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Bases for the General Licenses for Fissile Material and Exemptions from Classification as Fissile Material in 10 CFR Part 71, "Packaging and Transportation of Radioactive Material"

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Abstract:

Included within Title 10 of the *Code of Federal Regulations*, Part 71 (10 CFR 71), are general licenses for fissile material shipments and criteria that allow exemptions from classification as fissile material for transportation package evaluation. These provisions in Part 71 were modified in a 2004 rule-making to address potential safety concerns, as well as to provide a more straightforward set of criteria, consistent with other portions of 10 CFR 71. These rule modifications were based, in part, on the recommendations provided by NUREG/CR-5342, "Assessment and Recommendations for Fissile-Material Packaging Exemptions and General Licenses Within 10 CFR Part 71."

This paper will summarize the recommendations made by this NUREG/CR, as well as detail the bases for the version of the fissile material exemptions and general licenses that were subsequently adopted in the regulation. Additionally, this paper will provide examples that illustrate the intent and practical application of each fissile material exemption and general license.

I. Background

Title 10 of the Code of Federal Regulations, Part 71 (10 CFR 71)[1], paragraph 71.15 contains a set of criteria for exempting radioactive or other material from classification as fissile material for transportation considerations. Paragraph 71.22 of 10 CFR 71 contains a set of criteria under which a licensee of the Nuclear Regulatory Commission (NRC) may transport fissile material without a package application to the NRC.

The intent of the fissile exemptions in §71.15 is to provide criteria for fissile material for which there are no requirements for packaging assessment relative to criticality safety. These provisions provide limits on type, form, mass, moderation, and concentration, for which the material is expected to be adequately subcritical under normal and hypothetical accident conditions of transport, without any packaging requirements. For this reason, packaging and/or shipments of fissile material that meet the fissile exemption criteria require little or no regulatory oversight, and allow shippers flexibility in the shipment of low-risk fissile material.

The general license in §71.22 is intended for use by NRC licensees to ship small quantities of fissile material, in a Type A package, with a Criticality Safety Index (CSI) label to control accumulation of packages on a conveyance. The criteria in this paragraph include gram limits for mixtures of ^{235}U, ^{233}U, and Pu, as well as gram limits for various enrichments of ^{235}U without other fissile material.

Several instances in which exempt quantities of fissile material were demonstrated to be potentially unsafe were identified in the 1980s and 90s, which resulted in significant changes to these paragraphs. These changes included a consignment limit on the 15 gram per package exemption (previously §71.53(a)) of 400 grams, and a restriction on the presence of select moderators with very low neutron-absorption properties (i.e., "special" moderators)[2]. These changes were consistent with the 1996 version of International Atomic Energy Agency (IAEA) Safety Standards Series No. TS-R-1, *Regulations for the Safe Transport of Radioactive Material*.[3]

Prior to the 2004 10 CFR Part 71 rule-making, NRC undertook an assessment of the fissile exemptions and general licenses, in order to support a revision to this regulatory language.[4] This paper will discuss the results of this assessment, the resulting fissile exemption and general license criteria, and the intended uses for each exemption and general license.

II. NUREG/CR-5342: *Assessment and Recommendations for Fissile-Material Packaging Exemptions and General Licenses Within 10 CFR Part 71*

The objectives of the assessment performed in NUREG/CR-5342 were to:

1. document perceived deficiencies in the technical or licensing bases that might be adverse to maintaining adequate subcriticality under normal and hypothetical accident conditions of transport,

2. identify confusing or contradictory language in the regulatory text that could potentially lead to safety concerns,

3. identify the practical aspects of transportation or licensing that could mitigate, justify, or provide a historical basis for any identified deficiencies, and

4. develop recommendations for revising the regulations to minimize operational and economic impacts on licensees while maintaining safe practices and correcting identified deficiencies.

The assessment considered discussions with both industry and NRC staff regarding interpretation of the regulatory language and standard industry practice for shipments of fissile exempt or generally licensed materials. Additionally, the assessment considered available literature on parameters that ensure subcriticality of fissile material under various conditions, and performed independent computations to provide a basis for revised regulatory language. The independent analyses performed explored potential bounding specifications for fissile exemptions and general licenses, and considered the influence of common materials (e.g., water, polyethylene, silicon dioxide), as well as special moderators (e.g., beryllium(Be), graphite (C), deuterium (D_2O)).

The results of the assessment were used to develop fissile exemption and general license recommendations for consideration in future regulatory revisions. The recommendations were intended to provide a near-equivalent level of safety assurance to that required for packages certified to carry fissile material, and were based upon the lack of moderation control and

potential redistribution of material expected under normal and hypothetical accident conditions of transport.

The recommendations of NUREG/CR-5342 related to fissile exemptions in §71.15 included removing the mass-limited exemption (previously §71.53(a)) and replacing it several exemptions based of a ratio of fissile to non-fissile mass. Special moderators (Be, C, and D_2O) could be present in the package, but should be excluded from consideration as non-fissile material for the purposes of determining the ratio. This approach was believed to prevent potential criticality safety concerns in transport, while providing flexibility for regulators, licensees, and operators by precluding the need to prescribe and use a CSI for transport control. Additionally, mass ratios are believed to be easier for licensees to determine than values related to volumetric concentration, and they can be defined to provide sufficient control under realistic redistribution scenarios postulated to occur under hypothetical accident conditions.

Additional changes recommended for the fissile exemption language included removing the restriction on special moderators in the exemptions for low-enriched uranyl nitrate and low-fissile-content plutonium (previously §71.53(c) and (d)), as well as requiring the low-enriched uranyl nitrate to be in at least a Type A package. Additionally, it was recommended to remove the requirement from the low-enriched uranium exemption (previously §71.53(b)) for homogeneity and prevention of lattice arrangement, and replacing it with a restriction on special moderators. This was due to the fact that obtaining a criticality with less than 1.0 weight-percent enriched uranium is very difficult in the absence of special moderators, and requires large, heterogeneous arrays which are not likely to occur in transportation.

The recommendations of NUREG/CR-5342 related to the general license for fissile material in §71.22 included consolidation of the previous "controlled shipment" and "limited quantity" general licenses into a single, clearly defined set of criteria. This criteria should include a CSI determination for packages containing mixtures of fissile material types (^{235}U, ^{233}U, and Pu) of uranium of unknown enrichment, and a separate determination for packages containing only uranium of a known enrichment up to 24 weight-percent. The limits for mixtures of fissile material should be lower if the material is mixed with substances having a hydrogen density greater than water (e.g., polyethylene). Additionally, this general license should only apply to material in at least a Type A packaging, and the multiple limits on special moderators should be consolidated into a single, 500 gram limit, thus preventing their effectiveness as a reflector.

The recommended mass limits for the fissile material general license were obtained by raising the mass limits to just under the mass values that ensure subcriticality ($k_{eff} < 0.95$) based on critical and subcritical minimum mass values calculated for selected moderators. The fissile material mass limits for mixtures of fissile material with moderators having a hydrogen density higher than water were obtained via a scaling factor based on the ratio of ^{235}U critical mass values for water-moderated systems versus high-density polyethylene moderated systems. The mass limits for uranium of known enrichment were obtained via a scaling factor based on the ratio of a newly calculated water-moderated ^{235}U limit versus the lower value in use for the "limited quantity" exemption (previously §71.18).

The recommendations of NUREG/CR-5342 were considered as part of the 2004 10 CFR Part 71 rule-making process, and were modified based on comments by NRC staff, as well as by public stakeholders. The revised exemptions were developed by NRC using a risk based

approach to understand the various needs for shipping fissile-exempt or generally-licensed material and develop criteria that would not impede commerce while providing a pragmatic and reasoned basis for safety commensurate with the potential risk. The specific fissile exemption and general license language that was incorporated into the final rule is discussed in the next section.

III. Fissile Exemptions in §71.15

The fissile exemptions previously included in 10 CFR Part 71 consisted of four separate criteria, in §71.53(a), (b), (c), and (d), any one of which would exempt material from classification as fissile material and from the fissile material package standards of §71.55 and §71.59. §71.53(a) was removed and replaced with §71.15 (a), (b), and (c), while the remaining three exemptions were moved to §71.15(d), (e), and (f), with some modifications. Material that is to be exempted from classification as fissile material for transportation purposes must meet the requirements of at least one of the six paragraphs in §71.15. Each of the six paragraphs is presented in this section, along with a discussion of each exemption and some relevant examples.

§71.15(a) Individual package containing 2 grams or less fissile material.

This exemption paragraph is intended to limit a single package in a consignment to a "de minimis" value of 2 total grams of ^{233}U, ^{235}U, ^{239}Pu, or ^{241}Pu. The exemption paragraph allows ^{235}U samples up to 2 grams to be shipped with no packaging requirements since the A_1 and A_2 values are unlimited. However, for the other nuclides, a Type A package would be required for quantities over the radioactive exemption values, and a Type B package would be required for masses that exceed the A_1/A_2 values. For example, a Type B package would be needed for shipping a mass containing more than of 0.435 grams of ^{239}Pu or 0.016 grams of ^{241}Pu.

Although there are no specific accumulation controls for this exemption, the limit of 2 grams makes it unreasonable to transport large masses of material via large numbers of individual packages. One consideration of this risk-based rule-making was that licensees with sufficient fissile material in a form likely to pose a criticality potential via accumulation on a conveyance would view the 2 gram per package limit as imprudent and operationally impractical.

§71.15(b) Individual or bulk packaging containing 15 grams or less of fissile material provided the package has at least 200 grams of solid nonfissile material for every gram of fissile material. Lead, beryllium, graphite, and hydrogenous material enriched in deuterium may be present in the package but must not be included in determining the required mass for solid nonfissile material.

This exemption is intended to replace the previous 15 gram per package exemption (previously §71.53(a)), with an exemption that: 1) removes overly restrictive limitations on special moderators, 2) provides flexibility to shippers with larger amounts of dilute fissile material, and 3) mitigates criticality safety concerns by the presence of solid, non-fissile mass in the package together with the fissile mass limit per package. Although special moderators and reflectors (lead, beryllium, graphite, or deuterium) may be included in the package, they may not be included in calculating the mass of non-fissile material for dilution purposes. Even with large amounts of special moderators or reflectors in a package, the small amount of fissile material,

combined with the dilution effect of the required non-fissile material (up to 3000 grams for 15 grams of fissile material), makes these moderators and reflectors much less effective such that they no longer represent a realistic criticality safety concern for large accumulations of packages.

The non fissile material considered in the ratio determination should ideally be insoluble in water and non-combustible to survive the hypothetical accident condition. However, use of solid materials (that would remain solid under normal transport conditions) in the quantities specified should provide adequate mitigation against unacceptable accumulation of fissile material in the quantities necessary to pose a risk of criticality.

§71.15(c) *(1) Low concentrations of solid fissile material commingled with solid nonfissile material, provided that:*

(i) There is at least 2000 grams of solid nonfissile material for every gram of fissile material, and

(ii) There is no more than 180 grams of fissile material distributed within 360 kg of contiguous nonfissile material.

(2) Lead, beryllium, graphite, and hydrogenous material enriched in deuterium may be present in the package but must not be included in determining the required mass of solid nonfissile material.

This exemption is intended to accommodate shipments of large volumes of well-mixed, very dilute, fissile material, such as contaminated soil shipped in a rail car. Section (1)(ii) of the exemption includes a requirement on the distribution of the material, such that large, heterogeneous lumps of fissile material are not present, and the concentration of fissile material in any volume remains close to the 2000 to 1 non-fissile to fissile ratio.

This exemption arose from an expressed industry need to have bulk volume shipments with low concentrations of fissile material that sum to higher mass values than allowed by IAEA consignment mass limits. It was judged that the use of this exception to package high density masses of fissile material segregated from the non-fissile mass would be prohibited by the joint use of the words “low concentrations” and “commingled”.

§71.15(d) *Uranium enriched in uranium-235 to a maximum of 1 percent by weight, and with total plutonium and uranium-233 content of up to 1 percent of the mass of uranium-235, provided that the mass of any beryllium, graphite, and hydrogenous material enriched in deuterium constitutes less than 5 percent of the uranium mass.*

This exemption is similar to the previous exemption in §71.53(b), except that the restrictions on heterogeneity and lattice arrangement of the material have been replaced by a restriction on special moderators (Be, C, and D_2O) to less than 5 percent of the uranium mass. At the time NRC revised this exemption, it was judged that the requirements that the material is “distributed homogeneously throughout the package and does not form a lattice arrangement” were undefined and difficult in practice and enforcement. Since low-enriched systems of any kind are difficult to make critical in the absence of special moderators, NRC judged that limits on these moderators would make a clearer exemption that was easier to comply with.

Although large, heterogeneous, water moderator systems can be a criticality safety concern, it was believed at the time that very few, if any, licensees had this type of material to ship. Since the revised exemptions went into effect in October, 2004, the NRC has been notified of at least one instance where a shipper has identified a safety concern with the shipment of large, heterogeneous, low-enriched material, when water is assumed to moderate multiple conveyances of such material. NRC is currently considering revising this exemption to include a homogeneity requirement in the next revision of 10 CFR Part 71, although it is not believed that there are other licensees who possess such material in sufficient quantities to pose a criticality concern in transport.

§71.15(e) Liquid solutions of uranyl nitrate enriched in uranium-235 to a maximum of 2 percent by mass, with a total plutonium and uranium-233 content not exceeding 0.002 percent of the mass of uranium, and with a minimum nitrogen to uranium atomic ratio (N/U) of 2. The material must be contained in at least a DOT Type A package.

This exemption is similar to the previous exemption in §71.53(c), except that there is now a requirement that the packaging for liquid uranyl nitrate meet at least the Type A standards in §71.43. NRC judged that use of packages designed to meet such standards would be valuable and prudent to assure the uranyl nitrate is protected from adverse conditions that might affect the potential for criticality under normal conditions of transport. This exemption also recognizes that, at the low enrichment specified, the material is unlikely to accumulate in such a manner as to cause a criticality concern under accident conditions with a complete loss of packaging.

Additionally, NRC amended the requirement in 2004 to change the limits on ^{233}U and plutonium to less than 0.002 percent of the uranium mass, for consistency with the international regulations.

§71.15(f) Packages containing, individually, a total plutonium mass of not more than 20 percent by mass may consist of plutonium-239, plutonium-241, or any combination of these radionuclides.

This exemption paragraph is largely unchanged from the previous version of the regulations (previously §71.53(d)), and is intended to allow shipments of mostly non-fissile plutonium, such as heat-source plutonium. This exemption recognizes that, at very low quantities for any plutonium isotope, the material will become a Type B quantity, and accumulation under normal and hypothetical accident conditions of transport will be limited by the requirements for Type B packages.

IV. General License for Fissile Material in §71.22

A general license to transport fissile material may be issued to any licensee of the Commission provided that the provisions of this paragraph are satisfied. In order to transport fissile material a licensee must have a quality assurance (QA) program that is approved under Part 71 subpart H, and must meet certain criterion for the package contents.

Any given package must contain no more than a Type A quantity of radioactive material, which means that the aggregate radioactivity must not exceed A_1 for special form radioactive material, or A_2 for normal form radioactive material. Default A_1 and A_2 values are listed in Table A-1 of 10 CFR 71, although these values may also be determined by procedures described in Appendix A of this regulation. A package must also contain less than 500 total grams of beryllium, graphite, or hydrogenous material enriched in deuterium. Since the CSI (see below) limits the fissile mass on a conveyance to that less than the minimum mass that can achieve criticality in a system with optimum moderation, the only potential concern for special materials was that, when available as a reflector, they could lower the critical mass value. The 500 g value precludes accumulation of a sufficient mass to provide an effective reflector.

In addition, packages are also required to be labeled with the Criticality Safety Index (CSI), which is a dimensionless number that designates the degree of control of accumulation of packages containing fissile material and is calculated as follows:

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

where X, Y, and Z are obtained from Tables 71-1 and 71-2 of 10 CFR Part 71. The resulting CSI must be less than or equal to 10 when rounded up to the first decimal place. Table 71-1 is used for mixtures of all three fissile elements listed in the equation. Table 72-2 may only be used for enriched commercial grade uranium (ECGU) or recycled uranium of known enrichment ≤ 24 wt.% that does not contain ^{233}U, plutonium greater than 1.0% of the mass of ^{235}U, or substances that have a moderating effectiveness greater than that of H_2O (with the exception of polyethylene used for packing or wrapping the material).

V. Fissile Material Exceptions in TS-R-1

In the draft of TS-R-1 that is currently out for Member State comments, there are several changes to the international regulations pertaining to fissile material exceptions. One key change is that there is a provision for Member State Competent Authorities to invoke new exceptions for domestic use provided certain criteria have been demonstrated (e.g., assurance of subcriticality) for the specified material. Provisions similar to the U.S. provisions cited in 10 CFR 71 are presented within the proposed TS-G-1.1 guidance material as an example of an acceptable approach for Member States to approve exceptions for domestic use. Provisions on fissile-to-nonfissile mass ratio had been proposed for inclusion within the revised TS-R-1; however, consensus could not be reached on whether testing or pre-shipment measurements were needed to assure the material would retain the desired mass ratio under normal and accident conditions.

The proposed TS-R-1 provisions provide a 0.25 g limit as a quantity of fissile material that would not be defined as “fissile” for purposes of transport. Similarly, with a package having an overall external dimension of 10 cm, but no other requirements, up to 2 g of U-235 and 0.5 g of Pu could be transported given consignment limits of 45 g and 15 g respectively. The NRC will evaluate these proposed provisions in comparison to the 2 g provision of 10 CFR 15(a).

Additional changes in TS-R-1 require criticality safety consignment control that is not based on a CSI, and as a result both the consignment limits and the fissile nuclide mass per package that had been previously allowed have been substantially reduced from earlier versions of TS-R-1. Conveyance limits, set at 45 grams of fissile nuclides under exclusive use, were also added to allow shipment of small samples or small volumes of low concentration waste material.

Although these proposed changes make the TS-R-1 draft similar to those in the current U.S. regulations (10 CFR 71), the differences in the fissile-to-nonfissile mass ratios presented in Table M of the draft TS-R-1, the reduction of the 2 gram limit under paragraph 417, consignment controls and conveyance limits will need to be evaluated. The United States will consider adopting the proposed changes in the next major revision of 10 CFR Part 71 based on their applicability as well as the needs of their domestic stakeholders.

VI. Summary and Conclusions

The revision to 10 CFR Part 71 in the 2004 rule-making represented a simplified and risk-informed approach to allowing self-certified shipments of low-criticality-risk material in the U.S. The fissile exemptions in §71.15 and general license for fissile material in §71.22 provide a great deal of flexibility for shippers of small quantities or concentrations of fissile material, while providing a pragmatic and reasoned basis for safety commensurate with the potential risk. Although the need for minor changes to the current fissile exemptions and general license has been identified, licensees have expressed their satisfaction with the simplicity and utility of the revised regulation, and the experience thus far with these provisions indicate to NRC that they provide an adequate level of safety against inadvertent criticality. In future revisions of the fissile exemptions and general license, NRC will consider similar language in the IAEA TS-R-1 international transportation regulations, as well as the experience and insight gained by the industry in using these regulations.

References

1. Code of Federal Regulations, Title 10, Part 71, "Packaging and Transportation of Radioactive Material," January 1, 2010.

2. Federal Register, Vol. 62, No. 27, pg. 5907, 10 CFR Part 71, *Fissile Material Shipments and Exemptions*, Final Rule, Nuclear Regulatory Commission, February 10, 1997.

3. International Atomic Energy Agency, *Regulations for the Safe Transport of Radioactive Material*, IAEA Safety Standards Series No. TS-R-1, IAEA, Vienna (1996).

4. C.V. Parks, C.M. Hopper, and J.L. Lichtenwalter, *Assessment and Recommendations for Fissile-Material Packaging Exemptions and General Licenses Within 10 CFR Part 71*, NUREG/CR-5342, (ORNL/TM-13607), U.S. Nuclear Regulatory Commission, Oak Ridge National Laboratory, July, 1998.