A SIMPLIFIED ALARA APPROACH TO DEMONSTRATION OF COMPLIANCE WITH SURFACE CONTAMINATED OBJECT REGULATORY REQUIREMENTS

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SUMMARY

The U.S. Department of Transportation (DOT) and the U.S. Nuclear Regulatory Commission (NRC) have jointly prepared a comprehensive set of draft guidance for consignors and inspectors to use when applying the newly imposed regulatory requirements for low specific activity (LSA) material and surface contaminated objects (SCOs). The guidance is being developed to facilitate compliance with the new LSA material and SCO requirements, not to impose additional requirements. These new requirements represent, in some areas, significant departures from the manner in which packaging and transportation of these materials and objects were previously controlled. On occasion, it may be appropriate to use conservative approaches to demonstrate compliance with some of the requirements, ensuring that personnel are not exposed to radiation at unnecessary levels, so that exposures are kept as low as reasonably achievable (ALARA). In the draft guidance, one such approach would assist consignors preparing a shipment of a large number of SCOs in demonstrating compliance without unnecessarily exposing personnel. In applying this approach, users need to demonstrate that four conditions are met. These four conditions are used to categorize non-activated, contaminated objects as SCO-II. It is expected that, by applying this approach, it will be possible to categorize a large number of small contaminated objects as SCO-II without the need for detailed, quantitative measurements of fixed, accessible contamination, or of total (fixed and non-fixed) contamination on inaccessible surfaces. The method, which is based upon reasoned argument coupled with limited measurements and the application of a sum-of-fractions rule, is described and examples of its use are provided.

INTRODUCTION

During 1996 and 1997, the DOT and NRC, with the assistance of personnel from the Oak Ridge National Laboratory (ORNL) and its subcontractors, prepared a comprehensive set of draft guidance for consignors and inspectors to use when applying the newly imposed regulatory requirements for LSA material and SCOs. This draft guidance (DOT and NRC, 1997) was developed based upon the requirements for LSA materials and SCOs in the U.S. domestic regulations (49 CFR Part 173 and 10 CFR part 71), which are, in turn, based on

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the international transportation regulations issued by the International Atomic Energy Agency (IAEA), Safety Series No. 6, 1985 edition—as amended 1990 (IAEA, 1990a).

Since the regulatory requirements for LSA material and SCOs represent a significant departure in some areas from the manner in which the packaging and transportation of these materials and objects were controlled by the earlier editions of the regulations, the proper interpretation and application of these requirements can require a fairly complex set of decisions. In the case of mildly contaminated objects which themselves are not radioactive, strict application of the rules with detailed contamination level measurements could lead, potentially, to unnecessary exposure of personnel and a violation of the ALARA concept.

Recognizing this potential problem, the draft (DOT and NRC, 1997) includes a process for evaluating multiple, mildly contaminated objects in a fashion which uses a conservative approach to demonstrate compliance with categorization requirements while ensuring that personnel are not exposed to radiation unnecessarily (i.e., exposures are kept ALARA). This approach requires that four conditions be satisfied. The intent is that satisfying these conditions would be sufficient to demonstrate that a number of non-activated, contaminated objects meet the requirements of SCO-II, and could be shipped in a single packaging. The approach can provide relief from detailed characterization of the objects since it is expected that the application of these conditions will allow a large number of candidate SCO materials to be categorized as SCO-II even though more detailed assessments might show that the object could meet the requirements of an SCO-I. Thus, a tradeoff is made between making detailed measurements on the objects and packaging in more robust fashion than required by regulations. The advantage of this approach is that it can be accomplished without the need of a detailed, quantitative measurement of fixed contamination at accessible and inaccessible locations on the object.

PRACTICAL, CONSERVATIVE APPROACH TO CATEGORIZING A NUMBER OF OBJECTS AS SCO-II FOR SHIPMENT IN A SINGLE PACKAGE

The guidance document, which was prepared and issued within the United States for comment (DOT and NRC, 1997), provides guidance in the form of answers to questions. In the United States, the use of strong tight containers is still allowed for the domestic transport of LSA material or SCO, subject to (a) the shipment being under exclusive use, and (b) the amount of radioactive material not exceeding an A_2 quantity. With this approach, these two constraints establish a baseline conservative approach to the transport of these objects. For international applications, it appears that the same approach could be taken to provide a sound basis for categorizing objects as SCO-II, and then packaging them in Industrial, Type 2 packages (IP-2). Thus, for international purposes, the question which could be asked is:

> "What is a practical method for categorizing a large number of small, moderately contaminated objects as SCO for shipment under exclusive-use in an IP-2 package consistent with paragraph 426 of Safety Series No. 6 (IAEA, 1990a)?"

Phrasing the question this way retains consistency with alternate packaging require-ments allowed in the United States where an SCO-II is allowed to be shipped either in a strong tight package under exclusive use or in an IP-2 package independent of exclusive use [49

CFR Part 173.427(b)]. Shipment under exclusive use is used herein, to retain the conservative feature of the added controls provided by shipment under exclusive use.

A conservative approach to answering this question requires that the four conditions described below be satisfied in categorizing a radioactive material as an SCO-II. Utilizing this approach, it is expected that a large number of objects, which could be candidate SCOs could be categorized as SCO-II without having to undertake a detailed, quantitative assessment of the contamination levels on accessible and inaccessible surfaces of the object.

The four recommended conditions, which are to be satisfied under this approach, are:

- The total quantity of radioactive material in the package is determined to be less than 1 A_2, where the evaluation may be performed using a sum-of-fractions method specified in DOT regulations 49 CFR 173.433.
- The non-fixed (removable) contamination on the accessible surfaces is demonstrated to satisfy the SCO-II limits of 400 Bq/cm^2 beta, gamma, and low toxicity alpha emitters, and 40 Bq/cm^2 for other alpha-emitters, averaged over each 300 cm^2 (46.5 $in.^2$) area.
- The total activity on the object (fixed and non-fixed), divided by the mass of the object, meets the specific activity limit for LSA-II solids (i.e., $10^{-4} A_2/g$), and the activity is reasonably considered to be "distributed throughout" the object.
- The alpha-emitter contribution in the package totals less than 0.025 A_2 quantities.

If these four conditions can be satisfied, the draft guidance in the United States indicates that the object may be considered SCO-II and may be packaged appropriately for transport. Each of these conditions and the basis for them is discussed in more detail below.

<u>The First Condition</u>—The requirement to keep the total activity below 1 A_2 is imposed in this recommended procedure in order to keep the total activity in a given package below that allowed in Type A packages, which are not required to survive the regulatory "tests for demonstrating ability to withstand accident conditions in transport."

In addition, use of the sum-of-fractions rule as a means of defining the significant individual radionuclides is proposed to provide a mechanism for keeping personnel exposure ALARA while still ensuring that "the most restrictive nuclides" [see paragraphs 442 and 447(g) of Safety Series No. 6 (IAEA, 1990a)] are considered in the categorization of the object. This sum-of-fractions rule, which does not appear in international regulations, is currently applied in the U.S. regulations to define which radionuclides are to be listed on shipping papers. The application of the 95% sum-of-fractions rule in this condition extends that procedure (defined in the U.S. regulations) from defining not only the list of radionuclides to be listed on shipping papers to also providing (under certain limiting conditions) a basis for categorizing contamination on objects. Applying this rule will identify the most important and significant radionuclides on an object without having to specifically identify, for the purposes of categorization as an SCO, those radionuclides that are in such low concentrations that their contributions to exposure of the public would be negligible should they be inadvertently released. A more detailed discussion of this approach is provided in the next section of this paper.

The Second Condition—The requirement that the non-fixed (removable) contamination on the accessible surfaces satisfies the SCO-II limits is imposed in the recommended guidance to ensure that the accessible non-fixed contamination at least meets the SCO-II limit. The accessible non-fixed contamination is not restricted by the other conditions and has been assumed to be the most likely contamination on the object to cause personnel exposures. If wiping over 300 cm^2 areas is used, the number and location of areas wiped are expected to be consistent (a) with the consignor's standard survey procedures and (b) with the likelihood and type of contamination present on the accessible surfaces [e.g., see Sect. AII.3 of Safety Series No. 37 (IAEA, 1990b)]. Calculations, reasoned arguments, or measurements can be used for demonstration.

If this requirement is applied to a collection of similar objects that have been exposed to similar contaminating environments, it should not be necessary to physically smear each of the objects. In attempting to minimize personnel exposure, identification of the contamination level on a reasonable statistical sample of such objects should suffice for the entire group of objects similarly contaminated, and more extensive testing would not be needed. If the level of non-fixed contamination on accessible surfaces is greater than the SCO-II limit, but the combined fixed and non-fixed contamination on these surfaces is less than the SCO-II limit for fixed contamination (i.e., less than 8×10^5 Bq/cm^2 for beta, gamma, and low toxicity alpha emitters, and 8×10^4 Bq/cm^2 for other alpha emitters), consideration might then be given by the consignor to converting the non-fixed contamination to fixed contamination (e.g., through use of paint or wrapping).

The Third Condition—Condition 3 requires that the small objects meet the LSA-II specific activity and be distributed throughout requirements. The activity should be shown qualitatively to be distributed throughout the individual objects, such that the fixed and the inaccessible contamination does not exist on small portions of an object such that it might behave as a point source were that object to become separated from the package.

The Fourth Condition—The requirement that the alpha-emitter contribution be small is imposed in the recommended guidance because a material contaminated at the SCO-II alpha contamination limit (i.e., 80,000 Bq/cm^2) can reach the A_2 content limit for a Type A package with a relatively small surface area. This would be unacceptable for a reasoned-argument approach. Specifically, using the general A_2 value from Table 2 of Safety Series No. 6 (IAEA, 1990a) for low toxicity alpha emitters of 2×10^{-5} TBq, only 250 cm^2 of surface area contaminated at the SCO-II limit would be required to reach 1 A_2. Thus, in view of defining a conservative approach, this simplified approach should not be used if the object is likely to be contaminated with any significant amount of alpha emitters

In satisfying both conditions 3 and 4, where significant alpha contamination is present on an object, more detailed analyses of contamination levels will be necessary in order to categorize it as SCO. Otherwise, categorization as "RADIOACTIVE MATERIAL N.O.S.," with identification number "UN 2982," and shipment in a Type A or a Type B package may be required.

BASIS FOR THE SUM-OF-FRACTIONS RULE

The first condition specified in this approach indicates that the total quantity of radioactive material in the package shall be less than 1 A_2, where the evaluation may be performed using a sum-of-fractions method. In applying this method, it is emphasized that the regulations do not require measurement of contamination or radiation levels as the only means of demonstrating compliance; calculations, references to other determinations, or reasoned arguments can also be acceptable [e.g., see "Demonstration of Compliance,"[2] paragraphs 601 and 602 of Safety Series No. 6 (IAEA, 1990a)]. Although preshipment analyses are required to demonstrate compliance with the applicable SCO definition, the level of detail in these analyses is expected to be proportional to the potential hazard that the material represents. This concept was considered when developing the practical method described above for determination of contamination where the total activity is expected to be below the 1 A_2 value.

In applying this philosophy, it is recognized that the potential hazard is based on both (a) the activity and (b) the radiotoxicity (as indicated by the A_2 value, where a low A_2 value indicates a high radiotoxicity) of the radioactive material to be shipped, and that the approach taken must be consistent with requirements to maintain occupational exposures ALARA. Thus, it was felt that a method was needed for excluding from the categorization of objects those radionuclides whose radiotoxicity, combined with the activity present, indicate that they are radiologically insignificant (i.e., a method for excluding from consideration, low-hazard quantities). Since the identification of the "most restrictive nuclides" in the package is already required by the regulations [according to paragraphs 442 and 447(g) of the international regulations (IAEA, 1990a)] for entry on shipping papers and labels and since this requirement is independent of the categorization of contents, the determination of the nuclides representing at least 95% of the total A_2 fraction is thus not construed to cause additional doses and risks to personnel.

To assist consignors in defining which radionuclides can be excluded from being listed on shipping papers and labels, DOT has introduced into its regulations a "95% sum-of-fractions" rule [49 CFR 173.433]. Although this rule currently applies only to defining those radionuclides of significance which are to be listed on shipping papers and labels, it was felt that it may also be used to define—for the less hazardous situations—those nuclides which should be accounted for in determining compliance with contamination requirements. Since this rule accounts for both the quantity and radiotoxicity of a mixture of radionuclides, it was felt that it could also be applied to defining those radionuclides, on a given object, which truly pose a hazard during the packaging and transport of that object.

Based on this, if the total activity on the group of small objects is less than 1 A_2, the first step in characterizing the objects in the shipment could be the determination of the radionuclides constituting the A_2 fraction of Class 7 (radioactive) material in the package using the 95% sum-of-fractions method described by DOT in 49 CFR Part 173.433(f).

Specifically, the 95% sum-of-fractions rule states that

[2] Although this regulatory text applies to the tests in Sec. VI of Safety Series No. 6 (IAEA, 1990) and to the performance and acceptance standards in Sect. V of Safety Series No. 6, the philosophy put forward there can also apply to satisfying the definitional requirements for SCO in Sec. I of Safety Series No. 6.

$$\sum_{i=1}^{n} a_{(i)} / A_{(i)} \geq 0.95 \sum_{i=1}^{n+m} a_{(i)} / A_{(i)},$$

where

a_i = the activity of radionuclide i in the mixture;

A_i = the A_2 value, as appropriate, for radionuclide i;

m = the radionuclides that do not need to be considered in the determination;

n = the radionuclides of significance which must be considered in the determination; and

n + m = all the radionuclides present in the mixture.

This method is used to determine the significant contaminants because, when transported under exclusive use, the minimum packaging requirements for solid LSA material and for SCOs are identical [i.e., IP-2 packages (se Table V of Safety Series No. 6)]. Furthermore, there are no other requirements (e.g., emergency response requirements) in the regulations which would increase safety if an object were categorized as SCO as opposed to LSA material. Therefore, incurring additional dose during the categorization process in order to further demonstrate satisfaction of the conditions in the SCO definition would not provide any additional safety for such a shipment and would not be consistent with ALARA requirements.

EXAMPLE OF THE USE OF THE 95% SUM-OF-FRACTIONS RULE

An example of the use of the 95% sum-of-fractions rule to a mixture of radionuclides on a number of small objects, and how it might apply to SCO determinations is provided here using the data shown in Table 1.

Table 1. Example of application of the "95% sum-of-fractions" rule to a mixture of radionuclides

Nuclide	$a_{(i)}$, TBq	$A_{(i)}$, TBq	$a_{(i)}/A_{(i)}$	Sum $a_{(i)}/A_{(i)}$
^{14}C	8.4×10^{-4}	2.0×10^{0}	0.0004	0.0004
^{55}Fe	3.4×10^{-2}	$4.0 \times 10^{+1}$	0.0008	0.0012
^{60}Co	4.9×10^{0}	4.0×10^{-1}	12.2500	12.2512
^{59}Ni	1.0×10^{-2}	$4.0 \times 10^{+1}$	0.0002	12.2514
^{63}Ni	1.5×10^{0}	$3.0 \times 10^{+1}$	0.0500	12.3014
^{94}Nb	6.3×10^{-4}	6.0×10^{-1}	0.0105	12.3119
^{99}Tc	1.1×10^{-15}	9.0×10^{-1}	0.0000	12.3119

Here, the radionuclide mix represents an assay obtained from Inconel X-750 irradiated in a light-water reactor (LWR) (DOE, 1992). It is assumed that multiple objects have become contaminated by corrosion products from this activated Inconel X-750, and that a statistically-meaningful, but not exhaustive, sampling of the surfaces of the objects indicates that the mixture of radionuclides on the surfaces will be approximately as that shown in the first two columns of Table 1 (i.e., the consignor determines that there is a very low likelihood that other contaminants will be present on the objects). The 95% sum-of-fractions rule would be applied by considering that ^{60}Co represents (12.2500/12.3119) × 100 = 99.5% of the hazard of the radionuclides present by the rule, where the values determining this were taken from the data in the table. Thus, considering only the ^{60}Co nuclide in the assessment would be sufficient to allow the procedure of this paper to be applied since all the other nuclides shown in the table (^{14}C, ^{55}Fe, ^{59}Ni, ^{63}Ni, ^{94}Nb, and ^{99}Tc) are of sufficiently small consequence and can therefore be ignored in this evaluation.

EXAMPLE OF THE USE OF THE SIMPLIFIED APPROACH TO CATEGORIZING OBJECTS AS SCO-II

The following is a practical example taken from field operations data at a U.S. Department of Energy (DOE) facility in Oak Ridge, TN, USA. In this example, multiple flat, nonactivated metal plates are to be shipped. Each has a maximum accessible surface contamination level of 0.67 Bq/cm^2 and has no inaccessible surfaces. Study shows that the plates satisfy Conditions 3 and 4, and it also will be transported under exclusive use, thereby satisfying one of the bases for the question. Thus, to apply this method, it will be necessary to demonstrate compliance with Conditions 1 and 4.

The radionuclide mixture from statistically significant samples and the calculation for the 95% rule of fractions are shown in Table 2.

Table 2. Radionuclide mixture for flat contaminated flat plates

Nuclide	$a_{(i)}$, TBq	$A_{(i)}$, TBq	$a_{(i)}/A_{(i)}$	Sum $a_{(i)}/A_{(i)}$
Enriched Uranium, <5% Enriched	3.2×10^{-6}	Unlimited	0.00×10^{-0}	0.00×10^{-0}
^{232}Th	2.0×10^{-7}	Unlimited	0.00×10^{-0}	0.00×10^{-0}
^{234}Th	1.0×10^{-6}	2.0×10^{-1}	5.00×10^{-6}	5.00×10^{-6}
^{228}Ra	2.0×10^{-7}	4.0×10^{-2}	5.00×10^{-6}	1.00×10^{-5}
^{237}Np	2.0×10^{-7}	2.0×10^{-4}	1.00×10^{-3}	1.01×10^{-3}

It can be seen from the data in Table 2 that:

<u>The First Condition</u> is satisfied by the object, since it has less than 1 A_2, and the application of the 95% sum-of-fractions rule shows that for the plates, the only nuclide of concern is ^{237}Np, which represents (0.00100/0.00101) ×100 = 99% of the hazard of the radionuclides present by the rule; and

The Fourth Condition is satisfied by the object where, since all nuclides are either alpha-emitters or have daughter products that are alpha-emitters, the total activity is 4.8×10^{-6} Tbq (conservatively assumed to be all alpha-emitters); whereas, the maximum allowed alpha-emitter contribution is ($0.025 \times 2.0 \times 10^{-4}$ TBq) = 5.0×10^{-4} TBq. Thus, a simple and conservative assessment shows that the alpha emitter limit is not exceeded.

Thus, to ship these plates, the consignor need only assess the level of activity for ^{237}Np, and ensure the other conditions continue to be met for each plate to be shipped.

CONCLUSION

This approach in categorizing objects for shipment as SCO-II, if approved by the relevant competent authorities who have jurisdiction over the shipments of contaminated objects, could provide relief from detailed characterization of mildly contaminated objects by shippers in demonstrating compliance with regulatory requirements. This would relieve operating personnel from having to make unnecessary contamination measurements on the objects. Care must be taken to ensure that each object satisfies the four conditions presented in the approach and that it is shipped under exclusive use in an IP-2 package.

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REFERENCES

Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Objects—Draft Report for Comment, United States Department of Transportation and United States Nuclear Regulatory Commission, NUREG-1608 and RSPA Advisory Guidance 97-005 (1997).

Characteristics of Potential Repository Wastes, United States Department of Energy, DOE/RW-0184-R1, Vol. 1, pg 2.7-10 (1992).

Regulations for the Safe Transport of Radioactive Material—1985 Edition (As Amended 1990), International Atomic Energy Agency, Safety Series No. 6, Vienna, Austria (1990a).

Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1985 Edition)—Third Edition (As amended 1990), International Atomic Energy Agency, Safety Series No. 37, Vienna, Austria (1990b).

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CONCLUSION

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REFERENCES

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SESSION 12.4

Manufacturing