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Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Objects

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U.S. Department of Transportation

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ABSTRACT

The primary purpose of this guidance is to assist shippers in preparing low specific activity materials (LSA) and surface contaminated objects (SCOs) for shipment in compliance with Federal regulations. Guidance is provided in question and answer format on the classification, categorization, packaging and transportation of LSA and SCOs, including the definition of LSA and SCOs, the determination of distribution of activity in LSA material or on SCO surfaces, mixing LSA and SCOs in a package, radiation level measurements, and various other aspects of transporting LSA and SCOs.

There are many requirements, other than those addressed herein, imposed in the shipment of LSA and SCOs. The guidance represents one or more methods of demonstrating compliance with the regulatory requirements for LSA material and SCOs that have been found acceptable to NRC and DOT; however, additional methods may also be found to be acceptable with adequate justification.

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This guidance was jointly developed by the U.S. Department of Transportation and the U.S. Nuclear Regulatory Commission, with technical support from the Oak Ridge National Laboratory (ORNL).

In preparing the guidance, input was obtained from nuclear industry representatives, including NRC licensees, those shipping radioactive materials for the U.S. Department of Energy, and personnel involved in auditing or inspecting the packaging and transport of low specific activity materials and surface contaminated objects.

1 INTRODUCTION

Large volumetric quantities of low-level radioactive waste (LLW) have historically been shipped as low specific activity (LSA) material. In addition, radioactive ores, plant maintenance and outage equipment, and U.S. Department of Energy (DOE) wastes have typically been categorized as LSA. The regulations take into account the inherent properties of LSA materials and surface contaminated objects (SCOs), and allow for less-strict packaging requirements as compared to other radioactive materials, while retaining comparable levels of safety at lower costs.

Changes to NRC regulations in Title 10 of the *Code of Federal Regulations*, Part 71, "Packaging and Transportation of Radioactive Materials" (NRC, 1996a), and to DOT regulations in Title 49 of the *Code of Federal Regulations*, Part 172 - 178, "Shippers General Requirements for Shipments and Packaging" (DOT, 1996) have changed the regulatory framework under which LSA materials are shipped. These revised regulations, which became effective April 1, 1996, generally make domestic regulations for the safe transportation of radioactive materials compatible with requirements of the International Atomic Energy Agency's (IAEA) *Safety Series 6, Regulations for the Safe Transport of Radioactive Material, 1985 edition (as amended 1990)* (IAEA, 1990a).

Under the previous regulations, the old LSA material category included as a subcategory, requirements for SCOs. In contrast, under the revised rules, the scheme for shipping these materials has been refined such that SCOs are now defined as their own category. At first inspection, this differentiation between the two types of materials seems clear and definitive. However, the wording of the regulations, and practical considerations in characterizing, categorizing, handling, packaging, and transporting these materials, result in some uncertainty as to consistent, practical, and acceptable implementation of the revised requirements.

Under the revised regulations, it is expected that most equipment will be categorized for shipment as SCO-II, whereas most waste will be categorized as LSA-II. There will probably be many exceptions to this generalization, including a variety of materials and objects whose characteristics (both physical and radiological) are uncertain or difficult to characterize.

This guidance is intended to assist both shippers and regulators in applying the regulatory requirements for LSA material and SCOs properly. It should be recognized that no single document could address all issues related to the transport of these materials and objects.

This guidance, which is presented in the form of questions and answers, is provided in four sections addressing:

- issues related specifically to SCOs (Section 3);
- issues related specifically to LSA material (Section 4);
- issues relating to determination of the dose rate 3 m (9.9 ft) from the unshielded material, object or collection of objects (Section 5); and
- issues relating to the preparations for shipment and the packaging of LSA material and SCOs (Section 6).

In addition, an appendix (Appendix A) provides a logic flow process, based on the domestic regulations (DOT, 1996; NRC, 1996), which may be used to guide the characterization and

categorization of materials and objects as LSA material and SCOs. This appendix also contains a table which can be used to define packaging options available to shippers in the United States based upon the results of the characterization guided by the logic flow diagrams. The questions asked and answered in Sections 3 through 6 of this guidance are also identified in the diagrams presented in the appendix.

This Guidance was published in draft form for public comment. NRC and DOT appreciate the efforts on the part of all contributors, and have attempted to address the comments to the extent practicable. However, comments that, in the opinion of NRC and DOT staff, were unclear, inaccurate, contradictory to regulatory requirements, or non-compelling, were not adopted.

Nothing contained in this guide may be construed as having the force and effect of NRC or DOT regulations, or as relieving any shipper or licensee from compliance with the requirements of 10 CFR Part 71, 49 CFR Part 173, or any other applicable regulation.

The guidance describes one or more methods of demonstrating compliance with the regulatory requirements for LSA material and SCOs that NRC and DOT have found acceptable . However, use of these methods is not mandatory. Methods other than those described here may also be found to be acceptable based on reseasoned argument, or other adequate justification. Shippers are reminded that it is their responsibility to be able to demonstrate that their methods satisfy applicable regulatory requirements.

2 BACKGROUND

Although the new regulations for LSA material and SCOs are more prescriptive than were the previous regulations, DOT and NRC personnel have not observed a major economic or practical impact of the revised rules on the shipment of waste as LSA material or contaminated objects as SCOs. Specifically, experience shows that such activities have continued to take place in a safe manner under the new rules.

However, because of the more prescriptive nature of the new rules, many questions have been asked, and it was determined by DOT and NRC that guidance on the new LSA material and SCO requirements would benefit both the regulated and the regulators.

Areas of uncertainty in the revised regulations include:

(a) definitions, classification and categorization of materials and objects,
(b) determination of distribution of activity in LSA material or on SCO surfaces,
(c) determinations of the dose rate from the unshielded material or object, and
(d) preparation of materials and objects and selection of proper packaging for transport.

Many of these are related to changes made in the regulations, where, in addition to providing a category for SCOs separate from LSA materials:

(1) LSA materials are further divided into three subcategories (LSA-I, LSA-II, and LSA-III), and SCOs are further divided into two subcategories (SCO-I and SCO-II);

(2) the LSA material subcategory definitions make distinctions between the terms *essentially uniformly distributed* and *distributed throughout* depending upon the subcategory of LSA material;

(3) specific activity limits for LSA material have been tied to each nuclide's A_2 value, and have increased substantially for most nuclides [the A_2 quantity is the amount of normal form radioactive material which can be transported in a non-accident resistant, Type A package — see, for example 49 CFR 173.433 (DOT, 1996)];

(4) for SCOs, the radioactive material contamination is distributed on the surfaces of objects that are not themselves radioactive, and the definitions distinguish between fixed and non-fixed (i.e., removable) contamination on accessible surfaces but combines them for inaccessible surfaces;

(5) NRC certification of the package design for shipment of some LSA materials and SCOs is no longer required unless the dose rate from the unshielded material exceeds 10 mSv/h (1 rem/h) at 3 m (9.9 ft); and

(6) a new set of packages, industrial packages (IPs), has been authorized for use with LSA material and SCOs.

3 SURFACE CONTAMINATED OBJECTS

The previous regulations contained provisions for shipment of SCOs as a subset of LSA material. SCOs were included in the LSA material definition in the previous versions of both 10 CFR 71.4 and 49 CFR 173.403, and they were transported using the proper shipping name "Radioactive material, LSA." However, the previous regulations specified only limits for total (fixed plus non-fixed) contamination, did not specify accessible nor inaccessible surfaces, and allowed for averaging the contamination over a large area [i.e., 1 m^2 (10.8 ft^2)].

SCOs are no longer defined as a subset of LSA material (DOT, 1996; NRC, 1996a). SCOs have their own proper shipping name, "Radioactive material, surface contaminated object," or "Radioactive material, SCO;" and they have their own United Nations identification number, "UN2913," as specified in the hazardous material table [49 CFR 172.101(DOT, 1996)].

The SCO definitions [49 CFR 173.403 (DOT, 1996) and 10 CFR 71.4 (NRC, 1996a)] now specify separate limits for fixed and non-fixed (removable) contamination on accessible surfaces, and a limit for fixed plus non-fixed contamination on inaccessible surfaces. Compliance with each of these limits is necessary for categorization of an item as an SCO. However, compliance does not necessarily imply the need for explicit measurements of the contamination levels, as further discussed herein. In general, objects that satisfy the SCO definition will not satisfy the LSA definition, and should not be shipped as such. However, there are some circumstances where it is appropriate to ship collections of small objects as LSA material (see Section 4.1.4), or to ship SCOs mixed with LSA material as LSA material (see Section 6.1).

Section 3.1 provides guidance on materials which can be categorized as SCOs. Section 3.2 clarifies some of the technical terms used in the SCO definitions. Section 3.3 provides specific guidance for complying with the SCO definitions, based on the quantity of radioactivity in a package. Section 3.4 provides guidance for determining contamination levels on surfaces.

3.1 Categorizing a Class 7 (Radioactive) Material as an SCO

Categorizing an object contaminated with Class 7 (radioactive) material as an SCO is an option for transport as compared with categorizing the material as "Radioactive material, n.o.s.," with an identification number of "UN 2982." SCO means a solid object which itself is not radioactive, but which has Class 7 (radioactive) material distributed on its surfaces. Categorization as SCO provides some relief from the packaging requirements and communications requirements when compared with the alternative categorization of "Radioactive material, n.o.s."

Objects that are themselves radioactive (e.g., activated objects) and that are also contaminated cannot generally be categorized as SCO. The exception to this is discussed below. Objects that are radioactive and contaminated may be categorized as LSA material insofar as the requirements specified in the LSA definition are complied with (see Section 4.1.2).

3.1.1 If a contaminated object is also activated, can it be categorized as an SCO?

If a contaminated object is also activated to an average specific activity level less than 70 Bq/g (2 nCi/g)—see 49 CFR 173.403 (DOT, 1996)—the object itself is not classified as radioactive material according to 49 CFR 173.403 (DOT, 1996); however, the presence of the contamination on the object may require that it be classified as a Class 7 (radioactive) material. For such an object, if the SCO definition is satisfied, the object should then be classified as Class 7, and shipped as an SCO.

However, if a contaminated object is also activated to an average specific activity level in excess of 70 Bq/g (2 nCi/g), the object itself is classified as radioactive material according to 10 CFR 71.4 and 49 CFR 173.403 (DOT, 1996; NRC, 1996a). In this event, it may not be categorized as an SCO since SCOs are, by definition [49 CFR 173.403 and 10 CFR 71.4 (DOT, 1996; NRC, 1996a)], non-radioactive objects having radioactive-contaminated surfaces.

3.1.2 Is there a contamination level below which an object does not need to be categorized as an SCO or as radioactive material, n.o.s.?

International regulations (IAEA, 1990a) contain a threshold value for contamination, below which a nonradioactive object [i.e., an object having an average specific activity level less than 70 Bq/g (2 nCi/g)] can be shipped without regard to the radioactivity [See clarification of contamination in Section 3.2.1]. The contamination threshold value was inadvertently omitted from the 1996 DOT domestic regulatory revisions (DOT, 1989; DOT, 1996). Consequently, all objects which are themselves not radioactive, but are slightly contaminated, could still be construed to qualify as SCO-I. DOT is currently addressing this issue.

In the interim: an object with external contamination may be considered to be excepted from classification as Class 7 (radioactive) material if: (1) contamination when averaged over each 300 cm^2 (46.5 in^2) of all surfaces is less than 0.4 Bq/cm^2 (10^{-5} $\mu Ci/cm^2$) for beta and gamma emitters and low toxicity alpha emitters, and is also less than 0.04 Bq/cm^2 (10^{-6} $\mu Ci/cm^2$) for all other alpha emitters; and (2) the object itself has an average specific activity less than 70 Bq/g (2 nCi/g).

3.1.3 How should a contaminated object with a limited quantity of radioactive material be categorized?

Any radioactive material that meets the requirements in 49 CFR 173.421, for excepted packages of limited quantities of Class 7 (radioactive) materials, can be shipped as "Radioactive Material, excepted package, limited quantity of material, UN2910." Note, however, that the activity per package in a normal form shipment (such as a contaminated object) would be limited to 10^{-3} A_2 as given by Table 7 of 49 CFR 173.425. In such cases, there is no need to evaluate for compliance with the SCO contamination limits.

3.1.4 Must all radionuclides be individually accounted for, and is there an applicable sum or fractions rule which should be applied in assessing compliance with the SCO contamination limits?

The SCO limits for contamination apply to any 300 cm^2 (46.5 in^2) . There is no requirement to do a sum of fractions (or "unity") rule.

An object could be categorized as SCO, even if the surfaces were contaminated to both the limit for beta and gamma emitters and low toxicity alpha emitters, and to the limit for all other alpha emitters. Further, it could simultaneously have the contamination at the non-fixed (removable) limit on accessible surfaces, the fixed limit on accessible surfaces, as well as the limit on inaccessible surfaces.

Since the SCO limits are stated in terms of activity (i.e., a beta-gamma limit and an alpha limit), there is no explicit nuclide dependence, and there is no need to sum or identify nuclide fractions for complying with the SCO definition. However, for shipping papers and labels (if not excepted from labeling), the nuclides must be identified and listed in accordance with the "95% sum of fractions" rule in 49 CFR §§ 173.433 and 173.435.

3.1.5 Are there any constraints on mixing SCOs with nonhazardous materials in a package?

Generally, waste management considerations may affect this practice. Three examples of packages containing SCOs mixed with nonhazardous materials include: SCOs mixed with non-radioactive materials (e.g., binding agents such as grout, or paint), as a means to transform non-fixed (removable) contamination into fixed contamination; as a means to make an accessible surface into an inaccessible surface; and as a means of adding structural capability to the object to facilitate transport.

3.1.6 Can an object which might qualify as an SCO-I be categorized and shipped as an SCO-II?

Generally, the most appropriate category should be used to assure that response to any incidents is suitable for the materials present. However, for domestic transport, an SCO-II has equivalent packaging requirements to an SCO-I [49 CFR 173.427(b)(2), (b)(3) and (b)(4) (DOT, 1996)]. Further, since SCO-I poses less of a contamination hazard than does SCO-II, categorization of an object as SCO-II rather than as SCO-I is a conservative approach. It is permissible to categorize radioactive material to higher categorization levels and package and ship them accordingly. Thus, it is permissible to categorize and ship an object which meets the SCO-I definition as an SCO-II. Using a higher category for LSA materials may not be as straightforward, however, since the activity distribution and other conditions of the higher category must be satisfied.

3.2 Clarification of Terms Used in the SCO Definitions

Surface Contaminated Objects

The definition of SCO-I and SCO-II in 10 CFR 71.4 and 49 CFR 173.403 (DOT, 1996; NRC, 1996a) contains several technical terms that are not explicitly defined, namely: *contamination*, both *fixed* and *non-fixed*, *accessible surface*, and *inaccessible surface*. This section provides additional clarification of the intent and meaning of these terms as used in the regulatory definitions. The terms apply to SCO's as prepared for transport.

3.2.1 What is *contamination*?

For the purpose of complying with the SCO definitions in the domestic transportation regulations only (DOT, 1996; NRC, 1996a):

> *Contamination is the presence of a radioactive substance on a surface in quantities in excess of 0.4 Bq/cm^2 (10^{-5} μCi/cm^2, 22 dpm/cm^2) for beta and gamma emitters and low toxicity alpha emitters or 0.04 Bq/cm^2 (10^{-6} μCi/cm^2, 2.2 dpm/cm^2) for all other alpha emitters.*

This is consistent with the definition for contamination provided in the international regulations (IAEA, 1990a), although a similar definition is not currently included in the U.S. domestic regulations. DOT is currently considering addition of the contamination definition to 49 CFR Part 173.

This internationally-recognized lower limit for contamination serves a function in transport regulations comparable to the limit of 70 Bq/g (2 nCi/g) in the definition of radioactive material [49 CFR 173.403 (DOT, 1996)]; i.e., materials having specific activities less than this limit are below the scope of the hazardous material regulations. A definition of contamination is needed in order to properly utilize the SCO category because the radioactive material definition of 70 Bq/g (2 nCi/g), which is based on an activity per unit mass, is not readily or directly applicable to SCOs. For nonactivated objects, dividing the activity in the contamination by the mass of the nonactivated object (to determine whether the object as a whole should or should not be defined as radioactive material) is generally not appropriate because it opens the possibility for a massive object with significant amounts of contamination on its surfaces falling below the regulatory threshold definition of radioactive material [i.e., specific activity would be less than 70 Bq/g (2 nCi/g)]. This situation is not consistent with the intent of the regulatory exemption limit and should be avoided.

3.2.2 What is *fixed contamination* and *non-fixed (removable) contamination*?

For the purposes of complying with SCO definitions:

> *Fixed contamination is contamination that cannot be removed by the wiping procedure defined in 49 CFR 173.443, to a detection level of 0.4 Bq/cm^2 (10^{-5} μCi/cm^2) for beta and gamma emitters and low toxicity alpha emitters, or 0.04 Bq/cm^2 (10^{-6} μCi/cm^2) for all other alpha emitters. Any other contamination is non-fixed contamination.*

Although used in the definition of SCOs, there are no specific regulatory definitions of *fixed contamination* or *non-fixed contamination*. Therefore, other regulatory requirements [e.g., 49 CFR 173.443 (DOT, 1996)] have been considered in striving to develop consistent definitions. Specifically, 49 CFR 173.443(a)(1) describes a method for wiping a surface and determining the level of non-fixed (removable) contamination available from that surface. The text of 49 CFR 173.443(a)(1) reads, in part, that the process for determining the level of non-fixed (removable) contamination consists of "wiping an area of 300 square centimeters of the surface concerned with an absorbent material, using moderate pressure, and measuring the activity on the wiping material. Sufficient measurements must be taken in the most appropriate locations to yield a representative assessment of the non-fixed contamination levels."

3.2.3 What are *accessible surfaces* and *inaccessible surfaces* for SCOs?

For the purposes of complying with SCO definitions:

> *An accessible surface is any surface which can readily be wiped by hand, using standard radiation-measuring techniques. Any other surface is an inaccessible surface.*

The *accessible surface* could be contacted if the packaging is removed by an accident. Thus, re-orientation of the SCO should be considered in identifying the accessible surface. However, a shipper does not need to consider damage to the object itself in an accident. For example, the bottom, or top, of an object would be accessible, but surfaces which must be reached by probing small openings would be inaccessible. A good rule of thumb is that, if a 300 cm^2 (46.5 in^2) area could be reached by a person's hand, it is an *accessible surface*. The phrasing, "by hand" is not meant to discourage use of as low as is reasonably achievable (ALARA) tools such as telescopic sampling instruments. The phrasing, "standard radiation-measuring techniques," is intended to imply practices similar to those used for complying with package contamination limits in 49 CFR 173.443.

Note that this guidance would permit some objects, such as a tank, or a long 6 in. diameter pipe, to have some inaccessible surfaces that are readily measured/swiped. It is generally good practice to seal off the ends of pipes or tanks, such that a shock to the object could not result in contamination being easily released through the openings.

3.3 Quantity-Based Method for Compliance With the SCO Definitions

Although pre-shipment determinations are required to demonstrate compliance with the applicable SCO definition, the regulations do not require measurements of contamination and/or radiation levels as the only means of accomplishing the determinations. Alternate methods or combinations of methods may be used to demonstrate compliance. These methods may include—in addition to measurements—calculations, reasoned arguments, and reference to previous shipments of similar materials or objects (see section 3.4.1). This section describes a reasoned argument approach to categorizing SCOs.

The level of detail in these determinations is expected to be commensurate with the potential hazard that the contamination represents. The potential hazard is based on the quantity (i.e., activity) and radiotoxicity of the Class 7 (radioactive) material to be shipped, and the

combination of these two factors is associated with the relevant multiple or fraction of A_2 of the contaminants involved. Therefore, the first step in any shipment should be to determine the A_2 fraction in the package in accordance with 49 CFR 173.433.

For an SCO, the A_2 fraction would typically be determined by analyzing representative swipes of the accessible surface, gross gamma counts, the total surface area, and assuming the fixed and inaccessible contamination had a similar radionuclide distribution from a previously determined facility-specific sample data base. The techniques for determining radionuclide content used in the previous regulations remain acceptable under the revised regulations (note, however, that the number of nuclides in the Table of A_1/A_2 values has increased, and the values have changed).

It is possible to make SCO determinations in a manner consistent with 10 CFR Part 20 requirements to maintain occupational exposures as low as is reasonably achievable (ALARA). In practice, NRC and DOT anticipate that almost all SCO packages will contain less than 1 A_2 quantity, and therefore qualify for shipment in strong-tight containers (STCs) pursuant to 49 CFR 173.427(b)(3). A reasoned argument could be used to categorize the great majority of these candidate SCOs, without the need for detailed, quantitative measurement of fixed, accessible contamination or total (fixed plus non-fixed) inaccessible surface contamination. Both the beta-gamma A_2 fraction and the alpha A_2 fraction must be determined. The materials characterized using this reasoned argument would be shipped as "Radioactive - SCO."

3.3.1 What is a practical method for categorizing object(s) as SCO for shipment under exclusive-use in a strong tight container [using 49 CFR 173.427(b)(3)]?

Demonstration of all of the following 4 conditions can be used to categorize a radioactive material as an SCO-II. It is expected that these conditions would allow categorization of a great majority of candidate SCO materials as SCO-II, without the need for detailed, quantitative measurement of fixed, accessible contamination or total inaccessible surface contamination.

(1) The shipment of the SCO-II is made pursuant to 49 CFR 173.427(b)(3), for domestic, exclusive-use transport of SCOs in strong-tight containers (STCs). Note that this requires that the radioactive material in the package totals to less than 1 A_2 quantity as determined using the sum of fractions method in 49 CFR 173.433.

(2) The non-fixed (removable) contamination on the accessible surfaces satisfies the SCO-II limits of 400 Bq/cm^2 beta/gamma and 40 Bq/cm^2 alpha averaged over each 300 cm^2 (46.5 in^2) area.

(3) The total activity on the object(s) (fixed and non-fixed), divided by the mass of the object(s), 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(s).

(4) The alpha-emitter contribution in the package totals to less than 0.025 A_2 quantities.

The method described here allows categorization of a material as SCO through reasoned arguments, without detailed measurements of inaccessible and fixed-accessible contamination.

Condition (2) assures that the accessible non-fixed contamination meets the SCO-II limit. The accessible loose 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 swiping is used, the number and location of contamination swipes is expected to be consistent with the licensee's standard survey procedures, and the likelihood and type of contamination. Calculations, reasoned arguments, or measurements can be used for demonstration. For collections of similar objects, if the most radioactively contaminated object(s) meet the limit, the others could be presumed to meet the limit. An alternative method of demonstration that the non-fixed contamination is within the limit, is to render all contamination on the object's accessible surfaces "fixed" (for example, through use of paint or sealants). Under this method, if the other conditions are satisfied, determination of fixed contamination on accessible surfaces, or non-fixed or fixed contamination on inaccessible surfaces, is not required.

Condition (3) requires the LSA-II specific activity and distributed throughout requirements to be considered. The activity should qualitatively be determined to be distributed throughout the object(s).

Since this method does not require quantitative determination of all contamination sources, the possibility arises that the fixed and inaccessible contamination might exist on small portions of an object, which could behave as a point source if separated from the package after an accident. This condition provides assurance that the contamination is not highly localized, maintains a level of determination that is commensurate with the hazard posed by the contents, and provides relief from the determination of fixed contamination on accessible surfaces, and fixed and non-fixed contamination on inaccessible surfaces. [Note that under the previous regulations, SCO's were treated as a subset of LSA.]

Condition (4) is necessary because a material contaminated at the SCO-II alpha contamination limit (80,000 Bq/cm^2) can reach the 1 A_2 maximum STC contents in a relatively small surface area. Specifically, using the generic A_2 value from Table 10 in 49 CFR 173.433 of $2x10^{-5}$ TBq ($2x10^7$ Bq), only $2.5x10^2$ cm^2 (0.14 ft^2) of surface area contaminated at the limit would reach 1 A_2. If an SCO contaminated at this level were to be released from a package after an accident, the subsequent scraping of a small surface area could render a large portion of the activity available for inhalation. Where significant alpha contamination is present, more detailed analyses of contamination levels would be necessary for categorization as SCO. Alternatively, categorization as "Radioactive material, nos, UN 2982," and shipment in a Type A package could be used for such objects.

3.3.2 What methods should be used for categorizing an object containing greater than 1 A_2 as SCO?

For packages containing SCOs with greater than 1 A_2 quantity of radionuclides, a more rigorous, quantitative approach is expected than for packages with less than 1 A_2 quantity. Accident-resistant (i.e., Type B) packaging would be required for transport of radioactive material exceeding 1 A_2 in normal form and not categorized as either LSA Material or SCO. However, for SCOs having these larger quantities of radioactivity, the use of the non-accident resistant package is authorized, provided the radiation level at 3 m from the unshielded contents does not exceed 1 rem/hr. Strict compliance with the definition of SCO is important and must be

demonstrated, since it is the special properties of the SCO (e.g., diffuse activity, with much of the activity on inaccessible surfaces or as fixed contamination on inaccessible surfaces) that justifies the use of the non-accident resistant package.

3.4 Determining Contamination Levels on Surfaces

This section focuses on methods which may be used to determine contamination levels on the surfaces of objects which are being assessed for compliance with SCO requirements. It also further elaborates upon the issue of contamination limits as compared with wipe limits. Specifically, as noted in section 3.2.1, the non-fixed contamination limits in 49 CFR 173.403 and 10 CFR 71.4 (DOT, 1996; NRC, 1996a) for defining SCOs are specified in terms of "contamination limits," whereas the non-fixed limits for package contamination in 49 CFR 173.443(a)(1) are specified in terms of "wipe limits."

3.4.1 What methods are acceptable for determining fixed and non-fixed contamination on accessible and inaccessible surfaces of SCOs?

The regulations do not specify a particular method of determination of contamination levels. A number of methods may be used, including:

(1) wiping and analyzing for activity (non-fixed contamination),
(2) surface sampling and sample analysis (determining fixed plus non-fixed contamination),
(3) radiation level measurements (determining fixed plus non-fixed contamination),
(4) process knowledge,
(5) analyses,
(6) reference to previously satisfactory determinations of a sufficiently similar nature demonstrating compliance, or
(7) combinations of the above techniques.

Generally, characterization of an SCO necessitates, at a minimum, representative wiping of the accessible surfaces and some measurements of radiation levels. The other methods can then be used in concert with these determinations to categorize the object's fixed contamination on accessible surfaces, and its fixed plus non-fixed contamination on inaccessible surfaces. Section 3.3.1 presents a reasoned argument method which can be used for many SCOs (i.e., SCO packages containing less than 1 A_2 quantity). It is recommended that licensee wiping and measurement procedures used for SCO characterization be generally consistent with licensee wiping and measurement procedures used in determining compliance with 10 CFR Part 20.

3.4.2 When taking measurements, how can one distinguish fixed accessible contamination from total inaccessible contamination?

If the package contains less than 1 A_2 quantity and the quantity of alpha-emitters is less than 0.025 A_2, then the method described in section 3.3.1 eliminates the need to distinguish between the fixed accessible and fixed plus non-fixed inaccessible contamination.

However, if the package contains greater than 1 A_2 quantity of total radioactivity, or greater than 0.025 A_2 quantity of alpha-emitting radioactivity, then more demanding approaches are needed to define the types and levels of contamination, and the factors listed above must be addressed in defining the approach to be taken. One example is provided here to illustrate the approach a shipper might take.

Non-fixed (removable) contamination on accessible surfaces is readily determined by wiping a surface as discussed in sections 3.2.1 and 3.2.2, and in 49 CFR 173.443 (DOT, 1996). The fixed accessible contamination and total (i.e., fixed plus non-fixed) inaccessible contamination then need to be assessed using radiation level measurements combined with knowledge of the radionuclides constituting the contamination, the object's structure, and analyses.

Unless process knowledge indicates the contrary, it will generally be acceptable to assume that the nuclide distribution of the fixed, accessible contamination and the fixed plus non-fixed, inaccessible contamination is the same as that for the removable contamination. If there is reason to doubt this assumption (e.g., the inside of a pipe was exposed to a different contaminating environment than was the outside), then more detailed assessments would be expected for categorization of the object as an SCO.

Many factors need to be considered in distinguishing non-fixed, accessible contamination and fixed, accessible contamination from total (fixed and non-fixed), inaccessible contamination. These factors include: (a) the total quantity of radioactive material (activity) in and on the object, (b) the radionuclide mix of contamination on the different surfaces, (c) the relative uniformity of distribution of the contamination on the surfaces, (d) the physical makeup of the object and the role the object's structure plays in mitigating radiation emanating from contamination on inaccessible surfaces, and (e) how close the contamination levels are to the SCO limits.

3.4.3 How can fixed alpha contamination be measured?

For process wastes and dry active wastes, computer programs that determine alpha activity based on scaling to measured gamma and beta emitters would normally be acceptable. The methods for scaling factor determination used for 10 CFR Part 20 (NRC, 1996b) and 10 CFR Part 61 (NRC, 1996c) considerations are also acceptable for 10 CFR Part 71 and 49 CFR Part 173 (NRC, 1996a; DOT, 1996) determinations. Also, surfaces can be frisked directly with a portable zinc sulfide or gas-flow detector. For candidate SCO objects with significant quantities of alpha emitters, or contaminated objects which are expected to not have alpha contributions that are consistent with established scaling factors, categorization as an SCO would require a detailed investigation. NRC and DOT suggest that these objects not be categorized as SCO, but as "Radioactive material, n.o.s.," with identification number "UN 2982."

3.4.4 How can contamination level measurements be averaged?

The regulations [49 CFR 173.403 and 10 CFR 71.4 (DOT, 1996; NRC, 1996a)] specify that, for SCOs, the contamination "....on the ...surface averaged over 300 cm^2 (or the area of the surface if

less than 300 cm^2) does not exceed" [the applicable limit]. In satisfying this requirement, the methodology specified for determining non-fixed contamination on packages should be applied {49 CFR 173.443(a)(1) [DOT, 1996], see also sections 3.2.1 and 3.2.2}.

Contamination surveys involve wiping an area, using moderate pressure, of approximately 100 cm^2 (15.5 in^2). The amount of radioactivity measured on any single wiping material, when averaged over the surface wiped, cannot exceed the regulatory values. An acceptable practice is to average multiple wipe samples within any given 300 cm^2 (46.5 in^2). See NRC Information Notice No. 85-46. However, the same 100 cm^2 (15.5 in^2) should not be repeatedly wiped, unless done to establish a wiping efficiency.

Sufficient measurements must be taken in the appropriate locations to determine that the maximum likely contamination levels do not exceed the limits. Thus, the number of 300 cm^2 areas tested should be sufficient to provide a representative assessment of contamination, and their locations should be biased towards locating the higher contamination areas. It is important to remember that the level of contamination does not need to be precisely determined in most cases, but only that sufficient information is known such that a reasonable determination can be made that the contamination does not exceed the applicable SCO limit, and that the nuclides can be adequately identified for shipping papers (see section 3.3.1).

For small objects, a single 300 cm^2 (46.5 in^2) sample area should normally suffice. If the surface area of the object is less than 300 cm^2 (46.5 in^2) the activity levels could be averaged over the actual surface area wiped.

3.4.5 How is wiping efficiency used in the determination of contamination on package external surfaces versus SCOs?

Non-fixed contamination on package external surfaces is regulated by DOT in section 49 CFR 173.443 Contamination control. The contamination level may not exceed the non-fixed external radioactive contamination-wipe limits specified in Table 11, and must be determined by wiping or other methods of assessment of equal or greater efficiency. The amount of radioactive material on the wipe, when averaged over the surface area wiped, is limited to the values specified in Table 11 (e.g., 0.4 Bq/cm^2). DOT further specifies that the actual package surface contamination may not exceed ten times the Table 11 wipe material contamination limits.

In other words, the wipe limits in Table 11 are 10 percent of the maximum permitted surface contamination. The Table 11 values are based on the assumption that, unless otherwise specified and documented by the shipper, the efficiency of surface wiping, (i.e., the fraction of the surface contamination captured by the wipe) is 10 percent. For example, if a wipe measurement reaches the Table 11 contamination-wipe limit of 0.4 Bq/cm^2, the actual surface contamination is 4.0 Bq/cm^2, because the wipe is only capturing 10 percent of the contamination. The Table simplifies contamination determinations for many shippers, because it enables determination whether the shipment meets the contamination requirement without the need to determine their wiping efficiency. This is accomplished by dividing the radioactivity on a wipe by the area wiped and comparing the result to the Table 11 values.

DOT does provide, however, for the use of wiping efficiencies that are greater than 10 percent, provided those efficiencies are documented and accounted for in contamination determinations. For example, through improved techniques, a shipper may be able to increase wiping efficiency to 50 percent, i.e., the wipe captures half the non-fixed contamination on the area wiped. In this case, the contamination-wipe limit is increased from 0.4 Bq/cm^2 to 2.0 Bq/cm^2, to account for the five-fold increase in wiping efficiency. Note, however, that the surface contamination limit remains constant at 4.0 Bq/cm^2, regardless of the wiping efficiency and the derived contamination wipe-limit.

The SCO contamination limits do not incorporate a wiping efficiency. The wiping efficiency used by the shipper must be accounted for in all SCO contamination determinations. Failure to do so could result in underestimating the actual SCO contamination levels. Shippers are responsible for ascertaining the wiping efficiency used in determining contamination levels on SCOs. Shippers using the (assumed) 10 percent wiping efficiency for package external surface contamination determinations could use that method for SCOs, provided the contamination and surfaces are similar, and their SCO wipe measurements were compared to 10 percent of the SCO contamination limits. Similarly, shippers using wiping efficiencies that are greater than 10 percent for package external surfaces would need to account for that wiping efficiency in comparing wipe measurements to the SCO contamination limits.

4 LOW SPECIFIC ACTIVITY MATERIAL

The previous regulations contained provisions for shipment of LSA material. While the specific activity limit allowed in LSA material was significantly lower for essentially all radionuclides, there was no upper limit to the amount of LSA material that could be shipped in a non-accident resistant package. The LSA limits in the previous rules were basically: 0.1 μCi/g for nuclides with an $A_2 \leq 0.05$ Ci (most alpha emitters); 5 μCi/g if $0.05 < A_2 \leq 1$ Ci (i.e., mixed fission products, Sr-90, Cm-242, Pb-210, Po-210, Pu-241, Ra 223, Ra-224, and uranium isotopes); or 0.3 mCi/g for nuclides with an A_2 greater than 1 Ci (most gamma emitters).

The new limits are tied, on a nuclide-specific basis, to the A_2 values. In addition, the permissible concentration for almost all nuclides has more than doubled under the widely-applicable LSA-II solids limit of 10^{-4} A_2/g. For example, the previous limit for Co-60 was 0.3 mCi/g, whereas the LSA-II limit is now 1.08 mCi/g. Similarly, the previous limit for Sr-90 was 5 μCi/g, whereas the LSA-II limit is now 270 μCi/g. And the previous limit for Pu-239 was 0.1 μCi/g, whereas the LSA-II limit is now 0.54 μCi/g.

LSA material has been divided into groups in the 1996 domestic regulations (DOT, 1996; NRC, 1996a). It has retained its own proper shipping name and United Nations identification number, UN2912, in the hazardous material table [49 CFR 172.101 (DOT, 1996)]. Specific activity limits for the LSA material category are now specified for three different subcategories (i.e., LSA-I, LSA-II, and LSA-III), which are explicitly related to the A_2 of the material involved. Finally, the LSA definitions now distinguish between two types of distribution of activity in the material, *essentially uniformly distributed* (used in the definitions of LSA-I and LSA-III) and *distributed throughout* (used in LSA-II and LSA-III).

Section 4.1 provides guidance on grouping materials as LSA-I, LSA-II, or LSA-III. Section 4.2 clarifies some of the technical terms used in the LSA definitions, including specific guidance for complying with the distribution of radioactivity in the LSA material.

4.1 Categorizing a Class 7 (Radioactive) Material as LSA

Shipping a Class 7 (radioactive) material as LSA material is an option to shipping the material as "Radioactive material, n.o.s.," with identification number "UN 2982." LSA packaging requirements and communications requirements provide for some relief from the corresponding requirements for "Radioactive material, n.o.s." This relief is based primarily on the inherently safe nature of the quantity and distribution of activity in the LSA material.

4.1.1 What general categories of materials are intended to be shipped as LSA?

As in the past, LLW which has the activity incorporated into the waste matrix are the materials which will most likely satisfy the LSA material definitions. However, any radioactive material which can be demonstrated to satisfy the LSA definitions and the unshielded dose rate could be categorized as LSA and shipped in accordance with 49 CFR 173.427 (DOT, 1996). To be categorized as such, it must either be nonfissile or fissile excepted (49 CFR 173.427(a)(3).

Note that any radioactive material which meets the requirements in 49 CFR 173.421, for excepted packages of limited quantities of Class 7 (radioactive) materials, can be shipped as "Radioactive Material, excepted package, limited quantity of material," with an identification number of "UN2910." The activity per package in a normal form excepted package shipment (such as an activated or a contaminated object) would be limited to 10^{-3} A_2 as given by Table 7 of 49 CFR 173.425 (DOT, 1996). In such cases, there is no need to evaluate for compliance with the LSA definitions.

It is expected that much of the waste from nuclear power plant operations will be categorized as LSA-II material. Examples of candidate LSA-II materials from process waste streams would be dewatered ion exchange media (i.e., resins), evaporator bottoms, mechanical filters and filter media, absorbed liquids, and other similar process waste types. Other examples of LSA-II would be demolition rubble which exceeds LSA-I limits, activated metals, organic liquids (e.g., scintillation fluids or oils), removed paint, and biological wastes. Thus, the great majority of material that has previously been shipped as LSA material can continue to be shipped as LSA-II material under the revised regulations.

Compactable and noncompactable trash (e.g., dry active wastes, or "DAW") is an ambiguous category, possibly candidate for categorization as either LSA material or SCOs. For example, materials that absorb or incorporate the radioactivity (e.g., towels, rags, labwipes, clay for absorbing spills, or tape) would be candidate LSA material. Contaminated objects (e.g., tools, hardware, labware and glassware) might more appropriately be considered as candidate SCOs. However, it is not the intent of the transportation regulations to require segregation of these materials solely for purposes of categorization as LSA material or SCOs. A number of methods for determining SCO contamination, including process knowledge, are listed in 3.4.1. If qualitative judgement and experience indicates that there is no reason to believe that the SCO contamination limits on objects would be exceeded, then the objects could be mixed in a single package, along with materials which are clearly categorized LSA material by their nature (e.g., DAW or even LSA waste materials) and shipped according to the requirements of 49 CFR 173.427, as "Radioactive material, LSA, n.o.s." with identification number "UN2912." This practice is generally acceptable provided the LSA-II definition is otherwise satisfied, and the package contains less than 1 A_2 quantity (the great majority of DAW packages). In greater quantities, the practice may also be justified on a case-by-case basis. See section 6.1.1 for further details.

4.1.2 Is there a contamination limit for an LSA material's surfaces?

No, the current regulations do not place limits on contamination for LSA material. Therefore, there is no requirement to comply with the SCO surface contamination limits for LSA material. A contaminated, activated object may be categorized as LSA material insofar as it otherwise meets the requirements of the applicable LSA definition; however, an activated object may not be categorized as an SCO. Any contamination on the surfaces of LSA material must be accounted for in characterizing the material or object as LSA, and in determining the nuclides present in the package in accordance with 49 CFR §§ 173.433 and 173.435 (i.e., the "95%" A_2 sum of fractions rule), to be reported on shipping papers and labels (if not excepted from labeling). Also, since the contamination on the surface of LSA material may be from a different waste stream than the waste's (or object's) contained activity, it may not be accounted for in the

to estimate nuclide concentrations. In this event, any such contamination should be identified and properly accounted for in categorizing the material for shipment.

4.1.3 When an unshielded LSA material exceeds 10 mSv/hr (1 rem/hr) at 3 m (9.9 ft), what is the proper shipping name?

The proper shipping name in these cases is "Radioactive material, n.o.s." with the identification number of "UN2982" and, with one exception described below, a Type B package is required due to the quantity of material. If a material can otherwise satisfy the LSA requirements, but the 10 mSv/hr (1 rem/hr) at 3 m (9.9 ft) unshielded dose rate limit is exceeded, then the material no longer meets the intent of the LSA material regulations justifying the use of less robust packaging that would otherwise be required for Type B quantities of material. Also, Type B packages are not excepted from DOT marking and labeling requirements, as other packages for LSA sometimes are [49 CFR 173.427 (DOT, 1996)].

Further, for incidents involving packages marked "Radioactive materials, n.o.s." DOT's Emergency Response Guidebook (ERG) refers emergency responders to Guide No. 163. Guide 163 describe the potential health hazards of Type B quantities of radioactive materials, which is appropriate for unshielded LSA materials exceeding 10 mSv/hr (1 rem/hr) at 3 m (9.9 ft). The ERG Guide for packages marked "Radioactive Material, LSA" (Guide No. 162) does not acknowledge that Type B quantities could be present, and is therefore inappropriate for packages containing LSA materials exceeding 10 mSv/hr (1 rem/hr) at 3 m (9.9 ft).

NRC regulations [10 CFR 71.52 (NRC, 1996a)] allow that previously-certified NRC packages for LSA materials (i.e., NRC Type A-LSA packages) may continue to be used for LSA and SCO shipments until April 1, 1999. The "Directory of Certificates of Compliance for Radioactive Materials Packages," NUREG-0383 (NRC, 1996d) provides a compiled list of NRC certified package designs. These package designs can continue to be used as under previous regulations (see section 6.3.4), provided the conditions in the certificate of compliance (CoC) are complied with. They can be used for LSA material exceeding the 10 mSv/hr (1 rem/hr) at 3 m (9.9 ft) unshielded dose rate limit. The proper shipping name for LSA material shipped using these packages is "Radioactive material, LSA, n.o.s." with identification number "UN2912," and the packages are exempted from DOT marking and labeling requirements as specified in 49 CFR 173.427(a)(6)(vi) and (b)(4)[1].

4.1.4 Is there an object size below which collections of small, contaminated objects may be categorized and shipped as LSA material (as opposed to SCOs)?

No. NRC and DOT believe that the best approach to the small contaminated object issue is to simplify the process for their categorization as SCOs, rather than to classify them as LSA material. Nonradioactive objects whose surfaces are contaminated with radioactivity are clearly candidate SCOs, not LSA material, regardless of size. Accordingly, when possible, the method described in Section 3.3.1 should be used to categorize collections of small objects as SCO.

[1]Note: 49 CFR 173.427(b)(4) was issued in the corrections rule (61 FR 20747) to the initial rule (60 FR 50292)

The contamination on each small object is not required to be measured. A number of methods for determining SCO contamination, including representative sampling, are listed in Section 3.4.1. Representative sampling may be particularly appropriate for smaller objects. Small may be taken to mean less than approximately 280 cm^3 (17 in^3); objects exceeding this size are considered discreet for waste characterization purposes. Unless evidence suggests otherwise, it is generally acceptable to assume uniform contamination over the surfaces of collections of these small objects.

If successfully characterized as SCO-I or SCO-II, the objects should be shipped using the proper shipping name, "Radioactive material, SCO" with identification number "UN2913." See also section 6.1 for guidance on the mixing of LSA materials with SCOs.

4.1.5 Can activated metals, or a radioactive material which is solidified or absorbed on nonradioactive material, be categorized as LSA-II?

Yes. There are no restrictions which prohibit categorizing solidified, absorbed, or activated metal radioactive material as LSA-II, provided the definition is otherwise satisfied (i.e., specific activity limits, distribution requirement, and dose rate limits are met). Inclusion of the term *solid compact binding agent* in the LSA-III definition was not intended to preclude categorizing these materials as LSA-II. Similarly, activated metals are suitable for evaluation as possible LSA-II material, even though the term is explicitly cited as an example of a possible LSA-III material in 10 CFR 71.4 and 49 CFR 173.403.

Also, materials such as decommissioning wastes which exceed the LSA-I average specific activity limit, can also be evaluated as a possible LSA-II material.

4.1.6 Can the mass of grout or binding agents used in or on an object be included in the LSA specific activity or unshielded dose rate determinations?

No. In order to be considered in the determination of the average specific activity, or in the determination of unshielded dose rates, the radioactive material must be incorporated into the grout or binding agents.

If grout is used as shielding, structural support, or encapsulating material (i.e, the object or radioactive material is not incorporated into the grout), the grout should not be included in the LSA determinations. This situation would not meet the applicable LSA material definition's activity distribution requirement.

4.1.7 Can leach testing for disposal (10 CFR Part 61) substitute for the LSA-III leach test?

The LSA-III leach test is specified in 49 CFR 173.468 and 10 CFR 71.77 (DOT, 1996; NRC, 1996a). Radioactive waste forms that contain less than 1 A_2 quantity of radioactive material can be presumed to satisfy the LSA-III leach test requirements if they have been prepared under a

process control plan (PCP) associated with an approved waste solidification recipe in accordance with NRC's Technical Position (TP) on Waste Form, Rev. 1 (NRC, 1991). However, since the TP on waste form only addresses Class B and Class C LLW, only LLW which is stabilized by solidification in order to satisfy the 10 CFR 61 (NRC, 1996c), in compliance with the TP, can use this method for satisfying the leach test requirement for LSA-III shipments.

The utility of the condition that the radioactive waste form contain less than 1 A_2 quantity becomes apparent when comparing the transportation and disposal leach tests. Although the objective of both tests is to determine release of radionuclides from solids, the test conditions and measured parameters differ. The transportation leach test uses a smaller water volume and measures a single cumulative fraction leached after seven days. The ANS 16.1 procedure calculates the diffusion coefficient (or leach index) from incremental releases over 90 days. If diffusion is the primary release mechanism, the cumulative fraction released after 7 days can be calculated from the ANS 16.1 data, thus providing the information required for the transportation leach test.

The 1 A_2 value is based on a standard 55-gallon (208-liter) drum sized, solidified LLW form. Using this geometry it may be concluded that LLW meeting the disposal leach resistance criterion of a leach index of 6.0, will in general meet the transportation leach criterion of 0.1 A_2 released, with a safety margin (0.076 A_2 released vs. 0.1 A_2.). Larger waste forms can be expected to have a larger margin of safety, in that the cumulative fraction released will be lower for 7 days. Conversely, smaller waste packages can be expected to have a smaller margin of safety.

For purposes of this guidance, and considering: (1) other conservatism in the analyses (e.g., most LLW will exceed the minimum leach index of 6.0); (2) that the 1 A_2 value will be sufficient for many LLW packages; and (3) that a 55-gallon (208-liter) drum is a representative size for a solidified LLW form sent to disposal; the one A_2 quantity was adopted as a generally acceptable value (i.e., without further analyses), for all waste forms meeting the TP leach resistance criteria. However, on a case-by-case basis and using analyses similar to that described above, shippers can justify larger radionuclide quantities for larger packages.

4.1.8 Is it acceptable to use representative samples in the LSA-III leach test?

Yes, although the LSA-III leach test [49 CFR 173.468 and 10 CFR 71.77 (DOT, 1996; NRC, 1996a)] states that, "the specimen, representing no less than the entire contents of the package, must be immersed for 7 days in water at ambient temperature; ....", the wording is not intended to imply or require that the entire contents of each packaging being characterized must be leach-tested prior to transport. Also, the requirement is not meant to imply that full-scale tests are necessary to comply with the regulations. If frequent LSA-III shipments are expected, use of a process control program (PCP), similar to that used for compliance with the TP on waste form (Rev. 1) (see section 4.1.7 above), is one acceptable means of demonstrating compliance with the LSA-III leach test. At a minimum, such a program would include periodic sampling (i.e., control specimens), address waste stream consistency, and correlate lab-scale test results to full-scale test results.

4.1.9 Is it necessary to leach test activated metals?

Yes, but only if the activated metals are contaminated. If the activated metals are not surface contaminated, then they will not leach and completion of a leach test is not necessary.

Contaminated, activated metals will need to be assessed to determine their leach resistance. A simple assessment, which would not require the performance of tests, could assume that all surface contamination is leached and, based upon this assumption, determine whether the material satisfies the leach test requirements. If this assessment does not provide a satisfactory result, then the shipper should consider either decontaminating the material or conducting a leach test for LSA-III categorization.

4.2 Clarification of Terms Used in the LSA Definitions

The definitions of LSA-I, LSA-II, and LSA-III in 49 CFR 173.403 and 10 CFR 71.4 (DOT, 1996; NRC 1996a) contain several technical terms which are not explicitly defined. There is some guidance in the IAEA advisory material, Safety Series No 37 (IAEA, 1990c). This section provides additional clarification of the intent and meaning of these terms as used in the regulatory definitions. The terms include: *other debris* and *activated material* in the LSA-I definition, *distributed throughout* as used in the LSA-II and LSA-III definitions, and *essentially uniformly distributed* as used in the LSA-I and LSA-III definitions. The IAEA advisory material is used for clarification of the terms *distributed throughout* and *essentially uniformly distributed.*

4.2.1 What is the intent of the terminology *rubble, other debris and activated material* in the LSA-I definition?

The definition states that LSA-I consists of, among other things, "mill tailings, contaminated earth, concrete, rubble, other debris, and activated material in which the Class 7 (radioactive) material is essentially uniformly distributed and the average specific activity does not exceed 10^{-6} A_2 per gram of material." This part of the LSA-I definition is an area where domestic regulations are not compatible with the international regulations (IAEA, 1990a). This text was included in domestic regulations based on comments received on the proposed rules. A discussion of the changes appears in the statement of considerations for 10 CFR Part 71 (NRC, 1995b) .

The phrasing, "other debris, and activated material in which ... the average specific activity does not exceed 10^{-6} A_2 per gram," is somewhat ambiguous and can be misinterpreted to mean that many materials, including process wastes, could be placed in the LSA-I group. Based on the statement of considerations, LSA-I material should not include day-to-day wastes from plant operations. The LSA-I category is primarily intended for use with wastes from decommissioning activities.

Examples of *rubble, other debris and activated material* are: small fragments of mortar or broken concrete block or bricks; chipped or scabbled concrete vacuumed or swept into storage or handling receptacles; floor sweepings of small size; activated and contaminated materials stripped from laboratories, work areas or other locations; or activated non-masonry building materials, including fasteners (e.g., nails, screws, and rivets).

Examples of material that would not be *rubble, other debris and activated material* are: processed wastes or product streams; sludge; evaporator bottoms; non-activated surface contaminated building materials (panels, flooring, structural steel or aluminum, etc., that are more appropriately SCOs); and dry-active wastes including absorbent cloths, and protective clothing (LSA-II materials).

4.2.2 What is the difference between *distributed throughout* and *essentially uniformly distributed*?

Basically, the rationale for providing regulatory relief for LSA materials is that the average radioactivity concentration per gram of material is relatively low compared to other radioactive materials. If, however, the radioactivity is localized in a small portion of the volume of the material, a significant hazard could be posed if that portion of the material were released in an accident.

IAEA recognized that most LSA materials are not homogenous, and that the degree of non-homogeneity is an important factor in considering the probability of release and the consequences of potential dispersion in an accident. IAEA introduced *two qualitative terms* in the definitions of LSA material groups that allow different degrees of non-homogeneity.

The first term, *distributed throughout*, is used in defining both LSA-II and LSA-III materials, and allows the greater degree of non-homogeneity. If the activity is distributed throughout a material, and the specific activity does not exceed 10^{-4} A_2/g (for solids), the material is LSA-II. A greater specific activity (10^{-3} A_2/g) is permitted if the radioactive material is distributed throughout a solid or collection of solid objects (LSA-III). The LSA-III specific activity limit can apply to materials, as well as objects, provided the radioactivity is *essentially uniformly distributed*, that is, exhibits a lesser degree of non-homogeneity than *distributed throughout*, and is contained in a solid compact binding agent.

IAEA did not provide quantitative definitions for these terms. However, IAEA guidance (see Section 4.2.3) indicates that the specific activity among 0.1 m^3 volumes of objects or materials that are *distributed throughout* should not vary by more than a factor of 10; and, for materials that are *essentially uniformly distributed*, the specific activity should not vary by more than a factor of three. Thus IAEA indicates that the degree of non-homogeneity, as measured by variance in specific activity, may be approximately three times more for objects or materials that are *distributed throughout* than for materials that are *essentially uniformly distributed.*

4.2.3 What practical techniques can be used for demonstrating the activity in an LSA material is *distributed throughout* or *essentially uniformly distributed*, as applicable?

Low Specific Activity Material

It is permissible to apply qualitative techniques for LSA materials having radioactive materials in quantities less than 1 A_2, and to apply the more quantitative techniques in the IAEA's advisory material (IAEA, 1990c) for LSA materials having radioactive materials in quantities exceeding 1 A_2.

There is no need to quantitatively address the distribution of the nuclides in the LSA material for packages with radioactivity less than 1 A_2 in quantity. In this case, shippers may determine that the activity is adequately distributed within the material based upon a criterion that a large amount of non- or slightly-radioactive material has not been used in the specific activity determination with the radioactive material. If it is known that the material has a highly-stratified or significantly non-uniform distribution, then this criterion cannot be used, and a more rigorous assessment will be required. For example, most LLW packaged for disposal would typically have the radioactivity distributed within the package to an acceptable extent.

When a quantity of material has radioactivity exceeding 1 A_2, and a dose rate less than 10 mSv/hr (1 rem/hr) at 3 m (9.9 ft) from the unshielded surface of the material, a more quantitative determination of the distribution of activity is needed. This determination can be made through reasoned argument, reference, calculation, or measurement. The following, based upon the IAEA's advisory material (IAEA, 1999c), may be used:

- For *distributed throughout,* the material can be divided into ten or more equal volumes. The volume of each portion should be no greater than 0.1 m^3. The specific activity of each volume should then be assessed (through measurements, calculations, or process knowledge) and compared. Specific activity differences between any two volumes should not vary by more than a factor of 10.

- For *essentially uniformly distributed,* the material can be divided into ten or more equal volumes. The volume of each portion should be no greater than 0.1 m^3. The specific activity of each volume should then be assessed (through measurements, calculations, or process knowledge) and compared. Specific activity differences between any two volumes should not vary by more than a factor of 3.

For small (i.e., smaller than 0.2 m^3 (7.5 ft^3), or a 55 gal. drum) LSA material packages, the IAEA Safety Series No. 37 method described above should not be applied.

4.2.4 Can compliance with NRC's "Branch Technical Position on Concentration Averaging and Encapsulation" be used to demonstrate that a mixture of candidate LSA materials are *distributed throughout* or *essentially uniformly distributed*, as applicable?

Mixtures of LLW types or streams which meet the January 17, 1995, "Branch Technical Position on Concentration Averaging and Encapsulation," (NRC, 1995a) can be assumed to be either *distributed throughout* or *essentially uniformly distributed*, as applicable. This determination can be used in place of the determination described in Section 4.2.3, irrespective of the size of the container in which it is packaged for transport. Further, if averaging over the volume or mass of the waste is permitted by the concentration averaging Technical Position (TP) for disposal

classification purposes, similar averaging over the mass of the waste is generally acceptable for LSA specific activity determinations. However, materials which the TP recommends should be considered discrete items for LLW classification should also be considered discrete items and be evaluated individually against the LSA definitions, as appropriate. Further, it is assumed that nuclides important to transportation are distributed in the waste to the same degree as those important to waste classification. If it is believed that this assumption does not hold, a more detailed analysis would be expected by DOT and NRC.

Note that the TP contains guidance for classification and averaging of some materials (i.e., contaminated materials, encapsulated materials, and sealed sources), that should not be applied for LSA material determinations. Specifically:

- Nonradioactive, contaminated objects must be classed as SCO (see section 3).
- Encapsulated wastes should not be averaged over the weight of the solidified mass for determination of the material's average specific activity (as is allowed for LLW classification).
- Sealed sources cannot be considered LSA material unless the source itself meets the LSA definition (specific activity limit and distribution); although the TP allows averaging the sealed source activity over the entire waste form for LLW classification, this practice is not acceptable for LSA material determinations for transport.

4.2.5 What is a *combustible solid* with respect to the conveyance activity limit for LSA material of 100 A_2?

The meaning of *combustible solid* only becomes important for LSA-II and LSA-III material when the quantity on a conveyance exceeds 100 A_2 quantities [i.e., the conveyance activity limit in Table 9 of 49 CFR 173.427 (DOT, 1996)]. LSA-II and LSA-III noncombustible solids do not have a conveyance activity limit.

The National Fire Protection Association (NFPA) has published a standard which provides a guide on quantifying combustible hazards of materials, which can be used for characterizing combustibility of LSA material (NFPA, 1990). Based upon this standard, combustible LSA solids may be defined as follows:

> *Combustible solid* LSA materials are LSA-II and LSA-III materials in solid form which, under conditions encountered in transport, may cause or contribute to fire or are capable of sustaining combustion on their own or in a fire. The solid is combustible if the material has a flammability hazard ranking of 1 or 2 according to the test method in NFPA 704 (NFPA, 1990). Solid materials which have a flammability hazard ranking of 0 (zero) according to NFPA 704 are noncombustible.

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In assessing combustibility of a mixture of materials, the amount of material which is combustible will determine whether the entire mixture is combustible (i.e., capable of causing or contributing to fire or are capable of sustaining combustion on their own or in a fire). It is permissible, for conveyance quantities greater than 100 A_2, to have a small amount of combustible solid intermixed with noncombustible solids. If combustible solids do not exceed one percent, by mass, of the total material, the mixture shall be deemed to be noncombustible.

Examples of combustible solid materials are: insulating materials; building materials [polyvinyl chloride (PVC), plastic, wood, etc.]; filtering materials (charcoal, fiberglass, etc.); ion-exchange resins; cleaners; paints; personal protective equipment (PPE) such as clothing, booties, and cartridges; or other materials that would be assigned a flammability hazard ranking of 1 or 2 using NFPA 704 (NFPA, 1990). Examples of non-combustible solids are: cement building materials, metal components, or other materials assigned a flammability hazard ranking of 0 ("zero") using the definitions in NFPA 704.

4.2.6 What was the misprint in NRC's and DOT's September 28, 1995, *Federal Register* final rules (60 FR 50292 and 60 FR 50248) regarding the terms *distributed throughout* and *essentially uniformly distributed*?

Two misprints appear in both the NRC Final Rule *Federal Register* notice (NRC, 1995b) and the DOT notice (DOT, 1995), regarding the definitions of LSA-II solids and LSA-III objects that are not solidified in a binder. The use of the phrase "*essentially uniformly distributed*" in Item (2)(ii) of the LSA-II definition, is incorrect, and has been replaced with the term "*distributed throughout.*" The phrase "*essentially uniformly distributed throughout*" in item (3)(I) of the LSA-III definition is incorrect, and has been replaced with the term "*distributed throughout*". The use of the phrase "*essentially uniformly distributed*" in the LSA-I definition, and in the definition for LSA-III materials solidified in a binding agent, is correct as it appears in the regulations. The 1995 bound Title 49 Code of Federal Regulations (CFR) volume, and the 1996 bound Title 10 CFR, also contain the errors from the original *Federal Register* notice. NRC and DOT have since issued corrections notices (61 FR 28723 and 61 FR 20747) which clarify these and other misprints in the original notices.

5 UNSHIELDED DOSE RATE LIMIT

This section presents guidance for complying with requirements presented in 49 CFR 173.427(a)(1) and 10 CFR 71.10 (b)(2) (DOT, 1996; NRC, 1996a) which specify that the dose rate must not exceed an external radiation level of 10 mSv/hr (1 rem/hr) at 3 m (9.9 ft) from the unshielded material or object(s) in a packaging. LSA material and SCOs are the only Class 7 (radioactive) materials for which a dose rate limit has been specified for the package contents, in addition to the package and vehicle limits.

Under the previous regulations, NRC certification of the package for LSA material was required if the package contents exceeded an A_2 quantity, and then the LSA package was required to meet the Type A (non-accident) standards. Generally, there was no specific upper limit to the activity of LSA material which could be placed in a Type A package (practical limits resulted from vehicle dose rates).

Under the current rules, NRC certification of a package for LSA material and SCOs is required only when the dose rate at 3 m (9.9 ft) from the unshielded LSA material or SCO exceeds 10 mSv/hr (1 rem/hr). In excess of this, a Type B (accident resistant) package is required, except that previously approved NRC Type A-LSA packages are authorized until April 1999 [10 CFR 71.52 (NRC, 1996a)]. The effect of the new regulations is to limit the LSA material and SCO allowed in non-accident resistant packages.

Section 5.1 discusses the intent of the unshielded dose rate limit and how it is applied, and Section 5.2 describes a practical, quantity-based method for compliance with the limit.

5.1 Intent of the Dose Rate Limit

The intent of the dose rate limit is to restrict the LSA material and SCO contents allowed in non-accident resistant packages such that the post-accident external radiation hazard from the material would be comparable to that amount of non-LSA/SCO radioactive material allowed in a non-accident resistant package (i.e., to a 1 A_1 value). In practice, LSA material and SCO contents are limited to several multiples of the A_1 value (e.g., about 4 A_1 quantities - but this can vary significantly based on nuclides and geometry). For LSA materials, the specific activity limits and distribution limits, *distributed throughout* or *essentially uniformly distributed,* provide a degree of protection of public health and safety relative to non-LSA/SCO material. Likewise, for SCOs, the regulatory prescribed limits for radioactive material contamination on surfaces provide a similar degree of protection. The additional requirement, limiting the dose rate external to LSA material or SCOs to 10 mSv/h (1 rem/h) at 3 m (9.9 ft) from the unshielded material, provides an additional margin of safety in the event of an accident. This limit helps to ensure that any such releases of LSA material or SCOs would not present a significant radiation hazard to nearby members of the public or to emergency response personnel who are first to arrive at the accident scene.

The effect of the regulation is to limit the radionuclide contents of packages approved for transport of LSA materials and SCOs. These packages—Industrial Type IP-1, IP-2, and IP-3

and, for domestic transportation, strong-tight packages—are required to protect and contain contents during normal transportation but are not required to survive transportation accidents.

NRC and DOT staff believe that in the great majority of candidate LSA/SCO shipments, the dose rate would be much lower than the limit. The 3 m (9.9 ft) unshielded dose rate will generally not be an issue for SCOs, other than very large objects (e.g., discarded steam generators), because the surface contamination on objects should not present practical cases in which dose rates could reach such large values.

5.1.1 Where does the unshielded dose rate limit apply?

The unshielded dose rate limit applies at any point on an imaginary surface which envelopes the LSA material's or SCO's outermost dimensions, at a distance of 3 m (9.9 ft). For example, for a upright cylindrical waste container, the dose rate limit would apply at a cylindrical surface with a radius 3 m (9.9 ft) greater than that of the container radius, and the dose rate limit would also apply at two planes, one plane 3 m (9.9 ft) above the waste, and one plane 3 m (9.9 ft) below the waste. The latter plane would typically be below ground as the container is presented for transport; the dose rate would still need to be determined as meeting the limit, to account for package re-orientation following a transportation accident.

5.1.2 Do the possible effects of redistribution of the LSA material or SCOs in transport (and resultant loss of self-shielding) need to be assessed?

Provided that the material complies with the LSA material or SCO definition, the unshielded dose rate may be calculated on a waste geometry "as presented for transport." That is, the geometry of the LSA material should be the same as it would be on the loaded vehicle (e.g., an upright cylinder of diameter and height equal to the interior dimensions of the packaging). The LSA material or SCO definition would generally provide a level of distribution of activity within the material such that consideration of redistribution in transport (e.g., through an accident) is unnecessary. The packaging should not be included in the determination (see section 5.1.3).

5.1.3 Can liners (e.g., disposal containers), waste binders, or other packaging materials be considered in complying with the dose rate limit?

No packaging, vehicle, or other material providing external shielding may be included in the unshielded dose rate determination. This includes polyethylene liners (although the liner would be expected to provide only minimal shielding if gamma emitters were present). It is anticipated that licensees will base the determination on dose rates measured at or some distance away from the package surfaces (for example, dose measurements for compliance with 49 CFR 173.441 package and vehicle limits); and either on prior knowledge about the package contents through routine sampling (for process wastes), or through specific sampling of the contents (e.g., for objects/components). A back-calculation can then be performed which effectively removes *all* packaging (including liners) from the contents. Licensees may choose to develop or purchase systematic procedures or programs which relate measured package dose rates, frequently used package types, and waste stream data, to the unshielded dose rate at 3 meters.

Waste binders, such as grout or absorbent material, may be included in the unshielded dose rate determination if the grout or absorbent material is mixed with the LSA material. Under these conditions, the grout can also be included in determining the specific activity of the LSA material. However, concrete added to encapsulate a waste, or shield the waste (e.g., added to the top or bottom of a drum) cannot be included in either the dose rate determination or the specific activity determination, as the material would no longer meet the LSA definition's distribution requirement.

5.1.4 If slightly contaminated/activated materials are shipped in the same package as other LSA material, how should the external dose rate be calculated and/or measured for these non-uniform sources?

In cases where wastes are mixed in a manner consistent with and allowed by the NRC's "Branch Technical Position on Concentration Averaging and Encapsulation" (see section 4.2.4, and NRC, 1995a), the mixed materials can be considered together in the dose rate determination. Note that this may result in some shielding of a higher activity portion by a lower activity portion of the mixture. However, if application of the TP guidance suggests that the different materials should be considered separately (i.e., as discrete objects) for LLW classification purposes, they should also be considered discrete objects for determining the unshielded dose rate at 3 m (9.9 ft) from the material.

If the higher activity portion is a significant external hazard (i.e., contains greater than about 2 A_1 quantities), then it should be considered by itself for compliance with the dose rate from the unshielded material. Each material or object must meet the applicable LSA specific activity and material distribution limits, or the SCO contamination limits, as appropriate.

5.2 Quantity-Based Method for Compliance With the Dose Rate Limit

NRC and DOT staff believe that in the great majority of potential LSA material/SCO shipments, the dose rate will be much lower than the limit. Therefore, shippers would be expected to be able to use simple, reasoned arguments for meeting the requirement. This section provides a reasoned argument which could be used for all LSA material and SCOs containing radioactivity less than 2 A_1 quantity. In addition, it describes applicable methods for greater quantities.

5.2.1 What quantity of LSA material or SCOs in a package can be assumed, without further analysis, to comply with the dose rate limit?

The 10 mSv/hr (1 rem/hr) at 3 meter (9.9 ft) dose rate from the unshielded LSA material and SCO, is only a relevant concern when the package radioactive material contents exceed a total of 2 A_1 quantities. Analyses during development of the rulemaking demonstrated that it is unlikely that a package of LSA material or SCO containing 2 A_1 quantities or less would approach the 10 mSv/hr (1 rem/hr) dose rate limit at 3 m (9.9 ft) from the unshielded LSA material or SCO.

5.2.2 For explicit demonstrations of compliance with the dose rate limits, which methods are acceptable?

If the package radioactive material contents exceed a total value of 2 A_1, acceptable means of demonstrating compliance with the unshielded dose rate limit include: calculation; direct measurement; reference to a previous, satisfactory demonstration of compliance of a sufficiently similar nature; use of process knowledge; or combinations of these. Physical surveys of the dose rates 3 m (9.9 ft) from the unshielded material are not required, and may not be consistent with ALARA requirements, if alternative methods of demonstration are available.

It is anticipated that licensees will base the dose rate determination on measured dose rates from the package surfaces [performed pursuant to 49 CFR 173,441 (DOT, 1996)]; and prior knowledge about the package contents, either through process knowledge, through routine sampling (e.g., for process wastes), or through specific sampling of the contents (e.g., for activated hardware/components). A back-calculation (i.e., an inverse shielding calculation) can then be performed which effectively removes *all* packaging from the contents. Adherence to ALARA practices is still possible for these determinations.

It is recognized that back-calculations from measurements, for example, may mask uneven distributions or "hot spots" within the LLW. This issue should be addressed in the determination (see section 5.2.3).

5.2.3 If package measurements and back-calculations to unshielded dose rates are used, how can account be taken for the effects of the packaging (e.g., the smoothing of radiation readings, and the masking of "hot spots")?

For LSA material, the distribution of activity within the waste must meet the distribution requirements (i.e., *distributed throughout* or *essentially uniformly distributed*, as appropriate) of the applicable LSA material definition (see section 4.2.3). The maximum dose rate calculated or measured from the package surfaces, and pre-existing knowledge of the package contents, can then be used to calculate the dose rate at 3 m (9.9 ft) from the unshielded material.

Analyses for these cases do not need to further address either (a) the effects of the smoothing of radiation by the presence of the packaging when assessing the unshielded dose rates using radiation measurements in a shielded environment, or (b) the distribution of the activity within the waste and the potential for "hot spots". In many cases, compliance with the NRC's "Branch Technical Position on Concentration Averaging and Encapsulation" (NRC, 1995a) for LLW disposal classification, will further address concerns with possible "hot spots." For purposes of compliance with the unshielded dose rate limit at 3 m (9.9 ft), possible effects of the packaging, such as masking of "hot spots" can be disregarded for LSA material because compliance with the distribution requirement and the TP on concentration averaging will provide adequate protection.

For SCOs, the determinations of radiation level measurements performed for determining fixed contamination levels are to be made in areas where the highest radiation levels are expected to exist, and sufficient measurements are to be taken to provide a representative assessment (see

section 3.4.2). Thus, the determination of compliance with contamination levels should also account for any concerns for "hot spots."

6 PACKAGING AND SHIPPING REQUIREMENTS

Several changes to the packaging requirements for low specific activity (LSA) material and Surface Contaminated Objects (SCOs) were implemented by the 1996 domestic regulatory revisions. Among these changes, industrial packaging (IPs) were introduced into the domestic regulations, and an upper limit was placed on the amount of activity in LSA material or SCOs which could be shipped in a non-accident resistant package [controlled by the unshielded, 3 m (9.9 ft) dose rate requirement (see section 5)]. A limit was also placed on the amount of activity contained in SCOs and in LSA-II or LSA-III combustible solids which can be carried on a single conveyance [controlled by 49 CFR 173.427(a)(2) and Table 9 of 49 CFR 173.427 (DOT, 1996)].

Since LSA material and SCOs often result from similar operations or waste streams, and since the 1996 regulations have separated these class 7 (radioactive) materials into two categories, practical guidance on mixing these materials together is also needed.

Section 6.1 provides guidance on mixing LSA Materials and SCOs together or with other hazardous materials. Section 6.2 describes ways that pre-shipment processing could change the category of a material, fix contamination, or make surfaces inaccessible. Section 6.3 gives guidance on the application of the new packaging requirements, and on continued (grand fathered) use of pre-1996 NRC certified Type A LSA packages until April 1999.

6.1 Mixing LSA Materials and SCOs Together or with Other Hazardous Materials

Since both SCOs and LSA material often consist of waste products, it often makes operational, economic and radiological protection sense to mix these wastes together in a single package. NRC and DOT do not discourage this practice since the packaging, hazard communications, and modal requirements for transporting LSA material and SCOs are very similar (essentially identical for the majority of shipments).

6.1.1 What is the general rule for mixing LSA material and SCOs in a single package?

When mixing SCO and LSA materials in a single package, both the objects and the LSA materials should meet their respective definitions before being mixed together and then, when mixed, the contents of a package should be considered to be LSA.

This procedure should be followed, regardless of the respective amounts of the two materials, provided that the total quantity of material is less than 1 A_2.

The method in section 3.3.1 may be used to categorize collections of small SCOs prior to mixing them with LSA material provided the combined total quantity of radioactivity, in both the LSA material and SCOs to be included in a single package, does not exceed 1 A_2. In the event that this package quantity limit is satisfied, each small object is not required to be measured. Rather,

a representative sample of the small objects can be assessed and the activity and surface contamination in the entire collection can then be estimated. Unless evidence suggests otherwise, it is generally acceptable to assume uniform contamination over the surfaces of collections of these small objects. As noted in section 4.1.4, in this context, small can be interpreted to mean approximately 280 cm^3 (17 in^3) or less.

More rigorous approaches as discussed in section 3.3.2 to categorizing the SCOs to be mixed with LSA material should be used if the combined total quantity of radioactivity, in both the LSA material and SCOs to be included in a single package, exceeds 1 A_2.

6.1.2 What is the proper shipping name for a mixed LSA/SCO package?

The proper shipping name is "Radioactive Material, LSA, n.o.s.," with an identification number of "UN2912", provided the total quantity of radioactive material in a package containing a mixture of LSA material and SCO is less than 1 A_2, regardless of the respective amounts of LSA material and SCOs.

If the total quantity of radioactive material in the package is greater than 1 A_2, the proper shipping name should be based on the material contributing the greatest fraction to the A_2 quantity in the package.

6.1.3 When a material meets an LSA material definition but also the definition of another Hazard Class (e.g., corrosive liquid, n.o.s., PG II), how should the material be classified and prepared for shipment?

Situations may arise where the LSA material or the SCO could contain other hazardous materials. In these cases, the shipper must be clear on how to characterize, package and assign the proper shipping name to the material or object. Some examples:

- An acid solution may be used to process radioactive isotopes and, as a result, becomes contaminated with the radioisotope and then must be shipped. This type of material may meet the definitions of both Class 7 and Class 8 hazardous materials. The proper classification should be accomplished according to 49 CFR 173.2a.

- A solution of nitric acid used in the processing of radioisotopes which has become contaminated with the radioisotopes. Normally, spent nitric acid would be classified as a "corrosive liquid, n.o.s., PG II," with an identification number of "UN1760." However, if the spent solution has sufficient residual radioisotopes, it should be classified as Class 7 with a subsidiary hazard of Class 8. If the concentration of the radionuclides was sufficiently low, the correctly assigned proper shipping name would be "Radioactive material, LSA, n.o.s.," with an identification number of "UN2912."

It is noted that, when a material is both LSA and corrosive, 49 CFR 173.427(a)(6)(vi) excepts the shipper from placing the "Radioactive" label on certain exclusive use packages shipped domestically, but a "Corrosive" label would usually be required per 49 CFR 172.402(d).

this exception, if the shipper is concerned about the lack of hazard communication, the shipper is not prohibited by the regulations from fully marking, labeling and placarding the shipment.

6.2 Pre-Shipment Processing of LSA Material and SCOs

This section discusses ways of processing LSA material and SCOs prior to shipment.

6.2.1 How can *accessible surfaces* be converted into *inaccessible surfaces*?

Processing candidate SCOs prior to transport in a manner that effectively converts *accessible surfaces* into *inaccessible surfaces* is an acceptable practice. As examples of these techniques:

A shipper can assert that grout or a stable binding agent will transform *accessible surfaces* into *inaccessible surfaces.* Also, ends of pipes could be crushed or capped to make *accessible surfaces* into *inaccessible surfaces.* Wrapping is not considered an acceptable method for converting *accessible surfaces* into *inaccessible surfaces.*

Making *accessible surfaces* into *inaccessible surfaces* is one acceptable means of determining the non-fixed (removable) accessible contamination is within the applicable SCO limits.

6.2.2 How can *non-fixed (removable) contamination* be rendered fixed?

Fixing contamination on candidate SCOs prior to transport is an acceptable practice. Regardless of the process used for rendering non-fixed contamination as fixed contamination, if the contamination can then be shown to satisfy the definition of fixed contamination given in section 3.2.2, it can be deemed as fixed contamination. Fixing the contamination is one acceptable means of complying with SCO limits for accessible surface contamination where the non-fixed contamination on accessible surfaces exceed the applicable SCO limits. Paints, for example, could be used for this purpose. Wrapping is not considered an acceptable method for rendering removable contamination fixed.

6.2.3 Can grout or binding agents or encapsulating materials be considered in LSA-specific requirements?

Waste binders, such as grout or absorbent material, may be considered in the unshielded dose rate determination only if the material is mixed with the LSA material. In this situation the grout can also be considered in determining the specific activity of the LSA material.

However, concrete added to encapsulate a waste, or to shield a side of the waste (e.g., added to the top or bottom of a drum) cannot be accounted for in either the dose rate determination or the specific activity determination as the material would no longer meet the LSA definition's distribution requirement.

6.2.4 Is there a requirement to document the determinations which show compliance with regulatory requirements including categorization of a material or object as LSA material or SCO and the determination of unshielded dose rate?

No. However, NRC licensees would be expected, under inspection, to be able to explain and defend their determinations of categorization in terms of total activity in a package, levels of contamination, uniformity of mixture of radionuclides in a material, and the unshielded dose rate for any given shipment. Thus, one acceptable approach to this is through documentation of the determination.

6.3 Packaging Requirements for LSA Materials and SCOs

Table 6.1 presents the minimum packaging requirements for all radioactive materials as developed by NRC staff. The table shown in Appendix A provides a more detailed description of packaging requirements for the various forms of LSA material and SCOs.

6.3.1 What are the design requirements for a strong, tight package?

Strong-tight packages—which may be used for shipment of LSA material and SCOs domestically, under exclusive use [see 40 CFR 173.427(b)(3) (DOT, 1996)]—must be designed to meet the general design requirements for all packages specified in 49 CFR 173.410. Therefore, strong, tight packages are effectively equivalent to excepted packagings and industrial packaging Type-I (IP-I) packagings. Strong, tight packages used as packaging for LSA-I solid material or SCO-I, pursuant to 49 CFR 173.427(c), may be excepted from this design requirement (49 CFR 173.410), but are subject to the general requirements for packaging in 49 CFR 173.24(a). See section 6.3.2.

6.3.2 Can any LSA material or SCOs be shipped unpackaged or as its own packaging?

Domestic transportation regulations effective April 1, 1996, do not contain any provisions for unpackaged shipment of Class 7 (radioactive) material. In addition, the regulations do not address cases where the LSA material or the SCO may serve as its own packaging. However, DOT has previously allowed objects to serve as their own packaging, provided appropriate packaging requirements were satisfied. DOT is not aware of safety concerns with objects shipped in this manner. Based on this experience, DOT will continue to allow SCO to serve as its own packaging, provided the SCO satisfies appropriate packaging requirements.

Under certain conditions, the conveyance may sometimes serve the function of the packaging. LSA-I solids, LSA-I liquids and SCO-I may be transported in bulk packaging (i.e., strong, tight packaging), under "exclusive use" arrangements [49 CFR 173.427(a) and (c)].

Table 6.1 Minimum Packaging Requirements for Radioactive Materials[1]

Revised Regulations (April 1, 1996)				
DOT Regulatory Requirements (49 CFR ...)	[173.403]	[173.403]	[173.433]	[173.427(a)(1)]
NRC Regulatory Requirements (10 CFR ...)	[71.10(a)]		[71 App. A]	[71.10(b)(2)]
	70 Bq/g 0.002μCi/g	Limited Quantity	A_1/A_2	10 mSv/hr (1 rem/hr) @ 3 m Unshielded
	↓	↓	↓	↓
Non-LSA/SCO	**Excepted**	**Type A**		**Type B[2]**
Domestic or Non-Domestic, LSA or SCO: LSA-I Solid, and SCO-I *[49 CFR 173.427(c)]*	**Excepted**	**IP-1[4]; or strong, tight (bulk packaging)[3]**		**Type B[6]**
LSA-I Liquid Transported Under Exclusive Use *[49 CFR 173, Table 8, or 49 CFR 173.427(c)(2)]*		**IP-1[4], or Specification bulk packagings[3]**		
LSA-I Liquid, LSA-II Solid, and SCO-II not Transported Under Exclusive Use; and LSA-II Solid, LSA-II Liquid, LSA-II Gas, LSA-III and SCO-II Transported Under Exclusive Use *[49 CFR 173, Table 8]*		**IP-2[4]**		
LSA-II Liquid, LSA-II Gas, and LSA-III not Transported Under Exclusive Use *[49 CFR 173, Table 8]*		**IP-3[4]**		
Domestic only, LSA or SCO: LSA-I, LSA-II, LSA-III, SCO-I, and SCO-II *[49 CFR 173.427(b)(2), (b)(3), (b)(4), (b)(5)]*	**Excepted**	**Strong, tight[3]**	**Spec 7A Type A[5]**	**Type B[7]**

Regulations in Effect Prior to April 1, 1996			
Non-LSA	Excepted	Type A	Type B[2]
LSA	Excepted	Strong, tight[5], or Spec 7A Type A[5]	NRC Type A[2,3]
	↑	↑	↑ ↑
	70 Bq/g 0.002μCi/g	Limited Quantity	Old[8] A_1/A_2	10 mSv/h (1 rem/h) @ 3 m Unshielded

Notes to Table 6.1 are as follows:

[1]Table does not follow fissile materials.

[2]Subject to conditions in Certificate of Compliance.

[3]Exclusive use required.

[4]Transport of LSA material and SCOs by air is only allowed in IP packages as specified by Table 8 in 49 CFR 173 [49CFR 173.427 (a)(6)(vii)]

[5]The Specification 7A Type need not satisfy the security seal, minimum dimension, temperature and special liquid containment requirements for Type A packages specified in 173.412(a), (b), (c), and (k) [49 CFR 173.427((b)(2)].

[6]The material cannot be categorized as, or given the proper shipping names corresponding to either LSA material or SCOs. The material or object(s) must be shipped in a certified Type B package, subject to conditions in Certificate of Comlpiance *[49 CFR 173.427(b)(5)]*.

[7]The material or object(s) must be shipped either in a certified Type B package or an NRC-certified Type A package. Packaging and shipment are subject to conditions in Certificate of Compliance *[49 CFR 173.427(b)(5)]*. For carriage in an NRC-certified Type A package design, exclusive use is required, and use expires April 1, 1999 *[49 CFR 173.427(b)(4) and 10 CFR 71.52]*.

[8]A_1A_2 values in regulations effective prior to April 1, 1996.

When a conveyance serves the function of the strong, tight packaging, the LSA-I material or SCO-I may be loose in the conveyance; however, in this event the requirement of 49 CFR 173.427(a)(3)(iii) (DOT, 1996) must be satisfied (i.e., "there must be no leakage of Class 7 (radioactive) material from the conveyance.").

This requirement is similar to the regulations which were in effect prior to April 1, 1996, which also allowed LSA solid materials to be shipped in exclusive use, closed transport vehicles, where the closed transport vehicle had to meet the strong, tight container criterion.

Specifically, relative to transport of LSA-I and SCO-I in bulk packagings, the regulations specify that, for LSA-I solids and SCO-I, bulk packaging [as defined in 49 CFR 171.8 (DOT, 1996)] must be, as a minimum, strong, tight packaging. The general design requirements for packaging (49 CFR 173.410) do not apply for this special case; however, the general requirements for packagings [49 CFR 173.24(a)] do apply.

6.3.3 Could a shipper package and transport LSA material inside a packaging that would otherwise meet the definition of SCO?

As stated above, LSA material and SCOs may be used as their own packaging, provided appropriate packaging requirements are satisfied. The SCO may be used to transport LSA material, provided that material satisfies the applicable LSA definition, and provided the shipment otherwise complies with applicable requirements.

6.3.4 What are the rules for continued use of NRC-certified Type A LSA packages "grandfathered" by 10 CFR 71.52? Is exclusive-use required?

If the requirement of 49 CFR 173.427(a)(1) (DOT, 1996), for the unshielded dose rate limit for LSA material and SCOs, is not satisfied, accident-resistant (i.e., Type B) packages must be used. According to 49 CFR 173.427(e), LSA material or SCOs that exceed the packaging limits in 49 CFR 173.427 (i.e., unshielded dose rate limit), must be packaged in accordance with 10 CFR Part 71 (i.e., in accident-resistant, Type B packages). However, 10 CFR 71.52 (NRC, 1996a) contains an exemption for LSA/SCO material transported as exclusive use. The exemption results from the 10 CFR 71.51 requirements to make Type B packages accident resistant. This exemption is set to expire April 1, 1999, after which, these non-accident-resistant packages may no longer be used for the transport of LSA/SCO material which cannot satisfy the unshielded dose rate criteria.

While the exemption is in effect, NRC packages certified for LSA materials may continue to be used for LSA and SCO shipments, including those exceeding the unshielded dose rate limit of 10 mSv/hr (1 rem/hr) at 3 m (9.9 ft), provided the conditions described below are satisfied. NRC certified packages for LSA materials are listed in the "Directory of Certificates of Compliance for Radioactive Materials Packages," NUREG-0383 (NRC, 1996d).

- The authorized contents specified on these certificates are based on the LSA definitions from the previous (pre-1996) rules, except that the A_2 values from the revised rules can be used in place of the A_2 values from the previous rules.

- The certificates for these packages have been revised to: (1) show an expiration date of April 1, 1999; and (2) limit the specific activity allowed to correspond to that of the old rules (i.e., basically 0.1 μCi/g for nuclides with an $A_2 \leq 0.05$ Ci; 5 μCi/g if $0.05 < A_2 \leq 1$ Ci; or 0.3 mCi/g for nuclides with an A_2 greater than 1 Ci). Licensees must have a copy of the revised certificates before using an NRC certified package to ship LSA material or SCO (and must ship in compliance with the *revised* Certificate).

During their continued use, the NRC-certified Type A-LSA packages are required to be shipped as exclusive-use pursuant to 49 CFR 173.427(b)(4) (added in the DOT corrections notice, 61 FR 20752). These packages, therefore, qualify for the exception from marking and labeling in 49 CFR 173.427(a)(6)(vi). However, vehicles transporting these packages must be placarded.

Subparagraph 49 CFR 173.427(a)(6) provides relief from package marking and labeling requirements [173.427(a)(6)(vi)] "for LSA and SCO required by this section to be consigned as

exclusive use." Note that shippers may elect to comply with exclusive use provisions for shipments that are not required by the regulations to be consigned as exclusive use.

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APPENDIX A

Regulatory Process for Categorizing Materials and Objects as LSA Material or SCOs and Selecting Packaging Options

A detailed diagram of the DOT and NRC regulations as they pertain to LSA materials and SCOs is presented in Figures A-1 through A-3. This diagram may be used as a guide to facilitate determining whether materials and objects may be categorized as LSA material or SCOs; it can also be used by auditors and inspectors to facilitate their efforts in overseeing compliance with the regulations.

The diagram was derived from the regulatory text requirements of 10 CFR 71 and 49 CFR 173 (NRC, 1996a; DOT, 1996). It provides a tool for starting with a specific material's or object's characteristics and proceeds to determining whether a material or object may qualify for shipment as LSA material or SCO.

The diagrams are structured using:

a "diamond" —	which contains a question to be answered either "yes" or "no," where the text of the question does not replicate the actual regulatory text;
a "dashed box" —	which is located at the lower side of a "diamond," and provides the regulatory reference from which the question was derived;
a "solid box" —	which represents an outcome (a result); and
a "circle" —	which is a node point identifying transfer between figures.

In addition, the flow diagrams include a bold-bordered box at the upper side of many of the "diamonds" and two of the "solid boxes." The numbers in those boxes refer to the questions provided in the main body of this guidance which are pertinent to the query posed in the "diamond" or the outcome shown in the "solid box."

Once the appropriate categorization of the material or object has been reached using this process—i.e., the material or object has been successfully categorized as LSA-I, LSA-II, LSA-III, SCO-I or SCO-II—then the shipper may use Table A.1 to assist in identifying packaging options for the material or object.

Figure A.1 presents the initial steps of the categorization. Progressing through the four questions shown on the left side of the figure, one determines whether a more detailed categorization assessment is warranted. For example, if the material or object can satisfy the requirements for

regulations for packaging and transportation, and no further effort is needed. On the contrary, if the material or object is fissile or does not satisfy the 3 m radiation level requirement, then it cannot be packaged and transported in accordance with provisions for LSA or SCO, and further steps will be required beyond those addressed in this guidance.

If the material or object successfully passes the four tests described on the left side of Figure A.1, then further evaluation may be undertaken using the the right of Figure A.1. to address liquids and gases. If the intended contents of a package are not liquid or gas, then the user is directed to **"A"**, which is the beginning of Figure A.2. However, if the intended contents of a package are liquid or gas, a determination whether they can be transported as LSA-I material or LSA-II material can be made by answering four questions. If the liquid or gas cannot satisfy the four tests shown, then it cannot be transported as LSA material.

In Figure A.2, determination of whether screening as SCO should be pursued, or whether screening as LSA should be pursued. In the event that screening as SCO might be pursued, the user is directed to "**B**," which is the beginning point for Figure A.3.

For solids which can clearly not qualify as SCO as described by the first two questions of Figure A.2, the user then proceeds to assess whether the solids may qualify as LSA material. First, four separate tests are used to determine whether the material qualifies as LSA-I material. In the event that the material does not qualify as LSA-I, the user performs three tests to determine whether a material can qualify as LSA-II. If the material does not qualify as LSA-II, the user then performs up to five tests to determine whether a material can qualify as LSA-III. Failing these tests means that the material does not qualify for shipment as LSA material.

The beginning of Figure A.2 may have directed the user to evaluate whether the material (which in this case is an object or collection of objects) can be qualified as SCO *[The user is directed to **"B"** at the left side of the Figure A.2 chart].*

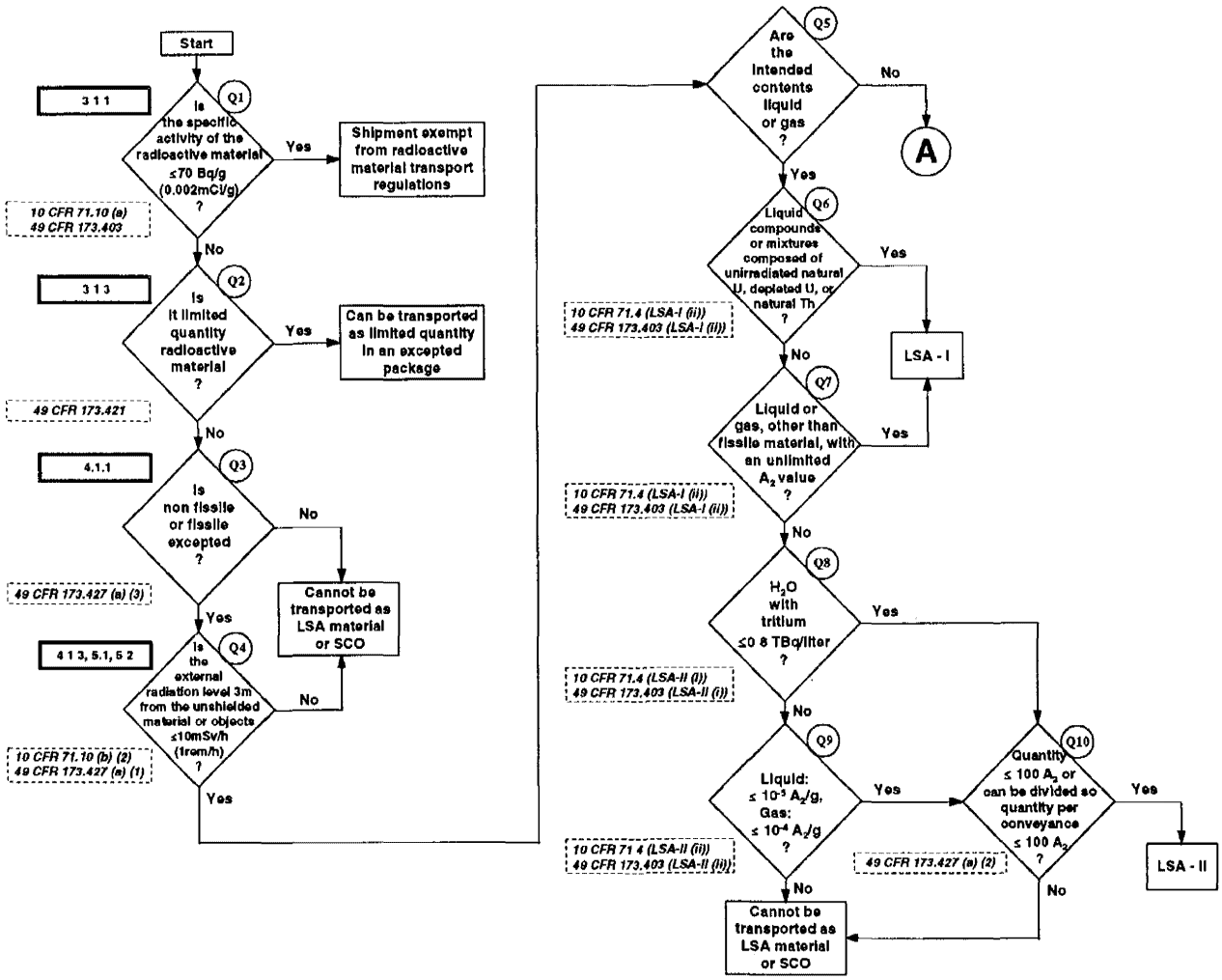

Figure A.1. Material/Object Categorization Process
Source: Oak Ridge National Laboratory

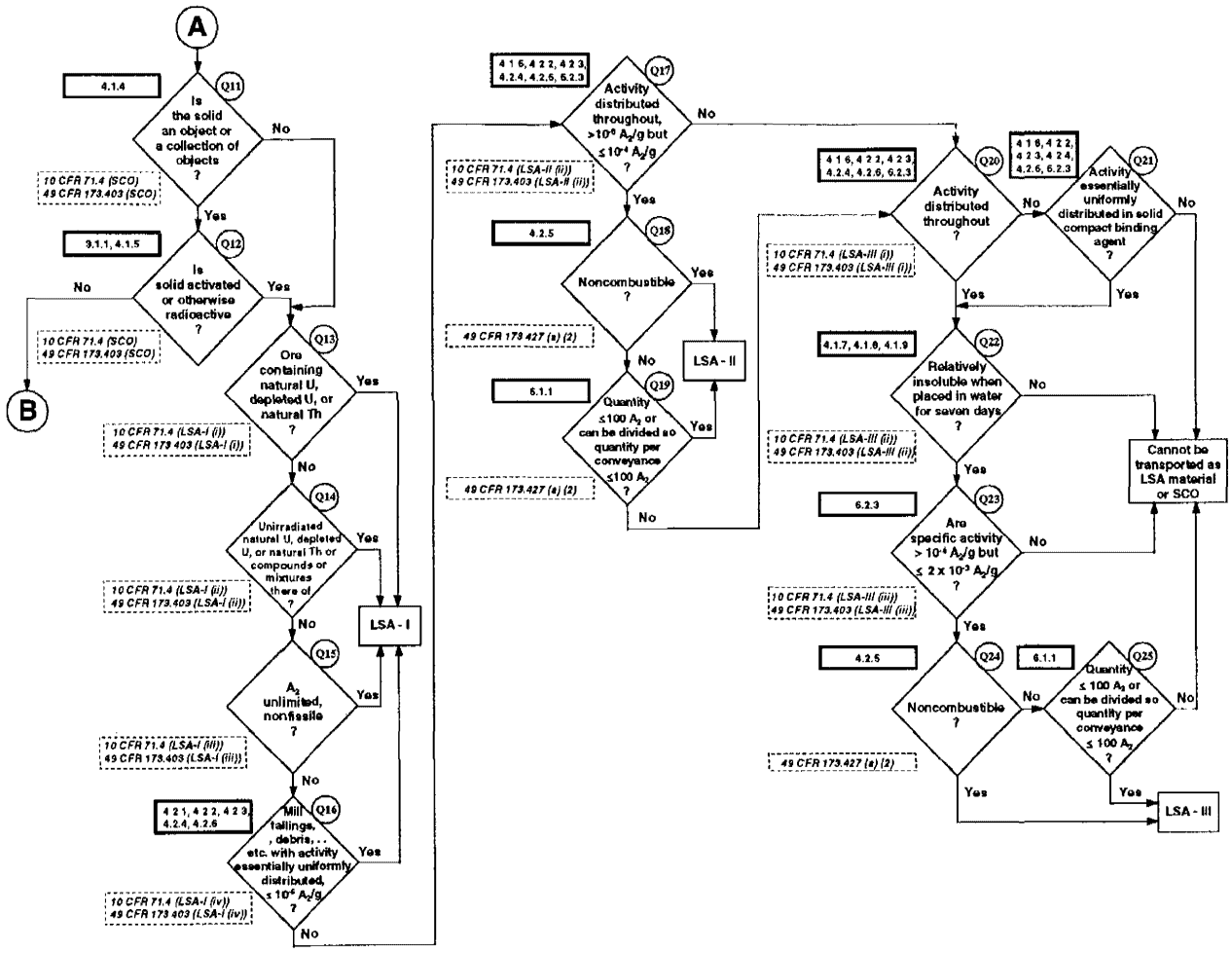

Figure A.2. Material/Object Categorization Process (Continued)
Source: Oak Ridge National Laboratory

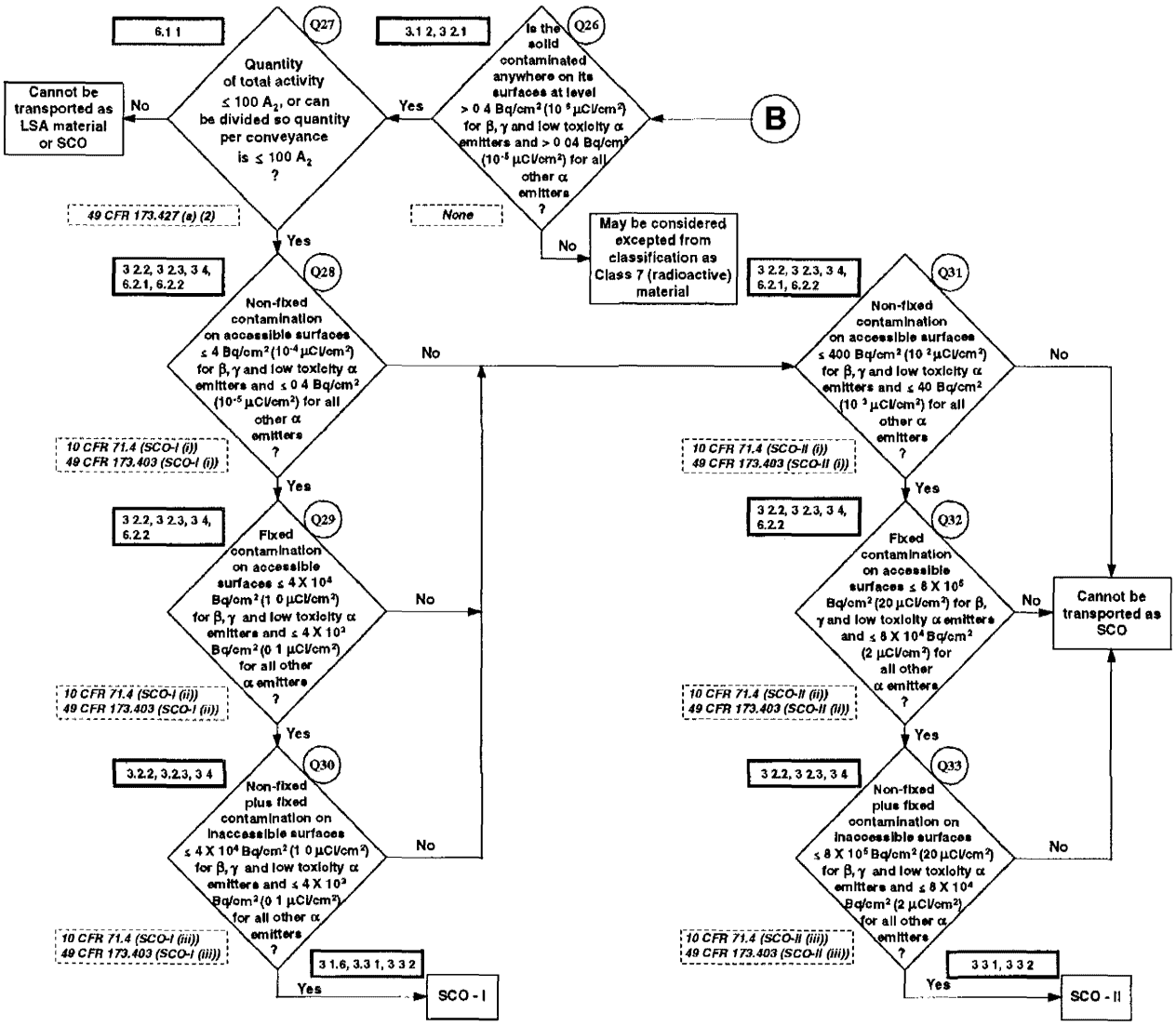

Figure A.3. Material/Object Categorization Process (Concluded)
Source: Oak Ridge National Laboratory

The logic steps for evaluating qualification as SCO are presented in Figure A.3. Here, the user follows a series of seven steps to determine whether the object(s) can qualify as SCO-I or SCO-II. Failing the tests of Figure A.3 means that the object(s) do not qualify for shipment as SCO. However, it must be noted that should the object(s) fail these tests, it (they) may still qualify as LSA material, and the user of the diagrams should consider performing the LSA-I, LSA-II and LSA-III tests on the object(s) using the steps presented in Figure A.2.

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The primary purpose of this guidance is to assist shippers in preparing low specific activity materials (LSA) and surface contaminated objects (SCOs) for shipment in compliance with Federal regulations. guidance is provided in question and answer format on the categorization, packaging and transportation of LSA and SCOs, including the definition of LSA and SCOs, the determination of distribution of activity in LSA material or on SCO surfaces, mixing LSA and SCOs in a package, radiation level measurement, and various other aspects of transporting LSA and SCOs.

There are many requirements, other than those addressed herein, imposed in the shipment of LSA and SCOs. The guidance represents one or more methods of demonstrating compliance with the regulatory requirements for LSA material and SCOs that have been found acceptable to NRC and DOT; however, additional methods may also be found to be acceptable with adequate justification.

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