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CHARACTERIZING, FOR PACKAGING AND TRANSPORT, LARGE OBJECTS CONTAMINATED BY RADIOACTIVE MATERIAL HAVING AN UNLIMITED A_2 VALUE

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SUMMARY

The International Atomic Energy Agency (IAEA) Regulations for the safe packaging and transportation of radioactive materials follow a graded approach to the requirements for both packaging and controls during transport. The concept is that, the lower the risk posed to the people and the environment by the contents, (a) the less demanding are the packaging requirements and (b) the smaller in number are the controls imposed on the transport of the material.

There are likely to be a great number of situations arising in coming years when large objects, contaminated with radioactive material having unlimited A_2 values will result from various decommissioning and decontamination (D&D) activities and will then require shipment from the D&D site to a disposal site. Such situations may arise relatively frequently during the cleanup of operations involving mining, milling, feedstock, and uranium enrichment processing facilities.

Because these objects are contaminated with materials having an unlimited A_2 value they present a low radiological risk to worker and public safety and to the environment during transport. However, when these radioactive materials reside on the surfaces of equipment and other large objects, where the equipment and objects themselves are not radioactive, the radioactive materials appear as surface contamination and, if the contaminated object is categorized as a surface contaminated object (SCO-II)—either as SCO-1 or SCO-II—it would need to be packaged for shipment according to the requirements of the Regulations for SCO. Despite this categorization, alternatives may be available which will allow these contaminants, when considered by themselves for packaging and transport, to be categorized as either (a) a limited quantity of radioactive material to be shipped in an excepted package or (b) low specific activity (LSA) materials –(SCO)–either as SCO-I or SCO-II–to be shipped in an IP-1 package or possibly even shipped unpackaged. These options, which offer alternatives to categorizing and packaging these large D&D objects either as SCO-II in IP-2 packages or as radioactive material in a Type A package, are discussed in this paper.

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INTRODUCTION

The IAEA regulations for the safe packaging and transport of radioactive materials, Safety Series No. 6, 1985 Edition (As Amended 1990) (IAEA, 1990), follow a graded approach to the requirements for both the packaging and the controls during transport. The specific concept followed in this graded approach is that, the lower the risk posed to the people and the environment by the contents of a package of radioactive material, the less demanding are the packaging requirements and the smaller in number are the controls imposed on the transport of the material. When implementing this approach, the risk posed by radioactivity that may be released from packages is correlated in the regulations through the A_1 and A_2 values of the isotopes. The A_1 and A_2 values, given in terabequerals (TBq) [and, alternatively in curies (Ci)], range from very small to unlimited values, depending upon the radiotoxicity of each individual radioisotope.

Especially within the United States, a great number of situations are likely to arise in coming years when large objects, contaminated with radioactive material having unlimited A_2 values will result from various D&D activities and will require shipment from the D&D site to a processing or disposal site. Situations such as these may arise relatively frequently during the cleanup of operations involving mining, milling, feedstock, and uranium enrichment processing facilities. For large D&D objects, categorized as SCO because of their surface contamination, some of the packaging requirements may be difficult to comply with if the equipment is physically large and awkward to handle.

Often, the equipment itself is not radioactive, but simply contaminated. A logical method for dealing with such contaminated equipment is to consider it to be an SCO and apply the rules that govern the shipment of SCO. When the radioactive contamination this equipment consists of isotopes that have an unlimited A_2 value, it is possible that the level of contamination, as measured in Bq/cm^2 (or Ci/cm^2), could be high enough on the surface so as to exceed the SCO-II limit,[2] which would require the equipment to be shipped in a Type A package. However, there are other options available according to the regulations. Radioactive materials which meet the definition of a low specific activity (LSA) non-fissile (or fissile-excepted) material and which have an unlimited A_2 value present a low radiological risk to workers, the public, and the environment during transport. Accordingly, these materials, when considered by themselves for transport, are subject to minimal packaging requirements. Therefore, if equipment is contaminated with materials having unlimited A_2 values and these contaminating materials are inherently LSA materials, the packaging requirements could be less than if this hardware were considered to be an SCO.

In this paper, two alternative concepts are explored for shipping a large piece of equipment contaminated with radioactive (non-fissile) materials having an unlimited A_2 value. Rather than

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[2] The limits for categorization as SCO-II, are (a) non-fixed contamination of <400 Bq/cm^2 for beta, gamma, and low toxicity alpha emitters, and <40 Bq/cm^2 for all other alpha emitters on accessible surfaces; (b) fixed contamination of $<8 \times 10^5$ Bq/cm^2 for beta, gamma ,and low toxicity alpha emitters, and $<8 \times 10^4$ Bq/cm^2 for all other alpha emitters on accessible surfaces; and (c) non-fixed plus fixed contamination of $<8 \times 10^5$ Bq/cm^2 for beta, gamma, and low toxicity alpha emitters, and $<8 \times 10^4$ Bq/cm^2 for all other alpha emitters on inaccessible surfaces.

considering the object as an SCO-II shipped in an IP-2 package or, when it exceeds SCO-II limits, shipped in a Type A package, the piece of equipment might be:

(a) prepared and shipped as a limited quantity in an excepted package with the object itself constituting the packaging containing the limited quantity of radioactive material that meets the applicable safety standards of an excepted packaging, or

(b) prepared as an LSA-I shipment, transported in an IP-1 package with the object itself constituting the packaging or it may even be transported unpackaged.

EXAMPLE OF LARGE OBJECTS CONTAMINATED BY RADIOACTIVE MATERIAL HAVING UNLIMITED A_2

For more than five decades, the United States has enriched uranium at facilities located at Oak Ridge, Tennessee; Portsmouth, Ohio; and Paducah, Kentucky. Ultimately, these facilities will require D&D. The low-enrichment stages of each of these plants consist of large converters. Each converter is fabricated as a large, relatively thin-walled, steel cylinder containing some inner structure and having outer diameters ranging from about 2.3 to 2.7 m (7.7 to 8.8 ft). The total number of large converters at each of the three sites are:

Oak Ridge, Tennessee	5,122
Portsmouth, Ohio	4,080
Paducah, Kentucky	1,820

These converters are used to process uranium hexafluoride, and are contaminated with uranium compounds having differing levels of enrichment. As long as the enrichment of these uranium compounds is 5% or less, IAEA Safety Series No. 6 (IAEA, 1990) indicates that the material has an unlimited A_2 value.[3] Thus, the material, particularly in the larger converters, offers the potential for qualifying as LSA-I material.

Once the converters are taken out of service, air with entrained water vapor will leak into them and react with the UF_6. In time, the uranium that contaminates the inner surfaces of these objects will consist of the decomposition products of UF_6 such as UO_2F_2 and UF_5, the daughter products of uranium, and possibly other contaminants that result from enriching recycled uranium. The material inside the converters should individually qualify as LSA material, and it may be assumed to have an unlimited A_2 value as long as the level of other contaminants in the material are sufficiently low.

Finally, it is noted that for each converter to be transported, there will also be a contaminated compressor which will require shipment, which are sometimes as large as the converters, and which may be treated in a fashion similar to that proposed in this paper for converters.

[3] The newly issued IAEA regulations (IAEA, 1996) have increased this level to 20%.

CONCEPT FOR TRANSPORT OF LARGE OBJECTS CONTAMINATED WITH UNLIMITED A_2 RADIOACTIVITY IN AN EXCEPTED PACKAGE

For large objects such as uranium enrichment plant converters (and their associated compressors), regardless of whether the contamination levels are within, or even above, SCO-II limiting values, an alternative may be to consider categorizing their contents as a limited quantity to be shipped in an excepted package. That is, when the object itself (e.g., the converter) can be prepared and shown to satisfy the requirements of the excepted package. In this alternative, a number of conditions must be satisfied, including the following:

- The radioactive contamination in the object must have an unlimited A_2 value. If the contamination is a mixture of materials, some of which do not have an unlimited A_2 value, the A_2 value for the mixture [as calculated from the equation given in paragraph 304 of Safety Series No. 6 (IAEA, 1990)] must be sufficiently low such that the total activity in the object is less than 10^{-3} A_2, as specified in paragraph 419 and Table IV of Safety Series No. 6 (IAEA, 1990).

- The other dangerous properties of the contents must be considered [paragraphs 105 and 407 of Safety Series No. 6 (IAEA, 1990)]. This will mean that if the contents have properties of other dangerous goods (such as a corrosive solid might have), it will be given a proper shipping name defined by that dangerous goods property will be labeled and marked accordingly, and will need to satisfy the packaging requirements for the additional hazard (i.e., satisfying PGI, PGII on PGIII criteria, as appropriate).

- The object must be sealed, and the behavior of the sealed object must be assessed to demonstrate that it can satisfy the General Requirements for all packagings and packages [paragraphs 505—514 of Safety Series No. 6 (IAEA, 1990)]. This preparation and assessment must specifically address the handling and securement to the conveyance of the object and its ability to withstand the effects of acceleration and vibration during routine transport.

- The contents must be shown to satisfy the "fissile-excepted" requirements of paragraph 560 of Safety Series No. 6 (IAEA, 1990). This will mean that either the large object must contain less than 15 g of fissile material or that the material is enriched to less than 1% in ^{235}U (by mass), with limitations also on any total plutonium and ^{233}U that might be contained in the object. The other excepting criteria in paragraph 560 might also be considered (e.g., not having more than 5g of fissile material in any 10 litre volume).

- The radiation level at any point on the external surface of the object, when prepared as the package for transport, cannot exceed 5 μSv/h (0.5 mrem/h) according to paragraph 415 of Safety Series No. 6 (IAEA, 1990).

- The contamination level on the external surfaces of the object will need to be less than 0.4 Bq/cm^2 for beta, gamma and low toxicity alpha emitters and less than 0.04 Bq/cm^2 for all other alpha emitters. These are values which are 10% of that allowed on other

packages, and they are imposed pursuant to the requirements of paragraph 417 of Safety Series No. 6 (IAEA, 1990).[4]

When the consignor can demonstrate that these five requirements are satisfied, then it may be possible to ship the sealed, contaminated object as an excepted package. Under these conditions, the extensive efforts to quantify internal contamination levels to demonstrate that the object can be shipped, or packaged for shipment, as SCO-II in an IP-2 would not be required.

CONCEPT FOR TRANSPORT OF LARGE OBJECTS CONTAMINATED WITH UNLIMITED A_2 RADIOACTIVITY AS LSA MATERIAL

An alternative to shipping as an excepted package is to consider shipping converters with contents categorized as LSA-I material. In this alternative, which would apply only when the radioactive contamination of an object can be demonstrated to have an unlimited A_2 value, the object itself, if it were sealed to prevent loss of any contamination under routine operating conditions and met certain minimum structural standards for IP-1 packages, would be adequate to also act as the shipping packaging.

In this categorization concept, two packaging options are allowed according to provisions in the international regulations, because material having an unlimited A_2 value:

- may be transported in an IP-1 package [see Table V of Safety Series No. 6 (IAEA, 1990)]; or

- may be transported unpackaged [see paragraph 425 of Safety Series No. 6 (IAEA, 1990)] subject to specific requirements (e.g., containment and retention of shielding during routine transport, and shipment under exclusive use).

In applying this concept, the consignor offering such an object, with its LSA-I contents, for transport without additional packaging would have to demonstrate that the object, as prepared for shipment, either (a) satisfies the general requirements for all packagings [specifically, the requirements specified in paragraphs 505 through 514 of Safety Series No. 6 (IAEA, 1990)], or (b) the requirements for shipping LSA-I unpackaged as specified in paragraph 425 of Safety Series No. 6.

To qualify the sealed converter as an IP-1 package, the consignor would need to perform necessary analyses and document the expected behavior of the contaminated object, including demonstrating that:

(a) it can be easily and safely handled and transported and can be properly secured in or on the conveyance [paragraph 505 of Safety Series No. 6 (IAEA, 1990)];

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[4] The requirement for reduced contamination levels on excepted packages has been modified in the new IAEA regulations (IAEA, 1996), increasing the levels allowed by an order of magnitude, making them consistent with those required for other packages. Once these are adopted into IAEA Member State regulations, satisfaction with this requirement will become easier.

(b) any lifting attachments will function properly and should they fail the package will satisfy all other applicable requirements of Safety Series No. 6 [paragraphs 506 and 507 (IAEA, 1990)];

(c) the outside of the sealed converter is free from projections, can be easily decontaminated, and does not readily collect and retain water [paragraphs 508 and 509 of Safety Series No. 6 (IAEA, 1990)]; and

(d) it can withstand without deterioration the effects of acceleration, vibration, etc. arising from the routine conditions of transport.

In contrast, to qualify the sealed converter for transport under the provision of paragraph 425 (i.e., that the LSA-I material is shipped "unpackaged"), the consignor would need to perform necessary analyses and document that, when the sealed converter is exposed to conditions likely to be encountered in routine transport, that:

(a) there would be no escape of the LSA-I contents from the conveyance (here, the converter would be considered to be part of the conveyance) [paragraphs 425(a) and 425(c) of Safety Series No. 6 (IAEA, 1990)], and

(b) should any shielding be required, there would be no loss of shielding under routine conditions of transport. In addition, the shipment would need to be accomplished under exclusive use.

It is noted that the international provision which allows the shipment of "unpackaged" LSA-I material is very similar to a provision in the U.S. regulations which allows the shipment of LSA-I material in "bulk packagings." Specifically, the U.S. Department of Transportation (DOT) regulations allow LSA-I material to be shipped domestically in bulk packaging so that, under conditions "normally incident to transport," [49 CFR Part 173.427(c)] various requirements must be satisfied (49 CFR Part 173.24), including the requirements that:

(a) there will be no release of contents to the environment, and

(b) the effectiveness of the package must be maintained over the temperature range encountered during transport.

It seems reasonable that the robust nature of the UF_6 converter structure, when appropriately sealed for transport, should be capable of serving the functions outlined above, so that the LSA-I material contents of the converters, when considered with the converters themselves, can either be shipped—internationally—"unpackaged," or—domestically within the United States—as being in "bulk packagings."

Two options discussed have for categorizing large objects, contaminated internally with radioactive materials which have unlimited A_2 values have been discussed. These options consider categorizing an object as either:

(a) containing a limited quantity of radioactive material shipped in an excepted package, when the object itself can serve as the packaging; or

(b) an LSA-I material shipped either (i) in an IP-1 package when the object can be demonstrated to be capable of satisfying the requirements for an IP-1 packaging, or (ii) unpackaged, when the object can be demonstrated to be capable of functioning as part of the conveyance.

Consideration of these options potentially offer a cost-effective, safe and fully regulatory compliant way of shipping.

HISTORICAL NOTE

Historically, it is noted that there have been instances when such shipments have occurred. For example, a large converter was recently shipped from the facility in Oak Ridge, Tennessee, USA, which was categorized as a limited quantity of radioactive material and transported in an excepted packaging where the converter—properly sealed—functioned as the excepted packaging. In this case, the radiation level on the surface of the package did not exceed 2 μSv/h (0.2 mrem/h), well within the limits specified in paragraph 415 of Safety Series No. 6 (IAEA, 1990) for transport of excepted packages. In addition, the non-fixed (removable) contamination of beta, gamma and low toxicity alpha emitters on the external surface of the converter—as prepared for shipment—did not exceed 1.1 Bq/cm^2; which is only 25% of the limit specified for limited quantity shipped in an excepted package as specified in the new IAEA regulations (IAEA, 1996), and which is consistent with current U.S. Department of Transportation regulations.

CONCLUSION

Because of the large number of UF_6 converters and compressors from gaseous diffusion plants which will ultimately require D&D, both in the United States and elsewhere in the world where uranium enrichment has occurred or is occurring, the detailed methodology for demonstrating (a) that the sealed converters can prevent release of the internal contamination under routine conditions of transport and (b) that the other requirements to ship as a limited quantity or as LSA-I material, should be aggressively pursued and documented as a possible option for shipping.

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