SELECTION OF SHIPPING CASKS FOR HETEROGENEOUS RADWASTE

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ABSTRACT

A technique has been developed to better define the shielding capabilities of low-level radioactive waste shipping casks. This technique called, "MaxPak", allows the shipper to select the shipping cask best suited to handle the specific mixture and concentration of radionuclides in a particular waste. The proper selection of the cask provides the maximum volume and activity per shipment, thereby reducing transportation and disposal costs. The MaxPak system is also a technique for more effective utilization of the output from the sophisticated computer programs used to design shipping casks. MaxPak allows these programs to be more thoroughly validated for hetrogeneous mixtures of radionuclides and actual operational situations.

PRESENT PRACTICE

A number of excellent programs are available to analyze the shielding capabilities of shipping casks. These programs are used primarily in the design of shipping casks. It is not practical to utilize these programs to analyze individual shipments because of the cost of preparing input data and the operating cost and availability of computers capable of handling the shielding programs. The cost of analyzing a single shipment would generally exceed the actual cost of making the shipment.

In current operations, the generators rely on data sheets supplied by the cask designers and owners. Most data sheets rate the shipping cask in terms of the maximum external radiation at the surface of the containers to be shipped, expressed as R per hour. Most data sheets give a single rating for a given cask. In most cases, the rating is based on waste having gamma emissions of 1 Mev. In some cases, the casks are rated in terms of their capability to handle Cobalt-60 (i.e., 1.173 and 1.332 Mev. gammas). A rating based on Cobalt-60 is very conservative and for shipment of mixtures of radionuclides, the external radiation will be a small percentage of the allowed 10 mR per hour at two meters.

There have been many attempts to better match the shipping cask with the waste. Figure 1 is a cask rating curve in which the maximum specific activity of the waste that can be transported is shown as a function of the energy of the gamma emissions and the form of the waste (e.g., dewatered resin or solidified with cement). The rating curve shown in Fig. 1 is an improvement over the single rating given in data sheets. However, these rating curves are cumbersome to use where a mixture of radionuclides is involved.

SHIPMENT OPTIMIZATION PROGRAM

The MaxPak program uses the design and performance data produced in the analysis of a cask, using one of the sophisticated shield analysis programs. The current version of the MaxPak program is based on the analysis of several shipping casks using the SPAN-4 computer code. SPAN-4 calculates gamma-ray

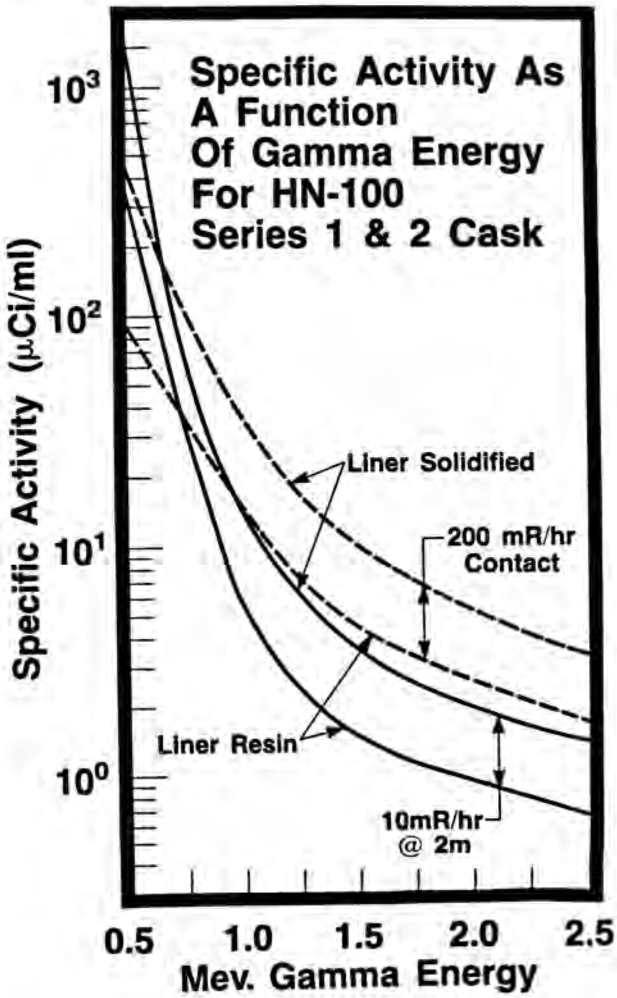

Fig. 1. Typical Rating Curve for Radioactive Waste Shipping Cask

flux in various geometries by integrating appropriate exponential kernals over a source distribution.

In the MaxPak program, the information generated by the SPAN-4 computer code, and shown on Fig. 2, is used as the basic input. Figure 2 shows the radiation level at 2 meters for each of the four shipping casks as a function of the energy of the gamma emissions. The radiation levels are shown as:

$$\frac{\text{mR per hour at 2 meters}}{\text{microcurie per milliliter of waste}}$$

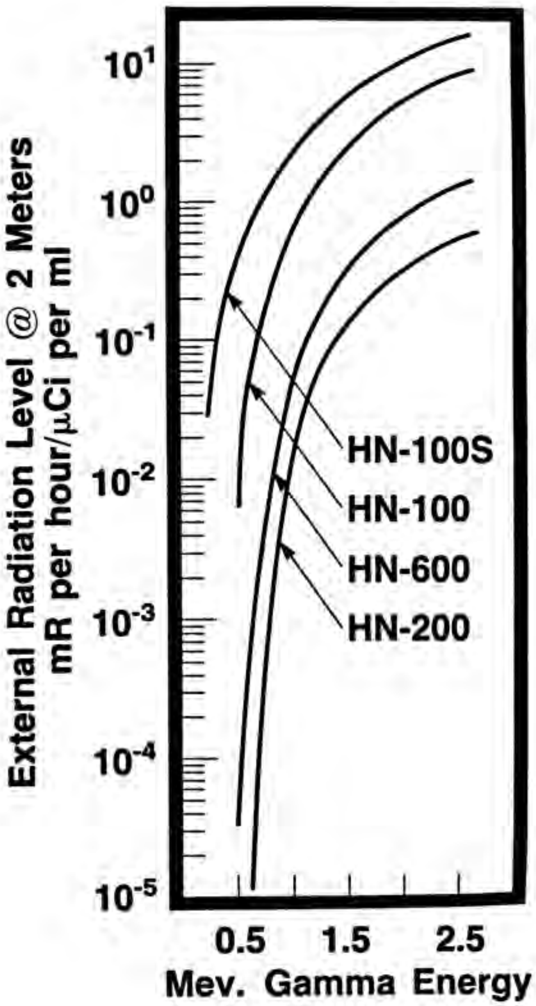

Fig. 2. External Radiation Levels as a Function of Gamma Energy for Designated Shipping Casks.

Figure 2 shows the radiation level for cement solidified waste. Three other sets of data are used in the MaxPak program. These are:

Radiation level at 2 meters, dewatered resin
Radiation level top surface, solidified waste
Radiation level top surface, dewatered resin

The compositions of the shielding for the four casks shown in Fig. 2 are tabulated in Table I. As shown in Fig. 2 and Table I, a relatively small incremental increase in the amount of shielding significantly reduces the external radiation levels for waste having gamma emitters below 1 Mev. Since many of the radionuclides present in low-level radiactive waste emit gammas with energies in the 0.4 to 1.0 Mev range, it is important that this be accounted for in the selection of shipping casks.

The MaxPak program uses a library of radiation coefficients to calculate the radiation dose attributable to each nuclide. This technique was first developed to estimate the surface radiation levels of unshielded containers[1]. Figure 3 shows how the radiation coefficients are derived for an individual radionuclide. Each radionuclide emits gamma rays having discrete energies. Further, the fractional abundance of these discrete gamma emissions is nearly constant. This allows a single radiation coefficient to be defined for each radioisotope for each cask, container, and waste form. Figure 3 and Table II show how the radiation coefficient for Cobalt-58 is calculated.

The library for the MaxPak program contains the radiation coefficients for the 24 radionuclides commonly found in low-level radioactive waste. There are coefficients for each cask, for solidified and dewatered waste and for the radiation levels at two meters from the side of the cask and at the top surface of the cask. The program will be expanded later to include drums and other types of shipping casks. The program includes about 100 coefficients for each cask and type of waste.

The MaxPak program is designed for use with personal computers. The user must first load the program and the library of radiation coefficients. The user must also input the waste type (i.e., solidified or

TABLE I

Shield Composition for Various Designated Shipping Casks

Cask Designation	Certificate of Compliance	Shielding Side Lead (in)	Shielding Side Steel (in)	Shielding Top Lead (in)	Shielding Top Steel (in)
HN-100S	9089	-	3.0	-	3.0
HN-100	9079	1.75	1.25	-	4.0
HN-600	9080	3.0	1.125	-	5.5
HN-200	6574	3.75	1.375	2.0	2.5

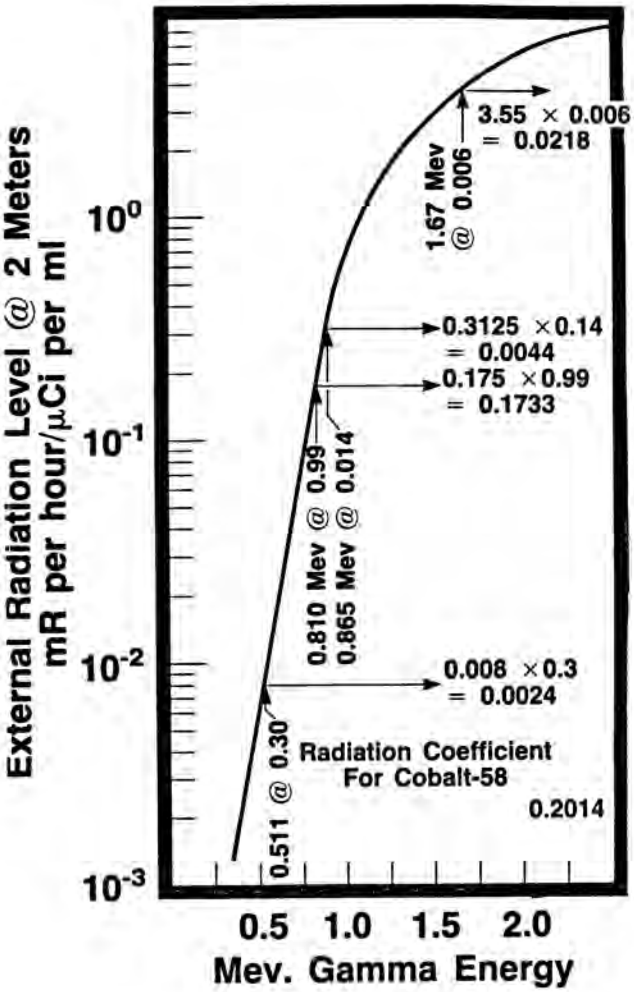

Fig. 3. Radiation Coefficients Derived for an Individual Radionuclide.

dewatered), the type of waste container (i.e., drum, liner, or high integrity container) and if solidified, the volumetric packaging efficiency. The user then inputs the specific activity of the waste for each radionuclide and any two shipping casks to be considered. The MaxPak program then produces a single input/output sheet. The specific activity by radionuclide is displayed as input data. The following output data is displayed for each shipping cask.

Specific activity at the specified packaging efficiency for each radionuclide

Radiation level at 2 meters from side for each radionuclide and total

Percent contribution by Isotope to side radiation

Radiation level on contact at top

Percent contribution by isotope to top radiation

The MaxPak program is used to screen the available casks until a cask meeting the following conditions is found:

Radiation level less than 10 mR per hour at 2 meters

Radiation level less than 200 mR per hour on top contact

The user then prints the MaxPak input/output sheet as backup to the cask selection. Figure 4 shows a typical input/output sheet. The input/output sheet contains blanks for entering the actual radiation levels measured for the shipment.

SHIELD ANALYSIS PROGRAM VALIDATION

The MaxPak program was also developed to permit the shield analysis programs used in the design of radioactive waste shipping to be validated. At the present time, these shield analysis programs have not been adequately validated. The reason these programs have not been validated is relatively simple. To experimentally validate these programs, one would need a large source to simulate the contents under operational conditions. Ideally, homogeneous sources with single discrete gamma energy emissions would be used and a number of sources with different energy levels would be used to validate the program over the total range of gamma energies. Obviously, this would be impractical and prohibitively expensive.

The MaxPak program provides a method for defining the spectrum of gamma energies being emitted by actual heterogeneous mixtures of radionuclides. These are combined with the output from the basic shielding analysis program in the form of radiation coefficients. By the use of these radiation coefficients, the shield analysis program can be validated using the specific activity of the actual waste and the radiation levels recorded for actual shipments.

TABLE II

Derivation of Radiation Coefficient

Cobalt-58 Solidified Liner, HN-100 Cask
Radiation Level at 2 Meters

Emission Energy Mev	Fractional Abundance % x 100	Radiation Factor mR/hr per Ci/ml	Radiation Factor x Abundance mR/hr per Ci/ml
0.511	0.30	0.008	0.0024
0.810	0.99	0.175	0.1733
0.865	0.014	0.3125	0.0044
1.67	0.006	3.55	0.0213
		Radiation Coefficient Cobalt-58 Side at 2 meters	0.2014

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*****************************************************************************************************************************************************
*############ WESTINGHOUSE HITTMAN NUCLEAR INCORPORATED ##########*      "MAXPAK" CASK        *############### WESTINGHOUSE HITTMAN NUCLEAR INCORPORATED ##############*
*################## All Rights Reserved  ########################*   OPTIMIZATION PROGRAM     *#####################       Copywrite 1986     ############################*
*****************************************************************************************************************************************************
*WASTE TREATMENT:          Solidified              Dewatered     CUSTOMER INPUT                 CASK TO BE ANALIZED:    HN100                                *
*PACKAGING EFFICIENCY:       80 %                   100 %                                                               Series 2 or 3                        *
*WASTE CONTAINER:          Liner                   HIC                                                                                                        *
*****************************************************************************************************************************************************
*   Radio   *                                                      CUSTOMER INPUT                                                                        *        *
*  Isotopes *   NA24  MN54  MN56  CO58  FE59  CO60  NI65  ZN65  SR90  Y91   ZR95  NB95  MO99  RU103 AG110 SB124 SB125 I131  I133  CS134 CS136 CS137 BA140 LA144 *  Total *
*   Waste   *                                                                                                                                            *(uci/ml)*
* Spec. Acty.*   0.0   0.0   0.0   1.2   0.0   0.9   0.0   0.0   0.0   0.0   0.0   0.1   0.0   0.0   0.0   0.0   0.0   0.0   0.0  16.0   0.0  12.0   0.0   0.0 *   30.2 *
*(uCi per ml)*                                                                                                                                            *        *
*****************************************************************************************************************************************************
*#######################################################*    RADIATION LEVELS SUMMARY BY CASK (Calculated)    *#######################################################* TOTALS *
*****************************************************************************************************************************************************
*           *                                   Specific Activity @ The Specified Packaging Efficiency                                                   *(uci/ml)*
*           *   0.00  0.00  0.00  1.20  0.00  0.90  0.00  0.00  0.00  0.00  0.00  0.10  0.00  0.00  0.00  0.00  0.00  0.00  0.00 16.00  0.00 12.00  0.00  0.00 *   30.2 *
*           *                                   Radiation Level @ 2 Meters From Side                                                                     *  (mR)  *
*           *   0.00  0.00  0.00  0.89  0.00  7.24  0.00  0.00  0.00  0.00  0.00  0.04  0.00  0.00  0.00  0.00  0.00  0.00  0.00 14.91  0.00  1.57  0.00  0.00 *24.6444 *
* Dewatered *                                   Percent Contribution By Isotope To Side Radiation                                                        *        *
*           *      0     0     0 3.597     0 29.36     0     0     0     0     0 0.156     0     0     0     0     0     0     0 60.49     0 6.388     0     0 *        *
*           *                                   Radiation Level @ Contact On Top                                                                         *  (mR)  *
*           *   0.00  0.00  0.00 11.37  0.00 49.16  0.00  0.00  0.00  0.00  0.00  0.62  0.00  0.00  0.00  0.00  0.00  0.00  0.00 ******  0.00 43.53  0.00  0.00 *307.302 *
*           *                                   Percent Contribution By Isotope To Top Radiation                                                         *        *
*           *      0     0     0 3.701     0 15.99     0     0     0     0     0 0.202     0     0     0     0     0     0     0 65.93     0 14.16     0     0 *        *
*****************************************************************************************************************************************************
*           *                                   Specific Activity @ The Specified Packaging Efficiency                                                   *(uci/ml)*
*           *   0.00  0.00  0.00  0.96  0.00  0.72  0.00  0.00  0.00  0.00  0.00  0.08  0.00  0.00  0.00  0.00  0.00  0.00  0.00 12.80  0.00  9.60  0.00  0.00 *  24.16 *
*           *                                   Radiation Level @ 2 Meters From Side                                                                     *  (mR)  *
*           *   0.00  0.00  0.00  0.19  0.00  2.58  0.00  0.00  0.00  0.00  0.00  0.01  0.00  0.00  0.00  0.00  0.00  0.00  0.00  3.58  0.00  0.34  0.00  0.00 *6.69725 *
* Solidified *                                  Percent Contribution By Isotope To Side Radiation                                                        *        *
*           *      0     0     0 2.885     0 38.57     0     0     0     0     0 0.139     0     0     0     0     0     0     0 53.39     0 5.002     0     0 *        *
*           *                                   Radiation Level @ Contact On Top                                                                         *  (mR)  *
*           *   0.00  0.00  0.00  2.63  0.00 16.29  0.00  0.00  0.00  0.00  0.00  0.16  0.00  0.00  0.00  0.00  0.00  0.00  0.00 50.47  0.00  9.63  0.00  0.00 *79.1731 *
*           *                                   Percent Contribution By Isotope To Top Radiation                                                         *        *
*           *      0     0     0 3.317     0 20.57     0     0     0     0     0 0.200     0     0     0     0     0     0     0 63.74     0 12.15     0     0 *        *
*****************************************************************************************************************************************************
* ACTUAL RADIATION LEVELS:    Dewatered (top):      0 Dewatered (side):      0 Solidified (top):      0 Solidified (side):     0                            *
*****************************************************************************************************************************************************
* WASTE VOLUME PER SHIPMENT:  Dewatered:     96  Solidified:   84                                                                   D.B. Jamieson  2/86  *
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Fig. 4. MaxPak Input/Output Sheet.

The validity of the shield analysis program at various energy levels can be verified by selectively grouping shipments. For the upper range, waste shipments containing primarily Cobalt-60 (i.e., gamma energy 1.173 and 1.332 Mev.) would be evaluated. For the lower range, shipments containing primarily Cesium-137 (gamma energy: 0.662 Mev) would be used.

STATUS OF PROGRAM VALIDATION

The development of the MaxPak program was completed in January 1986. As part of the development of the MaxPak program, the data from prior radioactive shipment records was used as input data to the MaxPak program and radiation levels were calculated for comparison with the radiation readings noted on the radioactive shipment records. Unfortunately, a direct comparison cannot be made. The radioactive shipment records record the radiation readings at one meter and the highest reading on the cask. The location of the highest reading is not noted. However, in most cases it will be the top of the cask. The radiation readings were measured at one meter because this value is used to assign the transport index. In many cases where the radiation reading at one meter is low, it is recorded as less than 0.5 mR. In the few instances where a direct comparison could be made the radiation levels reported for solidified waste shipments were about 25 percent higher than the values calculated using the MaxPak program. For dewatered resin shipments, the calculated values tend to be about 25 percent higher than the reported radiation readings.

The MaxPak program and the SPAN-4 computer code on which it is based cannot be fully validated until the actual radiation readings are recorded on the same basis as the values calculated for regulatory compliance (i.e., less than 10 mR per hour at two meters and less than 200 mR on contact with cover).

The review of the radioactive shipment records revealed other interesting information. In over half of the cask shipments reviewed, the recorded radiation levels at one meter were 0.5 mR per hour or less. This is about 20 times lower than the regulatory limit of 10 mR per hour at two meters. In all of these cases, a cask with less shielding and a greater capacity could have been used.

FUTURE PLANS

Over the next year it is planned to make the MaxPak program available to various nuclear utilities. The program is easy to use and it is expected that a number of generators will use the program on a routine basis. The generators will be asked to provide copies of the input/output sheets, including the actual radiation readings at two meter and on the top surface. At least 100 data points should become available within the first six months of use. With this many data points, it should be possible to make a thorough assessment of the validity of the MaxPak program and the shielding analysis program on which it is based. If the validity is not demonstrated, or if the program gives inconsistant results, the actual data can be used to upgrade the basic programs.

After the validity of the program is established, it will be placed in full operational use. Generators will then be able to optimize their radwaste shipments without the risk of creating waste containers that cannot be shipped in the designated casks because of radiation levels.

REFERENCES

1. C.W. Mallory, "Overall Efficiency of Reclassification of Low Specific Activity Radioactive Materials," Proceedings of the Symposium on Waste Management, Tucson, AZ, February 27 - March 3, 1983.