Dose Rate Visualization of Radioisotope Thermoelectric Generators

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Westinghouse Hanford Company  Richland, Washington

Management and Operations Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

Copyright License: By acceptance of this article, the publisher and/or recipient acknowledges the
U.S. Government's right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper.

Approved for public release

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED
DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.
Dose Rate Visualization of Radioisotope Thermoelectric Generators

R. A. Schwarz  
S. F. Kessler  
T. A. Tomaszewski

Date Published  
September 1995

To Be Presented at  
Space Technology & Applications International Forum (STAIF-96)  
Albuquerque, New Mexico  
January 7-11, 1996

Prepared for the U.S. Department of Energy  
Assistant Secretary for Environmental Management

Westinghouse Hanford Company  
P.O Box 1970  
Richland, Washington

Management and Operations Contractor for the  
U.S. Department of Energy under Contract DE-AC06-87RL10930

Copyright License: By acceptance of this article, the publisher and/or recipient acknowledges the U.S. Government’s right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper.

Approved for public release
LEGAL DISCLAIMER

This report was prepared as an account of work sponsored by
an agency of the United States Government. Neither the
United States Government nor any agency thereof, nor any of
their employees, nor any of their contractors, subcontractors
or their employees, makes any warranty, express or implied,
or assumes any legal liability or responsibility for the
accuracy, completeness, or any third party's use or the results
of such use of any information, apparatus, product, or process
disclosed, or represents that its use would not infringe
privately owned rights. Reference herein to any specific
commercial product, process, or service by trade name,
trademark, manufacturer, or otherwise, does not necessarily
constitute or imply its endorsement, recommendation, or
favoring by the United States Government or any agency
thereof or its contractors or subcontractors. The views and
opinions of authors expressed herein do not necessarily state
or reflect those of the United States Government or any
agency thereof.

This report has been reproduced from the best available copy.

Printed in the United States of America

DISCLM-2.CHP (1-91)
Abstract

Advanced visualization techniques can be used to investigate gamma ray and neutron dose rates around complex dose rate intensive operations. A method has been developed where thousands of dose points are calculated using the MCNP (Monte Carlo N-Particle) computer code (Briesmeister 1993) and then displayed to create color contour plots of the dose rate for complex geometries. Once these contour plots are created, they are sequenced together creating an animation to dynamically show how the dose rate changes with changes in the geometry or source over time.

INTRODUCTION

Advanced visualization techniques were used to investigate gamma ray and neutron dose rates around the Radioisotope Thermoelectric Generator (RTG) transportation system being designed for the shipment of RTG's from Mound, Ohio to the Kennedy Space Center in Florida. The radioactive material contained in the RTG's is plutonium oxide consisting of 80 to 86 atom percent $^{238}$Pu which produces heat as it decays.

The RTG produces a significant neutron and gamma ray source term. The neutron source is dominated by the spontaneous fission of the plutonium isotopes, the gamma ray source term is dominated by $^{208}$Tl which is a decay product of $^{236}$Pu. To minimize the gamma ray source term, the amount of $^{236}$Pu must be minimized. A typical RTG will have less than 1 ppm of $^{236}$Pu.

Because of the high dose rates associated with the RTG's it is necessary to have a method to accurately predict the dose rates for handling the RTG's. To meet this need a computer program has been developed that allows a user to select a shielding configuration and source term and calculated anticipated dose rate exposures to personnel.

DOSE RATE CALCULATION

The MCNP computer code was used to calculate the gamma and neutron dose rates using the source term for the General Purpose Heat Source (GPHS) RTG documented in the Safety Analysis Report for Packaging (Barklay 1993). The GPHS source configuration consists of 18 GPHS modules stacked vertically. Each GPHS module contains two impact shells with each impact shell containing two iridium clad fuel pellets encased in graphite. Included in Figure 1 is a plot of the MCNP model for the source configuration.

MCNP models were created for three shielding configurations. The first configuration is for a fully shielded transportation package. Include in Figure 1 shows an MCNP plot of this configuration. The shielding around the GPHS RTG
Cross Section of GPHS Module

Iridium clad

fuel

fuel

Graphite

GPHS Module Array

Steel

Close Up of Shields

Water

Steel

FIGURE 1. MCNP Model Showing the RTG Source and Shielding Configuration.
package consists of two bells, an external bell which contains a 3.2 cm thick water jacket for neutron shielding which is encased in steel and an inner steel bell 1.9 cm thick.

The second configuration consists of a GPHS RTG with the inner steel shield in place and with the outer shield raised 28.6 cm. The outer shield will be raised for installing and removing the hold down bolts for the inner shield.

The third configuration consists of a GPHS RTG with no external shielding. Both the inner and outer bells have been removed. This represents an initial configuration prior to installing the shielding for transporting the package.

The configurations were chosen to be representative of operational conditions expected when transporting the RTG packages. Both neutron and gamma ray calculations were made for each shielding configuration.

DOSE RATE VISUALIZATION

A computer program was written to read in the MCNP data and generate color contour plots of the dose rate around an RTG for the different shielding configurations. The computer program reads the dose rates associated with each shielding configuration calculated by the MCNP computer code then creates a contour plot for each time unit selected. The user can display either the gamma, neutron, or total dose rate.

The user selects a shielding configuration for the RTG or multiple RTG's to simulate an actual storage, shipping or handling operation. The user can then insert into the program the expected locations of personnel and the amount of time the personnel will be in each location to calculate the total dose that will be received by personnel.

The user can set up a number of frames to simulate an operation, such as removing an RTG from a truck and then removing the shields. These frames can then be sequenced together to create an animation that can be used to calculate the total dose for the personnel present within the animation. Individual color frames have proven to be useful pre-planning tools to communicate understanding about radiation levels and restriction zones to personnel who will be involved with the work.

Figure 2 shows a plot of the graphical user interface that is used to create the contour plots. The main portion of the interface consists of a plot window showing a contour plot of the dose rates for the specified geometry. In this case the geometry consists of a shielded RTG.

The geometry is constructed using the "setup" button which allows the user to define the location and shielding configuration for each RTG in each frame. Once these configurations are defined, the user can then use the control buttons shown at the top left of Figure 2 to run an animation.

The user is provided with numerous options shown on the left side of Figure 2. The "people" button allows for the insertion of personnel into the contour plot. These personnel will show up as stick figures on the plot. Other options allow the user to zoom, unzoom, print, specify contour levels, set the shield
Figure 2. Dose Rate Visualization Tool Showing Fully Shielded RTG.
configuration, and indicate the of dose rate type (neutron, gamma, or total) desired.

In Figure 2 a person has been inserted into the figure beside the RTG. The total accumulated dose is calculated at the cross point between the arms and the body. The person is located at 100 cm from the center of the RTG and his total accumulated dose is 98 mrem. This accumulated dose assumes the person is at this location for 1 hour.

Figure 3 shows the contour plot that is generated when the outer shield is raised 28.6 cm. Notice that the contour lines now indicate an increased source near the bottom of the RTG where there is less shielding. The person in Figure 3 is at the same location as in Figure 2, except now his accumulated dose is 101 mrem.

The computer program can also display the statistical errors associated with the data in the plot. Because the dose rate is calculated using the Monte Carlo N Particle (MCNP) computer code, each data point has a statistical uncertainty associated with it. The "Show Error" button will produce a color contour plot of the statistical uncertainty at each data point. The "Show Grid" button will show the location of the data points used to create the contour plot. Both the "Show Error" and "Show Grid" options can be used to understand if anomalies in the plot are due to a real effect or a statistical fluctuation.

SUMMARY

Advanced visualization techniques can be used to bring complex shielding calculations to a level that can be used for operational dose rate assessments, job planning, and personnel safety awareness.

Acknowledgments

Funding for the work reported in the paper was provided by The United States Department of Energy (DOE).

References
