THE U.S. DEPARTMENT OF ENERGY PERSONNEL DOSIMETRY EVALUATION AND UPGRADE PROGRAM

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INTRODUCTION

The U.S. Department of Energy (DOE) Personnel Dosimetry Evaluation and Upgrade Program is designed to identify and evaluate dosimetry deficiencies and to conduct innovative research and development programs that will improve overall capabilities, thus ensuring that DOE can comply with applicable standards and regulations for dose measurement. To achieve these goals, two programs were initiated to evaluate and upgrade beta measurement and neutron dosimetry.

DISCUSSION

Beta dosimetry has had radiation protection problems for many years, compounded by a need to improve the accuracy and precision of beta measurements. Generally, devices designed to measure other radiations (usually gamma) are adapted for beta measurement. These devices can underestimate beta dose by a factor of 10 or more because of the complex spectra and low-penetrating ability of beta radiation, which produce significant spatial and spectral variations in the radiation fields.

DOE facilities use a variety of instruments, calibration sources and procedures, and personnel dosimeters to assess beta exposure. In most cases, facilities cannot meet the accuracy criteria in national or international standards [1].

The measurement of neutron dose has similar problems. For the same dose, neutrons can produce many times the biological damage of gamma rays, indicating that the degree of hazard from neutron radiation may be higher than previously assumed. Previously, concerns about neutron dose were less because it was only a small fraction of the total dose. Anticipated changes in neutron quality factors increase that fraction and put greater emphasis on the need for improved measurements.

It is necessary to estimate the neutron dose at various depths in the body and on the surface. In January 1987, President Reagan signed the "Radiation Protection Guidance to Federal Agencies for Occupational Exposure; Approval of Environmental Protection Agency Recommendations," [2] which adopts the ICRP-26 [3] methods. The ICRP-26 recommends that in non-uniform fields the dose equivalent be determined by summing the dose equivalent to various specified tissues multiplied by a set of weighting factors. Almost all DOE radiation workers exposed to neutron radiations are in non-uniform fields. ICRP-26 and the proposed changes in quality factors require an assessment of neutron organ dose and improvement in neutron dosimetry capabilities.

The Neutron and Beta Programs are structured by tasks that address specific problem areas. Work is accomplished by a unique combination of contracts and subcontracts which focus the best possible expertise on the task. National laboratories, universities, and private companies act as subcontractors to PNL to accomplish this research. Consulting committees are used to guide program developments, and interactions with the National Bureau of Standards assure that measurements and results are consistent with national standards.

DOSIMETER DEVELOPMENT

Beta Dosimeters

New dosimeter configurations and materials are being developed as well as innovative techniques for evaluating dosimeter results. These include:

- A laser readout for conventional and experimental TLDs was developed, a prototype built, and problems limiting the usefulness of the concept identified. TLDs are being evaluated.

- A thin LiF dosimeter bonded to a graphite backing was developed to provide superior beta response. The units are being evaluated in badge configurations.

- Optically-stimulated luminescence dosimeters use light to de-excite trapped electrons in solid-state materials which then emit fluorescence radiation that is detected by a photomultiplier. The technique is used to anneal and read out dosimeters without increasing the temperatures.

- A re-evaluation of exoelectron dosimeters has occurred because of the recent development of new materials that are more sensitive than TLD materials and do not exhibit an energy dependence. Their superior performance has been demonstrated, resulting in their incorporation into a dosimeter for evaluation.

Neutron Dosimeters

In response to trends toward revising dose equivalents, standards, and limits, new dosimeters being developed include:

- An interim dosimeter was developed consisting of thermoluminescent (TL) and track-etch (TE) elements in a combination TL/TE dosimeter (TLD/TED). Neutrons above about 100 keV are detected by the TED plastic, CR-39. Lower-energy neutrons are detected by the TL component. The combination TLD/TED can nearly match the existing fluence-to-dose equivalent conversion curve.

- A newly-proposed personnel neutron dosimeter counts the noble gas atoms released from a solid matrix material by collision events that can be related to neutron dose. A laboratory reader counts the noble gas atoms released by using a modified laser-induced fluorescence technique that shelves the noble gas atoms in a metastable excited state. Krypton and xenon atoms will be the first evaluated.

- Recent findings regarding the sensitivity of optical fibers to neutron radiation show promise in detecting fast and thermal neutrons. Previous research was directed toward increasing radiation resistance of optical fibers. Optimizing their sensitivity will be key to their dosimetry application.

- Neutron dosimetry devices using semiconductor detectors being developed include: diode devices that collect electron hole pairs as a result of proton adsorption, semi-conductor devices for measuring neutron dose using deep-level transient spectroscopy measurement techniques, and a spectrometer to determine the energy distribution of charged particles.

- Superheated droplets are suspended in a solid-elastic or high-viscous liquid medium. When a neutron strikes a droplet, the energy from the recoil charged particle triggers the explosion of the droplet resulting in an acoustical signal which can be counted. In a solid medium, the gas bubbles are trapped and can be counted after an exposure as passive measure of the neutron dose.

INSTRUMENT DEVELOPMENT

Beta Instruments

Instruments must provide a correct reading of absorbed dose in a mixed beta-gamma radiation field and be able to differentiate between penetrating and nonpenetrating components of the radiation field. Reduction in geometry dependence of survey meters must also be accomplished.

- A thin scintillator (~5 mg/cm^2) was developed that shows excellent beta response; however, current cumbersome electronics make it impractical. Research is underway to develop a practical system using special scintillators to avoid the electronic complexity.

- A combined thin and thick scintillator can discriminate against the signal from gamma events occurring in the thick scintillator. Only the beta particles will deposit energy in both scintillators which can be identified by pulse shape discrimination techniques. A laboratory model of this technique has been demonstrated (phoswich counter).

- A thin proportional counter can be used to assist in separating the beta and gamma signals in a thick scintillator. The technique shows superior beta-gamma discrimination and less complexity than other techniques (phoswich).

- Evaluation of survey meters has shown that a thin (1 to 2 cm) ionization chamber with a large area (to compensate for loss of volume) will be superior for beta measurements. Prototype chambers are currently under evaluation.

Neutron Instruments

Instruments are being developed and sought that satisfy new measurement criteria; that are energy independent, economical, rugged, and easy to use; and that measure all types of radiation.

- The total dose meter is a small personnel monitor that simultaneously measures the dose equivalent from photon and neutron radiation with a single tissue equivalent proportional counter (TEPC). A unique determination of total dose equivalent from all penetrating radiations is possible.

- A prototype field neutron spectrometer has been built to determine neutron quality factor and dose equivalent in the workplace to determine calibration factors for dosimeters and other instruments. The system consists of ^3He and TEPC detectors, a modular multichannel analyzer, and a microcomputer. Components are packaged into a unit the size of a small suitcase. Programs were developed for the ^3He and TEPC data analyses, including display of the raw data, analyzed spectra, average neutron energy, average neutron quality factor, and dose equivalent rates with an error estimate of measurement accuracy.

CONCLUSIONS

With changing regulations, the most accurate and sensitive measurement techniques must be available for protecting workers in the nuclear industry. The Neutron and Beta Programs provide an effective mechanism for evaluating and developing the latest measurement techniques. The techniques described span the range of efforts from laboratory evaluation to field applications. As concepts are generated for improving dosimetry, they will continue to be evaluated and developed with the objective of providing better radiation protection in the workplace.

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