Proceedings of the 15th International Symposium on the Packaging and Transportation of Radioactive Materials
PATRAM 2007
October 21-26, 2007, Miami, Florida, USA

TN International Accurate Shielding Analysis for Casks

Stavros KITSOS
TN International (AREVA group)

ABSTRACT

A more in-depth shielding analysis leads to better exploitation of the casks, increased performances, and safer conditions. The new generation cask designs are optimized to obtain maximum payloads in order to reduce the number of shipments of the transport casks and decrease dose equivalent rates received by the personnel. As a result, shielding analysis for the new generation of casks is becoming more important as dose rates approach the limits set by the regulatory authorities. In order to achieve credible shielding analysis methods, advanced computational analysis techniques and data are implemented, including the three-dimensional Monte Carlo codes and recent evaluations of nuclear data (cross sections) with more evaluated treatment of cross sections. Finally, a large program of benchmarks involving the casks validates the dose rates calculations procedures. The dose rate measurements of several casks and the three-dimensional (3D) Monte Carlo code TRIPOLI-4.3 have been used to evaluate the performances on the shielding calculations of TN International. The comparisons between measured and calculated dose rates have a disparity of less than 10%.

INTRODUCTION

In recent years, the role of shielding analysis in the design of new casks and/or the renewing of licenses of existing casks has become increasingly important. In fact, the confidence in shielding evaluation has led to increasing usage of Monte-Carlo calculations which allow for an increase in the loading of the casks. These days, casks loading at 80% of the dose rate criteria imposed by the regulation are not so rare. This optimized-loading reduces the number of shipments of transport casks and increases safety as the most important risk of an accident during transportation becomes less important. For a storage cask, maximum loading improves both the capacity of the cask as well as its economic performance.

Finally the shielding calculations for TN International are validated by comparisons between the calculated and measured dose rates of the TN International casks. This process has been done for an important number of experiments (hereafter, the results of 32 experiments are presented).

CALCULATION METHODS AND CODES

The shielding calculations for the casks are composed of two steps: first, we evaluate the radioactive sources (neutron and gamma) and second, we evaluate the dose rates resulting from the particles that escape the shielding of the cask.

For the first step, we use the following codes at TN International: for the spent fuel ORIGEN 2 <1>, ORIGEN-S <2> and DARWIN 2 <3>, for the activation products of the fuel assemblies ends the APPOLO 2 <4> code, and for the dose rate evaluation the Monte-Carlo code TRIPOLI 4 <5>.

In recent years, depletion codes used for the spent fuel source calculations have benefited from an increase in their qualification, especially for the high burn up (up to 50GWj/tHM). With the increase of the cooling time of the spent fuel, the activation sources of the fuel assembly-ends become increasingly important; in case of storage casks (with a cooling time of more than 7 years for the spent fuel), the main gamma sources that contribute to the dose rates in the axial direction of the cask and also in the trunnions zone are the activation sources. An accurate evaluation of these sources contributes to much-improved calculations.

The improved performance of the computing machine leads to a computing time of the Monte-Carlo shielding calculations compatible with the design of the cask. The Monte-Carlo calculations have brought:

- 3D geometry description which eliminates approximations due to the modeling of the cask and sources and calculations in singular places such as trunnions and allows to make the loading plans,
- Fine description of the sources (geometry and spectrums),
- Point wise cross section representation which eliminates the multigroup approximation,
- Non-significant increase of the computing time in regards to those improvements.

CASK AND SOURCES MODELING

With the 3D Monte-Carlo codes, the shielding calculations have been largely improved by reducing the amount of errors due to suboptimal geometry modeling of the cask and sources. For example, modeling a cask and its loading by a one-dimensional geometry in the radial section, was made by a 1D cylindrical geometry (infinite in the axial directions). This modeling requires the homogenization of the loading with the basket; it also requires to take the most penalizing assumptions for all the loading (burn up maximum, cooling time minimum, etc…) even if these assumptions only apply to a part of the loading; finally, it requires the homogenization of layers of the cask, for example, the resin layer crossed by the cooper fins for the heating transfer. All these assumptions can be accepted only if they are penalizing and lead to overestimate of the dose rates around the cask.

In order to demonstrate the improvements incurred by using three-dimensional modeling, two calculations were performed to model a cask: one in 1D, the other in 3D.

In terms of neutron dose rate, the one-dimensional model is about 30% more penalizing than the three-dimensional cask model. For the gamma-ray dose rate, the penalty is more than 50%. In

this case, we have considered the same sources; with the 3D model, we also have the possibility to take into account the real loading which can increase the discrepancies between the 1D and 3D models.
The three-dimensional model allows us to evaluate the dose rate in the areas of trunnions or orifices. A TRIPOLI 4.3 detailed model of the cask is shown in figure 1.

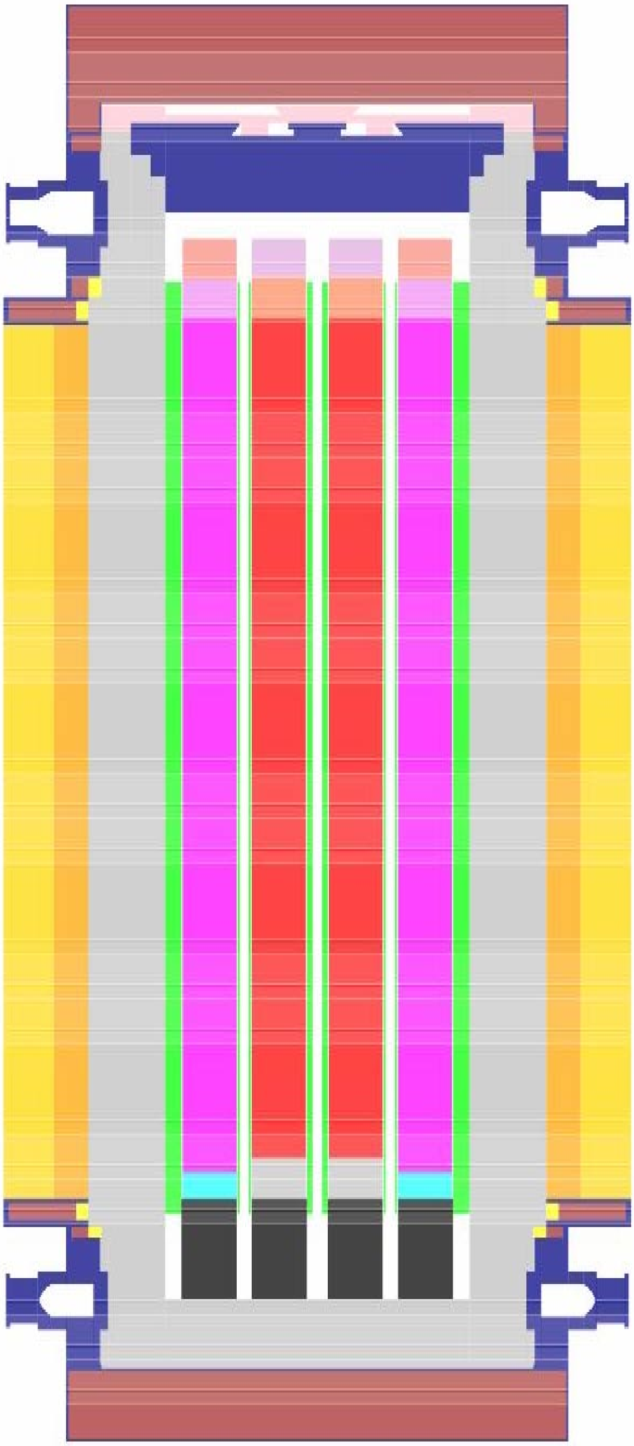

Figure 1 : TRIPOLI 4.3 three-dimensional calculations cask model.

BENCHMARK ANALYSIS

An important number of experiments of the TN International casks have validated our shielding calculations as shown in the following tables:

Table 1 : Summary of percentage differences* between measured and computed dose rates in radial (mid plane) direction at 2m from the cask.

Cask	Number of experiments	Average (%)	Max (%)	Min (%)
TN 12/2 – transport spent fuel	13	+9	+23	+3
TN 28 VT – transport vitrified glass	9	+12	+30	+1
FS 47 – transport Pu powder	3	+11	+14	+8
FS 65 1300 – fresh MOX fuel	1	+7	+7	+7
TN24 XLH – transport/storage spent fuel	2	+11	+15	+7
TN 24 DH – transport/storage spent fuel	1	+6	+6	+6
TN 52 L – transport/storage spent fuel	1	+9	+9	+9
TN 81 – transport/storage vitrified glass	2	+6	+11	+1
TOTAL	**32**	**+10**	**+30**	**+1**

* (calculated/measured -1) x 100%

Table 2: Summary of percentage differences* between measured and computed dose rates at the contact of the trunnions.

Cask	Number of experiments	Average (%)	Max (%)	Min (%)
TN 12/2 – transport spent fuel	13	+25	+46	+9
TN 28 VT – transport vitrified glass	9	+16	+38	+5
TN24 XLH – transport/storage spent fuel	2	+21	+28	+13
TN 24 DH – transport/storage spent fuel	1	+31	+31	+31
TN 52 L – transport/storage spent fuel	1	+25	+25	+25
TN 81 – transport/storage vitrified glass	2	+25	+31	+19
TOTAL	**28**	**+22**	**+46**	**+5**

* (calculated/measured -1) x 100%

For the large casks, the dimensional criterion imposed by the regulation for the shielding is 0.1 mSv/h at a distance of 2m from the lateral surface of the transport vehicle. Therefore, the comparison between calculated and measured dose rates presented in table 1 are made for a distance of 2m from the external surface of the cask. In this case, the position for the measurement instrument is not as important as the measurement at the contact of the cask. However, it is particularly important to choose loadings with measured dose rates that are not too low which can leads to a large uncertainty of measurements. In this case, the TN International calculations are very close to the measurements (on average, < 10% disparity).

Dose rates in the trunnions area, at the contact of the cask can also be a dimensional criterion as there is no place to insert shielding, especially neutron shielding. In table 2, we present a comparison between calculated and measured dose rates. We can see that the discrepancies are more important than in mid-high of the cask. The position of the measurements and the size of the instruments greatly affect the dose rate measurement because of the large heterogeneity of the shielding. Calculations are therefore made with conservative assumptions; we use Monte-Carlo code surface estimators which give exact dose rates at the surface of the cask considering a small surface area (~20cm²). In effect, measurement instruments integrate bigger surfaces and at some distance of the cask. Thus, the calculations are systematically on average ~20% more accurate than the measurements.

CONCLUSIONS

The improvements on the shielding calculations by using the Monte-Carlo 3D codes are validated by a pool of measurements involving the cask; this coherence has brought a confidence in the optimization of the new casks. They have increased the performances of the existing casks and the storage casks. Globally, the safety of the transport of radioactive material increases as the optimizations lead to fewer shipments.

REFERENCES

<1> ORIGEN 2 : "Isotropic Generation and Depletion Code. Matrix Exponential Method" ORNL CCC-371.

<2> ORIGEN-S : "ORIGEN-S: SCALE System Module to Calculate Fuel Depletion, Actinide Transmutation, Fission Product Buildup and Decay, and Associated Radiation Source Terms" NUREG/CR-0200, Rev. 6 (ORNL/NUREG/CSD-2/R6), Vol. II, Section F7.

<3> DARWIN 2 : User's Manual : Technical report CEA : SERMA/LEPP/RT/02-2128/B

<4> APOLLO 2 : User's Manual : Technical report CEA : DMT/96/104 SERMA/LENR/183.

<5> TRIPOLI 4 : "TRIPOLI-4 Monte-Carlo transport code - User's Manual" : Technical report CEA : SERMA/LEPP/RT/01-2901/C.