describes the various stages of the work since that time, summarizes the results, and makes recommendations for future work.

INITIAL STAGE OF THE WORK

The monitoring of radiation dose to skin and internal body organs during NASA Space Missions has traditionally been accomplished by a combination of an unshielded and a 5-g/cm^2-shielded tissue equivalent ion chamber. The applicability of such a dosimeter in monitoring dose to the distributed body organs was tested by making calculations of the dose reponse, as a function of proton energy, of a 5-g/cm^2 ion chamber. The ion chamber response was found to differ significantly with the dose response within the blood forming organ (BFO) of a human fantom. In these calculations, the body mass distribution data associated with a BFO was taken from the work of Billings and Langley. The results are described in reference [1].

INTERMEDIATE STAGE OF THE WORK

Having established the inadequacy of a 5-g/cm^2 ion chamber in monitoring dose to BFO and to its segments as described in the initial stage of the work, a search was pursued for a dosimeter which provides for the additivity of doses of different quality and provides a more accurate monitoring of distributed body organs. In order to make preliminary development of a proton dosimeter, the radiation was assumed isotropic and nuclear reactions were neglected in

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accounting for self-shielding when monitoring absorbed dose. The dose equivalent was developed by inclusion of a quality factor for low-energy protons; an "effective" quality factor of 2, which roughly corrects for nuclear reaction effects, was applied at high energy. In the spirit of these simplifying assumptions, the average BFO absorbed dose was obtained for the space radiation test spectrum of the form $E^{-\alpha}$. Similarly, the dose in rad was calculated for ion-chambers of thickness $t = 2, 3, 4 \ldots, 10$ g/cm^2 for the values of the spectral exponent $\alpha = 1.5, 2, \ldots 4$. It was seen that a dosimeter system consisting of a set of four ion chambers of thickness $t = 2, 3, 4$, and 5 g/cm^2 could reproduce the BFO dose with reasonable accuracy. This completed the preliminary development of a dosimeter which is rugged, reliable, sensitive, stable, simple, and composed of off-the-shelf items. The detailed description of this is given in reference [2].

FINAL STAGE OF THE WORK

A necessary requirement for radiation shield and dosimeter design and for space mission analysis is a reliable method of calculating the anticipated doses in the human body for the pertinent radiation environment. Customarily, the human body is approximated by a simple geometric object (such as a sphere, slab, cylinder, etc.) with resultant disagreement among the various approximations for the human geometry and consequent disagreement on shield and dosimeter design and impact on mission objectives.

As is known, a convenient property of energetic heavy charged particles in passing through matter is that the primaries and their secondary particles remain relatively confined to the primary beam axis. As a consequence, the particle beam in matter is not strongly affected by near boundaries and the problem of calculating dose in a complicated geometric object is greatly simplified. Thus, a series which rapidly converges for most practical dose calculations was developed in terms of power of the beam width parameter. The calculational procedure is described in references [3] and [4]. In these references, the final result relates dose at any point in an arbitrary convex region to an integral over the fluence-to-dose conversion factors for normal incidence on a semi-infinite slab. A representation of these fluence-to-dose conversion factors is given and all the necessary information required to calculate dose in arbitrary convex regions of tissue for proton energies below 1 Gev is presented.

Reference [5] describes a computer program which calculates proton dose averaged over five major segments (upper limbs, lower limbs, upper trunk, lower trunk, skull) of the BFO by treating the human body in detail but assuming isotropicity of the incident primary particles. The calculation, as described in the preceding paragraph, uses an approximate form of transport theory, in which nuclear star effects are incorporated (References [3] and [4]). The output of the program is in terms of physical dose (rad) and dose equivalent (rem).

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

It is demonstrated that a dosimeter which consists of four ion chambers, each with a different wall thickness, is able to reproduce the BFO dose with reasonable accuracy. This generalized dosimetric system is only slightly more complex than dosimeters in current use. However, as stated in reference [2], this preliminary development had two built-in assumptions; the isotropicity of the radiation and the neglect of nuclear reaction effects. Furthermore, it would be desirable to replace this cumbersome isolated ion chamber system by a compact system consisting of four concentric spherical chambers.

Of the three problems stated above, only the nuclear reaction effects have been calculated so far (see References [4] and [5]). The effects of anisotropicity, and a study of concentric multi-ion chambers, could not be pursued due to the lack of both time and funds. Availability of sufficient funds will most certainly aid in arriving at a desirable dosimeter, capable of monitoring a large number of dose points in the human body with accurate account of self-shielding, nuclear star effects, and having an output which is closely associated to biological response and allowing additivity (rem). In addition, the dosimeter output would be (automatically) reliable for a broad range of radiation environments, covering the full range of spectra, anisotropies, and spatial inhomogeneities (as observed in spacecraft interiors) for space radiation.

The funds made available in this task order have greatly aided the intellectual and educational advancement of the principal investigator and of the students working with him.

Mr. Bob Jones, a graduate student in physics, was furnished partial financial support for his M.S. studies in physics during the 1972-73 academic year. Mr. Chris Costner, then an undergraduate student in physics, was given financial support during 1972-73, and another undergraduate student in physics, Mr. John Lescher, was given financial support during the fall semester, 1973-74.

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