OVERALL EFFECTS OF THE RECLASSIFICATION

OF LOW SPECIFIC ACTIVITY RADIOACTIVE MATERIALS

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ABSTRACT

The International Atomic Energy Agency and the Nuclear Regulatory Commission are proposing changes in the classification of low specific activity materials. The proposed changes would limit the external radiation from unshielded packages to either 0.5 or 1.0 Rem per hour at three meters depending upon the type of material. The specific activity of the material that can be transported as L.S.A. is reduced significantly from the previous limits which were based on inhalation and ingestion. A technique for estimating the surface radiation levels of unshielded packages is presented. This technique is also used to assure compliance with the proposed regulations. Increased Type B cask shipments will result from these regulations and less emphasis may be placed on volume reduction.

BACKGROUND

The International Atomic Energy Agency (IAEA) is planning to make a major change in the classification of low specific activity radioactive materials in the 1984 regulations. The new regulations will impose limits on the external radiation from the unshielded and uncontained low specific activity packages. The IAEA is proposing a limit of one R per hour at three meters. The U.S. Nuclear Regulatory Commission is considering changing the U.S. regulations without waiting for the adoption of the IAEA regulations. As discussed in this paper, the proposed changes in the U.S. regulations will use the one R per hour at three meters for solidified wastes but will impose a lower limit of 0.5 R per hour at three meters on low specific activity material which has not been solidified.

The present classifications of low specific activity material were based on the handling of ores and other materials having concentrations of radioactivity so low that public health would not be adversely affected if a large quantity of low specific activity material was released. These classifications were based solely on the inhalation or ingestion of the material. Under present regulations, the limits on external radiation of individual packages is 1000 mR per hour at three feet. A regulation is being implemented which would reduce this to 1000 mR per hour on contact. Shielding as part of the package is permitted to meet the present regulations. The new IAEA regulations on low specific activity limits external radiation from the unshielded and unconfined package. The new limits on external radiation are based on exposure an individual could receive following a transport accident involving large quantities of gamma emitting isotopes.

PROPOSED CLASSIFICATION

The proposed U.S. regulations will classify materials as either "Low Specific Activity" materials (L.S.A.) or a "Surface Contaminated Object", (S.C.O.). The L.S.A. materials will be further classified into three categories and the S.C.O. materials into two categories. The changes in the classification of L.S.A. will have the greatest impact on future shipments and only L.S.A. is considered in this paper. Table I contains a summary of the proposed classifications for L.S.A. materials. The major change is the

Table I.
Proposed Classifications of
Low Specific Activity Materials

LSA-I

Ores containing naturally occurring radionuclides
Natural or depleted concentrates of such ores
Solid objects with distributed radioactivity
- Not soluable in water
- Not flammable
- Specific activity $< 5 \times 10^{-6}$ A_2/g*
- Surface radiation < 200 mRem/hr.

Exempt from packaging requirements except for nonexclusive use shipments.

LSA-II

Materials in any form with nonuniformly distributed radioactivity (scintillation vials, trash, clothing)

Specific Activity $< 5 \times 10^{-6}$ A_2/gm

Materials with essentially uniformly distributed radioactivity. (Dewatered resins, filter media, sludges)

Specific Activity:

Solid & Gases	$< 10^{-4}$ A_2/g
Liquids	$< 10^{-5}$ A_2/g
Surface Radiation	< 500 mRem @ 3 meters

Strong industrial package per IAEA definition.

LSA-III

Solid objects with radioactivity distributed throughout

Specific Activity $< 2 \times 10^{-3}$ A_2/g

Monolithic solid material with distributed radioactivity

- Solid non-flammable binding agent
- Specific Activity $< 2 \times 10^{-3}$ A_2/g
- Immersion Activity Loss < 0.1 A_2
- External Radiation < 1 Rem/hr. @ 3 meters**

Strong industrial package per IAEA definitions.

*A_2 = Allowable quantity for normal form Type A shipments.

**10 Rem/hr. @ 3 meters if shielding retained during hypothetical accident with radiation < 1 Rem/hr at one meter from package.

imposition of external radiation levels on the unshielded and uncontained materials with higher limits allowed if the package can retain shielding under the hypothetical accident conditions required for Type B packaging. These packages are not required to withstand the fire conditions.

EFFECTS OF NEW CLASSIFICATIONS

The waste that will be effected most by the change in the classification of L.S.A. materials will be those from nuclear power plants. The wastes from nuclear power plants contain fission products and activated corrosion products which are gamma emitters. Waste streams containing the radionuclides are concentrated by evaporation or are removed and concentrated by filtration, centrifuging or ion exchange. The concentrated wastes are dewatered or solidified and shipped to disposal sites in shielded packages which meet Department of Transportation or Nuclear Regulatory Commission requirements. In the U.S. practically all shielded shipments of radioactive waste are from nuclear power plants. When the amount of activity exceeds a Type A quantity, the shipment must be made as either an L.S.A. shipment or as a Type B shipment. If the material does not meet the requirements shown in Table I, for classification as L.S.A., it must be handled as a Type B shipment.

Figures 1 and 2 show the radiation levels on the side and top of a large disposable container as a function of the specific activity of the waste and the energy of the gamma emissions. Figure 1 is for dewatered resin and filter media and Fig. 2 is for waste material which has been solidified in cement. The figures were derived from a shielding analysis performed using the SPAN 4 computer code. To estimate the surface radiation level, one must consider the energy of all of the emissions that occur during the decay of the radionuclide and the fractional abundance of emission of the various energies. An example of this technique is illustrated in Table II and is described as follows:

- The emission energies and fractional abundance were taken from the Radiological Health Handbook.*

*U.S. Department of Health, Education and Welfare, January, 1970.

- The surface radiation factor is taken from Fig. 1 (or Fig. 2) and is the radiation level that would result from one microcurie per ml of material emitting gamma of this energy with 100 percent abundance.
- The product of the fractional abundance and the surface radiation factor defines the contribution of emission at the specified energy to the surface radiation.
- The summation provides a "Surface Radiation Coefficient" which can be used in subsequent calculations.

Table III and IV contain a listing of the "Surface Radiation Coefficients" for the radionuclides normally present in nuclear power plant wastes. These "Surface Radiation Coefficients" can be used directly to illustrate the limitations that will result from the new regulations on external radiation. Using an "R^2" relationship to estimate the radiation levels at three

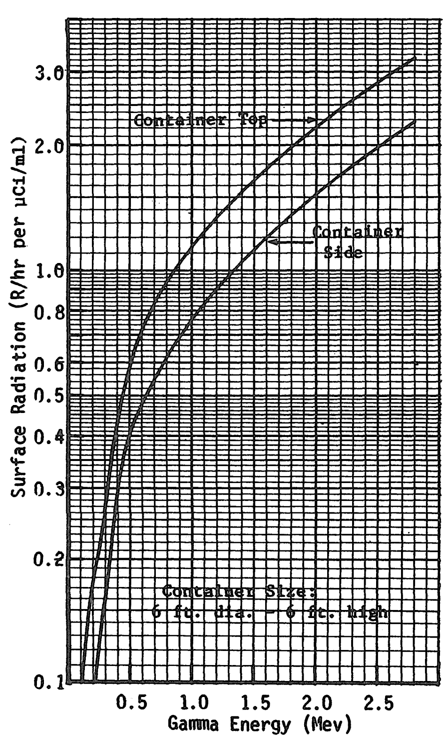

Fig. 1. Surface Radiation of Unshielded Containers as Function of Gamma Energy (Dewatered Resin)

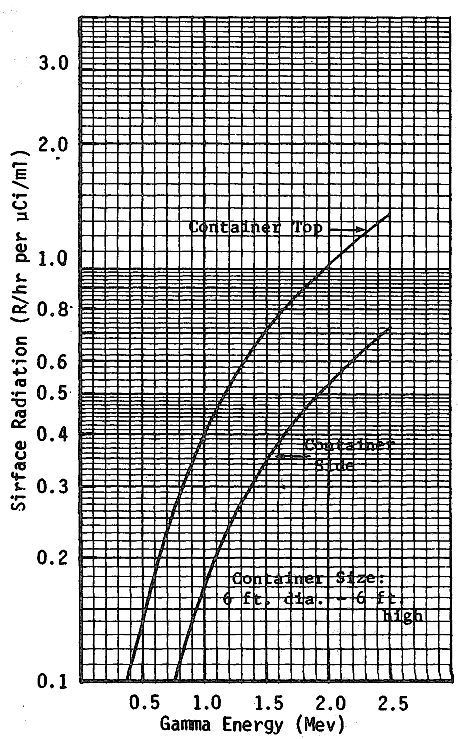

Fig. 2. Surface Radiation of Unshielded Containers as Function of Gamma Energy (Dewatered Resin)

Table II.
Estimating Surface Radiation Using
Specific Activity of Individual Iostopes

Cesium-134, Half Life 2.046 yrs.
Dewatered Resin - Container Top

Emission Energy (mev.)	Fractional Abundance % x 100	Surface Radiation Factor R/hr per μCi/ml	Radiation Factor x Abundance R/hr per μCi/ml
0.57	0.23	0.69	0.159
0.605	0.98	0.73	0.715
0.795	0.99	0.93	0.921
1.038	1.00	1.18	1.180
1.168	0.019	1.32	0.025
1.365	0.034	1.52	0.052
Surface Radiation Coefficient			3.052

Table III.
Surface Radiation Coefficients
Activation Products - Unshielded Liners

Surface Radiation Constants (R/hr per μCi/ml)

Isotope	Half Life	Dewatered Resin Side	Dewatered Resin Top	Solidified Waste Side	Solidified Waste Top
Na-24	15 h	3.240	4.620	1.156	2.184
Cr-51	27.8 d	0.014	0.023	0.001	0.005
Mn-54	303 d	0.630	0.960	0.118	0.303
Mn-56	2.58 h	1.276	1.897	0.344	0.734
Co-58	71.3 d	0.750	1.160	0.130	0.345
Fe-59	45.6 d	0.879	1.334	0.235	0.524
Co-60	5.26 y	1.870	2.800	0.519	1.136
Ni-65	2.56 h	0.420	0.627	0.122	0.260
Zn-65	245 d	0.421	0.645	0.105	0.243

Table IV.
Surface Radiation Coefficients
Fission Products - Unshielded Liners

Surface Radiation Constants (R/hr per μCi/ml)

Isotope	Half Life	Dewatered Resin Side	Dewatered Resin Top	Solidified Waste Side	Solidified Waste Top
SR-90	27.7 y	0.353	0.638	0.039	0.126
Y-91	58.8 d	0.027	0.041	0.007	0.016
Zr-95	65.5 d	0.554	0.853	0.092	0.246
Nb-95	35.0 d	0.590	0.900	0.101	0.264
Mo-99	66.7 h	0.094	0.144	0.017	0.042
Ru-103	39.5 d	0.362	0.572	0.043	0.133
$Ag110^m$	255 d	1.776	2.879	0.374	0.931
Sb-124	60.4 d	1.469	2.162	0.367	0.801
Sb-125	2.71 y	0.319	0.483	0.038	0.116
I-131	8.05 d	0.231	0.365	0.022	0.081
I-133	20.3 h	0.369	0.576	0.045	0.137
Cs-134	2.05 y	1.961	3.052	0.384	0.961
Cs-136	13.5 d	1.586	2.478	0.273	0.807
Cs-137	30.2 y	0.434	0.672	0.056	0.177
Ba-140	12.8 d	0.163	0.266	0.021	0.062
La-140	40.2 h	1.573	2.342	0.448	0.936

meters, the corresponding surface radiation levels would be:

Radiation Level @ 3 Meters	500 mR	1 R
Surface Radiation Level	8 R	16 R

The allowable specific activity for a single radionuclide to meet the specified radiation levels can be obtained by dividing the surface radiation level by the surface radiation coefficient. Table V lists the maximum specific activities for the radionuclides most commonly found in nuclear power plant wastes. The items to be noted from Table V are:

- For the longer life isotopes most commonly present in power plant waste (Coblat-60, Cesium-134 and Cesium-137) the allowable specific activity is quite low particularly for unsolidified LSA-2 material.

- A large number of shipments now made as "L.S.A. greater than Type A quantity" shipments will have to be made as Type B shipments in the future.

- The large difference in the allowable specific activity for solidified shipments compared to dewatered shipments results from two factors. These are the lower limit on external radiation (0.5 vs. 1 R per hour) and the self shielding provided by solidification.

- The differences in the allowable specific activity for the two categories of material are greatest for radioisotopes which emit a high fraction of soft gammas than those which emit high energy gammas.

- Cs-134 and Cs-137 have comparable fission yields and would normally be present in similar concentrations in new waste. Allowing the waste to decay and reduce the concentration of Cs-134 will be beneficial.

Table V.
Maximum Allowable Specific Activity
To Meet Limits on External Radiation

Isotope	Half Life	Specific Activity LSA-2 (μCi per ml)	Specific Activity LSA-3 (μCi per ml)
Mn-54	303 d	8.33	52.81
Co-58	71.3 d	6.90	46.38
Co-60	5.26 y	2.86	14.08
$Ag-110^m$	255 d	2.78	17.19
Sb-125	2.71 y	16.56	137.93
Cs-134	2.05 y	2.62	16.65
Cs-137	30.2 y	11.90	90.40

This table is based on radiation levels at the top of the container which is higher than the sides of the container.

EFFECTS ON WASTE TRANSPORTATION

The new classification of low specific activity material will cause a large number of the shipments currently being made from nuclear power plants to be classified as Type B shipments. These will require casks which are capable of meeting the hypothetical accident conditions including the thirty foot drop. The use of Type A casks certified by the Nuclear Regulatory Commission to handle greater than Type A quantities of LSA would be limited to handling containers with surface radiation levels of eight or sixteen Rems per hour, depending upon whether the waste is dewatered or solidified. Casks of this type characteristically have external shielding equivalant to 2.75 inches of lead. There are a large number of casks which have greater shield thickness but cannot meet the requirements for Type B packages. These casks will essentially become obsolete because their payload is limited due to the increased shielding which can no longer be used effectively. A method might be developed to provide impact protection for these casks to allow them to be used up to their full capability under the exception contained in the L.S.A.-3 classification.

There are a limited number of Type B casks in operation today. The number of available Type B casks probably will not be adequate to serve the nuclear power industry with the reclassification of L.S.A. There is a need to design and license additional Type B casks to meet this need. The capacity of Type B casks is generally lower than the Type A cask used to transport LSA materials. The weight of the impact protection and thicker shields require the payload to be decreased. On a per unit volume basis, Type B shipments are inherently more expensive.

BROADER IMPLICATIONS

The proposed definition of L.S.A. may also affect an aspect of the processing and packaging of radioactive waste. As indicated above, the specific activity of the waste can be increased by factors of five to eight by solidifying the waste using cement. Solidification could be used to increase the number of curies that can be transported and still meet the new L.S.A. regulations.

At some nuclear power plants, waste is not concentrated above the point where shielded shipments are required and the two to three containers are transported on a flat bed trailer. The reduced cost of shipping and handling offset the additional cost of containers and burial. With the introduction of the new regulations, a similar situation is likely to develop with respect to L.S.A. shipments. Volume reduction will be limited to taking the waste to the maximum concentration levels which will still allow L.S.A. shipments.

The proposed changes in the L.S.A. regulations will necessitate a new look at volume reduction systems in general. The waste from most volume reduction systems will have to be handled as Type B shipments. The rather sizable expenditures for the installation of volume reduction system will not be justified if there is inadequate Type B shipping capacity to support the operations.

In some cases, on-site storage to allow decay may be beneficial. Of the radioisotope commonly found in nuclear power plant wastes, Cesium 137 has the longest half life, 30.2 years. Cesium 137 emits a relatively low energy gamma (0.662 mev) with a fractional abundance of 0.85. The "Surface Radiation Coefficient" for Cesium 137 is only 0.672 for dewatered resin and 0.177 for solidified material. The radionuclides that will be controlling in terms of external surface radiation will be Cobalt-60 and Cesium 134. These isotopes have half lives of 5.26 years and 2.05 years respectively. With storage and decay, the radiation limits for L.S.A. shipments could be met.

The role of the high integrity container under the proposed L.S.A. regulations is questionable. These containers were developed specifically to allow resin and filter media to be shipped without solidification. Accordingly, the future use of these containers would be governed by the low radiation levels specified for L.S.A.-2 material. In addition, the amount of activity that can be shipped will be limited since there will be limited self shielding. A situation could develop where wastes are only concentrated to the limits for L.S.A. material and shipped in high integrity containers with limited volume reduction.

REGULATORY COMPLIANCE

When the new classifications of low specific activity materials go into effect, licensees will have to demonstrate that the shipments are in compliance with the regulations. The actual measurement of the radiation levels after packaging is generally not practical since it would involve removal of the package from a shield to make the radiation measurements. Further, if the package is not in compliance with the requirements for external radiation, it would be extremely difficult, if not impossible, to repackage the container. A technique will be required to permit the packaging to be preplanned in such a way as to assure compliance.

The "Surface Radiation Coefficients" previously discussed and listed in Tables II and III can also be used to establish the parameters for packaging which will assure compliance with the limits on external radiation. Figure 3 is an example of a calculation sheet which could be used for this purpose.

Low Specific Activity Material
External Surface Radiation

Calculation Sheet
Shipment No. #00146

Isotopes	Co-58	Co-60	Cs-134	Cs-137
Specific Activity Pre-Solidification	2.9	6.4 (μCi/ml)	6.5	32.8
Packaging Efficiency		75 %		
100 / Packaging Efficiency		1.333		
Specific Activity Post-Solidification	2.18	4.80 (μCi/ml)	4.86	24.6
Surface Radiation Coefficient (R/hr per μCi/ml)	0.345	1.136	0.961	0.177
Surface Radiation by Isotope	0.75	5.45 (R/hr)	4.68	4.35
Total Surface Radiation		15.23 (R/hr)		
External Radiation @ 3 meters		0.95 (R/hr)		

Fig. 3. Sample Calculaton Sheet

If the specific activity of the waste is too high to meet the external radiation requirements, there are a number of actions that can be taken. These include:

- o Solidify rather than dewater wastes.
- o Decrease the packaging efficiency to reduce concentration of waste.
- o Blend waste with wastes having lower specific activity.

- Place inert material on top of waste to reduce radiation at top of containers.

- Store waste and allow decay, if external radiation is due to short life isotopes.

IMPLEMENTATION

The Nuclear Regulatory Commission and the Department of Transportation expect to implement the revised regulations proposed in 1979 during 1983. They also plan to proceed with rule making to adopt the new definition of LSA in advance of the adoption by the International Atomic Energy Agency. Presumably, the new regulations could be in effect before the end of 1983.

The nuclear power industry and the service companies that provide radioactive waste disposal equipment and services must be in a position to respond to the changing requirements. Procedures, process controls and techniques for complying with these regulations must be developed. The effects on future shipments must be analyzed and new casks must be designed, licensed and fabricated to meet the future needs of the nuclear power industry.