IAEA TECDOC SERIES

IAEA-TECDOC-1768

IAEA-TECDOC-1768

Application of the Revised Provisions for Transport of Fissile Material in the IAEA Regulations for the Safe Transport of Radioactive Material

2012 Edition

IAEA
International Atomic Energy Agency

IAEA SAFETY STANDARDS AND RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards.

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety. The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

Information on the IAEA's safety standards programme is available at the IAEA Internet site

http://www-ns.iaea.org/standards/

The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at PO Box 100, 1400 Vienna, Austria.

All users of IAEA safety standards are invited to inform the IAEA of experience in their use (e.g. as a basis for national regulations, for safety reviews and for training courses) for the purpose of ensuring that they continue to meet users' needs. Information may be provided via the IAEA Internet site or by post, as above, or by email to Official.Mail@iaea.org.

RELATED PUBLICATIONS

The IAEA provides for the application of the standards and, under the terms of Articles III and VIII.C of its Statute, makes available and fosters the exchange of information relating to peaceful nuclear activities and serves as an intermediary among its Member States for this purpose.

Reports on safety and protection in nuclear activities are issued as **Safety Reports**, which provide practical examples and detailed methods that can be used in support of the safety standards.

Other safety related IAEA publications are issued as **Radiological Assessment Reports**, the International Nuclear Safety Group's **INSAG Reports**, **Technical Reports** and **TECDOCs**. The IAEA also issues reports on radiological accidents, training manuals and practical manuals, and other special safety related publications.

Security related publications are issued in the **IAEA Nuclear Security Series**.

The **IAEA Nuclear Energy Series** consists of reports designed to encourage and assist research on, and development and practical application of, nuclear energy for peaceful uses. The information is presented in guides, reports on the status of technology and advances, and best practices for peaceful uses of nuclear energy. The series complements the IAEA's safety standards, and provides detailed guidance, experience, good practices and examples in the areas of nuclear power, the nuclear fuel cycle, radioactive waste management and decommissioning.

APPLICATION OF THE REVISED PROVISIONS FOR TRANSPORT OF FISSILE MATERIAL IN THE IAEA REGULATIONS FOR THE SAFE TRANSPORT OF RADIOACTIVE MATERIAL

The following States are Members of the International Atomic Energy Agency:

AFGHANISTAN
ALBANIA
ALGERIA
ANGOLA
ARGENTINA
ARMENIA
AUSTRALIA
AUSTRIA
AZERBAIJAN
BAHAMAS
BAHRAIN
BANGLADESH
BELARUS
BELGIUM
BELIZE
BENIN
BOLIVIA, PLURINATIONAL STATE OF
BOSNIA AND HERZEGOVINA
BOTSWANA
BRAZIL
BRUNEI DARUSSALAM
BULGARIA
BURKINA FASO
BURUNDI
CAMBODIA
CAMEROON
CANADA
CENTRAL AFRICAN REPUBLIC
CHAD
CHILE
CHINA
COLOMBIA
CONGO
COSTA RICA
CÔTE D'IVOIRE
CROATIA
CUBA
CYPRUS
CZECH REPUBLIC
DEMOCRATIC REPUBLIC OF THE CONGO
DENMARK
DJIBOUTI
DOMINICA
DOMINICAN REPUBLIC
ECUADOR
EGYPT
EL SALVADOR
ERITREA
ESTONIA
ETHIOPIA
FIJI
FINLAND
FRANCE
GABON
GEORGIA
GERMANY
GHANA
GREECE
GUATEMALA
GUYANA
HAITI
HOLY SEE
HONDURAS
HUNGARY
ICELAND
INDIA
INDONESIA
IRAN, ISLAMIC REPUBLIC OF
IRAQ
IRELAND
ISRAEL
ITALY
JAMAICA
JAPAN
JORDAN
KAZAKHSTAN
KENYA
KOREA, REPUBLIC OF
KUWAIT
KYRGYZSTAN
LAO PEOPLE'S DEMOCRATIC REPUBLIC
LATVIA
LEBANON
LESOTHO
LIBERIA
LIBYA
LIECHTENSTEIN
LITHUANIA
LUXEMBOURG
MADAGASCAR
MALAWI
MALAYSIA
MALI
MALTA
MARSHALL ISLANDS
MAURITANIA
MAURITIUS
MEXICO
MONACO
MONGOLIA
MONTENEGRO
MOROCCO
MOZAMBIQUE
MYANMAR
NAMIBIA
NEPAL
NETHERLANDS
NEW ZEALAND
NICARAGUA
NIGER
NIGERIA
NORWAY
OMAN
PAKISTAN
PALAU
PANAMA
PAPUA NEW GUINEA
PARAGUAY
PERU
PHILIPPINES
POLAND
PORTUGAL
QATAR
REPUBLIC OF MOLDOVA
ROMANIA
RUSSIAN FEDERATION
RWANDA
SAN MARINO
SAUDI ARABIA
SENEGAL
SERBIA
SEYCHELLES
SIERRA LEONE
SINGAPORE
SLOVAKIA
SLOVENIA
SOUTH AFRICA
SPAIN
SRI LANKA
SUDAN
SWAZILAND
SWEDEN
SWITZERLAND
SYRIAN ARAB REPUBLIC
TAJIKISTAN
THAILAND
THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA
TOGO
TRINIDAD AND TOBAGO
TUNISIA
TURKEY
UGANDA
UKRAINE
UNITED ARAB EMIRATES
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND
UNITED REPUBLIC OF TANZANIA
UNITED STATES OF AMERICA
URUGUAY
UZBEKISTAN
VENEZUELA, BOLIVARIAN REPUBLIC OF
VIET NAM
YEMEN
ZAMBIA
ZIMBABWE

The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

IAEA-TECDOC-1768

APPLICATION OF THE REVISED PROVISIONS FOR TRANSPORT OF FISSILE MATERIAL IN THE IAEA REGULATIONS FOR THE SAFE TRANSPORT OF RADIOACTIVE MATERIAL

2012 EDITION

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2015

COPYRIGHT NOTICE

For further information on this publication, please contact:

Regulatory Infrastructure and Transport Safety Section
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
Email: Official.Mail@iaea.org

Printed by the IAEA in Austria
August 2015

IAEA Library Cataloguing in Publication Data

Application of the revised provisions for transport of fissile material in the IAEA regulations for the safe transport of radioactive material, 2012 edition. — Vienna : International Atomic Energy Agency, 2015.
p. ; 30 cm. — (IAEA-TECDOC series, ISSN 1011–4289 ; no. 1768)
ISBN 978–92–0–106215–4
Includes bibliographical references.

1. Radioactive substances — Transportation — Safety measures. 2. Radioactive substances — Safety regulations. 3. Radioactive substances — Packaging — Safety measures. I. International Atomic Energy Agency. II. Series.

IAEAL 15–00983

FOREWORD

The Statute of the IAEA authorizes it to establish or adopt standards of safety for protection of health and minimization of danger to life and property — standards that the IAEA uses in its own operations and which States can apply by means of their regulatory provisions for nuclear and radiation safety. The IAEA does this in consultation with the competent organizations of the United Nations and with the specialized agencies concerned. A comprehensive set of high quality standards under regular review is a key element of a stable and sustainable global safety regime, as is the IAEA's assistance in their application. The IAEA commenced its safety standards programme in 1958.

In 2012, the IAEA published IAEA Safety Standards No. SSR-6, Regulations for the Safe Transport of Radioactive Material, 2012 Edition, a revision of the IAEA regulations. The 2012 Edition includes major revisions to the provisions that allow exceptions to the use of competent authority approved package designs for the transport of fissile material. These revisions address safety concerns identified by Member States by providing a graded approach with consistent assurance of criticality safety. Where possible, practical needs identified by industry as beneficial to efficiency and clarity in applying the regulations are addressed. This publication provides the background and overview to the revised requirements, as well as providing practical advice regarding the use of the revised provisions.

The IAEA would like to express its gratitude to N. Barton (United Kingdom), C. Parks (United States of America) and I. Reiche (Germany) for their significant contributions and the finalization of this publication. In addition, the IAEA aknowledges and appreciates the financial contribution made by the UK Office for Nuclear Regulation to support the preparation of this publication and the World Nuclear Transport Institute for supporting the experts' participation. The IAEA officer responsible for this publication was N. Capadona of the Division of Radiation, Transport and Waste Safety.

EDITORIAL NOTE

This publication has been prepared from the original material as submitted by the contributors and has not been edited by the editorial staff of the IAEA. The views expressed remain the responsibility of the contributors and do not necessarily represent the views of the IAEA or its Member States.

Neither the IAEA nor its Member States assume any responsibility for consequences which may arise from the use of this publication. This publication does not address questions of responsibility, legal or otherwise, for acts or omissions on the part of any person.

The use of particular designations of countries or territories does not imply any judgement by the publisher, the IAEA, as to the legal status of such countries or territories, of their authorities and institutions or of the delimitation of their boundaries.

The mention of names of specific companies or products (whether or not indicated as registered) does not imply any intention to infringe proprietary rights, nor should it be construed as an endorsement or recommendation on the part of the IAEA.

The IAEA has no responsibility for the persistence or accuracy of URLs for external or third party Internet web sites referred to in this publication and does not guarantee that any content on such web sites is, or will remain, accurate or appropriate.

CONTENTS

1. INTRODUCTION

The IAEA Regulations for Safe Transport of Radioactive Material, including fissile material, have been in place since 1961 and have been periodically reviewed by Member State experts and revised by the IAEA as needed to address safety concerns. The Regulations have historically provided requirements for package design, package performance, and operations based, in part, on the type of radioactive material that would be included in the package. Since their introduction the Regulations have included criteria to permit the transport of fissile material in packages not requiring competent authority (CA) approval of the design for the transport of fissile material.

With the 2012 Edition of the Regulations (hereafter referred to as the 2012 Edition), the IAEA has significantly revised the approach used to allow for transport of fissile material in packages of designs other than those approved by CA for fissile material. The new approach establishes a set of provisions in a graded manner and, for each provision, establishes criteria and requirements that consistently assure criticality safety.

The 2012 Edition has four clear groups of provisions for the transport of material containing fissile nuclides:

1. Transport where the material is excluded from the definition of fissile material,
2. Transport with exception from UN "FISSILE" classification and criticality safety index (CSI) accumulation control,
3. Transport with UN "FISSILE" classification and CSI control but without CA approval as a package design for fissile material.[1]
4. Transport in a package for which the design is approved by the CA to contain fissile material (unchanged from the 2009 Edition).

These are illustrated in Figure 1.

The first set of provisions provides exclusion to the fissile definition and most of the provisions within the second set of provisions are new ones that replace the familiar provisions of past editions to the Regulations. The third set of provisions is newly introduced to the Regulations with the 2012 Edition. Since industry use of these provisions may not require any review or approval by the Member State CA, it is important that the overall graded approach and the specific provisions be well understood. Thus, this publication will provide Member States with an overview of the provisions for transport of fissile material together with an understanding of the technical basis for safety. However, the primary purpose of the publication is to provide guidance on how to appropriately identify if fissile material can be shipped in packages whose designs do not require CA approval for fissile material and to provide advice on the proper implementation of each provision. Practical examples describing implementation of the exception provisions will be provided and discussed. These examples will illustrate the benefits of using the different exceptions and highlight particular challenges or issues that may need to be considered. The guidance material will help not only in improving the performance of industry in preparing consignments that include fissile nuclides, but also in avoiding possible occurrences of denials or delays of this type of shipment due to the lack of knowledge on the new provisions.

---

[1] Package design approval may be required even though it does not contain fissile material.

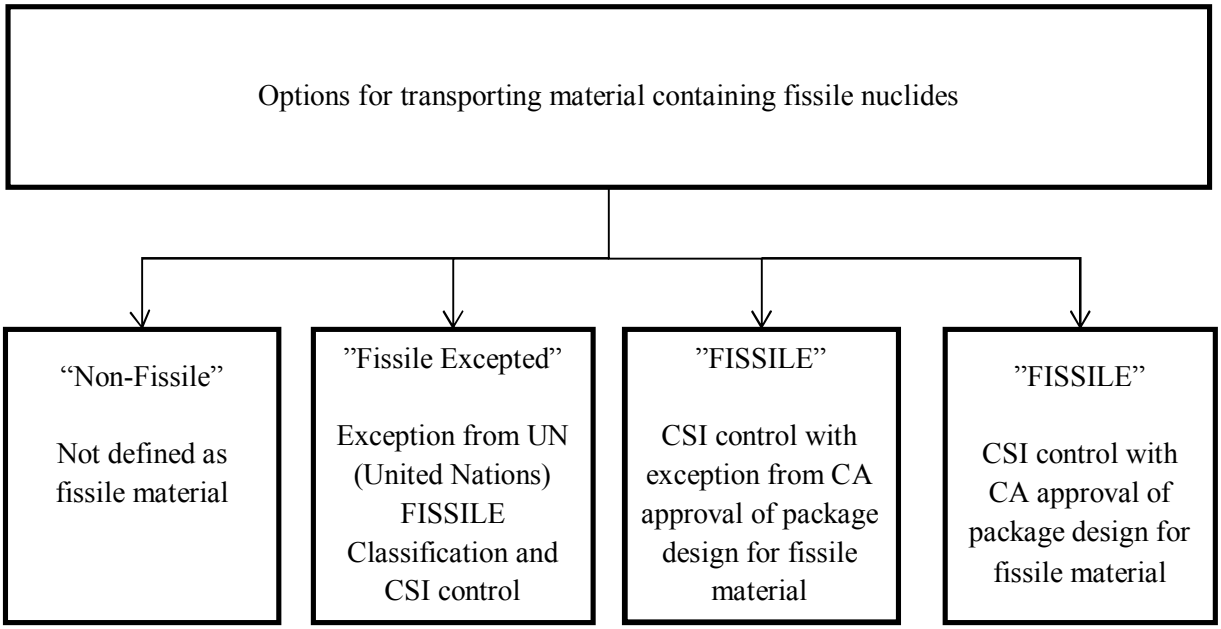

FIG. 1: Provisions for the transport of material containing fissile nuclides.

2. BACKGROUND

Provisions that provided criteria whereby package designs approved by a CA to contain fissile material were not required to transport fissile nuclides have existed in the Regulations since 1961. In the edition of the regulations immediatley prior to 1996 [1] none of these criteria required control of accumulation of packages. Yet for some provisions, large accumulations of packages, particularly under accident conditions, clearly presented a potential challenge to criticality safety. The adequacy of many of these criteria was challenged, particularly in regards to the accumulation of material and assurance of continued adherence to the criterion under accident conditions of transport. Thus, with the introduction of the 1996 Edition of the regulations [2], many of the exception criteria were constrained by a limit on the total mass of fissile nuclides that could be shipped in a consignment.

Rather than resolve the discussion on exceptions for transport of fissile material, the 1996 Edition seemed to introduce additional concerns from Member States. For example, imposing a mass limit on a consignment provides insufficient control for criticality safety since the approach did not prevent consignment accumulation or unintended mixing of multiple consignments during shipment. However, the imposition of a mass limit per consignment further highlighted concerns with industry's growing need for transport of what was perceived by many to be very low-risk fissile material (e.g., large volumes of waste products with very low concentrations of fissile nuclides). By 2009 the IAEA had accumulated over 100 proposals related to the development of improved criteria [3].

Through extensive efforts on the part of many individuals and organizations representing many of the Member States, the 2012 Edition provides a significant modification to the options for transport of fissile nuclides not requiring UN FISSILE classification. Throughout the process leading up to the issuance of the 2012 Edition, there was an effort to (1) ensure identified safety concerns were addressed, (2) strive for consistency in terms of the margin of safety provided with each provision, (3) seek industry input to understand the types of material perceived to be of sufficiently low risk not to require classification as FISSILE, (4) establish package designs for fissile material that are both flexible and sufficiently specified not to require additional criticality safety demonstration of their designs, and (5) minimise the impact of the transition from the 2009 Edition [4].

3. OVERVIEW OF THE PROVISIONS FOR THE TRANSPORT OF FISSILE NUCLIDES

This section provides a simplified overview of the requirements for the transport of fissile material as well as the provisions in the 2012 Edition for transport without CA approval of the package designs for fissile material, along with the bases for revising the 2009 Edition. The relevant paragraphs related to the transport of material containing fissile nuclides from the 2012 Edition are provided in the Appendix for reference. Figure 2 provides a simplified overview of the provisions for transport of material containing fissile nuclides discussed in this section.

Sections 3.1-3.4 give details of each of the provisions summarised in Figure 2.

3.1. EXCLUSION FROM DEFINITION AS FISSILE MATERIAL

The 2009 and 2012 Editions properly define fissile material as material containing fissile nuclides, which, for the interpretation of the Regulations, are defined as uranium-233, uranium-235, plutonium-239 and plutonium-241. Excluded from the definition of fissile material is natural uranium or depleted uranium that is unirradiated or that has been irradiated in thermal reactors only. In the 2012 Edition, the definition was expanded to exclude material with less than 0.25 g of fissile nuclides. This exclusion was added in recognition that many materials have trace quantities of fissile nuclides and that the intent of the Regulations is not to have such materials governed under the requirements set forth for fissile material. Another clarifying point provided with the 2012 Edition is that the exclusions cited are valid only if there is no other material with fissile nuclides in the package, or in the consignment if shipped unpackaged. This last clarification was added recognizing that some criticality safety assessments for packages designed to transport fissile material might not account for the potential impact the presence of the fissile nuclides within natural or depleted uranium in the contents or packaging design (e.g., depleted uranium as shielding) could have on reactivity.

3.2. EXCEPTION FROM CLASSIFICATION AS FISSILE AND FROM CSI CONTROL

In the edition [1] prior to the 1996 Edition, provisions regarding the transport of fissile material in packages whose designs were not approved by a CA for fissile material were considered to be safe based on the inherent characteristics included in the IAEA provisions and on the assumed industry application of those provisions. They were considered as “fissile-exceptions” in the sense that they were not classified as FISSILE and there was no accumulation control. In the 1996 Edition a limit placed on each consignment was introduced for some of the exceptions, but given that there was no control over accumulation of multiple consignments, the three provisions that limited the mass per consignment (see para. 417(a) of the 2009 Edition) were challenged and were subsequently removed in the 2012 Edition.

The removal of two of those exceptions was of significant concern to industry due to their widespread use. These two exceptions were for shipments of up to 15 g of fissile nuclides in a package and the shipment of material where there was no more than 5 g of fissile nuclides in any 10 litre volume of material. Although safe in the vast majority of situations, accumulation of multiple packages with up to 15 g of fissile nuclides per package could in some cases present a challenge to criticality safety. Depending on the material media and the potential for redistribution, the limit of 5 g of fissile in any 10 litre volume created the possibility of configurations that could approach criticality [5, 6]. Industry identified a continuing need for the shipment both of small quantities of fissile material as well as larger masses of fissile material in forms judged to pose a very low risk for potential criticality. CAs concurred with these needs, and the Member State experts sought to address the issue while ensuring that criticality safety was maintained in a manner consistent with that of package designs approved by a CA for fissile material.

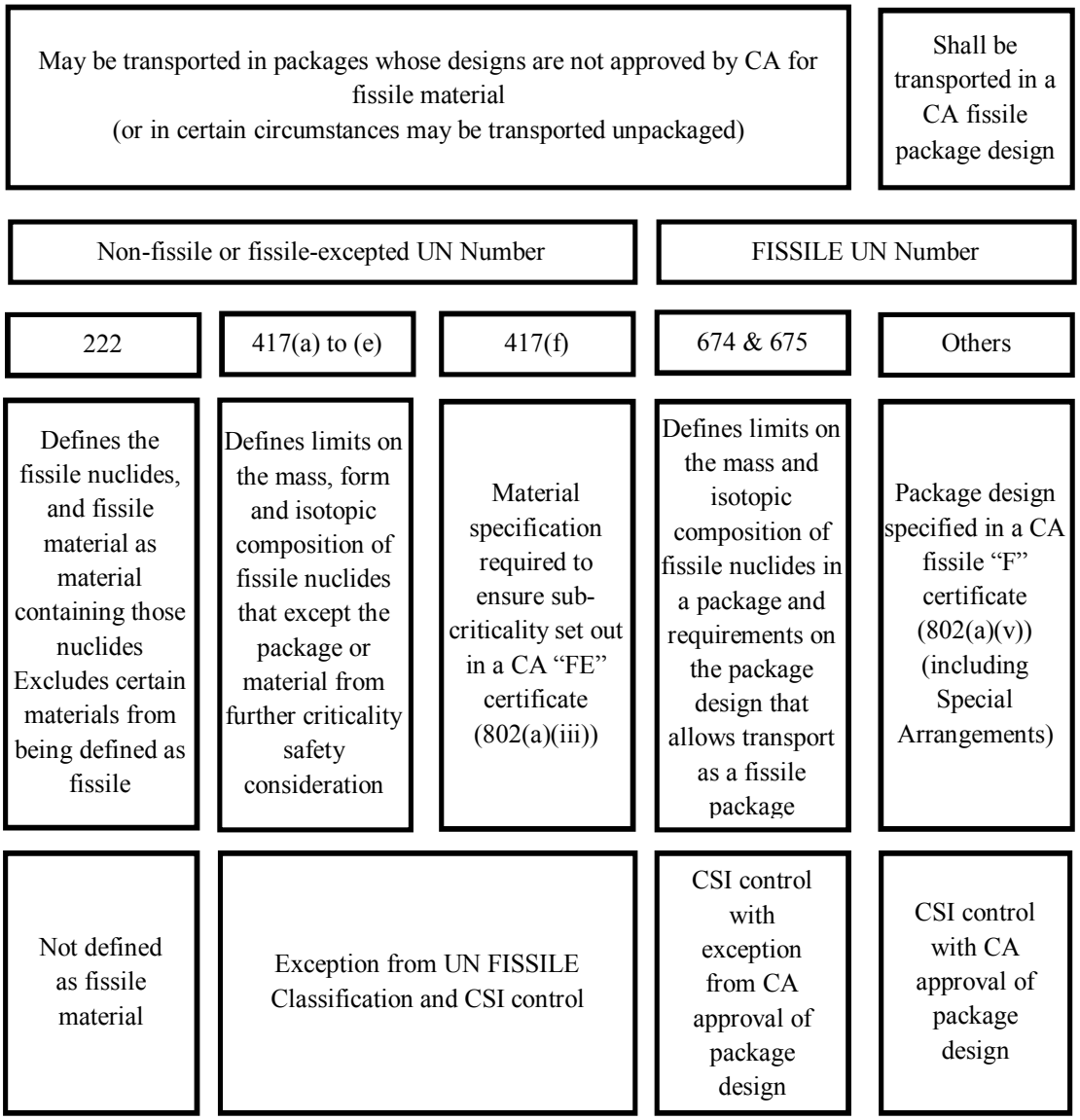

FIG. 2. Overview of the provisions for the transport of fissile nuclides.

3.2.1. Small quantities of fissile material

Member State experts sought to determine an exception limit for small masses of fissile nuclides based on some equivalency with CSI-controlled packages. In a strict quantitative sense, such an exception was not possible; rather, risk-based judgment on unintended errors or inadvertent mixing during shipment had to be carefully considered in determining the value of the small quantity of fissile material per package that would be excepted from CSI control. Values of less than a gram to several grams were proposed, and industry input was sought to best understand the types of such shipments that were currently in commerce. The key identified need was for shipment of samples to support various activities including environmental sampling, research and testing.

The approach agreed to by the Member State experts was to use the same general approach provided in para. 417(a)(i) of the 2009 Edition — a mass limit on fissile nuclides per package, combined with a mass limit on the fissile nuclides per consignment. However, compared to the 2009 Edition, the 2012 Edition [see para. 417(d) and para. 570(d)] provides a significant restriction on both the allowed mass of fissile nuclides per package (from 15 g to 2 g) and on the allowed mass of fissile nuclides per

consignment (from 400/250 g for fissile uranium/plutonium nuclides to a uniform 15 g for all fissile nuclides). Therefore, it would take 2 g of uranium-235 per package, 7 or 8 packages per consignment, and an accumulation of at least 30 consignments before the 450 g safe subcritical uranium-235 mass is approached (see Table 1 in Section 3.4.3). The low probability and consequential risk associated with such an accumulation was judged, in comparison to the 5N/2N criteria (see Section 4.3) for package designs approved by CA for fissile material, to provide a sufficient margin of safety for transport. Plutonium, of high concentration and with fissile isotopes in a mass greater than about 1 g, would have to be shipped in a Type B(U) or B(M) package, mitigating concerns about the lower number of consignments (18 consignments per paras 417(d) and 570(d)) needed before approaching the 280 g safe subcritical limit as given in Table 1 for fissile plutonium nuclides.

One area of concern expressed early by industry was the long-established commercial practice of shipping sample bottles with UF_6 having uranium enrichments less than 5 wt% uranium-235. Using a ratio between the values for uranium enriched to 5 wt% and 100 wt% uranium-235 from Table 1, it was judged that the mass limit of fissile nuclides could be increased to 3.5 g uranium-235 per package, provided that the enrichment was limited to 5 wt% uranium-235 [see para. 417(c) of the 2012 Edition]. For this situation, the mass of uranium-235 per consignment was raised to 45 g per para. 570(c) of the 2012 Edition. At 3.5 g uranium-235 per package, it would take 12 or 13 packages per consignment and at least 19 consignments to approach the 850 g uranium-235 safe subcritical mass.

Provisions for unpackaged material in the 2009 Edition [see para. 417 (a) (i)] limited the consignment quantity of fissile nuclides to the 15 g package limit. The approach for unpackaged material was modified with the 2012 Edition [see paras 417(e) and 570(e)] in that unpackaged fissile material now requires exclusive-use shipment; however, the allowed mass of fissile nuclides was raised to 45 g. In comparison to paras 417(d) and 570(e) a lower number of accumulated conveyances would be required before approaching the subcritical limit as provided in Table 1 (10 for uranium-235 and 6 for plutonium). This is mitigated by the limit being applied to the conveyance rather than a consignment and the requirement for shipment under exclusive use. Para. 417(e) is the only provision that can be applied to both unpackaged and packaged material.

3.2.2. Exception based on fissile material characteristics

Compared to the 2009 Edition, the 2012 Edition carries forward only two exceptions where classification as fissile continues not to be required. Thus, fissile material that meet the criteria of either of these exceptions can be transported in package designs that do not require CA approval and CSI control is not required during transport. These exceptions are for homogeneous systems of uranium enriched to less than 1wt% uranium-235 [para. 417(a) of the 2012 Edition] and uranyl nitrate solutions enriched to less than 2 wt% uranium-235 [para. 417(b) of the 2012 Edition].

After discussions for nearly a decade, the Member State experts could not reach consensus on other general characteristics of fissile material that could be excepted from classification as FISSILE and thus from CSI control. The approach most discussed was one proposed by the United States, where a ratio of nonfissile-to-fissile solid mass is used to provide mass dilution of fissile nuclides that are judged sufficient for exception by the US transport regulations [7]. In light of concerns raised about a mass ratio exception and concerns from industry that such an approach might not be suitable for all perceived needs for shipping low-risk material (e.g., low-reactivity material such as process waste), it was decided that the best option was to provide flexibility for each Member State. The flexibility is provided through the potential for a new fissile material to be excepted from classification as FISSILE. The procedure is to (1) demonstrate criticality safety for a fissile material design [para. 606[2]], (2)

[2] Paras, 606, 805, 806 and 835 (and subheadings): See footnote for para. 802(a)(v).

obtain CA approval [para. 802(a)(v)][3] of the fissile material design and (3) apply the CA approval to actual packaged [para. 417(f)] and consigned [subparagraphs 570(a) and (b)] fissile material. Guidance on obtaining CA approval is provided in Section 6.3.

A regulator's perspective [6] on typical challenges and uncertainties that may be faced by industry and the CAs in order to support an application and to issue a certificate for fissile material to be excepted from classification as FISSILE per para. 417(f) is informative. New advisory material SSG-26 [8] has been prepared in order to help clarify what applicants need to consider in preparing their safety case. However, implementation of this provision will involve new areas for industry and CAs until more experience is gained and some initial certificates are issued. Some examples [9] of potential materials that might be good candidates for consideration have been prepared during the preparations of the 2012 Edition.

3.3. PACKAGE DESIGNS WITH CA APPROVAL FOR FISSILE MATERIAL

Para. 417 of the 2012 Edition requires packages containing fissile material to be classified as FISSILE, with some exceptions provided in subparagraphs 417(a)-(f). Packages classified as FISSILE according to para. 417 must either comply with one of the provisions in paras 674 or 675 or with CA certificates of approval for package designs for fissile material [para. 802(a)(v)].

If none of the provisions in paras 417(a)-(f), 674 or 675 are applicable and if no appropriate CA package design approval certificate for fissile material is available, an application to and approval certificate by the CA is required.

Package designs requiring CA approval for fissile material must adhere to the requirements and provisions specified in paras 673 and 676–686 of the 2012 Edition. These paragraphs specify the expectations that an applicant must demonstrate subcriticality of individual packages and arrays of packages under routine conditions of transport (RCT), normal conditions of transport (NCT) and accident conditions of transport (ACT). Packaging tests representative of NCT and ACT are referenced, and requirements that must be met and conditions considered are specified in these paragraphs. Key requirements are as follows.

A number N shall be derived, such that

- "5 times N packages shall be subcritical for the arrangement and package conditions that provide the maximum neutron multiplication" (k-eff) [4], consistent with NCT, and

- "2 times N packages shall be subcritical for the arrangement and package conditions that provide the maximum neutron multiplication" under ACT.

For each requirement, the "package conditions" should assume a range of specified contents for the package, and unknown values associated with the contents should[5] be assumed such that the highest value of k-eff is obtained for the intended application of the design. Based on an assessment of these key requirements, the CSI for each package is established to be

---

[3] Para. 802(a)(v): "A *fissile material* excepted … under para. 417(f)" should be "intended for exception".

[4] k_{inf} is the neutron multiplication factor for a infinite quantity of material in contrast to keff which applies to a finite quantity of material

[5] Para. 676 is expressed as a design requirement but is guidance. It is a requirement for the package to be transported.

$$CSI = 50/N \quad (1)$$

where N is the smaller of the two values determined from the subcriticality assessments for NCT and ACT.

The CSI value is included in the package design approval certificate issued by the CA and is used to provide a means of control over the accumulation of packages during transport. For example, if N = 5 for the purpose of determining the CSI per Equation (1), then CSI = 10 for the package. Per paras 525 and 566(c) of the 2012 Edition, the CSI of any package is generally limited to 50 and the sum of the CSIs in a freight container or aboard a conveyance must be limited to the values in Table 11 of the 2012 Edition (e.g., for a vehicle, the sum of CSIs must be limited to 50 unless it is loaded, transported, and unloaded by a single consignor under exclusive use, in which case a total CSI up to 100 is allowed subject to CA shipment approval).

Finally, a package design approved by a CA for fissile material will include a letter "F" as part of the type code of the identification mark that each package and each certificate will bear. Each package must be shipped with a label that identifies the contents as having been classified as FISSILE. The label (see Fig. 5 of the 2012 Edition) also must include the CSI as stated in the certificate of approval issued by the CA.

3.4. "FISSILE" PACKAGE DESIGN NOT REQUIRING CA APPROVAL

A key section of the 2012 Edition is entitled "REQUIREMENTS FOR PACKAGES CONTAINING FISSILE MATERIAL" and encompasses paras 673–686. Para. 673 (a) provides a general expectation that all fissile material be transported so as to maintain subcriticality and (b) states that exceptions to requirements[6] of paras 676-686 are provided in paras 417, 674, and 675. The provisions of paras 674–675 are distinctly different from those of para. 417(a)-(f), in that transport consistent with paras 674–675 is classified as "FISSILE" and subject to CSI control, while transport as per para. 417(a)-(f) is not classified as "FISSILE" and is not subject to CSI control (fissile-excepted material).

3.4.1. CSI control with exception from CA approval of package design for fissile material

Para. 674 provides three provisions for consignors to transport fissile material without the need for additional criticality safety assessment of the design. Para. 802(a)(v) allows package designs complying with para. 674 without specific approval by a CA to contain fissile material. These provisions require using a simple formula to calculate a CSI for each package which will ensure that 5N packages are subcritical under NCT and 2N packages are subcritical under ACT (consistent with paras 684-686). The mass of fissile nuclides is limited by use of CSI control—implying that each package must be classified as "FISSILE" and labeled with the proper calculated CSI to keep accumulation below the limiting safe mass values for the fissile nuclides.

3.4.2. Determination of the CSI

For a package that has not been demonstrated to keep both containment and a minimum external dimension under NCT, criticality safety must be ensured under conditions that give the maximum neutron multiplication for the fissile material that might be present in 5N packages; that is, the package integrity cannot be credited to survive NCT. To obtain a formula for the CSI, consider a mass of uranium-235 in a package such that

$$5Nz < Z, \quad (2)$$

---

[6] Para. 673(b)(iv) refers to exception from "requirements" but intends "demonstration of compliance with requirements"

where z equals the mass of uranium-235 per package and Z is the limiting uranium-235 mass (depending on the uranium-235 enrichment) below which subcriticality in transport is ensured. Substitution of Equation (2) into Equation (1) yields the following:

$$CSI = 50 \times 5\ (z/Z)\ . \tag{3}$$

A further constraint imposed by the Member State experts was to limit the CSI per package to 10 to reduce the fraction critical in any given package (i.e., the maximum mass per package is 1/25 of the safe subcritical mass, Z).

For multiple fissile nuclides and using a fractional equivalency for the reactivity, one can show that Equation (3) can be expanded to produce the following formula:

$$CSI = 50 \times 5\ (z/Z + y/Y)\ , \tag{4}$$

where y is the mass per package of other fissile nuclides and Y is the safe subcritical mass for other fissile nuclides (besides uranium-235).

For a package that has been demonstrated to keep both containment and a minimum external dimension under NCT credit may be taken, however, the package cannot be credited for containment under ACT and 2N packages under conditions that give the maximum neutron multiplication must have a safe subcritical mass. The equivilent to Equation (2) is therefore

$$2Nz = Z \tag{5}$$

and the formula for CSI becomes:

$$CSI = 50 \times 2\ (z/Z + y/Y)\ . \tag{6}$$

To restrict the maximum CSI of Equation (5) to 10, the mass of fissile nuclides per package can never be more than 1/10 of the safe subcritical mass under conditions that give the maximum neutron multiplication.

3.4.3. Determination of safe subcritical mass

Equations (4) and (5) provide an approach for shipping limited quantities of fissile nuclides with accumulation control that is consistent with the method used for package designs approved by a CA to contain fissile material. Member State experts agreed upon consensus values for Z and Y based upon best available safe subcritical mass data, taking into account all credible hydrogeneous moderators (e.g., oils or polyethelene). This is in contrast to the consignment limits in the 2009 Edition which provided two sets of values depending on whether materials with a hydrogen density greater than water were present.

Reference [9] discusses the general approach and summarizes the analysis methodology used to obtain limiting values for the mass of fissile nuclides demonstrated to be safely subcritical. The minimum mass of fissile nuclides needed for criticality will be a mixture of fissile nuclides in hydrogen. (As the lightest element, hydrogen is optimum at slowing fission neutrons from their initial high energy to thermal energies where the probability for subsequent fission interaction with a fissile nuclide is highest.) Water is the common material to assume for optimal (i.e., to minimize critical mass) mixing of fissile nuclides, but substances like polyethylene, which can be present as a packaging material, have a higher density of hydrogen than water and can produce a somewhat lower critical mass. It follows then that fissile nuclides mixed with water and separately with polyethylene provide the two

systems that need to be assessed to determine the fissile nuclide mass values below which one can ascertain a 5N (NCT) or 2N (ACT) group of packages will be safe.

The criticality safety experts from numerous Member States worked to obtain consensus values for the minimum critical mass and the mass determined to be safely subcritical for uranium with uranium-235 enrichments between 1.5 wt% and 100wt% and for plutonium -239 (acting as surrogate for "all other fissile nuclides"). Literature references, consensus standards, and independent analyses by many of the experts were used to obtain values of Z and Y for both polyethylene- and water-moderated systems (surrounded by 20 cm of water reflection) [6]. The potential complexity (and confusion) of having different values based on the presence of polyethylene led to further deliberations that yielded the one set of values for Z reported in Table 13 of the 2012 Edition and reported here in Table 1 along with the value for Y. These Z and Y values were selected to be about 15-20% lower than the consensus set of limiting safe subcritical values for water-moderated systems.

Heterogeneous and homogeneous arrangements were considered, noting that for low-enriched uranium systems the critical mass for heterogeneous systems (e.g., lattices or units of uranium) are generally lower than that for homogeneous mixtures.

TABLE 1. VALUES OF SAFE SUBCRITICAL MASS OF FISSILE NUCLIDES FOR CALCULATION OF CSI

Symbol	**Enrichment**[7]	**Mass of fissile nuclides (g)**
Z	*Uranium* enriched up to 1.5%	2200
	Uranium enriched up to 5%	850
	Uranium enriched up to 10%	660
	Uranium enriched up to 20%	580
	Uranium enriched up to 100%	450
Y	Other fissile nuclides	280

The missing step in the discussion above is confirmation that the use of Equation (5) together with the selected Z and Y values not only ensure safety for 2N packages under ACT but also criticality safety for 5N packages under NCT. A discussion [9] of the extensive set of nearly 75,000 array configurations (with various content arrangements, packaging materials, and non-fissile media) that demonstrates that all conceived 5N arrays of packages under NCT would be subcritical if constrained to the allowed mass per package of Equation (5) for a CSI = 10. Packages were assumed to have no external dimension less than 30 cm in order to provide sufficient spacing between the fissile contents of each individual package to ensure safety [10].

Hopefully, the above discussion provides some clarification regarding the provisions of paras 674(a) and 674(b) of the 2012 Edition, which allow fissile nuclides to be transported based on the CSI definitions of Equations (4) and (5), respectively, and the assumptions described (e.g., regarding package integrity). Considering pure uranium-235, Equation (4) and Z = 450 g from Table 1 indicate

---

[7] If a *package* contains *uranium* with varying enrichments of uranium-235, then the value corresponding to the highest enrichment shall be used for Z.

that a maximum (CSI = 10) of 18 g per package could be transported under para. 674(a). The provision of para. 674(b) using Equation (5) would allow 45 g of uranium-235 per package; however, the smallest external dimension of the package must be at least 30 cm and be preserved under NCT. To provide a provision for packages that meet NCT similar to para. 674(b) but have external dimensions down to 10 cm, para. 674(c) was included. Safety under NCT for the provision of para. 674(c) was based on lessons learned from the results of the 75,000 analyses noted above and is ensured by limiting the mass per package to 15 g and always using the Z = 450 value in the CSI evaluation per Equation (5). The purpose of this added provision was to ascertain that previously loaded and closed packages (using the 15 g exception of previous versions of the Regulations) that meet NCT, but have external dimensions less than 30 cm, could be accommodated with the advantage of a lower CSI than if it will be shipped under para. 674 (a). Para. 674(c) allows much more fissile nuclides than para. 674(b) in a specific volume. 450 g uranium-235 under para. 674(c) fits in 30 packages with a volume, e.g., in an overpack, of 30 liters. Para. 674(b) would require 10 packages, requiring a volume of 270 liters, to ship 450 g of high-enriched uranium.

For each of the provisions (a)–(c) of para. 674, the quantities of beryllium, deuterium and allotropic forms of carbon are restricted to the mass of fissile nuclides in the package. As noted above, a hydrogen-moderated system provides the minimum critical mass; however, replacing the water reflector region with a material such as beryllium (good moderator with a very low absorption cross section) can potentially lower the minimum mass further. Thus, mass restrictions on these materials were added to prevent the possibility of their effect as a moderator or as a reflector. Per para. 674(d) of the 2012 Edition, some allowances are provided for relaxing this restriction based on demonstrated need and safety assessments performed by industry and reviewed by the Member State experts.

3.4.4. Special case provision for plutonium

The Regulations have historically included a special provision for plutonium whereby up to 1 kg of plutonium did not have to be shipped in a package whose design is approved by CA to contain fissile material, provided not more than 20% of the plutonium mass consisted of fissile nuclides (i.e., plutonium-239 and plutonium-241). This historic provision has been included in the 2012 Edition as para. 675 but with the new requirement that the package be classified as “FISSILE” and a CSI be provided on the package label to ensure accumulation control. The package used for the shipment of these quantities of plutonium would require CA approval of the package design due to its radiological properties, indicating the package would meet NCT tests. Thus, the CSI formula for this exception is

$$\text{CSI} = 50 \times 2\,(\text{mass of plutonium in gram}/1000)\,. \qquad (7)$$

Explicit limitation of additional fissile nuclides from uranium was not seen to be necessary, but an allowance for uranium up to 1% of the plutonium mass is provided.

4. DETERMINING THE APPROPRIATE PROVISION FOR TRANSPORT

A consignor responsible for the transport of material containing fissile nuclides is faced with the challenge of understanding the available options and determining if the material of interest can be packaged and shipped using one of the options. Across the breadth of the international nuclear industry, there is a large variety of materials that contain fissile nuclides.

Table 2 provides a high-level summary of the allowed mass of fissile nuclides and material types in the various provisions should transport be made using packages whose designs are not approved by the CA for transport of fissile material. Given that the consignor can assure the material characteristics (e.g., the uranium-235 enrichment) and how it is packaged (e.g., the mass of fissile nuclides per package), Table 2 can be used to help direct the consignor to the potential paragraphs that might be used. Once potential paragraphs are identified, the consignor should further study the specific package requirements (e.g., minimum external dimensions) or package performance (e.g., retention of contents under NCT) requirements. In addition, the consignor must be mindful of the

TABLE 2. SUMMARY OF MASS LIMITS FOR FISSILE NUCLIDES FOR TRANSPORT WITHOUT CA APPROVED PACKAGE DESIGNS FOR FISSILE MATERIAL

Paragraph See section 0 for full details for each provision	Natural or depleted uranium Per package mass of uranium-235	Low enriched uranium (up to 20% by mass in uranium-235) Per package mass of uranium-235	High enriched uranium (>20% by mass in uranium-235) Per package mass of uranium-235	Per package mass of other fissile nuclides	Notes
222	Unlimited (including if irradiated in a thermal reactor)	0.25 g			
417a	Unlimited, provided material is homogenous (but para. 222 has to be considered)	Unlimited, provided up to 1% enrichment by mass in uranium-235 and material is homogenous	-	Up to 1 % of the mass of uranium-235	For example, heterogeneous lumps such as pins and lumps are not allowed
417b	-	Unlimited for uranyl nitrate with up to 2% enrichment by mass in uranium-235	-	Up to 0,002 % of the mass of uranium	Atomic ratio of nitrogen to uranium at least 2
417c	-	3.5 g provided enrichment is up to 5% by mass in uranium-235	-	Up to 1% of the mass of uranium-235	Consignment restricted to 45 g per 570(c)
417d	2 g				Consignment restricted to 15 g fissile nuclides per 570(d)
417e	45 g				The limit applies to the conveyance. Exclusive use shipment per 570(e), can be transported unpackaged
417f	As specified in CA approval certificate				Subcriticality per the conditions of para. 606 must be demonstrated.
674a	88 g up to 1.5% enriched in uranium-235 34 g up to 5% enriched in uranium-235 26.4 g up to 10% enriched in uranium-235 23.2 g up to 20% enriched in uranium-235		18 g	11.2 g	Mix of uranium-235 and other fissile nuclides allowed subject to CSI formula and maximum CSI =10
674b	220 g up to 1.5% enriched uranium-235 85 g up to 5% enriched in uranium-235 66 g up to 10% enriched in uranium-235 58 g up to 20% enriched in uranium-235		45 g	28 g	Mix of uranium-235 and other fissile nuclides allowed subject to CSI formula and maximum CSI =10.
674c	15 g				Mix of uranium-235 and other fissile nuclides allowed subject to sum up to 15 g
675	-			1000 g Pu with up to 20% fissile nuclides of Pu	

operational requirements (e.g., labeled as FISSILE and shipped per CSI control) in Sections IV and V of the 2012 Edition for application of the paras 674 and 675. In many cases multiple paragraphs will be found to be applicable per Table 2 and the consignor should be mindful of the variation in provisions. For example, paras 417(c) and 417(e) can both be applied to ship small quantities of uranium enriched to <5% by mass, however para. 417(e) would require exclusive use. On the other hand, para. 417(e) is the only provision where unpackaged fissile material is allowed.

Para. 417(f) provides an opportunity for transport under exception from classification as FISSILE, provided that verifiable information can be obtained in order to demonstrate that the fissile material complies with an approved design of fissile material (para. 802(a)(iii).

5. GUIDANCE ON THE USE OF EACH PROVISION

5.1. PARAGRAPH 222 - EXCLUSION FROM DEFINITION OF FISSILE MATERIAL

Para. 222 defines what are considered to be fissile nuclides (uranium-233, uranium-235, plutonium-239 and plutonium-241) for the purpose of the Regulations. Material containing no more than trace quantities (defined in para. 222(c) as being 0.25 g) of these nuclides do not need to be considered further for criticality safety purposes.

However, there are other nuclides that are capable of supporting a chain reaction and guidance on this matter is available in the current issue of the Advisory Material [8].

Paras 222(a) and 222(b) exclude natural and depleted uranium from the definition of fissile material provided the natural or depleted uranium has not been irradiated in a fast reactor, since such irradiation could increase the production of fissile material. Packages transporting fissile nuclides in the form only of these materials or which contain these materials as part of their construction do not need to be considered further for criticality safety purposes. One potential caveat not specificied in the regulations is that operators that have natural or depleted uranium that has been irradiated in a thermal reactor [and excluded as fisile material per para 222(b)] should also ensure that any processing or degredation subsequent to irradiation will not have increased the concentration of the plutonium. For example, production of plutonium during irradiation in a thermal reactor can be greater at the fuel surface. The surface layer will have a significantly higher plutonium concentration than the “average” value throughout the fuel and can have criticality characteristics similar to those of low enriched uranium. If this surface layer has been separated from the bulk of the fuel, then material containing it (e.g., cladding residues or corrosion products) may not be suitable for exclusion under para. 222(b).

5.2. PARAGRAPH 417(A)-(E) - NON FISSILE UN NUMBERS (SPECIFIED IN REGULATIONS)

Para. 417 contains provisions in subparagraphs (a)-(f) whereby material and packages can be excepted from classification with a FISSILE UN number. These provisions must be combined with para. 570 which provides additional requirements relating to the transport of such material.

Subparagraphs 417(a) and 417(b) concern exceptions based on fissile material characteristics. These exceptions are for homogeneous systems of uranium enriched in uranium-235 to a maximum of 1% by mass (subject to limitations on the plutonium and uranium-233 content) (para. 417(a)) and for solutions of uranyl nitrate enriched in uranium-235 to a maximum of 2% by mass (para. 417(b)). Compliance with either of these paragraphs will ensure that the material will be safe in any quantity under normal and accident conditions of transport. These are carried forward from the 2009 Edition without change.

The Advisory Material [8] discusses the homogeneity requirement in para. 417(a) and the N/U ratio in para. 417(b).Subparagraphs 417(c), 417(d) and 417(e) concern exceptions based on a limit on the mass

of fissile nuclides per package combined with a mass limit on the consignment (paras 570(c) and 570(d)) or on the conveyance (para. 570(e)).These exceptions apply to packages containing:

- not more than 3.5 g of uranium-235 at a maximum enrichment of 5 % by mass (subject to limitations on the plutonium and uranium-233 content) transported in a consignment with no more than 45 g of fissile nuclides (para. 417(c)),
- not more than 2 g of fissile nuclides transported in a consignment with no more than 15 g of fissile nuclides (para. 417(d)),
- not more than 45 g of fissile nuclides per conveyance under exclusive use (para. 417(e)).
- These mass limits are significantly reduced from those formerly allowed by the 2009 Edition. This was determined based on the concerns of accumulation of such consignments.

Para. 417(c) allows continuing the shipment of UF_6 samples based on historic practice (less than 100 grams of UF_6 per package), para. 417(d) is intended to enable shipment of small samples of unirradiated or irradiated fissile material or environmental samples with unspecified composition of fissile material and para. 417(e) can be used for packaged and unpackaged material such as waste containing a small mass of fissile nuclides. Note that para. 417(e) is the only provision that currently allows unpackaged fissile material.

Then if the package is intended to be excepted from classification as "FISSILE", the consignor needs to assure that the mass of fissile nuclides loaded in a package is within the limits specified by paras 417(c), (d) or (e) and that the mass of fissile nuclides in a consignment is within the limits specified by paras 570(c)-(d). The uranium-235 content of any natural or depleted uranium present in either the content or packaging material must be included when calculating the mass of total fissile nuclides for the purposes of paras 417(c)-(e). Pragmatism should be applied and trace quantities present in packaging materials such as steel or irradiated non-fissile reactor components need not be included in the mass of fissile nuclides for paras 417(c)-(e).

In addition, para. 636 requires that the smallest external dimension of the package shall not be less than 10 cm under RCT in order to avoid that a small package could be mislaid. This also needs to be assured by the consignor.

The consignor is responsible for ensuring that the consignment and conveyance limits are met bearing in mind that the CSI mechanism is not available.

The low consignment limits in paras 570(c)-(d) are intended to make it very unlikely that a conveyance used to transport more than one consignment will contain a potentially unsafe mass of fissile nuclides. Nevertheless the deliberate splitting of material on a conveyance into multiple consignments to circumvent the consignment limits in paras 570(c)-(d) is not in keeping with the spirit of the regulations and is to be discouraged.

The requirement in para. 417(e) for shipment under exclusive use is to ensure the consignor has control over all parts of the shipment. The consignor must ensure safety during the entire shipment, including in-transit storage and handling. For example, the conveyance limit specified in para. 417(e) should apply to any group of packages during in-transit storage. It is recommended that each such group of packages is separated from each other.

5.3. PARAGRAPH 417(F) – NON FISSILE UN NUMBERS (CA APPROVED FISSILE MATERIAL DESIGN)

Material transported under this provision is subject to the requirements of a certificate of approval issued according to para. 802(a)(iii).

Such material must have been demonstrated to be adequately subcritical. The material will be assigned a "non-fissile or fissile-excepted" UN number from Table 1 of SSR-6 and may be transported in any package complying with paras 417(f) and 570 and suitable for its other radioactive and/or dangerous properties.

The remainder of this section provides guidance to a potential applicant for an approval under para. 802(a)(iii) when such an approval is not already available.

Para. 417(f) is analogous to paras 417(a)-(b) rather than paras 417(c)-(e) where accumulation controls are required.

It may be possible to claim credit for the general design requirements for package types (Industrial, Types A, B or C) in Section VI. In this case it would be specified that a particular package type (e.g., Type B) must be used. However, if it is necessary to claim credit for any specific package design feature then subpara. 417(f) is not appropriate and an alternative provision should be used.

Para. 417(f) calls up para. 802, which is required to apply para. 417(f) and para. 606 and thence para 673(a). This para. 673(a) sets out the contingencies under which packages containing fissile material must remain subcritical. The same contingencies need to be considered for material intended to be granted approval under para. 802(a)(iii).

The guidance presented here is intended to set general guidelines rather than set a proscriptive formula for attaining CA approval. An application for design approval must take into account the properties of the material necessary to assure subcriticality and should include alowances for any uncertainties that may be inherent in some candidate materials. Allowance for uncertainties may be reduced for more well defined materials.

An operator must be able to demonstrate compliance with all material specifications defined in the certificate. An applicant to a CA for a certificate should liaise closely with potential users to ensure that the resulting certificate can be complied with for intended shipments.

There are some items which are likely (but not certain) to result in the rejection of an application:

- The need to limit the quantity of material loaded into a package
- The need to control package accumulations
- The need to claim a specific packaging
- The need to protect the material from water
- The need to take criticality safety into account at any stage in transport, including emergency response. Pre-shipment criticality safety controls may be required.

An application for CA fissile material design approval under para. 606 should consist of three components:

5.3.1. Specification

A candidate fissile material may be specified in a general manner to cover a range of actual materials or be more specific and limited to fissile materials known to reside in a particular location.

The only way that a material would remain subcritical without further criticality safety control during transport is if any fissile nuclides (as defined in para. 222) are diluted by non-fissile nuclides. The primary controlling parameter in the specification of a fissile material in an application for approval of a para. 606 design under para. 802(a)(iii) is likely to be the extent of this dilution expressed as a fissile to non-fissile ratio.

This approach is analogous to previously existing provisions 417(a) - (b) for fissile exceptions and to low specific activity (LSA) material (see the Advisory Material [8] on para. 409) where radioactive nuclides are diluted by non-radioactive nuclides. For subparagraphs 417(a)-(b), as well as for LSA, the level of dilution is specified in the regulations but for para. 417(f) the specifications for criticality safety considerations are contained in a CA certificate of approval for a fissile material design. In both cases (specifications in the Regulations and in CA certificates), the extent of mixing and the extent to which there may be areas having a higher concentration of fissile/radioactive nuclides than specified/permitted is an important consideration. Whereas the LSA material guidance gives suggestions for the extent of uniformity, this guidance does not. The extent of permissible heterogeneity will depend on the results of the criticality safety assessment.

An operator must be able to demonstrate compliance with any specification in the CA certificate of approval for the fissile material design.

Another item that could be included in a specification would be the proportion and nature of specific non-fissile nuclides whose neutron absorbing properties may be claimed in the criticality safety assessment.

5.3.2. Behaviour under routine, normal and accident conditions

The general requirement for subcriticality under RCT, NCT and ACT under para. 673(a), including accounting for the listed contingencies, applies to para. 606. The application must contain an assessment of the extent to which the distribution of the fissile nuclides and other nuclides, as defined in the specification of the material, would change during demonstration of compliance with the performance standards required by paras 684, 685 and (if air transport required) 683(a) as specified in para. 606.

The behaviour of the material under these conditions must be assessed based on sound scientific principles.

In addition to impact and fire any other reasonably foreseeable mechanism that may change the specification (e.g., vibration) should also be considered.

The assessment of how the characteristics of the fissile material may change may be made by reasoned argument, calculation or reference to physical tests.

The extent to which a CA will require demonstration of the changes in the distribution of the fissile nuclides would be based on scientific considerations and likely to be the subject of member state advice. However, the physical behaviour (e.g., combustibility or solubility) of the material and the distribution of the fissile-nuclides (e.g., dissolved, as a surface contaminant or as bulk material in unspecified discrete locations) are likely to be factors to be considered.

The evolution of a material over time needs to be considered. However the timescales should be consistent with likely transport operations (including storage before transport) rather than (in the case of waste products) final disposal.

5.3.3. Criticality safety assessment

The criticality safety assessment should demonstrate that the material as specified will remain subcritical following an accident. The effect of changes in the distribution of the fissile nuclides should be assessed. This should cover both the uncertainties in the specification as well as assessed changes during transport.

Ideally $a\ k_{inf}<(1-X)$ criterion would be demonstrated with X being the safety margin (e.g., 0.05 or 0.03) to be defined by individual member states and which may differ under routine and accident

conditions as is the case for CA approved package designs for fissile material. However, a $k_{inf}>1$ could be acceptable if the mass of material required to give an unacceptable k-eff is so large as to be extremely unlikely for any realistic transport operation. The extent to which this might be acceptable is subject to agreement with the CA.

5.4. PARAGRAPH 570–CONSIGNMENT REQUIREMENTS FOR SUBPARAS 417 (A-F)

The consignor needs to make sure that there is no mixture of packages or unpackaged material based on different exception provisions under para. 417 in the same consignment according to para. 570(a). The reason for the requirement is that the safety of mixture under accident conditions of transport has not been demonstrated.

Paragraphs 222(a)-(b) and 417(a)-(b) could lead to unlimited quantities of natural or slightly enriched uranium to be transported along with packages classified as fissile. The presence of large amounts of neutron multiplying material could change the criticality characteristics of the fissile packages. Caution should therefore be applied if transporting mixtures of fissile packages and those classified as "non-fissile per 222(a)-(b) or fissile excepted per 417 (a)-(b)".

5.5. PARAGRAPHS 674 & 675 – CA APPROVAL OF PACKAGE DESIGN FOR FISSILE MATERIAL NOT REQUIRED

Paragraph 674(a)-(c) and 675 provide a new concept to permit transport of fissile material classified as FISSILE but without the need to use packages whose design requires CA approval for fissile material.The requirements specified in paras 674 and 675 are important to assuring criticality safety in the selection, loading, and transport of the package. Thus, it is crucial that a vigilant self-assessment program consistent with an adequate management system accepted by CAs is in place.

Common requirements for the application of paras 674 and 675 include:

- Adequate knowledge of the mass of fissile nuclides to be loaded into each package and determination of the CSI value per the appropriate sub-paragraph of 674-675;
- UN number and proper shipping name for fissile material (entry FISSILE in Table 1 of SSR-6) appropriate to its radioactive properties (LSA, surface contaminated object (SCO), Type A, Type B(U), Type B(M)…);
- Labelled as FISSILE according to paras 538 and 541 of SSR-6;
- Compliance of packages to requirements prescribed elsewhere in the regulations that pertain to the radioactive properties of the material is required;
- Total CSI per conveyance limited according to para 566(c) of SSR 6 in the same manner as for package designs approved by the CA for transport of fissile material;
- Loading together with all other packages containing fissile material is allowed provided the CSI limits per conveyance are complied with. CSI values derived via para. 674 are used in exactly the same way as CSIs derived for CA approved fissile package designs;
- Transporting along with other packages containing material excepted from classifcation as FISSILE under para. 417(a)-(f) is not prohibited by the regulations, however caution should be applied (see section 5.4).

Demonstration that the package specifications and fissile material mass quantities provided in paras 674 and 675 meet the safety requirements commensurate with package designs approved by CAs to

contain fissile material (paras 676 - 686 of SSR-6) was performed by the Member State criticality safety experts as part of the revision process leading to the 2012 Edition. It is this demonstration effort that led to the Z and Y values of Table 1 (see "Determination of Safe Subcritical Mass" in Section 4.3). Thus, operators that use the provisions of paras 674-675 are required only to meet the specifications required therein.

Paras 674 (a)–(c) can be applied for all fissile nuclides. However, para. 675 is limited to specific plutonium compositions. When one of paras 674 (a)–(c) is applied to a package containing certain special materials, the limits of para. 674 (d) shall be complied with.

The following provisions are used to permit the transport of fissile material classified as FISSILE but without a requirement for CA approval for a specific package design for fissile material. Also, the detailed background and some examples related to para. 674 are described in the advisory material SSG-26 [8].

5.5.1. Sub para. 674(a) - no specific requirements for package performance

Para. 674(a) doesn't require anything for the package except 10 cm for the minimum external dimension under RCT. CSI should be calculated from the masses of the fissile nuclides in the package using the following equation:

$$CSI = 50 \times 5 \times \left(\frac{\text{mass of uranium-235(g)}}{Z} + \frac{\text{mass of other fissile nuclides(g)}}{280} \right) \quad (8)$$

(8)

The value of Z should be chosen from Table 13 of SSR-6 consistent with the highest enrichment of uranium in the package. The mass of fissile nuclides has to be limited such that the value of CSI of any package does not exceed 10.

The limit on a single CSI of 10 was intended to avoid having the entire fissile inventory in a single package. The requirement to spread the fissile mass over several (at least 5) packages provides an additional safety factor (see also section 3.4).

Limiting the CSI for an individual package to 10 means that the maximum allowed mass for uranium-235 is between 18 g to 88 g (depending upon enrichment) and for other fissile nuclides up to 11.2 g for any package. For a mixture of uranium-235 and other fissile nuclides the maximum mass of fissile nuclides is limited by the sum of the ratios of each fissile nuclide mass to its respective limit.

674(a) applies to packages that have not been demonstrated to retain their contents under NCT (paras 719-724). Some material which may be transported in such packages is LSA-I or SCO-I . Currently there are no UN numbers for fissile LSA-I, thus limiting the use of this provision. Small IP-2 or Type A packages that have not been demonstrated to preserve the 30 cm minimum dimension under NCT, and IP-2 or IP-3 packages that have been qualified under the alternative requirements in paras 626-630 and thus have not been shown to retain its contents under NCT are candidate packages that could be used for transport under para. 674(a). Although the CSI formula for para. 674(a) restricts the fissile mass because the minimum outer dimension or performance under NCT has not been confirmed for the package, the consignor may deem this mass restriction an acceptable alternative to fulfilling the required evaluation for the package performance

5.5.2. Subpara. 674(b) – Limited requirements for package performance and size

Para. 674(b) requires that the package shall retain its fissile material contents, preserve the smallest external dimension to be at least 30 cm and prevent the entry of a 10 cm cube after the NCT tests described in paras 719 – 724 (not the alternative tests for IP-2 and IP-3 in paras 626 - 630). CSI should be calculated from the masses of the fissile nuclides in the package using the following equation:

$$CSI = 50 \times 2 \times \left(\frac{\text{mass of uranium-235(g)}}{Z} + \frac{\text{mass of other fissile nuclides(g)}}{280} \right) \quad (9)$$

The value of Z should be chosen from Table 13 of SSR-6 consistent with the highest enrichment of uranium in the package. The mass of fissile nuclides has to be limited such that the value of CSI of any package does not exceed 10.

Limiting the CSI for an individual package to 10 means that the maximum allowed mass for uranium-235 is between 45 g to 220 g (depending upon enrichment) and for other fissile nuclides up to 28 g for any package. For a mixture of uranium-235 and other fissile nuclides the maximum mass of fissile nuclides is limited by the sum of the ratios of each fissile nuclide mass to its respective limit.

Para 674(b) covers packages which will retain their contents under the NCT tests specified in para 684(b) (ie those in paras 719-724). These tests are the same as those specified in the requirements for IP-2 (para. 624), IP-3 (para. 626) and Type A (para. 648) packages. If a package meets the requirements of Type A, B(U), B(M) or C then 674(b) can be used subject to ensuring the smallest external dimension is not less than 30 cm However, there are options (paras 626-630) to approve packages as IP-2 using an alternative test regime to that in paras 719-724. Before transporting material in an IP-2 package using para 674(b) it must be ensured that the package would retain its contents under paras 719-724 and not to assume that classification as an IP-2 package automatically fufills that requirement.

In carrying out an assessment of an IP-2 package design for complience with paras 719-724 it should be borne in mind that "release of contents" here means release in quantities of significance to criticality; an example guideline for what is of significance to criticality might be found in para. 222(c) which defines "fissile" as being more than 0.25 g of fissile nuclides. Releases of a fraction of a gram, which may be important for radiological reasons, are not important for criticality purposes. Package design documentation should be updated to confirm that the package meets the requirements necessary for the use of para. 674(b).

An IP-2 or IP-3 package designed under the alternative requirements in paras 626-630 could still be used to transport fissile material under para. 674 but subpara. 674(a) would have to be used with the subsequent higher CSI.

5.5.3. Para. 674(c) – Limited requirements for package performance and a 15g mass limit

Para 674(c) requires that the package shall retain its fissile material contents, preserve the smallest external dimension of not less than 10 cm and prevent the entry of a 10 cm cube after the NCT tests described in paras 719 – 724 (not the alternative tests for IP-2 and IP-3 in paras 626 - 630). CSI should be calculated with the following equation and the maximum mass of fissile nuclides is 15 g per package.

$$CSI = 50 \times 2 \times \left(\frac{\text{mass of uranium-235(g)}}{450} + \frac{\text{mass of other fissile nuclides(g)}}{280} \right) \quad (10)$$

An explicit 15 g individual package limit for fissile nuclides was selected and used (instead of a CSI limit) because 15 g is the same limit as para 417(a)(i) in the TS-R-1 (2009) in order to facilitate transition from previous regulations. The above equation uses the most conservative value for 100% enriched uranium in Table 13 of SSR-6.

As with para. 674(b) the discussion regarding IP-2 and IP-3 package design qualification in terms of the alternative tests for IP-2 and IP-3 packages in paras 626-630 and the requirements to retain fissile contents and minimum dimension also apply to para. 674(c).

5.5.4. Para. 674(d) Limitations on Beryllium, Deuterium and Graphite

It must be demonstrated that the limits on beryllium, deuterium and graphite in 674(d) are met when the package is prepared for transport. There is no requirement to demonstrate that these limits would be preserved during normal or accident conditions of transport.

5.5.5. Para. 675 Specific Plutonium Isotopic Composition

The para. 675 provision was excepted from classification FISSILE in the 2009 Edition and previous regulations (para. 417(d)) but now now requires FISSILE classification and is included in the system of CSI control. It is intended to facilitate the transport of high-concentration plutonium-238 for use as a power source. This provision does not specify anything for the package type, however a Type B(U) or Type B(M) package is likely to be required due to the plutonium mass. Not more than 20% of the plutonium by mass shall be fissile nuclides and the mass of uranium, if present, shall be no more than 1% of plutonium. CSI should be calculated with the following equation and the maximum mass of plutonium is explicitly set as 1000 g per package:

$$CSI = 50 \times 2 \times \frac{\text{mass of plutonium (g)}}{1000} \tag{11}$$

6. MARKING AND LABELLING REQUIREMENTS FOR EACH SET OF PROVISIONS

Table 3 summarises the marking, labelling and consignment documentation requirements associated with shipments made according to each of the provisions for transport of material containing fissile nuclides (including material not defined as fissile material). It is intended to guide consignors but will also inform carriers and consignees what will be seen on a package and its documentation for each provision.

6.1. NOTE FOR CARRIERS

Packages being shipped under the provisions of para. 674 or 675 will carry a CSI label as required by para. 541 and will be classified as FISSILE. However, the package design does not require CA approval for the fissile properties of its contents and consequently any identification number present will not have the “F” used to signify a package design for fissile materials (e.g., B(U)F-96). This is the intention of the revised regulations and does not indicate an inconsistency or error. The identification mark is not directly used for criticality safety control during transport or under emergency conditions but the requirements for total CSI must be complied with. The consignment documents will refer to paras 674 or 675 as appropriate.

6.2. TRANSPORT DOCUMENTS

6.2.1. Paras 417(a)-(f)

According to para. 546, the consignor shall include in the transport documents with each consignment (other than consignments consisting of excepted packages only) the reference to the paragraph under which it is shipped and if shipped under paras 417(c)-(e) the total mass of fissile nuclides. In the case of consignments consisting of excepted packages only, it is encouraged that the transport documents include the same information.

The transport documents for consignments consisting of packages shipped under para. 417(f) shall also include a reference to the approval certificate for the fissile material design.

6.2.2. Paras 674(a)-(c) and 675

According to para. 546, the consignor shall include in the transport documents with each consignment the reference to the paragraph under which it is shipped and the CSI.

TABLE 3. REQUIREMENTS OF SHIPMENT FOR MARKING, LABELLING AND CONSIGNMENT DOCUMENTATION

Para.	Provision	Consignment documentation relevant to fissile properties Para. 546(j)-(k)	UN number	Marking and labeling of package for fissile properties	Additional requirements due to fissile properties during shipment	Remarks
222	Not defined as fissile material	None	Non-fissile or fissile-excepted or excepted package	None	None	
417 (a), (b), (c), (d)	Exception from UN FISSILE Classification and CSI control	The relevant 417 sub-para. (one only per consignment) Mass of fissile nuclides if subparas 417(c) or (d)		Total mass of fissile nuclides instead of activity (para. 540(b) possible)	None	
417 (e)		Reference to para. 417(e) Mass of fissile nuclides		Total mass of fissile nuclides instead of activity (para. 540(b) possible, may be unpackaged)	Exclusive use shipment, limit of 45 g of fissile nuclides per conveyance	
417 (f)		Reference to para. 417(f) and the relevant CA certificate of approval for the fissile material design		Total mass of fissile nuclides instead of activity (para. 540(b) possible)	None	Needs multilateral approval of fissile material design (para. 802(a)(iii))
674, 675	CSI control with exception from CA approval of package design to contain fissile material	The CSI for each package and the sub-para. of 674 or 675 used	FISSILE	Total mass of fissile nuclides instead of activity (para. 540(b) possible, CSI label required (para. 541) Any package identification mark will not include "…F"	Conveyance total CSI limit (para. 566(c), Limit for total CSI for group of packages during transport or storage in transit (para. 568, 569)	Approval may be required for non-fissile reasons
Others	CSI control with CA approval of package design for fissile material or special arrangement	CA certificate of approval identification marks for package designs for fissile material or for special arrangement		Total mass of fissile nuclides instead of activity (para. 540 (b) possible, CSI required (para. 541), The identification mark (para. 535) will end "…F" except in the case of special arrangement		Needs multilateral package design approval (para. 814)

7. TRANSITIONAL ARRANGEMENTS

Para. 822 gives the transitional arrangements for packages "prepared for transport" in the expectation that they would be transported under the provisions of para. 417(a)(i) or 417(a)(iii) in the 2009 Edition.

The aim of transitional arrangements is for transport to continue past the 1st January 2015 without needing any repacking of material to meet the revised requirements. However, the limitation to already filled packages is intended to ensure that the preparation of packages is, from 2015 onwards carried out in accordance with the requirements of the 2012 Edition.

By prepared for transport it is meant that the package has been filled and closed by 31th December 2014. Any final pre-dispatch activities that may be required (e.g., labelling, the addition of impact limiters or closing of vents), which may take place long after the package was filled and closed, does not prevent the use of this transitional arrangement.

The consignment limits in paras 417(a)(i) and 417(a)(iii) of the 2009 Edition have been replaced by a conveyance limit and all such shipments must take place under exclusive use.

8. EXAMPLES

List of examples described below.

Example No.	Description	Paras. In SSR-6
1	Packages containing 5% enriched uranium with 15 g of uranium-235 (no other fissile nuclides present)	674(a)-(c), 417(e)
2	Contaminated moderator/reflector materials	417 (e), 417(f)
3	200 litre Type A package containing 100 g of fissile nuclides	417(f), 674(b)
4	Package previously requiring fissile design approval, now transportable under paras 674(b) or 417(e)	674(b), 417(e)
5	Waste materials containing small quantities of fissile nuclides	417(f)

The following subsections set out the possible provisions that may be used for each example. In each case an alternative option would be to use a CA approved package design for fissile material and the package transported under a FISSILE UN number subject to CSI control. This could be either through use of an existing approval, or, if a suitable approval is not available, then a new approval could be sought.

8.1. EXAMPLE 1 - PACKAGES CONTAINING 5% ENRICHED URANIUM WITH 15 G OF URANIUM-235 (NO OTHER FISSILE NUCLIDES PRESENT)

The packages were formerly transportable under para. 417(a)(i) of the 2009 Edition as "fissile-excepted" with a limit of 15 g of fissile nuclides in a package and a consignment limit of 400 g uranium-235. This allowance has been withdrawn from the 2012 Edition.
Under the 2012 Edition:

- If the packages have a smallest external dimension of not less than 30 cm and are demonstrated to retain their fissile material contents, preserve the smallest dimension of no less than 30 cm and prevent the entry of a 10 cm cube after the NCT tests described in paras 719 – 724 the packages may be transported under para. 674(b). Using this provision, the individual package CSI would be 1.8 and up to 27 packages could be transported and maintain a conveyance limit less than 50. The packages would further need to meet the limits on graphite, beryllium and deuterium from para. 674(d) and would need to be transported under a FISSILE UN number and subject to CSI control.

- If the smallest external dimension of the packages is less than 30 cm but not less than 10 cm and the packages are demonstrated to retain their fissile material contents, preserve the smallest dimension of no less than 10 cm and prevent the entry of a 10 cm cube after the NCT tests described in paras 719 – 724 the packages may be transported under para. 674(c). Using this provision, the individual package CSI would be 3.4 and up to 14 packages could be transported and maintain a conveyance limit less than 50. The packages would further need to meet the limits on graphite, beryllium and deuterium from para. 674(d) and would need to be transported under a FISSILE UN number and subject to CSI control.

- Para. 674(a) would be an option for IP-2 and IP-3 packages designed to the alternative requirements in paras 626-630 or which have not been demonstrated to preserve the smallest dimension of no less than 30 cm (required for use of para 674(b)) and prevent the entry of a 10 cm cube after the NCT tests described in paras 719 – 724. Use of this provision would further increase the individual package CSI to 4.5 and allow only 11 packages prior to meeting a conveyance limit of 50. This would further reduce the uranium-235 limits for the package and conveyance, derived from the package CSI formula, to 34 g and 170 g (or 340 g for shipment under exclusive use and subject to shipment approval), respectively. The packages would need to meet the limits on graphite, beryllium and deuterium from para. 674(d) and would further need to be transported under a FISSILE UN number and subject to CSI control.

- If the total uranium-235 mass per conveyance can be limited to 45 g and the shipment can be made under exclusive use conditions the exception of para. 417 (e) could be used.

For each of the provisions that might be selected for this example package, shipment under exclusive use might be an option that would double the number of packages allowed on a conveyance (i.e., raise the conveyance CSI limit to 100. However, shipment approval would be required.

8.2. EXAMPLE 2 - CONTAMINATED MODERATOR/REFLECTOR MATERIALS

A package containing graphite (or another allotropic form of carbon) contaminated with up to 15 g of fissile nuclides of unknown isotopic compostion. Under the 2009 Edition a shipment of this package could be classified as fissile-excepted subject to the limits of para. 417(a)(i), 15 g of fissile nuclides in a package and a consignment limit of 250 g of fissile nuclides. This allowance has been withdrawn from the 2012 Edition.

Under the 2012 Edition:

- Para. 674 cannot be used because of the limits on graphite, beryllium and deuterium in para. 674(d)

- The package could be transported as fissile-excepted according to para. 417(e), so long as shipment is under conditions of exclusive use and the accumulation of fissile nuclides on a conveyance is controlled to a maximum of 45 g.

- The material may be a suitable candidate for classification as fissile-excepted under para. 417(f). This could be either through use of an existing certificate of approval or, if a suitable approval is not available, a design of the fissile material according to para. 606 could be prepared. If approved by the CA in a certificate according to para. 802(a)(iii), it could be transported under para. 417(f) and this would result in the removal of consignment controls.

8.3. EXAMPLE 3 - 200 LITRE TYPE A PACKAGES CONTAINING 100 G OF FISSILE NUCLIDES

The package was formerly transportable under para. 417(a)(iii) of the 2009 Edition as fissile-excepted, subject to the limits of para 417(a)(iii), a material limit of 5 g of fissile nuclides in 10 litres and a consignment limit of up to 400 g of fissile nuclides. This allowance has been withdrawn in the 2012 Edition.

Under the 2012 Edition:

- The contents exceed the limits for paras 417(c)-(e).

- Para. 417(f) can be used if there is sufficient knowledge about the distribution of the fissile nuclides and the nature of any non-fissile materials. This could be either through use of an existing approval or, if a suitable approval is not available, a design of the fissile material according to para. 606 could be prepared. If approved by the CA, in a certificate according to para. 802(a)(iii), it could be transported under para. 417(f) and there would be no limit on the amount of appropriate fissile materal material to be shipped per package, consignment or conveyance.

- Whether para. 674(b) can be used depends on the type and mass of fissile nuclides and the properties of the packaging. The packages are Type A and therefore will retain their contents under NCT so 674(b) is an option provided the 30 cm minimum dimension is maintained under NCT. In the case of uranium-235 being the only fissile nuclide the mass of uranium-235 per package is limited to 220 g up to 1.5% enrichment, 85 g up to 5% enrichment, 66 g up to 10% enrichment, 58 g up to 20% enrichment and 45 g up to 100% enrichment (and for unknown enrichment). For other fissile nuclides the possible mass per package would be only 28 g. Therefore it may be possible to use 674(b) if the packages contain only very low enriched uranium. The packages would further need to meet the limits on graphite, beryllium and deuterium from para. 674(d)

- If the packages did not preserve a 30 cm dimension then under 674(a) the limit for 1.5% enriched uranium falls to 88 g so this is not an option. Clearly 674(c) would be also not useable in this example.

8.4. EXAMPLE 4 - PACKAGE PREVIOUSLY REQUIRING FISSILE DESIGN APPROVAL, NOW TRANSPORTABLE UNDER PARAS 417(E) OR 674(B).

The package contains 45 g of uranium-235 at 100% enrichment concentrated into one location. The package would have required CA package design approval for fissile material under the 2009 Edition. Under the 2012 Edition:

- The package could be transported as fissile-excepted according to para. 417(e), so long as shipment is under conditions of exclusive use and the accumulation of fissile nuclides on a conveyance is controlled to a maximum of 45 g.

- The package may be transportable under para. 674(b) which would imply fissile nuclide limits for the package and conveyance, derived from the package CSI formula, of 45 g and 225 g, respectively. The package would need to meet additional requirements on the design as specified in para. 674(b), on the content as specified in para. 674(d) and would need to be classified under a FISSILE UN number and to be subject to CSI control.

8.5. EXAMPLE 5 – WASTE CONTAINING A SMALL CONCENTRATION OF FISSILE NUCLIDES

Waste is known to contain some fissile nuclides in the form of highly enriched uranium and the operator estimates that there is no more than 1 g of uranium-235 for every 2 kg of material. The density of the waste exceeds 1 g/cm^3 so a 200 L drum of such material would contain at least 0.1 kg of uranium-235 which would exceed the limits in paras 417(d)-(e). Para. 674 could not be used as the calculated CSI for each drum would exceed 10. The operator estimates that the intended processing of the waste ensures the uranium is evenly mixed among the material and that 1 g is a good upper bound on the uranium content of the vast majority of 2 kg samples of material that may be taken. The operator does not identify any mechanism whereby this ratio would change significantly in an accident or following human intervention (whether intended or not) during transport or emergency response. Such a material would be a candidate for an exception under para. 417(f) if an adequate criticality safety case could be made.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material-2012 Edition, Specific Safety Requirements No. SSR-6, IAEA, Vienna (2012).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material-1996 Edition, Safety Standards Series No. ST-1, IAEA, Vienna (1996).

[3] Y. ZHAO, J. STEWART, D. MENNERDAHL, "Influence on Transport of Fissile Material by Proposed Changes to TS-R-1" (Proc. Symp. PATRAM 2010, 16th International Symposium on the Packaging and Transport of Radioactive Materials), United Kingdom (2010).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material-2009 Edition, Safety Requirements No. TS-R-1, IAEA, Vienna (2009).

[5] N. J. BARTON, C. WILSON, "Review of Fissile Exception Criteria in IAEA," (Proc. of The Fifth International Conference on Nuclear Criticality Safety (ICNC '95), Vol. II), Albuquerque, New Mexico, United States of America (1995) 9.15–9.22

[6] N. BARTON, "Competent Authority Approved Fissile Exceptions One Regulator's View," (*Proc. of PATRAM 2010,* 16th International Symposium on the Packaging and Transport of Radioactive Materials), London, United Kingdom (2010).

[7] Title 10 of the *Code of Federal Regulations* Part 71, *Energy*, Office of the Federal Register National Archives and Records Administration, January 1, 2012.

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, Specific Safety Guidance, No. SSG-26, IAEA, Vienna (2014)

[9] W. P. DARBY, L. GRAY, J. MOSSOP, "The Application of the Competent Authority Route to Fissile Exception for Some UK Waste Streams," (Proc. of The International Conference on Nuclear Criticality (ICNC 2011), 2011), Edinburgh, Scotland (2011).

[10] S. DARBY, N. BARTON, M. NUTTALL, D. MENNERDAHL, "Fissile Exceptions – A General Scheme for Packages Based on CSI Control," (*Proc. of PATRAM 2010, 16th International Symposium on the Packaging and Transport of Radioactive Materials*, 2010), London, United Kingdom (2010).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 1985 Edition (as amended 1990), Safety Series 6, IAEA, Vienna (1990).

ABBREVIATIONS

CA	Competent Authority
CSI	Criticality Safety Index
RCT	Routine Conditions of Transport
NCT	Normal Conditions of Transport
ACT	Accident Conditions of Transport
LSA	Low Specific Activity
SCO	Surface Contaminated Object
UN	United Nations

Annex

REPRODUCTION OF RELEVANT NEW AND SIGNIFICANTLY REVISED PARAGRAPHS FROM SSR-6

A-1. INTRODUCTION

This Annex provides the text of relevant paragraphs related to fissile materials and fissile exceptions in SSR-6[1]. They are a literal copy of such paragraphs including their numbering and the Table 13included also maintains the numbering given in SSR-6 for easier reference.

Design

220. *Design* shall mean the description of *fissile material* excepted under para. 417(f)[8] … that enables such an item to be fully identified...

Fissile nuclides and fissile material

222. *Fissile nuclides* shall mean uranium-233, uranium-235, plutonium-239 and plutonium-241. *Fissile material* shall mean a material containing any of the *fissile nuclides*. Excluded from the definition of *fissile material* are the following:
(a) *Natural uranium* or *depleted uranium* that is unirradiated;
(b) *Natural uranium* or *depleted uranium* that has been irradiated in thermal reactors only;
(c) Material with *fissile nuclides* less than a total of 0.25 g;
(d) Any combination of (a), (b) and/or (c).
These exclusions are only valid if there is no other material with *fissile nuclides* in the *package* or in the *consignment* if shipped unpackaged

Fissile material

417. *Fissile* material and *packages* containing *fissile material* shall be classified under the relevant entry as "FISSILE", in accordance with Table 1 unless excepted by one of the provisions of subparagraphs (a)–(f) of this paragraph and transported subject to the requirements of para. 570. All provisions apply only to material in *packages* that meets the requirements of para. 636, unless unpackaged material is specifically allowed in the provision:

(a) *Uranium* enriched in uranium-235 to a maximum of 1% by mass, and with a total plutonium and uranium-233 content not exceeding 1% of the mass of uranium-235, provided that the *fissile nuclides* are distributed essentially homogeneously throughout the material. In addition, if uranium-235 is present in metallic, oxide or carbide forms, it shall not form a lattice arrangement.
(b) Liquid solutions of uranyl nitrate enriched in uranium-235 to a maximum of 2% by mass, with a total plutonium and uranium-233 content not exceeding 0.002% of the mass of *uranium,* and with a minimum nitrogen to *uranium* atomic ratio (N/U) of 2.
(c) *Uranium* with a maximum *uranium* enrichment of 5% by mass of uranium-235 provided:
  (i) There is no more than 3.5 g of uranium-235 per *package*.
  (ii) The total plutonium and uranium-233 content does not exceed 1% of the mass of uranium-235 per *package*.
  (iii) Transport of the *package* is subject to the *consignment* limit provided in para. 570(c).
(d) *Fissile nuclides* with a total mass not greater than 2.0 per *package,* provided the *package* is transported subject to the *consignment* limit provided in para. 570(d).

---

[8] The design is prepared and approved long before the fissile-exception of para. 417(f) is applied.

(e) *Fissile nuclides* with a total mass not greater than 45 g, either packaged or unpackaged, subject to the limits provided in para. 570(e).
(f) A fissile material that meets the requirements of paras 570(b), 606 and 802.

570. *Fissile material* meeting one of the provisions (a)–(f) of para. 417 shall meet the following requirements:

(a) Only one of the provisions (a)–(f) of para. 417 is allowed per *consignment*.
(b) Only one approved *fissile material* in *packages* classified in accordance with para. 417(f) is allowed per *consignment* unless multiple materials are authorized in the certificate of *approval*.
(c) *Fissile material* in *packages* classified in accordance with para. 417(c) shall be transported in a *consignment* with no more than 45 g of *fissile nuclides*.
(d) *Fissile material* in *packages* classified in accordance with para. 417(d) shall be transported in a *consignment* with no more than 15 g of *fissile nuclides*.
(e) Unpackaged or packaged *fissile material* classified in accordance with para. 417(e) shall be transported under *exclusive use* on a *conveyance* with no more than 45 g of *fissile nuclides*.

Requirements for material excepted from fissile classification[9]

606. A *fissile material* excepted from classification as "FISSILE" under para. 417(f) shall be subcritical without the need for accumulation control under the following conditions:
(a) The conditions of para. 673(a);
(b) The conditions consistent with the assessment provisions stated in paras 684(b) and 685(b) for *packages*;
(c) The conditions specified in para. 683(a), if transported by air.

674. *Packages* containing *fissile material* that meets the requirements of para. 674(d) and one of the provisions of para. 674(a)–(c) are excepted from the requirements of paras 676–686[10].

(a) *Packages* containing *fissile material* in any form provided that:
  (i) The smallest external dimension of the *package* is not less than 10 cm;
  (ii) The *CSI* of the *package* is calculated using the following formula:A-2
    CSI = 50 × 5 × {[mass of uranium-235 in *package* (g)]/Z
    + [mass of other *fissile nuclides*[1] in package (g)]/280}
    where the values of Z are taken from Table 13;
  (iii) The *CSI* of any package does not exceed 10.
(b) *Packages* containing *fissile material* in any form provided that:
  (i) The smallest external dimension of the *package* is not less than 30 cm;
  (ii) The *package*, after being subjected to the tests specified in paras 719–724:
    - Retains its *fissile* material contents;
    - Preserves the minimum overall outside dimensions of the *package* to at least 30 cm;
    - Prevents the entry of a 10 cm cube.
  (iii) The *CSI* of the *package* is calculated using the following formula:
    CSI = 50 × 2 × {[mass of uranium-235 in *package* (g)]/Z
    + [mass of other *fissile nuclides*[1] in package (g)]/280}
    where the values of Z are taken from Table 13.
  (iv) The *CSI* of any *package* does not exceed 10.

[1] Plutonium may be of any isotopic composition provided that the amount of plutonium-241 is less than that of plutonium-240 in the *package*.

[9] "Intended to be excepted" from fissile classification is more appropriate.

[10] Compliance with those requirements have been demonstrated so no additional CA approval is required.

TABLE 13. VALUES OF Z FOR CALCULATION OF CSI IN ACCORDANCE WITH PARA. 674

Enrichment[a]	**Z**
Uranium enriched up to 1.5%	2200
Uranium enriched up to 5%	850
Uranium enriched up to 10%	660
Uranium enriched up to 20%	580
Uranium enriched up to 100%	450

[a] If a *package* contains *uranium* with varying enrichments of uranium-235, then the value corresponding to the highest enrichment shall be used for Z.

(c) *Packages* containing *fissile material* in any form provided that:
  (i) The smallest external dimension of the *package* is not less than 10 cm.
  (ii) The *package*, after being subjected to the tests specified in paras 719–724:
    - Retains its *fissile* material contents;
    - Preserves the minimum overall outside dimensions of the *package* to at least 10 cm;
    - Prevents the entry of a 10 cm cube.
  (iii) The *CSI* of the *package* is calculated using the following formula:
    CSI = 50 × 2 × {[mass of uranium-235 in *package* (g)]/450
    + [mass of other *fissile nuclides*1 in package (g)]/280}.
  (iv) The *maximum* mass of *fissile nuclides* in any *package* does not exceed 15 g.
(d) The total mass of beryllium, hydrogenous material enriched in deuterium, graphite and other allotropic forms of carbon in an individual *package* shall not be greater than the mass of *fissile nuclides* in the *package* except where their total concentration does not exceed 1 g in any 1000 g of material. Beryllium incorporated in copper alloys up to 4% by weight of the alloy does not need to be considered.

675. *Packages* containing not more than 1000 g of plutonium are expected from the application of paras 676–686 provided that:

(a) Not more than 20% of the plutonium by mass is *fissile nuclides*.
(b) The CSI of the *package* is calculated using the following formula:
$$CSI = 50 \times 2 \text{ [mass of plutonium (g)/1000]}.$$
(c) If *uranium* is present with the plutonium, the mass of *uranium* shall be no more than 1% of the mass of the plutonium.

802. *Competent authority approval* shall be required for the following:
(a) *Designs* for:
(i) ...;
(ii) ...;
(iii) *Fissile material* excepted[11] under para. 417(f) (see paras 805 and 806);
(iv) ...;
(v) *Packages* containing *fissile material*, unless excepted[12] by para. 417, 674 or 675 (see paras 81406); plutonium;
(vi) ...

Approval of material excepted from fissile classification[13]

---

[11] If already excepted, no additional approval would be required – ”intended to be excepted” is more appropriate

[12] … unless subject to one of the paras 417(a)-(f), 674 or 675.

805. The *design* for a *fissile material* excepted from "FISSILE" classification in accordance with Table 1, under para. 417(f) shall require *multilateral approval*. An application for *approval* shall include:

(a) A detailed description of the material; particular reference shall be made to both physical and chemical states.
(b) A statement of the tests that have been carried out and their results, or evidence based on calculative methods, to show that the material is capable of meeting the requirements specified in para. 606.
(c) A specification of the applicable *management system* as required in para. 306.
(d) A statement of specific actions to be taken prior to *shipment*.

806. The competent authority shall establish a certificate of approval stating that the approved material meets the requirements for fissile material excepted by the competent authority in accordance with para. 606 and shall attribute to that design an identification mark.

814. Each *package design* for *fissile material* that is not excepted[14] by any of the paras 417(a)y shall establish a certificate *multilateral approval*.

Certificates of approval for material excepted from fissile classification

835. Each certificate of *approval* issued by a *competent authority* for material excepted from classification as "FISSILE" shall include the following information:

…

(d) List of applicable national and international regulations, including the edition of the IAEA Regulations for the Safe Transport of Radioactive Material under which the exception is approved;
(e) A description of the excepted material;
(f) Limiting specifications for the excepted material.

---

[13] At this time the fissile material is not excepted from anything and certainly not from classification as FISSILE.

[14] 814. "Complies with any of the paras 417(a)–(f), 674 and 675 shall not require multilateral approval" is more appropriate.

CONTRIBUTORS TO DRAFTING AND REVIEW

Barton, N.	Office for Nuclear Regulation, United Kingdom
Capadona, N.	International Atomic Energy Agency
Desnoyers, B.	World Nuclear Transport Institute (WNTI)
Hirose, M	Nuclear Regulation Authority, Japan
Ito, D.	World Nuclear Transport Institute (WNTI)
Jutier, L.	Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France
Leblanc, V.	Federal Agency for Nuclear Control, Belgium
Mennerdahl, D.	E Mennerdahl Systems, Sweden
Milin, M.	Institute de Radioprotection et de Sûreté Nucléaire (IRSN), France
Parks, C.	Oak Ridge National Laboratory, United States of America
Phimister, I	Radioactive Waste Management Limited, United Kingdom
Reiche, I.	Bundesamt für Strahlenschutz (BfS), Germany
Ruprecht, B.	Bundesamt für Strahlenschutz (BfS), Germany
Zamora Martin, F.	Consejo de Seguridad Nuclear (CSN), Spain

Consultants Meetings

Vienna, Austria: 9-12 December 2013
Vienna, Austria: 12-16 May 2014

Technical Committee Meeting

Vienna, Austria: 10-14 November 2014

IAEA
International Atomic Energy Agency

No. 23

ORDERING LOCALLY

In the following countries, IAEA priced publications may be purchased from the sources listed below or from major local booksellers.

Orders for unpriced publications should be made directly to the IAEA. The contact details are given at the end of this list.

AUSTRALIA
DA Information Services
648 Whitehorse Road, Mitcham, VIC 3132, AUSTRALIA
Telephone: +61 3 9210 7777 • Fax: +61 3 9210 7788
Email: books@dadirect.com.au • Web site: http://www.dadirect.com.au

BELGIUM
Jean de Lannoy
Avenue du Roi 202, 1190 Brussels, BELGIUM
Telephone: +32 2 5384 308 • Fax: +32 2 5380 841
Email: jean.de.lannoy@euronet.be • Web site: http://www.jean-de-lannoy.be

CANADA
Renouf Publishing Co. Ltd.
5369 Canotek Road, Ottawa, ON K1J 9J3, CANADA
Telephone: +1 613 745 2665 • Fax: +1 643 745 7660
Email: order@renoufbooks.com • Web site: http://www.renoufbooks.com

Bernan Associates
4501 Forbes Blvd., Suite 200, Lanham, MD 20706-4391, USA
Telephone: +1 800 865 3457 • Fax: +1 800 865 3450
Email: orders@bernan.com • Web site: http://www.bernan.com

CZECH REPUBLIC
Suweco CZ, spol. S.r.o.
Klecakova 347, 180 21 Prague 9, CZECH REPUBLIC
Telephone: +420 242 459 202 • Fax: +420 242 459 203
Email: nakup@suweco.cz • Web site: http://www.suweco.cz

FINLAND
Akateeminen Kirjakauppa
PO Box 128 (Keskuskatu 1), 00101 Helsinki, FINLAND
Telephone: +358 9 121 41 • Fax: +358 9 121 4450
Email: akatilaus@akateeminen.com • Web site: http://www.akateeminen.com

FRANCE
Form-Edit
5 rue Janssen, PO Box 25, 75921 Paris CEDEX, FRANCE
Telephone: +33 1 42 01 49 49 • Fax: +33 1 42 01 90 90
Email: fabien.boucard@formedit.fr • Web site: http://www.formedit.fr

Lavoisier SAS
14 rue de Provigny, 94236 Cachan CEDEX, FRANCE
Telephone: +33 1 47 40 67 00 • Fax: +33 1 47 40 67 02
Email: livres@lavoisier.fr • Web site: http://www.lavoisier.fr

L'Appel du livre
99 rue de Charonne, 75011 Paris, FRANCE
Telephone: +33 1 43 07 50 80 • Fax: +33 1 43 07 50 80
Email: livres@appeldulivre.fr • Web site: http://www.appeldulivre.fr

GERMANY
Goethe Buchhandlung Teubig GmbH
Schweitzer Fachinformationen
Willstätterstrasse 15, 40549 Düsseldorf, GERMANY
Telephone: +49 (0) 211 49 8740 • Fax: +49 (0) 211 49 87428
Email: s.dehaan@schweitzer-online.de • Web site: http://www.goethebuch.de

HUNGARY
Librotade Ltd., Book Import
PF 126, 1656 Budapest, HUNGARY
Telephone: +36 1 257 7777 • Fax: +36 1 257 7472
Email: books@librotade.hu • Web site: http://www.librotade.hu

INDIA
Allied Publishers
1st Floor, Dubash House, 15, J.N. Heredi Marg, Ballard Estate, Mumbai 400001, INDIA
Telephone: +91 22 2261 7926/27 • Fax: +91 22 2261 7928
Email: alliedpl@vsnl.com • Web site: http://www.alliedpublishers.com

Bookwell
3/79 Nirankari, Delhi 110009, INDIA
Telephone: +91 11 2760 1283/4536
Email: bkwell@nde.vsnl.net.in • Web site: http://www.bookwellindia.com

ITALY
Libreria Scientifica "AEIOU"
Via Vincenzo Maria Coronelli 6, 20146 Milan, ITALY
Telephone: +39 02 48 95 45 52 • Fax: +39 02 48 95 45 48
Email: info@libreriaaeiou.eu • Web site: http://www.libreriaaeiou.eu

JAPAN
Maruzen Co., Ltd.
1-9-18 Kaigan, Minato-ku, Tokyo 105-0022, JAPAN
Telephone: +81 3 6367 6047 • Fax: +81 3 6367 6160
Email: journal@maruzen.co.jp • Web site: http://maruzen.co.jp

NETHERLANDS
Martinus Nijhoff International
Koraalrood 50, Postbus 1853, 2700 CZ Zoetermeer, NETHERLANDS
Telephone: +31 793 684 400 • Fax: +31 793 615 698
Email: info@nijhoff.nl • Web site: http://www.nijhoff.nl

Swets Information Services Ltd.
PO Box 26, 2300 AA Leiden
Dellaertweg 9b, 2316 WZ Leiden, NETHERLANDS
Telephone: +31 88 4679 387 • Fax: +31 88 4679 388
Email: tbeysens@nl.swets.com • Web site: http://www.swets.com

SLOVENIA
Cankarjeva Zalozba dd
Kopitarjeva 2, 1515 Ljubljana, SLOVENIA
Telephone: +386 1 432 31 44 • Fax: +386 1 230 14 35
Email: import.books@cankarjeva-z.si • Web site: http://www.mladinska.com/cankarjeva_zalozba

SPAIN
Diaz de Santos, S.A.
Librerias Bookshop • Departamento de pedidos
Calle Albasanz 2, esquina Hermanos Garcia Noblejas 21, 28037 Madrid, SPAIN
Telephone: +34 917 43 48 90 • Fax: +34 917 43 4023
Email: compras@diazdesantos.es • Web site: http://www.diazdesantos.es

UNITED KINGDOM
The Stationery Office Ltd. (TSO)
PO Box 29, Norwich, Norfolk, NR3 1PD, UNITED KINGDOM
Telephone: +44 870 600 5552
Email (orders): books.orders@tso.co.uk • (enquiries): book.enquiries@tso.co.uk • Web site: http://www.tso.co.uk

UNITED STATES OF AMERICA
Bernan Associates
4501 Forbes Blvd., Suite 200, Lanham, MD 20706-4391, USA
Telephone: +1 800 865 3457 • Fax: +1 800 865 3450
Email: orders@bernan.com • Web site: http://www.bernan.com

Renouf Publishing Co. Ltd.
812 Proctor Avenue, Ogdensburg, NY 13669, USA
Telephone: +1 888 551 7470 • Fax: +1 888 551 7471
Email: orders@renoufbooks.com • Web site: http://www.renoufbooks.com

United Nations
300 East 42nd Street, IN-919J, New York, NY 1001, USA
Telephone: +1 212 963 8302 • Fax: 1 212 963 3489
Email: publications@un.org • Web site: http://www.unp.un.org

Orders for both priced and unpriced publications may be addressed directly to:

IAEA Publishing Section, Marketing and Sales Unit, International Atomic Energy Agency
Vienna International Centre, PO Box 100, 1400 Vienna, Austria
Telephone: +43 1 2600 22529 or 22488 • Fax: +43 1 2600 29302
Email: sales.publications@iaea.org • Web site: http://www.iaea.org/books

15-26311

International Atomic Energy Agency
Vienna
ISBN 978–92–0–106215–4
ISSN 1011–4289