LA-UR-02-0450
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Submitted to: The 12th Biennial Topical Meeting of the Radiation Protection and Shielding Division of the American Nuclear Society (ANS), Santa Fe, NM, April 14–18, 2002

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FORM 836 (10/96)

NEUTRON AND PHOTON EFFECTIVE DOSE EQUIVALENT RATE CALCULATIONS FOR THE REPACKAGING OF TRU WASTE

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SUMMARY
Neutron and photon effective dose equivalent rates were estimated for operations that will occur in the characterization and repackaging of transuranic (TRU) waste drums. These activities will be performed in structures called Mobile Units (MU). A MU is defined as a modular and transportable container, also called a transportainer.[1] The transportainers have been designed to house a process required for certification of TRU wastes. The purpose of these calculations was to provide dose rates from Pu-238 TRU waste in various locations in the transportainer using MCNP-4C. In addition to dose rates for the various radiological operations in the repackaging area, the dose rate from the adjacent storage area was calculated to determine the contribution to the total dose rate.

I. METHODOLOGY

The radiation transport code MCNP-4C[a] was used to determine dose rates at various locations within the transportainers.

A. Model description

The transportainer was modeled according to diagrams provided by the owners of the process. The transportainer dimensions were 3.66 m high by 3.2 m wide by 13.6 m long and it was assumed the walls were 0.635 cm thick carbon steel. In this model, the area that connects the transportainer and the storage area is called the spool (Figure 1 and 2). The spool was 1.83 m long and the storage area was 3.05 m long and both have the same height and width as the transportainer.

The transportainer contained a horizontal TRU waste supply drum on a drum lift and four vertical drums into which the TRU waste would be repackaged (Figures 1 and 2). The repackaging process involves attaching the horizontal feed drum to a glove box and removing the contents. The walls of the glove box consist of 0.48 cm stainless steel. The contents are sorted and then repackaged in the vertical drums. Leaded glass (0.16 cm) was also considered in the model as an option to further reduce dose rates.

In terms of TRU waste content for each drum, each of the four vertical drums was assumed to contain a quantity equivalent to 1 Watt (W) of Pu-238 and the horizontal drum could contain 0.5-40 W of Pu-238. The TRU waste is housed in 55 gallon drums that are 88.9 cm high and have a diameter of 58.4 cm. The drum walls consist of 0.16 cm of steel.

The TRU waste drum storage area adjacent to the transportainer was modeled to estimate the contribution to the dose rate inside and outside the transportainer, as well as dose rates inside the storage area. The 3.05 m by 3.05 m storage area contains a maximum of twenty drums and is located 1.83 m from the repackaging end of the transportainer (Figures 1 and 2). For the purpose of these calculations, it was assumed the storage area contained 20 W of Pu-238.

B. Source term

The Pu-238 sources in the various drums were modeled as point sources located in the center of each drum. The neutron spectrum for Pu-238 represents plutonium oxalate with 2.94e+04 neutrons/second-gram of plutonium.[2] Plutonium oxalate was chosen because it yields the highest neutron production rate from Pu-238 for the materials considered. The photon spectrum represents $^{238}PuO_2$ decayed 20 years with 2.76e+08 photons/second-gram of plutonium.[2] The photon source was decayed 20 years to allow for the growth of daughters that may contribute to photon dose.

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[a] MCNP is a trademark of the Regents of the University of California, Los Alamos National Laboratory

The horizontal supply drum contained a source term ranging from 0.5 to 40 Watts of Pu-238. The four vertical repackaged drums each contained 1 watt (1 W = 1.762 g Pu-238)[3] of Pu-238 for a total of 4 watts. The 20 drums in the storage area were not modeled individually. The source volume was covered with a 0.16 cm layer of steel to represent the inherent shielding provided by the steel drums. Dose rates were calculated in units of mSv/hr.

C. Tally

Using the design drawing and several source geometries, dose rates inside the transportainer were calculated at a distance of one foot from the drums. To determine the dose rate as a function of height within the transportable, a tally plane, located 30.48 cm from the drums, was segmented in both the horizontal and vertical directions and dose rates were determined in the areas defined by the segments (Figure 1). Dose rates tallied outside the transportainer were also segmented to specifically consider relevant locations.

In addition to calculating dose rates inside the transportainer, dose rates were calculated on the roof of the transportainer and outside the transportainer. Dose rates outside the transportainer were evaluated with various doors open and closed as well to determine how the dose rate increases. One door connects the storage area with the outside, one door is between the storage area and the spool and the third door is between the spool and the repackaging area. For radiation protection purposes the latter two doors cannot be opened simultaneously.

D. Dose Rate Calculations

Neutron and photon effective dose equivalent rates (mSv/hr) were calculated by transporting the appropriate neutron and photon energy source term with MCNP-4C[4] to the specified locations. Once at the tally locations, the fluence was converted to effective dose equivalent rates using the appropriate source strength and the ANSI 1977 Photon and Neutron Fluence to Dose conversion factors.[5]

II. RESULTS

Dose rates were calculated at numerous locations inside and outside the transportainer. However, for this report, six locations were chosen to provide a conservative estimate of dose rates when all the source drum locations contained the maximum amount of TRU waste material. The locations are represented by letters in Figures 1 and 2 and are described below.

Location A	In front of horizontal supply drum
Location B	In front of glovebox
Location C	In front of vertical repackaged drum
Location D	Above storage area (0.9 m above roof)
Location E	Outside transportainer (30.48 cm away from storage area)
Location F	In storage area

Neutron and photon dose rates were calculated at the locations listed above for the scenarios in which the source was located in all possible locations. Dose rates in locations A-F are presented in Table 1. For each location, it was assumed that 1 W of Pu-238 was available in each of the vertical repackaged drums, the storage area contained the maximum number of drums (20) each containing 1 W of material, and the wattage of the horizontal supply drum ranged from 0.5 W to 40 W.

Table 1. Total (Neutron and Photon) Dose Rates in Locations A-F (mSv/hr).

Horizontal Supply Drum Content (W)	Location					
	A	B	C	D	E	F
0.5 W	3.42E-03	7.67E-03	9.63E-03	1.68E-03	5.44E-03	1.16E-01
1 W	5.16E-03	7.73E-03	9.67E-03	1.70E-03	5.46E-03	1.16E-01
5 W	1.91E-02	8.16E-03	1.00E-02	1.85E-03	5.66E-03	1.17E-01
10 W	3.66E-02	8.70E-03	1.04E-02	2.03E-03	5.90E-03	1.18E-01
20 W	7.15E-02	9.78E-03	1.12E-02	2.40E-03	6.39E-03	1.20E-01
30 W	1.06E-01	1.09E-02	1.20E-02	2.77E-03	6.88E-03	1.21E-01
40 W	1.41E-01	1.19E-02	1.28E-02	3.14E-03	7.37E-03	1.23E-01

The highest dose rate occurs in Location A (Figure 1), in front of the horizontal feed drum when it contains 40 W. This is expected because 40 W is the maximum amount of material in any of the source geometries. However, the wattage of the supply drum will vary as will the dose rate. A greater concern will be the dose in the storage area. The storage area will hold 20 drums with a minimum of 1 W each. The dose rate in the storage area is 0.12 mSv/hr.

Photon dose rates are lowered by the stainless steel glove box. If the material from the drum is inside the glove box, the dose rate will be reduced by a factor of four. The 0.16 cm leaded glass placed over the glove box windows will reduce the dose by a factor of nine.

The aforementioned calculations were based on the assumption that all doors to the transportainer and the storage area were closed. Three doors were considered to be important for additional calculations: the door between the storage area and the spool, the door between the spool and the transportainer and the door in the storage area opening to the outside. If the door between the storage area and the outside is open, the photon dose in front of the open door (location E, Figure 2) is a factor of 10 higher than if the door were shut. The neutron dose remains the same.

The dose inside the transportainer is affected when the door between the storage area and the spool is open or the door between the spool and the transportainer is open. The neutron dose remains the same regardless if one door or the other is open. The photon dose rate in this case increases by 30-50% pending the location in the transportainer.

CONCLUSION

These calculations indicate that the dose rates from the repackaging process can be accommodated in the transportainer.

REFERENCES

1. "Design Requirements Document and Preconceptual Design, Modular Characterization and Repackaging Units for TRU Wastes," TWCP-05503 (June, 2001).

2. George, G., "Effective Dose Equivalent (EDE) Rate Calculations for the Pu-238 Recovery Process," ESH-12-00-34 (March 27, 2000).

3. Reilly, D., N. Ensslin, H. Smith, Jr., S. Kreiner, Eds., *Passive Nondestructive Assay of Nuclear Materials*, Nuclear Regulatory Commission Report NUREG/CR-5550 (1991).

4. Briesmeister, J.F., Ed., "MCNP™ A General Monte Carlo N-Particle Transport Code," Version 4C, Los Alamos National Laboratory Report LA-13709-M (2000).

5. "American National Standard for Neutron and Gamma-Ray Flux to Dose Rate Factors," American Nuclear Society, ANSI/ANS-6.1.1-1977.

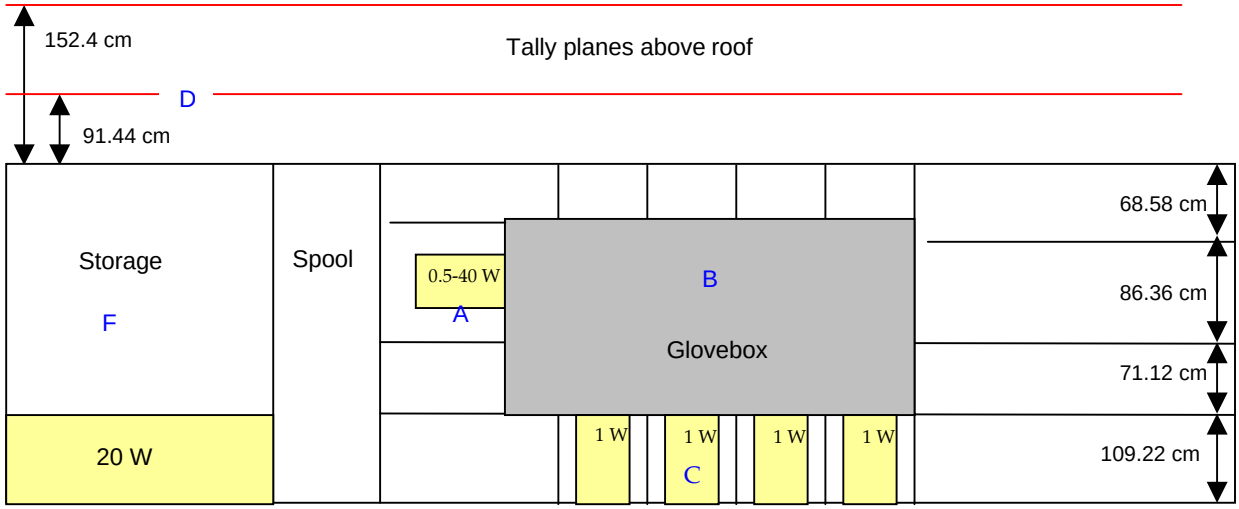

Figure 1. Side view of transportainer (not to scale).

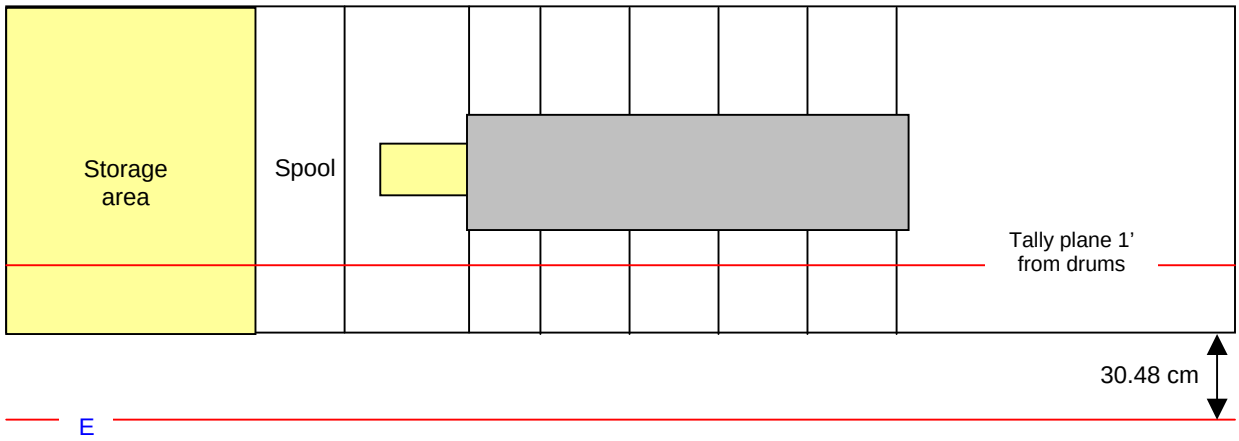

Figure 2. Top view of transportainer (not to scale).