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Draft Regulatory Analysis of Major Revision of 10 CFR Part 71

Proposed Rule

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Prepared by:
D. Hammer, H. Finkel, K. Blake

ICF Consulting, Inc.
9300 Lee Highway
Fairfax, Va 22031-1207

N. Tanious, NRC Project Manager

Prepared for
Division of Industrial and Medical Nuclear Safety
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
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ABSTRACT

This report presents the regulatory analysis of the Nuclear Regulatory Commission's (NRC or Commission) rulemaking that would modify 10 CFR Part 71 requirements pertaining to the packaging and transport of radioactive materials, including fissile materials. The rulemaking is intended to: (1) harmonize 10 CFR Part 71 with the most recent transportation standards established by the International Atomic Energy Agency (IAEA), and the U.S. Department of Transportation's (DOT) requirements at 49 CFR; and (2) address the Commission's goals for risk-informed regulations and eliminating inconsistencies between Part 71 and other parts of 10 CFR. This report includes: (1) a summary of the findings, (2) a discussion of the regulatory options analyzed, (3) an assessment of the estimate values (benefits) and impacts (costs) identified for each regulatory option, (4) a rationale for the determination of the preferred option, and (5) supplementary information and analyses used in the development of this report. Based on this analysis, none of the 19 potential changes evaluated are expected to result in significant impacts. In fact, the analysis indicates that most of the changes will have negligible effects or result in slight increases in values.

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ABBREVIATIONS

ANI	Authorized Nuclear Inspector
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
Bq	Becquerel
CFR	Code of Federal Regulations
Ci	Curie
CoC	Certificate of Compliance
CRP	Coordinated Research Project
CSI	Criticality Safety Index
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
g	Gram
GSA	U.S. General Services Administration
HLW	High Level Waste
IAEA	International Atomic Energy Agency
ICC	Interstate Commerce Commission
INEEL	Idaho National Engineering and Environmental Laboratory
ISFSI	Indpendent Spent Fuel Storage Installation
LDM	Low Dispersible Material
LSA-III	Low Specific Activity
MOU	Memorandum of Understanding
NMSS	U.S. NRC Office of Nuclear Material Safety and Safeguards
NON	Notice of Non-compliance
NORM	Naturally Occurring Radioactive Material
NOV	Notice of Violation
NRC	U.S. Nuclear Regulatory Commission
NUREG	Nuclear Regulatory Publication
ORNL	Oak Ridge National Laboratory
PE	Licensed Professional Engineer
PGE	Portland General Electric
PRM	Petition for Rulemaking
QA	Quality Assurance
Rem	Roentgen Equivalent Man
SI	Systeme` Internationale
SMAC	Shipment Mobility/Accountability Collection
SSC	Systems, Structures, and Components
Sv	Sievert
TI	Transport Index
TS-R-1	IAEA Safe Transportation Standards
μCi/g	Microcuries per gram
UF_6	Uranium Hexafluoride
U.S.	United States
USEC	United States Enrichment Company

GLOSSARY

A_1 means the maximum activity of special form radioactive material permitted in a Type A package. These values are listed in Appendix A or Table A-1 of 10 CFR Part 71 and may be derived in accordance with the procedure prescribed in Appendix A of 10 CFR Part 71.

A_2 means the maximum activity of radioactive material, other than special form, LSA and SCO material, permitted in a Type A package. These values are listed in Appendix A or Table A-1 of 10 CFR Part 71 and may be derived in accordance with the procedure prescribed in Appendix A of 10 CFR Part 71.

Becquerel means the special unit of activity in the SI system, equal to 1 disintegration per second.

Certificate holder means a person who has been issued a certificate of compliance or other package approval by NRC.

Committed dose equivalent means the total dose equivalent (averaged over a given tissue) deposited over the 50-year period following the intake of a radionuclide.

Committed effective dose equivalent means the weighted sum of committed dose equivalents to specific organs and tissues, in analogy to the effective dose equivalent.

Consignee means any person, organization, or government which receives a consignment.

Consignment means any package or packages, or load of radioactive material, presented by a consignor for transport.

Consignor means any person, organization, or government which prepares a consignment for transport, and is named as consignor in the transport documents.

Conveyance means any vehicle for transport by road or rail, any vessel for transport by water, and any aircraft for transport by air.

Criticality Safety Index means a number which is used to provide control over the accumulation of packages, overpacks, or freight containers containing fissile material.

Curie means the unit of radioactivity, equal to the amount of a radioactive isotope that decays at the rate of 3.7×10^{10} disintegrations per second.

Dose equivalent means the product of the absorbed radiation dose, the quality factor for the particular kind of radioactivity absorbed, and any other modifying factors. The SI unit of dose equivalent is the sievert (Sv) and the English or conventional unit is the rem.

Effective dose equivalent means the sum over specified tissues of the products of the dose equivalent in a tissue or organ and the weighting factor for that tissue or organ.

Exclusive use means sole use by a single consignor of a conveyance for which all initial, intermediate, and final loading and unloading are carried out in accordance with the direction of the consignor or consignee. The consignor and the carrier must ensure that any loading or unloading is performed by personnel having radiological training and resources appropriate for

safe handling of the consignment. The consignor must issue specific instructions in writing for maintenance of exclusive use shipment controls, and include them with the shipping paper information provided to the carrier by the consignor.

Exempt packages means packages exempt from the requirements of 10 CFR Part 71.

Fissile material means plutonium-238, plutonium-239, plutonium-241, uranium-233, uranium-235, or any combination of these radionuclides. Unirradiated natural uranium and depleted uranium, and natural uranium or depleted uranium that has been irradiated in thermal reactors only are not included in this definition. Certain exclusions from fissile material controls are provided in 10 CFR Part 71.53.

Licensed material means by-product, source, or special nuclear material received, possessed, used, or transferred under a general or specific license issued by NRC pursuant to 10 CFR Part 71.

Low dispersible radioactive material means either a solid radioactive material or a solid radioactive material in a sealed capsule, that has limited dispersibility and is not in powder form.

Low Specific Activity (LSA) material means radioactive material with limited specific activity that satisfies the descriptions and limits set forth in 10 CFR Part 71.4. Shielding materials surrounding the LSA material may not be considered in determining the estimated average specific activity of the package contents.

Non-special form (or normal form) radioactive material means radioactive material that has not been demonstrated to qualify as "special form radioactive material," as defined below.

Q system is a series of models to consider radiation exposure routes to persons in the vicinity of a package involved in a hypothetical severe transport accident. The five models are for external photon does, external beta dose, inhalation dose, skin and ingestion dose due to contamination transfer, and submersion in gaseous isotopes dose.

Radioactive material means any material having a specific activity greater than 70 Bq per gram (0.002 microcurie per gram).

Radionuclide means the type of atom specified by its atomic number, atomic mass, and energy state that exhibits radioactivity.

Special arrangement means those provisions, approved by the competent authority, under which consignments which do not satisfy all the applicable requirements may be transported.

Special form radioactive material means either an indispersible solid radioactive material or a sealed capsule containing radioactive material.

Specific activity of a radionuclide means the activity of the radionuclide per unit mass of that nuclide. The specific activity of a material in which the radionuclide is essentially uniformly distributed is the activity per unit mass of the material.

Surface contaminated object (SCO) means a solid object which is not itself radioactive, but which has radioactive material distributed on its surfaces.

Transport Index (TI) means the dimensionless number (rounded up to the next tenth) placed on the label of a package, to designate the degree of control to be exercised by the carrier during transportation. The TI is determined as specified in 10 CFR Part 71.4.

Type A package means a packaging that, together with its radioactive contents limited to A_1 or A_2 as appropriate, meets the requirements of 49 CFR 173.410 and 173.412, and is designed to retain the integrity of containment and shielding required by this part under normal conditions of transport.

Type B package means a Type B packaging together with its radioactive contents. A type B package design is designated by NRC as B(U) unless the package has a maximum normal operating pressure of more than 700 kPa (100 lb/in2) gauge or a pressure relief device that would allow the release of radioactive material to the environment under tests specified in 10 CFR Part 71.73, in which case it will receive a designation B(M). B(U) refers to the need for unilateral approval of international shipments. B(M) refers to the need for multilateral approval of international shipments. To determine this distinction see DOT regulations in 49 CFR Part 173.

Type C package means a new package type described in IAEA's ST-1 that could withstand severe accident conditions in air transport without loss of containment or increase in external radiation.

EXECUTIVE SUMMARY

This document presents the Regulatory Analysis of the U.S. Nuclear Regulatory Commission's (NRC or Commission's) proposed rulemaking that would modify Title 10 of the Code of Federal Regulations, Part 71 (10 CFR Part 71) requirements pertaining to the packaging and transport of radioactive materials, including fissile materials. The rulemaking is intended to:

(1) Harmonize transportation regulations found in 10 CFR Part 71 with the most recent transportation standards established by the International Atomic Energy Agency (IAEA) (*Regulations for the Safe Transport of Radioactive Material*, IAEA Safety Standards Series No. TS-R-1, June 2000), and the U.S. Department of Transportation's requirements at 49 CFR; and

(2) Address the Commission's goals for risk-informed regulations and eliminate inconsistencies between Part 71 and other parts of 10 CFR.

The intended effects of the regulatory action are to develop a level of consistency with other regulatory agencies, and to implement other NRC-initiated changes needed to simplify the regulations applicable to licensees shipping radioactive materials, while maintaining adequate protection of public health, safety, and the environment. The rulemaking would accomplish these objectives by adopting a number of requirements that are consistent with the safe transportation standards contained in IAEA's TS-R-1, implementing other non-IAEA related changes, and implementing a number of recommendations contained in NUREG/CR-5342 (*Assessment and Recommendations for Fissile-Material Packaging Exemptions and General Licenses Within 10 CFR Part 71,* Oak Ridge National Laboratory, July 1998). The proposed rulemaking addresses a total of 19 issues.

Table ES-1 provides a summary of the preferred option for each of the 19 individual issues described in Chapter 2 and analyzed in Chapter 3 of this document. In the paragraphs following this table, further description of the values and impacts of the options is provided. Chapters 2 and 3 provide additional detail on the changes and associated values and impacts.

For purposes of this analysis, the proposed rulemaking has been grouped into 19 different potential changes to Part 71, which could be adopted either all together as one list or independently in a partial list. None of the 19 potential changes, which are described and evaluated in turn in the remainder of this report, are expected to result in significant impacts (costs), whether promulgated individually or together. In fact, most of the changes would have negligible effects or result in slight increases in values (benefits). In particular, the following changes are primarily administrative in nature and would result in the beneficial effect of simplifying and/or harmonizing the NRC's regulations with the latest international standards:

- Changing Part 71 to the International System of Units (SI) Only (see Sections 2.1.1 and 3.3.1);
- Revision of A_1 and A_2 (see Sections 2.1.3 and 3.3.3);
- A new requirement to display the Criticality Safety Index on shipping packages of fissile material (see Sections 2.1.5 and 3.3.5);

Table ES-1. Summary of Preferred Options

Technical Issue		Preferred Option
1.	Changing Part 71 to the International System of Units (SI) Only	Option 1 (No Action)
2.	Radionuclide Exemption Values	Option 2
3.	Revision of A_1 and A_2	Option 2
4.	Uranium Hexafluoride Package Requirements	Option 2
5.	Introduction of the Criticality Safety Index Requirements	Option 2
6.	Type C Packages and Low Dispersible Material	Option 1 (No Action)
7.	Deep Immersion Test	Option 2
8.	Grandfathering Previously Approved Packages	Option 2
9.	Changes to Various Definitions	Option 2
10.	Crush Test for Fissile Material Package Design	Option 2
11.	Fissile Material Package Designs for Transport by Aircraft	Option 2
12.	Special Package Authorizations	Option 2
13.	Expansion of Part 71 Quality Assurance Requirements to Certificate of Compliance (CoC) Holders	Option 2
14.	Adoption of ASME Code	Option 1 (No Action)
15.	Change Authority	Option 2
16.	Fissile Material Exemptions and General License Provisions	Option 2
17.	Double Containment of Plutonium (PRM-71-12)	Option 2
18.	Contamination Limits as Applied to Spent Fuel and High Level Waste (HLW) Packages	For information only. No options identified.
19.	Modifications of Event Reporting Requirements	Option 2

- A provision to “grandfather” older shipping packages under the Part 71 requirements in existence when their Certificates of Compliance (CoC) were issued (see Sections 2.1.8 and 3.3.8);

- Procedures for approval of special arrangements for shipment of special packages (see Sections 2.2.1 and 3.4.1);

- Modifications to Event Reporting Requirements (see Sections 2.2.8 and 3.4.8).

IAEA-Related Changes

The proposed changes to harmonize Part 71 with TS-R-1 are expected to result in a net benefit in terms of regulatory efficiency, which will result in reduced costs. In addition, the change to various definitions would result in clarification of the requirements, thus slightly reducing burden for licensees. In whole, however, each potential change will result in mixed, but overall minor, effects. Due to a lack of quantitative data it is not possible to describe the net value or impact of each potential change in terms of costs. The following paragraphs describe the preferred option for each issue, and further provide a qualitative summary of the values and impacts associated with the changes.

Changing Part 71 to the International System of Units (SI) Only. The preferred option is Option 1, the No-Action alternative. As described in section 3.3.1, the change to the use of SI units only would result in minor values and impacts. While regulatory efficiency would be increased, the change could result in additional exposure of workers and the public to radiation due to possible flawed conversions from SI units to customary units. However, the frequency to which these individuals are exposed to radiation is not expected to increase because transportation accident frequency would not increase as a result of this change. Finally, additional costs would be incurred by licensees, the NRC, and other government agencies to implement the change.

Radionuclide Exemption Values. The preferred option is Option 2. Under this option, NRC would adopt the radionuclide exemption values contained in TS-R-1. Adoption of the TS-R-1 radionuclide exemption values is expected to have minor benefits as well as impacts (see Section 3.3.2). Licensees may incur some minor administrative costs as well as costs to determine whether exemption levels are met. However, these costs are outweighed by the increase in regulatory efficiency between regulatory agencies and the facilitation of international shipments of exempted packages.

Revision of A_1 and A_2. The preferred option is Option 2. Option 2 recommends the adoption of the newly revised A_1 and A_2 values in TS-R-1, with the exception of the values for ^{99}Mo and ^{252}Cf. Overall, it is expected that there would be a slight benefit in terms of potential exposure as a result of changing to the more refined values contained in TS-R-1 (see Section 3.3.3). Minor costs could be realized by licensees, the NRC, and other government agencies as a result of this change. In particular, licensees could incur implementation costs if licensees must revise various aspects of shipping programs or modify shipping processes to assure compliance with the proposed A_1 and A_2 values. These one-time costs, however, are expected to be minimal and are outweighed by the benefit of reduction in potential exposure.

Uranium Hexafluoride (UF_6) Package Requirements. Option 2 is the preferred option. NRC would promulgate a new section 71.55(g), consistent with the UF_6 exception requirements contained in TS-R-1, while restricting the use of this exception to packages with a maximum enrichment of 5 weight percent ^{235}U. Adoption of Option 2 (see Section 3.3.4) is expected to have mixed effects. Risk of exposure is expected to decrease slightly, while implementation and operational costs for licensees are expected to increase. Regulatory efficiency also would show a slight increase with respect to international shipments, and thus provide a slight net reduction in costs to the NRC. Further, damage to the environment will be less likely to occur due to radiation in the event of a vehicular accident that results in a fire. Overall, the net reduction in risk, potential exposure, and environmental damage is expected to be greater than the additional implementation and operational costs for licensees.

Introduction of the Criticality Safety Index Requirements. Option 2, the preferred option, would require labels indicating both the Transportation Index (TI) and the Criticality Safety Index

(CSI) for transport of fissile material packages. The addition of the CSI in transport (see Section 3.3.5) is expected to result in minor implementation and operational costs for licensees, while providing a benefit to emergency responders in the case of transportation accidents. Additional benefits would be realized by the NRC for international shipments because regulatory efficiency would be increased.

Type C Packages and Low Dispersible Material. The preferred option is Option 1, the no-action alternative. Under this option, NRC would not adopt the Type C package or low dispersible radioactive material concepts for air transportation contained in TS-R-1. Incorporation of these concepts would result in an increase in regulatory efficiency as a result of the adoption of the TS-R-1 requirements, which would facilitate international shipments (see Section 3.3.6). Additional resource costs would, however, be incurred by NRC and the licensees. These additional costs to licensees would include implementation costs for the design of new packages to meet the Type C requirements rather using existing Type B packages. However, NRC currently has in place, requirements governing domestic shipments of plutonium by air (which would be shipped in the new Type C packages), and because there are very few shipments of this nature, there is little need for this new type of package design in domestic commerce. As a result, the potential impacts outweigh the benefits of adopting these concepts.

Deep Immersion Test. Option 2 is the preferred option. Option 2 recommends revising Part 71 to require an enhanced water immersion test for transporting packages containing radioactive materials with activity greater than 10^5 A_2. Requiring an enhanced deep immersion test (see Section 3.3.7) would improve regulatory efficiency by bringing U.S. regulations in harmony with the standards contained in TS-R-1. This would improve the efficiency of handling imports and exports and would make U.S. standards compatible with other IAEA member states. However, the requirement could result in costs to licensees as they test and certify packages to the proposed standard. The NRC also may incur costs for developing procedures, reviewing and approving test results, and recertifying packages. Alternatively, the proposed change may reduce impacts to public health in the case of an accident. Adoption of the change would prevent the possible expenses of restricting the accident area (to prevent users such as boaters or fishers from entering the vicinity) and remediating any contamination of the marine environment. The net effect is that the values of adopting Option 2 outweigh the potential costs to licensees.

Grandfathering Previously Approved Packages. The preferred option is Option 2. Option 2 would modify Part 71 to phase out packages approved under IAEA Safety Series 6 (1967). This option would include a 3-year transition period for the grandfathering provision on packages approved under Safety Series 6. In addition, packages approved under Safety Series 6 (1985) would not be allowed to be fabricated after December 31, 2006. The purpose of grandfathering is to minimize the costs and impacts of implementing changes in the regulations on existing package designs and packagings. The proposed revisions related to grandfathering of previously approved packages (see Section 3.3.8) would result in enhanced regulatory efficiency by bringing NRC's requirements in harmony with those contained in TS-R-1. The proposed change would, however, result in implementation costs to the NRC because the Agency would have to revise regulatory guides and NUREG-series documents. The change could result in implementation and operation costs to Agreement States if they adopt and implement parallel requirements. While minimal costs may be realized by licensees, it is expected that, the overall expected benefits outweigh the additional potential costs.

Changes to Various Definitions. Option 2 is the preferred option. Under Option 2, NRC would add various definitions to 10 CFR 71.4 and modify existing definitions to ensure compatibility with definitions found in TS-R-1, and to improve clarity in NRC regulations. These changes would provide greater internal consistency with other NRC regulations and greater compatibility with TS-R-1, thus improving regulatory efficiency (see Section 3.3.9). By modifying existing definitions and adding new definitions, licensees also will benefit through more effective understanding of the requirements of Part 71. The changes would result in implementation costs to the NRC, with respect to revisions necessary to regulatory guides and NUREG-series documents. The changes could affect Agreement States in a similar fashion. However, the increased regulatory efficiency and greater clarification for licensees outweigh the costs to NRC.

Crush Test for Fissile Material Package Design. The preferred option is Option 2. Option 2 recommends adoption, in part, of the TS-R-1 requirement for a crush test for radioactive contents of Type B packages greater than 1000 A_2. In addition, Option 2 would extend the crush test requirement to fissile material package designs regardless of the level of radioactive contents. Adoption of Option 2 (see Section 3.3.10) would result in enhanced regulatory efficiency by correcting inconsistencies between Part 71 requirements and TS-R-1. However, further information on the impact of the TS-R-1 requirement for fissile material package testing is required. The change also would result in implementation costs imposed on licensees to demonstrate compliance and may lead to the redesign of packages. Lastly, the change would result in NRC implementation costs associated with modifying the regulations and revising guidance documents.

Fissile Material Package Designs for Transport by Aircraft. Option 2, the preferred option, would result in the adoption of the TS-R-1 criticality evaluation requirements for shipment of fissile packages by aircraft. Option 2 would provide the NRC with the regulatory framework for approving package designs that will be used internationally (see Section 3.3.11). NRC costs would be reduced while maintaining consistency with international requirements, thus enhancing regulatory efficiency. Shippers will be required to meet these requirements even if the NRC does not adopt them, because the International Civil Aviation Organization (ICAO) is adopting regulations consistent with TS-R-1 effective July 1, 2001; thus, no additional costs are imposed on licensees. Further, some U.S. domestic air carriers are already requiring compliance with the ICAO regulations even for domestic shipments.

NRC-Initiated Changes

Special Package Authorizations. Option 2 is the preferred option. Under this option, NRC would incorporate new regulations in Part 71 that address approval for shipment of special packages and that demonstrate an acceptable level of safety. Incorporation of the new regulations (see Section 3.4.1) would result in enhanced regulatory efficiency by standardizing the requirements for special package approval to provide greater regulatory certainty and clarity. It also would ensure consistent treatment among licensees requesting authorization for shipment of special packages. Since the change is expected to streamline the process for handling nonstandard packages, considerable savings would be realized, both in NRC staff time and licensee staff time. Further, the regulations would require a demonstration of an acceptable level of safety for shipment of these packages, and the result is expected to be a decreased risk of radiation exposure to the public and workers as opposed to the shipment alternatives.

Expansion of Part 71 Quality Assurance Requirements to Certificate of Compliance (CoC) Holders. The preferred option is Option 2. Option 2 recommends that NRC explicitly subject CoC holders and CoC applicants to the requirements contained in 10 CFR Part 71. NRC also would add recordkeeping and reporting requirements for CoC holders and CoC applicants. Adoption of the change for bringing CoC holders and applicants under authority of Part 71 (see Section 3.4.2) would ensure that Part 71 is more consistent with other NRC regulations (thus enhancing regulatory efficiency) in that certificate holders and applicants for a CoC would be responsible for the behavior of their contractors and subcontractors. CoC holders and applicants for a CoC will incur costs associated with understanding and implementing the new regulations, as well as in preparing and submitting reports. NRC will incur costs associated with supervising certificate holders and applicants for a CoC and maintaining and reviewing the records for certificate holder submittals. Overall, the increased efficiency and improved consistency with other NRC regulations outweigh the potential costs to CoC holders and applicants.

Adoption of ASME Code. Option 1, the No-Action alternative, is the preferred option. The adoption of the changes to incorporate the ASME Code (see Section 3.4.3) would result in additional implementation and operational costs to licensees. Adoption of this code is expected to result in some benefit with respect to public health. However, because of the potential for the ASME code to be revised over the next several years, adoption at this time could result in additional costs to both NRC and licensees should the regulations need to be revised in the future.

Change Authority. Option 2 is the preferred option. Option 2 would revise Part 71 to add a new general license section for dual-purpose packages (i.e., packages designed for both shipment and storage of spent nuclear fuel) and a new subpart which provides requirements for submission, approval, and amendment of these new packages. In addition to providing a new process for approving dual-purpose transportation packages, the new requirements would provide authority for certificate holders to make changes to a dual-purpose package design without prior NRC approval. The subpart also would include new requirements for submitting and updating a final safety analysis report describing the package's design. Adoption of this change authority would result in implementation and operational costs to licensees associated with understanding and implementing this change in licensing requirements. Licensees and CoC holders also will incur costs when submitting reports every 24 months. However, the licensees and CoC holders will realize cost savings associated with preparing license amendments and paying fees to NRC that are required under current regulations. NRC will incur some costs in reviewing reports submitted by licensees and CoC holders, but these costs will be offset by increased regulatory efficiency resulting from a clearer and more consistent interpretation between NRC, licensees, and CoC holders. As a result, NRC would be able to better direct resources that would be spent reviewing license amendments to areas where measurable improvements in safety can be made.

Fissile Material Exemptions and General License Provisions. The preferred option is Option 2. Option 2 recommends adoption of a subset of the 17 recommendations contained in NUREG/CR-5342, *Assessment and Recommendations for Fissile-Material Packaging Exemptions and Licenses Within 10 CFR Part 71*. The effects of adoption of the recommended changes would be both positive and negative, depending on the specific recommendation (see Section 3.4.5). Recommendations 1, 2, and 5 would enhance regulatory efficiency due to increased clarity of NRC regulations. Recommendations 3, 4, 6, 9, and 12 would increase costs to licensees. Recommendations 7, 8, 10, 13, 14, 15, and 16 would eliminate the potential

for criticality accidents, which would, in turn, yield environmental and public health and safety benefits. Finally, recommendations 11 and 17 would result in savings to licensees.

Double Containment of Plutonium. Option 2 is the preferred option. Under Option 2, NRC would adopt, in part, the recommended action of Petition PRM-71-12. Specifically, NRC would remove the double containment requirement of section 71.63(b). However, the NRC would retain the package contents requirement in section 71.63(a) — for shipments whose contents contain greater than 0.74 TBq (20 Ci) of plutonium must be made with the contents in solid form. Adoption of the change for the double containment of plutonium (see Section 3.4.6) would result in implementation and operational savings for licensees and other government agencies (DOE). However, because the NRC believes that the current Type B package requirements are sufficient to protect human health and safety, the change is not expected to result in increased costs as a result of exposure to radiation during an accident and may result in decreased worker exposure.

Contamination Limits as Applied to Spent Fuel and High Level Waste (HLW) Packages. No options have been identified for this issue. The issue was included in the proposed rule in response to Commission direction in SRM-SECY-00-0117. NRC is seeking input on whether the Agency should address this issue in future rulemaking activities. As a result, no regulatory options were developed in this document and no regulatory analysis conducted.

Modification of Event Reporting Requirements. The preferred option is Option 2. Option 2 recommends revising section 71.95 to require that the licensee and certificate holder jointly submit a written report for the criteria in new subparagraphs (a)(1) and (a)(2). The NRC also would add new paragraphs (c) and (d) to section 71.95 which would provide guidance on the content of these written reports. The NRC also would update the submission location for the written reports from the Director, Office of Nuclear Material Safety and Safeguards to the NRC Document Control Desk. Additionally, the NRC would remove the specific location for submission of written reports from section 71.95(c) and instead require that reports be submitted in accordance with section 71.1. Lastly, the NRC would reduce the regulatory burden for licensees by lengthening the report submission period from 30 to 60 days. Adoption of the conforming change to Part 71 for event reporting requirements (see Section 3.4.8) would result in an increase in regulatory efficiency within NRC. There would be a one-time implementation cost for licensees for revising procedures and for training. Additionally, licensees would benefit due to a reduction in the recurring annual reporting burden as a result of reducing the efforts associated with reporting events of little or no risk or safety significance. It is anticipated that the NRC's recurring annual review efforts for telephone notifications and written reports will not be significantly reduced.

1. Introduction

The U.S. Nuclear Regulatory Commission (NRC or Commission) has initiated a proposed rulemaking to: (1) harmonize its transportation regulations found in 10 CFR Part 71 with the most recent transportation standards established by the International Atomic Energy Agency (IAEA) in TS-R-1 and the U.S. DOT's regulations at 49 CFR; and (2) address the Commission's goals for risk-informed regulations and eliminating inconsistencies with other regulatory approaches.

This document presents ICF's Regulatory Analysis of the regulatory options being considered by NRC. The purpose of this regulatory analysis is to evaluate the costs and benefits associated with the regulatory changes being considered by NRC. Although no statutory mandates exist for the NRC to conduct regulatory analyses, the Commission voluntarily began performing these types of studies in 1976 to ensure that all regulatory burdens will achieve intended regulatory objectives with minimal impacts to licensees. Hence, the NRC considers the regulatory analysis process an integral part of its statutory mission to ensure the protection of public health and safety, property, environmental quality, and national defense and security from civilian uses of nuclear materials.

The remainder of the introduction is divided into two sections. Section 1.1 provides background information on the history, extent, and relationship of this problem; and Section 1.2 states the objectives of the rulemaking.

1.1 Background

As part of its mission to regulate the domestic use of byproduct, source, and special nuclear materials to ensure adequate protection of health and safety and the environment, NRC is responsible for controlling the transport of radioactive materials. NRC shares responsibility for radioactive material transport with the U.S. Department of Transportation (DOT). DOT's regulations in 49 CFR Parts 171 through 180 (often called the "Hazmat Regulations") address packaging, shipper and carrier responsibilities, documentation, and radioactivity limits. In contrast, NRC's regulations are primarily concerned with special packaging requirements for large quantities of radioactive materials. A Memorandum of Understanding (MOU) published July 2, 1979 (44 FR 38690) specifies the roles of DOT and NRC in the regulation of the transportation of radioactive materials. The MOU outlines that DOT is responsible for regulating safety in transportation of all hazardous materials, including radioactive materials, whereas the NRC is responsible for regulating safety in receipt, possession, use, and transfer of byproduct, source, and special nuclear materials. This joint regulatory system protects health and safety and the environment by setting performance standards for the packages and by setting limits on the radioactive contents and radiation levels for packages and vehicles.

On June 28, 2000, the Commission directed the staff in SRM-SECY-00-0117 to both use an enhanced-public-participation process (web-site and facilitated public meetings) to solicit public input in the 10 CFR Part 71 rulemaking; and also to publish, for public comment, the staff's Part 71 issue paper in the Federal Register (65 FR 44360, July 17, 2000). The issue paper discussed the NRC's plan to revise 10 CFR Part 71 and provided a summary of the changes being considered, both IAEA-related changes and Non-IAEA changes. The NRC published the Part 71 issue paper to begin an enhanced-public-participation process designed to solicit public input on the Part 71 upcoming changes. In addition to publication of the issue paper, this process included establishing an interactive web-site and holding three facilitated public meetings: a "roundtable" workshop with invited stakeholders and the general public at the NRC

Headquarters, Rockville, MD, on August 10, 2000, and two "townhall" meetings, one in Atlanta, GA, on September 20, 2000, and one in Oakland, CA, on September 26, 2000.

SRM-SECY-00-0117 also directed the staff to proceed, after completion of the public meetings, to develop a proposed rule for submittal to the Commission by March 1, 2001. Oral and written comments received from the public and invited stakeholders in the public meetings, and written comments received in response to the issue paper by mail, and electronic comments received on the NRC web site, were considered in preparing this Regulatory Analysis.

IAEA Transportation Standards

Before NRC and DOT began regulating the transportation of radioactive materials, the Interstate Commerce Commission (ICC) established the first regulations governing the safe shipment of radioactive materials during the 1950s.[1] In 1961, partially based on regulations similar to those of the ICC, IAEA adopted regulations for the transport of radioactive materials. The IAEA recommended that these regulations, which appeared in Safety Series No. 6 (SS-6), be adopted by Member States and international transport organizations. After the initial harmonization of international and U.S. standards with the IAEA regulations, four comprehensive revisions to SS-6 were published in 1964, 1967, 1973, and 1985.

The revision of the IAEA transport regulations in 1967 led to the revision of the DOT Hazmat Regulations in 1968. This revision also was the basis for a major revision to the NRC's transport regulations. In 1973, additional revisions were made to the international regulations to include a new system for classifying radionuclides. DOT and NRC adopted these revisions in 1983. In 1985, the IAEA issued a comprehensive revision of SS-6 that was later reprinted in 1990 with minor revisions.[2]

In 1995 (60 FR 50248, September 28, 1995), the NRC published a final rule amending the regulations in 10 CFR Part 71 in order to conform with the 1985 (as amended in 1990) revision of the IAEA transportation standards. The IAEA has since published a revised version of its regulations, "Regulations for the Safe Transport of Radioactive Materials," 1996 Edition, No. ST-1, in December 1996. The designation of ST-1 was changed, along with minor revisions to the document, to TS-R-1 in June 2000. NRC is currently working to harmonize 10 CFR Part 71 with the latest IAEA TS-R-1 transportation standards. At the same time, NRC is considering additional Part 71 changes to address other issues that have come up during the course of implementing the existing regulations.

On October 19, 1998, the Commission decided in SRM-SECY-98-168 to promulgate a rule to conform 10 CFR Part 71 with TS-R-1. Accordingly, the NRC staff prepared a draft rulemaking plan to be supported by a Regulatory Analysis and an Environmental Assessment.

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[1] Grella, A. "Summary of the Regulations Governing Transport of Radioactive Materials in the USA." RAMTRANS, Volume 9. No.4, pp. 279-292 (1999).

[2] Ibid.

Fissile Material Shipments and Exemptions

Included within 10 CFR Part 71 are criteria that allow (1) exemptions from classification as a fissile material package and (2) general licenses for fissile material shipments.[3] Specifically, the regulations for fissile material exemptions are provided in section 71.53 and the regulations for general licenses are provided in sections 71.18, 71.20, 71.22, and 71.24. The exemptions and general licenses pertaining to requirements for packaging, preparation of shipments, transportation of licensed materials, and NRC approval of packaging and shipping procedures have not been significantly altered since their initial promulgation. Available knowledge of radioactive material transport and historic practice have indicated that little or no regulatory oversight is needed for the packaging or transport of certain quantities of fissile material that meet the criteria established in 10 CFR Part 71. Therefore, the fissile material exemptions and general license provisions allow licensees to make shipments without first seeking approval from the NRC.

Before February 1997, section 71.53(d) exempted fissile material from the requirements in sections 71.55 and 71.59,[4] provided the package did not contain more than five grams of fissile material in any ten-liter (610-cubic inch) volume. The fissile exemptions appearing in 10 CFR 71.53 provide inherent criticality control for all practical cases in which fissile materials existed at or below the applicable regulatory limits (i.e., independent calculations would generally not be expected nor required). Thus, the fissile exemptions did not generally place limits on either the types of moderating/reflecting material present in fissile exempt packages or the number of fissile exempt packages that could be shipped in a single consignment. Also, these exemptions did not require the assignment of a transport index (TI) for criticality control.[5]

In February 1997, the NRC completed an emergency final rulemaking (62 FR 5907, February 10, 1997) to address newly encountered situations regarding the potential for inadequate criticality safety in certain shipments of exempted quantities of fissile material (beryllium oxide containing a low-concentration of highly-enriched uranium). The emergency rule revised portions of 10 CFR Part 71 that limited the consignment mass for fissile material exemptions and restricted the presence of beryllium, deuterium, and graphite moderators.[6] Subsequent to its release, the NRC solicited public comments on the emergency rule. Five fuel cycle facility licensees and two other interested parties responded with comments that supported the need for the emergency rule but questioned whether some of the new restrictions were excessive. For example, some commenters noted that they had not encountered any problems shipping wastes that would have violated the emergency rule. Others stated that the new restrictions would at least double the number of waste shipments, thereby increasing costs, decreasing worker safety, and increasing the risk of accidents.

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[3] Section 71.4 currently defines fissile material as: "Plutonium-238, plutonium-239, plutonium-241, uranium-233, uranium-235, or any combination of these radionuclides. Unirradiated natural uranium and depleted uranium that has been irradiated in thermal reactors only are not included in this definition. Certain exclusions from fissile material controls are provided in section 71.53."

[4] These sections place additional requirements on fissile packages and shipments to preclude criticality.

[5] Transport index is defined in 10 CFR 71.4 as: "The dimensionless number (rounded up to the next tenth) placed on the label of a package to designate the degree of control to be exercised by the carrier during transportation." See 10 CFR 71.4 for calculation criteria.

[6] For purposes of this report, the term "consignment mass" means the amount of fissile material offered by a consignor to a carrier for transport to a new location.

Based on these public comments and other relevant concerns, the NRC decided that further assessment was required, including a comprehensive assessment of all exemptions, general licenses, and other requirements pertaining to any fissile material shipment (i.e., not just fissile material shipments addressed by the emergency rulemaking). The NRC contracted Oak Ridge National Laboratory (ORNL) to conduct the assessment, and ORNL reviewed 10 CFR Part 71 (as modified by the emergency rule) in its entirety to assess its adequacy relative to the technical basis for assuring criticality safety. The results of the ORNL study were published as NUREG/CR-5342.[7] ORNL indicated that 10 CFR Part 71 needs updating, particularly to provide a simpler and more straightforward interpretation of the restrictions and criteria set in the regulations. Specific changes recommended in NUREG/CR-5342 are presented in Appendix A.

Based on the findings contained in NUREG/CR-5342, the NRC found it appropriate to evaluate the revisions to 10 CFR Part 71, with the objectives of:

- simplifying the regulations applicable to licensees shipping fissile materials;
- relaxing restrictions on fissile material packages and shipments that are not justified based on plausible criticality concerns; and
- adequately addressing criticality safety for a number of newly considered plausible transportation and packaging situations.

In addition to the changes described above, the NRC has determined that there are other actions that can be taken efficiently as part of one rulemaking package. These other changes, which relate to several different SECY papers and a petition for rulemaking (PRM), include the following:

Packaging and Transportation

- SECY-97-161: Major on-going activities include: (1) a limited re-evaluation of the Commission's generic environmental impact statement on transportation (NUREG-0170) to address the impact of spent fuel shipments to a repository or central interim storage facility; (2) a joint DOT/NRC initiative to revise the IAEA process for adopting transportation regulations; and (3) development of standard review plans for both spent fuel and non-spent fuel applications.
- PRM-71-12 (International Energy Consultants): The petitioner requested that the NRC amend its regulations governing shipments of high-level waste under Part 71. The petitioner requested that paragraph 71.63(b), special requirements for plutonium shipments, be deleted in their entirety. This petition will be resolved as part of this rulemaking.

Other Regulations

- SECY-99-174: The objective is to revise 10 CFR 50.59 and 10 CFR 72.48 to clearly define those licensee procedural changes, tests, and experiments for which prior approval is required by the NRC.

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[7] NUREG/CR-5342, *Assessment and Recommendations for Fissile-Material Packaging Exemptions and General Licenses Within 10 CFR Part 71,* Oak Ridge National Laboratory, July 1998.

- SECY-99-130: The objective is to expand the applicability of Part 71 to holders of, and applicants for, certificates of compliance (and also their contractors and subcontractors).

- SECY-99-100: The objective is to address commitments made by the Commission staff in SECY-98-138 to develop and implement a framework for risk-informed regulations in the Office of Nuclear Material Safety and Safeguards (NMSS).

- SECY-00-0117: The objective is to discuss the current IAEA standards for package surface removable contamination.

- SECY-00-0093: The objective is to review the reporting requirements contained in SECY-00-0093 to determine applicability to Part 71.

- Special Package Approval: The objective is to evaluate the need for revision to the current requirements for approval of special packages based on staff experience with recent exemption requests.

- Adoption of ASME Code: The objective is to evaluate the need for adoption into regulations of portions of the ASME code based on staff experience with spent fuel cask fabricators.

1.2 Objectives of the Proposed Rulemaking

The objectives of the rulemaking are to both (1) harmonize NRC’s transportation regulations with other regulatory agencies (DOT, IAEA), and (2) implement other NRC-initiated changes in order to simplify the regulations applicable to licensees shipping radioactive materials, while maintaining adequate protection of public health, safety, and the environment.

2. Identification of Alternative Regulatory Options

NRC is considering 19 changes to its radioactive material transportation regulations. The first 11 changes are related to harmonizing the radioactive transportation regulations in 10 CFR Part 71 with the IAEA standards from "Regulations for the Safe Transport of Radioactive Materials," 1996 Edition, No. ST-1. The remaining eight changes are regulatory modifications that could be considered by NRC to reduce paperwork and burden for licensees, while maintaining protection of public health, safety, and the environment. (In addition, one of these 19 changes [Section 2.2.5] is based in part on the specific recommendations presented in NUREG/CR-5342.)

For each of the 19 changes, this Regulatory Analysis considers two regulatory options. Option 1 is the No-Action Alternative. Option 2 is based in part on TS-R-1, Safe Transportation Standards. The discussion that follows assumes a familiarity with and understanding of TS-R-1. Option 2 also is based on Commission direction for staff to evaluate additional changes to reduce regulatory burden on licensees.

For the changes to fissile material license provisions, Option 2 is based in part on the specific recommendations presented in NUREG/CR-5342. Due to the complexity of the technical basis for the various recommendations posed in NUREG/CR-5342, this Regulatory Analysis does not provide a detailed description of either the rationale for each recommendation or how the recommendation would be implemented in regulatory text (except where doing so is relatively simple). Consequently, the discussion assumes a familiarity with and understanding of NUREG/CR-5342.

The potential changes to 10 CFR Part 71 are summarized in Table 2-1 below and are described in more detail in the sections that follow.

Table 2-1. List and Summary Description of Potential Changes to 10 CFR Part 71

Technical Issue	Summary Description of Potential Requirements
IAEA-related changes	
1. Changing Part 71 to the International System of Units (SI) Only	Require the use of SI units exclusively in shipping papers and labels.
2. Radionuclide Exemption Values	Adopt IAEA's radionuclide-specific exemption values for some or all radionuclides.
3. Revision of A_1 and A_2	Change the A_1 and A_2 values promulgated in 10 CFR Part 71, and in standard review plans and guidance documents pertaining to 10 CFR Part 71, to the new values published in TS-R-1.
4. Uranium Hexafluoride Package Requirements	Incorporate the TS-R-1 language into Part 71.
5. Introduction of the Criticality Safety Index Requirements	The action would require labels indicating both the CSI and Transport Index (TI) for fissile material shipments.
6. Type C Packages and Low Dispersible Material	Incorporate provisions from TS-R-1 for Type C packages and low dispersible radioactive material.

Table 2-1. List and Summary Description of Potential Changes to 10 CFR Part 71 (continued)

Technical Issue	Summary Description of Potential Requirements
7. Deep Immersion Test	Modify the requirements to state that a package for radioactive contents greater than 10^5 A_2 shall be designed to withstand an external water pressure of 2 MPa (290 psi) for a period of not less than one hour without collapse, buckling, or inleakage of water.
8. Grandfathering Previously Approved Packages	Modify Part 71 to subject all packages to regulations in place at the time a Certificate of Compliance was issued. The revised regulations would apply to all new packages, and existing packages after renewal of the Certificate of Compliance.
9. Changes to various definitions	Add a number of definitions to 10 CFR 71.4 to ensure compatibility with TS-R-1.
10. Crush test for fissile material package design	Require crush test for fissile material package designs regardless of package activity.
11. Fissile Material Package Designs for Transport by Aircraft	Subject shipped-by-air fissile material packages with quantities greater than excepted amounts to additional criticality evaluation.
NRC-Initiated changes	
12. Special Package Authorizations	Incorporate requirements into Part 71 that address shipment of special packages and the demonstrated level of safety.
13. Expansion of Part 71 Quality Assurance Requirements to Certificate of Compliance (CoC) Holders	Subject cask certificate holders and applicants for a CoC to the requirements of Part 71.
14. Adoption of ASME Code	Adopt the American Society of Mechanical Engineers Boiler and Pressure Vessel (ASME B&PV) Code Section III, Division 3, for spent fuel transportation casks in Part 71.
15. Change Authority	Incorporate a new subpart in Part 71 that would allow licensees to make minimal changes to their packaging and transportation procedures, without license amendments (for dual purpose casks only).
16. Fissile Material Exemptions and General License Provisions	Modify Part 71 in numerous ways, as needed, to implement some or all of the 17 recommendations contained in NUREG/CR-5342.
17. Double Containment of Plutonium (PRM-71-12)	Remove the 10 CFR 71.63(b) requirements for plutonium shipments. Plutonium packaging requirements would be handled no differently than requirements for other nuclear material (i.e., the A_1/A_2 system), except that plutonium shipped in the U.S. would have to be shipped as a solid.
18. Contamination Limits as Applied to Spent Fuel and High Level Waste (HLW) Packages	For information only. No regulatory action taken. No regulatory analysis performed.
19. Modifications of Event Reporting Requirements	Conform Part 71 to the revised requirements in Part 50 (65 FR 63769) for event notification.

2.1 Actions to Harmonize NRC Transportation Regulations with IAEA Safe Transport Standards

2.1.1 Changing Part 71 to the International System of Units (SI) Only

TS-R-1 uses the SI units exclusively. This change is stated in TS-R-1, Annex II, page 199. TS-R-1 also requires that activity values entered on shipping papers and displayed on package labels be expressed only in SI units (paragraphs 543 and 549). Safety Series No. 6, the TS-R-1 predecessor, used SI units as the primary controlling units, with subsidiary units in parentheses (Safety Series 6, Appendix II, page 97), and either units were permissible on labels and shipping papers (paragraphs 442 and 447).

On August 10, 1988, Congress passed the Omnibus Trade and Competitiveness Act (the Act), which amended the Metric Conversion Act of 1975. Section 5164 of the Act designates the metric system[8] as the preferred system of weights and measures for U.S. trade and commerce. Congress noted that use of the metric system would improve the competitive position of U.S. products in international markets because world trade is increasingly conducted in metric units. In an effort to have an orderly change to metric units, the Act also requires that all Federal agencies convert to the metric system of measurement in their procurements, grants, and other business-related activities by the end of fiscal year 1992, unless this was impractical or likely to cause significant efficiencies or loss of markets to U.S. firms.

In order to implement the Congressional designation of the metric system as the preferred system of weights and measures for U.S. trade and commerce, Presidential Executive Order 12770 of July 25, 1991, designated the Secretary of Commerce to direct and coordinate metric conversion efforts by all Federal departments and agencies. Executive Order 12770 also directed all executive branch departments and agencies of the U.S. Government to establish an effective process for a policy-level and program-level review of potential exceptions to metric usage. The transition to use of metric units in Government publications would be made as publications are revised on normal schedules or new publications are developed, or as metric publications are required in support of metric usage.

In response to the Act and Executive Order 12770, as well as concerns of certain NRC licensees and other interested parties, NRC, on February 10, 1992, issued a proposed policy statement on metrication for public comment (57 FR 4891). After reviewing public comments, the NRC issued its policy on metrication on October 7, 1992 (57 FR 46202). The metrication policy stated that, after three years, the NRC was to assess the state of metric use by the licensed nuclear industry in the United States to determine whether the metrication policy should be modified.

In accordance with the NRC's policy statement of October 7, 1992, the NRC issued a request for public comment on its existing metrication policy on September 27, 1995 (60 FR 49928). After contacting various industrial, standards, and governmental organizations to determine their view of the policy and reviewing comments submitted in response to the request for public comment, the NRC issued its final Statement of Policy on Conversion to the Metric System on June 19, 1996 (61 FR 31169). The NRC considers its metrication policy to be final, and its conversion to the metric system complete.

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[8] The term "metric system" refers to the International System of Units as established by the General Conference of Weights and Measures in 1960 as interpreted or modified for the U.S. by the Secretary of Commerce.

Metrication Policy

The metrication policy, which affects NRC licensees and applicants, was designed to allow for response to market forces in determining the extent and timing for the use of the metric system of measurement. The policy also affects the Commission in that the NRC will adhere to the Federal Acquisition Regulations and the General Service Administration (GSA) metrication program for its own purchases.

The NRC's metrication policy commits the Commission to work with licensees and applicants and with national, international, professional, and industry standards-setting bodies (e.g., ANSI, ASTM, ASME) to ensure metric-compatible regulations and regulatory guidance. Through its metrication policy, the NRC encourages its licensees and applicants to employ the metric system of measurement wherever and whenever its use is not potentially detrimental to public health and safety or is uneconomic. The NRC did not want to make metrication mandatory by rulemaking because no corresponding improvement in public health and safety would result, but rather, costs would be incurred without benefit. As a result, there is a mix of licensees and applicants using both the metric and the customary systems of measurement.[9]

According to the NRC's metrication policy, the following documents should be published in dual units (beginning January 7, 1993):

- new regulations
- major amendments to existing regulations
- regulatory guides
- NUREG-series documents
- policy statements
- information notices
- generic letters
- bulletins
- all written communications directed to the public

The metrication policy also states that, in dual-unit documents, the first unit presented will be in the International System of Units with the customary unit shown in parenthesis. In addition, documents specific to a licensee, such as inspection reports and docketed material dealing with a particular licensee, will be in the system of units employed by the licensee.

It should be noted that, currently, NRC requires shipping papers and labels to be completed according to DOT regulations in 49 CFR Part 172. In its regulations, DOT does not specify the unit of measurement in which shipping papers used in the transportation of radioactive materials have to be completed (49 CFR 172.203(d)(4)). Further DOT regulations do not specify the units of measurement for labels used in the packaging and transportation of radioactive materials (49 CFR 172.403(g)(2)).

Option 1: No-Action Alternative

The No-Action Alternative (Option 1) would not modify Part 71 regarding the use of SI units exclusively. With this option, the NRC adheres to its policy of dual units.

[9] Based on telephone conversations with Mr. Felix Killar, NEI on August 30, 1999 and Ms. Lynette Hendricks, NEI on August 31, 1999.

Option 2: Amendments to 10 CFR Part 71

Under Option 2, NRC would amend Part 71 to make it compatible with TS-R-1 by requiring the use of SI units only. This would mean requiring a single system of units for both domestic and international shipments.

2.1.2 Radionuclide Exemption Values

NRC currently uses one specific activity limit for exemption of any type of radionuclide from its packaging and transportation regulations. Specifically, 10 CFR 71.10(a) states "[a] licensee is exempt from all requirements of this part with respect to shipment or carriage of a package containing radioactive material having a specific activity not greater than 70 Bq/g (0.002 μCi/g)." Similarly, DOT regulations in 49 CFR 173.403 define radioactive material as "any material having a specific activity greater than 70 Bq/g (0.002 μCi/g)."

TS-R-1, Table I, has been revised to include new, radionuclide-specific values for exempt materials. The IAEA activity concentrations for exempt material range from 1×10^{-1} to 1×10^{7} Bq/g. TS-R-1 also provides a formula to be used to determine the exemption of mixtures of radionuclides. The radionuclide-specific concentration limits are based on IAEA's Basic Safety Standards No. 115 (SS-115, entitled "International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources"), which applies to those natural materials or ores that are part of the nuclear fuel cycle or that will be processed in order to use their radioactive properties.

The general principles for the IAEA exemptions are:

- The radiation risks to individuals caused by the exempted practice or source be sufficiently low as to be of no regulatory concern;

- The collective radiological impact of the exempted practice or source is sufficiently low as not to warrant regulatory control under the prevailing circumstances; and

- The exempted practices and sources are inherently safe, with no appreciable likelihood of scenarios that could lead to a failure to meet the first two criteria.

IAEA exemption values have been derived in SS-115 on the following basis:

- An individual effective dose of 10 μSv per year for normal conditions;
- A collective dose of 1 person-Sv per year of practice for normal conditions;
- An individual effective dose of 1 mSv for accidental conditions; and
- An individual dose to the skin of 50 mSv for both normal and accidental conditions.

These levels were derived for SS-115 using scenarios that did not explicitly address the transport of radioactive material. Additional derivations were performed by IAEA for transport-specific scenarios, and the results were found to be similar to those in SS-115. Therefore, the exemption levels of SS-115 were adopted in TS-R-1.

The nature of the change makes it difficult to quantify the values or impacts. The most significant impact would be on shippers of materials which are not currently subject to the regulations (i.e., less than 70 Bq/g) and which would become subject to them (for example, NORM [Naturally Occurring Radioactive Materials] in natural ores and minerals, or piping,

drilling equipment, or drilling waste products from the oil & gas industry). There is no known reliable information on the nature and amounts of materials which would be so affected.

This change would conform Part 71 to DOT's recommended change in its proposed rule. To determine whether Part 71 amendments are appropriate, the following two alternatives were considered:

Option 1: No-Action Alternative

Under the No-Action Alternative (Option 1), NRC would continue to use one specific activity limit for exemption of any type of radionuclide.

Option 2: Amendments to 10 CFR Part 71

Under Option 2, NRC would adopt, in 10 CFR Part 71, IAEA's radionuclide-specific exemption values for all radionuclides.

2.1.3 Revision of A_1 and A_2

TS-R-1 includes numerous revisions to the individual A_1 and A_2 values for radionuclides. The A_1 and A_2 values are used for determining what type of package must be used for the transportation of radioactive material. The A_1 values are the maximum activity of special form material allowed in a Type A package. The A_2 values are the maximum activity of "other than special" form material allowed in a Type A package. A_1 and A_2 values also are used for several other packaging limits throughout TS-R-1, such as specifying Type B package activity leakage limits, low-specific activity limits, and excepted package contents limits. (These specified values are included in Part 71 - Appendix A.)

The basic radiological criteria for determining A_1 and A_2 values are:

- The effective or committed effective dose to a person exposed in the vicinity of a transport package following an accident should not exceed a reference dose of 50 mSv (5 rem).

- The dose or committed equivalent dose received by individual organs, including the skin, of a person involved in the accident should not exceed 0.5 Sv (50 rem), or in the special case of the lens of the eye, 0.15 Sv (15 rem). A person is unlikely to remain at 1 m from the damaged package for more than 30 minutes.

The IAEA revised A_1 and A_2 values in TS-R-1 based on an analysis technique that includes improved dosimetric models that use the Q System (see Appendix D for the values contained in TS-R-1). The Q System includes consideration of a broader range of specific exposure pathways than the earlier A_1 and A_2 calculations. The five Q models are for external photon dose, external beta dose, inhalation dose, skin and ingestion dose due to contamination transfer, and dose from submersion in gaseous isotopes. The value of A_1 is determined from the most restrictive of the photon and beta doses, and the value of A_2 is determined from the most restrictive of the A_1 value and remaining Q model values.

The impact of these analyses is that the radionuclides have now been subjected to a more realistic assessment concerning exposure to an individual should a Type A transport package

of radioactive material encounter an accident condition during transport. The new A_1 and A_2 values reflect that assessment.

During the enhanced public participation process, commenters requested that NRC and DOT retain the current exceptions of A_1 and A_2 for two radionuclides - ^{99}Mo and ^{252}Cf.

Option 1: No-Action Alternative

Under the No-Action Alternative (Option 1), NRC would retain the current A_1 and A_2 values promulgated in 10 CFR Part 71.

Option 2: Amendments to 10 CFR Part 71

Under Option 2, NRC would revise Part 71 to incorporate the TS-R-1 A_1 and A_2 values maintaining the current exceptions for ^{252}Cf and ^{99}Mo.

2.1.4 Uranium Hexafluoride (UF_6) Package Requirements

Uranium hexafluoride is generated as a result of uranium processing to prepare enriched uranium for use in nuclear power plants. Natural uranium ore is mined and milled to produce an intermediate product known as yellow cake. Yellow cake is then converted into UF_6. This UF_6 is sent to an enrichment facility in Paducah, Kentucky to increase the relative abundance of the fissile isotope ^{235}U from its natural abundance of 0.711 percent by weight to greater than one percent. It is then sent to another enrichment plant in Portsmouth, Ohio where it is further enriched. The enriched UF_6 is then sent to private fuel fabricators where it is converted to uranium oxide for use in nuclear power plants. Both of the existing enrichment facilities (in Portsmouth and Paducah) are run by the United States Enrichment Corporation (USEC), and produce depleted UF_6 as a waste. This depleted UF_6, which contains less than the natural abundance of ^{235}U, is stored in large cylinders in outdoor storage yards. Additionally, DOE operates the K-25 site at Oak Ridge, Tennessee, which in the past had been an enrichment facility and at which there also are cylinders of depleted UF_6 stored in outdoor yards. Depleted UF_6 is usually stored in Type 48 cylinders, while enriched UF_6 is transported in smaller Type 30 cylinders with overpacks.[10] Type 48 cylinders, which can contain either 10 or 14 short tons, are usually 9 to 12 feet long and 4 feet in diameter, while the Type 30 cylinders, which can contain 2.5 short tons, are usually about 7 feet long and 2.5 feet in diameter. Smaller amounts of UF_6 are occasionally shipped in smaller cylinders, such as for laboratory analysis. These smaller cylinders are usually overpacked.

The enrichment facility in Paducah receives about seven Type 48 cylinders a day of UF_6 from the private conversion facilities.[11] Because the UF_6 leaving Paducah and destined for Portsmouth is enriched, it is typically sent in Type 30 cylinders that are overpacked. As reported in the *Cost Analysis Report for the Long Term Management of Depleted Uranium Hexafluoride*, the stockpiles of depleted UF_6 cylinders at the USEC and DOE sites are extensive: Paducah had 28,351 cylinders, Portsmouth had 13,388 cylinders, and K-25 had 4,683 cylinders as of May 1997. In addition, between the two operating sites, approximately 2,000 and 2,500 new cylinders are generated per year for storage. DOE recently issued a

[10] Overpacks are enclosures used by a single consigner to provide protection or convenience in handling a package or to consolidate two or more packages.

[11] Personal communication with Randy Reynolds, Bectel Jacobs Energy Systems, September, 1998.

record of decision outlining the plan for future management of these cylinders,[12] which involves building at least one conversion facility at either Paducah or Portsmouth to convert the depleted UF_6 back to uranium oxide, which is a more stable form. Another possibility being considered is that a conversion facility will be built at both of these sites.

Current regulation of UF_6 packaging and transportation is a combination of NRC and DOT requirements. The DOT regulations contain provisions which govern many aspects of packaging and shipment preparation, including a requirement that the material be packaged in cylinders that meet the ANSI N14.1 standard. The NRC regulates fissile and Type B packaging designs for all materials, including the fissile UF_6.

Previous editions of the IAEA regulations did not specifically address UF_6 , but TS-R-1 contains detailed requirements for UF_6 packages designed for more than 0.1 Kg UF_6. First, TS-R-1 requires the use of an international standard, ISO 7195 Packaging of Uranium Hexafluoride for Transport, instead of the ANSI N14.1 standard, with the condition that approval by all countries involved in the shipment is obtained (i.e., multilateral approval, (Para 629)). Second, TS-R-1 requires that all packages containing more than 0.1 kg UF_6 must meet the "normal conditions of transport" drop test, a minimum internal pressure test, and the hypothetical accident condition thermal test (Para 630). [However, TS-R-1 does allow a competent national authority to waive certain design requirements, including the thermal test for packages designed to contain greater than 9,000 kg UF_6 , provided that multilateral approval is obtained.] Third, TS-R-1 prohibits packages from utilizing pressure relief devices (Para 631). Fourth, TS-R-1 includes a new exception for UF_6 packages, regarding the evaluation of a single package. The new provision (Para 677(b)) allows UF_6 packages to be evaluated without considering the in-leakage of water into the containment system. This provision means that a single fissile UF_6 package does not have to be subcritical assuming that water leaks into the containment system. This provision only applies when: (1) there is no contact of the cylinder under hypothetical accident tests and the valve remains leak-tight, and (2) when there is a high degree of quality control in the manufacture, maintenance, and repair of packagings coupled with tests to demonstrate closure of each package before each shipment.

Option 1: No-Action Alternative

Under the No-Action Alternative (Option 1), NRC would not modify Part 71 to incorporate the TS-R-1 UF_6 requirements.

[12] *Record of Decision for Long-Term Management and Use of Depleted Uranium Hexafluoride*, U.S. Department of Energy, August 3, 1999, http://web.ead.anl.gov/uranium/new/index.cfm.

Option 2: Amendments to 10 CFR Part 71

Under Option 2, NRC would revise Part 71 to incorporate the TS-R-1 UF_6 packaging requirement by promulgating new section 71.55(g), while restricting use of the exception to a maximum enrichment of 5 weight percent ^{235}U.

2.1.5 Introduction of the Criticality Safety Index Requirements

In current NRC and DOT regulations, the Transport Index (TI) is defined as follows:

> *Transport Index (TI) means the dimensionless number (rounded up to the next tenth) placed on the label of a package to designate the degree of control to be exercised by the carrier during transportation. The transport index is determined as follows:*
>
> *(1) For nonfissile material packages, the number determined by multiplying the maximum radiation level in millisievert (mSv) per hour at one meter (3.3 feet) from the external surface of the package by 100 (equivalent to the maximum radiation level in millirem per hour at one meter (3.3 feet)); or*
>
> *(2) For fissile material packages, the number determined by multiplying the maximum radiation level in millisievert per hour at one meter (3.3 feet) from any external surface of the package by 100 (equivalent to the maximum radiation level in millirem per hour at one meter (3.3 feet)) or, for criticality control purposes, the number obtained by dividing 50 by the allowable number of packages which may be transported together, whichever number is larger.*

TS-R-1 has a requirement (paragraphs 541, 544, and 545) that a Criticality Safety Index (CSI) (paragraph 218), as well as the TI, be posted on packages of fissile material. The CSI assigned to a package, overpack, or freight container containing fissile material shall mean a number that is used to provide control over the accumulation of such containers containing fissile material. Previously, the IAEA regulations used a TI that used one number to accommodate both radiological safety and criticality safety.

The CSI for packages would be determined by using a formula provided by TS-R-1, which is the same as the formula for the TI for criticality control purposes found in NRC and DOT regulations. The CSI for each consignment would be determined as the sum of the CSIs of all the packages in that consignment. In addition, TS-R-1 states that the CSI of any package or overpack should not exceed 50, except for exclusive use consignments.

In order to make NRC regulations consistent with TS-R-1, a definitions for CSI would have to be added, and the CSI component would need to be removed from the current definition of TI.

Option 1: No-Action Alternative

Under the No-Action Alternative (Option 1), NRC would not require labels or modify definitions for CSI and would retain the current TI label requirement.

Option 2: Amendment to 10 CFR Part 71

Under Option 2, NRC would revise 10 CFR Part 71 to include a definition of CSI for fissile material packages and revise the existing TI definition.

2.1.6 Type C Packages and Low Dispersible Material

Analogous to a Type B package, IAEA has devised the concept of a Type C package that could withstand severe accident conditions in air transport without loss of containment or increase in external radiation (see TS-R-1 paragraphs 230, 667-670, 730, and 734-737). However, the design-basis accident conditions are somewhat different.

- One of the potential post-crash environments that a Type C package is more likely to see than a Type B package is burial. If a package whose contents generate heat becomes buried, an increase in package temperature and internal pressure could result. Therefore, Type C packages are required to meet heat-up and corrosion tests to which Type B packages are not subject.

- Type C packages are more likely to end up in deep water after an accident, so all Type C packages, no matter the design curie content, are required to undergo deep immersion testing.

- Puncture/tearing tests are required to account for the possibility of rigid parts of the air craft damaging the package.

- Since aircraft carry much more fuel than trucks, Type C packages are subjected for 60 minutes to a thermal test similar to the 30-minute Type B package test.

- Since aircraft travel at higher speeds than surface vehicles, the impact test is done at 90 m/s.

- Tests for Type C packages are not sequential because of the velocities and the space involved in aircraft accidents reduce the likelihood of a cask receiving high levels of multiple stresses.

U.S. regulations have no Type C package requirements, but have specific requirements for the air transport of plutonium. In addition to meeting Type B package requirements, to be certified for the air transport of plutonium, a package must withstand:

- an impact velocity of 129 m/sec;
- a compressive load of 31,800 kg;
- impact of a 227 kg dropped weight (small packages);
- impact of a structural steel angle falling from a height of 46 m;
- a 60 minute fire;
- a terminal velocity impact test; and
- deep submersion to 4 MPa (600 lbs/in^2).

The Type C package tests in IAEA's TS-R-1 are less rigorous than the U.S. tests for air transport of plutonium.

The LDM has limited radiation hazard and low dispersibility; as such, it could continue to be transported by aircraft in Type B packages (i.e., LDM is excepted from the TS-R-1 Type C package requirements). The LDM specification was added in TS-R-1 to account for radioactive materials (package contents) that have inherently limited dispersibility, solubility, and external radiation levels. The test requirements for LDM to demonstrate limited dispersibility and leachability are a subset of the Type C package requirements (90-m/s impact and 60-minute

thermal test) with an added solubility test, and must be performed on the material without packaging. The LDM also must have an external radiation level below 10 mSv/hr (1 rem/hr) at 3 meters. Specific acceptance criteria are established for evaluating the performance of the material during and after the tests (less than 100 A_2 in gaseous or particulate form of less than 100-mm aerodynamic equivalent diameter and less than 100 A_2 in solution). These stringent performance and acceptance requirements are intended to ensure that these materials can continue to be transported safely in Type B packages aboard aircraft.

Option 1: No-Action Alternative

Under the No-Action Alternative (Option 1), NRC would not adopt Type C packages or the "low dispersible radioactive material" concepts into 10 CFR Part 71.

Option 2: Amendments to 10 CFR Part 71

Under Option 2, NRC would revise 10 CFR Part 71 to incorporate the Type C Package and low dispersible radioactive material concepts for air transportation but retain section 71.74, the accident conditions for air transport of plutonium.

2.1.7 Deep Immersion Test

The NRC currently requires a deep immersion test for some packages of irradiated nuclear fuel. This requirement is contained in 10 CFR 71.61 and states that "a package for irradiated nuclear fuel with activity greater than 37 PBq (10^6 Ci) must be so designed that its undamaged containment system can withstand an external water pressure of 2 MPa (290 psi) for a period of not less than one hour without collapse, buckling, or inleakage of water."

The revised IAEA requirement in TS-R-1 (paragraphs 657 and 730) no longer specifically states that it applies only to packages of irradiated fuel, but instead applies to all Type B(U) and B(M) packages containing more than 10^5 A_2, as well as Type C packages. In addition, TS-R-1 states only that the containment system can not fail, and does not require that the containment system not buckle or allow inleakage of water. ST-2 (para. 730.3) states that some degree of buckling or deformation is acceptable provided that there is no rupture. ST-2 (para. 657.5) also states that it is recognized that leakage into and out of the package is possible, and the aim is to ensure that only dissolved activity is released.

This expansion in the types of materials required to meet this requirement in TS-R-1 was due to the fact that radioactive materials, such as plutonium and high-level radioactive wastes, are increasingly being transported by sea in large quantities. The threshold defining a large quantity as a multiple of A_2 is considered to be a more appropriate criterion to cover all radioactive materials, and is based on a consideration of radiation exposure as a result of an accident.

The pressure requirement of 2 MPa (which is equivalent to 200 m of water submersion) corresponds approximately to the continental shelf and the depths where some studies indicated that radiological impacts could be important. Recovery of a package from this depth would be possible and salvage would be facilitated if the containment system did not rupture.

Currently, there are no Type C packages licensed for use in the U.S. If a Type C package design was developed and certified, it would need to pass the enhanced deep immersion test. Type C packages are addressed further in Section 2.1.6.

Option 1: No-Action Alternative

Under Option 1, the No-Action Alternative, NRC would not require design of a package with radioactive contents greater than 10^5 A_2 or irradiated nuclear fuel with activity greater than 37 PBq to withstand external water pressure of 2 MPa for a period of one hour or more without rupture of the system.

Option 2: Amendments to 10 CFR Part 71

Under Option 2, the NRC would revise Part 71 to require an enhanced water immersion test for packages used for radioactive contents with activity greater than 10^5 A_2. Section 71.61 currently refers to packages for irradiated fuel with activity greater than 37 PBq (10^6 Ci); the water immersion test would need to be changed to apply to Type B packages containing greater than 10^5 A_2 and Type C packages.

2.1.8 Grandfathering Previously Approved Packages

The purpose of grandfathering is to minimize the costs and impacts of implementing changes in the regulations on existing package designs and packagings. Grandfathering typically includes provisions that allow: (1) continued use of existing package designs and packagings already fabricated, although some additional requirements may be imposed; (2) completion of packagings which are in the process of being fabricated or which may be fabricated within a given time period after the regulatory change; and (3) limited modifications to package designs and packagings without the need to demonstrate full compliance with the revised regulations, provided that the modifications do not significantly affect the safety of the package.

TS-R-1 grandfathering provisions (see TS-R-1, paragraphs 816 and 817) are more restrictive than those previously in place in Safety Series 6 (1985) or 1985 (as amended 1990). The primary impact of these two paragraphs is that Safety Series 6 (1967) approved packagings are no longer grandfathered, i.e., cannot be used. The second impact is that fabrication of packagings designed and approved under Safety Series 6 (1985) or 1985 (as amended 1990) must be completed by a specified date.

In TS-R-1, packages approved for use based on Safety Series 6 1973 or 1973 (as amended) can continue to be used through their design life, provided the following conditions are satisfied: multilateral approval is obtained for international shipment, applicable TS-R-1 QA requirements and A_1 and A_2 activity limits are met, and, if applicable, the additional requirements for air transport of fissile material are met. While existing packagings are still authorized for use, no new packagings can be fabricated to this design standard. Changes in the packaging design or content that significantly affect safety require that the package meet current requirements of TS-R-1.

TS-R-1 further states that those packages approved for use based on Safety Series 6 (1985) or 1985 (as amended 1990) may continue to be used until December 31, 2003, provided the following conditions are satisfied: TS-R-1 QA requirements and A_1 and A_2 activity limits are met, and, if applicable, the additional requirements for air transport of fissile material are met. After December 31, 2003, use of these packages for foreign shipments may continue under the additional requirement of multilateral approval. Changes in the packaging design or content that significantly affect safety require that the package meet current requirements of TS-R-1. Additionally, new fabrication of this type packaging must not be started after December 31,

2006. After this date, subsequent package designs must meet TS-R-1 package approval requirements.

Option 1: No-Action Alternative

Under the No-Action Alternative (Option 1), NRC would not adopt the new grandfathering provisions contained in TS-R-1.

Option 2: Amendments to 10 CFR Part 71

Under Option 2, NRC would modify section 71.13 to phase out packages approved under Safety Series 6. This Option would include a 3-year transition period for the grandfathering provision on packages approved under Safety Series 6 (1967). This period will provide industry the opportunity to phase out old packages and phase in new ones. In addition, packages approved under Safety Series 6 (1985) would not be allowed to be fabricated after December 31, 2006.

2.1.9 Changes to Various Definitions

The changes contemplated by NRC in this proposed rulemaking would require changes to various definitions in order to improve consistency with IAEA safe transportation standards contained in TS-R-1.

Option 1: No-Action Alternative

Under the No-Action alternative (Option 1), NRC would not adopt any new definitions, nor modify any existing definitions concurrent with the modifications addressed in the proposed rule.

Option 2: Amendments to 10 CFR Part 71

Under Option 2, NRC proposes to add various definitions to 10 CFR 71.4 and modify existing definitions to both ensure compatibility with definitions found in TS-R-1 and to improve clarity in NRC regulations. Specifically, the proposal would add or modify the following:

- Criticality Safety Index
- Certificate of Compliance
- Department of Transportation
- Deuterium
- A_1
- A_2
- LSA-III
- Fissile Material
- Graphite
- Package
- Spent Nuclear Fuel/Spent Fuel
- Structures, Systems, and Components Important to Safety (SSCs)
- Transport Index

2.1.10 Crush Test for Fissile Material Package Design

IAEA's TS-R-1 broadened the crush test requirements to apply to fissile material package designs (regardless of package activity). [IAEA Safety Series 6 and Part 71 have previously required the crush test for certain Type B packages.] This was done in recognition that the crush environment was a potential accident force which should be protected against for both radiological safety purposes (packages containing more than 1,000 A_2 in normal form) and criticality safety purposes (fissile material package design).

Under requirements for packages containing fissile material, TS-R-1 682(b) requires tests specified in paragraphs 719-724 followed by whichever of the following is the more limiting: (1) the tests specified in paragraph 727(b) (drop test onto a bar) and, either paragraph 727(c) (crush test) for packages having a mass not greater than 500 kg and an overall density not greater than 1,000 kg/m^3 based on external dimensions, or paragraph 727(a) (nine meter drop test) for all other packages; or (2) the test specified in paragraph 729 (water immersion test).

Safety Series 6 (paragraph 548) required and 10 CFR Part 71 (71.73) presently requires the crush test for packages: (1) having a mass not greater than 500 kg and an overall density not greater than 1,000 kg/m^3 based on external dimensions; and (2) radioactive contents greater than 1000 A_2 not as special form radioactive material. Under TS-R-1, the radioactive contents greater than 1,000 A_2 criterion has been eliminated for packages containing fissile material. The 1,000 A_2 criterion still applies to Type B packages and also is applied to the IAEA newly created Type C package category.

To be consistent with TS-R-1, the NRC would have to revise 10 CFR Part 71 wording to recognize that the 1,000 A_2 criterion does not apply to fissile material package designs.

Option 1: No-Action Alternative

Under the No-Action Alternative (Option 1), the NRC would not modify Part 71 to incorporate the crush test requirement for fissile material packages.

Option 2: Amendments to 10 CFR Part 71

Under Option 2, the NRC staff would revise section 71.73(c)(2) wording to agree with TS-R-1 and extend the crush test requirement to fissile material package designs.

2.1.11 Fissile Material Package Designs for Transport by Aircraft

The IAEA's TS-R-1 introduced new requirements for fissile material package designs that are intended to be transported aboard aircraft (paragraph 680). TS-R-1 requires that shipped-by-air fissile material packages with quantities greater than excepted amounts (which would include all the NRC certified fissile packages) be subjected to an additional criticality evaluation. Specifically, TS-R-1 paragraph 680 requires that packages must remain subcritical, assuming 20 centimeters of water reflection but not inleakage (i.e., moderation) when subjected to the tests for Type C packages[13]. The specification of no water ingress is given because the objective of this requirement is protection from criticality events resulting from mechanical

[13] The ST-1 imposition of Type C and LDM requirements (see Section 2.1.6) were in recognition that severe aircraft accidents could result in forces exceeding those of the "accident conditions of transport" that are imposed on Type B and fissile package designs. Since the hypothetical accident conditions for Type B packages are the same as those applied to package designs for fissile material there also was a need to consider how these more severe test conditions should be applied to fissile package designs transported by air.

rearrangement of the geometry of the package (i.e., fast criticality). The provision also states that if a package takes credit for "special features," this package can only be presented for air transport if it is shown that these features remain effective even under the Type C test conditions followed by a water immersion test. "Special features" generally mean features that could prevent water inleakage (and therefore could be taken credit for in criticality analyses) under the hypothetical accident conditions. Special features are permitted under current 10 CFR 71.55(c).

The application of the para 680 requirement to fissile-by-air packages is in addition to the normal condition tests (and possibly accident tests) that the package already must meet. Thus:

- Type A fissile package by air must:

  (A) withstand incident-free conditions of transport with respect to release, shielding, and maintaining subcriticality (single package and 5xN array),

  (B) withstand accident condition tests with respect to maintaining subcriticality (single package and 2xN array), and

  (C) comply with para 680 with respect to maintaining subcriticality. (single package).

- Type B fissile package by air must:

  (A) withstand incident-free conditions of transport and Type B tests with respect to release, shielding, and maintaining subcriticality (single package and 5xN array/normal and 2xN array/accident), and

  (B) comply with para 680 with respect to maintaining subcriticality. (single package)

- Type C fissile material package must withstand:

  (A) Incident-free conditions of transport (single package and 5xN array), Type B tests (single package and 2xN array), and Type C tests (single package) with respect to release, shielding, and maintaining subcriticality.

The draft advisory material for the IAEA transport regulations (ST-2) indicates that the requirement "... is provided to preclude a rapid approach to criticality that may arise from potential geometrical changes in a single package..." ST-2 also indicates that "...Where the condition of the package following the tests cannot be demonstrated, worst case assumptions regarding the geometric arrangement of the package and contents should be made taking into account all moderating and structural components of the packaging."

There are no provisions in TS-R-1 for "grandfathering" fissile material package designs which will be transported by air. TS-R-1 paragraphs 816 and 817 state that these packages are not allowed to be grandfathered. Consequently all fissile package designs intended to be transported by aircraft would have to be evaluated prior to their use.

Option 1: No-Action Alternative

Under the No-Action Alternative (Option 1), the NRC would not modify Part 71 to incorporate the TS-R-1 requirements contained in paragraph 680.

Option 2: Amendments to 10 CFR Part 71

Under Option 2, the NRC would include this new TS-R-1 require for an additional criticality evaluation, in a new paragraph 71.55(f), that only applies to air transport.

2.2 NRC-Specific Changes

2.2.1 Special Package Authorizations

IAEA's TS-R-1 establishes procedures for demonstrating the level of safety for shipment of packages under special arrangements. Paragraphs 312 and 824 through 826 of TS-R-1 address approval of shipments under special arrangement and are provided verbatim below:

> *312. Consignments for which conformity with the other provisions of these regulations is impracticable shall not be transported except under special arrangement. Provided the competent authority is satisfied that conformity with the other provisions of the regulations is impracticable and that the requisite standards of safety established by these regulations have been demonstrated through means alternative to the other provisions, the competent authority may approve special arrangement transport operations for a single or a planned series of multiple consignments. The overall level of safety in transport shall at least be equivalent to that which would be provided if all the applicable requirements had been met. For international consignments of this type, multilateral approval shall be required.*
>
> *824. Each consignment transported internationally under special arrangement shall require multilateral approval.*
>
> *825. An application for approval of shipments under special arrangement shall include all the information necessary to satisfy the competent authority that the overall level of safety in transport is at least equivalent to that which would be provided if all the applicable requirements of these Regulations had been met. The application shall also include:*
>
> *A statement of the respects in which, and of the reasons why, the consignment cannot be made in full accordance with the applicable requirements; and*
>
> *A statement of any special precautions or special administrative or operational controls which are to be employed during transport to compensate for the failure to meet the applicable requirements.*
>
> *826. Upon approval of shipments under special arrangement, the competent authority shall issue an approval certificate.*

A Memorandum of Understanding (MOU) published July 2, 1979 (44 FR 38690) specifies the roles of DOT and NRC in the regulation of the transportation of radioactive materials. The MOU outlines that DOT is responsible for regulating safety in transportation of all hazardous materials, including radioactive materials, whereas the NRC is responsible for regulating safety in receipt, possession, use, and transfer of byproduct, source, and special nuclear materials. Thus DOT serves the role of U.S. Competent National Authority and NRC certifies packages for domestic transport of radioactive material. Consequently, a shipper of radioactive materials

must first obtain an NRC Certificate of Compliance for the package. Before the package may be exported the shipper must apply for and receive a competent authority certificate from DOT.

According to statistics compiled by the Nuclear Energy Institute, 31 states have operating nuclear reactors with a total of 103 operating reactors. After a nuclear power plant is closed and removed from service it must be decommissioned. As explained in NUREG-1628, *Staff Responses to Frequently Asked Questions Concerning Decommissioning of Nuclear Power Reactors*, decommissioning a nuclear power plant requires the licensee to reduce radioactive material on site. This effort to terminate the NRC license entails removal and disposal of all radioactive components and materials at each site, including the reactor.

Current NRC practice is to grant exemptions for package approval on special arrangement shipments, as the Commission did for the Portland General Electric (PGE) Trojan Reactor Vessel. 10 CFR 71.8 states:

> *On application of any interested person or on its own initiative, the Commission may grant any exemption from the requirements of the regulations in this part that it determines is authorized by law and will not endanger the life or property nor the common defense and security.*

In October 1998, the NRC staff used this provision to grant a request for approval from PGE to transport the Trojan reactor vessel to a disposal site at the Hanford Nuclear Reservation near Richland, Washington. Specifically, PGE was exempted from 10 CFR 71.71(c)(7), which requires transport packages to be capable of surviving a 30-foot drop, and 71.73(c)(1), which requires the integrity of transport packages to be tested by a one-foot drop onto a flat, unyielding surface prior to shipment. PGE requested these exemptions in order to ship the reactor vessel and internals via barge and land transport to the disposal facility. This scenario was preferred to the alternative separate disposal of the reactor vessel and internals because it resulted in lower radiation exposures to the general public and workers, a shortened decommissioning schedule, and lower overall costs.

Although approval of designs for packages to be used for the transportation of licensed materials qualifies for a categorical exclusion, the exception from preparing an environmental assessment or an environmental impact statement (10 CFR 51.22(c)(13)) does not apply to NRC packages authorized under an exemption. Consequently, the Trojan shipment was authorized for transport only after an Environmental Assessment and Finding of No Significant Impact had been published in the *Federal Register*. Additionally, PGE was required to apply for an exemption from DOT regulations governing radioactive material shipments that do not recognize packages approved under an NRC exemption.

NUREG-1628 reports that as of January 1998, three NRC-licensed power reactors had completed decommissioning. In addition to the Trojan plant, five other nuclear power reactors are now in various stages of dismantlement and decontamination. Because decommissioning is a condition for obtaining a 40-year NRC nuclear power operating license, further decommissioning efforts of the nuclear power reactors can be anticipated for the future.

<u>Option 1: No-Action Alternative</u>

Under the No-Action Alternative (Option 1), NRC would continue to address approval of special packages using exemptions under 10 CFR 71.8.

<u>Option 2: Amendments to 10 CFR Part 71</u>

Under Option 2, the NRC would incorporate new requirements in 10 CFR Part 71 that address approval for shipment of special packages and that demonstrate an acceptable level of safety. These requirements would be based on paragraph 312 of TS-R-1, but also would address regulatory and environmental conditions and requirements that are characteristic to the nuclear industry in the U.S.

2.2.2 Expansion of Part 71 Quality Assurance Requirements Certificate of Compliance (CoC) Holders

NRC has determined that 10 CFR Part 71 is not clear when addressing the issue of applicability of the regulations contained therein (i.e., who is covered by and must comply with the regulations). In fiscal year 1996, NRC staff identified several instances of nonconformance by CoC Holders and their contractors. Nonconformance was observed in the following areas: design, design control, fabrication, and corrective actions. Due to the fact that these problems are typically addressed under a quality assurance program, the proposed rulemaking focuses on amending regulations in Subpart H of Part 71, Quality Assurance. The regulations contained in Subpart H will explicitly include CoC Holders and CoC applicants. Recordkeeping and reporting requirements for these entities also will be established.

The following citation discusses the applicability of Part 71:

> *10 CFR Part 71.0(c) The regulations in this part apply to any licensee authorized by specific or general license issued by the Commission to receive, possess, use, or transfer licensed material, if the licensee delivers that material to a carrier for transport, transports the material outside the site of usage as specified in the NRC license, or transports that material on public highways.*

CoC Holders and CoC applicants appear to be outside the applicability of 10 CFR Part 71.0(c). As noted above, the regulations in Part 71 apply only to NRC licensees. CoC Holders are not necessarily NRC licensees. In fact, a CoC Holder must only abide by the requirements of Part 71, Subpart D to obtain a CoC.

Because CoC Holders and CoC applicants would be subject to the regulations contained in 10 CFR Part 71 under the action, they also would be subject to NRC enforcement actions if they fail to comply with the regulations. Currently, CoC Holders and CoC applicants are only subject to administrative Notices of Noncompliance (NONs). Adding these entities to the applicability of Part 71 would allow NRC to issue Notices of Violation (NOVs), which assign graduated severity levels to violations. The issuance of an NOV performs the following functions: (1) conveys to the entity violating the requirement and to the public that a violation of a legally binding requirement has occurred; (2) uses graduated severity levels to convey the severity level of the violation; and (3) shows that NRC has concluded that a potential risk to public health and safety could exist. The evidence gathered to formulate an NOV can then be used to support the issuance of further enforcement sanctions such as NRC orders.

<u>Option 1: No-Action Alternative</u>

Under the No-Action Alternative (Option 1), NRC would not subject CoC Holders or CoC applicants to the requirements contained in 10 CFR Part 71.

<u>Option 2: Amendments to 10 CFR Part 71</u>

Under Option 2, NRC would explicitly subject CoC Holders and CoC applicants to the requirements contained in 10 CFR Part 71. NRC also would add recordkeeping and reporting requirements for CoC Holders and CoC applicants.

2.2.3 Adoption of ASME Code

Currently, licensees are responsible for implementing and describing a quality assurance (QA) plan as part of the package approval process. The following citation discusses quality assurance:

> *10 CFR Part 71.37(a) The applicant shall describe the quality assurance program [...] for the design, fabrication, assembly, testing, maintenance, repair, modification, and use of the proposed package.*

In addition to licensee QA programs, NRC inspects licensee and licensee contractor operations from time-to-time. NRC inspections of vendor/fabricator shops have uncovered, over the past several years, QA problems with the production of transportation and storage casks. In some instances, QA problems have persisted in spite of repeated NRC deficiency findings. Implementation of the QA provisions set forth in Subpart H of 10 CFR Part 71 is the responsibility of the individual licensees. Because a specific ASME code was not available for spent fuel containers in the past, only portions of various ASME pressure vessel codes were employed in their design and construction. Many QA procedures employed as part of ASME code implementation were therefore not implemented by container designers and fabricators. ASME recently issued “Containment Systems and Transport Packages for Spent Fuel and High Level Radioactive Waste,” Boiler and Pressure Vessel Code, Division 3 Section III. Fabricators manufacturing transportation cask containment systems subject to this specific ASME code would therefore be permitted to stamp components. ASME also is developing a code which, if approved, would allow the stamping of the confinement component for storage casks.

Three principal QA activities are employed when conforming to the ASME code:

- Preparation for and passing of an ASME Survey of each shop and field site involved in fabrication;
- Preparation of a Design Report certified by a licensed professional engineer (PE); and
- Introduction of a full-time Authorized Nuclear Inspector (ANI) on site during fabrication.

The most important aspect of the ASME QA program is the on-site presence of the ANI. The ANI is an independent professional capable of reporting QA issues to the management of the licensee/fabricator, and to the NRC. This on-site expert presence would alleviate the need for NRC inspections of licensee and fabrication facilities.

Implementation of the ASME Code would be consistent with the National Technology Transfer and Advancement Act of 1995, Public Law 104-113, Section 12(d), which requires governmental agency adoption of consensus technical standards. Government agencies are required to adopt these standards unless doing so would be inconsistent with other laws or would be impractical to implement. The proposed rule implementing the ASME consensus technical standards will conform to NRC's "Interim Guidance on the Use of Government-Unique and Voluntary Consensus Standards," May 3, 1999.

Option 1: No-Action Alternative

Under the No-Action Alternative (Option 1), NRC would retain the current QA provisions for the package approval process so that the on-site presence of the ANI would not be required and NRC inspections of licensee and fabrication facilities would continue.

Option 2: Amendments to 10 CFR Part 71

Under Option 2, NRC would adopt the American Society of Mechanical Engineers Boiler and Pressure Vessel (ASME B&PV) Code Section III, Division 3, for spent fuel transportation casks in 10 CFR Part 71. This action would currently apply to spent fuel transportation cask containments. The industry is in the process of revising Division 3 to include storage casks and when re-issued (2 to 5 years), would broaden its current scope to include spent fuel storage canisters and internals, in addition to transportation casks containment and internals. The action also would apply to dual-purpose casks.

2.2.4 Change Authority

Part 71 currently contains no regulations that would: (1) provide a Part 71 certificate holder (for a transportation cask) with the authority to make changes, tests, and experiments equivalent to Part 72.48, or (2) instruct a Part 71 certificate holder on how to apply to amend the Part 71 CoC equivalent to Part 72.244. Part 71 also does not require the user to have a copy of the safety analysis report or other documents that describe the design of the package. In addition, Part 71, Subpart D, currently uses the terminology submission of a "package description" in an application, rather than the terminology submission of a "safety analysis report." Lastly, Part 71 currently contains no regulations that would require an update of a FSAR — reflecting any changes made under a Part 71.48 — equivalent to Part 72.248.

The NRC has recently issued a final rule in 10 CFR Part 72 to allow licensees and cask certificate holders to perform minor changes, tests and experiments relative to an Independent Spent Fuel Storage Installation (ISFSI) or spent fuel storage cask design or to conduct tests and experiments — without prior NRC approval — if certain conditions are met. The NRC staff initially considered, based on: (1) public comment received on the Part 72 proposed rule; (2) the staff's discussions of technical issues in SECY-99-130; and (3) the subsequent Commission approval, to extend the approach used in the Part 72 final rule to Part 71 for domestic dual-purpose casks (i.e., casks used for both transportation and storage of spent nuclear fuel).

Subsequently, NRC staff have determined that the regulatory structure of Part 71 does not lend itself to implementing a parallel change with Part 72. The result could be a situation in which one licensee could make an authorized change to a package, without prior NRC approval, transfer that package to another registered user, without forwarding all change summaries to the next user, who would then be unable to verify or recognize that the package is acceptable for use under section 71.87.

<u>Option 1: No-Action Alternative</u>

Under the No-Action Alternative (Option 1), licensees or cask certificate holders would still be required to gain NRC approval for changes to procedures, or cask designs, through license amendments.

<u>Option 2: Amendments to 10 CFR Part 71</u>

Under Option 2, NRC would revise 10 CFR Part 71 to add a new section regulating dual-purpose transportation packages (i.e., casks designed for both shipment and storage of spent nuclear fuel) used for domestic purposes only. In addition to providing a new process for approving dual purpose transportation packages, the new requirements would provide for the authority for CoCs to make changes to a dual purpose package design without prior NRC approval. The section also would include new requirements for submitting and updating a final safety analysis report describing the package's design.

2.2.5 Fissile Material Exemptions and General License Provisions

Included within 10 CFR Part 71 are criteria that allow exemptions from classification as a fissile material package and general licenses for fissile material shipments:

1. Subpart B -- Exemptions
    - Exemption for low-level material (section 71.10)

2. Subpart C -- General Licenses
    - Fissile material, limited quantity per package (section71.18)
    - Fissile material, limited moderator per package (section 71.20)
    - Fissile material, limited quantity, controlled shipment (section 71.22)
    - Fissile material, limited moderator, controlled shipment (section 71.24)

3. Subpart E -- Package Approval Standards
    - Fissile material exemptions (section 71.53)

Since their initial promulgation, the exemptions and general licenses pertaining to requirements for packaging, preparation of shipments, transportation of licensed materials, and NRC approval of packaging and shipping procedures have not been significantly altered. Available knowledge on radioactive materials transportation and historic practices confirmed the need for little or no regulatory oversight of packaging or shipment of fissile materials meeting the criteria established in 10 CFR Part 71. The fissile material exemptions and general license provisions allowed licensees to prepare and send shipments of such fissile materials without obtaining specific approval from NRC.

Before February 1997, section 71.53(d) exempted fissile material from the requirements in sections 71.55 and 71.59, provided the package did not contain more than 5 grams of fissile material in any 10-liter (610-cubic inch) volume. The fissile exemptions appearing in 10 CFR 71.53 were assumed to provide inherent criticality control for all practical cases in which fissile materials existed at or below the applicable regulatory limits (i.e., independent calculations would generally not be expected nor required). Thus, the fissile exemptions did not generally place limits on either the types of moderating/reflecting material present in fissile exempt packages or the number of fissile exempt packages that could be shipped in a single consignment. Also, these exemptions did not require the assignment of a transport index for criticality control.

In February 1997, NRC completed an emergency final rulemaking (62 FR 5907, February 10, 1997) to address newly-encountered situations regarding the potential for inadequate criticality safety in certain shipments of exempted quantities of fissile material (beryllium oxide containing a low-concentration of high-enriched uranium). The emergency rule revised portions of 10 CFR Part 71 that limited the consignment mass for fissile material exemptions and restricted the presence of beryllium, deuterium, and graphite moderators. Subsequent to its release, NRC solicited public comments on the emergency rule. Five NRC fuel cycle facility licensees and two other interested parties responded with comments that supported the need for the emergency rule, but argued that the restrictions imposed therein were excessive. For example, several commenters noted that they had shipped wastes that violated the emergency rule in the past without any problems and that the new restrictions would at least double the number of waste shipments, thereby increasing costs, decreasing worker safety, and increasing the risk of accidents.

Based on these public comments and other relevant concerns, NRC decided that further assessment was required, including a comprehensive assessment of all exemptions, general licenses, and other requirements pertaining to *any* fissile material shipment (i.e., not just fissile material shipments addressed by the emergency rulemaking). NRC contracted Oak Ridge National Laboratory (ORNL) to conduct the assessment, and ORNL reviewed 10 CFR Part 71 (as modified by the emergency rule) in its entirety to assess its adequacy relative to the technical basis for assuring criticality safety. Specifically, ORNL:

- documented perceived deficiencies in the technical or licensing bases that might be incapable of maintaining subcriticality under normal conditions of transport and hypothetical accident conditions;

- identified areas where regulatory wording could cause confusion among licensees and potentially lead to subsequent safety concerns;

- studied and identified the practical aspects of transportation and licensing that could mitigate, justify, or provide a historical basis for any identified potential deficiency; and

- developed recommendations for revising the current regulations to minimize operational and economic impacts on licensees, while maintaining safe practices and correcting licensing deficiencies.

The results of the ORNL study (NUREG/CR-5342) indicated that the fissile material exemptions and general licenses need updating, particularly to provide a simpler and more straightforward interpretation of the restrictions and criteria set in the regulations. The regulatory options are based on the recommendations contained in NUREG/CR-5342.

Option 1: No-Action Alternative

Under the No-Action Alternative (Option 1), NRC would not modify 10 CFR Part 71 to implement the 17 recommendations contained in NUREG/CR-5342, but would continue to use the modified regulations promulgated under 10 CFR Part 71, RIN 3150-AF58, Fissile Material Shipments and Exemptions, final rule. This alternative involves amendments of regulations for the shipment of exempt quantities of fissile material and the shipment of fissile material under a general license through the restriction of the use of beryllium and other special moderating materials in the shipment of fissile materials and the consignment of limits on fissile exempt shipments.

Option 2: Amendments to 10 CFR Part 71

Under Option 2, NRC would modify the 10 CFR Part 71 regulations in numerous ways, as needed, to implement the entire set of 17 recommendations contained in NUREG/CR-5342. These recommendations and the changes to Part 71, which are summarized in Table 2-2 below, involve the exemption of fissile material from shipment as radioactive material; the shipment of fissile material under general licenses; and the shipment of fissile material classified as exempt.

2.2.6 Double Containment of Plutonium (PRM-71-12)

NRC's regulations in section 71.63 include the following special requirements for plutonium shipments:

> *§71.63 Special requirements for plutonium shipments.*
>
> *(a) Plutonium in excess of 0.74 TBq (20 Ci) per package must be shipped as a solid.*
>
> *(b) Plutonium in excess of 0.74 TBq (20 Ci) per package must be packaged in a separate inner container placed within outer packaging that meets the requirements of Subparts E and F of this part for packaging of material in normal form. If the entire package is subjected to the tests specified in §71.71 ("Normal conditions of transport"), the separate inner container must not release plutonium as demonstrated to a sensitivity of 10^{-6} A_2/h. If the entire package is subjected to the tests specified in §71.73 ("Hypothetical accident conditions"), the separate inner container must restrict the loss of plutonium to not more than A_2 in 1 week. Solid plutonium in the following forms is exempt from the requirements of this paragraph:*

Table 2-2. Recommendations and Changes Related to Fissile Material Packaging Exemptions and General Licenses

NUREG/CR-5342 Recommendation	Summary of Recommended Action
1. Revise the definitions in §71.4 and other text in 10 CFR Part 71 (perhaps considering relationships between 49 CFR Part 173 and IAEA No. TS-R-1) to ensure consistency and to clarify any intended distinctions between words/phrases such as: - exemption, exception, and exclusion - manifest, consignment, shipment, and conveyance - consignment, consignor, and shipper - controlled shipment, exclusive use, etc.	Amend definitions and phrases in 10 CFR Part 71 to ensure consistency between 10 CFR Part 71, IAEA safe transportation standards in TS-R-1, and DOT requirements contained in 49 CFR Part 173.
2. Revise the definition of “fissile material” in §71.4 and other text in 10 CFR Part 71 to (1) eliminate the nuclide ^{238}Pu from the definition, and (2) clarify whether “fissile material” consists of fissile nuclides or of materials containing fissile nuclides.	Amend 10 CFR 71.4 by revising the definitions of “fissile material,” “package,” and “transportation index.” The definition of “fissile material” would be revised by removing ^{238}PU from the list of fissile nuclides; clarifying that fissile material means the fissile nuclides, not materials containing fissile nuclides, and redesignating the reference to exclusions from the fissile material controls from §71.53 to new §71.11. The definition of “package” would be revised by redefining “Type A packages” in accordance with DOT regulations contained in 49 CFR Part 173. The definition of “transport index” (TI) would be revised to provide greater clarity on the two different bases for the TI: radiation safety and criticality safety, and to clarify where equations for calculating the TI are located within the regulations.
3. Revise §71.11 so that, if the radioactive material contains fissile material, the exemption applies only if the specific activity is not greater than 43 Bq/g.	Amend 10 CFR 71.11 to exempt radioactive material containing fissile material if the mass ratio of iron to fissile material is greater than 200:1 and the package contents contain less than 15 g of fissile material.
4. Revise the §71.10(b) exemption so that it does not include fissile material that should meet a packaging requirement.	Revise paragraph (b) by redesignating the reference to fissile material exemption standards from §71.53 to new §71.11.

Table 2-2. Recommendations and Changes Related to Fissile Material Packaging Exemptions and General Licenses (Continued)

NUREG/CR-5342 Recommendation	Summary of Recommended Action
5. Move the §71.53 fissile material exemptions to Subpart B of Part 71, from Subpart E.	Redesignate §71.53 as §71.11 and relocate these requirements to Subpart B with the other Part 71 exemptions. This section also would be amended by adding new paragraphs to provide mass-based limits in classifying fissile material. In addition, the concentration or consignment based limits currently described in §71.53 would be removed with the exception of the 15 g limit; and a new ratio of fissile to non-fissile material would be added.
6. Establish at NRC or DOE a fissile shipment database to help NRC better understand fissile shipments and make more informed regulatory determinations in the future. This recommendation would probably require regulatory changes to either or both of §71.91 (“Records) and §71.95 (“Reports”), depending on how shipment information would be obtained.	Add new reporting and recordkeeping requirements to §71.19 to track information pertaining to fissile material shipments.
7. Create a separate general license for Pu-Be sources, revise the quantity of plutonium allowed to be shipped as Pu-Be neutron sources, and/or provide packaging requirements that prevent challenges to the basis for criticality safety.	Replace existing §71.20 with a new section to provide regulations on the shipment of Pu-Be special form material, consolidating regulations contained in §§71.18 and 71.22. The overall effect of the change to be to permit shipments of Pu-Be sealed sources containing between 24 and 240 g of fissile Pu on exclusive use shipments. Shipments containing less than 240 g could be made under the revisions to §71.18 and on exclusive or non-exclusive use conveyances. Shipment of Pu-Be sealed sources containing greater than 240 g fissile Pu would be made in Type B packages on an exclusive use conveyance.
8. Simplify the general license provisions and make them consistent with §71.59 by (1) merging sections addressing general licenses for controlled shipments (§71.22 and §71.24) along with sections addressing general licenses for limited quantity/moderator per package (§71.18 and §71.20), and (2) specifying the aggregate transport index (TI) allowed for non-exclusive use and exclusive use.	Remove §§71.22 and 71.24. 10 CFR 71.59 would be revised to use the term “criticality safety index” consistently between §§71.59, 71.18 and 71.20. The action also will be revised such that packages shipped under these sections should use the criticality control transport index determined by those sections. The action would revise the phrase “[n]ot in excess of 10” instead of the phrase “[l]ess than or equal to 10.0.” In addition, the section will be revised to provide guidance when the criticality control transport index is exactly 10.0.

Table 2-2. Recommendations and Changes Related to Fissile Material Packaging Exemptions and General Licenses (Continued)

NUREG/CR-5342 Recommendation	Summary of Recommended Action
9. Revise §71.20 and §71.24 to use bounding non-uniform quantities of ^{235}U rather than to distinguish between uniform and non-uniform distributions. Alternatively, add a definition of "non-uniform distribution" that can be clearly interpreted by licensees to §71.4.	Remove the requirements contained in §§ 71.20 and 71.24 and incorporated into the new §71.18 - General license: Fissile material.
10. Delete/revise §71.18(e) and §71.22(e), which address the shipment under general licenses of fissile materials containing Be, C, and D_2O, to remove the Be, C, and D_2O quantity restrictions, except to note that these materials should not be present as a reflector material (limiting the quantity of these materials to 500g per package should eliminate any concern relative to their effectiveness as a reflector).	See recommended action for Recommendation 8.
11. Revise the mass control in 10 CFR 71.18(d) and the mass restriction in 10 CFR 71.20(c)(4) for moderators having a hydrogen density greater than water to apply (only) whenever such high-density hydrogenous moderator exceeds 15 percent of the mass of hydrogenous moderator in the package.	Revise the gram limits for fissile material mixed with material having a hydrogen density greater than water and place them in new Table 71-1.
12. Specify minimum package requirements as provided by §71.43 and §71.45 for shipments under the general licenses to help ensure good shipping practices for fissile materials with low specific activity.	Specify that fissile material shipped under the general license provisions of new §71.18 would be contained in a Type A package.
13. Given the implementation of Recommendation 12, increase the package mass limits allowed by §71.18 and §71.20 to provide similar safety equivalence as certified packages defined under §71.55 and §71.59.	See recommended action for Recommendation 12.
14. Revision to mass-limited exemptions. Provide criteria based on a ratio of the mass of fissile material per mass of nonfissile material that is non-combustible, insoluble in water, and not Be, C or D_20. Alternatively, incorporate into §71.53 a conveyance control based on a TI of 100. Given one of the above, remove the restriction on Be, C, and D_2O from §71.53 except for §71.53(b).	Provide mass-based limits in classifying fissile material. The recommended action would allow for increasing quantities of fissile material to be shipped; however, there would be additional restrictions in the form of ratios of the mass of the fissile material to non-fissile material present in the package. The mass of moderating materials would not be allowed in the mass of the package when calculating the ratio of fissile to non-fissile material.
15. Revise §71.53(a), (c), and (d) by deleting restrictions on Be, C, and D_2O.	The current restrictions on Be, C, and D_2O would be removed as licensees would be allowed to us a mass-ratio rather than a mass-limit.

Table 2-2. Recommendations and Changes Related to Fissile Material Packaging Exemptions and General Licenses (Continued)

NUREG/CR-5342 Recommendation	Summary of Recommended Action
16. Revise §71.53(c) by adding the minimum packaging standard at §71.43 to the exemption for uranyl nitrite solutions transport.	Amend the current requirement to clarify that the nitrogen to uranium atomic ratio for shipments of liquid uranyl nitrate must be greater than or equal to 2.0 Further, a requirement specifying the use of Type A packages would be added.
17. Revise §71.53(b) by removing the requirement that the fissile material be distributed homogeneously throughout the package contents and that the material not form a lattice arrangement within the package. (Maintain the moderator criteria restricting the mass of Be, C, and D_2O to less than 0.1 percent of the fissile material mass.)	Revise the requirement in §71.53(b) to provide that beryllium, graphite, and hydrogenous material enriched in deuterium, constitute less than 0.1 percent of the fissile material mass.

(1) Reactor fuel elements;

(2) Metal or metal alloy; and

(3) Other plutonium bearing solids that the Commission determines should be exempt from the requirements of this section.

The NRC received a petition for rulemaking on behalf of International Energy Consultants, Inc. dated September 25, 1997. In this petition, the petitioner requested that section 71.63(b) be deleted. The petitioner believed that provisions stated in this regulation cannot be supported technically or logically. The petitioner stated that based on the "Q-System for the Calculation of A_1 and A_2 Values," an A_2 quantity of any radionuclide has the same potential for damaging the environment and the human species as an A_2 quantity of any other radionuclide. The petitioner further stated that the requirement that a Type B package must be used whenever package content exceeds an A_2 quantity should be applied consistently for any radionuclide. The petitioner believed that if a Type B package is sufficient for a quantity of a radionuclide X which exceeds A_2, then a Type B package should be sufficient for a quantity of radionuclide Y which exceeds A_2, and this should be similarly so for every other radionuclide.

The petitioner stated that while, for the most part, the regulations embrace this simple logical congruence, the congruence fails under section 71.63(b) because packages containing plutonium must include a separate inner container for quantities of plutonium having an activity exceeding 0.74 TBq (20 Ci). The petitioner believed that if the NRC allows this failure of congruence to persist, the regulations will be vulnerable to the following challenges:

(1) The logical foundation of the adequacy of A_2 values as a proper measure of the potential for damaging the environment and the human species, as set forth under the Q-System, is compromised;

(2) The absence of a radioactivity limit for every radionuclide which, if exceeded, would require a separate inner container, is an inherently inconsistent safety practice; and

(3) The performance requirements for Type B packages as called for by 10 CFR Part 71 establish containment conditions under different levels of package trauma. The satisfaction of these requirements should be a matter of proper design work by the package designer and proper evaluation of the design through regulatory review. The imposition of any specific package design feature such as that contained in 10 CFR 71.63(b) is gratuitous. The regulations are not formulated as package design specifications, nor should they be.

The petitioner believed that the continuing presence of section 71.63(b) engenders excessively high costs in the transport of some radioactive materials without a clearly measurable net safety benefit. The petitioner stated that this is so in part because the ultimate release limits allowed under Part 71 package performance requirements are identical with or without a "separate inner container," and because the presence of a "separate inner container" promotes additional exposures to radiation through the additional handling required for the "separate inner container." The petitioner further stated that "...excessively high costs occur in some transport campaigns," and that one example "... of damage to our national budget is in the transport of transuranic wastes." Because large numbers of transuranic waste drums must be shipped in packages that have a "separate inner container" to comply with the existing rule, the petitioner believed that large savings would accrue without this rule. Therefore, the petitioner believed that elimination of section 71.63(b) would resolve these regulatory "defects."

As a corollary to the primary petition, the petitioner believed that an option to eliminate section 71.63(a) as well as section 71.63(b) also should be considered. This option would have the effect of totally eliminating section 71.63. The petitioner believed that the arguments propounded to support the elimination section 71.63(b) also support the elimination of section 71.63(a).

By letter dated April 30, 1999, the NRC informed the petitioner that it had considered the petition and the public comments and decided to defer final action on the petition. The NRC informed the petitioner of its development of the current Part 71 rulemaking and that the subject matter of the petition and elements of the rulemaking address similar issues, and that resolution of the petition would be conducted with the rulemaking action.

The NRC anticipated in 1974 that a large number of shipments of plutonium nitrate liquids could result from spent nuclear fuel reprocessing and revised its regulations to require that plutonium in excess of 0.74 TBq (20 Ci) be shipped in solid form. The NRC did so because shipment of plutonium liquids is susceptible to leakage (if the shipping package is improperly or not tightly sealed). The value of 0.74 TBq (20 Ci) was chosen because it was equal to a large quantity of plutonium as defined in 10 CFR Part 71 in effect in 1974. Although this definition no longer appears in 10 CFR Part 71, the value as applied to double containment of plutonium has been retained. The concern about leakage of liquids arose because of the potential for a large number of packages (probably of more complex design) to be shipped due to reprocessing and the increased possibility of human error resulting from handling this expanded shipping load.

The NRC treats dispersible plutonium oxide powder in the same way because it also is susceptible to leakage if packages are improperly sealed. Plutonium oxide powder was of particular concern because it was the most likely alternative form (as opposed to plutonium nitrate liquids) for shipment in a fuel reprocessing economy. To address the concern with dispersible powder, the NRC required that plutonium not only must be in solid form, but also that solid plutonium be shipped in packages requiring double containment. Moreover, the NRC stated that the additional inner containment requirements are intended to take into account that the plutonium may be in a respirable form and that solid forms that are essentially nonrespirable, such as reactor fuel elements, are suitable for exemption from the double containment requirement.

The Commission further stated:

> Since the double containment provision compensates for the fact that the plutonium may not be in a “nonrespirable” form, solid forms of plutonium that are essentially nonrespirable should be exempted from the double containment requirement. Therefore, it appears appropriate to exempt from the double containment requirements reactor fuel elements, metal or metal alloy, and other plutonium bearing solids that the commission determines suitable for such exemption. The latter category provides a means for the Commission to evaluate, on a case-by-case basis, requests for exemption of other solid material where the quantity and form of the material permits a determination that double containment is unnecessary.

Placing the 1974 decision in the context of the times, in a document dated June 17, 1974, titled “Environmental Impact Appraisal Concerning Proposed Amendments to 10 CFR Part 71 Pertaining to the Form of Plutonium for Shipment” the following statements were made:

Using the present criteria and requirements of Part 71, hundreds of packages containing plutonium nitrate solutions have been shipped with no reported instances of plutonium leaks from the containment vessel.

The present situation with respect to the quantity and specific activity (radioactivity per unit mass) of plutonium involved in transportation is expected to change significantly over the next several years. Increasingly large quantities of plutonium shipped and the number of shipments made are expected to increase. For example, the amount of plutonium available for recovery was estimated to be about 500 kg in 1974 as compared to 20,000 kg in 1980. In addition, the specific activity of the plutonium will increase with higher reactor fuel burn-up, resulting in higher gamma and neutron radiation levels, greater heat generation, and greater potential for pressure generation (through radiolysis) in shipping packages containing plutonium nitrate solutions.

Because of expected changes in the quantities and characteristics of plutonium to be transported and because of the inherent susceptibility of liquids to leakage, the Commission believes that safety would be enhanced if the physical form of plutonium for shipment was restricted to a solid, except for packages containing less than 20 curies.

Further, in SECY-R-74-5, dated July 6, 1973, it was acknowledged by NRC that:

The arguments for requiring a solid form of plutonium for shipment are largely subjective, in that there is no hard evidence on which to base statistical probabilities or to assess quantitatively the incremental increase in safety which is expected. The discussion in the Regulatory staff paper, SECY-R-702, is not intended to be a technical argument which incontrovertibly leads to the conclusion. It is, rather, a presentation of the rationale which has led the Regulatory staff to its conclusion that a possible problem may develop and that the proposed action is a step towards increasing assurance against the problem developing.

On November 30, 1993, the DOE petitioned the Commission to amend section 71.63 to add a provision that would specifically remove canisters containing plutonium-bearing vitrified waste from the packaging requirement for double containment. DOE's main arguments were that the canistered vitrified waste provided a comparable level of protection to reactor fuel elements, that the plutonium concentrations in the vitrified waste will be lower than in spent nuclear fuel, and that the vitrified waste is in an essentially nonrespirable form. The Commission published a notice of receipt for the petition, docketed as PRM-71-11, in the *Federal Register* on February 18, 1994, requesting public comment by May 4, 1994. The public comment period was subsequently extended to June 3, 1994, at the request of the Idaho National Engineering and Environmental Laboratory (INEEL) Oversight Program of the State of Idaho.

On June 1, 1995, the NRC staff met with the DOE in a public meeting to discuss the petitioner's request and the possible alternative of requesting an NRC determination under section 71.63(b)(3) to exempt vitrified high level waste from the double containment requirement. The DOE informed the NRC in a letter dated January 25, 1996, of its intent to seek this exemption and the NRC received DOE's request on July 16, 1996. The original petition for rulemaking was requested to be held in abeyance until a decision was reached on the exemption request.

In response to DOE's request, the NRC staff prepared a Commission paper (SECY-96-215, dated October 8, 1996) outlining and requesting Commission approval of the NRC staff's proposed approach for making a determination under section 71.63(b)(3). The determination would have been the first made after the promulgation of the original rule, "Packaging of Radioactive Material for Transport and Transportation of Radioactive Materials Under Certain Conditions," published on June 17, 1974 (39 FR 20960). In a staff requirements memorandum dated October 31, 1996, the Commission disapproved the NRC staff's plan and directed that this policy issue be addressed by rulemaking.

In response, the NRC staff reactivated the DOE petition and developed a proposed rule. On June 15, 1998, the final rule was noticed in the *Federal Register*. In summary, the NRC amended its regulations to add vitrified high level waste, contained in a sealed canister designed to maintain waste containment during handling activities associated with transport, to the forms of plutonium which are exempt from the double containment packaging requirements for transportation of plutonium.

In a October 31, 1996, SRM for SECY-96-215 (dealing with the vitrified waste issue) the Commission directed the staff to "address whether the technical basis for 10 CFR 71.63 remains valid, or whether a revision or elimination of portions of 10 CFR 71.63 is needed to provide flexibility for current and future technologies." In SECY-97-218, dated September 29, 1997, the Commission was informed that "the staff believes the technical bases for 10 CFR 71.63 remain valid and that the provisions provide adequate flexibility for current and future technologies. The staff believes it is desirable to retain those provisions of 10 CFR 71.63 that are not being covered by a separate rulemaking currently underway." The rulemaking underway referred to the DOE petition regarding transport of vitrified high level waste containing plutonium. In the discussion section of SECY-97-218, the staff again admitted that the special provisions (of 10 CFR 71.63) were not based on quantitative evidence of statistical analysis. Instead, subjective arguments regarding experience with shipment and design of packages were used as the basis to support the conclusion.

It should be noted that in press release No. 97-070, dated May 8, 1997, announcing the change in the regulations to allow shipment of plutonium-bearing vitrified waste, the NRC stated:

> *When the existing rule was published, the NRC anticipated that a large number of shipments of plutonium nitrate liquids or plutonium oxide powder could result from spent fuel reprocessing. However, the anticipated large number of shipments has not occurred, because commercial reprocessing is currently not taking place in this country for policy and economic reasons.*

Option 1: No-Action Alternative

Under the No-Action Alternative (Option 1), NRC would retain the section 71.63 special requirements for plutonium shipments, which would place increased plutonium shipping requirements in the U.S. compared to the IAEA requirements.

Option 2: Amendments to 10 CFR Part 71

Under Option 2, NRC would adopt, in part, the recommended action of PRM-71-12. Specifically, the NRC would remove the double containment requirement of section 71.63(b). However, the NRC would retain the package contents requirement in section 71.63(a) — for shipments whose contents contain greater than 0.74 TBq (20 Ci) of plutonium must be made with the contents in solid form.

2.2.7 Contamination Limits as Applied to Spent Fuel and High Level Waste (HLW) Packages

TS-R-1 contains contamination limits for all packages of 4.0 Bq/cm^2 (22,000 dpm/100 cm^2) for beta and gamma and low toxicity alpha emitting radionuclides, and 0.4 Bq/cm^2 (2,200 dpm/100 cm^2) for all other alpha emitting radionuclides. Although TS-R-1 uses the term “limit,” IAEA considers these to be guidance values, or derived limits, above which appropriate action should be considered. In the case of contamination, that action is to decontaminate to within the limits.

TS-R-1 further provides that in transport, “...the magnitude of individual doses, the number of persons exposed, and the likelihood of incurring exposure shall be kept as low as reasonable, economic and social factors being taken into account...”   The IAEA contamination regulations have been applied to radioactive material packages in international commerce for almost 40 years and practical experience demonstrates that the regulations can be applied successfully. With respect to contamination limits, TS-R-1 contains no changes from previous versions of IAEA’s regulations.

Part 71 does not contain contamination limits, but section 71.87(i) requires that licensees determine that the level of removable contamination on the external surface of each package offered for transport is as low as is reasonably achievable and within the limits specified in DOT regulations in 49 CFR 173.443. The DOT contamination limits differ from TS-R-1 in that the contamination limits apply to the wipe material used to survey the surface of the package, not the surface itself. Also, the contamination limits are only 10 percent of the TS-R-1 values (e.g., wipe limit of 0.4 Bq/cm^2 for beta and gamma and low toxicity alpha emitting radionuclides), because the DOT limits are based on the assumption that the wipe removes 10 percent of the surface contamination. In this regard, the DOT and TS-R-1 limits are equivalent.

The DOT contamination regulations contain an additional provision for which there is no counterpart in TS-R-1. Section 173.443(b) provides that, for packages transported as exclusive use (see 49 CFR 173.403 for exclusive use definition) shipments by rail or public highway only, the removable contamination on any package at any time during transport may not exceed 10 times the contamination limits (e.g., wipe contamination of 4 Bq/cm^2 for beta and gamma and low toxicity alpha emitting radionuclides). In practice, this means that packages transported as exclusive use shipments (this includes spent fuel packages) that meet the contamination limits at shipment departure may have 10 times that contamination upon arrival at the destination. This provision is intended to address a phenomenon known as “cask-weeping,” in which surface contamination that is nonremovable at the beginning of a shipment becomes removable

during the course of the shipment. Nonremovable contamination is not measurable using wipe surveys and is not subject to the removable contamination limits. At the destination facility, a package exhibiting cask-weeping can exceed the contamination limits by a considerable margin, even though the package met the limits at the originating facility, and was not subjected to any further contamination sources during shipment. Environmental conditions are believed to affect the cask-weeping phenomenon.

The IAEA has plans to establish a Coordinated Research Project (CRP) to review contamination models, approaches to reduce package contamination, strategies to address cask-weeping, and possible recommendations for revisions to the contamination standard that consider risks, costs, and practical experience. IAEA establishes CRPs to facilitate investigation of radioactive material transportation issues by key member States. IAEA will then consider CRP report and any further actions or remedies that may be warranted at periodic meetings.

No regulatory change is proposed at this time. Therefore, no regulatory options have been identified. The above discussion is for information purposes only.

2.2.8 Modifications of Event Reporting Requirements

The current regulations in section 71.95 require that a licensee submit a written report to the NRC within 30 days of three events: (1) a significant decrease in the effectiveness of a packaging while is in use to transport radioactive material, (2) details of any defects with safety significance found after first use of the cask, and (3) failure to comply with conditions of the certificate of compliance (CoC) during use.

The Commission recently issued a final rule to revise the event reporting requirements in 10 CFR Part 50 (see 65 FR 63769). This final rule revised the verbal and written event notification requirements for power reactor licensees in 10 CFR 50.72 and 50.73. In SECY-99-181,[14] NRC staff informed the Commission that public comments on the proposed Part 50 rule had suggested that conforming changes also be made to the event notification requirements in 10 CFR Part 72 (Licensing Requirements for the Independent Storage of Spent Fuel) and 10 CFR Part 73 (Physical Protection of Plants and Material). In response, the Commission directed the NRC staff to study whether conforming changes should be made to Parts 72 and 73. During this study, the NRC staff also reviewed the Part 71 event reporting requirements in 10 CFR 71.95 and concluded that conforming changes should be made to the Part 71 event report requirements. NRC staff also concluded that this proposed rule was the appropriate vehicle to consider such changes.

The NRC staff has identified three principal concerns with the existing requirements in 71.95. First, the existing requirements only apply to licensees and not to certificate holders. Second, the existing requirements do not contain any direction on the content of these written reports. Third, the Commission recently reduced the reporting burden on reactor licensees in the Part 50 final rule from submitting written reports in 30 days to 60 days.

<u>Option 1: No-Action Alternative</u>

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[14] SECY-99-181, "Proposed Plans and Schedules to Modify Reporting Requirements Other than 10 CFR 50.72 and 50.73 for Power Reactors and Material Licensees;" dated July 9, 1999.

Under the No-Action Alternative (Option 1), NRC would not modify section 71.95 and would continue to require that a licensee submit a written report to the NRC within 30 days of three events: (1) a significant decrease in the effectiveness of a packaging while it is in use to transport radioactive material, (2) details of any defects with safety significance found after first use of the cask, and (3) failure to comply with conditions of the certificate of compliance (CoC) during use.

Option 2: Amendments to 10 CFR Part 71

Under Option 2, NRC would revise section 71.95 to require that the licensee and certificate holder jointly submit a written report for the criteria in new subparagraphs (a)(1) and (a)(2). The NRC also would add new paragraphs (c) and (d) to section 71.95 which would provide guidance on the content of these written reports. This new requirement is consistent with the written report requirements for Part 50 and 72 licensees (i.e., sections 50.73 and 72.75) and the direction from the Commission in SECY-99-181 to consider conforming event notification requirements to the recent changes made to Part 50. The NRC also would update the submission location for the written reports from the Director, Office of Nuclear Material Safety and Safeguards to the NRC Document Control Desk. Additionally, the NRC would remove the specific location for submission of written reports from section 71.95(c) and instead require that reports be submitted "in accordance with section 71.1." Lastly, the NRC would reduce the regulatory burden for licensees by lengthening the report submission period from 30 to 60 days.

3. Analysis of Values and Impacts

This chapter examines the values and impacts expected to result from NRC's proposed rulemaking. It is divided into four main sections. Section 3.1 identifies attributes that are and are not expected to be affected by the rulemaking. Section 3.2 describes how values and impacts were analyzed. Section 3.3 examines the projected values and impacts associated with the actions to harmonize NRC's transportation regulations with the IAEA's latest safety standards. Finally, Section 3.4 examines the projected values and impacts associated with the NRC-specific actions.

NRC's proposed rulemaking would modify 10 CFR Part 71 to incorporate the IAEA safe transportation standards contained in TS-R-1 and other changes, in addition to the recommendations contained in NUREG/CR-5342. Each of the actions would result in certain values and/or impacts. Thus, the values and impacts of NRC's proposed rulemaking as a whole consist of the sum of all values and impacts associated with each of the actions. For many of the affected attributes, the values and impacts are expected to be negligible. These values and impacts, therefore, are difficult to estimate, and have not been quantified in this analysis.

3.1 Identification of Affected Attributes

This section identifies and describes the factors within the public and private sectors that the regulatory alternatives (discussed in Section 2) are expected to affect. These factors were classified as "attributes," using the list of attributes provided by NRC in Chapter 5 of its *Regulatory Analysis Technical Evaluation Handbook*.[15] Each attribute listed in Chapter 5 was evaluated, and the basis for selecting those attributes expected to be affected by the action is presented in the balance of this section.

Affected Attributes

- Public Health (Accident) -- Changes to radiation exposures to the public, due to changes in accident frequencies and accident consequences, could result from the proposed rule. The regulatory options could both alter the number of shipments (thereby altering the accident frequency) and reduce the likelihood of occurrences of criticality (thereby reducing accidental consequences).

- Occupational Health (Accident) -- Changes to radiation exposures to workers, due to changes in accident frequencies and accident consequences, could result from the proposed rule. The regulatory options could both alter the number of shipments (thereby altering the accident frequency) and reduce the likelihood of occurrences of criticality (thereby reducing accidental consequences).

- Occupational Health (Routine) -- Changes to radiation exposures to workers during normal packaging and transportation operations could result from the proposed rule. The regulatory options could alter the number of packages or shipments, thereby altering the number of workers exposed or the duration of the exposure.
- Offsite Property -- Effects on offsite property, due to changes in accident frequencies and accident consequences, could result from the action. The regulatory options could

[15] *Regulatory Analysis Technical Evaluation Handbook*, *Final Report*, NUREG/BR-0184, Office of Nuclear Regulatory Research, January 1997.

both alter the number of shipments (thereby altering the accident frequency) and reduce the likelihood of occurrences of criticality (thereby reducing accidental consequences).

- Onsite Property -- Effects on onsite property (direct and indirect), due to changes in accident frequencies and accident consequences, could result from the action. The regulatory options could both alter the number of shipments (thereby altering the accident frequency) and reduce the likelihood of occurrences of criticality (thereby reducing accidental consequences).

- Industry Implementation -- The regulatory options would result in implementation costs and savings to industry if industry must evaluate and/or enact changes to ensure that its operating procedures will comply with the actions.

- Industry Operation -- The regulatory options would result in industry operation costs and savings to industry if industry must alter its current packaging and shipping procedures to comply with the action.

- NRC Implementation -- The regulatory options would result in NRC implementation costs and savings to put the actions into operation. Specifically, NRC would incur implementation costs to revise guidance documents, and where applicable, develop new guidance.

- NRC Operation -- The regulatory options would result in NRC operation costs or savings if the number of shipments requiring specific NRC approval changes (e.g., the number of shipments that fail to qualify for the fissile exemption and the general licenses).

- Regulatory Efficiency -- The requirements would be expected to result in enhanced regulatory efficiency by clarifying the meaning and applicability of specific terms and requirements, increasing the level of consistency among different regulations, and reducing the potential for noncompliance.

- Environmental Considerations -- Effects on the environment, due to changes in accident frequencies and accident consequences, could result from the action. The regulatory options could both alter the number of shipments (thereby altering the accident frequency) and reduce the likelihood of occurrences of criticality (thereby reducing accidental consequences). These environmental effects are being addressed separately in the Environmental Assessment being developed in support of the proposed rulemaking.

- Other Government -- The regulatory options could affect implementation and operation costs of DOE, to the extent that its material shipments must comply with NRC regulations. The regulatory options also could affect implementation and operation costs of Agreement States if they must enact and implement parallel requirements. The regulatory options would not be expected to affect implementation or operation costs of DOT.

- Improvements in Knowledge -- The regulatory options could result in improved data collection that may ultimately result in more robust risk assessments and safety evaluations (i.e., less uncertainty) and, consequently, in improvements in regulatory policy and regulatory requirements.

Attributes *Not* Affected

- Public Health (Routine) -- No significant changes are expected with respect to routine radiation exposures to the public. Even if the number of shipments of radioactive materials significantly increases or decreases as a result of the rule, the change in exposure to members of the public as a result of routine shipments would be negligible.

- Safeguards and Security Considerations -- The regulatory options, if they alter the costs associated with accepting or downblending weapons-grade uranium from the former Soviet Union, could have some effect on security considerations. The magnitude of this effect is likely to be small, however, due to the U.S. government's role in funding these operations.

- General Public -- The action is not expected to have any effects on the general public.

- Antitrust Considerations -- The action is not expected to have any antitrust effects.

3.2 Analytical Methodology

This section describes the process used to evaluate values and impacts associated with the regulatory options. The *values* (benefits) of the rule include any desirable changes in affected attributes (e.g., improved public health due to a reduced potential for criticality) while the *impacts* (costs) include any undesirable changes in affected attributes (e.g., increased staff requirements to conduct NRC operations). As described in Section 3.1, the attributes expected to be affected include the following:

- Public Health (Accident)
- Occupational Health (Accident)
- Occupational Health (Routine)
- Offsite Property
- Onsite Property
- Industry Implementation
- Industry Operation
- NRC Implementation
- NRC Operation
- Regulatory Efficiency
- Environmental Considerations
- Other Government
- Improvements in Knowledge

For many of these attributes, the nature or cause of a value or impact is straightforward. For example, values and impacts associated with the attribute "NRC operations" should result from, respectively, either a decrease or increase in the number of NRC staff hours (or other NRC resources) required to oversee the Part 71 requirements on a day-to-day basis. Similarly, values and impacts associated with the attribute "regulatory efficiency" should result from changes to the overall clarity, consistency, or level of consolidation of applicable regulations.

The overall value or impact for some attributes, however, results from the interaction of several influencing factors. For example, a regulatory option that increases the number of packages and/or shipments required of licensees could simultaneously (1) reduce the potential for criticality and (2) increase the potential for routine radiological exposure. In this case, it would

be the *net effect* of the influencing factors (i.e., criticality potential and radiological exposure) that would govern whether an overall value or impact would result for several affected attributes, including public health, occupational health, on- and off-site property, and environmental considerations. Similarly, a single regulatory option could affect licensee costs in multiple ways (e.g., it might conceivably increase packaging and shipping costs but decrease costs associated with making transport index calculations).

Ideally, a value-impact analysis quantifies these net effects and calculates the overall values and impacts of each regulatory option. This requires a baseline characterization of the transportation universe, including factors such as the number of licensees affected, the number of shipments and packages affected, the types of packaging used, the transportation method, and the transportation distance. Data availability is a severely limiting factor for the purposes of establishing a baseline characterization of the affected universe.

Data Collection Activities

In support of the development of the value-impact analysis, ICF undertook a significant data collection effort. The first step in the data collection was to determine specific data needs to support the analysis of values and impacts for each of the actions that, in total, make up each of the regulatory options. Specifically, ICF identified the following types of information necessary to develop the value-impact analysis:

Baseline Information

- Number of exempt packages
- Number of non-exempt packages
- Number of exempt shipments
- Number of non-exempt shipments
- Cost per exempt package
- Cost per non-exempt package
- Cost per exempt shipment
- Cost per non-exempt shipment
- Average number of packages per exempt shipments
- Average number of packages per non-exempt shipment

Information for Each action

- Change in occupational person-rems per year from exposure due to criticality accidents
- Change in public person-rems per year from exposure due to criticality accidents
- Change in occupational person-rems per year from exposure due to traffic accidents
- Change in public person-rems per year from exposure due to traffic accidents
- Change in occupational person-rems per year from routine radiological exposures
- Change in number of exempt packages
- Change in number of non-exempt packages
- Change in number of exempt shipments
- Change in number of non-exempt shipments
- Change in cost per exempt package
- Change in cost per non-exempt package
- Change in cost per exempt shipment
- Change in cost per non-exempt shipment
- Average number of packages per exempt shipment

- Average number of packages per non-exempt shipment
- Cost to clean up and repair criticality accidents
- Cost to clean up and repair traffic accidents
- Change in time required for record-keeping/reporting
- Change in time for regulatory determinations/calculations
- Change in time for regulatory review

ICF conducted numerous searches of existing literature using several databases. For example, ICF reviewed information contained in DOE's Shipment Mobility/Accountability Collection (SMAC) database in an attempt to identify technical information on exempted shipments of fissile materials and fissile material shipments of exempted quantities, or those made under a general license. In addition, extensive searches were conducted via the Internet. Each search was targeted at obtaining specific information related to a change.

Further, for the NUREG/CR-5342 recommendations to change the fissile material requirements, ICF conducted a survey of licensees that currently ship fissile materials to identify the change in the number of packages/shipments and associated costs for each of the actions. The questions developed for this survey are listed in Appendix C. ICF, however, received only one survey response. While the information was useful, it did not provide nearly the level of detail necessary to assist the Commission in developing a quantitative value-impact analysis for the actions for fissile materials.

3.3 Values and Impacts of actions to Harmonize 10 CFR Part 71 with IAEA TS-R-1

3.3.1 Changing Part 71 to the International System of Units (SI) Only

<u>Values and Impacts of Option 1</u>

Under the No-Action alternative (Option 1), NRC licensees and applicants would continue to use their preferred system of measurement for completing shipping papers and SI units for completing labels used in the transportation of radioactive materials. Thus, no values or impacts would result from Option 1.

Although an increase in the current number of flawed conversions or accident rates within the U.S. is not expected under Option 1, there would continue to be some instances of confusion, possibly resulting in mishandling or accidents, when packages are received from or shipped to international locations that all use SI units only.

<u>Values and Impacts of Option 2</u>

Under Option 2, NRC would require the use of the International System of Units (SI), also known as the metric system, in shipping papers and labels used in the transportation of radioactive materials. By doing this, the units in shipping papers and labels associated with the packaging and transportation of radioactive materials would be consistent with the units used in the IAEA and guidance documents associated with IAEA.

It should be noted that, currently, NRC requires shipping papers and labels to be completed according to DOT regulations in 49 CFR Part 172. In its regulations, DOT does not specify the unit of measurement in which shipping papers used in the transportation of radioactive materials have to be completed (49 CFR 172.203(d)(4)). Further, DOT regulations do not

specify the units of measurement for labels used in the packaging and transportation of radioactive materials (49 CFR 172.403(g)(2)).

The following attributes are expected to be affected by adoption of this action:

- Public Health (Accident) – Changes in radiation exposures to the public, due to changes in accident frequencies and accident consequences, could result from the change. The change would require, in some instances, conversion from customary units to SI units in order to satisfy Part 71 reporting requirements. Thus, radiation exposure to the public may change due to possible flawed unit conversions. In addition, the use of SI units only may be a safety issue in an emergency if responders are unfamiliar with the SI system. An estimation of the values/impacts associated with this attribute will be completed in concurrence with the Environmental Assessment being developed in support of this rulemaking.

- Occupational Health (Accident) – Changes in radiation exposures to workers, due to changes in accident frequencies and accident consequences, could result from the change. The change would require, in some instances, conversion from customary units to SI units in order to satisfy Part 71 reporting requirements. Thus, radiation exposure to workers may change due to possible flawed unit conversions. In addition, the use of SI units only may be a safety issue in an emergency if responders are unfamiliar with the SI system. An estimation of the values/impacts associated with this attribute will be completed in concurrence with the Environmental Assessment being developed in support of this rulemaking.

- Offsite Property – Effects on offsite property, due to changes in accident frequencies and accident consequences, could result from the change. The change would require, in some instances, conversion from customary units to SI units in order to satisfy Part 71 reporting requirements. Thus, accident frequencies and offsite property consequences resulting from the occurrence of an accident may increase due to possible flawed unit conversions. An estimation of the values/impacts associated with this attribute will be completed in concurrence with the Environmental Assessment being developed in support of this rulemaking.

- Onsite Property – Effects on onsite property, due to changes in accident frequencies and accident consequences, could result from the change. The change would require, in some instances, conversion from customary units to SI units in order to satisfy Part 71 reporting requirements. Thus, accident frequencies and onsite property consequences resulting from the occurrence of an accident may increase due to possible flawed unit conversions. An estimation of the values/impacts associated with this attribute will be completed in concurrence with the Environmental Assessment being developed in support of this rulemaking.
- Industry Implementation -- The change would result in implementation costs to industry sectors currently using customary units (e.g., companies who ship spent fuel, regular fuel, and/or low-specific activity material to destination sites within the U.S.).

- Industry Operation – The change would result in additional operational costs to sectors of industry currently using customary units. These sectors would have to convert from customary units to SI units, altering their current procedures in completing shipping papers and labels used in the packaging and transportation of radioactive materials.

- Other Government – The change could affect implementation and operation costs of Agreement States because they would have to adopt and implement parallel requirements. The change also could affect DOE if it currently submits information in customary units. It is expected, however, that DOE submits data in SI units. In addition, the change could affect DOT's implementation costs, if regulations in 49 CFR 172.202 (shipping papers) were revised to be consistent with this change. However, the change is not expected to affect DOT's operation costs.

- Regulatory Efficiency – The change is expected to result in enhanced regulatory efficiency because the units in shipping papers and labels associated with the packaging and transportation of radioactive materials would be consistent with international standards groups (e.g., IAEA).

- Environmental Considerations -- Effects on the environment, due to changes in accident frequencies and accident consequences, could result from the change. The change would require, in some instances, conversion from customary units to SI units in order to satisfy Part 71 reporting requirements. Thus, effects on the environment could result due to possible flawed unit conversions. In addition, the use of SI units only may be a safety issue in an emergency if responders are unfamiliar with the SI system.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs to Industry

In the U.S., approximately 2.8 million shipments of radioactive materials are made annually by nuclear power reactor licensees and materials licensees.[16] ICF estimates that approximately 70 to 90 percent of these licensees currently use customary units in their daily operations, including completion of shipping papers and preparation of labels for shipments sent off site.[17] Thus, the annual number of shipments with shipping papers and labels in Customary units ranges between approximately 1.96 million to 2.52 million.

Licensees who currently complete shipping papers and prepare labels in customary units may have to revise their procedural and administrative activities to convert from customary units to SI units. ICF assumes that unit conversions would be done once, and would be used to complete the shipping paper and label for the corresponding shipment. On average, the time needed to make unit conversions is estimated to be 0.05 hours (or 3 minutes) per shipment.[18] Therefore, at a rate of $129 per hour of professional staff, the annual cost for making unit conversions would range between approximately $12.6 million and $16.3 million per year (see Table 3-1).

Table 3-1. Implementation Costs to Industry Sectors Currently Using Customary Units

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[16] U.S. Department of Transportation, Office of Hazardous Materials Safety, Research and Special Programs Administration, *Hazardous Materials Shipments*, October 1998.

[17] ICF estimated a lower (70 percent) and upper (90 percent) bound of the number of licensees using Customary units. ICF believes that users of SI units primarily include those licensees involved in international shipments (i.e., exports and/or imports).

[18] Based on best professional judgment.

Estimate	Annual number of shipments with shipping papers and labels in customary units (million)	Annual cost for licensees converting from customary to SI units ($ million)
Low	1.96	12.6
High	2.52	16.3

Estimated Costs to Other Government

As noted above, it is expected that DOE already uses SI units. If this were not the case, however, DOE would incur implementation costs for creating a system to convert from customary units to SI units. DOE makes approximately 5,500 shipments of radioactive material per year.[19] Assuming a rate of $129 per hour for professional staff and 0.05 hours per package to make unit conversions (as used above for industry), DOE also could incur costs of up to $35,475 per year.

3.3.2 Radionuclide Exemption Values

Values and Impacts of Option 1

Under the No-Action alternative (Option 1), NRC would continue to use one specific activity limit for exemption of any type of radionuclide. Thus, no values or impacts would result for domestic shipments from Option 1.

Option 1 would keep the current U.S. exemption value of 70 Bq/g (0.002 μCi/g). This would make U.S. standards inconsistent with countries who adopt the international standards. A package being imported into the U.S. carrying an isotope that has an exemption limit greater than 70 Bq/g could be violating U.S. laws. A package being exported from the U.S. carrying an isotope that has an exemption limit less than 70 Bq/g could be in violation of another country's laws. However, since most import/export shipments contain highly purified and/or highly radioactive isotopes, these scenarios would rarely, if ever, occur.

Values and Impacts of Option 2

Under Option 2, NRC would adopt, in 10 CFR Part 71, IAEA's radionuclide-specific exemption values for all materials. The nature of the changes under Option 2 makes it difficult to quantify the values or impacts. Because exempt packages are not subject to the reporting requirements for NRC and DOT-regulated packages, there are no data on the number or frequency of exempt packages shipped in the U.S.

In order to gain some insight into how the changes could affect regulated packages, ICF examined a Sandia report titled "Transport of Radioactive Material in the United States: Results of a Survey to Determine the Magnitude and Characteristics of Domestic, Unclassified Shipments of Radioactive Materials." Appendix B provides additional detail regarding the

[19] U.S. Department of Transportation, Office of Hazardous Materials Safety, Research and Special Programs Administration, *Hazardous Materials Shipments*, October 1998.

estimation of the values and impacts of this action, based on ICF's review of this report. The values and impacts are summarized below:

- Industry Implementation – Minor administrative and procedural changes would be necessary to provide the framework for operation under radionuclide-specific exemptions.

- Industry Operation – In some cases, shippers would have to expend resources to identify the isotopes in material to ensure that it is exempt instead of verifying that it is less than 70 Bq/g.

- NRC Implementation -- Under this option, NRC would incur costs to revise guidance documents and related materials.

- Regulatory Efficiency – Implementing this change would make U.S. regulations more consistent with international regulations. International shipment could be affected by the differences in national regulations.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs to NRC

NRC would be required to make revisions to guidance documents and related materials. It is estimated that these revisions would take approximately two staff-months to complete. Assuming a cost of $129 per hour for staff, and 20 days per month at 8 hours each, this results in a total cost of approximately $41,280.

3.3.3 Revision of A_1 and A_2

Values and Impacts of Option 1

Under the No-Action Alternative (Option 1), NRC would retain the current A_1 and A_2 values promulgated in 10 CFR Part 71. Thus, no significant values or impacts would result from Option 1. There would be an impact in that NRC regulations would not be consistent with TS-R-1, but the overall impact of this inconsistency is estimated to be minimal.

Values and Impacts of Option 2

Under Option 2, NRC would revise Part 71 to incorporate the TS-R-1 A_1 and A_2 values, while maintaining the current exceptions for ^{252}Cf and ^{99}Mo.

In general, the new A_1 and A_2 values are within a factor of about 3 of the earlier values; there are a few radionuclides where the new A_1 and A_2 values are outside this range. Nearly 40 radionuclides have new A_1 values higher than previous values by factors ranging between 10 and 100. This is due mainly to improved modeling for beta emitters. There are no new A_1 or A_2 values that are lower than the previous figures by more than a factor of 10. A few radionuclides previously listed are now excluded but two additional ones have been added, both isomers of ^{150}Eu and ^{236}Np.

In order to gain some insight into how the revisions could affect packages in the U.S., ICF examined a report titled "Transport of Radioactive Material in the United States: Results of a Survey to Determine the Magnitude and Characteristics of Domestic, Unclassified Shipments of Radioactive Materials." Appendix B provides additional information on the estimated values and impacts associated with this action, which are summarized below:

- Public Health (Accident) – Changes to radiation exposure to the public due to accident consequences could result from the change. The A_1 and A_2 values were revised by IAEA based on refined modeling of possible doses from radionuclides. It is unclear whether the change for each individual radionuclide would slightly increase or decrease the total risk to public health, but the change to the refined values would be an overall value to public health by ensuring that the A_1 and A_2 values are more precisely based on risk. Analysis of the change showed no significant change in the number of shipments per year; therefore, accident frequency would not be affected.

- Occupational Health (Accident) – Changes to radiation exposure to workers due to accident consequences could result from the change. The A_1 and A_2 values were revised by IAEA based on refined modeling of possible doses from radionuclides. It is unclear whether the change for each individual radionuclide would slightly increase or decrease the total risk to workers, but the change to the refined values would be an overall value to worker health. Analysis of the change showed no significant change in the number of shipments per year; therefore, accident frequency would not be affected.

- Occupational Health (Routine) – Changes to radiation exposure to workers due to normal transportation conditions could result from the change. The A_1 and A_2 values were revised by IAEA based on refined modeling of possible doses from radionuclides. It is unclear whether the change for each individual radionuclide would slightly increase or decrease the total risk to workers, but the change to the refined values would be an overall value to worker health. Analysis of the change showed no significant change in the number of shipments per year; therefore, shipment frequency and routine worker dose would not be affected.

- Industry Implementation – The action could result in implementation costs to industry if industry must revise various aspects of shipping programs or modify shipping processes to assure compliance with the proposed A_1 and A_2 values. However, the cost is expected to be negligible since industry already has programs in place that use A_1 and A_2 values.
- NRC Implementation – The change is expected to result in implementation costs to the NRC to revise the A_1 and A_2 values.

- Other Government – The action could affect implementation and operation costs of DOE to the extent that its shipments must comply with NRC regulations. The action also could affect implementation and operation costs of Agreement States if they must enact and implement parallel requirements. There is not enough available information about the costs to DOE and Agreement States to quantify the resultant impact. The action also would affect the DOT in that DOT A_1 and A_2 values would need to be revised to be consistent with those in Part 71. DOT costs are expected to be similar to those of the NRC.

- Regulatory Efficiency – The action would improve regulatory efficiency by bringing U.S. regulations in compliance with the standards of the IAEA. This would improve the efficiency of handling imports and exports and would make U.S. standards compatible with other IAEA members.

- Environmental Considerations – Effects on the environment due to accident consequences could result from the change. The A_1 and A_2 values were revised by IAEA based on refined modeling of possible doses from radionuclides. It is unclear how the change for each individual radionuclide would affect the total risk to the environment, but the change to the refined values would be an overall value to environmental protection. Analysis of the change showed no significant change in the number of shipments per year; therefore, accident frequency would not be affected.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs to NRC

The changes to the A_1 and A_2 values are estimated to require approximately two staff-months of effort. Assuming a cost of $129 per hour for staff, and 20 days per month at 8 hours each, this results in a total cost of approximately $41,280. This cost is expected to consist mostly of development costs, such as preparing documents. This estimation of staff time is consistent with that estimated by the NRC during the last revision of the A_1 and A_2 values.

Estimated Costs to Other Government

The changes to the A_1 and A_2 values are estimated to require approximately two staff-months of effort for DOT. Assuming a cost of $129 per hour for staff, and 20 days per month at 8 hours each, this results in a total cost of approximately $41,280.

3.3.4 Uranium Hexafluoride (UF_6) Package Requirements

Values and Impacts of Option 1

Under the No-Action Alternative (Option 1), the TS-R-1 requirements regarding the packaging of UF_6 would not be included in 10 CFR Part 71. Thus, no values or impacts would result from Option 1.

Values and Impacts of Option 2

Under Option 2, NRC would revise Part 71 to incorporate the TS-R-1 UF_6 packaging requirement by promulgating new section 71.55(g), while restricting use of the exception to a maximum enrichment of 5 weight percent ^{235}U. This would make Part 71 consistent with TS-R-1, enhance NRC regulatory efficiency and provide a uniform approval basis for designs which are used internationally. The following attributes are likely to be affected by this option:

- Public Health (Accident) – Under the action, cylinders containing UF_6 that meet the hypothetical fire test (a measure of resistance to release in the event of a fire) may cause less public health damage in the event of a vehicular accident. That is, residents along trucking routes will have a lower risk of exposure to radiation in the event of a fire following a vehicular accident.

- Occupational Health (Accident) – Similarly, cylinders containing UF_6 that meet the hypothetical fire test (a measure of resistance to release in the event of a fire) may cause less occupational health damage in the event of a vehicular accident. That is, truck operators will have a lower risk of exposure to radiation in the event of a fire following a vehicular accident.

- Offsite Property – Offsite property will be less likely to be exposed to and damaged from radiation in the event of a vehicular accident that results in a fire.

- Industry Implementation -- Industry might need to provide training to workers on how to handle the overpacks (e.g., proper loading of cylinders into overpacks, proper methods to secure the overpacked cylinder to tie down points on trailers, etc.).

- Industry Operation – Industry operations are likely to be affected through an increase in cost of either proving current cylinders would pass the hypothetical fire test or, more likely, overpacking the existing cylinders. This impact would be spread between private sector conversion facilities that produce UF_6 from yellow cake and the USEC facilities for any occasional shipment of depleted UF_6 between sites. In addition, when a depleted UF_6 conversion facility comes online at one or more sites, there will be an additional cost of shipping the stockpiled UF_6 cylinders.

- Regulatory Efficiency – Under the action, regulatory efficiency is likely to increase as a result of U.S. regulations being consistent with the international community.

- Environmental Considerations – Damage to the environment will be less likely to occur due to radiation in the event of a vehicular accident that results in a fire.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs to Industry

In developing this analysis, it was determined that there is no substantial difference between the ANSI N14.1 standard and the ISO 7195 standard for UF_6 packaging, and therefore, there would be no cost impacts, provided older cylinders that are stockpiled at sites are not required to be repackaged. Similarly, if the thermal test is waived for cylinders containing more than 9,000 kg UF_6, there will be little to no cost impact on industry. This is because only small cylinders, which are typically not used for natural or depleted UF_6, would be the only types of cylinders that have to meet the thermal test requirements, and it is believed that many of these small cylinders are already overpacked. (Smaller cylinders are typically used to transport enriched UF_6, but these cylinders are already believed to be overpacked.)

If, however, NRC did not waive the thermal test requirement for cylinders containing more than 9,000 kg UF_6, between 2,000 and 2,500 cylinders per year would need to be overpacked in the course of normal operations. In addition, at some point in the future when a conversion facility or facilities are built to process the stockpiled depleted UF_6, between 4,683 and 50,000+ cylinders could be affected. The costs to industry would be two-fold. First, there would be a one-time cost of $9 million to $13 million to design overpacks, purchase overpacks, and purchase additional trailers with the proper tie-down locations. Second, ongoing costs based on a cost of approximately $1,480 per shipment could result in an annual cost of $3.0 million to $3.7 million for routine operations, and $350,000 to $3.7 million per year to ship stockpiled cylinders to a conversion facility over a 20-year period.[20]

Most of the impact of adopting the TS-R-1 UF_6 provisions will fall on the 30-inch and 48-inch bare cylinders which are within the purview of the DOT and for which there is a "multilateral" approval option that could be used to mitigate most of this potential impact. Therefore, the adoption of the TS-R-1 requirements are not expected to have significant impact on fissile package designs for UF_6.

3.3.5 Introduction of the Criticality Safety Index Requirements

Values and Impacts of Option 1

Under the No-Action Alternative (Option 1), NRC would not require labels or modify definitions for CSI. Thus, no values or impacts would result from Option 1.

Values and Impacts of Option 2

Under Option 2, NRC would revise 10 CFR Part 71 to include a definition of CSI for fissile material packages and revise the existing TI definition. The values and impacts are summarized below:

- Public Health (Accident) – Emergency responders would benefit from additional information upon arrival at the accident scene. However, this additional information would only affect their actions in the most severe and unusual accident circumstances.

[20] These costs were based on the April 18, 1985, *Draft U.S. Position Paper on Proposed Changes to the IAEA Regulatory Requirements for the Packaging of Uranium Hexafluoride*, R. Pope, F. Kovac, and R. Michelhaugh.

- Industry Implementation – Minor administrative and procedural changes would be necessary to provide the framework for marking packages for both criticality and radiation.

- Industry Operation – The action would result in minor additional effort for marking to ensure that packages are marked with both transportation indices.

- NRC Implementation – Under the option, NRC would incur costs to revise guidance documents and related materials.

- Other Government – Emergency responders would have to be notified of the changes to the information on the labels, and references would be provided. In addition, DOE would incur implementation and operation costs in complying with the new requirements.

- Regulatory Efficiency – Implementing this change would make U.S. regulations more consistent with international regulations. International shipment could be affected by the differences in national regulations.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs to Industry

In the U.S., approximately 2.8 million shipments of radioactive materials are made annually by nuclear power reactor licensees and materials licensees.[21] A very conservative estimate would be that 10 percent of these shipments (or 280,000) contain fissile material requiring labels indicating the CSI and TI. Assuming 5 packages per shipment and $1 per package for labeling, the total annual costs to licensees would be approximately $1.4 million.

Estimated Costs to NRC

NRC would be required to make revisions to guidance documents and related materials. It is estimated that these revisions would take approximately two staff-months to complete. Assuming a cost of $129 per hour for staff, and 20 days per month at 8 hours each, this results in a total cost of approximately $41,280. These costs have already been accounted for in this analysis.

[21] U.S. Department of Transportation, Office of Hazardous Materials Safety, Research and Special Programs Administration, *Hazardous Materials Shipments*, October 1998.

Estimated Costs to Other Government

DOE makes approximately 22 fissile material shipments per year.[22] Assuming increased costs of $5 per shipment to comply with the labeling requirement, DOE would incur annual costs of $110.

3.3.6 Type C Packages and Low Dispersible Material

Values and Impacts of Option 1

Under the No-Action Alternative (Option 1), NRC would not adopt Type C packages or the “low dispersible radioactive material” concepts into 10 CFR Part 71. Thus, no values or impacts would result from Option 1.

Values and Impacts of Option 2

Under Option 2, NRC would revise 10 CFR Part 71 to incorporate the Type C Packages and low dispersible radioactive material concepts for air transportation but retain section 71.74, the accident conditions for air transport of plutonium. There would be an increase in regulatory efficiency as a result of the nonadoption of the TS-R-1 requirements, which would enhance international shipments. Additional resource costs would be incurred by NRC. Costs also would be incurred by industry. These additional costs to industry would include implementation costs for the design of new packages to meet the Type C requirements rather using existing Type B packages.

The following attributes are expected to be affected:

- Public Health (Accident) – The accident risk of air shipments is higher than the accident risk of ground shipments.

- Public Health (Routine) -- The public receives lower routine exposures from an air shipment than from an overland shipment. People in their homes and on the highway do not receive measurable exposure from air shipments, and Type C packages would not be carried on passenger aircraft.

- Occupational Health (Routine) – Workers receive additional exposure using air transportation. Although the en route exposure is about the same, air transportation leads to additional handling since the originating and receiving facilities do not have air strips. Packages will normally be trucked to an airport, requiring more loading and unloading than a ground shipment.

- Offsite Property – The consequences to offsite property increase in proportion to the increased radiological accident consequences.

- Industry Implementation -- Industry would need to develop and certify Type C packages.
- Industry Operation – DOE was the only user for Type C packages identified. (See Other Government.)

[22] The estimated annual number of fissile material shipments by DOE is based on the number of such shipments that occurred in fiscal years 1995 and 1996, as reported in DOE’s *Transportation Activities Summary Report for Fiscal Years 1995 and 1996*.

- NRC Implementation -- NRC development costs would include such activities as preparation of documents, publishing notices of rulemakings, holding public hearings, and responding to public comments.

- Other Government – Several foreign research reactor spent fuel casks have been shipped by air to port cities and loaded onto a ship for delivery to the U.S. DOE would realize operational cost savings if the aircraft were allowed to fly directly to the U.S.

- Regulatory Efficiency – Under the action, regulatory efficiency is likely to increase as a result of U.S. regulations being consistent with the international community.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs to NRC

NRC would be required to prepare documents and conduct other activities (such as publishing notices of rulemakings, holding public hearings, and responding to public comments) as a result of the action. It is estimated that these activities would take approximately two staff-months to complete. Assuming a cost of $129 per hour for staff, and 20 days per month at 8 hours each, this results in a total cost of approximately $41,280.

3.3.7 Deep Immersion Test

Values and Impacts of Option 1

Under Option 1, the No-Action Alternative, NRC would not require design of a package with radioactive contents greater than 10^5 A_2 or irradiated nuclear fuel with activity greater than 37 PBq to withstand external water pressure of 2 MPa for a period of one hour or more without rupture of the system. Thus, no values or impacts would result from Option 1.

Values and Impacts of Option 2

Under Option 2, the NRC would revise Part 71 to require an enhanced water immersion test for packages used for radioactive contents with activity greater than 10^5 A_2.

Appendix B provides additional information on the estimation of the values and impacts associated with the action. The affected attributes are described below:

- Public Health (Accident) – The action may reduce the impact to public health in the case of an accident. The package would be able to withstand the pressure at increased depths without rupturing, thereby keeping the radioactive materials enclosed. The likelihood of a member of the public receiving a dose from a package resting in deep water is exceedingly small and would be even smaller if the action were implemented.
- Occupational Health (Accident) – The action could decrease occupational exposure in the event of an accident in which the package was submersed in water at a depth of less than 200 m (660 ft). The package would be able to withstand the pressure at this depth without rupturing, thereby keeping the radioactive materials enclosed.

- Offsite Property – The action is intended to prevent the containment system from rupturing and possibly releasing radioactive material if a package was lost in deep water. Retaining package integrity would prevent the possible expenses of restricting the area (to prevent users such as boaters or fishers from entering the vicinity) and remediating any contamination of the marine environment.

- Industry Implementation -- Implementation of the action could result in costs to licensees as they test and certify packages to the standard.

- NRC Implementation -- NRC development costs would include such activities as preparation of documents, publishing notices of rulemakings, holding public hearings, and responding to public comments. It also is anticipated that NRC staff may incur costs for developing procedures, reviewing and approving test results, and recertifying packages.

- NRC Operation – NRC could incur recurring costs to ensure continued compliance with the proposed rule, although these costs are not expected to be significant.

- Other Government – The action could affect implementation and operation costs of the DOE to the extent that its shipments must comply with NRC regulations. There is not enough available information to quantify the resultant costs, but it is expected to be similar to those of industry.

- Regulatory Efficiency – The action would improve regulatory efficiency by bringing U.S. regulations in compliance with the standards of the IAEA. This would improve the efficiency of handling imports and exports and would make U.S. standards compatible with other IAEA members.

- Environmental Considerations – Effects on the environment due to changes in accident consequences could result from the change. The revised testing requirement would prevent the rupture of package containment at deeper depths, thereby preventing possible contamination of the marine environment.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs to Industry

Implementation of the action could result in costs to licensees as they test and certify packages to the standard. This total cost to industry is estimated to range from $245,000 to $2,928,000, with the expected total cost to be near $734,000. (See Appendix B for additional information on how these costs were estimated.)

Estimated Costs to NRC

NRC would be required to prepare documents and conduct other activities (such as publishing notices of rulemakings, holding public hearings, and responding to public comments) as a result of the action. It is estimated that these activities would take approximately two staff-months to complete. Assuming a cost of $129 per hour for staff, and 20 days per month at 8 hours each, this results in a total cost of approximately $41,280.

The estimated costs for NRC review and recertification of cask designs is estimated to be approximately $20,640 per cask design or $495,360 for all casks. (See Appendix B for additional information on how these costs were estimated.)

3.3.8 Grandfathering of Previously Approved Packages

<u>Values and Impacts of Option 1</u>

Under the No-Action Alternative (Option 1), NRC would not adopt the new grandfathering provisions contained in TS-R-1. Thus, no values or impacts would result from Option 1.

<u>Values and Impacts of Option 2</u>

Under Option 2, NRC would modify section 71.13 to phase out packages approved under Safety Series 6. This Option would include a 3-year transition period for the grandfathering provision on packages approved under Safety Series 6 (1967). This period will provide industry the opportunity to phase out old packages and phase in new ones. In addition, packages approved under Safety Series 6 (1985) would not be allowed to be fabricated after December 31, 2006. The affected attributes are described below:

- NRC Implementation -- The change would result in implementation costs to the NRC. The NRC would have to revise regulatory guides and NUREG-series documents in order to indicate which packages are covered by the "grandfathering of older packages" provision.

- Other Government – The change could affect implementation and operation costs of Agreement States if they adopt and implement parallel requirements. (The change is not expected to affect implementation or operation costs of DOT.) If Agreement States adopt the "grandfathering of older packages" provision, they would only need to revise documents that they have developed specifically for their licensees (e.g., application materials).

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs to NRC

The NRC estimates that it would need to revise approximately 30 documents. On average, the time needed to make the necessary revisions is estimated to be 0.5 hours per document. Thus, the total burden for revising the documents is approximately 15 hours. At a rate of $129 per hour for professional staff, the cost for revising regulatory guides and NUREG-series documents to include the "grandfathering of older packages" provision is estimated to be $1,935.

Estimated Costs to Other Government

The number of documents that Agreement States would need to revise is estimated to be approximately 15. On average, the time needed to make the necessary revisions is estimated to be 0.5 hours per document. Thus, the total burden for revising the documents is approximately 7.5 hours. At a rate of $129 per hour for professional staff, the cost for revising Agreement State documents to include the "grandfathering of older packages" provision is estimated to be $968.

3.3.9 Changes to Various Definitions

Values and Impacts of Option 1

Under the No-Action Alternative (Option 1), NRC would not add or make changes to definitions in 10 CFR Part 71.4. Thus, no values or impacts would result from Option 1.

Values and Impacts of Option 2

Under Option 2, NRC would add and change various definitions to 10 CFR 71.4 to ensure compatibility with definitions found in IAEA's TS-R-1. The affected attributes are expected to include:

- Industry Implementation -- The change would result in implementation cost savings to industry. By modifying existing definitions and adding new definitions, licensees will benefit through more effective understanding of the requirements of Part 71.

- NRC Implementation -- The change would result in implementation costs to the NRC. The NRC would have to revise regulatory guides and NUREG-series documents in order to include the new or revised definitions of 10 CFR 71.4.

- Other Government – The change could affect implementation and operation costs of Agreement States because they would have to adopt the revision to the various definitions in 10 CFR 71.4. (The change is not expected to affect implementation or operation costs of DOT.) It is assumed that Agreement States use regulatory guides and NUREG-series documents published by the NRC. Thus, Agreement States would only need to revise documents that they have developed specifically for their licensees (e.g., application materials).

- Regulatory Efficiency – The change is expected to improve regulatory efficiency by achieving consistency with international standards groups (e.g., IAEA).

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs to NRC

It is estimated that approximately 30 documents would require revision. On average, the time needed to make the necessary revisions to the various definitions is estimated to be 0.5 hours per document. Thus, the total burden for revising the various definitions included in the 30 documents is approximately 15 hours. At a rate of $129 per hour for professional staff, the cost for revising the definitions in regulatory guides and NUREG-series documents is estimated to be $1,935.

Estimated Costs to Other Government

The number of documents that Agreement States would need to revise is estimated to be approximately 15. On average, the time needed to make the necessary revisions to the various definitions is estimated to be 0.5 hours per document. Thus, the total burden for revising the various definitions included in the 15 documents is approximately 7.5 hours. At a rate of $129 per hour for professional staff, the cost for revising the various definitions in Agreement State documents is estimated to be $968.

3.3.10 Crush Test for Fissile Material Package Design

Values and Impacts of Option 1

Under the No-Action Alternative (Option 1), the NRC would not modify Part 71 to incorporate the crush test requirement for fissile material packages. Thus, no values or impacts would result from Option 1.

Values and Impacts of Option (2)

Under Option 2, the NRC staff would revise section 71.73(c)(2) wording to agree with TS-R-1 and extend the crush test requirement to fissile material package designs. The affected attributes are described below:

- Regulatory Efficiency – The requirement would result in enhanced regulatory efficiency by correcting inconsistencies between Part 71 requirements and TS-R-1. However, further information on the impact of the TS-R-1 requirement for fissile material package testing is required.

- Industry Implementation -- The change would result in implementation costs imposed to demonstrate compliance and may lead to the redesign of packages.

- NRC Implementation – The regulatory change would result in NRC implementation costs associated with modifying the regulations and revising guidance documents.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs to NRC

NRC would be required to prepare documents and conduct other activities (such as publishing notices of rulemakings, holding public hearings, and responding to public comments) as a result of the action. It is estimated that these activities would take approximately two staff-months to

complete. Assuming a cost of $129 per hour for staff, and 20 days per month at 8 hours each, this results in a total cost of approximately $41,280.

3.3.11 Fissile Material Package Designs for Transport by Aircraft

Values and Impacts of Option 1

Under the No-Action Alternative (Option 1), the NRC would not modify Part 71 to incorporate the TS-R-1 requirements contained in paragraph 680. Thus, no values or impacts would result from Option 1.

Values and Impacts of Option (2)

Under Option 2, the this new TS-R-1, additional criticality evaluation would be included in a new proposed paragraph 71.55(f) that only applies to air transport. The affected attributes are described below:

- Industry Implementation – The regulatory change would result in implementation savings to industry by eliminating the need for two different package designs.

- NRC Implementation – The change would result in NRC implementation costs associated with revising guidance manuals.

- NRC Operation – The change would result in NRC operation savings by eliminating the need for two different package designs and evaluations.

- Regulatory Efficiency – The requirement would result in enhanced regulatory efficiency by eliminating dual requirements for package design.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs to NRC

NRC would be required to prepare documents and conduct other activities (such as publishing notices of rulemakings, holding public hearings, and responding to public comments) as a result of the action. It is estimated that these activities would take approximately two staff-months to complete. Assuming a cost of $129 per hour for staff, and 20 days per month at 8 hours each, this results in a total cost of approximately $41,280.

3.4 Values and Impacts of NRC-Specific actions

3.4.1 Special Package Authorizations

The December 1996 revision of the safe transport standards (TS-R-1) developed by the IAEA, provides specific procedures for demonstrating the level of safety for shipment of special packages.

Values and Impacts of Option 1

Under the No-Action Alternative (Option 1), NRC would continue to address approval of special packages using exemptions under 10 CFR 71.8. Thus, no values or impacts would result from Option 1.

Values and Impacts of Option 2

Under Option 2, NRC would incorporate new regulations into 10 CFR Part 71 that similarly address shipment of special packages and demonstrate an acceptable level of safety. These requirements would essentially be equivalent to Paragraph 312 of TS-R-1 and would contain specific requirements for licensees to (1) demonstrate that the object/material is not readily packageable using available packages and that other shipment options are not preferable, (2) demonstrate that the special package generally complies with regulations, (3) specify the to-be-shipped configuration, (4) identify all deviations from regulations, and (5) identify measures that compensate for deviations from the regulations, commit to the use of these measures, and demonstrate the effectiveness of these measures in assuring shipment safety. The requirements would permit NRC staff review and authorization of special packages without issuing exemptions. The following attributes are expected to be affected:

- Public Health (Accident) – The action would provide added safeguards against radiation exposure to humans. Special package shipments are likely to increase regardless of the outcome of this rulemaking, as a result of future decommissioning activities. The justification for authorizing special packages for shipment is a decreased risk of radiation exposure to the public and workers as opposed to the shipment alternatives. Standardizing the health and safety collection requirements for these shipments will benefit human health by reducing the need to dispose of reactors and components in multiple shipments. In contrast, a failure to provide consistent health and safety information could lead to increased risk to health and property in some instances.

- Occupational Health (Accident) – See discussion for Public Health (Accident) above.

- Occupational Health (Routine) – See discussion for Public Health (Accident) above.

- Industry Implementation and Operation – Although licensees would realize savings by not having to prepare exemptions for special packages, the information collection requirements for shipment of special packages require the demonstration of a level of safety. Providing a consistent standard for the health and safety information collection is not expected to reduce this burden on licensees.

- NRC Implementation and Operation – The action would result in savings to NRC by reducing the burden of case-by-case review in authorizing packaging and shipping procedures for licensed material in excess of Type A quantities. Specifically, the action would eliminate the need for evaluating the health and safety information collection requirements for shipment of every special package.

- Regulatory Efficiency – The action would result in enhanced regulatory efficiency by standardizing the requirements to provide greater regulatory certainty and clarity than the no-action option, and would ensure consistent treatment among licensees requesting authorization for shipment of special packages. This increase in regulatory efficiency, however, would depend in part on modifications to DOT’s regulations to recognize NRC special package exemptions.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs to Industry

The information collection requirements for shipment of special packages require the demonstration of a level of safety. Providing a consistent standard for the health and safety information collection is not expected to reduce this burden on licensees.

The Supporting Statement for 10 CFR Part 71, Revision to the Extension, discusses information collection requirements for packaging, preparation for shipment, and transport of licensed material. The burden estimates for 10 CFR Part 71 information collection requirements include a rate of $125 per hour for professional staff for preparation of the reports prepared in response to the 10 CFR Part 71 information collection requirements.[23] The annual burden for complying with the information collection requirements in Part 71 is estimated to be about 180 hours per licensee.[24] However, the licensee staff hours per submittal for 10 CFR 71.31, application for package approval, is estimated to be 300.

In estimating the additional preparation of health and safety information for shipment of special packages it was assumed that an additional 75 staff hours (25 percent of 300) would be required. At the rate of $129 per hour for professional staff, this additional cost amounts to $9,675 per shipment. Also, there may be some inherent cost savings to industry with respect to preparing health and safety information, but they are not expected to be significant.

Estimated Costs and Savings to NRC

The action would benefit NRC in that NRC would realize savings by reducing the number of case-by-case reviews for shipment of special packages. Due to limited data availability, the values of this change to the NRC have not been quantified in this analysis. The change under Option 2 would result in other values that are not quantified in this analysis. In particular, the change would result in enhanced regulatory efficiency because it would provide greater regulatory certainty and clarity than the no-action option and would ensure consistent treatment among all licensees requesting authorization for shipment of special packages.

The annual cost for the NRC to process and review the records and reports required by 10 CFR Part 71 is estimated to be approximately $3,182,585.[25] This estimate is based on 20,800 staff review hours for a total of 350 licensees (approximately 60 hours per licensee). It was assumed that the additional review of health and safety information for each shipment of special packages would result in an additional 30 staff hours (50 percent of 60). Assuming decommissioning efforts result in 5 shipments per year under special arrangement, this additional cost to NRC amounts to $19,350 annually. A reduced burden given the elimination of case-by-case evaluation of health and safety requirements is expected. However, the increase in the number of special arrangement shipments due to anticipated decommissioning efforts is likely to offset any savings.

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[23] This rate is based on NRC's fully recoverable fee rate and includes both salaries and overhead.

[24] This estimate is based upon a total annual burden to 350 licensees of 63,537 hours.

[25] These costs are fully recovered through fee assessments to NRC licensees pursuant to 10 CFR Parts 170 and/or 171.

3.4.2 Expansion of Part 71 Quality Assurance Requirements to Certificate of Compliance (CoC) Holders

Values and Impacts of Option 1

Under the No-Action Alternative (Option 1), NRC would not subject CoC Holders or CoC applicants to the requirements contained in 10 CFR Part 71. Thus, no values or impacts would result from Option 1.

Values and Impacts of Option 2

Under Option 2, NRC would explicitly subject CoC Holders and CoC applicants to the requirements contained in 10 CFR Part 71. NRC also would add recordkeeping and reporting requirements for CoC Holders and CoC applicants. The attributes expected to be affected by this action are described below:

- Public Health, Onsite and Offsite Property -- By incorporating CoCs and CoC applicants in Part 71, any deficiencies noted by NRC will result in a notice of violation (NOV). This enforcement action will allow NRC to issue orders or take other enforcement actions necessary to ensure compliance with Part 71 requirements. This will ultimately lead to safer transportation casks, although this benefit is small and impossible to quantify relative to the current safety levels of transportation casks.

- Industry Implementation and Operation – CoCs and CoC applicants will incur costs associated with understanding and implementing the new regulations. They also will have to submit reports under Part 71 that they were not submitting previously. These reports are described in SECY 99-174; it is assumed that similar reports will be required if CoCs and CoC applicants are incorporated in the Part 71 applicability. SECY 99-174 states that "Additional requirements for recordkeeping and reporting for certificate holders are needed, to include records required to be kept as a condition of the CoC [certificate of compliance]. This will provide an enforcement basis equivalence to the record keeping and reporting regulations for licensees."

- NRC Implementation and Operation – NRC will incur costs associated with supervising CoCs and CoC applicants, and maintaining and reviewing the records for submittals.

- Regulatory Efficiency – NRC's ability to issue NOVs to CoCs and CoC applicants will improve the regulatory efficiency of NRC enforcement actions. NRC can follow up the issuance of NOVs with more strict regulatory enforcement actions. This is not currently possible under Part 71, because CoCs and CoC applicants are not explicitly subject to the regulations of Part 71.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs to Industry

For the 31 CoC Holders, the burden associated with recordkeeping and reporting was determined to be 100 hours per year, from the Part 72 rulemaking. Assuming a cost of $129 per hour for staff, the estimated total cost to these entities is therefore approximately $400,000 per year.

Estimated Costs to NRC

NRC will incur costs associated with tracking submissions to the agency. It was assumed that NRC will spend approximately 20 hours per year per CoC Holder for these activities. Assuming a cost of $129 per hour, the total cost to the NRC is estimated at approximately $80,000.

3.4.3 Adoption of ASME Code

Values and Impacts of Option 1

Under the No-Action Alternative (Option 1), NRC would retain the current QA provisions for the package approval process so that the on-site presence of the ANI would not be required and NRC inspections of licensee and fabrication facilities would continue. Thus, no values or impacts would result from Option 1.

NRC notes that, if the ASME code is not implemented for spent fuel casks, the current inconsistent system of licensee QA procedures would remain in place. NRC and the licensees would be responsible for ensuring that adequate QA procedures are followed. NRC does not have the staffing capability to engage in full-time fabricator supervision. Licensees and contractors would therefore continue to self-certify that they are implementing a competent QA plan and continue their own QA procedures. The marginal improvement in cask safety obtained through implementation of the ASME code would therefore not be achieved.

Values and Impacts of Option 2

Under Option 2, NRC would adopt the ASME B&PV Code Section III, Division 3, for spent fuel transportation casks in 10 CFR Part 71. This action would eventually apply to spent fuel storage canister confinement and spent fuel transportation cask containment for all applications, including dual-purpose casks. The attributes expected to be affected by this action include:

- Public Health, Onsite and Offsite Property -- Transportation and dual-purpose casks manufactured under the ASME B&PV Code, Section III, Division 3 will be manufactured using QA/QC procedures that are more complete than those presently in place. The casks are therefore less likely to fail during a transportation accident and are less likely to contain a design flaw that would lead to a leak of radioactive material. For these reasons, the ASME-certified casks provide a lesser risk to public health and property. Although this is clearly a benefit of the proposed rule, the likelihood of a flawed cask being involved in an accident or leak is so remote that the public health/property benefits of the ASME QA/QC program relative to the current licensee/NRC program are impossible to quantify.

- Industry Implementation and Operation – CoC Holders and manufacturers will incur additional costs due to: (1) conducting a site survey of the production facility, (2) the review of cask design plans by a professional engineer, and (3) the employment of an on-site authorized nuclear inspector (ANI). CoC Holders and manufacturers will save costs associated with fabrication errors, such as having to repair faulty casks, and lost sales during faulty cask repair. They also will save the costs associated with employing an onsite QA/QC inspector. However, because of the potential for the ASME code to be revised over the next several years, adoption at this time could result in additional costs to licensees should the regulations be revised in the future.

- NRC Implementation and Operation – NRC will save some costs, by reducing the need for full-time inspectors who periodically inspect CoC Holders and fabricators. This on-site inspection function will be carried out by the authorized nuclear inspector (ANI). However, because of the potential for the ASME code to be revised over the next several years, adoption at this time could result in additional costs to NRC should the regulations need to be revised in the future.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs and Savings to Industry

Currently, there are six transportation cask fabricators.[26] On-site, one-time ASME survey costs will total approximately $440,000. Costs for ASME certification and the on-site authorized nuclear inspector (ANI) will total approximately $765,000 per year, although the fabricators will save approximately $450,000 per year because they will not have to employ an on-site QA/QC inspector (this function is filled by the ANI). Thus, the net yearly cost increase to the fabricators is $315,000.

In addition, industry will save costs associated with avoiding fabrication errors that will be discovered by the ANI. Although these savings are impossible to quantify on a per year basis, NRC documented one case in which a fabricator and NRC spent $570,000 inspecting and repairing flawed casks. The fabricator was estimated to have lost $2.1 million in sales during this time, because its resources were directed at affecting repairs to the flawed casks and not to cask production. It is assumed that an on-site ANI would have discovered the production flaw.

3.4.4 Change Authority

Values and Impacts of Option 1

Under the No-Action Alternative (Option 1), licensees or cask certificate holders would still be required to gain NRC approval for changes to procedures, or cask designs, through license amendments. Thus, no values or impacts would result from Option 1.

[26] Personal communication with Ron Parkhill, U.S. Nuclear Regulatory Commission, October, 1999.

Values and Impacts of Option 2

Under Option 2, NRC would revise 10 CFR Part 71 to add a new section regulating dual-purpose transportation packages (i.e., casks designed for both shipment and storage of spent nuclear fuel) used for domestic purposes only. In addition to providing a new process for approving dual purpose transportation packages, the new requirements would provide the authority for CoCs to make changes to a dual purpose package design without prior NRC approval. The section also would include new requirements for submitting and updating a final safety analysis report describing the package's design. A discussion of the attributes expected to be affected by the action is provided below:

- Industry Implementation and Operation – Licensees and CoC Holders will have to spend time and incur costs associated with understanding and implementing the new requirements. CoC Holders will incur costs when submitting an FSAR detailing minor changes, tests, and experiments they make with regard to transportation package design. The CoC Holders will save costs associated with preparing license amendments and paying fees to NRC that are required under the current regulations (i.e., because these will no longer be required if provisions similar to 10 CFR 72.48 are implemented in Part 71).

- NRC Implementation and Operation – NRC will realize cost savings associated with no longer having to review license amendments for CoC Holders making minimal changes to their procedures. These cost savings will be partially offset in that NRC will need to review reports that are required to be submitted CoC Holders making minor changes.

- Regulatory Efficiency – There would be a clearer and more consistent interpretation between the NRC, licensees, and CoC Holders regarding requirements necessitated by changes in procedures. It will therefore be possible to direct NRC resources that would be spent reviewing license amendments to areas where measurable improvements in safety can be achieved.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs and Savings to Industry

For the 350 record-keeping licensees listed in the Part 71 Supporting Statement, professional judgment was used to assume that in any given year 50 percent of licensees will perform a "minimal change." Submittals under section 72.48 are required every two years (as is the case with the proposed Part 71 requirements) and therefore, approximately 88 submittals are expected per year. The total cost savings of reporting the "minimal changes" versus preparing license amendments is estimated at approximately $2.4 million per year. However, the 350 licensees will incur a one-time recordkeeping cost of approximately $2.3 million in the first year the proposed rule is implemented.

Estimated Cost Savings to NRC

NRC costs are projected to decline slightly under the proposed rule, because the agency will not have to review as many license amendments each year. This cost savings was determined to be negligible in the section 72.48 regulatory analysis and will be offset by the agency having

to adopt new document controls to handle the “minimal change” submissions required every two years for licensees making “minimal changes.”

3.4.5 Fissile Material Exemptions and General License Provisions

Values and Impacts of Option 1

Under the No-Action Alternative (Option 1), NRC would not modify 10 CFR Part 71 to implement the 17 recommendations contained in NUREG/CR-5342, but would continue to use the modified regulations promulgated under 10 CFR Part 71, RIN 3150-AF58, Fissile Material Shipments and Exemptions, final rule. Thus, no values or impacts would result from Option 1.

Values and Impacts of Option 2

Under Option 2, NRC would modify the 10 CFR Part 71 regulations as necessary to implement the entire set of 17 recommendations contained in NUREG/CR-5342. The attributes expected to be affected by the actions include:

- Public Health (Accident) – Changes to radiation exposures to the public, due to changes in accident frequencies and accident consequences, could result from the action. The regulatory options could both alter the number of fissile shipments (thereby altering the accident frequency) and reduce the likelihood of occurrences of criticality (thereby reducing accidental consequences).

- Occupational Health (Accident) – Changes to radiation exposures to workers, due to changes in accident frequencies and accident consequences, could result from the action. The regulatory options could both alter the number of fissile shipments (thereby altering the accident frequency) and reduce the likelihood of occurrences of criticality (thereby reducing accidental consequences).

- Occupational Health (Routine) – Changes to radiation exposures to workers during normal packaging and transportation operations could result from the action. The regulatory options could alter the number of fissile packages or shipments, thereby altering the number of workers exposed or the duration of the exposure.

- Offsite Property – Effects on offsite property, due to changes in accident frequencies and accident consequences, could result from the action. The regulatory options could both alter the number of fissile shipments (thereby altering the accident frequency) and reduce the likelihood of occurrences of criticality (thereby reducing accidental consequences).

- Onsite Property – Effects on onsite property (direct and indirect), due to changes in accident frequencies and accident consequences, could result from the action. The regulatory options could both alter the number of fissile shipments (thereby altering the accident frequency) and reduce the likelihood of occurrences of criticality (thereby reducing accidental consequences).

- Industry Implementation -- The action would result in implementation costs or savings to industry if industry must evaluate and/or enact changes to ensure that its operating procedures will comply with the action.

- Industry Operation – The action would result in industry operation costs or savings if industry must alter its current packaging and shipping procedures to comply with the action.

- NRC Implementation -- The action would result in NRC implementation costs or savings to put the action into operation. Specifically, NRC would incur implementation costs to revise guidance documents and possibly to establish a data collection system and database infrastructure.

- NRC Operation – The action would result in NRC operation costs or savings if the number of shipments requiring specific NRC approval changes (i.e., the number of shipments that fail to qualify for the fissile exemption and the general licenses) and possibly to operate and maintain a data collection system and database.

- Regulatory Efficiency – The action would be expected to result in enhanced regulatory efficiency by clarifying the meaning and applicability of specific terms and requirements, and by reducing noncompliance.

- Environmental Considerations – Effects on the environment, due to changes in accident frequencies and accident consequences, could result from the action. The regulatory options could both alter the number of fissile shipments (thereby altering the accident frequency) and reduce the likelihood of occurrences of criticality (thereby reducing accidental consequences).

- Other Government – The action could affect implementation and operation costs of the U.S. Department of Energy, to the extent that its fissile material shipments must comply with NRC regulations. The action also could affect implementation and operation costs of Agreement States if they must enact and implement parallel requirements. (The action would not be expected to affect implementation or operation costs of DOT.)

- Improvements in Knowledge – The action, if it includes a data collection requirement, could result in improved knowledge that may ultimately result in more robust risk assessments and safety evaluations (i.e., less uncertainty) and, consequently, in improvements in regulatory policy and regulatory requirements.

As discussed previously, ICF has been seeking detailed information from industry to assist in developing a quantitative estimate of the values and impacts associated with the changes to the fissile material packaging and transportation requirements. In order to develop these estimates, significant data needs must be met, including the following:

- Number/types of packages/shipments containing the radionuclide ^{238}Pu.

- Number of packages/shipments of fissile material having a specific activity greater than 43 Bq/g but less than 70 Bq/g.

- Number/type of packages/shipments containing Pu-Be sources, including the quantity of plutonium.

- Number of packages/shipments falling under each of sections 71.18, 71.20, 71.22, and 71.24, and the TI and/or aggregate TI further distinguished by exclusive use versus non-exclusive use.

- Number/types of packages/shipments per conveyance.

- Number/type of packages/shipments currently falling under sections 71.20 and 71.24 that contain ^{235}U broken out by (1) the number of grams for each ^{235}U enrichment weight percentage, and (2) whether the fissile radionuclides are distributed uniformly and cannot form a lattice arrangement within the packaging.

- Number/types of packages/shipments currently shipped under sections 71.18(e) and 71.22(e) containing Be, C, and D_2O, and how much Be, C, and D_2O is contained (in grams and as a percent of fissile material mass).

- Number/types of packages/shipments of fissile materials with high-density hydrogenous moderators exceeding 15% of the mass of hydrogenous moderator in the package.

- Number/types of packages/shipments of fissile materials broken out by the ratio of the mass of fissile material per mass of nonfissile material that is non-combustible, insoluble in water, and not Be, C, or D_2O.

- Number/type of packages/shipments that both currently fall under section 71.53 and contain Be, C, and D_2O.

- Number/type of package/shipments broken out by TI.

- Number/type of package/shipments that currently fall under the section 71.53(c) exemption for uranyl nitrite solutions transport.

- Number/type of additional packages/shipments that would fall under section 71.53(b) absent the requirement that the fissile material were distributed homogeneously throughout the package contents and that the material not form a lattice arrangement within the package.

- To the extent not determinable based on the above information, the number/types of such packages meeting section 71.53, and currently shipped under sections 71.18, 71.20, 71.22, 71.24, and/or under Subparts E and F.

Such data are not readily available, and much of the data may not exist at all.[27] Consequently, this study analyzes values and impacts on a qualitative basis taking into account the regulatory option, each individual affected attribute, other factors influencing these attributes (e.g., potential for criticality, potential for radiation exposure, number of required packages and/or shipments, efforts required to make regulatory determinations or calculations, recordkeeping and reporting requirements), and applicable discussion and analysis contained in NUREG/CR-5342. Values and impacts reported for several attributes are based on analysis presented in a related environmental assessment prepared for this rulemaking.

Each of the 17 recommendations would, if implemented, result in certain values and/or impacts. Thus, the values and impacts of Option 2 as a whole consist of the sum of all values and impacts associated with the 17 recommendations.

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[27] Survey data on radioactive material shipments are not specific enough for use in the present analysis and, moreover, are more than a decade old (*Transport of Radioactive Material in the United States,* SRI International, April 1985).

Table 3-2 summarizes the values and impacts associated with each of the 17 recommendations contained in NUREG/CR-5342.

- Recommendation 1 – The action would result in enhanced regulatory efficiency due to increases in the clarity of NRC's regulations and improvements in the consistency between 10 CFR Part 71, 49 CFR Part 173, and IAEA No. TS-R-1. It also is conceivable that the action could result in a reduced potential for criticality due to the increased understanding of the regulations that would likely result.

- Recommendation 2 – The action would result in enhanced regulatory efficiency due to increases in the clarity of NRC's regulations and improvements in the consistency between 10 CFR Part 71 and IAEA No. TS-R-1. Also, licensees potentially could incur lower costs primarily due to reduced fissile shipments. As a result of the reduction in total fissile shipments, the potential for radiological exposures also would be reduced, yielding environmental, health, safety, and avoided offsite and onsite property damage benefits.

- Recommendation 3 – The action would increase costs to licensees, but would reduce the potential for criticality and thus would yield environmental, health, safety, and avoided offsite and onsite property damage benefits.

- Recommendation 4 – The action would most likely increase the regulatory burden on licensees and could result in increased costs to licensees due to necessary increases in the number of fissile material shipments. An increase in total fissile shipments would, in turn, increase the potential for radiological exposures, yielding possible negative impacts on the environment, health, safety, and offsite and onsite property. The net effect is uncertain, however, because of the potential for reductions in criticality.

- Recommendation 5 – The action would result in enhanced regulatory efficiency by consolidating the sections of 10 CFR Part 71 that pertain to exemptions into a single subpart.

- Recommendation 6 – The action would impose a recordkeeping and reporting burden on licensees, and would impose a recordkeeping and review burden on NRC. The added burden would consist of both initial costs (e.g., development of reporting formats, establishment of a fissile shipment database) and ongoing costs (e.g., periodic preparation and review of reports, maintenance of the database) to licensees and NRC. The action also would lead to improvements in knowledge for both licensees and NRC, and would enable NRC to better understand and regulate the shipment of fissile materials.

Table 3-2. Values and Impacts Associated with Actions Related to NUREG/CR-5342 Recommendations

ATTRIBUTE	ACTION																
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Public Health (Accident)		V(X)	V(C)	?			V(C) I(X)	V(C)	?(X)	V(C) ?(X)	?(X)	V(X)	V(C) I(X)	V(C) ?(X)	V(C)?(X)	V(C,X)	
Occupational Health (Accident)		V(X)	V(C)	?			V(C) I(X)	V(C)	?(X)	V(C) ?(X)	?(X)	V(X)	V(C) I(X)	V(C) ?(X)	V(C)?(X)	V(C,X)	
Occupational Health (Routine)		V(X)		?			I(X)		I(X)	?(X)	V(X)	?(X)	V(X)	?(X)	?(X)		
Offsite Property		V(X)	V(C)	?			V(C) I(X)	V(C)	?(X)	V(C) ?(X)	?(X)	V(X)	V(C) ?(X)	V(C) ?(X)	V(C)?(X)	V(C,X)	
Onsite Property		V(X)	V(C)	?			V(C) I(X)	V(C)	?(X)	V(C) ?(X)	?(X)	V(X)	V(C) ?(X)	V(C) ?(X)	V(C)?(X)	V(C,X)	
Industry Implementation		V(S,G)	I(S)	I(S,G)		I(R)	I(S,G)	I(G)	V(G) ?(S)	V(G) ?(S)	V(G)	I(S)	V(S)	V(G) ?(S)	V(G) ?(S)	I(S)	V(G)
Industry Operation		V(S,G)	I(S)	I(S,G)		I(R)	I(S,G)	I(G)	?(S)	V(G) ?(S)	V(S,G)	I(S)	V(S)	V(G) ?(S)	V(G)?(S)	I(S)	V(G)
NRC Implementation	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
NRC Operation		V(G)	?			I				?	V(G)			?	?		V(G)
Regulatory Efficiency	V	V			V		V	V		V	V	V	V	V	V	V	V
Environmental Considerations		V(X)	V(C)	?			V(C) I(X)	V(C)	?(X)	V(C) ?(X)	?(X)	V(X)	V(C) ?(X)	V(C) ?(X)	V(C)?(X)	V(C,X)	
Other Government		V(S,G)	I(S)	I(S,G)			I(S,D)	I(G)	V(G) I(S)	V(G) ?(S)	V(S,G)	I(S)	V(S)	V(G) ?(S)	V(G) ?(S)	I(S)	V(G)
Improvements in Knowledge						V											

KEY:
Values/Impacts: V = Value; I = Impact; ? = Direction of effect is uncertain due to data limitations
Factors influencing attributes: C = Criticality potential; X = Radiological exposure; S = number (or cost) of packages and/or shipments; G = Regulatory determinations/ calculations; R = Recordkeeping/reporting

- Recommendation 7 – The action would eliminate the potential for criticality and thus would yield environmental, health, safety, and avoided offsite and onsite property damage benefits. The action also would impose costs on licensees through added packaging requirements, increased shipments, and increased regulatory burden. The increase in shipments could, in turn, increase the potential for radiological exposures during shipping. However, the reduction in criticality risk would largely outweigh the risks from these exposures. The recommendation also would result in enhanced regulatory efficiency by creating a separate general license for Pu-Be sources, thus increasing the clarity of NRC's regulations.

- Recommendation 8 – The action would eliminate the potential for criticality and thus would yield environmental, health, safety, and avoided offsite and onsite property damage benefits. The action would impose an increased regulatory burden on licensees, however, in that it would require licensees to perform additional calculations related to the aggregate transport index. This recommendation also would result in enhanced regulatory efficiency by consolidating certain sections of 10 CFR Part 71 and by increasing the clarity of NRC's regulations.

- Recommendation 9 – The action would affect licensees' costs and may have, potentially, minor effects on radiological exposures. The action also would reduce the regulatory burden on licensees by reducing their administrative implementation costs (i.e., it would reduce the number of calculations licensees would need to make in determining permissible masses).

- Recommendation 10 – The action would eliminate the potential for criticality and thus would yield environmental, health, safety, and avoided offsite and onsite property damage benefits. Also, by modifying the Be, C, and D_2O quantity restrictions to incorporate a mass-based limit rather than a percentage-based limit, the action would reduce the number of calculations licensees would need to make in order to determine compliance with the regulations, thus reducing regulatory burden. The action also would result in enhanced regulatory efficiency by simplifying and clarifying NRC's regulations.

- Recommendation 11 – The action would reduce regulatory burden on licensees by simplifying the calculation of fissile material quantities and the categorization of mass limits. The action also would result in enhanced regulatory efficiency by simplifying and clarifying NRC's regulations.

- Recommendation 12 – The action would result in licensees incurring higher costs in meeting the added packaging requirements for shipments under the general licenses. As a result of these requirements, however, the potential for radiological exposures would be reduced, yielding environmental, health, safety, and avoided offsite and onsite property damage benefits. (The potential for criticality would not be affected by this recommendation.) The action also would result in enhanced regulatory efficiency due to increases in consistency within NRC's regulations.

- Recommendation 13 – The action would eliminate the potential for criticality and thus would yield environmental, health, safety, and avoided offsite and onsite property damage benefits. Also, the action would reduce regulatory burden on licenses by simplifying the calculation of fissile material quantities and the categorization of mass limits. The action also would result in enhanced regulatory efficiency due to increases in consistency within NRC's regulations.

- Recommendation 14 – The action would eliminate the potential for criticality and thus would yield environmental, health, safety, and avoided offsite and onsite property damage benefits. Also, the action would reduce regulatory burden on licenses by simplifying certain calculations that would need to be made in order to comply with the regulations. The action also would result in enhanced regulatory efficiency due to increases in consistency within NRC's regulations.

- Recommendation 15 – The action would eliminate the potential for criticality and thus would yield environmental, health, safety, and avoided offsite and onsite property damage benefits. Also, the action would reduce regulatory burden on licenses by simplifying certain calculations that would need to be made in order to comply with the regulations. The action also would result in enhanced regulatory efficiency due to increases in consistency within NRC's regulations.

- Recommendation 16 – The action would eliminate the potential for criticality and thus would yield environmental, health, safety, and avoided offsite and onsite property damage benefits. However, some licensees would incur higher costs under this action in meeting the added packaging requirements for transport of uranyl nitrite solutions. The action also would result in enhanced regulatory efficiency by simplifying NRC's regulations.

- Recommendation 17 – The action would result in savings to licensees with respect to determining whether package contents are homogeneous and form a lattice arrangement within the package. The action also would result in enhanced regulatory efficiency by simplifying NRC's regulations.

Given the severe data limitations, this analysis provides only minimal quantitative analysis of values and impacts associated with the changes to the fissile material requirements. ICF is continuing its data collection efforts, and is evaluating ways to develop surrogate data should actual industry data not be made available.

Estimated Costs to Industry

For the action associated with Recommendation 6, industry would incur additional costs to submit recordkeeping/reporting information electronically. (This analysis assumes that NRC will bear the costs for development, implementation, and maintenance of the database system.) It is estimated that an additional 0.2 hours per submission would be required to submit these data. The Supporting Statement for Part 71 indicates that approximately 122 submissions are made annually by licensees. At a cost of $129 per hour, this results in an estimated cost to licensees of $3,150 to submit data to the NRC electronically for input into the database.

Estimated Costs to NRC

For the action associated with Recommendation 6, NRC would incur capital and O&M costs to develop a database system. NRC also would incur costs associated with review of data submitted by industry. It is estimated that approximately 0.75 FTE would be required initially to establish the database. This would result in a cost to NRC of approximately $201,240. Annual maintenance and data review are estimated to cost NRC an additional $268,320 (or one FTE). Capital and O&M costs for the computer hardware are difficult to analyze without specific information concerning the type of system to be developed and, therefore, have not been quantified.

3.4.6 Double Containment of Plutonium (PRM-71-12)

Values and Impacts of Option 1

Under the No-Action Alternative (Option 1), NRC would retain the section 71.63 special requirements for plutonium shipments, which would place increased plutonium shipping requirements in the U.S. compared to the IAEA requirements. Thus, no values or impacts would result from Option 1.

Values and Impacts of Option 2

Under Option 2, NRC would delete section 71.63 special requirements for plutonium shipments. Plutonium packaging requirements would be handled no differently than requirements for other nuclear material (i.e., the A_1/A_2 system to determine if a Type B package is required). The attributes expected to be affected are described below:

- Public Health (Accident) – Removing a layer of packaging (protection) increases the probability and consequences of accidents that can breach the Type B package. It is anticipated, therefore, that an increase in exposure could result during an accident. The additional costs that might be incurred as a result will be developed with the preparation of the Environmental Assessment supporting this proposed rulemaking.

- Occupational Health (Routine) – Workers receive additional exposure while sealing the second layer of packaging. Eliminating this step and the associated radiation exposure results in a reduction in possible exposure. The cost savings that might be incurred as a result will be developed with the preparation of the Environmental Assessment supporting this proposed rulemaking.

- Offsite Property – The consequences to offsite property increase in proportion to the increase radiological accident consequences. The costs/savings that might be incurred as a result will be developed with the preparation of the Environmental Assessment supporting this proposed rulemaking.

- Industry Implementation -- Removing the requirement for double containment could reduce packaging costs. However, much of DOE's plutonium is stored in containers qualified as one level of containment and thus, would meet the double containment criteria when shipped whether or not it is required. Packages being used for plutonium shipments and packages that are planned for plutonium shipments in the next decade, such as packages that carry DOE-STD-3013 containers and SAFKEG packages, meet the double containment requirement. It would cost DOE more to redesign to a lower level of safety than to continue to use double containment. After this next decade, the major plutonium transportation affected by this regulation will be the continued repository shipments in TRUPAC-II packaging systems. Since these packages are already being produced and handling and shipping fixtures are designed around these packages, it is unlikely that DOE would change these operations. Therefore, future DOE shipments of plutonium in single containment packages cannot be predicted at this time.

- Industry Operation – Essentially all anticipated plutonium shipments would be done by DOE. (See Other Government.)

- NRC Implementation – Under the options, NRC would incur costs to revise guidance documents and related materials.

- Other Government – Removing the requirement for double containment could reduce operational costs. However, DOE has already spent a great deal developing transportation and storage containers that can be used under double containment.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below.

Estimated Costs to NRC

NRC would be required to make revisions to guidance documents and related materials. It is estimated that these revisions would take approximately two staff-months to complete. Assuming a cost of $129 per hour for staff, and 20 days per month at 8 hours each, this results in a total cost of approximately $41,280. These costs, however, have already been accounted for previously in the analysis.

3.4.7 Contamination Limits as Applied to Spent Fuel and High Level Waste (HLW) Packages

No regulatory changes are being proposed. Therefore, no regulatory options have been identified. As a result, no analysis was conducted.

3.4.8 Modifications of Event Reporting Requirements

Values and Impacts of Option 1

Under the No-Action Alternative (Option 1), NRC would not modify section 71.95 and would continue to require that a licensee submit a written report to the NRC within 30 days of three events: (1) a significant decrease in the effectiveness of a packaging while is in use to transport radioactive material, (2) details of any defects with safety significance found after first use of the cask, and (3) failure to comply with conditions of the certificate of compliance (CoC) during use. Thus, no values or impacts would result from Option 1.

Values and Impacts of Option (2)

Under Option 2, NRC would revise section 71.95 to require that the licensee and certificate holder jointly submit a written report for the criteria in new subparagraphs (a)(1) and (a)(2). The NRC also would add new paragraphs (c) and (d) to section 71.95 which would provide guidance on the content of these written reports. This new requirement is consistent with the written report requirements for Part 50 and 72 licensees (i.e., sections 50.73 and 72.75) and the direction from the Commission in SECY-99-181 to consider conforming event notification requirements to the recent changes made to Part 50. The NRC also would update the submission location for the written reports from the Director, Office of Nuclear Material Safety and Safeguards to the NRC Document Control Desk. Additionally, the NRC would remove the specific location for submission of written reports from section 71.95(c) and instead require that reports be submitted "in accordance with section 71.1." Lastly, the NRC would reduce the regulatory burden for licensees by lengthening the report submission period from 30 to 60 days. The affected attributes are described below:

- Regulatory Efficiency – The change would result in enhanced conformity among Parts 50, 71, and 72.

- NRC Implementation – The change would result in NRC implementation costs for licensees for revising procedures and for training. A key benefit of the proposed amendments would be a reduction in the recurring annual reporting burden on licensees, as a result of reducing the efforts associated with reporting events of little or no risk or safety significance. It is anticipated that the NRC's recurring annual review efforts for telephone notifications and written reports will not be significantly reduced.

Due to data limitations, only a portion of the values and impacts described above can be quantified. The results that can be quantified based on available data are described below

Estimated Costs to NRC

NRC would be required to prepare documents and conduct other activities (such as publishing notices of rulemakings, holding public hearings, and responding to public comments) as a result of the action. It is estimated that these activities would take approximately two staff-months to complete.   Assuming a cost of $129 per hour for staff, and 20 days per month at 8 hours each, this results in a total cost of approximately $41,280.

4. Backfit Analysis

The regulatory options examined in this regulatory analysis do not involve any provisions that would require backfits as defined in 10 CFR Part 50.109(a)(1). Consequently, a backfit analysis is not necessary.

5. Decision Rationale

As discussed earlier in this analysis, NRC's regulatory action consists of 19 individual changes that are intended to (1) harmonize the radioactive transportation regulations in 10 CFR Part 71 with the IAEA's TS-R-1, and (2) simplify NRC's regulations, while maintaining the safety standards for containers used to ship and store radioactive waste, and reduce paperwork and burden for licensees seeking to make minor changes in their operations. For each of the 19 issues addressed by the proposed rulemaking, the values and impacts associated with modifying its transportation regulations in 10 CFR Part 71 (as proposed under Option 2) and with adopting the No-Action alternative (Option 1) have been considered.

Due to severe data limitations on radioactive material shipments and other factors related to the rulemaking, ICF was unable to quantify a number of the values and impacts that are expected to occur as a result of Option 2. Nevertheless, given that the amendments described in Option 2 for each issue would simplify the Part 71 requirements applicable to licensees shipping radioactive materials, increase consistency with other regulatory programs, relax certain restrictions on radioactive material packages and shipments that are not justified based on plausible criticality concerns, and ensure adequate criticality safety for a number of newly-considered plausible transportation and packaging situations, these options are generally preferable to Option 1. For some issues, however, it was determined that revising the regulations would not result in any net economic or safety-related benefits to licensees, NRC, other government agencies (e.g., DOE, DOT), or the public.

For each of the 19 changes under consideration, Table 5-1 below summarizes the options determined to be most preferable based on professional judgment and limited quantitative analysis.

Table 5-1. Summary of Preferred Options

Technical Issue	Preferred Option
1. Changing Part 71 to the International System of Units (SI) Only	Option 1 (No-Action)
2. Radionuclide Exemption Values	Option 2
3. Revision of A_1 and A_2	Option 2
4. Uranium Hexafluoride Package Requirements	Option 2
5. Introduction of the Criticality Safety Index Requirements	Option 2
6. Type C Packages and Low Dispersible Material	Option 1 (No-Action)
7. Deep Immersion Test	Option 2
8. Grandfathering Previously Approved Packages	Option 2
9. Changes to Various Definitions	Option 2
10. Crush Test for Fissile Material Package Design	Option 2
11. Fissile Material Package Designs for Transport by Aircraft	Option 2
12. Special Package Authorizations	Option 2
13. Expansion of Part 71 Quality Assurance Requirements to Certificate of Compliance (CoC) Holders	Option 2
14. Adoption of ASME Code	Option 1 (No-Action)
15. Change Authority	Option 2
16. Fissile Material Exemptions and General License Provisions	Option 2
17. Double Containment of Plutonium (PRM-71-12)	Option 2
18. Contamination Limits as Applied to Spent Fuel and High Level Waste (HLW) Packages	For information only. No options identified.
19. Modifications of Event Reporting Requirements	Option 2

6. Implementation

Any action would be enacted through a Proposed Rule Notice, a public comment period, and a Final Rule. Implementation can begin immediately following the enactment of the final rule. No impediments to implementation of the recommended alternatives have been identified. Regulatory Guides for licensees would be required to provide an explanation of the regulatory requirements and methods for complying with the revised packaging and transport requirements for fissile material shipments.

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APPENDIX A

APPENDIX A
NUREG/CR-5342 Recommendations

The bases for and clarity of the general licenses for fissile material and the exemptions for fissile material in 10 CFR Part 71 have become increasingly unclear with adjustments and accommodations of the regulations over time, as well as with shipper (consignor) interpretations and applications. Any proposed revision of these portions of the regulations should seek to provide clear, unambiguous, and straightforward specifications. The regulations should specify simplified bounding requirements that provide fissile material general licenses and exemptions with a near equivalency in safety as that applied to packages certified to transport fissile material.

This section provides and discusses a consistent set of recommendations that are judged to be the most straightforward and effective for consideration in any future rule making process.

A.1 General Recommendations

- Consistency in definition and stated intent needs to be provided to the extent possible. It is recommended that definitions for “consignment,” “consignor,” and “shipper” be provided. Furthermore, the licensee is subject to possible confusion because of the differences between the wording used in 49 CFR 173 and 10 CFR 71. Even within 10 CFR Part 71 there are instances where no guidance or definition of words is provided to help clearly identify or explain the required specifications. For example, the regulations need to eliminate the wording “controlled shipment” or distinguish it from “exclusive-use shipment.”

- The definition of fissile material should be simplified and made technically correct by eliminating the nuclide ^{238}Pu from the definition. The impracticality of obtaining a large enough mass required for criticality (6 kg) and the high decay heat rate prevent any conceived consequences of this change that are adverse to criticality safety. Similarly, the usage of the words “fissile material” in the regulations needs to be clarified; sometimes it is used to specify fissile nuclides, while other times it is used to imply material containing fissile nuclides.

- The criteria for exempting fissile material from consideration as radioactive material regulated by 10 CFR Part 71 [e.g., section 71.10(a)] should be revised to not allow material with known quantities of fissile material from being included in the radioactive material exemption. This is the simplest and most straightforward approach. An alternative would be to lower the exemption concentration such that an infinite system would be subcritical. These criteria correspond to a value of 43 Bq/g (0.001 µCi/g) and are judged to be sufficiently limiting for all materials. An infinite medium subcritical concentration is sufficiently small, and the associated volume for criticality so large, that a change in concentration associated with the required volume for criticality is not deemed probable in a practical system.

- Although not discussed previously in the assessment, it also is recommended that 71.10(b) be modified to ensure that exemptions are not provided to fissile material that should meet some packaging requirements (e.g., section 71.53(d)). The recommendations under Section A.3 include some additional packaging requirements for selected fissile-material exemptions.

- The fissile-material exemptions should be moved to Subpart B – “Exemptions.” Placement of the fissile-material exemptions under Subpart B would be more consistent with the placement of other exemptions of 10 CFR 71.

- The NRC or DOT should consider keeping a database of shipments made under fissile-material exemptions and general license(s). The database should include a description of material shipped; the mass of fissile material in the consignment or shipment; the TI of the shipment, if applicable; the exemption criteria satisfied, if applicable; and the package description, if applicable. The database would be used to provide the NRC with historical information to better understand the type of material being shipped under the fissile-material exemptions and general licenses so that a more informed decision can be made relative to the impacts of any future changes to these portions of the regulations.

A.2 Recommendations for General Licenses

- The provisions related to shipment of Pu-Be sources should be removed from the general licenses. It may be possible to develop a separate general license for Pu-Be sources. The quantity of plutonium currently allowed to be shipped as Pu-Be sources is not technically justified based on available information and the lack of packaging requirements provided in the current regulations. Any new section that is developed should revise the quantity of plutonium allowed to be shipped as Pu-Be neutron sources and/or provide packaging requirements that prevent challenges to the basis for criticality safety.

- The general licenses for controlled shipments (sections 71.22 and 71.24) should be merged with the general licenses for limited quantity per package (sections 71.18 and 71.20) to provide a single general license paragraph that consolidates the needed technical criteria and operational controls. This merger, together with a clear specification of the aggregate TI allowed for nonexclusive use and exclusive use, should provide consistency with the approach of section 71.59 and simplify the regulations.

- The distinction between quantities of ^{235}U that can be shipped as a uniform distribution and nonuniform distribution should be eliminated. The bounding nonuniform quantities should be used. This change is recommended because the simplicity offered by this solution outweighs the complexity and confusion that would result from trying to develop a comprehensive definition for “nonuniform,” which is currently lacking in the regulations.

- Restrictions on quantities of Be, C, and D_2O should be removed from the general licenses, except perhaps to indicate these materials should not be present as a reflector material. Restricting its presence in quantities that might provide reflection of neutrons should be fairly simple and would be prudent since these packages are not under regulatory review. Limiting the quantity of these materials to 500 g per package should eliminate any concern relative to their effectiveness as a reflector.

- Maintaining a separate mass control (e.g., section 71.18) or restriction (e.g., section 71.20) for moderators having a hydrogen density greater than water is recommended. Where separate mass limits are provided, the fissile mass limit associated with moderators having hydrogen density greater than water should be used whenever such a high-density hydrogenous moderator exceeds 15% of the mass of hydrogenous moderator in the package.

- Minimum package requirements as provided by section 71.43 should be specified for shipments under the general licenses. The intent is to include good practice that an NRC licensee should have in place under a quality assurance program that handles shipment of fissile material with low specific activity.

- The package mass limits currently allowed by sections 71.18 and 71.20 should be increased to provide similar safety equivalence provided by certified packages per the criteria of sections 71.55 and 71.59. Justification for these increases is based partly on the implementation of an improved minimum packaging standard (section 71.43), as discussed above. The recommended mass values are provided in Tables A-1 and A-2. The values in Table A-1 were obtained by raising the mass limits to just under the mass values that ensure subcriticality ($k_{eff} \leq 0.95$) based on the information of Table 3. The fissile-material mass values for systems with moderators having a hydrogen density greater than water were subsequently obtained by using a scaling factor based on the ^{235}U critical mass values for a water-moderated system (820 g) and a system moderated by high-density polyethylene (527 g). The values of Table A-3 were obtained using a scaling factor based on the ratio of the new water-moderated ^{235}U limit shown in Table A-2 (60 g) and the existing value of section 71.18 (40 g).

A.3 Recommendations for Fissile-Material Exemptions

- The mass-limited exemptions of section 71.53(a) should be revised to provide criteria based on a ratio of the mass of fissile material per mass of nonfissile material. The nonfissile material considered in the ratio determination should be insoluble-in-water and noncombustible. It may be necessary to provide a definition and/or criteria for such material. Mass quantities of Be, C, and D_2O should be excluded from consideration as nonfissile material for the purposes of determining the ratio value. This approach would:

  1. Add enhanced assurance in preventing a potential transport situation that could provide a criticality safety concern; and

  2. Maintain flexibility for regulators, licensees, and operators by precluding the need to prescribe and use a TI for transport control.

  Mass ratios are often easier for licensees to determine than values related to volumetric concentration, and they can be defined to provide sufficient control under hypothetical accident conditions (i.e., assurance that desired volumes are maintained during hypothetical accident conditions is much more difficult than assurance that mass values are maintained). The recommended ratios of fissile-to-nonfissile mass for the various exemption considerations are provided in Table A-3. If the approach using mass ratios is not acceptable, then conveyance control based on a TI should be incorporated into the fissile exemptions.

Table A-1. Mass Limits for General-License Packages Containing Mixed Quantities of Fissile Material or ^{235}U of Unknown Enrichment

Fissile material	Fissile-material mass (g) mixed with moderating substances having an average hydrogen density less than or equal to H_2O	Fissile-material mass (g) mixed with moderating substances having an average hydrogen density greater than H_2O^{a}
$Uranium^{235}$ (*X*)..	60	38
$Uranium^{233}$ (*Y*)..	43	27
$Plutonium^{239}$ or $Plutonium^{241}$ (Z)....................	37	24

[a]For mixtures of moderating substances: if more than 15 percent of the moderating substance has an average hydrogen density greater than H_2O, then the lower mass limits shall be used.

Table A-2. Mass Limits for General-License Packages Containing ^{235}U of Known Enrichment

Uranium enrichment in weight percent of ^{235}U not exceeding	Permissible maximum grams of ^{235}U per package (X)
24	60
20	63
15	67
11	72
10	76
9.5	78
9	81
8.5	82
8	85
7.5	88
7	90
6.5	93
6	97
5.5	102
5	108
4.5	114
4	120
3.5	132
3	150
2.5	180
2	246
1.5	408
1.35	480
1	1,020
0.92	1,800

Table A-3. Proposed Fissile-exempt Mass Ratios to Replace Criteria of Section 71.53(a)

Package fissile material limit	Ratio: Fissile-to-nonfissile
15 g	1:200
350 g	1:2,000
350 g	1:200[a]

[a]Packaging required to satisfy standards for normal transport condition.

- The restriction on Be, C, and D_2O in sections 71.53(a), 71.53(c), and 71.53(d) should be removed if either approach (defined mass ratios or TI) discussed in the previous bullet is adopted.

- The exemption for uranyl nitrate solutions should be revised to incorporate packaging standards of section 71.43.

- The exemption for uranium enriched to less than 1 wt percent ^{235}U should be modified to remove the requirement for homogeneity and prevention of a lattice arrangement. Instead, the moderator criteria restricting the mass of Be, C, or D_2O to less than 0.1 percent of the fissile mass should be maintained. This change removes the need to provide definitions which are difficult to define and to apply practically, such as "homogeneous"and "lattice arrangement."

APPENDIX B

APPENDIX B
Estimation of Values and Impacts for Proposed Actions

Technical Issue 2: Revision to Radionuclide Exemption Values

The nature of the proposed change makes it difficult to quantify the safety impacts or benefits. Because exempt packages are not required to adhere to the reporting requirements of NRC and DOT-regulated packages, there are no data on the number or frequency of exempt packages shipped in the U.S.

In order to gain some insight into how the proposed change could affect regulated packages, ICF examined a Sandia report titled "Transport of Radioactive Material in the United States: Results of a Survey to Determine the Magnitude and Characteristics of Domestic, Unclassified Shipments of Radioactive Materials." This report presents the estimated number of packages shipped, organized by radionuclide. The six radionuclides that comprised the largest number of shipments were identified and compared to the corresponding exemption amount in IAEA's TS-R-1. The results are shown in the Table B-1 below.

Table B-1. Radionuclide Shipments

Radionuclide[1]	Number of Packages[1]	Annual Curies Shipped[2]	IAEA Exemption Level (Bq/g)
Am-241	395,000	60,300	1
Co-60	283,000	2,430,000	10
Tc-99m	570,000	69,900	100
Mo-99	219,000	1,210,000	100
Ir-192	80,500	4,930,000	10
Cs-137	196,000	48,600	10

[1] - From Sandia report
[2] - Derived from Sandia report

Out of the six radionuclides examined, two (Tc-99m and Mo-99) would have a higher exemption level than the current 70 Bq/g, and the other four would have a lower exemption value. For the purpose of discussion, changing the 70 Bq/g level to either 1 Bq/g, 10 Bq/g, or 100 Bq/g will have an impact too small to measure. In general, higher exemption levels could lead to an increase in the number of exempted shipments and lower exemption levels could lead to a decrease in the number of exempted shipments. IAEA has judged that the exemption levels that are less restrictive (i.e., higher) than NRC values do not cause a significant risk to individuals.

The above mentioned isotopes, as most others in normal commerce, are shipped in highly purified forms. Typically, they are shipped in Type-B quantities from initial production at a reactor or accelerator, and then distributed in small quantities to medical and/or industrial users. Since these shipments contain highly purified forms, the change to the exemption limit will not have a significant effect on the total number of shipments or impacts of commercially shipping these items (in other words, these radionuclides will continue to be shipped in relatively high concentrations regardless of the exemption limits). Additionally, based on a review of the entire

list of radionuclides with new exemption limits in IAEA's TS-R-1, most exemption limits would only change from 70 Bq/g to either 100 Bq/g or 10 Bq/g. These changes would not affect how the material was handled, since it is generally at or near a level that would affect contaminated waste handling, not product distribution.

The following isotopes have IAEA exemption limits of 1,000 Bq/g or higher: Ag-111, Ar-37, Ar-39, As-73, As-77, At-211, Be-10, C-14, Ca-41, Ca-45, Co-58m, Cs-134m, Cs-135, Eu-150, Fe-55, Ge-71, Ho-166, Kr-81, Kr-85, Lu-177, Mn-53, Ni-59, Ni-63, Np-235, Np-236, Os-191m, P-33, Pb-205, Pd-107, Pm-147, Pm-149, Pt-193, Pr-143, Pt-197, Rb-87, Rb(nat), Re-187, Re(nat), Rb-103m, S-35, Se-79, Si-31, Si-32, Sn-119m, Sn-121m, Sn-123, Sr-89, Ta-179, Tb-157, Tc-96m, Tc-97, Tc-97m, Th-231, Th-234, Tl-204, Tm-170, Tm-171, V-49, W-181, W-185, Xe-127, Xe-131m, Xe-133, Xe-135, Y-90, Y-91, Yb-175, Zn-69, and Zr-93. Of these isotopes, the only ones that contribute 0.01 percent or more of the total curie amount transported are Ni-63 (0.01 percent) and Xe-133 (0.49 percent). Both of these are generally found only in fission products, and are shipped as spent fuel or high level waste. Therefore, the change should not impact the package used or the number of shipments.

The following isotopes have IAEA exemption limits of 1 Bq/g or lower: Ac-277, Am-241, Am-242m, Am-243, Bk-247, Cf-249, Cf-251, Cf-254, Cm-243, Cm-245, Cm-246, Cm-247, Cm-248, Np-237, Pa-231, Pu-238, Pu-239, Pu-240, Pu-242, and U-232. Of these, the isotopes that contribute 0.01 percent or more of the total curie amount transported are the americium, neptunium and plutonium isotopes. No significant change in the impacts of americium shipments would be expected. The lowering of the plutonium and neptunium limits from 70 Bq/g to 1 Bq/g might have an impact on transporting low-level wastes from DOE facilities. In particular, packages containing between 1 and 69 Bq/g that used to qualify for an exemption would now be subject to the reporting requirements for NRC and DOT-regulated packages. This change would result in a decrease in the number of these shipments and/or some level of improved protection for the shipments that continue to be made.

The DOE Waste Management EIS (DOE, 1997) was reviewed to determine if significant amounts of radioisotopes would be transported under exemptions. No such shipments were mentioned in the EIS. Since most waste shipments would be using Type A packages and most impacts were attributed to the smaller number of Type B packages that would be shipped, the change in regulation would have little or no impact on DOE site clean-up activities.

No public health or safety problems were identified for the current exemption level of 70 Bq/g for all radionuclides. In the hundreds of thousands of shipments that span five decades, no public health or safety impact attributable to the current exemption value provision has been identified.

The proposed exemption values do not provide a significant improvement in safety. The draft provisions would impose new complexity and economic burdens to the transportation industry. The new use of a formula to determine the exemption of mixtures of radionuclides would be a burden on licensees and may lead to errors in use. The draft provisions may decrease harmony between IAEA and member states' regulations if the lack of economic merit for the proposed changes leads to the U.S. and other member states adopting provisions different from those in TS-R-1.

Technical Issue 3: Revision of A_1 and A_2 Values

In general, the new A_1 and A_2 values are within a factor of about 3 of the earlier values; there are a few radionuclides where the new A_1 and A_2 values are outside this range. Approximately 40 radionuclides have new A_1 values higher than previous values by factors ranging between 10 and 100. This is due mainly to improved modeling for beta emitters. There are no new A_1 or A_2 values that are lower than the previous figures by more than a factor of 10. A few radionuclides previously listed are now excluded, but two additional ones have been added, i.e., both isomers of Eu-150 and Np-236.

In order to gain some insight into how the proposed revisions could affect packages in the U.S., ICF examined a report titled "Transport of Radioactive Material in the United States: Results of a Survey to Determine the Magnitude and Characteristics of Domestic, Unclassified Shipments of Radioactive Materials." This report presents the estimated number of packages shipped, organized by radionuclide. The six radionuclides that comprised the largest number of shipments were identified and compared to the new IAEA A_1 and A_2 values for the radionuclide. The results are shown in Table B-2.

Table B-2. A_1 and A_2 Values for Commonly Shipped Radionuclides

Radionuclide	Number of Packages Shipped Annually	Part 71 A_1 Values (TBq)	TS-R-1 A_1 Values (TBq)	Part 71 A_2 Values (TBq)	TS-R-1 A_2 Values (TBq)
Am-241	395,000	2	10	$2x10^{-4}$	$1x10^{-3}$
Tc-99m	570,000	8	10	8	4
I-125	267,000	20	20	2	3
Mo-99	219,000	0.6	1	0.5[a]	0.6
Ir-192	80,500	1	1	0.5	0.6
Cs-137	196,000	2	2	0.5	0.6

a. Part 71 allows 0.74 TBq (20 Ci) for domestic shipping of Mo-99.

For these six radionuclides, all of the A_1 values either increased or stayed the same. Five of the A_2 values increased and one A_2 value decreased. These proposed A_1 and A_2 values were compared to the average activity per package to determine whether the proposed change would have much impact on shippers. Without detailed information on the distribution of material quantities in packages actually transported, this average value is used for evaluation of impacts.

Americium-241: The A_1 and A_2 values for Am-241 increased by a factor of 6.75 during the last revision of Part 71 in 1995 (60 FR 50248). ICF evaluated these changes to the A_1 and A_2 values using the same data available for this analysis. ICF found that practically all Am-241 was shipped in special form in packages with average curie values that were well below the proposed A_1 limit. Therefore, ICF concluded that the revised A_1 and A_2 values would not lead to changes in the amount of material transported per package, the number of packages transported per year, the type of package used for these shipments, or the risk impact for Am-241 shipments.

The proposed A_1 and A_2 values are 10 TBq and 1×10^{-3} TBq, respectively, which are both higher by a factor of 5 than those currently in Part 71. The average curie quantity per package of Am-241 is 0.153 Ci (5.66×10^{-3} Tbq). Since the average value is well

below the proposed A_1 limit, and the fact that these changes would be smaller than the 1994 changes, it is concluded that the proposed change would have no impact on these shipments.

Technicium-99m: Under the proposed action, the A_1 value for Tc-99m would increase from 8 TBq to 10 TBq and the A_2 value would decrease from 8 TBq to 4 TBq. The average curie quantity per package of Tc-99m is 0.123 Ci (4.55 x 10^{-3} TBq) (Javitz et. al., 1985). This value is well below the proposed A_1 or A_2 value; therefore, it is concluded that the proposed change would have no impact on these shipments.

Iodine-125: Under the proposed action, the A_1 value for I-125 would stay the same while the A_2 value would increase from 2 to 3 TBq. The average curie quantity per package of I-125 is 0.001 Ci (3.7 x 10^{-5} TBq) (Javitz et. al., 1985). This value is well below the proposed A_1 or A_2 value; therefore, it is concluded that the proposed change would have no impact on these shipments.

Molybdenum-99: Under the proposed action, the A_1 value for Mo-99 would increase from 0.6 to 1 TBq. The current A_2 value for Mo-99 is 0.5 TBq per package. Adoption of the proposed regulation would increase that limit to 0.6 TBq per package. The average quantity of Mo-99 currently being transported is 5.53 curies (0.20 TBq) per package (Javitz et. al., 1985). This average value is below both the current and proposed A_2 limits. There may be, however, specific cases in which the quantity currently being shipped exceeds the proposed A_2 limit. A specific example is the shipment of Mo-99/Tc-99m radiopharmaceutical generators. The NRC allows up to 0.74 TBq (20 Ci) for domestic shipments in a Type A package.

Since, on the average, neither the quantity shipped per package nor the package type used is likely to be affected, no change in the consequences of a hypothesized accident can be expected. Therefore, no significant change in the risk impact of these shipments is expected.

Iridium-192: Under the proposed action, the A_1 value for Ir-192 would remain at 1 TBq while the A_2 value would increase from 0.5 to 0.6 TBq. The average curie quantity per package of Ir-192 is 61.5 Ci (2.28 Tbq). This average value is already above the current limits on shipment in Type A packages; therefore, Type B packages would be used for these shipments. Since the A_1 value would stay the same and the A_2 value would increase only slightly, and the fact that the average Ir-192 shipment is already above the Type A package limit, it is concluded that the proposed change would have little impact on these shipments.

Cesium-137: Under the proposed action, the A_1 value for Cs-137 would remain at 2 TBq while the A_2 value would increase from 0.5 to 0.6 TBq. The average curie quantity per package of Cs-137 is 0.268 Ci (0.01 TBq). This average value is well below the proposed A_1 or A_2 value; therefore, it is concluded that the proposed change would have no impact on these shipments.

The A_1 and A_2 values in Part 71 were last revised in 1995. A regulatory and environmental impact analysis was developed for these revisions and concluded that there was no significant impact from adjusting the A_1 and A_2 values. This conclusion is still valid for these proposed changes.

For mixtures for which relevant data are not available, Table II of TS-R-1 provides A_1 and A_2 values. Unlike Part 71, the new Table II separates mixtures of alpha emitters from mixtures of unknown radionuclides. The current and proposed values are shown in Table B-3.

Table B-3. A_1 and A_2 Values for Mixtures of Unknown Radionuclides

Contents	Part 71 A_1 Values (TBq)	TS-R-1 A_1 Values (TBq)	Part 71 A_2 Values (TBq)	TS-R-1 A_2 Values (TBq)
Only beta or gamma emitting nuclides known to be present	0.2	0.1	0.02	0.02
Only alpha emitting nuclides are known to be present	0.10	0.2	2×10^{-5}	9×10^{-5}
No relevant data are available	0.10	0.001	2×10^{-5}	9×10^{-5}

The A_1 values have increased for alpha emitters and decreased for beta and gamma emitters and unknown radionuclides. The A_2 values have stayed the same for beta and gamma emitters and increased for alpha emitters and unknown radionuclides. There are no data available that estimate the number of packages of unknown radionuclides shipped each year for each of these categories; however, the number is believed to be small. Because the number is believed to be small, and because the above analysis shows little or no impact for changes in A_1 and A_2 values for packages with known radionuclides, it is concluded that changes in A_1 and A_2 for packages of unknown radionuclides also would have negligible impact.

Estimated Costs to Licensees

Licensee resources will have to be spent to evaluate changes reflected in Tables I and II of TS-R-1. As a result of the review of the changes, the licensees will have to expend varying levels of resources to update various aspects of their shipping programs. The licensees also may have to modify their shipping processes to assure compliance with new A_1 and A_2 values. However, these costs are expected to be small since shippers already have programs in place that use the A_1 and A_2 limits. Additionally, the analysis performed for the 1995 revision of the A_1 and A_2 values concluded that the cost to licensees would be negligible. This conclusion is still considered to be valid.

The revised A_1 and A_2 values may change the package types that must be used by a shipper; for example, an increased A_1 value may allow a shipper to use a Type A package rather than a more expensive Type B package. However, as discussed in the previous paragraphs, the six isotopes that are most commonly shipped were evaluated and it was determined that the proposed changes would not have a significant impact or cost to shippers due to changes in package types.

Estimated Costs to NRC

The changes to the A_1 and A_2 values are estimated to require approximately two staff-months of effort. Assuming a cost of $129 per hour for staff, and 20 days per month at 8 hours each, this results in a total cost of approximately $41,280. This estimation of staff time is consistent with that estimated by the NRC during the last revision of the A_1 and A_2 values.

Technical Issue 7: Deep Immersion Test

The proposed scope expansion to all packages containing more than 10^5 A_2 and all Type C packages may increase the number of shipments that are required to use packages that can successfully pass the enhanced deep immersion test. Under current Part 71 requirements, only some shipments of irradiated nuclear fuel are required to pass the deep immersion test. For the revised A_2 values in TS-R-1, 10^5 A_2 is a number ranging from 9 TBq (243 Ci) for Ac-227 to 4,000,000 TBq (1.08 x 10^8 Ci) for Ar-37, As-73, Co-58m, Fe-55, Ge-71, Kr-81, Np-235, Pd-103, Pt-193, Rh-103m, T (H-3), Tb-157, Tm-171, V-49, and Xe-131m.

Of approximately 2.9 million commercial packages of radioactive material shipped per year, only about 129,000 packages (4.4 percent) contain a curie content of more than 100 Ci. About 397 packages, or 0.01 percent, contain a curie content of more than 1,000 Ci. Out of a total of 32,000 DOE packages shipped annually, it is estimated that approximately 833 packages (2.6 percent) contain a curie content of more than 100 Ci; approximately 409 packages (1.3 percent) contain more than 1,000 Ci; approximately 124 packages (0.4 percent) contain more than 10,000 Ci; approximately 25 packages (0.08 percent) contain more than 100,000 Ci; and 17 packages (0.05 percent) contain more than 1,000,000 Ci. Most, if not all, of these high activity DOE packages are probably shipments of spent fuel, which may already be shipped in packages that meet the deep immersion requirement. These small percentages indicate that a very small number of packages would be affected by the proposed change in the testing requirement.

The package types that would certainly be affected by the proposed change would be those for spent fuel. The two largest shipping campaigns for spent fuel are expected to be the movement of commercial and DOE spent fuel to Yucca Mountain (or other approved repository) and the importation of foreign research reactor fuel for storage and disposal in the U.S. The typical inventories for these spent fuels were determined and the appropriate A_2 for the mixture of radionuclides was calculated, using the equation given in TS-R-1. The A_2 value was then multiplied by 10^5 and compared to the total activity of the package to assess whether the package would be required to meet the deep immersion test if Part 71 is revised. The formula for calculating the A_2 value for a mixture is:

$$A_2 = 1/\sum[f(i)/A_2(i)]$$

where A_2 is the A_2 for the mixture, f(i) is the fraction of activity of radionuclide i in the mixture, and $A_2(i)$ is the appropriate value of A_2 from TS-R-1.

The typical radionuclide activity for a pressurized water reactor fuel assembly that would be shipped to Yucca Mountain would have decayed for approximately 26 years. The total activity of the package would not exceed 1,000,000 Ci unless more than 12 assemblies were placed in a package. Therefore, under the current Part 71 regulations, the package would not have to meet the deep immersion test if less than 12 assemblies were shipped in one package. Evaluation against the proposed requirement revealed that, regardless of how many assemblies were shipped in a package, the activity of the average package would be higher than 10^5 A_2; therefore, the package would have to meet the deep immersion test if Part 71 is revised. These results are shown in Table B-4, assuming six fuel assemblies in a package.

Table B-4. Steps in Calculation of A_2 for PWR Spent Fuel

Isotope (i)	Curies per Assembly[a]	Curies per Package	TBq per Package	f(i)	A_2 from TS-R-1 (TBq)	f(i)/A_2
H-3	98.0	588.0	21.8	1.25E-03	40	3.13E-05
Co-60	150.0	900.0	33.3	1.92E-03	0.4	4.80E-03
Ni-59	1.3	7.8	0.3	1.66E-05	unlimited	0.00E+00
Ni-63	180.0	1,080.0	40.0	2.30E-03	30	7.68E-05
Kr-85	930.0	5,580.0	206.5	1.19E-02	10	1.19E-03
Sr-90	21,000.0	126,000.0	4,662.0	2.69E-01	0.3	8.96E-01
Zr-93	1.2	7.2	0.3	1.54E-05	unlimited	0.00E+00
Tc-99	7.1	42.6	1.6	9.08E-05	0.9	1.01E-04
Cs-134	16.0	96.0	3.6	2.05E-04	0.7	2.92E-04
Cs-137	31,000.0	186,000.0	6,882.0	3.97E-01	0.6	6.61E-01
Sm-151	190.0	1,140.0	42.2	2.43E-03	10	2.43E-04
Pu-238	1,700.0	10,200.0	377.4	2.17E-02	0.001	2.17E+01
Pu-239	180.0	1,080.0	40.0	2.30E-03	0.001	2.30E+00
Pu-240	270.0	1,620.0	59.9	3.45E-03	0.001	3.45E+00
Pu-241	20,000.0	120,000.0	4,440.0	2.56E-01	0.06	4.26E+00
Am-241	1,700.0	10,200.0	377.4	2.17E-02	0.001	2.17E+01
Am-242/242m	11.0	66.0	2.4	1.41E-04	0.001	1.41E-01
Am-243	13.0	78.0	2.9	1.66E-04	0.001	1.66E-01
Cm-242	8.7	52.2	1.9	1.11E-04	0.01	1.11E-02
Cm-243	8.3	49.8	1.8	1.06E-04	0.001	1.06E-01
Cm-244	700.0	4,200.0	155.4	8.96E-03	0.002	4.48E+00
Total	**78,164.6**	**468,987.6**	**17,352.5**	**1.0**		**60.0**

a. Obtained from DOE 1999.

B-5. Steps in Calculation of A_2 for BR-2 Spent Fuel (Continued)

Using the f(i)/A_2 value obtained from Table B-4, the A_2 for the mixture equals 0.017 TBq and 10^5 A_2 equals 1,700 TBq. Therefore, the activity of the spent fuel (17,352.5 TBq) is higher than the 10^5 A_2 value for the mixture (1,700 Tbq), and the fuel would need to be shipped in a cask that can pass the deep immersion test.

The bounding fuel type for foreign research reactors would be BR-2 fuel that had decayed for less than one year. The total activity of the package would be slightly less than 1,000,000 Ci. Therefore, under the current Part 71 requirements, the package would not be required to meet the deep immersion test. Additionally, the calculation of A_2 for this fuel type revealed that the total activity of the package would not exceed 10^5 A_2; therefore, the package also would not have to meet the deep immersion test if Part 71 was revised. However, since these packages are coming from foreign countries that may already have regulations that are consistent with IAEA standards, any such packages that exceed the 10^5 A_2 limit may already be certified to the deep immersion test. A shipment of research reactor fuel from South Korea was in fact placed in a cask that meets the deep immersion test. Additionally, shipments of these foreign fuel types are only slightly below the limits of 1,000,000 Ci or 10^5 A_2. These results are shown in Table B-5.

Table B-5. Steps in Calculation of A_2 for BR-2 Spent Fuel

Isotope (i)	Curies per package[b]	TBq per package	f(i)	A_2 from TS-R-1 (TBq)	f(i)/A_2
H-3	86.4	3.2	9.28E-05	40.0	2.32E-06
Kr-85	2,470.0	91.4	2.65E-03	10.0	2.65E-04
Sr-89	40,800.0	1,509.6	4.38E-02	0.6	7.30E-02
Sr-90	20,800.0	769.6	2.23E-02	0.3	7.45E-02
Y-90	20,800.0	769.6	2.23E-02	0.3	7.45E-02
Y-91	73,000.0	2,701.0	7.84E-02	0.6	1.31E-01
Zr-95	107,000.0	3,959.0	1.15E-01	0.8	1.44E-01
Nb-95	220,000.0	8,140.0	2.36E-01	1.0	2.36E-01
Ru-103	8,900.0	329.3	9.56E-03	2.0	4.78E-03
Rh-103m	8,900.0	329.3	9.56E-03	40.0	2.39E-04
Ru-106	21,500.0	795.5	2.31E-02	0.2	1.15E-01
Sn-123	427.0	15.8	4.59E-04	0.6	7.64E-04
Sb-125	890.0	32.9	9.56E-04	1.0	9.56E-04
Te-125m	212.0	7.8	2.28E-04	0.9	2.53E-04
Te-127m	887.0	32.8	9.53E-04	0.5	1.91E-03
Te-129m	189.0	7.0	2.03E-04	0.4	5.07E-04
Cs-134	16,400.0	606.8	1.76E-02	0.7	2.52E-02
Cs-137	20,600.0	762.2	2.21E-02	0.6	3.69E-02
Ce-141	5,740.0	212.4	6.16E-03	0.6	1.03E-02

B-5. Steps in Calculation of A_2 for BR-2 Spent Fuel (Continued)

Isotope (i)	Curies per package[b]	TBq per package	f(i)	A_2 from TS-R-1 (TBq)	f(i)/A_2
Ce-144	312,000.0	11,544.0	3.35E-01	0.2	1.68E+00
Pm-147	48,300.0	1,787.1	5.19E-02	2.0	2.59E-02
Pm-148m	75.6	2.8	8.12E-05	0.7	1.16E-04
Eu-154	620.0	22.9	6.66E-04	0.6	1.11E-03
Eu-155	130.0	4.8	1.40E-04	3.0	4.65E-05
U-234	0.0	0.0	9.82E-10	0.006	1.64E-07
U-235	0.0	0.0	1.48E-08	unlimited	0.00E+00
U-238	0.0	0.0	3.66E-10	unlimited	0.00E+00
Pu-238	64.2	2.4	6.90E-05	0.001	6.90E-02
Pu-239	1.8	0.1	1.98E-06	0.001	1.98E-03
Pu-240	1.2	0.0	1.29E-06	0.001	1.29E-03
Pu-241	284.0	10.5	3.05E-04	0.06	5.08E-03
Am-241	0.4	0.0	4.25E-07	0.001	4.25E-04
Am-242m	0.0	0.0	1.13E-09	0.001	1.13E-06
Am-243	0.0	0.0	4.65E-09	0.001	4.65E-06
Cm-242	1.8	0.1	1.88E-06	0.01	1.88E-04
Cm-244	1.3	0.0	1.43E-06	0.002	7.14E-04
Total	**931,081.7**	**34,450.0**	**1.0**		**2.7**

b. Obtained from DOE 1996.

Using the f(i)/A_2 value obtained from Table B-5, the A_2 for the mixture equals 0.369 TBq and 10^5 A_2 equals 36,900 TBq. Therefore, the activity of the spent fuel (34,450 TBq) is lower than the 10^5 A_2 value for the mixture (36,900 TBq), and the fuel would not need to be shipped in a cask that can pass the deep immersion test.

The fact that some packages for spent fuel are currently required to pass the deep immersion test indicates that some spent fuel casks already meet this requirement. However, large quantities of other types of materials, which are currently shipped in other types of Type B packages, also may need to use a package that passes this requirement. Therefore, a new Type B package that meets the proposed standard may have to be designed, developed, and certified.

The radionuclides that comprise the largest number of commercial shipments (more than 100,000 packages per year), as well as radionuclides that had the highest average activity per package shipped (more than 1 Ci per package), were identified. The applicable 10^5 A_2 value was then compared to the average curie value per package. The results are shown in Table B-6.

B-5. Steps in Calculation of A_2 for BR-2 Spent Fuel (Continued)

Table B-6 shows that the average activity value per package is much lower than the 10^5 A_2 value for each of these radionuclides. This indicates that these packages would not be affected by the proposed change and would not have to meet the deep immersion test.

Table B-6. Comparison of 10^5 A_2 with Average Commercial Shipping Values

Radionuclide	10^5 A_2 from TS-R-1 (TBq)	Average TBq per Package[a]
Most Frequently Shipped Packages		
Am-241	100	0.004
Co-60[b]	40,000	0.3
Cs-137	60,000	0.01
I-123	300,000	0.0002
I-125	300,000	0.00004
I-131	70,000	0.0006
Mo-99[b]	60,000	0.2
Tc-99m	400,000	0.005
Tl-201	400,000	0.0006
Xe-133	1,000,000	0.01
Packages with Highest Average Curies per Package		
Au-198	60,000	0.2
Ce-144	20,000	0.04
Fe-55	4,000,000	0.05
Ir-192	60,000	2.3
Rb-86	50,000	0.08
U (natural)	Unlimited	0.07

a. From Javitz et. al.
b. Also has high average curies per package shipped

The DOE packages with high activity levels (more than 1,000 Ci per package) also were compared to the corresponding values of 10^5 A_2. The results are shown in Table B-7.

Table B-7. Comparison of 10^5 A_2 with Average DOE Shipping Values

Radionuclide	10^5 A_2 from TS-R-1 (TBq)	Average TBq per Package[a]
Ce-144	20,000	212
Cm-244	200	70
Cs-137	60,000	216
H-3	4,000,000	105
Ir-192	60,000	360
Kr-85	1,000,000	1,473
Sr-90	30,000	127
U-234	600[b]	2,675

a. From Javitz et. al.
b. Assumes the most conservative A_2 value for slow lung absorption.

For DOE packages, all the reviewed radionuclides would have an activity much less than 10^5 A_2, except for U-234. Although the packages containing U-234 have high activity, the number

of packages shipped represents only 0.04 percent of the 32,000 packages shipped annually. Therefore, the number of packages affected would be small.

Occupational Health (Accident)

The deep immersion test would be for packages containing activity of more than 10^5 A_2, so as to ensure that the containment system does not fail and create a radiation hazard or inflict environmental harm. If such a package were lost in water less than 200 m deep, it is likely that the package would be recovered.

The occupational dose from the recovery operation of a ruptured spent fuel cask that has a dose rate at the regulatory limit has been estimated to be approximately 410 person-mrem. This estimate is still considered to be valid, although somewhat conservative, since shielding effects of water were not considered and the package may in fact be well below the regulatory limits for dose rate.

The proposed action would affect the accident consequences of a package being lost in water of less than 200 m in depth. This type of scenario may result from severe accidents involving truck or rail transportation over or near coastal areas, rivers, or lakes. A scenario in which a severe accident takes place near or over deep water, resulting in the package being rolled or dropped into the water, is an extremely unlikely event and is possibly beyond reasonable credibility.

Another applicable accident scenario would be the sinking or capsizing of a ship or barge while at sea over the continental shelf, near port in a bay channel or river, or in port. The probability of the loss of a vessel has been approximated to be 0.001 per trans-Pacific trip. It is assumed that approximately 100 such shipments would occur each year. The probability of 0.001 accidents per trip multiplied by 100 shipments per year results in an annual probability of a deep immersion accident of 0.1 per year. This annual probability combined with the estimated 410 person-mrem dose results in an expected annual radiological exposure of 41 person-mrem/yr, or 0.041 person-rem/yr.

Estimated Costs to Industry

The implementation of additional deep immersion testing will require manufacturers to evaluate testing procedures and container designs. This may require significant amounts of time. Some spent fuel packages already meet the requirement for the deep immersion test, although it is unclear how many. Therefore, it was assumed that all 24 currently licensed spent fuel casks would be tested.

Most container models certified for spent fuel have metal-on-metal seals and heavy closure devices. External pressure will help seal the cask unless a pressure level is reached at which significant deformation of the closure mechanism or the seals or lids occurs.

Cask designs are currently evaluated by the use of air pressure tests, computer simulations, and material strength calculations. The added need to evaluate cask designs for the possibility of loss of containment integrity could considerably increase the time required for certification. At a minimum, the manufacturers could expend one month to reevaluate designs and apply for recertification. A month of such work has been estimated to cost approximately $8,300 in 1994. Assuming an escalation of 4 percent per year would increase this cost to $10,200 in 1999. More typically, a cask design would be evaluated with special attention to seals and closures. This is expected to take approximately three months and cost about $30,600. At a maximum,

some cask designers would find it necessary to review test calculations, check seals and closure mechanisms, and modify the designs to withstand the deep immersion test. This effort may require up to one full year for each design and could cost as much as $122,000.

If each of the 24 casks is required to undergo the reevaluation, the total costs to industry could range from $245,000 to $2,928,000, with the expected typical total cost to be near $734,000. These costs are an upper bound, because some casks are already certified as meeting the deep immersion test.

It is possible that packages of materials other than spent fuel may exceed the 10^5 A_2 limit. In this case, licensee resources may be expended to design and develop a new Type B package. Additional licensee resources may have to be expended if the enhanced Type B package must be used for shipments that previously would have been acceptable in another Type B package, assuming the new package is more expensive. However, the number of packages exceeding 10^5 A_2 that are not spent fuel is estimated to be exceedingly small, and thus licensees may be inclined to ship multiple packages containing less material rather than design a new package.

Estimated Costs to the NRC

NRC development costs would include such activities as preparation of documents, publishing notices of rulemaking, holding public hearings, and responding to public comments. It is estimated that the revision of the limits for the deep immersion test would require approximately two staff-months to complete. Assuming a cost of $129 per hour for staff, and 20 days per month at 8 hours each, this results in a total cost of approximately $41,280.

If the proposed action is adopted, the NRC will incur costs to implement the revised requirements. This may consist of such activities as developing procedures, reviewing and approving test results, recertifying packages, and taking other actions to assure compliance. It is expected that the revision of limits for the deep immersion test would require approximately one month per cask design. Assuming a cost of $129 per hour for staff, and 20 days per month at 8 hours each, this results in a total cost of approximately $20,640 per cask design and $495,360 for all casks.

The NRC also may incur operation costs. These are the recurring costs that are necessary to ensure continued compliance with the proposed rule. It is expected that implementation of the revised deep immersion testing limits will not create any significant change to current NRC operating costs.

APPENDIX C

APPENDIX C
Questions Developed for Survey of Fissile Material Licensees

Packages

- How many packages of exempted and general licensed fissile materials does your firm typically prepare each year?

- How much does it cost your firm to prepare these fissile material packages?

- Which factors (e.g., labor, material, manifest, insurance, etc.) contribute to this cost?

- What is the typical dose rate at one meter from the surface for these fissile material packages?

Shipments

- How many shipments of exempted and general licensed fissile materials does your firm typically make each year?

- How much does it cost your firm to make these fissile material shipments?

- Which factors (e.g., labor, material, manifest, insurance, etc.) contribute to this cost?

- What is the average number of exempted and general license fissile material packages in a single shipment?

- What is the most common destination for these shipments, or the average distance shipped? (Please distinguish between truck and rail shipments, if applicable)

Material Characterization

- Which other radioactive materials (please specify by radionuclide, activity, and volume) are included in the packages containing fissile material?

Recommendations in NUREG/CR-5342 (provide separate information for each recommendation)

- How many more (less) fissile material packages will your firm prepare each year?

- What is the basis for this increase (decrease) in fissile material packages?

- Would your firm expect any increase (decrease) in worker or driver dose from shipping and handling? (If so, then how much increase [decrease] is expected?)

- What will be the average number of fissile material packages in a single shipment?

- Will your firm experience a change in the time required for recordkeeping or reporting?
- Will your firm experience a change in the time required for regulatory determinations or calculations?

APPENDIX D

Table D-1. A_1 and A_2 Values for Radionuclides

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific activity (TBq/g)	Specific activity (Ci/g)
Ac-225 (a)	Actinium (89)	$8.0X10^{-1}$	$2.2X10^{1}$	$6.0X10^{-3}$	$1.6X10^{-1}$	$2.1X10^{3}$	$5.8X10^{4}$
Ac-227 (a)		$9.0X10^{-1}$	$2.4X10^{1}$	$9.0X10^{-5}$	$2.4X10^{-3}$	2.7	$7.2X10^{1}$
Ac-228		$6.0X10^{-1}$	$1.6X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$8.4X10^{4}$	$2.2X10^{6}$
Ag-105	Silver (47)	2.0	$5.4X10^{1}$	2.0	$5.4X10^{1}$	$1.1X10^{3}$	$3.0X10^{4}$
Ag-108m (a)		$7.0X10^{-1}$	$1.9X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	$9.7X10^{-1}$	$2.6X10^{1}$
Ag-110m (a)		$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$1.8X10^{2}$	$4.7X10^{3}$
Ag-111		2.0	$5.4X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$5.8X10^{3}$	$1.6X10^{5}$
Al-26	Aluminum (13)	$1.0X10^{-1}$	2.7	$1.0X10^{-1}$	2.7	$7.0X10^{-4}$	$1.9X10^{-2}$
Am-241	Americium (95)	$1.0X10^{1}$	$2.7X10^{2}$	$1.0X10^{-3}$	$2.7X10^{-2}$	$1.3X10^{-1}$	3.4
Am-242m (a)		$1.0X10^{1}$	$2.7X10^{2}$	$1.0X10^{-3}$	$2.7X10^{-2}$	$3.6X10^{-1}$	$1.0X10^{1}$
Am-243 (a)		5.0	$1.4X10^{2}$	$1.0X10^{-3}$	$2.7X10^{-2}$	$7.4X10^{-3}$	$2.0X10^{-1}$
Ar-37	Argon (18)	$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{1}$	$1.1X10^{3}$	$3.7X10^{3}$	$9.9X10^{4}$
Ar-39		$2.0X10^{1}$	$5.4X10^{2}$	$4.0X10^{1}$	$1.1X10^{3}$	1.3	$3.4X10^{1}$
Ar-41		$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$1.5X10^{6}$	$4.2X10^{7}$
As-72	Arsenic (33)	$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$6.2X10^{4}$	$1.7X10^{6}$
As-73		$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{1}$	$1.1X10^{3}$	$8.2X10^{2}$	$2.2X10^{4}$
As-74		1.0	$2.7X10^{1}$	$9.0X10^{-1}$	$2.4X10^{1}$	$3.7X10^{3}$	$9.9X10^{4}$
As-76		$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$5.8X10^{4}$	$1.6X10^{6}$
As-77		$2.0X10^{1}$	$5.4X10^{2}$	$7.0X10^{-1}$	$1.9X10^{1}$	$3.9X10^{4}$	$1.0X10^{6}$
At-211 (a)	Astatine (85)	$2.0X10^{1}$	$5.4X10^{2}$	$5.0X10^{-1}$	$1.4X10^{1}$	$7.6X10^{4}$	$2.1X10^{6}$
Au-193	Gold (79)	7.0	$1.9X10^{2}$	2.0	$5.4X10^{1}$	$3.4X10^{4}$	$9.2X10^{5}$
Au-194		1.0	$2.7X10^{1}$	1.0	$2.7X10^{1}$	$1.5X10^{4}$	$4.1X10^{5}$
Au-195	Gold (79)	$1.0X10^{1}$	$2.7X10^{2}$	6.0	$1.6X10^{2}$	$1.4X10^{2}$	$3.7X10^{3}$
Au-198		1.0	$2.7X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$9.0X10^{3}$	$2.4X10^{5}$
Au-199		$1.0X10^{1}$	$2.7X10^{2}$	$6.0X10^{-1}$	$1.6X10^{1}$	$7.7X10^{3}$	$2.1X10^{5}$
Ba-131 (a)	Barium (56)	2.0	$5.4X10^{1}$	2.0	$5.4X10^{1}$	$3.1X10^{3}$	$8.4X10^{4}$
Ba-133		3.0	$8.1X10^{1}$	3.0	$8.1X10^{1}$	9.4	$2.6X10^{2}$
Ba-133m		$2.0X10^{1}$	$5.4X10^{2}$	$6.0X10^{-1}$	$1.6X10^{1}$	$2.2X10^{4}$	$6.1X10^{5}$
Ba-140 (a)		$5.0X10^{-1}$	$1.4X10^{1}$	$3.0X10^{-1}$	8.1	$2.7X10^{3}$	$7.3X10^{4}$
Be-7	Beryllium (4)	$2.0X10^{1}$	$5.4X10^{2}$	$2.0X10^{1}$	$5.4X10^{2}$	$1.3X10^{4}$	$3.5X10^{5}$
Be-10		$4.0X10^{1}$	$1.1X10^{3}$	$6.0X10^{-1}$	$1.6X10^{1}$	$8.3X10^{-4}$	$2.2X10^{-2}$
Bi-205	Bismuth (83)	$7.0X10^{-1}$	$1.9X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	$1.5X10^{-3}$	$4.2X10^{4}$
Bi-206		$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$3.8X10^{3}$	$1.0X10^{5}$
Bi-207		$7.0X10^{-1}$	$1.9X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	1.9	$5.2X10^{1}$
Bi-210		1.0	$2.7X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$4.6X10^{3}$	$1.2X10^{5}$
Bi-210m (a)		$6.0X10^{-1}$	$1.6X10^{1}$	$2.0X10^{-2}$	$5.4X10^{-1}$	$2.1X10^{-5}$	$5.7X10^{-4}$
Bi-212 (a)		$7.0X10^{-1}$	$1.9X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$5.4X10^{5}$	$1.5X10^{7}$

Table D-1. A_1 and A_2 Values for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific activity (TBq/g)	Specific activity (Ci/g)
Bk-247	Berkelium (97)	8.0	$2.2X10^{2}$	$8.0X10^{-4}$	$2.2X10^{-2}$	$3.8X10^{-2}$	1.0
Bk-249 (a)		$4.0X10^{1}$	$1.1X10^{3}$	$3.0X10^{-1}$	8.1	$6.1X10^{1}$	$1.6X10^{3}$
Br-76	Bromine (35)	$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$9.4X10^{4}$	$2.5X10^{6}$
Br-77		3.0	$8.1X10^{1}$	3.0	$8.1X10^{1}$	$2.6X10^{4}$	$7.1X10^{5}$
Br-82		$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{4}$	$1.1X10^{6}$
C-11	Carbon (6)	1.0	$2.7X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$3.1X10^{7}$	$8.4X10^{8}$
C-14		$4.0X10^{1}$	$1.1X10^{3}$	3.0	$8.1X10^{1}$	$1.6X10^{-1}$	4.5
Ca-41	Calcium (20)	Unlimited	Unlimited	Unlimited	Unlimited	$3.1X10^{-3}$	$8.5X10^{-2}$
Ca-45		$4.0X10^{1}$	$1.1X10^{3}$	1.0	$2.7X10^{1}$	$6.6X10^{2}$	$1.8X10^{4}$
Ca-47 (a)		3.0	$8.1X10^{1}$	$3.0X10^{-1}$	8.1	$2.3X10^{4}$	$6.1X10^{5}$
Cd-109	Cadmium (48)	$3.0X10^{1}$	$8.1X10^{2}$	2.0	$5.4X10^{1}$	$9.6X10^{1}$	$2.6X10^{3}$
Cd-113m		$4.0X10^{1}$	$1.1X10^{3}$	$5.0X10^{-1}$	$1.4X10^{1}$	8.3	$2.2X10^{2}$
Cd-115 (a)		3.0	$8.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$1.9X10^{4}$	$5.1X10^{5}$
Cd-115m		$5.0X10^{-1}$	$1.4X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$9.4X10^{2}$	$2.5X10^{4}$
Ce-139	Cerium (58)	7.0	$1.9X10^{2}$	2.0	$5.4X10^{1}$	$2.5X10^{2}$	$6.8X10^{3}$
Ce-141		$2.0X10^{1}$	$5.4X10^{2}$	$6.0X10^{-1}$	$1.6X10^{1}$	$1.1X10^{3}$	$2.8X10^{4}$
Ce-143		$9.0X10^{-1}$	$2.4X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$2.5X10^{4}$	$6.6X10^{5}$
Ce-144 (a)		$2.0X10^{-1}$	5.4	$2.0X10^{-1}$	5.4	$1.2X10^{2}$	$3.2X10^{3}$
Cf-248	Californium (98)	$4.0X10^{1}$	$1.1X10^{3}$	$6.0X10^{-3}$	$1.6X10^{-1}$	$5.8X10^{1}$	$1.6X10^{3}$
Cf-249		3.0	$8.1X10^{1}$	$8.0X10^{-4}$	$2.2X10^{-2}$	$1.5X10^{-1}$	4.1
Cf-250		$2.0X10^{1}$	$5.4X10^{2}$	$2.0X10^{-3}$	$5.4X10^{-2}$	4.0	$1.1X10^{2}$
Cf-251		7.0	$1.9X10^{2}$	$7.0X10^{-4}$	$1.9X10^{-2}$	$5.9X10^{-2}$	1.6
Cf-252		$5.0X10^{-2}$	1.4	$3.0X10^{-3}$	$8.1X10^{-2}$	$2.0X10^{1}$	$5.4X10^{2}$
Cf-253 (a)		$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{-2}$	1.1	$1.1X10^{3}$	$2.9X10^{4}$
Cf-254		$1.0X10^{-3}$	$2.7X10^{-2}$	$1.0X10^{-3}$	$2.7X10^{-2}$	$3.1X10^{2}$	$8.5X10^{3}$
Cl-36	Chlorine (17)	$1.0X10^{1}$	$2.7X10^{2}$	$6.0X10^{-1}$	$1.6X10^{1}$	$1.2X10^{-3}$	$3.3X10^{-2}$
Cl-38		$2.0X10^{-1}$	5.4	$2.0X10^{-1}$	5.4	$4.9X10^{6}$	$1.3X10^{8}$
Cm-240	Curium (96)	$4.0X10^{1}$	$1.1X10^{3}$	$2.0X10^{-2}$	$5.4X10^{-1}$	$7.5X10^{2}$	$2.0X10^{4}$
Cm-241		2.0	$5.4X10^{1}$	1.0	$2.7X10^{1}$	$6.1X10^{2}$	$1.7X10^{4}$
Cm-242	Curium (96)	$4.0X10^{1}$	$1.1X10^{3}$	$1.0X10^{-2}$	$2.7X10^{-1}$	$1.2X10^{2}$	$3.3X10^{3}$
Cm-243		9.0	$2.4X10^{2}$	$1.0X10^{-3}$	$2.7X10^{-2}$	$1.9X10^{-3}$	$5.2X10^{1}$
Cm-244		$2.0X10^{1}$	$5.4X10^{2}$	$2.0X10^{-3}$	$5.4X10^{-2}$	3.0	$8.1X10^{1}$
Cm-245		9.0	$2.4X10^{2}$	$9.0X10^{-4}$	$2.4X10^{-2}$	$6.4X10^{-3}$	$1.7X10^{-1}$
Cm-246		9.0	$2.4X10^{2}$	$9.0X10^{-4}$	$2.4X10^{-2}$	$1.1X10^{-2}$	$3.1X10^{-1}$
Cm-247 (a)		3.0	$8.1X10^{1}$	$1.0X10^{-3}$	$2.7X10^{-2}$	$3.4X10^{-6}$	$9.3X10^{-5}$
Cm-248		$2.0X10^{-2}$	$5.4X10^{-1}$	$3.0X10^{-4}$	$8.1X10^{-3}$	$1.6X10^{-5}$	$4.2X10^{-3}$

Table D-1. A_1 and A_2 Values for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific activity (TBq/g)	Specific activity (Ci/g)
Co-55	Cobalt (27)	$5.0X10^{-1}$	$1.4X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$1.1X10^{5}$	$3.1X10^{6}$
Co-56		$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$1.1X10^{3}$	$3.0X10^{4}$
Co-57		$1.0X10^{1}$	$2.7X10^{2}$	$1.0X10^{1}$	$2.7X10^{2}$	$3.1X10^{2}$	$8.4X10^{3}$
Co-58		1.0	$2.7X10^{1}$	1.0	$2.7X10^{1}$	$1.2X10^{3}$	$3.2X10^{4}$
Co-58m		$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{1}$	$1.1X10^{3}$	$2.2X10^{5}$	$5.9X10^{6}$
Co-60		$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$4.2X10^{1}$	$1.1X10^{3}$
Cr-51	Chromium (24)	$3.0X10^{1}$	$8.1X10^{2}$	$3.0X10^{1}$	$8.1X10^{2}$	$3.4X10^{3}$	$9.2X10^{4}$
Cs-129	Cesium (55)	4.0	$1.1X10^{2}$	4.0	$1.1X10^{2}$	$2.8X10^{4}$	$7.6X10^{5}$
Cs-131		$3.0X10^{1}$	$8.1X10^{2}$	$3.0X10^{1}$	$8.1X10^{2}$	$3.8X10^{3}$	$1.0X10^{5}$
Cs-132		1.0	$2.7X10^{1}$	1.0	$2.7X10^{1}$	$5.7X10^{3}$	$1.5X10^{5}$
Cs-134		$7.0X10^{-1}$	$1.9X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	$4.8X10^{1}$	$1.3X10^{3}$
Cs-134m		$4.0X10^{1}$	$1.1X10^{3}$	$6.0X10^{-1}$	$1.6X10^{1}$	$3.0X10^{5}$	$8.0X10^{6}$
Cs-135		$4.0X10^{1}$	$1.1X10^{3}$	1.0	$2.7X10^{1}$	$4.3X10^{-5}$	$1.2X10^{-3}$
Cs-136		$5.0X10^{-1}$	$1.4X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$2.7X10^{3}$	$7.3X10^{4}$
Cs-137 (a)		2.0	$5.4X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	3.2	$8.7X10^{1}$
Cu-64	Copper (29)	6.0	$1.6X10^{2}$	1.0	$2.7X10^{1}$	$1.4X10^{5}$	$3.9X10^{6}$
Cu-67		$1.0X10^{1}$	$2.7X10^{2}$	$7.0X10^{-1}$	$1.9X10^{1}$	$2.8X10^{4}$	$7.6X10^{5}$
Dy-159	Dysprosium (66)	$2.0X10^{1}$	$5.4X10^{2}$	$2.0X10^{1}$	$5.4X10^{2}$	$2.1X10^{2}$	$5.7X10^{3}$
Dy-165		$9.0X10^{-1}$	$2.4X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$3.0X10^{5}$	$8.2X10^{6}$
Dy-166 (a)		$9.0X10^{-1}$	$2.4X10^{1}$	$3.0X10^{-1}$	8.1	$8.6X10^{3}$	$2.3X10^{5}$
Er-169	Erbium (68)	$4.0X10^{1}$	$1.1X10^{3}$	1.0	$2.7X10^{1}$	$3.1X10^{3}$	$8.3X10^{4}$
Er-171		$8.0X10^{-1}$	$2.2X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$9.0X10^{4}$	$2.4X10^{6}$
Eu-147	Europium (63)	2.0	$5.4X10^{1}$	2.0	$5.4X10^{1}$	$1.4X10^{3}$	$3.7X10^{4}$
Eu-148		$5.0X10^{-1}$	$1.4X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$6.0X10^{2}$	$1.6X10^{4}$
Eu-149		$2.0X10^{1}$	$5.4X10^{2}$	$2.0X10^{1}$	$5.4X10^{2}$	$3.5X10^{2}$	$9.4X10^{3}$
Eu-150 (short lived)		2.0	$5.4X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	$6.1X10^{4}$	$1.6X10^{6}$
Eu-150 (long lived)		2.0	$5.4X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	$6.1X10^{4}$	$1.6X10^{6}$
Eu-152		1.0	$2.7X10^{1}$	1.0	$2.7X10^{1}$	6.5	$1.8X10^{2}$
Eu-152m		$8.0X10^{-1}$	$2.2X10^{1}$	$8.0X10^{-1}$	$2.2X10^{1}$	$8.2X10^{4}$	$2.2X10^{6}$
Eu-154		$9.0X10^{-1}$	$2.4X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	9.8	$2.6X10^{2}$
Eu-155		$2.0X10^{1}$	$5.4X10^{2}$	3.0	$8.1X10^{1}$	$1.8X10^{1}$	$4.9X10^{2}$
Eu-156		$7.0X10^{-1}$	$1.9X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	$2.0X10^{3}$	$5.5X10^{4}$
F-18	Fluorine (9)	1.0	$2.7X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$3.5X10^{6}$	$9.5X10^{7}$

Table D-1. A_1 and A_2 Values for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific activity (TBq/g)	Specific activity (Ci/g)
Fe-52 (a)	Iron (26)	$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$2.7X10^{5}$	$7.3X10^{6}$
Fe-55		$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{1}$	$1.1X10^{3}$	$8.8X10^{1}$	$2.4X10^{3}$
Fe-59		$9.0X10^{-1}$	$2.4X10^{1}$	$9.0X10^{-1}$	$2.4X10^{1}$	$1.8X10^{3}$	$5.0X10^{4}$
Fe-60 (a)		$4.0X10^{1}$	$1.1X10^{3}$	$2.0X10^{-1}$	5.4	$7.4X10^{-4}$	$2.0X10^{-2}$
Ga-67	Gallium (31)	7.0	$1.9X10^{2}$	3.0	$8.1X10^{1}$	$2.2X10^{4}$	$6.0X10^{5}$
Ga-68		$5.0X10^{-1}$	$1.4X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$1.5X10^{6}$	$4.1X10^{7}$
Ga-72		$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$1.1X10^{5}$	$3.1X10^{6}$
Gd-146 (a)	Gadolinium (64)	$5.0X10^{-1}$	$1.4X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$6.9X10^{2}$	$1.9X10^{4}$
Gd-148		$2.0X10^{1}$	$5.4X10^{2}$	$2.0X10^{-3}$	$5.4X10^{-2}$	1.2	$3.2X10^{1}$
Gd-153		$1.0X10^{1}$	$2.7X10^{2}$	9.0	$2.4X10^{2}$	$1.3X10^{2}$	$3.5X10^{3}$
Gd-159		3.0	$8.1X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$3.9X10^{4}$	$1.1X10^{6}$
Ge-68 (a)	Germanium (32)	$5.0X10^{-1}$	$1.4X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$2.6X10^{2}$	$7.1X10^{3}$
Ge-71		$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{1}$	$1.1X10^{3}$	$5.8X10^{3}$	$1.6X10^{5}$
Ge-77		$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$1.3X10^{5}$	$3.6X10^{6}$
Hf-172 (a)	Hafnium (72)	$6.0X10^{-1}$	$1.6X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$4.1X10^{1}$	$1.1X10^{3}$
Hf-175		3.0	$8.1X10^{1}$	3.0	$8.1X10^{1}$	$3.9X10^{2}$	$1.1X10^{4}$
Hf-181		2.0	$5.4X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$6.3X10^{2}$	$1.7X10^{4}$
Hf-182		Unlimited	Unlimited	Unlimited	Unlimited	$8.1X10^{-6}$	$2.2X10^{-4}$
Hg-194 (a)	Mercury (80)	1.0	$2.7X10^{1}$	1.0	$2.7X10^{1}$	$1.3X10^{-1}$	3.5
Hg-195m (a)		3.0	$8.1X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	$1.5X10^{4}$	$4.0X10^{5}$
Hg-197		$2.0X10^{1}$	$5.4X10^{2}$	$1.0X10^{1}$	$2.7X10^{2}$	$9.2X10^{3}$	$2.5X10^{5}$
Hg-197m		$1.0X10^{1}$	$2.7X10^{2}$	$4.0X10^{-1}$	$1.1X10^{1}$	$2.5X10^{4}$	$6.7X10^{5}$
Hg-203		5.0	$1.4X10^{2}$	1.0	$2.7X10^{1}$	$5.1X10^{2}$	$1.4X10^{4}$
Ho-166	Holmium (67)	$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$2.6X10^{4}$	$7.0X10^{5}$
Ho-166m		$6.0X10^{-1}$	$1.6X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$6.6X10^{-2}$	1.8
I-123	Iodine (53)	6.0	$1.6X10^{2}$	3.0	$8.1X10^{1}$	$7.1X10^{4}$	$1.9X10^{6}$
I-124		1.0	$2.7X10^{1}$	1.0	$2.7X10^{1}$	$9.3X10^{3}$	$2.5X10^{5}$
I-125		$2.0X10^{1}$	$5.4X10^{2}$	3.0	$8.1X10^{1}$	$6.4X10^{2}$	$1.7X10^{4}$
I-126		2.0	$5.4X10^{1}$	1.0	$2.7X10^{1}$	$2.9X10^{3}$	$8.0X10^{4}$
I-129		Unlimited	Unlimited	Unlimited	Unlimited	$6.5X10^{-6}$	$1.8X10^{-4}$
I-131		3.0	$8.1X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	$4.6X10^{3}$	$1.2X10^{5}$
I-132		$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$3.8X10^{5}$	$1.0X10^{7}$
I-133		$7.0X10^{-1}$	$1.9X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$4.2X10^{4}$	$1.1X10^{6}$
I-134		$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$9.9X10^{5}$	$2.7X10^{7}$
I-135 (a)		$6.0X10^{-1}$	$1.6X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$1.3X10^{5}$	$3.5X10^{6}$

Table D-1. A_1 and A_2 Values for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific activity (TBq/g)	Specific activity (Ci/g)
In-111	Indium (49)	3.0	$8.1X10^{1}$	3.0	$8.1X10^{1}$	$1.5X10^{4}$	$4.2X10^{5}$
In-113m		4.0	$1.1X10^{2}$	2.0	$5.4X10^{1}$	$6.2X10^{5}$	$1.7X10^{7}$
In-114m (a)		$1.0X10^{1}$	$2.7X10^{2}$	$5.0X10^{-1}$	$1.4X10^{1}$	$8.6X10^{2}$	$2.3X10^{4}$
In-115m		7.0	$1.9X10^{2}$	1.0	$2.7X10^{1}$	$2.2X10^{5}$	$6.1X10^{6}$
Ir-189 (a)	Iridium (77)	$1.0X10^{1}$	$2.7X10^{2}$	$1.0X10^{1}$	$2.7X10^{2}$	$1.9X10^{3}$	$5.2X10^{4}$
Ir-190		$7.0X10^{-1}$	$1.9X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	$2.3X10^{3}$	$6.2X10^{4}$
Ir-192		1.0	$2.7X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$3.4X10^{2}$	$9.2X10^{3}$
Ir-194		$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$3.1X10^{4}$	$8.4X10^{5}$
K-40	Potassium (19)	$9.0X10^{-1}$	$2.4X10^{1}$	$9.0X10^{-1}$	$2.4X10^{1}$	$2.4X10^{-7}$	$6.4X10^{-6}$
K-42		$2.0X10^{-1}$	5.4	$2.0X10^{-1}$	5.4	$2.2X10^{5}$	$6.0X10^{6}$
K-43		$7.0X10^{-1}$	$1.9X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$1.2X10^{5}$	$3.3X10^{6}$
Kr-81	Krypton (36)	$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{1}$	$1.1X10^{3}$	$7.8X10^{-4}$	$2.1X10^{-2}$
Kr-85		$1.0X10^{1}$	$2.7X10^{2}$	$1.0X10^{1}$	$2.7X10^{2}$	$1.5X10^{1}$	$3.9X10^{2}$
Kr-85m		8.0	$2.2X10^{2}$	3.0	$8.1X10^{1}$	$3.0X10^{5}$	$8.2X10^{6}$
Kr-87		$2.0X10^{-1}$	5.4	$2.0X10^{-1}$	5.4	$1.0X10^{6}$	$2.8X10^{7}$
La-137	Lanthanum (57)	$3.0X10^{1}$	$8.1X10^{2}$	6.0	$1.6X10^{2}$	$1.6X10^{-3}$	$4.4X10^{-2}$
La-140		$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$2.1X10^{4}$	$5.6X10^{5}$
Lu-172	Lutetium (71)	$6.0X10^{-1}$	$1.6X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$4.2X10^{3}$	$1.1X10^{5}$
Lu-173		8.0	$2.2X10^{2}$	8.0	$2.2X10^{2}$	$5.6X10^{1}$	$1.5X10^{3}$
Lu-174		9.0	$2.4X10^{2}$	9.0	$2.4X10^{2}$	$2.3X10^{1}$	$6.2X10^{2}$
Lu-174m		$2.0X10^{1}$	$5.4X10^{2}$	$1.0X10^{1}$	$2.7X10^{2}$	$2.0X10^{2}$	$5.3X10^{3}$
Lu-177		$3.0X10^{1}$	$8.1X10^{2}$	$7.0X10^{-1}$	$1.9X10^{1}$	$4.1X10^{3}$	$1.1X10^{5}$
Mg-28 (a)	Magnesium (12)	$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$2.0X10^{5}$	$5.4X10^{6}$
Mn-52	Manganese (25)	$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$1.6X10^{4}$	$4.4X10^{5}$
Mn-53		Unlimited	Unlimited	Unlimited	Unlimited	$6.8X10^{-5}$	$1.8X10^{-3}$
Mn-54		1.0	$2.7X10^{1}$	1.0	$2.7X10^{1}$	$2.9X10^{2}$	$7.7X10^{3}$
Mn-56		$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$8.0X10^{5}$	$2.2X10^{7}$
Mo-93	Molybdenum (42)	$4.0X10^{1}$	$1.1X10^{3}$	$2.0X10^{1}$	$5.4X10^{2}$	$4.1X10^{-2}$	1.1
Mo-99 (a)		1.0	$2.7X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$1.8X10^{4}$	$4.8X10^{5}$
N-13	Nitrogen (7)	$9.0X10^{-1}$	$2.4X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$5.4X10^{7}$	$1.5X10^{9}$
Na-22	Sodium (11)	$5.0X10^{-1}$	$1.4X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$2.3X10^{2}$	$6.3X10^{3}$
Na-24		$2.0X10^{-1}$	5.4	$2.0X10^{-1}$	5.4	$3.2X10^{5}$	$8.7X10^{6}$
Nb-93m	Niobium (41)	$4.0X10^{1}$	$1.1X10^{3}$	$3.0X10^{1}$	$8.1X10^{2}$	8.8	$2.4X10^{2}$
Nb-94		$7.0X10^{-1}$	$1.9X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	$6.9X10^{-3}$	$1.9X10^{-1}$
Nb-95		1.0	$2.7X10^{1}$	1.0	$2.7X10^{1}$	$1.5X10^{3}$	$3.9X10^{4}$
Nb-97		$9.0X10^{-1}$	$2.4X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$9.9X10^{5}$	$2.7X10^{7}$
Nd-147	Neodymium (60)	6.0	$1.6X10^{2}$	$6.0X10^{-1}$	$1.6X10^{1}$	$3.0X10^{3}$	$8.1X10^{4}$

Table D-1. A_1 and A_2 Values for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific activity (TBq/g)	Specific activity (Ci/g)
Nd-149		6.0×10^{-1}	1.6×10^{1}	5.0×10^{-1}	1.4×10^{1}	4.5×10^{5}	1.2×10^{7}
Ni-59	Nickel (28)	Unlimited	Unlimited	Unlimited	Unlimited	3.0×10^{-3}	8.0×10^{-2}
Ni-63		4.0×10^{1}	1.1×10^{3}	3.0×10^{1}	8.1×10^{2}	2.1	5.7×10^{1}
Ni-65		4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}	7.1×10^{5}	1.9×10^{7}
Np-235	Neptunium (93)	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{3}	5.2×10^{1}	1.4×10^{3}
Np-236 (short-lived)		2.0×10^{1}	5.4×10^{2}	2.0	5.4×10^{1}	4.7×10^{-4}	1.3×10^{-2}
Np-236 (long-lived)		2.0×10^{1}	5.4×10^{2}	2.0	5.4×10^{1}	4.7×10^{-4}	1.3×10^{-2}
Np-237		2.0×10^{1}	5.4×10^{2}	2.0×10^{-3}	5.4×10^{-2}	2.6×10^{-5}	7.1×10^{-4}
Np-239		7.0	1.9×10^{2}	4.0×10^{-1}	1.1×10^{1}	8.6×10^{3}	2.3×10^{5}
Os-185	Osmium (76)	1.0	2.7×10^{1}	1.0	2.7×10^{1}	2.8×10^{2}	7.5×10^{3}
Os-191		1.0×10^{1}	2.7×10^{2}	2.0	5.4×10^{1}	1.6×10^{3}	4.4×10^{4}
Os-191m		4.0×10^{1}	1.1×10^{3}	3.0×10^{1}	8.1×10^{2}	4.6×10^{4}	1.3×10^{6}
Os-193		2.0	5.4×10^{1}	6.0×10^{-1}	1.6×10^{1}	2.0×10^{4}	5.3×10^{5}
Os-194 (a)		3.0×10^{-1}	8.1	3.0×10^{-1}	8.1	1.1×10^{1}	3.1×10^{2}
P-32	Phosphorus (15)	5.0×10^{-1}	1.4×10^{1}	5.0×10^{-1}	1.4×10^{1}	1.1×10^{4}	2.9×10^{5}
P-33		4.0×10^{1}	1.1×10^{3}	1.0	2.7×10^{1}	5.8×10^{3}	1.6×10^{5}
Pa-230 (a)	Protactinium (91)	2.0	5.4×10^{1}	7.0×10^{-2}	1.9	1.2×10^{3}	3.3×10^{4}
Pa-231		4.0	1.1×10^{2}	4.0×10^{-4}	1.1×10^{-2}	1.7×10^{-3}	4.7×10^{-2}
Pa-233		5.0	1.4×10^{2}	7.0×10^{-1}	1.9×10^{1}	7.7×10^{2}	2.1×10^{4}
Pb-201	Lead (82)	1.0	2.7×10^{1}	1.0	2.7×10^{1}	6.2×10^{4}	1.7×10^{6}
Pb-202		4.0×10^{1}	1.1×10^{3}	2.0×10^{1}	5.4×10^{2}	1.2×10^{-4}	3.4×10^{-3}
Pb-203		4.0	1.1×10^{2}	3.0	8.1×10^{1}	1.1×10^{4}	3.0×10^{5}
Pb-205		Unlimited	Unlimited	Unlimited	Unlimited	4.5×10^{-6}	1.2×10^{-4}
Pb-210 (a)		1.0	2.7×10^{1}	5.0×10^{-2}	1.4	2.8	7.6×10^{1}
Pb-212 (a)		7.0×10^{-1}	1.9×10^{1}	2.0×10^{-1}	5.4	5.1×10^{4}	1.4×10^{6}
Pd-103 (a)	Palladium (46)	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{3}	2.8×10^{3}	7.5×10^{4}
Pd-107		Unlimited	Unlimited	Unlimited	Unlimited	1.9×10^{-5}	5.1×10^{-4}
Pd-109		2.0	5.4×10^{1}	5.0×10^{-1}	1.4×10^{1}	7.9×10^{4}	2.1×10^{6}

Table D-1. A_1 and A_2 Values for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific activity (TBq/g)	Specific activity (Ci/g)
Pm-143	Promethium (61)	3.0	$8.1X10^{1}$	3.0	$8.1X10^{1}$	$1.3X10^{2}$	$3.4X10^{3}$
Pm-144		$7.0X10^{-1}$	$1.9X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	$9.2X10^{1}$	$2.5X10^{3}$
Pm-145		$3.0X10^{1}$	$8.1X10^{2}$	$1.0X10^{1}$	$2.7X10^{2}$	5.2	$1.4X10^{2}$
Pm-147		$4.0X10^{1}$	$1.1X10^{3}$	2.0	$5.4X10^{1}$	$3.4X10^{1}$	$9.3X10^{2}$
Pm-148m (a)		$8.0X10^{-1}$	$2.2X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	$7.9X10^{2}$	$2.1X10^{4}$
Pm-149		2.0	$5.4X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$1.5X10^{4}$	$4.0X10^{5}$
Pm-151		2.0	$5.4X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$2.7X10^{4}$	$7.3X10^{5}$
Po-210	Polonium (84)	$4.0X10^{1}$	$1.1X10^{3}$	$2.0X10^{-2}$	$5.4X10^{-1}$	$1.7X10^{2}$	$4.5X10^{3}$
Pr-142	Praseodymium (59)	$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$4.3X10^{4}$	$1.2X10^{6}$
Pr-143		3.0	$8.1X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$2.5X10^{3}$	$6.7X10^{4}$
Pt-188 (a)	Platinum (78)	1.0	$2.7X10^{1}$	$8.0X10^{-1}$	$2.2X10^{1}$	$2.5X10^{3}$	$6.8X10^{4}$
Pt-191		4.0	$1.1X10^{2}$	3.0	$8.1X10^{1}$	$8.7X10^{3}$	$2.4X10^{5}$
Pt-193		$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{1}$	$1.1X10^{3}$	1.4	$3.7X10^{1}$
Pt-193m		$4.0X10^{1}$	$1.1X10^{3}$	$5.0X10^{-1}$	$1.4X10^{1}$	$5.8X10^{3}$	$1.6X10^{5}$
Pt-195m		$1.0X10^{1}$	$2.7X10^{2}$	$5.0X10^{-1}$	$1.4X10^{1}$	$6.2X10^{3}$	$1.7X10^{5}$
Pt-197		$2.0X10^{1}$	$5.4X10^{2}$	$6.0X10^{-1}$	$1.6X10^{1}$	$3.2X10^{4}$	$8.7X10^{5}$
Pt-197m		$1.0X10^{1}$	$2.7X10^{2}$	$6.0X10^{-1}$	$1.6X10^{1}$	$3.7X10^{5}$	$1.0X10^{7}$
Pu-236	Plutonium (94)	$3.0X10^{1}$	$8.1X10^{2}$	$3.0X10^{-3}$	$8.1X10^{-2}$	$2.0X10^{1}$	$5.3X10^{2}$
Pu-237		$2.0X10^{1}$	$5.4X10^{2}$	$2.0X10^{1}$	$5.4X10^{2}$	$4.5X10^{2}$	$1.2X10^{4}$
Pu-238		$1.0X10^{1}$	$2.7X10^{2}$	$1.0X10^{-3}$	$2.7X10^{-2}$	$6.3X10^{-1}$	$1.7X10^{1}$
Pu-239		$1.0X10^{1}$	$2.7X10^{2}$	$1.0X10^{-3}$	$2.7X10^{-2}$	$2.3X10^{-3}$	$6.2X10^{-2}$
Pu-240		$1.0X10^{1}$	$2.7X10^{2}$	$1.0X10^{-3}$	$2.7X10^{-2}$	$8.4X10^{-3}$	$2.3X10^{-1}$
Pu-241 (a)		$4.0X10^{1}$	$1.1X10^{3}$	$6.0X10^{-2}$	1.6	3.8	$1.0X10^{2}$
Pu-242		$1.0X10^{1}$	$2.7X10^{2}$	$1.0X10^{-3}$	$2.7X10^{-2}$	$1.5X10^{-4}$	$3.9X10^{-3}$
Pu-244 (a)		$4.0X10^{-1}$	$1.1X10^{1}$	$1.0X10^{-3}$	$2.7X10^{-2}$	$6.7X10^{-7}$	$1.8X10^{-5}$
Ra-223 (a)	Radium (88)	$4.0X10^{-1}$	$1.1X10^{1}$	$7.0X10^{-3}$	$1.9X10^{-1}$	$1.9X10^{3}$	$5.1X10^{4}$
Ra-224 (a)		$4.0X10^{-1}$	$1.1X10^{1}$	$2.0X10^{-2}$	$5.4X10^{-1}$	$5.9X10^{3}$	$1.6X10^{5}$
Ra-225 (a)		$2.0X10^{-1}$	5.4	$4.0X10^{-3}$	$1.1X10^{-1}$	$1.5X10^{3}$	$3.9X10^{4}$
Ra-226 (a)		$2.0X10^{-1}$	5.4	$3.0X10^{-3}$	$8.1X10^{-2}$	$3.7X10^{-2}$	1.0
Ra-228 (a)		$6.0X10^{-1}$	$1.6X10^{1}$	$2.0X10^{-2}$	$5.4X10^{-1}$	$1.0X10^{1}$	$2.7X10^{2}$
Rb-81	Rubidium (37)	2.0	$5.4X10^{1}$	$8.0X10^{-1}$	$2.2X10^{1}$	$3.1X10^{5}$	$8.4X10^{6}$
Rb-83 (a)		2.0	$5.4X10^{1}$	2.0	$5.4X10^{1}$	$6.8X10^{2}$	$1.8X10^{4}$
Rb-84		1.0	$2.7X10^{1}$	1.0	$2.7X10^{1}$	$1.8X10^{3}$	$4.7X10^{4}$
Rb-86		$5.0X10^{-1}$	$1.4X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$3.0X10^{3}$	$8.1X10^{4}$
Rb-87		Unlimited	Unlimited	Unlimited	Unlimited	$3.2X10^{-9}$	$8.6X10^{-8}$
Rb(nat)		Unlimited	Unlimited	Unlimited	Unlimited	$6.7X10^{6}$	$1.8X10^{8}$
Re-184	Rhenium (75)	1.0	$2.7X10^{1}$	1.0	$2.7X10^{1}$	$6.9X10^{2}$	$1.9X10^{4}$

Table D-1. A_1 and A_2 Values for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific activity (TBq/g)	Specific activity (Ci/g)
Re-184m		3.0	$8.1X10^{1}$	1.0	$2.7X10^{1}$	$1.6X10^{2}$	$4.3X10^{3}$
Re-186		2.0	$5.4X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$6.9X10^{3}$	$1.9X10^{5}$
Re-187		Unlimited	Unlimited	Unlimited	Unlimited	$1.4X10^{-9}$	$3.8X10^{-8}$
Re-188		$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$3.6X10^{4}$	$9.8X10^{5}$
Re-189 (a)		3.0	$8.1X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$2.5X10^{4}$	$6.8X10^{5}$
Re(nat)		Unlimited	Unlimited	Unlimited	Unlimited	0.0	$2.4X10^{-8}$
Rh-99	Rhodium (45)	2.0	$5.4X10^{1}$	2.0	$5.4X10^{1}$	$3.0X10^{3}$	$8.2X10^{4}$
Rh-101		4.0	$1.1X10^{2}$	3.0	$8.1X10^{1}$	$4.1X10^{1}$	$1.1X10^{3}$
Rh-102		$5.0X10^{-1}$	$1.4X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$4.5X10^{1}$	$1.2X10^{3}$
Rh-102m		2.0	$5.4X10^{1}$	2.0	$5.4X10^{1}$	$2.3X10^{2}$	$6.2X10^{3}$
Rh-103m		$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{1}$	$1.1X10^{3}$	$1.2X10^{6}$	$3.3X10^{7}$
Rh-105		$1.0X10^{1}$	$2.7X10^{2}$	$8.0X10^{-1}$	$2.2X10^{1}$	$3.1X10^{4}$	$8.4X10^{5}$
Rn-222 (a)	Radon (86)	$3.0X10^{-1}$	8.1	$4.0X10^{-3}$	$1.1X10^{-1}$	$5.7X10^{3}$	$1.5X10^{5}$
Ru-97	Ruthenium (44)	5.0	$1.4X10^{2}$	5.0	$1.4X10^{2}$	$1.7X10^{4}$	$4.6X10^{5}$
Ru-103 (a)		2.0	$5.4X10^{1}$	2.0	$5.4X10^{1}$	$1.2X10^{3}$	$3.2X10^{4}$
Ru-105		1.0	$2.7X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$2.5X10^{5}$	$6.7X10^{6}$
Ru-106 (a)		$2.0X10^{-1}$	5.4	$2.0X10^{-1}$	5.4	$1.2X10^{2}$	$3.3X10^{3}$
S-35	Sulphur (16)	$4.0X10^{1}$	$1.1X10^{3}$	3.0	$8.1X10^{1}$	$1.6X10^{3}$	$4.3X10^{4}$
Sb-122	Antimony (51)	$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$1.5X10^{4}$	$4.0X10^{5}$
Sb-124		$6.0X10^{-1}$	$1.6X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$6.5X10^{2}$	$1.7X10^{4}$
Sb-125		2.0	$5.4X10^{1}$	1.0	$2.7X10^{1}$	$3.9X10^{1}$	$1.0X10^{3}$
Sb-126		$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$3.1X10^{3}$	$8.4X10^{4}$
Sc-44	Scandium (21)	$5.0X10^{-1}$	$1.4X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$6.7X10^{5}$	$1.8X10^{7}$
Sc-46		$5.0X10^{-1}$	$1.4X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$1.3X10^{3}$	$3.4X10^{4}$
Sc-47		$1.0X10^{1}$	$2.7X10^{2}$	$7.0X10^{-1}$	$1.9X10^{1}$	$3.1X10^{4}$	$8.3X10^{5}$
Sc-48		$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$5.5X10^{4}$	$1.5X10^{6}$
Se-75	Selenium (34)	3.0	$8.1X10^{1}$	3.0	$8.1X10^{1}$	$5.4X10^{2}$	$1.5X10^{4}$
Se-79		$4.0X10^{1}$	$1.1X10^{3}$	2.0	$5.4X10^{1}$	$2.6X10^{-3}$	$7.0X10^{-2}$
Si-31	Silicon (14)	$6.0X10^{-1}$	$1.6X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$1.4X10^{6}$	$3.9X10^{7}$
Si-32		$4.0X10^{1}$	$1.1X10^{3}$	$5.0X10^{-1}$	$1.4X10^{1}$	3.9	$1.1X10^{2}$
Sm-145	Samarium (62)	$1.0X10^{1}$	$2.7X10^{2}$	$1.0X10^{1}$	$2.7X10^{2}$	$9.8X10^{1}$	$2.6X10^{3}$
Sm-147		Unlimited	Unlimited	Unlimited	Unlimited	$8.5X10^{-1}$	$2.3X10^{-8}$
Sm-151		$4.0X10^{1}$	$1.1X10^{3}$	$1.0X10^{1}$	$2.7X10^{2}$	$9.7X10^{-1}$	$2.6X10^{1}$
Sm-153		9.0	$2.4X10^{2}$	$6.0X10^{-1}$	$1.6X10^{1}$	$1.6X10^{4}$	$4.4X10^{5}$

Table D-1. A_1 and A_2 Values for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific activity (TBq/g)	Specific activity (Ci/g)
Sn-113 (a)	Tin (50)	4.0	$1.1X10^{2}$	2.0	$5.4X10^{1}$	$3.7X10^{2}$	$1.0X10^{4}$
Sn-117m		7.0	$1.9X10^{2}$	$4.0X10^{-1}$	$1.1X10^{1}$	$3.0X10^{3}$	$8.2X10^{4}$
Sn-119m		$4.0X10^{1}$	$1.1X10^{3}$	$3.0X10^{1}$	$8.1X10^{2}$	$1.4X10^{2}$	$3.7X10^{3}$
Sn-121m (a)		$4.0X10^{1}$	$1.1X10^{3}$	$9.0X10^{-1}$	$2.4X10^{1}$	2.0	$5.4X10^{1}$
Sn-123		$8.0X10^{-1}$	$2.2X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$3.0X10^{2}$	$8.2X10^{3}$
Sn-125		$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{3}$	$1.1X10^{5}$
Sn-126 (a)		$6.0X10^{-1}$	$1.6X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$1.0X10^{-3}$	$2.8X10^{-2}$
Sr-82 (a)	Strontium (38)	$2.0X10^{-1}$	5.4	$2.0X10^{-1}$	5.4	$2.3X10^{3}$	$6.2X10^{4}$
Sr-85		2.0	$5.4X10^{1}$	2.0	$5.4X10^{1}$	$8.8X10^{2}$	$2.4X10^{4}$
Sr-85m		5.0	$1.4X10^{2}$	5.0	$1.4X10^{2}$	$1.2X10^{6}$	$3.3X10^{7}$
Sr-87m		3.0	$8.1X10^{1}$	3.0	$8.1X10^{1}$	$4.8X10^{5}$	$1.3X10^{7}$
Sr-89		$6.0X10^{-1}$	$1.6X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$1.1X10^{3}$	$2.9X10^{4}$
Sr-90 (a)		$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	5.1	$1.4X10^{2}$
Sr-91 (a)		$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$1.3X10^{5}$	$3.6X10^{6}$
Sr-92 (a)		1.0	$2.7X10^{1}$	$3.0X10^{-1}$	8.1	$4.7X10^{5}$	$1.3X10^{7}$
T(H-3)	Tritium (1)	$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{1}$	$1.1X10^{3}$	$3.6X10^{2}$	$9.7X10^{3}$
Ta-178 (long-lived)	Tantalum (73)	1.0	$2.7X10^{1}$	$8.0X10^{-1}$	$2.2X10^{1}$	$4.2X10^{6}$	$1.1X10^{8}$
Ta-179		$3.0X10^{1}$	$8.1X10^{2}$	$3.0X10^{1}$	$8.1X10^{2}$	$4.1X10^{1}$	$1.1X10^{3}$
Ta-182		$9.0X10^{-1}$	$2.4X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$2.3X10^{2}$	$6.2X10^{3}$
Tb-157	Terbium (65)	$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{1}$	$1.1X10^{3}$	$5.6X10^{-1}$	$1.5X10^{1}$
Tb-158		1.0	$2.7X10^{1}$	1.0	$2.7X10^{1}$	$5.6X10^{-1}$	$1.5X10^{1}$
Tb-160		1.0	$2.7X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$4.2X10^{2}$	$1.1X10^{4}$
Tc-95m (a)	Technetium (43)	2.0	$5.4X10^{1}$	2.0	$5.4X10^{1}$	$8.3X10^{2}$	$2.2X10^{4}$
Tc-96		$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$1.2X10^{4}$	$3.2X10^{5}$
Tc-96m (a)		$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$1.4X10^{6}$	$3.8X10^{7}$
Tc-97		Unlimited	Unlimited	Unlimited	Unlimited	$5.2X10^{-5}$	$1.4X10^{-3}$
Tc-97m		$4.0X10^{1}$	$1.1X10^{3}$	1.0	$2.7X10^{1}$	$5.6X10^{2}$	$1.5X10^{4}$
Tc-98		$8.0X10^{-1}$	$2.2X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	$3.2X10^{-5}$	$8.7X10^{-4}$
Tc-99		$4.0X10^{1}$	$1.1X10^{3}$	$9.0X10^{-1}$	$2.4X10^{1}$	$6.3X10^{-4}$	$1.7X10^{-2}$
Tc-99m		$1.0X10^{1}$	$2.7X10^{2}$	4.0	$1.1X10^{2}$	$1.9X10^{5}$	$5.3X10^{6}$

Table D-1. A_1 and A_2 Values for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific activity (TBq/g)	Specific activity (Ci/g)
Te-121	Tellurium (52)	2.0	$5.4X10^{1}$	2.0	$5.4X10^{1}$	$2.4X10^{3}$	$6.4X10^{4}$
Te-121m		5.0	$1.4X10^{2}$	3.0	$8.1X10^{1}$	$2.6X10^{2}$	$7.0X10^{3}$
Te-123m		8.0	$2.2X10^{2}$	1.0	$2.7X10^{1}$	$3.3X10^{2}$	$8.9X10^{3}$
Te-125m		$2.0X10^{1}$	$5.4X10^{2}$	$9.0X10^{-1}$	$2.4X10^{1}$	$6.7X10^{2}$	$1.8X10^{4}$
Te-127		$2.0X10^{1}$	$5.4X10^{2}$	$7.0X10^{-1}$	$1.9X10^{1}$	$9.8X10^{4}$	$2.6X10^{6}$
Te-127m (a)		$2.0X10^{1}$	$5.4X10^{2}$	$5.0X10^{-1}$	$1.4X10^{1}$	$3.5X10^{2}$	$9.4X10^{3}$
Te-129		$7.0X10^{-1}$	$1.9X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$7.7X10^{5}$	$2.1X10^{7}$
Te-129m (a)		$8.0X10^{-1}$	$2.2X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$1.1X10^{3}$	$3.0X10^{4}$
Te-131m (a)		$7.0X10^{-1}$	$1.9X10^{1}$	$5.0X10^{-1}$	$1.4X10^{1}$	$3.0X10^{4}$	$8.0X10^{5}$
Te-132 (a)		$5.0X10^{-1}$	$1.4X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$1.1X10^{4}$	$8.0X10^{5}$
Th-227	Thorium (90)	$1.0X10^{1}$	$2.7X10^{2}$	$5.0X10^{-3}$	$1.4X10^{-1}$	$1.1X10^{3}$	$3.1X10^{4}$
Th-228 (a)		$5.0X10^{-1}$	$1.4X10^{1}$	$1.0X10^{-3}$	$2.7X10^{-2}$	$3.0X10^{1}$	$8.2X10^{2}$
Th-229		5.0	$1.4X10^{2}$	$5.0X10^{-4}$	$1.4X10^{-2}$	$7.9X10^{-3}$	$2.1X10^{-1}$
Th-230		$1.0X10^{1}$	$2.7X10^{2}$	$1.0X10^{-3}$	$2.7X10^{-2}$	$7.6X10^{-4}$	$2.1X10^{-2}$
Th-231	Thorium (90)	$4.0X10^{1}$	$1.1X10^{3}$	$2.0X10^{-2}$	$5.4X10^{-1}$	$2.0X10^{4}$	$5.3X10^{5}$
Th-232		Unlimited	Unlimited	Unlimited	Unlimited	$4.0X10^{-9}$	$1.1X10^{-7}$
Th-234 (a)		$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$8.6X10^{2}$	$2.3X10^{4}$
Th(nat)		Unlimited	Unlimited	Unlimited	Unlimited	$8.1X10^{-9}$	$2.2X10^{-7}$
Ti-44 (a)	Titanium (22)	$5.0X10^{-1}$	$1.4X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	6.4	$1.7X10^{2}$
Tl-200	Thallium (81)	$9.0X10^{-1}$	$2.4X10^{1}$	$9.0X10^{-1}$	$2.4X10^{1}$	$2.2X10^{4}$	$6.0X10^{5}$
Tl-201		$1.0X10^{1}$	$2.7X10^{2}$	4.0	$1.1X10^{2}$	$7.9X10^{3}$	$2.1X10^{5}$
Tl-202		2.0	$5.4X10^{1}$	2.0	$5.4X10^{1}$	$2.0X10^{3}$	$5.3X10^{4}$
Tl-204		$1.0X10^{1}$	$2.7X10^{2}$	$7.0X10^{-1}$	$1.9X10^{1}$	$1.7X10^{1}$	$4.6X10^{2}$
Tm-167	Thulium (69)	7.0	$1.9X10^{2}$	$8.0X10^{-1}$	$2.2X10^{1}$	$3.1X10^{3}$	$8.5X10^{4}$
Tm-170		3.0	$8.1X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$2.2X10^{2}$	$6.0X10^{3}$
Tm-171		$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{1}$	$1.1X10^{3}$

Table D-1. A_1 and A_2 Values for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific activity (TBq/g)	Specific activity (Ci/g)
U-230 (fast lung absorption) (a)(d)	Uranium (92)	$4.0X10^{1}$	$1.1X10^{3}$	$1.0X10^{-1}$	2.7	$1.0X10^{3}$	$2.7X10^{4}$
U-230 (medium lung absorption) (a)(e)		$4.0X10^{1}$	$1.1X10^{3}$	$1.0X10^{-1}$	2.7	$1.0X10^{3}$	$2.7X10^{4}$
U-230 (slow lung absorption) (a)(f)		$4.0X10^{1}$	$1.1X10^{3}$	$1.0X10^{-1}$	2.7	$1.0X10^{3}$	$2.7X10^{4}$
U-232 (fast lung absorption) (d)		$4.0X10^{1}$	$1.1X10^{3}$	$1.0X10^{-2}$	$2.7X10^{-1}$	$8.3X10^{-1}$	$2.2X10^{1}$
U-232 (medium lung absorption) (e)		$4.0X10^{1}$	$1.1X10^{3}$	$1.0X10^{-2}$	$2.7X10^{-1}$	$8.3X10^{-1}$	$2.2X10^{1}$
U-232 (slow lung absorption) (f)		$4.0X10^{1}$	$1.1X10^{3}$	$1.0X10^{-2}$	$2.7X10^{-1}$	$8.3X10^{-1}$	$2.2X10^{1}$
U-233 (fast lung absorption) (d)		$4.0X10^{1}$	$1.1X10^{3}$	$9.0X10^{-2}$	2.4	$3.6X10^{-4}$	$9.7X10^{-3}$
U-233 (medium lung absorption) (e)		$4.0X10^{1}$	$1.1X10^{3}$	$9.0X10^{-2}$	2.4	$3.6X10^{-4}$	$9.7X10^{-3}$
U-233 (slow lung absorption) (f)		$4.0X10^{1}$	$1.1X10^{3}$	$9.0X10^{-2}$	2.4	$3.6X10^{-4}$	$9.7X10^{-3}$
U-234 (fast lung absorption) (d)		$4.0X10^{1}$	$1.1X10^{3}$	$9.0X10^{-2}$	2.4	$2.3X10^{-4}$	$6.2X10^{-3}$
U-234 (medium lung absorption) (e)		$4.0X10^{1}$	$1.1X10^{3}$	$9.0X10^{-2}$	2.4	$2.3X10^{-4}$	$6.2X10^{-3}$
U-234 (slow lung absorption) (f)		$4.0X10^{1}$	$1.1X10^{3}$	$9.0X10^{-2}$	2.4	$2.3X10^{-4}$	$6.2X10^{-3}$
U-235 (all lung absorption types) (a),(d),(e),(f)		Unlimited	Unlimited	Unlimited	Unlimited	$8.0X10^{-8}$	$2.2X10^{-6}$
U-236 (fast lung absorption) (d)		Unlimited	Unlimited	Unlimited	Unlimited	$2.4X10^{-6}$	$6.5X10^{-5}$
U-236 (medium lung absorption) (e)		Unlimited	Unlimited	Unlimited	Unlimited	$2.4X10^{-6}$	$6.5X10^{-5}$

Table D-1. A_1 and A_2 Values for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific activity (TBq/g)	Specific activity (Ci/g)
U-236 (slow lung absorption) (f)		Unlimited	Unlimited	Unlimited	Unlimited	$2.4X10^{-6}$	$6.5X10^{-5}$
U-238 (all lung absorption types) (d),(e),(f)		Unlimited	Unlimited	Unlimited	Unlimited	$1.2X10^{-8}$	$3.4X10^{-7}$
U (nat)		Unlimited	Unlimited	Unlimited	Unlimited	$2.6X10^{-8}$	$7.1X10^{-7}$
U (enriched to 20% or less)(g)		Unlimited	Unlimited	Unlimited	Unlimited	N/A	N/A
U (dep)		Unlimited	Unlimited	Unlimited	Unlimited	0.0	(See Table A-3)
V-48	Vanadium (23)	$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$6.3X10^{3}$	$1.7X10^{5}$
V-49		$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{1}$	$1.1X10^{3}$	$3.0X10^{2}$	$8.1X10^{3}$
W-178 (a)	Tungsten (74)	9.0	$2.4X10^{2}$	5.0	$1.4X10^{2}$	$1.3X10^{3}$	$3.4X10^{4}$
W-181		$3.0X10^{1}$	$8.1X10^{2}$	$3.0X10^{1}$	$8.1X10^{2}$	$2.2X10^{2}$	$6.0X10^{3}$
W-185		$4.0X10^{1}$	$1.1X10^{3}$	$8.0X10^{-1}$	$2.2X10^{1}$	$3.5X10^{2}$	$9.4X10^{3}$
W-187		2.0	$5.4X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$2.6X10^{4}$	$7.0X10^{5}$
W-188 (a)		$4.0X10^{-1}$	$1.1X10^{1}$	$3.0X10^{-1}$	8.1	$3.7X10^{2}$	$1.0X10^{4}$
Xe-122 (a)	Xenon (54)	$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$4.8X10^{4}$	$1.3X10^{6}$
Xe-123		2.0	$5.4X10^{1}$	$7.0X10^{-1}$	$1.9X10^{1}$	$4.4X10^{5}$	$1.2X10^{7}$
Xe-127		4.0	$1.1X10^{2}$	2.0	$5.4X10^{1}$	$1.0X10^{3}$	$2.8X10^{4}$
Xe-131m		$4.0X10^{1}$	$1.1X10^{3}$	$4.0X10^{1}$	$1.1X10^{3}$	$3.1X10^{3}$	$8.4X10^{4}$
Xe-133		$2.0X10^{1}$	$5.4X10^{2}$	$1.0X10^{1}$	$2.7X10^{2}$	$6.9X10^{3}$	$1.9X10^{5}$
Xe-135		3.0	$8.1X10^{1}$	2.0	$5.4X10^{1}$	$9.5X10^{4}$	$2.6X10^{6}$
Y-87 (a)	Yttrium (39)	1.0	$2.7X10^{1}$	1.0	$2.7X10^{1}$	$1.7X10^{4}$	$4.5X10^{5}$
Y-88		$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$5.2X10^{2}$	$1.4X10^{4}$
Y-90		$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$2.0X10^{4}$	$5.4X10^{5}$
Y-91		$6.0X10^{-1}$	$1.6X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$9.1X10^{2}$	$2.5X10^{4}$
Y-91m		2.0	$5.4X10^{1}$	2.0	$5.4X10^{1}$	$1.5X10^{6}$	$4.2X10^{7}$
Y-92		$2.0X10^{-1}$	5.4	$2.0X10^{-1}$	5.4	$3.6X10^{5}$	$9.6X10^{6}$
Y-93		$3.0X10^{-1}$	8.1	$3.0X10^{-1}$	8.1	$1.2X10^{5}$	$3.3X10^{6}$
Yb-169	Ytterbium (79)	4.0	$1.1X10^{2}$	1.0	$2.7X10^{1}$	$8.9X10^{2}$	$2.4X10^{4}$
Yb-175		$3.0X10^{1}$	$8.1X10^{2}$	$9.0X10^{-1}$	$2.4X10^{1}$	$6.6X10^{3}$	$1.8X10^{5}$
Zn-65	Zinc (30)	2.0	$5.4X10^{1}$	2.0	$5.4X10^{1}$	$3.0X10^{2}$	$8.2X10^{3}$
Zn-69		3.0	$8.1X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$1.8X10^{6}$	$4.9X10^{7}$
Zn-69m (a)		3.0	$8.1X10^{1}$	$6.0X10^{-1}$	$1.6X10^{1}$	$1.2X10^{5}$	$3.3X10^{6}$
Zr-88	Zirconium (40)	3.0	$8.1X10^{1}$	3.0	$8.1X10^{1}$	$6.6X10^{2}$	$1.8X10^{4}$

Table D-1. A_1 and A_2 Values for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific activity (TBq/g)	Specific activity (Ci/g)
Zr-93		Unlimited	Unlimited	Unlimited	Unlimited	$9.3X10^{-5}$	$2.5X10^{-3}$
Zr-95 (a)		2.0	$5.4X10^{1}$	$8.0X10^{-1}$	$2.2X10^{1}$	$7.9X10^{2}$	$2.1X10^{4}$
Zr-97 (a)		$4.0X10^{-1}$	$1.1X10^{1}$	$4.0X10^{-1}$	$1.1X10^{1}$	$7.1X10^{4}$	$1.9X10^{6}$

Table D-2. Exempt Material Activity Concentrations and Exempt Consignment Activity Limits for Radionuclides

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Ac-225 (a)	Actinium (89)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Ac-227 (a)		$1.0X10^{-1}$	$2.7X10^{-12}$	$1.0X10^{3}$	$2.7X10^{-8}$
Ac-228		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ag-105	Silver (47)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ag-108m (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ag-110m (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ag-111		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Al-26	Aluminum (13)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Am-241	Americium (95)	1.0	$2.7X10^{-11}$	$1.0X10^{4}$	$2.7X10^{-7}$
Am-242m (a)		1.0	$2.7X10^{-11}$	$1.0X10^{4}$	$2.7X10^{-7}$
Am-243 (a)		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
Ar-37	Argon (18)	$1.0X10^{6}$	$2.7X10^{-5}$	$1.0X10^{8}$	$2.7X10^{-3}$
Ar-39		$1.0X10^{7}$	$2.7X10^{-4}$	$1.0X10^{4}$	$2.7X10^{-7}$
Ar-41		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{9}$	$2.7X10^{-2}$
As-72	Arsenic (33)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
As-73		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
As-74		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
As-76		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
As-77		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
At-211 (a)	Astatine (85)	$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Au-193	Gold (79)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Au-194		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Au-195		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Au-198		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Au-199		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ba-131 (a)	Barium (56)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ba-133		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ba-133m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ba-140 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Be-7	Beryllium (4)	$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Be-10		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{6}$	$2.7X10^{-5}$
Bi-205	Bismuth (83)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Bi-206		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Bi-207		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Bi-210		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Bi-210m (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Bi-212 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$

Table D-2. Exempt Material Activity Concentrations and Exempt Consignment Activity Limits for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Bk-247	Berkelium (97)	1.0	$2.7X10^{-11}$	$1.0X10^{4}$	$2.7X10^{-7}$
Bk-249 (a)		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Br-76	Bromine (35)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Br-77		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Br-82		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
C-11	Carbon (6)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
C-14		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Ca-41	Calcium (20)	$1.0X10^{5}$	$2.7X10^{-6}$	$1.0X10^{7}$	$2.7X10^{-4}$
Ca-45		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Ca-47 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Cd-109	Cadmium (48)	$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{6}$	$2.7X10^{-5}$
Cd-113m		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Cd-115 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Cd-115m		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ce-139	Cerium (58)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ce-141		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Ce-143		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ce-144 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Cf-248	Californium (98)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Cf-249		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
Cf-250		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Cf-251		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
Cf-252		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Cf-253 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Cf-254		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
Cl-36	Chlorine (17)	$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{6}$	$2.7X10^{-5}$
Cl-38		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Cm-240	Curium (96)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Cm-241		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Cm-242		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Cm-243		1.0	$2.7X10^{-11}$	$1.0X10^{4}$	$2.7X10^{-7}$
Cm-244		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Cm-245		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
Cm-246		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
Cm-247 (a)		1.0	$2.7X10^{-11}$	$1.0X10^{4}$	$2.7X10^{-7}$
Cm-248		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
Co-55	Cobalt (27)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$

Table D-2. Exempt Material Activity Concentrations and Exempt Consignment Activity Limits for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Co-56		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Co-57		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Co-58		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Co-58m		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Co-60		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Cr-51	Chromium (24)	$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Cs-129	Caesium (55)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Cs-131		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Cs-132		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Cs-134		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Cs-134m		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{5}$	$2.7X10^{-6}$
Cs-135		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Cs-136		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Cs-137 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Cu-64	Copper (29)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Cu-67		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Dy-159	Dysprosium (66)	$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Dy-165		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Dy-166 (a)		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Er-169	Erbium (68)	$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Er-171		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Eu-147	Europium (63)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Eu-148		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Eu-149		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Eu-150 (short lived)		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Eu-150 (long lived)		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Eu-152		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Eu-152 m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Eu-154		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Eu-155		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Eu-156		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
F-18	Fluorine (9)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Fe-52 (a)	Iron (26)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Fe-55		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{6}$	$2.7X10^{-5}$
Fe-59		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Fe-60 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$

Table D-2. Exempt Material Activity Concentrations and Exempt Consignment Activity Limits for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Ga-67	Gallium (31)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ga-68		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Ga-72		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Gd-146 (a)	Gadolinium (64)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Gd-148		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Gd-153		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Gd-159		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ge-68 (a)	Germanium (32)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Ge-71		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{8}$	$2.7X10^{-3}$
Ge-77		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Hf-172 (a)	Hafnium (72)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Hf-175		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Hf-181		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Hf-182		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Hg-194 (a)	Mercury (80)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Hg-195m (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Hg-197		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Hg-197m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Hg-203		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Ho-166	Holmium (67)	$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{5}$	$2.7X10^{-6}$
Ho-166m		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
I-123	Iodine (53)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
I-124		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
I-125		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
I-126		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
I-129		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
I-131		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
I-132		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
I-133		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
I-134		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
I-135 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
In-111	Indium (49)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
In-113m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
In-114m (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
In-115m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ir-189 (a)	Iridium (77)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Ir-190		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$

Table D-2. Exempt Material Activity Concentrations and Exempt Consignment Activity Limits for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Ir-192		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Ir-194		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
K-40	Potassium (19)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
K-42		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
K-43		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Kr-81	Krypton (36)	$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Kr-85		$1.0X10^{5}$	$2.7X10^{-6}$	$1.0X10^{4}$	$2.7X10^{-7}$
Kr-85m		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{10}$	$2.7X10^{-1}$
Kr-87		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{9}$	$2.7X10^{-2}$
La-137	Lanthanum (57)	$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
La-140		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Lu-172	Lutetium (71)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Lu-173		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Lu-174		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Lu-174m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Lu-177		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Mg-28 (a)	Magnesium (12)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Mn-52	Manganese (25)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Mn-53		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{9}$	$2.7X10^{-2}$
Mn-54		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Mn-56		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Mo-93	Molybdenum (42)	$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{8}$	$2.7X10^{-3}$
Mo-99 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
N-13	Nitrogen (7)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{9}$	$2.7X10^{-2}$
Na-22	Sodium (11)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Na-24		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$

Table D-2. Exempt Material Activity Concentrations and Exempt Consignment Activity Limits for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Nb-93m	Niobium (41)	$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Nb-94		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Nb-95		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Nb-97		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Nd-147	Neodymium (60)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Nd-149		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ni-59	Nickel (28)	$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{8}$	$2.7X10^{-3}$
Ni-63		$1.0X10^{5}$	$2.7X10^{-6}$	$1.0X10^{8}$	$2.7X10^{-3}$
Ni-65		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Np-235	Neptunium (93)	$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Np-236 (short-lived)		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Np-236 (long-lived)		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Np-237		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
Np-239		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Os-185	Osmium (76)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Os-191		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Os-191m		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Os-193		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Os-194 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
P-32	Phosphorus (15)	$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{5}$	$2.7X10^{-6}$
P-33		$1.0X10^{5}$	$2.7X10^{-6}$	$1.0X10^{8}$	$2.7X10^{-3}$
Pa-230 (a)	Protactinium (91)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Pa-231		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
Pa-233		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Pb-201	Lead (82)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Pb-202		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Pb-203		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Pb-205		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Pb-210 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Pb-212 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Pd-103 (a)	Palladium (46)	$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{8}$	$2.7X10^{-3}$
Pd-107		$1.0X10^{5}$	$2.7X10^{-6}$	$1.0X10^{8}$	$2.7X10^{-3}$
Pd-109		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$

Table D-2. Exempt Material Activity Concentrations and Exempt Consignment Activity Limits for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Pm-143	Promethium (61)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Pm-144		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Pm-145		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Pm-147		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Pm-148m (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Pm-149		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Pm-151		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Po-210	Polonium (84)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Pr-142	Praseodymium (59)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Pr-143		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{6}$	$2.7X10^{-5}$
Pt-188 (a)	Platinum (78)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Pt-191		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Pt-193		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Pt-193m		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Pt-195m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Pt-197		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Pt-197m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Pu-236	Plutonium (94)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Pu-237		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Pu-238		1.0	$2.7X10^{-11}$	$1.0X10^{4}$	$2.7X10^{-7}$
Pu-239		1.0	$2.7X10^{-11}$	$1.0X10^{4}$	$2.7X10^{-7}$
Pu-240		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
Pu-241 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Pu-242		1.0	$2.7X10^{-11}$	$1.0X10^{4}$	$2.7X10^{-7}$
Pu-244 (a)		1.0	$2.7X10^{-11}$	$1.0X10^{4}$	$2.7X10^{-7}$
Ra-223 (a)	Radium (88)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Ra-224 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Ra-225 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Ra-226 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Ra-228 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Rb-81	Rubidium (37)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Rb-83 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Rb-84		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Rb-86		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Rb-87		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Rb(nat)		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Re-184	Rhenium (75)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$

Table D-2. Exempt Material Activity Concentrations and Exempt Consignment Activity Limits for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Re-184m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Re-186		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Re-187		$1.0X10^{6}$	$2.7X10^{-5}$	$1.0X10^{9}$	$2.7X10^{-2}$
Re-188		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Re-189 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Re(nat)		$1.0X10^{6}$	$2.7X10^{-5}$	$1.0X10^{9}$	$2.7X10^{-2}$
Rh-99	Rhodium (45)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Rh-101		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Rh-102		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Rh-102m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Rh-103m		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{8}$	$2.7X10^{-3}$
Rh-105		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Rn-222 (a)	Radon (86)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{8}$	$2.7X10^{-3}$
Ru-97	Ruthenium (44)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Ru-103 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ru-105		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ru-106 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
S-35	Sulphur (16)	$1.0X10^{5}$	$2.7X10^{-6}$	$1.0X10^{8}$	$2.7X10^{-3}$
Sb-122	Antimony (51)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{4}$	$2.7X10^{-7}$
Sb-124		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Sb-125		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Sb-126		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Sc-44	Scandium (21)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Sc-46		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Sc-47		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Sc-48		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Se-75	Selenium (34)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Se-79		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Si-31	Silicon (14)	$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Si-32		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Sm-145	Samarium (62)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Sm-147		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Sm-151		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{8}$	$2.7X10^{-3}$
Sm-153		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Sn-113 (a)	Tin (50)	$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Sn-117m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Sn-119m		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$

Table D-2. Exempt Material Activity Concentrations and Exempt Consignment Activity Limits for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Sn-121m (a)		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Sn-123		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Sn-125		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Sn-126 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Sr-82 (a)	Strontium (38)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Sr-85		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Sr-85m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Sr-87m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Sr-89		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Sr-90 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{4}$	$2.7X10^{-7}$
Sr-91 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Sr-92 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
T(H-3)	Tritium (1)	$1.0X10^{6}$	$2.7X10^{-5}$	$1.0X10^{9}$	$2.7X10^{-2}$
Ta-178 (long-lived)	Tantalum (73)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Ta-179		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Ta-182		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Tb-157	Terbium (65)	$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Tb-158		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Tb-160		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Tc-95m (a)	Technetium (43)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Tc-96		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Tc-96m (a)		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Tc-97		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{8}$	$2.7X10^{-3}$
Tc-97m		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Tc-98		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Tc-99		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
Tc-99m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Te-121	Tellurium (52)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Te-121m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Te-123m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Te-125m		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Te-127		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Te-127m (a)		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Te-129		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Te-129m (a)		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Te-131m (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Te-132 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$

Table D-2. Exempt Material Activity Concentrations and Exempt Consignment Activity Limits for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Th-227	Thorium (90)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Th-228 (a)		1.0	$2.7X10^{-11}$	$1.0X10^{4}$	$2.7X10^{-7}$
Th-229		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
Th-230		1.0	$2.7X10^{-11}$	$1.0X10^{4}$	$2.7X10^{-7}$
Th-231		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Th-232		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
Th-234 (a)		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{5}$	$2.7X10^{-6}$
Th (nat)		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
Ti-44 (a)	Titanium (22)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
Tl-200	Thallium (81)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Tl-201		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Tl-202		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Tl-204		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{4}$	$2.7X10^{-7}$
Tm-167	Thulium (69)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Tm-170		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Tm-171		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{8}$	$2.7X10^{-3}$
U-230 (fast lung absorption) (a)(d)	Uranium (92)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
U-230 (medium lung absorption) (a)(e)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
U-230 (slow lung absorption) (a)(f)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
U-232 (fast lung absorption) (d)	Uranium (92)	1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
U-232 (medium lung absorption) (e)		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
U-232 (slow lung absorption) (f)		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
U-233 (fast lung absorption) (d)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
U-233 (medium lung absorption) (e)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
U-233 (slow lung absorption) (f)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
U-234 (fast lung absorption) (d)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$

Table D-2. Exempt Material Activity Concentrations and Exempt Consignment Activity Limits for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
U-234 (medium lung absorption) (e)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
U-234 (slow lung absorption) (f)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
U-235 (all lung absorption types) (a),(d),(e),(f)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
U-236 (fast lung absorption) (d)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
U-236 (medium lung absorption) (e)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
U-236 (slow lung absorption) (f)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
U-238 (all lung absorption types) (d),(e),(f)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{4}$	$2.7X10^{-7}$
U (nat)		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
U (enriched to 20% or less)(g)		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
U (dep)		1.0	$2.7X10^{-11}$	$1.0X10^{3}$	$2.7X10^{-8}$
V-48	Vanadium (23)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$
V-49		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$

Table D-2. Exempt Material Activity Concentrations and Exempt Consignment Activity Limits for Radionuclides (Continued)

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
W-178 (a)	Tungsten (74)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
W-181		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
W-185		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{7}$	$2.7X10^{-4}$
W-187		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
W-188 (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Xe-122 (a)	Xenon (54)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{9}$	$2.7X10^{-2}$
Xe-123		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{9}$	$2.7X10^{-2}$
Xe-127		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{5}$	$2.7X10^{-6}$
Xe-131m		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{4}$	$2.7X10^{-7}$
Xe-133		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{4}$	$2.7X10^{-7}$
Xe-135		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{10}$	$2.7X10^{-1}$
Y-87 (a)	Yttrium (39)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Y-88		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Y-90		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{5}$	$2.7X10^{-6}$
Y-91		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{6}$	$2.7X10^{-5}$
Y-91m		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Y-92		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Y-93		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{5}$	$2.7X10^{-6}$
Yb-169	Ytterbium (79)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{7}$	$2.7X10^{-4}$
Yb-175		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Zn-65	Zinc (30)	$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Zn-69		$1.0X10^{4}$	$2.7X10^{-7}$	$1.0X10^{6}$	$2.7X10^{-5}$
Zn-69m (a)		$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Zr-88	Zirconium (40)	$1.0X10^{2}$	$2.7X10^{-9}$	$1.0X10^{6}$	$2.7X10^{-5}$
Zr-93		$1.0X10^{3}$	$2.7X10^{-8}$	$1.0X10^{7}$	$2.7X10^{-4}$
Zr-95 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{6}$	$2.7X10^{-5}$
Zr-97 (a)		$1.0X10^{1}$	$2.7X10^{-10}$	$1.0X10^{5}$	$2.7X10^{-6}$