



CHANGES IN THE TRANSPORT OF FISSILE MATERIAL RESULTING FROM THE LATEST PROPOSED REVISION OF THE IAEA TRANSPORT REGULATIONS

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ABSTRACT

Currently the IAEA is reviewing and revising the Regulations for the Safe Transport of Radioactive Material (TS-R-1). A draft of the new revision has been published by IAEA for commenting by the member states. In this revision process important changes have been made to the classification and transport requirements for fissile material.

In the paper at first the current alternatives for shipping material containing fissile nuclides are recalled. Then it is analyzed how these different types and quantities of materials could be transported under the provisions of the latest draft of the new revision of TS-R-1. The schemes for transition from the old to the new system are intended to provide some guidance for continuing the transport of fissile material under the proposed new provisions.

INTRODUCTION

Most provisions in the IAEA transport requirements TS-R-1 regarding the classification and transport of fissile material have been in the regulations for a long time with only minor changes. However, the regulatory framework as well as the transport practice and needs have changed over the years. Therefore activities have been carried out by IAEA to reassess the complete system of classification and transport of fissile material. In March 2009 the IAEA initiated a review of TS-R-1 and associated guidance TS-G-1.1 which will lead to a new revision of these standards. The draft of these new regulations contains significant changes to the provisions related to fissile materials with focus on fissile excepted material. These changes, if getting approved, will considerably influence the practice of transporting fissile material. Most impact will be on packages containing fissile material but currently being excepted by para. 417 of TS-R-1 from classification with a "FISSILE" UN number. This paper concentrates on these packages and shows some principles how they can be classified according to the draft of the new revision of the regulations.

CURRENT CLASSIFICATION OF MATERIAL CONTAINING FISSILE NUCLIDES

According to the current IAEA Regulations for the Safe Transport of Radioactive Material [1], para. 222, material containing fissile nuclides (U-233, U-235, Pu-239 and Pu-241) is defined as:

- Non-fissile material, if the material is natural uranium or depleted uranium which is unirradiated or which has been irradiated in thermal reactors only, or
- Fissile material otherwise.



Packages containing fissile material:

- May be classified by a “non fissile or fissile excepted” UN number, if the requirements of para. 417 are met, or
- Otherwise have to be classified by a “FISSILE” UN number, and the requirements of paras 671, 673-683 (including a criticality safety assessment) and para. 812 (multilateral approval) have to be met.

Exceptions to the classification of packages as fissile (para. 417) cover packages containing:

- At maximum 15 g of fissile nuclides (subject to a consignment limit and limitations in beryllium and deuterium contents and minimum package dimensions, subpara. 417(a)(i)),
- A homogeneous hydrogenous solution or mixture where the ratio of fissile nuclides to hydrogen is less than 5% by mass (subject to a consignment limit and limitations in beryllium and deuterium contents and minimum package dimensions, subpara. 417(a)(ii)),
- Not more than 5 g of fissile nuclides in any 10 L volume of material (subject to a consignment limit and limitations in beryllium and deuterium contents and minimum package dimensions, subpara. 417(a)(iii)),
- Uranium enriched in U-235 to a maximum of 1% by mass (subject to limitations in the U-233 and plutonium content and the distribution of the fissile nuclides, subpara. 417(b)),
- Liquid solutions of uranyl nitrate enriched in U-235 to at maximum 2% by mass (subject to restrictions in the plutonium and U-233 content and the N/U ratio, subpara. 417(c)) and
- Plutonium containing not more than 20% of fissile nuclides by mass up to a maximum plutonium mass of 1 kg per consignment shipped under exclusive use (subpara. 417(d)).

CLASSIFICATION OF MATERIAL CONTAINING FISSILE NUCLIDES ACCORDING TO THE DRAFT OF THE NEW REGULATIONS

Currently IAEA is reviewing and revising the system of classification and transport of fissile material. In the current draft of the revised regulations [2] the classification of materials containing fissile nuclides is planned as follows:

Material containing fissile nuclides (U-233, U-235, Pu-239 and Pu-241) is intended (para. 222) to:

- Be defined as non-fissile material, if:
 - The material is unirradiated natural or depleted uranium and there is no other material with fissile nuclides in the package, or
 - The material is natural or depleted uranium which has been irradiated in thermal reactors only and there are no other fissile nuclides in the package, or
 - The package contains not more than 0.25 g of fissile nuclides.
- Be classified as fissile material otherwise.

The changes to para. 222 reflect the need to include natural and depleted uranium in the criticality safety assessment if there are additional fissile nuclides in the same package and to exclude packages containing only traces of fissile nuclides from being classified as fissile.

Packages containing fissile material:

- May be classified by a “non fissile or fissile excepted” UN number, if the requirements of para. 417 are met, or
- Have to be classified by a “FISSILE” UN number otherwise and



- If meeting the conditions of paras 672 or 672bis may be transported applying these paras without the need for criticality safety assessment and multilateral approval but subject to CSI labeling requirements, or
- Otherwise have to meet the requirements of paras 671, 673-683 (including a criticality safety assessment for the package) and para. 812 (multilateral approval).

As a result of the review the provisions excepting packages containing fissile material from being classified as fissile have been changed significantly. In the draft the exceptions to the classification of packages containing fissile material as fissile (para. 417) apply to packages containing:

- Uranium enriched in U-235 to a maximum of 1% by mass (subject to limitations in the U-233 and plutonium content and the distribution of the fissile nuclides, subpara. 417(a)),
- Liquid solutions of uranyl nitrate enriched in U-235 to at maximum 2% by mass (subject to restrictions in the plutonium and U-233 content and the N/U ratio, subpara. 417(b)),
- Not more than 3.5 g of U-235 at a maximum enrichment of 5% by mass or 2.0 g of U-235 at a higher enrichment (subject to a consignment limit and limitations in U-233 and Pu content and package size, subpara. 417(c)),
- Not more than 0.5 g of fissile nuclides (subject to a consignment limit, subpara. 417(d)),
- Not more than 45 g of fissile nuclides per conveyance under exclusive use (subpara. 417(e)),
- Other materials having received multilateral approval (criteria for approval provided in para. 605bis, subpara. 417(f))

The requirement for approval of fissile material to be excepted from classification as fissile under para. 417(f) is that this material is subcritical under conditions consistent with normal and accident conditions of transport without the need for accumulation control, considering assessment conditions for the material including water leakage that result in maximum neutron multiplication and taking into account enhanced testing conditions if transported by air.

Packages containing fissile material not meeting the above mentioned criteria have to be classified as fissile. If the package meets the conditions of para. 672 or 672bis it may be transported applying these paras. These paras are a new component of the graded approach for transporting fissile material. They represent certain package designs generally approved for the transport of fissile material, therefore no criticality safety assessment for the specific package has to be done, and no specific multilateral package design approval is required. In these cases criticality safety is ensured by a comparably high criticality safety index (CSI) assigned to the packages computed directly from the type and mass of fissile nuclides and some basic properties of the package.

EXAMPLES FOR TRANSITION FROM THE OLD TO THE NEW SYSTEM

Material currently shipped under para. 417(a)(i) of TS-R-1

Currently packages containing fissile material with up to 15 g of fissile nuclides per package are excepted from classification by a “FISSILE” UN number, if a given mass limit per consignment is met, the smallest external dimension of each package is not less than 10 cm and the beryllium and deuterium contents in the package are below certain limits. This exception is no longer supported by the draft of the new revision of TS-R-1. For continuing transport of packages currently covered by this rule several possibilities provided by the draft of the new revision may be considered. All of these options have advantages and disadvantages; therefore for every concrete transport need the

appropriate option should be selected. The following scheme assumes that a package fulfills the requirements of the current para. 417(a)(i) and suggests ways for classification of the package according to the draft of the new revision of TS-R-1.

Table 1. Classification options according to the draft of the new revision of TS-R-1 for packages currently meeting para. 417(a)(i) of TS-R-1

Requirements to the package	Applicable para. in the draft	Classification	Further conditions
≤ 0.25 g of fissile nuclides (excepted package allowed)	222	non fissile	
≤ 3.5 g U-235, enrichment ≤ 5% (excepted package allowed)	417(c)(i)	fissile excepted	consignment limited to 45 g of U-235 with a total Pu and U-233 content ≤ 1% of the U-235 mass *)
≤ 2 g U-235, enrichment > 5% (excepted package allowed)	417(c)(ii)		
≤ 0.5 g of fissile nuclides (excepted package allowed)	417 (d)	fissile excepted	consignment limited to 45 g of fissile nuclides*)
≤ 45 g of fissile nuclides (excepted package allowed)	417 (e)	fissile excepted	≤ 45 g of fissile nuclides per conveyance under exclusive use *)
only materials meeting the requirements of para. 605bis of the draft and having been multilaterally approved (excepted package allowed)	417(f)	fissile excepted	only one such material allowed per consignment unless specifically subject to multilaterally approval *)
no excepted package, mass limits for fissile nuclides see Table 3, limitations on the contents of beryllium and other materials **)	672(a)	fissile	accumulation control via CSI, see Table 3
no excepted package; smallest external dimension ≥ 30 cm; retention of the content and preservation of smallest external dimension ≥ 30 cm and prevention of the entry of a 10 cm cube under normal conditions of transport; mass limits for fissile nuclides see Table 4; limitations on the contents of beryllium and other materials **)	672(b)	fissile	accumulation control via CSI, see Table 4
no excepted package; smallest external dimension ≥ 10 cm; retention of the content and preservation of a smallest external dimension ≥ 10 cm and prevention of the entry of a 10 cm cube under normal conditions of transport; ≤ 15 g of fissile nuclides; limitations on the contents of beryllium and other materials **)	672(c)	fissile	accumulation control via CSI, see Table 5
multilateral approval of package design	673	fissile	accumulation control

			via CSI, value specified in the package design approval certificate
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*) May not be combined in one consignment with packages excepted by other subparagraphs of para. 417.

***) 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 10³ g of material. Beryllium incorporated in copper alloys up to 4% in weight of the alloy does not need to be considered.

Examples for application of the revised criteria according to the draft of TS-R-1: Typical UF₆ samples with max. 5% enrichment, smallest external dimension ≥ 10 cm, containing up to 3.5 g of U-235 per package may be shipped as “fissile excepted”, subject to a consignment limit of 45 g U-235. If the radiological requirements are fulfilled, these may even be excepted packages. Larger amounts of fissile material may be shipped as “fissile excepted” up to 45 g of fissile nuclides according to para. 417(e), but requiring shipment under exclusive use. If the samples are to be shipped together with large quantities of fissile material in approved packages (para. 673), then application of para. 672 may be considered to avoid low consignment or conveyance limits.

Material currently shipped under paras 417(a)(ii) and 417(a)(iii) of TS-R-1

The current IAEA regulations allow exception of packages containing fissile material based on the ratio of the mass of fissile nuclides to the volume of material, see para. 417(a)(iii). This exception was deliberately removed during the review of the regulations. Another exception which is intended to be removed from the regulations is that for homogeneous hydrogenous solutions or mixtures where the ratio of fissile nuclides to hydrogen is less than 5% by mass (para. 417(a)(ii) of the current TS-R-1).

The Table 2 presents solutions for classifying materials currently excepted by the two subparagraphs mentioned according to the draft of the new regulations.

Table 2. Classification options according to the draft of the new revision of TS-R-1 for packages containing more than 15 g of fissile nuclides and currently meeting para. 417(a)(ii) or 417(a)(iii) of TS-R-1

Requirements to the package	Para. in the draft	Classification	further conditions
≤ 45 g of fissile nuclides	417 (e)	fissile excepted	≤ 45 g of fissile nuclides per conveyance under exclusive use *)
only materials meeting the requirements of para. 605bis of the draft and having been multilaterally approved	417(f)	fissile excepted	only one such material allowed per consignment unless specifically subject to multilaterally

			approval *)
no excepted package, mass limits for fissile nuclides see Table 3, limitations on the contents of beryllium and other materials **)	672(a)	fissile	accumulation control via CSI, see Table 3
no excepted package; smallest external dimension ≥ 30 cm; retention of the content and preservation of a smallest external dimension ≥ 30 cm and prevention of the entry of a 10 cm cube under normal conditions of transport; mass limits for fissile nuclides see Table 4; limitations on the contents of beryllium and other materials **)	672(b)	fissile	accumulation control via CSI, see Table 4
multilateral approval of package design	673	fissile	accumulation control via CSI, value specified in the package design approval certificate

*) and **) see Table 1

Some materials currently transported using the exception in para. 417(a)(iii) (5 g of fissile nuclides in any 10 L volume of material) should be suitable to be approved by the competent authority according to para. 417(f) of the draft. Guidance is provided in the draft of the new revision of TS-G-1.1 [3], paras 417.8 and 417.9. The latter paragraph gives examples for specification of materials possibly appropriate for approval by the competent authority, based on the mass ratio of fissile nuclides to non-fissile material. For the remaining materials for which compliance with the principles of para. 615bis of the draft can not be shown, e.g. because the fissile nuclides are not homogeneously distributed or because the fissile nuclides can be easily separated from the non fissile material, other possibilities according to the table should be checked.

In the case of a 200 L drum containing 100 g of fissile nuclides, according to the draft of the new revision of TS-R-1 classification as fissile excepted is possible only if the content is approved for exception under para. 417(f) by the competent authority. Para. 417.9 of the draft of TS-G-1.1 provides as an example a material containing at least 2000 g of non-fissile material per gram of fissile nuclides, subject to additional considerations about homogeneity and non-separability under normal and accident conditions of transport. If para 417(f) can not be applied the package has to be labeled with a "FISSILE" UN number. Under certain conditions (U-235 is the only fissile nuclide present in substantial quantities, enrichment in U-235 $\leq 5\%$, no more than 20 g of material with a hydrogen density greater than that of water in the package, restrictions on the deuterium and beryllium content, the drum has a smallest external dimension of at least 30 cm and retains its contents, preserves a smallest external dimension ≥ 30 cm and prevents the entry of a 10 cm cube under normal conditions of transport) para. 672(b) may be applied. In this case approval of the package design by the competent authority is not required. At 5% enrichment the drum containing 100 g of U-235 applying para. 672(b) would be labeled with a CSI of 10, therefore 5 such drums could be loaded on a conveyance for a total CSI of 50. If the conditions of para. 672(b) are not met or if this paragraph is not applied for other reasons the package design has to be multilaterally approved.

Permissible masses of fissile nuclides per package and per conveyance for applying para. 672 of the draft of the new revision of TS-R-1

The following tables provide values calculated from the draft of the new revision of TS-R-1 regarding permissible masses of fissile nuclides per package and per conveyance (assuming a CSI sum on the conveyance of 50) for applying para. 672 of the draft of the new revision of TS-R-1.

Table 3. Permissible mass of fissile nuclides per package and per conveyance (assuming a CSI sum on the conveyance of 50) for applying para. 672(a) of the draft new revision of TS-R-1

Fissile nuclide	Enrichment in U-235 max.	Max. mass of fissile nuclides per package [g]		Max. mass of fissile nuclides per conveyance for CSI=50 [g]	
		general use	limited use ^{#)}	general use	limited use ^{#)}
U-235	1.5	80	96	400	480
	5	30.8	40	154	200
	10	22	32.4	110	162
	20	18.8	28	94	140
	100	14.4	21.6	72	108
other	-	9.2	14	46	70

Table 4. Permissible mass of fissile nuclides per package and per conveyance (assuming a CSI sum on the conveyance of 50) for applying para. 672(b) of the draft new revision of TS-R-1

Fissile nuclide	Enrichment in U-235 max.	Max. mass of fissile nuclides per package [g]		Max. mass of fissile nuclides per conveyance for CSI=50 [g]	
		general use	limited use ^{#)}	general use	limited use ^{#)}
U-235	1.5	200	240	1000	1200
	5	77	100	385	500
	10	55	81	275	405
	20	47	70	235	350
	100	36	54	180	270
other	-	23	35	115	175

Table 5. Permissible mass of fissile nuclides per package and per conveyance (assuming a CSI sum on the conveyance of 50) for applying para. 672(c) of the draft new revision of TS-R-1

Fissile nuclide	Enrichment in U-235 max.	Max. mass of fissile nuclides per package [g]		Max. mass of fissile nuclides per conveyance for CSI=50 [g]	
		general use	limited use ^{#)}	general use	limited use ^{#)}
U-235	1.5	15	15	1000	1200
	5	15	15	385	500
	10	15	15	275	405
	20	15	15	235	350
	100	15	15	180	270
other	-	15	15	115	175

^{#)} Limited use: only when there is no more than 20 grams of material with a hydrogen density greater than water in a package.



CONCLUSIONS

The draft of the new revision of the IAEA transport regulations provides a new graded approach to the classification and transport of material containing fissile nuclides. Such material may be classified as non-fissile, fissile excepted or fissile; in the case of packages classified as fissile there are new specifications of general package designs without competent authority approval and packages requiring multilateral approval as currently. For every transport need concerning material containing fissile nuclides including the category of fissile excepted packages the appropriate way of classification and transport should be sought, taking into account the various possibilities.

REFERENCES

- [1] Regulations for the Safe Transport of Radioactive Material: Safety Requirements (TS-R-1), 2009 Edition, IAEA, 2009
- [2] Regulations for the Safe Transport of Radioactive Material, 20XX Edition, Draft Safety Requirement DS437, IAEA, 2010
- [3] Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, TS-G-1.1, WM Draft 0.5, IAEA, 2010