

ASSESSMENT OF THE U.S. REGULATIONS FOR FISSILE EXEMPTIONS AND FISSILE MATERIAL GENERAL LICENSES*

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SUMMARY

The paragraphs for general licenses for fissile material and exemptions (often termed exceptions in the international community) for fissile material have long been a part of the *U.S. Code of Federal Regulations* (CFR)—10 CFR Part 71, "Packaging and Transportation of Radioactive Material." Although Part 71 has been revised to provide consistency with the 1985 Edition of the *IAEA Regulations for the Safe Transport of Radioactive Material* (IAEA 1985), general licenses that provide for transport of fissile material in nonapproved packages or controlled shipments remain a part of Part 71. More recently, the Nuclear Regulatory Commission (NRC) issued a final rule on Part 71 via emergency rule-making procedures (*Federal Register* 1997) in order to address an identified deficiency related to one of the fissile exemptions. To address the specified deficiency in a general fashion, the emergency rule adopted the approach of the 1996 Edition of the *IAEA: Regulations for the Safe Transport of Radioactive Material* (IAEA 1996), which places restrictions on certain moderating materials and limits the quantity of fissile material in a consignment. The public comments received by the NRC indicated general agreement with the need for restrictions on certain moderators (beryllium, deuterium, and graphite). The comments indicated concern relative to both the degree of restriction imposed (not more than 0.1% of fissile material mass) and the need to limit the fissile material mass of the consignment, particularly in light of the subsequent NRC staff position that the true intent (consistent with draft IAEA advisory information) was to provide control for limiting the fissile mass of the conveyance.

Even though the NRC emergency rule remains in place, staff at Oak Ridge National Laboratory (ORNL) are working with the NRC staff to perform a coherent review and documentation of the technical and licensing bases for the general licenses for fissile material and the fissile material exemptions. The purpose of the review is to identify potential deficiencies that might be adverse to maintaining adequate subcriticality under normal conditions of transport (NCT) and hypothetical accident conditions (HAC). In addition, ORNL has been asked to identify changes that would address any identified safety issues, enable inherently safe packages to continue to be unencumbered in transport, and seek to minimize the impact on current safe practices. This paper will examine the complex issues that must be addressed in the assessment and will discuss potential recommendations under consideration.

*This work was performed by Oak Ridge National Laboratory, managed by Lockheed Martin Energy Research Corp. for the U.S. Department of Energy under contract number DE-AC05-96OR22464.

BACKGROUND

In 1992 the IAEA formed a Consultants Services Meeting (CSM) to review and address Member State comments and identified issues related to criticality safety requirements and criticality safety controls provided in the 1985 Edition of the IAEA Regulations. For the next three years issues related to fissile material exemptions were constantly on the agenda at the subsequent CSMs on criticality safety issues and the pertinent Revision Panel Working Groups. The identified problem that opened the discussion was the concern that carriers would be provided a large quantity of packages containing fissile-exempt quantities that, taken as a whole on one conveyance, could provide an unacceptable risk to criticality safety.

As one might imagine, the issue of changing basic exemptions that had been a part of the regulations since inception and which had not previously posed any known safety risk during transport created some very intense discussions: How could the exempt fissile material be altered credibly be altered during loading and transport to cause a criticality concern? During the discussions it became apparent that there had been shipments where (intentionally or unintentionally) the accumulation of exempted 15-g packages had yielded an unacceptable quantity of uncontrolled fissile mass on one conveyance. This identified case, together with questions regarding credible changes to the loaded material during transport (normal and accident), led to the agreement to propose a method to control the quantity of fissile material in a shipment. Because of strong arguments against incorporating transport controls (e.g., a criticality safety index) in shipments of exempted packages, the 1996 Edition of the IAEA Regulations adopted wording that limits the quantity of exempt fissile mass per **consignment**. This change was perceived as an ad hoc control that would minimize impact on existing operational practice while limiting the fissile mass per conveyance (since Member State experts did not envision multiple consignments being provided to a carrier for a single conveyance).

The second change in the 1996 Edition of the IAEA Regulations related to fissile material exemptions was that beryllium and deuterium were restricted to 0.1% of the fissile mass. This proposed change came very late in the revision process and was accepted because it was recognized that the mass concentration limits provided per consignment were inadequate if these two materials were present to any significant degree. There was no technical basis for the 0.1% other than to ensure that the quantity was insignificant. Graphite, in its purest form, can also significantly reduce the mass concentration needed for criticality; however, concern over limiting waste shipments rich in carbon caused this material not to be considered until further study could be performed.

In 1996, an USNRC licensee informed the NRC staff of a potential situation where one of the fissile material exemptions in Part 71 would not have been adequate for criticality safety concerns if shipped in large quantities in the presence of beryllium (NRC 1996). The material being considered for transport was a uranium-beryllium filtercake, a waste product of a process involving weapons-grade uranium materials. The filtercake met the fissile material exemption provisions of Part 71 and the 1985 Edition of the IAEA Regulations, but the presence of beryllium caused large volumes of low concentration material to exceed safe values (Green 1997). Alerted to a potential practical transport situation where the regulations were deficient, the NRC initially issued an information notice (NRC 1996) and subsequently issued an emergency rule (*Federal Register* 1997) that effectively adopted the fissile material exemptions of the 1996 Edition of the IAEA Regulations and added graphite to the list of

restricted moderators. The NRC emergency rule also modified the general licenses for limited quantities per package and per shipment to restrict the identified moderators.

REVIEW OF THE ISSUES

One of the basic premises of the transport regulations is that subcriticality be maintained under normal conditions of transport (NCT) and hypothetical accident conditions (HAC). The regulations attempt to ensure that subcriticality by specifying requirements that must be met for packages containing fissile material and implementing operational controls (e.g., transport index) for the shipment. The package requirements seek to ensure that the chemical, physical, and material conditions of the package necessary for subcriticality are maintained under NCT and HAC. The operational controls have been implemented to allow straightforward procedures for safe handling of the packages by transportation personnel who are not criticality specialists.

To be exempt from the requirements and controls for packages containing fissile material, both the NRC and the IAEA regulations specify that the fissile material must be less than certain quantities (e.g., 15 g per package) or meet prescribed conditions related to concentration (e.g., 5 g in a 10-liter volume), homogeneity, enrichment etc. The general licenses for fissile material provided in the United States per Part 71 also dispense with the requirements for packages containing fissile material if the fissile material quantity is limited per package or controlled shipment and certain select conditions on the contents or package are met. Fissile material quantities with and without moderator limitations (beryllium, deuterium, and hydrocarbon oils excluded and carbon limited to 7.7 times the total mass of ^{235}U and plutonium) are provided in tables. A prescription for determining a transport index to provide shipment control is provided with the general license for packages.

The requirements and controls for certified packages containing fissile material are constantly under scrutiny as the knowledge base and experience are expanded because of the need to perform and submit package safety assessments for review and because of the oversight provided each shipment. Similar scrutiny has not been applied to the fissile exemptions or general license provisions, nor has there been a mechanism to expand the knowledge base or practical experience associated with allowed shipments. However, for years criticality specialists have postulated a number of situations where the conditions specified by the exemptions might not be sufficient in themselves to prevent a potential for a critical or near-critical situation (Mennerdahl 1996 and Shaeffer et al. 1997) under NCT or HAC. For example, the basis of safety for the HAC is not theoretically justified for an exempt concentration of 5 g of fissile material per 10 liters of contaminated combustibles if one has a large volume and considers the effect of a fire, concentration of the fissile material, and moderation.

The potentially unsafe situations reviewed by Mennerdahl and Shaeffer et al. are generally characterized by large volumes, lack of absorbing impurities, and/or the presence of very selective materials. With the consignment mass limitation and the moderator restrictions in the 1996 Edition of the IAEA Regulations and the emergency rule issued by the NRC, there was an attempt to address these known situations that could compromise safety. However, although identified situations of potential safety concern have been addressed, some might question the need for the changes based on «practical» aspects of a shipment. Similarly, Shaeffer et al. present impacts of the changes that need to be considered: The applicability of using 0.1% of the fissile mass as the measure to restrict selected moderators (e.g., it could

remove some small quantity, inherently safe packages from exempt status) and the increased number of shipments and/or measurement scrutiny that may be needed to abide by the consignment mass limitation.

The objectives of the current assessment are broader than simply addressing issues such as those discussed by Shaeffer et al. Instead, the assessment seeks to do the following:

1. Perform a review of the regulations (exemptions and general licenses) to document the technical basis and identify any potential deficiencies that might be adverse to criticality safety.
2. Address the question of whether shipments that use the fissile exemptions and general licenses provide similar assurance of public health and safety as that provided by shipments with packages meeting the requirements for fissile material contents.
3. Identify areas where regulatory wording might cause confusion among licensees and potentially lead to safety concerns.
4. Provide a justifiable technical and licensing basis for either using the existing regulations or changing the regulations as recommended based on the findings of items 1 through 3. As appropriate, practical aspects of transportation or licensing that could mitigate, justify, or provide a historical basis for any identified potential deficiencies will be considered. Recommendations to change the current regulations should seek to minimize the impact on current safe practice while correcting identified deficiencies.

The approach has been to consider the potential for simplifying the regulations on fissile material exemptions and fissile material general licenses, removing possible conditions that may present identified safety concerns without excluding shipment conditions that are inherently safe, and providing a technical basis for future reference.

ASSESSMENT OF PRACTICES

Discussions with various licensees have revealed that multiple consignments, individually qualifying as fissile material exemptions, have been offered (by single consignors) for transport on a single conveyance, thereby potentially exceeding a minimum subcritical mass of fissile material. The logic behind the limit on fissile mass in a consignment was that a consignor would not typically provide multiple consignments to a carrier. In the United States the carriers have been dividing their waste material for transport into separate consignments because the receiving site that disposes of the material **below ground** can only handle 350 g on-site **above ground**. Thus, multiple consignments on a transport allow the transport vehicle to remain at the site boundary while each single consignment is brought on site and disposed. This practice and the associated regulations that «encourage» it are beyond the scope of this paper, but note that the practice was perfectly legitimate under previous regulatory rules and could be interpreted as legitimate under the wording of the current rule. The occurrence of this practice would potentially indicate that shipment control should be extended to cover the conveyance and **not** be limited to the consignment.

In general, it has been difficult to obtain feedback on the recent NRC rule change, not because of a resistance from shippers, but because they do not seem to have fully assessed the impact of the changes and their effect on future shipments. It is suspected that U.S. Department of

Energy (DOE) sites may have concern with the moderator exclusion portion of the rule change because they are more likely to transport small-quantity fissile packages with some amounts of the excluded moderators. Discussions of the changes in the regulations, together with interpretations of the nature of the implications have, as much as anything, invoked incredulous responses: Why has this been done? Haven't these types of shipments been made safely for years? Is there some other method whereby I can ship this material and still be exempt?

ASSESSMENT OF THE REGULATORY LANGUAGE

The bases for and clarity of the general licenses for fissile material and the exemptions for fissile material in Part 71 (and correspondingly, the IAEA regulations) have become increasingly confusing with adjustments and accommodations of the regulations over time, as well as with shipper (consignor) interpretations and applications.

Although many of the specifications in the fissile material exemptions have a tie to readily available information on critical safe parameters, it is clear that an understanding of the tie between this information and acceptable practice has sometimes been obscured. For example, the advisory material developed (available as final draft; not published to date) for the 1996 Edition of the IAEA Regulations gives some background on the 15-g-per-package limitation in the fissile exemptions. The 15-g value was derived from analysis of 250 1-liter packages considering only water moderation. Although 15 g in a package is safe, it is obvious from the latest regulatory changes that the need to prevent a large accumulation of packages was lost to the practitioner over the years.

It would be difficult to formulate a definitive argument that the transport safety criteria for fissile material general licenses and exemptions for fissile material conform to the transport safety criteria imposed by the standard requirements and controls for packages containing fissile material. Limiting conditions for the general licenses and fissile material exemptions do not clearly correlate with subcriticality and safety for the packaging and transportation of fissile material under both NCT (where five times the number of undamaged packages per shipment is adequately subcritical) and HAC (where two times the number of damaged packages per shipment is adequately subcritical). In other words, it is easy to conceive of instances (perhaps not altogether practical, but nevertheless allowed by the regulations) where the margin of safety provided by a shipment exempted from classification as fissile material is less than that provided by the shipment of a package certified for transport of fissile material.

Various instances occur in the fissile material exemptions where the intent of both Part 71 and the IAEA regulations can be questioned or, perhaps worse, misunderstood, especially in the use of qualifying words. For example:

1. One must consider the presence of material with **average** hydrogen density less than or equal to water. What procedure should be used to determine the average?
2. The fissile material must be distributed **homogeneously** throughout the package contents and not form a **lattice** arrangement. The distinction between homogeneous and heterogeneous can be very difficult to ascertain, yet the classification can have a distinct impact on criticality safety.

In addition, in the United States, the licensee is subjected to possible confusion because of the differences between the wording used in the Department of Transportation regulations and the NRC regulations. Consistency in definition and stated intent needs to be provided.

POTENTIAL CRITERIA MODIFICATIONS

A fundamental question to address when considering criteria modifications is whether the exemptions for fissile material must be inherently safe based on improbable events and theoretical bases or can credible realistic arguments be formulated about what can and will be shipped or what can and will happen. The latter approach seems to be the basis for the initial formulation of the exemptions and general licenses for fissile material. The difficulty here is that «what can and will be shipped» changes with the needs of the industry and «what can and will happen» varies with the shipper and the conditions of shipment. Taking a strict theoretical approach leads one to criteria that are viewed as unreasonable based on historic practices and safety records.

As an extreme example, consider Part 71 and the 1985 Edition of the IAEA Regulations where 70 Bq/g is the radiation limit below which the regulations do not apply. Assuming some extrapolation of critical mass curves for uranium enriched to 93 wt % ^{235}U , one can estimate that about 800 liters (less than 1 m³) of BeO can be brought to critical with a uranium concentration that would be less than the radioactive material exemption limit. Obviously, obtaining the purity of BeO and uranium needed throughout such a large volume is not a simple task and the practicality of having a safety problem is extremely remote, but it appears that the exemption limit was developed with little sensitivity relative to potential criticality safety concerns. And to categorically state that such a system would not be considered for transport would be unfounded based on the recent issue surrounding the uranium-beryllium filtercake.

The approach currently being applied in this assessment is to develop theoretically defensible arguments that seek to incorporate practical constraints and consistency with the licensing concepts of the requirements and controls for packages containing fissile material. The first phase of the work is to investigate the technical basis of the existing criteria for the fissile material exemptions and general licenses. The review indicates that the criteria for the exemptions are valid for the 1996 Edition of IAEA Regulations and the recently revised Part 71. The technical bases for the criteria are discussed in the advisory material that will soon be published for the 1996 Edition of the Regulations. As indicated earlier, the criteria assume water moderation and no change of conditions during transport. Additional work is needed to determine criteria for a revision of the 0.1% restriction on admixing of materials, such as beryllium, deuterium, or graphite.

Some of the existing criteria for the general licenses for fissile material are somewhat more tenuous. For example, the permissible mass limits based on ^{235}U enrichment and uniformity (homogeneous vs heterogeneous) appear to be consistent with early reference material (Paxton et al. 1964) but not with more recent revisions of the same report (Paxton and Pruvost 1986). Obviously, if nothing else is altered, these criteria should be investigated and changed as needed based on the most recent technical information related to critical systems.

To this end ORNL has initiated work to calculate concentration and mass criteria that will maintain subcriticality for homogeneous and heterogeneous systems. Potential criteria are

being derived by considering the following combination of parameters:

- fissile nuclides: ^{233}U , ^{235}U , ^{239}Pu , ^{241}Pu , or a combination thereof;
- typical moderator materials: CH_4 , H_2O , D_2O , BeO , soil (SiO_2), Be , or a combination thereof;
- ^{235}U enrichment;
- infinite systems and finite systems;
- heterogeneity/homogeneity; and
- packaging materials (iron, wood, etc.).

Initial considerations have been directed towards infinite homogeneous systems of ^{235}U metal with the listed moderating materials. Insight gained from infinite system calculations has been applied to finite-system calculations in order to narrow the number of calculations. The finite systems will be used to consider recommended changes to the general licenses. For homogeneous systems of finite volume, the volume is taken to be limited by that available in a typical tractor trailer and the calculated effective neutron multiplication factor is limited to 0.93 after consideration of appropriate bias and uncertainties. Optimum interspersed moderation and close-water reflection are being considered for all finite system calculations. Package-specific calculations of arrays of damaged 110-gal., 20-gauge steel, tight-head steel drums are being evaluated to ascertain the effect of packaging materials on reactivity. Wood boxes may also be considered as needed. With the exception of uranium and water, the contents of the damaged package are assumed to be compacted and to constitute a more realistic 60% of the bulk volume, leaving a void fraction of at least 40% available for water flooding.

The initial set of analyses focus on fully enriched uranium as the prototypic system that can be used to formulate and test possible recommendations for future revisions to the regulations. Subsequent to selecting final recommendations, this process will be repeated using other uranium enrichments and fissile materials beside ^{235}U , and for heterogeneous systems as the need arises.

CONCLUSIONS

The 1996 Edition of the IAEA Regulations and the recent changes to Part 71 provide some needed modifications that will help ensure that fissile material transported under exemption and general license clauses will not present a potential criticality safety concern. However, the reduced regulatory oversight provided to exempt and general license shipments makes it important that the technical and licensing basis for these portions of the regulations be well documented and understood by the transport community. The need for clear, unambiguous, and straightforward specifications and language in the regulations is of paramount importance.

The current assessment has confirmed that there are no routine or significant criticality safety hazards associated with the practical applications of the general licenses and exemptions. The reason for this conclusion is that the typical qualifying fissile material matrix in a general license or exempt consignment is relatively stable as dry, activated waste or in a nearly noncombustible form. The primary concern is that the fissile material general licenses and exemptions do not have a theoretically defensible equivalency of safety with shipments that must meet the requirements and controls for fissile material. In addition, confusion over what

is intended by the general provisions and exemptions could lead to unsafe practices. Countering these concerns is the fact that the tight restriction on deuterium, beryllium, and graphite is so low as to exclude inherently safe packages of fissile material from being exempt. In fact, the restriction of deuterium to 0.1% of the fissile mass can even prevent some inherently safe, water-moderated shipments from being made as an exempted shipment.

The assessment work to date indicates that consideration needs to be given to providing some type of transport control (e.g., a transport index or criticality safety index) on exempt shipments in order to ensure adherence to a **conveyance** limit. It appears from a review of existing practices in the United States that a consignment limit is not altogether satisfactory for limiting quantities on a conveyance. Furthermore, it is obvious that restricting certain low-neutron-absorbing materials to less than 0.1% of the fissile mass is not a satisfactory approach because of the deuterium noted above and the potential to restrict transport of some inherently safe packages of very small fissile material quantities. There will also surely be a desire to provide for simple and easy transport of very small quantities of fissile materials for which any type of consignment or conveyance limit would not seem applicable. To provide defensible and straightforward limits for the general licenses, additional analyses may need to be performed to develop and justify criteria that are consistent with current information on nuclear data and critical systems.

In light of both recent domestic and international situations where the transport community has presented practical examples that challenge the safety criteria of the regulations, it is felt that the current assessment of fissile material exemptions and general licenses will benefit future deliberations related to potential needs for regulatory changes.

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