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THE QUALITY FACTOR AND OTHER CONSIDERATIONS IN RADIATION PROTECTION AT THE AGS

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Introduction

The prompt radiation environment outside the primary and secondary AGS beams consists mainly of neutrons, muons, and electromagnetic components. The energy distribution and the relative numbers of each vary as a function of the beam intensity, energy, optics, angular position from the source, and shield density thickness.

Health Physics measurements performed throughout the experimental halls use certain simplifying assumptions to make conservative first approximations to the exposure conditions. In the majority of cases, the techniques used result in an overestimate of the dose to personnel. This paper will review how raw data are collected and what steps are taken to ensure that Health Physics data are conservative.

Instrumentation and Data Collection

During periods of extracted beam, two health physics instruments are used to measure pulsed (neutron) radiation fields. Fixed area monitoring is done with Fermilab Chipmunks and general hand held surveys are accomplished with the HPI-1010. Both instruments measure absorbed dose. The unit of absorbed dose is rads, where 1 rad = 100 ergs/g. To account for the difference in biological response between radiation species, the rad dose must be adjusted by the Quality Factor (Q) to convert the measurement into rem, the unit of dose equivalent, where:

$$H \text{ (rem)} = \text{rad} \times Q.$$

Even though the above relation looks simple, in practice it is non-trivial to evaluate precisely when instantaneous readout is required for routine radiation protection. Therefore, the method is simplified and designed to err conservatively.

As mentioned above, these devices respond in rad and it follows that it is not possible to readily separate the rads from neutrons and the rads from the gamma-muon response. Therein lies the problem. In addition, the Quality Factor for neutrons is energy dependent and varies between 2 and 10. Fortunately, we know from neutron spectroscopy done at the Cosmotron, AGS, CERN-PS, and other facilities, that the Quality Factor, on average at a high energy accelerator is about 5. So the rads measured by the chambers are assumed to be from only neutrons and are then multiplied by 5. The typical radiation fields around the AGS are about 50-50 neutron and gamma-muon. Muons deliver dose biologically the same as gamma or beta particles and have a Q of 1 since they also are minimum ionizing. Therefore, that portion of the dose equivalent is overestimated a factor of 5. In cases where the neutron Quality Factor is greater than 5, the inevitable gamma-muon component will compensate for the measurement error. Typically, the overestimate will be in the range of 50 - 100%.

Another factor that causes differences between the active instruments and badge results is the fact that the Chipmunks are often located at the "worst case" point of highest exposure and the occupants of a given area usually incur lower average dose rates than seen by the Chipmunk.

Conclusions

So when your film badge comes back low or minimal, or your local Chipmunk seems high, there really is not a wide variation. The difference resides mainly in the fact that the badge dose is realistic and Health Physics survey data are comfortably pessimistic. Of course, the survey data could be corrected on a daily basis, but for productivity reasons, we only convert it when detailed interpretation is required for planning purposes.