GAMMA-RAY SKYSHINE FROM AN ON-SITE RADWASTE STORAGE FACILITY

J. M. Tuohy
C. S. Yeh
Burns and Roe, Inc.
633 Industrial Avenue
Paramus, NJ 07652

ABSTRACT

The gamma-ray skyshine doses from an on-site radwaste storage facility were calculated, using the G^3-36ED computer code. Although the G^3 is a general purpose gamma-ray scattering code, simple and economical to use, the calculation can, however, yield fairly accurate results, if certain cautions and efforts, as described in the text, are exercised. The accuracy of the present calculations was established by comparing the calculated results, with the measured results of a recent benchmark skyshine experiment. The agreement was good. Some regulatory aspects of the skyshine dose to members of the public at the site boundary and beyond are also discussed.

INTRODUCTION AND BACKGROUND

Operating nuclear power plants generate various types of solid, liquid and gaseous radioactive wastes as by-products. For economical plant operation and for ease of complying with regulatory requirements, the liquid and wet solid wastes are volume reduced and sometimes solidified before storage and shipment. Given the current burial site situation, it is likely that most of the radwastes produced by the plant processing systems will eventually end up as solidified or dewatered wastes in the plant storage facility prior to shipment.

The gamma-ray skyshine dose form an on-site radwaste storage facility can be a radiation protection problem because:

1. the radiation source intensities are high in solidified radwastes containing spent resin, filter sludge, concentrated liquids, etc;
2. the gamma emitting surface is extensive, since a large number of radwaste containers/drums will be in storage;
3. the storage facility is usually a one-story building with only a simple roof to attenuate the skyward gamma-ray radiations, and it is difficult and expensive to build a concrete roof of several feet thickness to cover the span of a large storage area, for gamma-ray attenuation;
4. Environmental Protection Agency regulation 40 CFR Part 190 permits an annual whole-body dose of only 25 milli-rem/year to any member of the public, arising from operations of a whole uranium fuel cycle.

This paper endeavors to evaluate the skyshine dose problem and to show how, by exercising certain cautions and efforts, one can achieve fairly accurate skyshine dose evaluations by using comparatively simple calculational techniques, without resorting to time-consuming and costly programs such as Monte Carlo methods. The accuracy of the present calculation was established by comparing the calculated dose results with the measured results for a recent benchmark skyshine experiment. Finally, some regulatory aspects of the impact of the skyshine dose to members of the public at the plant site boundary and beyond, are discussed.

SKYSHINE DOSE CALCULATION OF A STORAGE FACILITY

The radwaste storage facility used for this skyshine dose calculation has a storage area of 84-ft by 84-ft surrounded by a 45-ft high concrete wall, 3-ft thick from elevation 0 to 30-ft and 2-ft thick above elevation 30-ft. The area can accommodate 288 HN-100 liners (163 ft^3 each), stacked in two layers to about 12-ft high. The liners are filled with radwastes consisting of concentrated liquids, spent resin and filter sludges, solidified in cements. The source intensity is eleven micro-curie per milli-liter. Immediately above the stacked liners, there are thirty-six pieces of 18-inch thick removable concrete slabs, to attentuate the upward gamma radiations.

The skyshine doses were calculated by the G^3-36ED code - a general purpose gamma-ray scattering code.[1] In using this code, the skyshine gamma-ray radiation is treated by a point kernel approach which combines single scattering calculations with appropriate buildup factors. The gamma flux above the 18-inch slabs was first calculated by the bulk shielding code QAD-CG1. This gamma flux was used as the source for the skyshine scattered dose calculations. The skyshine doses for the facility in storage mode (18-inch slabs in place) are shown in Fig. 1, where dose rates versus distance from the storage facility toward the site boundary and beyond are plotted.

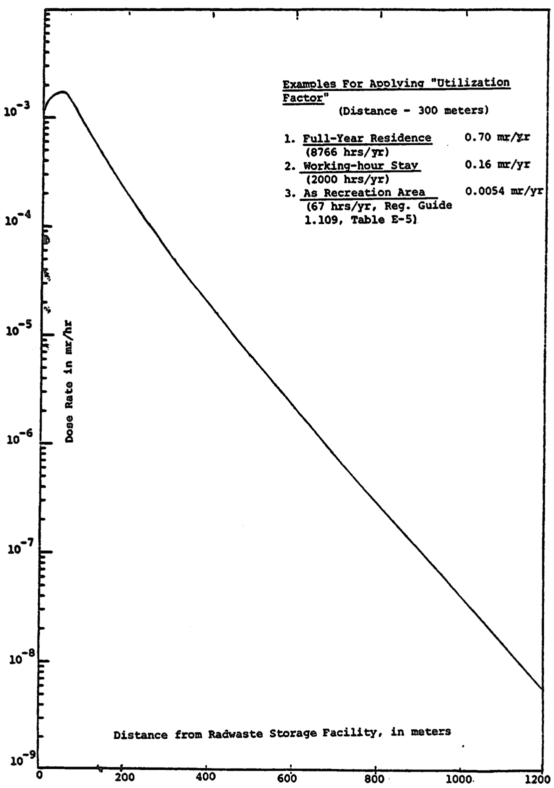

Fig. 1 - Skyshine Dose Versus Distance for a Solidified Radwaste Facility in Storage Mode, mr/hr

In using the G^3 code calculations, the following calculational techniques and efforts were found necessary in order to attain better accuracy in dose results:

1. In establishing the scattering grid configuration in the atmosphere, the reflecting layer of the atmosphere should be two mean free path (mfps) in thickness in both the vertical and horizontal directions for the gamma-ray energies concerned. In the direction of dose receiver points, the chosen atmosphere should be extended to a greater distance, but rarely beyond 4 mfps.

2. The scattering grids (boxes) should be as small as possible in comparison with the mfps, without incurring excessive computing cost. Also, the scattering angle representing a box should have a small range of variation across the extent of the box, i.e., the length of the box in the direction of scattered gammas should be small.

3. Some scattering grids are more important than the others in their dose contributions to a distant receiving point. The important grids are the ones that can be readily seen by the source points, usually in the close vicinity above the storage facility. These important grids (boxes) should be weighted more heavily, i.e., with smaller grid spaces in the code calculations.

4. Gamma-ray point sources are used in the G^3 code to calculate the skyshine dose. The gamma point source (gammas/sec) was obtained by multiplying the gamma flux (calculated by the QAD-CG code) with the gamma emitting area above the concrete slabs covering the radwaste containers. For better accuracy, the gamma emitting area should be subdivided and the source location and magnitude for each subdivided area used separately to obtain partial contributions to the total skyshine dose. This process should be repeated until further subdivision of the gamma emitting areas results in no significant change in total skyshine dose from the storage facility. Advantage should be taken of configurational symmetry to reduce the numbers of calculations in such subdivisions.

COMPARISON WITH AN EXPERIMENT

In order to establish the accuracy of calculating skyshine dose by the simple calculational technique described above, the same technique was used to calculate a recent skyshine experiment[2]. The experiment used a Co-60 source in an annular concrete silo of 2.5 meter i.d., 4.35-meter o.d. and 2.29-meter high. The source is at 1.98 meter elevation. There is a 21-cm thick concrete roof above the silo. The G^3-code calculated results together with the measured dose results of the experiment are shown in Fig. 2. The agreement is found to be good. The measured dose rates in the close vicinity to the experimental facility are somewhat higher than the calculated results because reflected dose from the facility walls could affect this region of close vicinity; while the G^3-code only makes single scattering calculations for the gammas striking the atmosphere. The calculated dose rates at further distances tend to be higher than the measured ones because the buildup factor used in the calculations was based on isotropic point source in an infinite medium. This use of buildup factor tends to make dose rates higher for calculated results. From the above discussions, we may conclude that by employing the techniques described above, a comparatively simple calculation can attain dose results good enough for the radiation protection design of a radwaste storage facility.

REGULATORY REQUIREMENT

EPA 40 CFR 190 sets the annual whole body dose limit to any member of the public at 25 mr/yr, arising from all operations of a uranium fuel cycle. The amount of annual dose the public can receive from a particular radwaste storage facility is dependent on:

1. the site boundary distance from the facility;

2. the duration of time (hours/year) an individual will stay at or near site boundary;

3. the fraction of the total annual dose limit (25 mr/yr) that can be allotted to operation of the storage facility, among all other contributing origins.

The storage facility should be located as far away from the site boundary as possible, particularly in the direction of inhabited areas. It is unlikely that a member of the public will stay at site boundary continuously. Hence, a "utilization factor," particular to an individual site, can be introduced to such site boundary locations. Such application of a utilization factor is shown in the tabulation of Fig. 1. Allotment of annual dose for a particular operation in the uranium cycle will help the radiation protection design of the specific operation (e.g., operating on-site radwaste storage). For example, 10 CFR 50, Appendix I allots 5 mr/yr in total body dose, maximum, to an individual in off-site location, due to liquid or gaseous radioactive releases from a plant site. It is believed that items 2 and 3 described above, are matters requiring regulatory guidance.

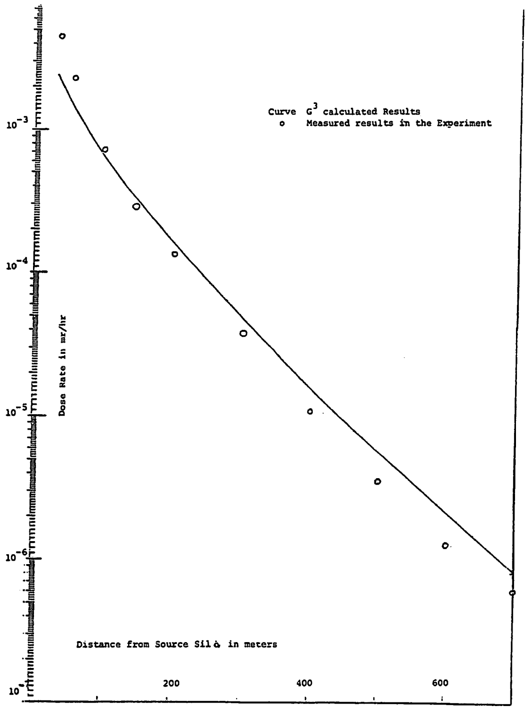

Fig. 2 - Benchmark Skyshine Experiment, Comparison of Calculation With Measurement, Dose Rate vs Distance, mr/hr/Ci-Co-60

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2. R. R. Nason, J. K. Shultis, R. E. Jaw and C. E. Clifford, A Benchmark Gamma-Ray Skyshine Experiment, Nucl. Sci. & Eng., 79, 404-416 (1981).