BASES AND GUIDANCE ON FISSILE MATERIAL EXEMPTION AND GENERAL LICENSES IN 10 CFR PART 71

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ABSTRACT

Title 10 of the Code of Federal Regulations, Part 71 (10 CFR 71), issued in 2004, includes provisions for general licenses of fissile material shipments and criteria that allow licensees to exempt certain fissile material packages for transportation purposes. Since Part 71 was issued, the Nuclear Regulatory Commission (NRC) has received many requests for the interpretation of these requirements. A reference document is in development that is intended to provide guidance for the fissile material exception and general license regulations in 10 CFR §71.15, §71.22, and §71.23 for fissile material licensees. This reference document will include the background and technical basis behind the development of the current fissile exemption and general license criteria in 10 CFR Part 71. The background section of the report will include a discussion of an emergency final rule issued by the NRC in 1997 that amended the regulations in 10 CFR Part 71 regarding the shipment of exempt quantities of fissile material. The emergency final rule restricted the use of beryllium, graphite, and deuterium in shipments of fissile material in addition to consignment mass limits. These regulations in Part 71 were later modified in a 2004 rule-making to improve implementation and to address some potential issues that might lead to safety concerns. These modifications, in part, were based upon recommendations made in NUREG/CR-5342, *Assessment and Recommendations for Fissile-Material Packaging Exemptions and General Licenses within 10 CFR Part 71*. The concepts of fissile exemptions and general licenses will be presented in the reference document in addition to the technical bases for these requirements. In addition, realistic examples are in development to assist fissile material licensees in complying with fissile exemption and general license criteria.

INTRODUCTION

Title 10 of the US Code of Federal Regulations (CFR), Part 71, "Packaging and Transportation of Radioactive Material" [1], contains requirements for exemption from classification of fissile material (§71.15) and requirements for the general licenses for fissile material and plutonium-beryllium special form sources (§71.22 and §71.23, respectively). These regulations were revised by the US Nuclear Regulatory Commission (NRC) as part of a larger rule-making effort in 2004. The International Atomic Energy Agency (IAEA) has created similar regulations that are contained within SSR-6, *Regulations for the Safe Transport of Radioactive Material*, 2012 Edition [2]. The NRC has received many requests for the interpretation of the revised fissile exemption and fissile material general license provisions that were implemented in 10 CFR Part 71 in 2004. A reference document, which is in development by Oak Ridge National Laboratory (ORNL) for the NRC, will provide guidance to fissile material licensees on how to apply

the fissile material exemption and general license regulations. In addition, the document will contain the intent and technical basis for each of the requirements, including a variety of example problems to illustrate how to comply with the requirements.

BACKGROUND

The goal of the fissile material exemption and general license regulations is to ensure that individual packages and arrays of packages are safe from a criticality accident during transportation activities. Criticality accidents can pose a significant safety hazard to the workers and to the public. To ensure a transportation package is incapable of inadvertent criticality, that is, the package is subcritical, the principal parameters of concern from a nuclear criticality safety (NCS) perspective are

1. type, mass, and form of the fissile material,
2. moderator-to-fissile material ratio (degree of moderation),
3. amount and distribution of moderator and absorber materials,
4. package geometry – internal and external, and
5. reflector effectiveness.

The fissile material exemption and general license regulations in 10 CFR Part 71 do not require a criticality safety evaluation for the actual fissionable material package; thus, only the parameters specified in items 1 and 2 are applicable to determine whether or not the fissile exemption criteria apply. The remaining parameters in items 3–5 apply to providing some control and cannot be relied upon to meet the fissile material exemption and general license criteria. For example, the package can provide control of neutron interaction because the package material provides spacing between the fissile material present and other containers. The general license and exemption requirements applied to a transportation package must ensure that the type, form, and mass of the fissile material, with any degree of moderation or configuration, must remain in a subcritical condition at all times and that there are no credible means to alter these subcritical conditions during shipment.

The NRC does not review or certify package shipments made in accordance with the fissile material exemption or general license criteria in 10 CFR Part 71. Thus, the NRC is not completely aware of specific items being shipped under the 10 CFR §71.15, §71.22, or §71.23 requirements. Although 10 CFR §71.22 and §71.23 require the licensee to have an NRC-approved quality assurance (QA) program that satisfies the provisions of subpart H of 10 CFR 71, the fissile exemption criteria of §71.15 can be applied by licensees without an NRC-approved QA program.

1997 NRC Emergency Rule-making

In September 1996, the NRC was notified by one of its licensees regarding an issue involving the use of the fissile material exemption criteria included as 10 CFR §71.53(d) prior to 2004 that stated that a package is exempt if it contains less than 5 grams of fissile radionuclides in a 10 liter volume as long as items are packaged such that this concentration is maintained during normal conditions of transport [3]. The licensee was

planning to ship significant quantities of a mixture of enriched uranium and beryllium oxide (uranium-beryllium filter cake) that was the waste product of a process involving weapons-grade uranium materials. Based upon licensee calculations [4], a criticality accident was possible by simply complying with the concentration exemption limits specified in 10 CFR §71.53(d). This was possible because the exemption limits assume that water is the most limiting moderator and reflector material that can be credibly present in a package. Based on licensee calculations, the NRC declared 10 CFR §71.53 deficient [5] and decided that the regulations should be changed to ensure "special" moderating materials (those special materials that have absorption cross section less than that of water and limited to beryllium, graphite, and heavy water) were sufficiently limited to ensure subcriticality. A subsequent study by ORNL substantiated the licensee's findings [6]. Further review of 10 CFR Part 71 by the NRC resulted in identifying similar issues with the general license criteria in 10 CFR §71.18 and 10 CFR §71.22, and the NRC identified another issue during its review with respect to limiting the total amount of fissile material in a conveyance. In 1997, 10 CFR Part 71 was modified to correct these perceived deficiencies.

Revision to 10 CFR Part 71 (1997)

Due to the emergency rule-making discussed in the previous section, the transport regulations in the United States were revised to adopt the IAEA fissile exemption criteria [7]. This revision resulted in a modification to the exemption to limit the quantity of beryllium, hydrogenous material enriched in deuterium, and graphite (not considered a special moderator in IAEA regulations) present in the package to preclude the addition of "special" moderators to packages that are to be handled as exempt fissile material. In fact, the exemptions were only applicable when these moderating materials were not present in quantities exceeding 0.1 percent of the fissile material mass [8]. There was also another issue based on ad hoc control of consignment mass limits that were found to be inadequate. These limits were assumed to provide a conservative level of control from a criticality safety perspective during transportation; however, the approach did not appear to be satisfactory since some shippers viewed the mass limits as only administrative requirements and had plans to divide a conveyance into multiple consignments to comply with the mass limits [9,10]. Thus, the revision to the regulations included consignment limits on shipments of fissile materials [3] to ensure that a load of exempted packages would remain subcritical. The possibility that the uncontrolled accumulation of packages containing exempt quantities of fissile material could be a criticality safety issue during transportation was also of concern to the IAEA during the 1996 revision of the IAEA regulations [7].

Issuance of NUREG/CR-5342 (1998)

The emergency rule issued by the NRC in 1997 resulted in numerous public concerns and comments because the rule was issued without a public comment period. Based on these issues and NRC staff concerns regarding unidentified deficiencies and potential inconsistencies in the regulations, a decision was made to further assess the 10 CFR Part 71 revision of the fissile exemption and general license requirements. The NRC consulted

with ORNL to assess the 1997 revision of 10 CFR Part 71 with the following objectives in mind.

1. Document perceived deficiencies in the technical or licensing bases that might be adverse to maintaining adequate subcriticality under normal conditions of transport and hypothetical accident conditions
2. Identify areas where regulatory wording could cause confusion among licensees and potentially lead to subsequent safety concerns
3. Study and identify the practical aspects of transportation or licensing that could mitigate, justify, or provide an historical basis for any identified potential deficiencies
4. Develop recommendations for revising the current regulations to minimize operational and economic impacts on licensees while maintaining safe practices and correcting identified deficiencies

The assessment details and resulting recommendations can be found in [6]. The report also summarized that there were no significant or immediate criticality safety issues with the exemption and general license criteria based on the inherent characteristics of the fissile material matrices. Further, the report concluded that shippers could misinterpret the current regulations. The fissile exemption and general license requirements may be applied inconsistently based on potential confusion over the intent of the regulations. The lack of guidance and interpretation of the standards and regulations leaves compliance up to the interpretation of the end users, and safety issues could potentially result. The reduced regulatory oversight provided to exempt and general-license shipments makes it crucial that the technical and licensing basis in 10 CFR Part 71 regulations be realistic, well documented, and well understood by the transportation community [6]. The NRC considered the recommendations documented in [6] and proposed to amend 10 CFR Part 71 in 2002 [11] to make them compatible with the IAEA regulations [12] and to codify other applicable requirements. This revision would allow the NRC to address unintended impacts to some end users of the regulations of the NRC emergency rule in 1997. The NRC provided extensive opportunities for the public to provide comments [13,14] and issued a final 10 CFR Part 71 rule that was effective in October 2004 [15].

10 CFR Part 71 Final Rule (2004)

The final rule [16] for a revision to 10 CFR Part 71 was effective on October 1, 2004. This rule made changes to the regulation to make it generally more consistent with the 2003 revision of the IAEA regulations [17] for the safe transport of radioactive material. The final rule also considered changes in the fissile material exemption requirements as a result of public comments that indicated the changes made during the 1997 emergency rule-making were economically difficult for many end users of the regulations, with no commensurate benefit to safety. This revision of 10 CFR Part 71 was the last major revision made to the fissile exemption and general license regulations. A new rule-making effort [18] is currently in progress by the NRC to revise the regulations to ensure consistency with the updated IAEA regulations [2] for the transportation of radioactive

material and to maintain consistency with Department of Transportation (DOT) requirements.

Fissile Exemptions

The existing fissile material exemptions from 10 CFR §71.53 [19] were redesignated as 10 CFR §71.15, "Exemption from classification as fissile material," under subpart B, "Exemptions" in [20]. Three new fissile exemptions in [20] were included in this revision: 2 grams of fissile material per package, 15 grams of fissile material with a ratio of nonfissile to fissile material of 200:1, and 180 grams of fissile material distributed within 360 kg of contiguous non-fissile material. There were also limitations included to minimize the presence of lead, beryllium, graphite, and hydrogenous material enriched in deuterium, although these materials are not to be designated as solid non-fissile material mass. The exemption in 10 CFR §71.53(3)(b) [19] for ^{235}U enriched up to 1 weight percent was modified to replace the requirement for "…does not form a lattice arrangement within the package…" with a restriction on the quantities of beryllium, graphite, hydrogenous material enriched in deuterium of less than 5 percent of the uranium mass [19]. The exemption for liquid solutions of uranyl nitrate, 10 CFR §71.53(3)(c) [19], was modified to require the material be present in at least a DOT Type A package. Finally, the exemption for plutonium, 10 CFR §71.53(3)(d) [19], was modified slightly to note that the requirement is applicable to individual packages only.

General Licenses

The existing general license requirements from 10 CFR §§ 71.18, "General license: Fissile material, limited quantity per package," 71.20, "General license: Fissile material, limited moderator per package," 71.22, "General license: Fissile material, limited quantity, controlled shipment," and 71.24, "General license: Fissile material, limited moderator, controlled shipment" from [19] were combined under a single section, 10 CFR §71.22, "General license: Fissile Material" in [20]. This section contains mass-based fissile material limits and requires a Criticality Safety Index (CSI). The concentration-based limits used previously were removed in this final rule based on the recommendations in [6]. This combined section also includes a new requirement, 10 CFR §71.22(a), that directs licensees to ship fissile material under a general license in a Type A package to ensure the requirements of 49 CFR §173.417(a) [21] are met. Prior regulations required only that a Type A quantity of radioactive material or less be included in a package. The revised regulations in [20], 10 CFR §71.22(b), require that the general license regulations apply to only those licensees who have an NRC-approved QA program that satisfies the requirements of 10 CFR Part 71, subpart H, "Quality Assurance." The general license criteria in [20] under 10 CFR §71.22(c)(1) and (c)(2) limit the quantity of fissile material allowed in a Type A package to no more than a Type A quantity and the fissile material present must contain less than 500 total grams of beryllium, graphite, or hydrogenous materials enriched in deuterium, respectively. The new requirements in this section should be more convenient from a licensee compliance perspective because the content quantities, for example, fissile material and moderating material, are easier to determine than the content concentration, in most cases.

The general license criteria under 10 CFR §71.22(d) in [20] provide the requirements for calculating the CSI of packages containing fissile material and the CSI limits for shipment as either an exclusive use conveyance (CSI ≤ 100) or nonexclusive use conveyance (CSI ≤ 50) for the shipment of multiple packages containing fissile material in a Type A package. For known quantities of ^{235}U, ^{233}U, and plutonium present in a package, the CSI for a fissile material general license, provided in §71.22(e)(1), is calculated as

$$\mathrm{CSI} = 10\left[\frac{\text{grams of U-235}}{\mathrm{X}} + \frac{\text{grams of U-233}}{\mathrm{Y}} + \frac{\text{grams of Pu}}{\mathrm{Z}}\right],$$

where X, Y, and, Z represent the mass limits for ^{235}U, ^{233}U, and plutonium, respectively. The appropriate fissile material mass limit data are provided in 10 CFR 71, Tables 71–1 and 71–2 in [20]. Table 71–1 is a listing of mass limits for general license packages containing mixed quantities of fissile material or ^{235}U of known enrichment. Specifically, mass limits are provided for ^{235}U, ^{233}U, and ^{239}Pu/^{241}Pu mixed with moderating substances with hydrogen densities that are either greater than or less than that of water. Table 71–2 is a listing of mass limits for general license packages containing ^{235}U of known enrichment, up to 24 wt. % enriched uranium. For known quantities of ^{239}Pu and ^{241}Pu present in a package, the CSI for a general license for plutonium-beryllium special form material, provided in §71.23(e)(1), is calculated as

$$\mathrm{CSI} = 10\left[\frac{\text{grams of Pu-239} + \text{grams of Pu-241}}{24}\right],$$

where the “24” in the denominator represents the mass limit for the total quantity of plutonium present, 24 grams.

CONCEPT AND TECHNICAL BASES OF THE FISSILE EXEMPTIONS AND THE GENERAL LICENSE CRITERIA

The exemption from classification as fissile material indicates that the fissile concentration, fissile mass, and/or fissile enrichment is/are sufficiently low that accidental criticality is not possible under the normal conditions of transport or under the hypothetical accident conditions. Under normal conditions a single package could easily be shown to remain subcritical; however, the fissile exemptions also consider the accumulation of fissile mass as a result of the commingling of multiple packages in a single shipment. Thus, the fissile mass exemptions are sufficiently low, based on conservative assumptions, to ensure a subcritical arrangement for transport. The exemption criteria are based on worst-case (optimal) conditions such as full-water reflection, optimum moderation by water, beryllium, graphite, or hydrogenous material enriched in deuterium, optimal geometry, and pure fissile content, that is, ^{239}Pu, ^{235}U, or ^{233}U. The exemption criteria also consider the rearrangement or reconfiguration of fissile material during transport to ensure all realistic and foreseen arrangements will remain subcritical during the transport operations to ensure worker and public safety. The

exemption criteria in 10 CFR §71.15 do not take credit for packaging materials or packing geometry because there are no packaging requirements listed with the provisions.

A general license for fissile material applies to the shipment of less than a Type A quantity of fissile material in a Type A package or fissile material in the form of plutonium-beryllium (Pu-Be) special form sealed sources. The quantity of fissile material (^{235}U, ^{233}U, and plutonium) and moderating materials, such as beryllium, graphite, or hydrogenous material enriched in deuterium, is limited for the fissile material criteria. The quantity of fissile material in sealed source capsules (^{239}Pu and ^{241}Pu) is also limited to preclude criticality. A Type A package must prevent the loss or dispersal of the radioactive contents and maintain its radioactive shielding properties for all normal conditions of transportation. Normal conditions of transport for a Type A package include [22] 1. changing climate conditions: humidity, temperature, pressure, solar heating, and rain; 2. dynamic and static mechanical effects: limited shock, repeated bumping, and/or vibration; and 3. compressive forces due to stacking or load movement. The provisions in the general license criteria ensure that the fissile material configuration (fissile material mass mixed with other materials or Pu-Be sealed sources) present in a shipment will remain below the minimum critical mass for water-reflected, water-moderated systems. The quantity of fissile material in a single package is limited to a CSI of 10 for the fissile material general licenses and to a CSI of 100 for the Pu-Be general licenses. For the shipment of multiple packages on a nonexclusive use conveyance, the CSI must be less than or equal to 50. For the shipment of multiple packages on an exclusive use conveyance, the CSI must be less than or equal to 100 because more control is required during the shipping process, that is, radiological worker training and resources appropriate for the safe handling of the consignment.

The guidance document will also provide the background and the technical basis for each of the requirements in 10 CFR §71.15 and §71.22. This information supplements the conceptual meaning of these requirements to ensure criticality safety during transport operations. The document describes the bases behind the requirements from the perspective of the licensee, i.e., the end-user of the regulations. Licensees can benefit from understanding the technical bases for each of the requirements. If a licensee can understand why the fissile exemption and general license requirements exist, it is much easier and safer for them to apply the requirements to their transportation problems. Qualitative and quantitative example problems are being developed in the guidance document to assist end users attempting to understand these requirements.

REGULATIONS APPLIED TO REALISTIC SITUATIONS

A suite of example problems have been developed based on the experiences of numerous nuclear facilities throughout the United States. Several example problems will be provided for each fissile exemption and general license requirement. The example problems are meant to assist the licensee in identifying the potential use of the licensing requirements and the criteria that must be satisfied for safety and compliance. The examples also provide guidance on what items cannot be shipped using the regulations based on the intentions and technical bases for the requirements.

Example Problems from the Guidance Document

Example Problem for 10 CFR §71.15 – The Shipment of Multiple Drums of Fissile Material

A landfill that was used to bury metal drums of various kinds of wastes, for example, uranium-contaminated piping, motors, tools, personnel protective equipment, etc., has been exhumed for disposition to waste site. During the excavation, operations personnel noticed that most of the metal drums had rusted sufficiently that the surrounding soil is suspected of being contaminated with radiological material, most of which is low enriched uranium based upon historical records of the buried materials. The material was exhumed, including the contaminated soil and repackaged into numerous steel drums with reasonable efforts made to ensure the fissile material was distributed throughout the nonfissile materials present. No lead, beryllium, graphite, or hydrogenous material enriched in deuterium was known to be present in the loaded drums or detected through practical inspection and measurement techniques. Sample analysis results for the packaged drums indicate that all drums except one comply with the requirement §71.15(c)(1) that there is at least 2000 grams of solid nonfissile material for every gram of fissile material present. The shipper noted that if all the drum ratio sample results were averaged together, all the drums meet the 2000:1 fissile material-to-nonfissile material ratio. However, this does not meet the intent of §71.15(c) because the outlier drum could be separated from the rest of the drums during transportation operations. Thus, this activity is not allowed by this exemption. The shipper has several options available: 1. the outlier drum could be repacked into two drums with a diluent added that effectively reduces the fissile concentration below the 2000:1 ratio; 2. ship all the waste, except the outlier drum, under §71.15(c); or 3. if possible, ship the packages, including the outlier drum, under §71.15(b), which allows for up to 15 grams of ^{235}U in a single package provided the package has at least 200 grams of solid nonfissile material for every gram of fissile material present.

Example Problem for 10 CFR §71.23 – The Shipment of Plutonium-Beryllium Sources

Three plutonium-beryllium sources are to be shipped in a Type A package from one licensee to another to extract the plutonium from the sources for recycling purposes. The fissile content of the three sources is listed in Table 1. The licensee who will ship the package has an NRC-approved quality assurance program as required by 10 CFR Part 71 Subpart H.

Table 1 – Isotopic Breakdown of Pu-Be Sources for 10 CFR 71.23 Example Problem

Source Number	Fissile Content (grams)		Total (grams)
	^{239}Pu	^{241}Pu	
01-XYZ42	1.5	0.75	**2.25**
02-XYZ43	4.2	0.13	**4.33**
03-XYZ44	3.0	0.62	**3.62**
Total (grams)	**8.7**	**1.5**	**10.2**

To support a general license for plutonium-beryllium special form material, the CSI, defined previously, can be calculated by using the total quantities for each fissile isotope, 8.7 g ^{239}Pu and 1.5 g ^{241}Pu, from Table 1. These mass values are known to have measurement uncertainties conservatively factored into them. The CSI for the sources are calculated as follows:

$$\text{CSI} = 10\left[\frac{\text{grams of Pu-239} + \text{grams of Pu-241}}{24}\right]$$

$$\text{CSI} = 10\left[\frac{8.7 \text{ grams Pu-239} + 1.5 \text{ grams Pu-241}}{24}\right] = 4.3.$$

The calculated CSI for the single package is less than the limit of 100. The package will be shipped on a nonexclusive-use conveyance, which has a total CSI limit of 50. The shipper can ship multiple Type A containers if it is desired based upon the results of the CSI calculated for the package contents.

CONCLUSIONS

Title 10 of the US Code of Federal Regulations, Part 71 [1], *Packaging and Transportation of Radioactive Material*, contains requirements for exemption from classification of fissile material (§71.15) and requirements for the general licenses for fissile material and plutonium-beryllium special form sources (§71.22 and §71.23, respectively). The US regulations in 10 CFR Part 71 and corresponding IAEA regulations internationally have undergone significant evolution throughout the years. An overview of the history, technical basis, and intent of each of the fissile material exemptions and general licenses will be provided in an NRC guidance document, currently in development, along with examples of their use, to assist end users of these regulations with utilizing the requirements to transport fissile material.

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