INTERCOMPARISON OF PERSONAL DOSIMETERS USED IN U.S. DEPARTMENT OF ENERGY ACCELERATOR FACILITIES

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An intercomparison of the dose equivalent response of personal dosimeters in use at U.S. Department of Energy (DOE) accelerator facilities took place at the European Laboratory for Particle Physics (CERN). This is the third such intercomparison sponsored by the DOE. The two previous intercomparisons were performed in a U.S. laboratory using a source of high energy neutrons. In this intercomparison dosimeters were exposed at CERN in two shielded positions relative to a production target that was hit by a positive hadron beam of 205 GeV/c. The neutron energy spectra present at these two locations had been calculated earlier using Monte Carlo methods and agreed well with those that had been determined experimentally using Bonner sphere spectrometer systems. The dose equivalents at these two positions were measured by CERN personnel using a tissue equivalent proportional counter system. For exposure, the dosimeters were mounted onto spherical phantoms made of polyethylene at several angular positions. The DOE dosimeters were mailed to CERN and following exposure returned for readout. The results of this intercomparison are relatively consistent with the two others previously performed in the U.S. The relative dose equivalent responses of neutron dosimeter types such as: albedo, nuclear emulsion and track etch plastics were found to have variations relative to the mean value responses of up to a factor of three. The possible causes for such large variations will be discussed.

INTRODUCTION

The U.S. Department of Energy (DOE) currently administers 12 laboratories that perform high-energy accelerator-based research. The accelerators at these laboratories produce radiations having energies ranging from a few MeV to the TeV range. The high-energy neutrons produced by these accelerators present a difficult radiation protection problem, because they can penetrate large thicknesses of shielding (1,2).

The DOE operates a program to accredit suppliers of personnel dosimetry for DOE facilities. This program is entitled the Department of Energy Laboratory Accreditation Program (DOELAP)(3). The two neutron sources used for DOELAP proficiency testing are unmoderated and D_2O-moderated ^{252}Cf. The unmoderated ^{252}Cf source has a mean energy of about 2.3 MeV with a high-energy tail extending to approximately 10 MeV. However, this source is not appropriate for testing personal dosimeters that are expected to measure dose equivalents produced by neutrons with energies of several hundred MeV.

The intercomparison of dose equivalents determined with personal dosimeters used at DOE high-energy accelerator facilities was intended to show the degree of consistency in high-energy neutron dosimetry at the participating laboratories. The high-energy neutron fields generated at CERN provided a more realistic approximation to the actual fields encountered at DOE high-energy accelerator facilities than could be provided by the two neutron sources used in the DOELAP program.

MATERIALS AND METHODS

The neutron fields used for this intercomparison were generated at CERN by bombarding a copper target with a beam of positive hadrons (protons and pions) with a momentum of 205 GeV/c. The secondary radiation produced by this interaction at 90° passes through shields of either concrete or iron (4). The radiation fields outside these shields contains a large portion of high-energy neutrons that can be used to irradiate personal dosimeters or area survey meters. Determinations of the neutron energy spectra for the two experimental conditions were carried out using Monte Carlo methods and Bonner sphere spectrometer systems (4). Good agreement was found between these two methods.

Personal dosimeters from participating DOE facilities were mailed to CERN from the Pacific Northwest National Laboratory. Appropriate numbers of control dosimeters were not irradiated, so that the background and transit doses could be evaluated. At CERN, the dosimeters were irradiated on two types of plastic phantoms.

Calibration exposures were performed using a rectangular solid phantom measuring 40 x 40 x 15-cm and an irradiation distance of 2 m from a ^{238}Pu-Be neutron source. For exposures at the accelerator experimental positions, dosimeters were mounted on spherical polyethylene phantoms at several angular positions. Following exposures at CERN, the dosimeters were mailed back to the participants for readout.

RESULTS AND DISCUSSION

Dose equivalents determined from the readings of the personal dosimeters used in this study were compared to the mean of all values determined by all of the participants. The dose equivalents determined by the participants were also compared to the values determined by CERN. The ratios of average readings to the mean for the participants are shown in Figure 1, for the concrete shielding configuration and 2, for the iron shielding configuration.

It can be seen from this plot that the extremes of average readings for dosimeters used by different participants vary from the mean by up to a factor of 3. The variations are in both directions and do not appear to correlate to dosimeter type or participant. The results for the concrete shielding configuration seem to be somewhat more consistent.

The dosimeter types used in this study had different dose equivalent responses as a function of neutron energy. In addition, the dosimeters were calibrated using different reference neutron sources. Therefore, it is not surprising that their responses to this high-energy neutron field varied by large amounts. In order to determine whether the inherent dose equivalent response of the dosimeters as a function of energy, the reference calibration source or other uncertainties were responsible for these differences, it would be necessary to design a specific experiment to test the effect of each influence quantity. It is expected that future intercomparison exercises will include such tests.

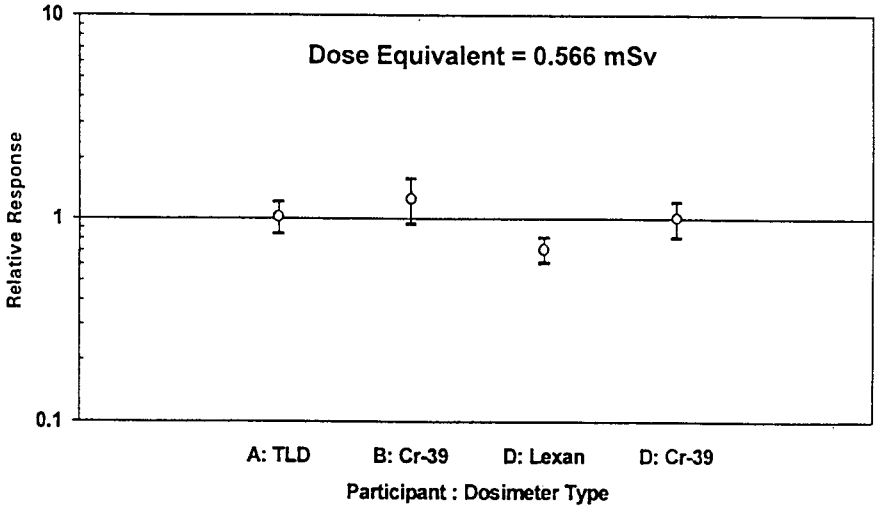

Figure 1. Dose equivalent responses relative to the mean for participants A-D in concrete shielding configuration.

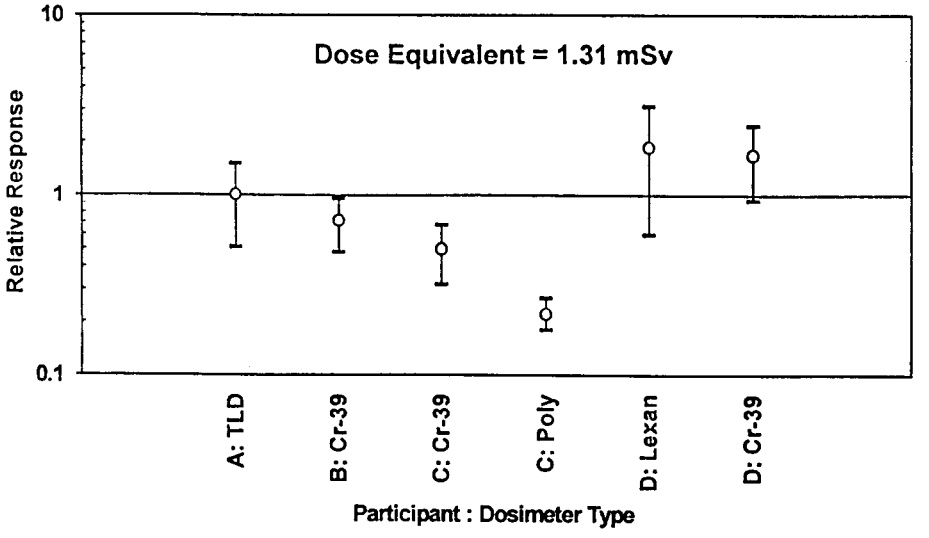

Figure 2. Dose equivalent responses relative to the mean for participants A, B, D in iron shielding configuration.

ACKNOWLEDGMENTS

We wish to thank our colleagues at CERN for providing beam time for this study and for their expertise in carrying out the exposures. This work was supported in part by the Health Physics Program Division of the U.S. Department of Energy. The Pacific Northwest National Laboratory is operated for the US Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

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