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FEEDBACK FROM IAEA TRANSSC WORKING GROUP AND TECHNICAL EXPERT GROUP ON CRITICALITY

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ABSTRACT

One of IAEA's missions is to establish model regulations for the safe transport of radioactive material by all modes. The Transport Regulations (SSR-6) are important for all stakeholders in transport including governments, regulators, operators of nuclear facilities, carriers, producers of radiation sources, cargo-handlers and the public. This mission for the evolution of SSR-6 is performed by the TRANsport Safety Standards Committee (TRANSSC). Four TRANSSC Technical Expert Groups (TTEG) are being established to deal with four subject areas for the Committee. The Criticality TTEG is one of them. The Criticality Working Group (CWG) is the first WG under this TTEG and has met for two days, just before the TRANSSC meetings.

The first part of this paper aims to summarize the CWG exchanges, in particular on the following topics:

- Proposals on criticality safety for evolution of the Regulations or the Advisory Material SSG-26. Some of these issues are the resolution of an inconsistency between SSR-6 and the International Maritime Dangerous Goods (IMDG) code for sea transport of large freight containers, a solution under development for the transport of empty washed UF_6 cylinders.
- Justification for the provisions of the Regulations. In support of a future Technical Basis Document (TBD) development, the CWG has collected some topics that have been identified as being unclear or missing. Consensus explanations have been reached on some provisions that have been questioned (for example, high-speed air accidents, 10 cm minimum external package dimensions and 10 cm cube entry, intent of confinement system, etc.). Remaining topics, including those that are perceived as understood, need to be provided with documented justifications.
- The interpretation of the Regulations. Examples include nuclear data at temperatures other than room temperature (including those at very low temperatures), "exclusive use" of large freight containers and conveyances, criticality safety at less severe test conditions than maximum (fire and others), etc. Usually, these discussions involve the technical basis for the provisions or guidance.

A part of these exchanges is detailed in this paper and the other part in a paper for ICNC2019.

The second part of this paper presents a questionnaire which is designed to share technical basis information between countries, to learn about current use of SSR-6 and to encourage proposals for improvements. The final purpose is to compile all the answers of the questionnaire to support future use and development of the SSR-6, SSG-26 and Technical Basis Document.

INTRODUCTION

One of IAEA's missions is to establish model regulations for the safe transport of radioactive material by all modes. The Transport Regulations (currently SSR-6 [1]) are important for all stakeholders in transport including governments, regulators, operators of nuclear facilities, carriers, producers of radiation sources, cargo-handlers and the public. This mission is performed by the TRANsport Safety Standards Committee (TRANSSC). Four TRANSSC Technical Expert Groups (TTEG) are being established to deal with four subject areas for the Committee:

- Criticality;
- Package performance and assessment;
- Radiation protection;
- Transport operational matters.

The IAEA Terms of Reference [2] for a TTEG starts with a background: *The retirement of long serving members of TRANSSC during the last 4-year term of TRANSSC, the development of the Technical Basis Document and the ongoing need to demonstrably justify the technical basis of the SSR-6 requirements, led to the need and creation of TRANSSC Technical Expert Groups (TTEGs).*

Each TTEG could have one or more Working Group (WG). Since TRANSSC 34th (July 2017), the WGs have met for two days, just before each TRANSSC meeting. Since TRANSSC 36th (June 2018), the TTEGs have met the first or second day of each TRANSSC meeting.

Concerning criticality, the Criticality Working Group (CWG), already established at TRANSSC n°34 as a general criticality safety WG, is the first WG under the Criticality TTEG. This WG has remained the only WG of this TTEG. The discussions during the past CWG meetings include the following topics:

- Proposals on criticality safety for evolution of the Regulations or the Advisory Material SSG-26. Some of these issues are the resolution of an inconsistency between SSR-6 and the IMDG code for sea transport of large freight containers, a solution under development for the transport of empty washed UF_6 cylinders;
- Justification for the provisions of the Regulations. In support of a future Technical Basis Document development, the CWG has collected some topics that have been identified as being unclear or missing. Consensus explanations have been reached on some provisions that have been questioned (for example, high-speed air accidents, 10 cm minimum external package dimensions and 10 cm cube entry, intent of confinement system, etc.). Remaining topics, including those that are perceived as understood, need to be provided, with documented justifications;
- The interpretation of the Regulations. Examples include nuclear data at temperatures other than room temperature (including those at very low temperatures), "exclusive use" of large freight containers and conveyances, criticality safety at less severe test conditions than maximum (fire and others), etc. Usually, these discussions involve the technical basis for the provisions or guidance.

The first part of this paper aims to summarize the CWG exchanges about the three previous topics.

The second part of this paper aims to present a questionnaire which is designed to share technical basis information, to learn about current use of SSR-6 and to encourage proposals for improvements.

TOPICS DISCUSSED BY THE WG

Criticality safety at low temperatures

The effect of low temperatures on the criticality safety of fissile package design has been discussed during the WG in order to share finished or ongoing studies on this subject in different countries. These exchanges are detailed in [3].

CSI limits for seagoing vessel

The Criticality Safety Index (CSI) limits (Table 11 in SSR-6 [1]) for seagoing vessel have been discussed during the WG. These exchanges are detailed in [3]. To summarize this point, International Maritime Organization (IMO) experts decided to maintain the requirement that only “closed containers” can be considered as “large freight containers” as regards the CSI assigned for fissile material in a seagoing vessel. This situation leads to the fact that open freight containers, like “flat-racks” currently used to carry enriched UF_6 packages, cannot be considered as “large freight containers”, and that for them the limits assigned for “packages, overpacks and small containers” shall apply. As a consequence, shipment of fissile material contained in packages loaded in open containers currently cannot use the “no limit” assigned to the total ship in case of use of large freight containers. The working group was asked to clarify this, and to propose a technical basis for the differences on CSI limits on the total vessel between the “large freight containers” and “packages, overpacks and small containers”.

Confinement system

The confinement system requirements have been discussed during WG meetings and there has been a general agreement that its use and understanding is different in function of countries. Thus, confinement system is the subject of several questions in the draft questionnaire (see later chapter on this). Moreover, technical exchanges about this subject are detailed in [3].

Definition of exclusive use for fissile package

The definition of exclusive use on the para 570(e) of SSR-6 was discussed during the WG. These exchanges are detailed in [3].

Concept of preventing entry of 10 cm cube and birdcage design

Exchanges took place within the WG to explain the concept of preventing entry of 10 cm cube and birdcage design. These exchanges are detailed in [3].

Empty UF_6 cylinders

SSR-6 [1], introduced significant changes as regards the definitions and criteria for “fissile-excepted material”. One of these changes is the significant decrease of the maximum quantity of fissile nuclides allowed in a package to conform to the “fissile excepted material” definition. Another significant change was also introduced at that time: it was confirmed that all the excepted packages may contain fissile material, provided the criteria for “fissile excepted material” are complied with. As a consequence, this requirement applies also to empty packagings that have contained fissile material as it is the case of emptied, cleaned and washed 30B cylinders. The 30B cylinders are the primary receptacles (pressure vessel) used to carry enriched uranium up to 5 % in weight in ^{235}U in the form of uranium hexafluoride (UF_6).

Figure 1 - A cylinder 30B
(external diameter: 762 mm, total length: 2070 mm, internal volume: 736 litres)

The feedback on the internal radiological conditions of the “cleaned and washed” 30B cylinders shows that the residual level of contamination is compatible with the contamination limits allowed for the internal surfaces of the empty packaging transported as excepted packages (up to an average value of 400 Bq/cm², this material being a low toxicity alpha emitter). Based on this maximum contamination level and all the inner surface of the cylinder, this leads to less than 15 g of ^{235}U per empty packaging. Before SSR-6 2012 edition [4], it was then easy to demonstrate the compliance with the 15 g of fissile nuclides per package and the 400 g of ^{235}U per consignment (requirement to classify the package as fissile excepted). This was only based on the fact that at maximum about 24 empty cylinders can be carried together in a same 40-foot ISO flat rack, and on the inner maximum contamination level of less than 400 Bq/cm² that is reached after several cycles of washing.

This situation changed completely with the enter into force of the IAEA SSR-6 2012 edition. The fissile excepted criteria that can be now use for these empty cleaned and washed cylinders are the followings:

- Up to 3.5 g of ^{235}U (U enriched up to 5 % by mass of ^{235}U) per package and up to 45 g of ^{235}U per consignment, or
- Up to 45 g of ^{235}U per conveyance, without any specific package limit, and transport under exclusive use.

More accurate measurements were performed to determine whether it can be possible to demonstrate compliance with the 3.5 g of ^{235}U limit or not. It appears that in average the value is less than 3.5 g, however, this value may reach about 5 g. It is recognized that the 3.5 g of ^{235}U limit was specifically adapted, in the 2012 edition of SSR-6, to solve the perceived need of the nuclear industry.

As a consequence the number of emptied cleaned and washed 30B cylinders carried together in a same flat rack was reduced in order to respect the conveyance limit, and to consider the transport of these cylinders to be under exclusive use. When real measurements are performed, an alternative is to adjust the number of cylinders measured at 3.5 g or less of ^{235}U in order to comply with the consignment limit of 45 g. In this case, transport under exclusive use is not required.

This is not satisfactory as it is clear that the criticality risk is mitigated since the material is essentially fixed contamination on internal surfaces of a voluminous packaging (736 litres) made of thick steel walls.

After discussion, it was agreed in the working group that this kind of empty cleaned and washed cylinders could justify a proposal for an additional fissile exception based on contamination level of internal surfaces in the next revision process of SSR-6.

IAEA fire test

The performance standards refer to sequences of tests specified in Section VII of SSR-6. Each test provides a reference for the minimum severity of the assumptions to be made in the safety evaluation of Section VI requirements. Each test may also be used to demonstrate the assumptions made during a safety evaluation based on general safety requirements. The test specifications and results are not intended to be interpreted literally. It is not only the end result but the whole range of conditions that may be relevant. Each test result needs to be accounted for in context of the Section VI performance standards requirements.

Some examples are:

- results from drop tests of packages need to account for all heights from zero up to the specified drop height.
- results from thermal tests need to account for all temperatures up to 800 ºC and all lengths from zero to 30 minutes.
- results from water immersion of packages should include conditions while being flooded, not only after the flooding is ended.

The Criticality WG members have discussed their experience on the IAEA fire test, see [3].

Configuration of fissile units with different properties

The basis of the criticality safety index (CSI) for retaining subcriticality in package array configurations has been discussed by the WG. Technical exchanges about this subject are detailed in [3]. Moreover, the use of this index for array configurations is the subject of one question in the draft questionnaire (see later chapter on this).

TECHNNICAL BASIS AND TECHNNICAL BASIS DOCUMENT

A technical basis (TB) comes before adding, removal or modification of a provision (requirement or option) in SSR-6. Justification in the form of needs, benefits, costs, consequences (expected and potential), consistency, practicability, previous provisions, long-term stability, etc. are involved. The TB needs to be re-evaluated continuously, to consider changes in the justifications.

SSR-6 has a fundamental TB in Woodcock and Paxton document [5] from late 1960. Since then, there have been few major changes to the TB. However, there are no documents gathering these TB. The Explanatory Material [6] had related intentions. It was eventually included in the Advisory Material SSG-26 [7].

In 2010, IAEA started an ambitious plan to establish the current TB for SSR-6. In search for justifications of current provisions, old documents had to be found and interpreted. A complete understanding of the TB evolved [8], including appropriate references, not only opinions and vague memories.

A draft TB Document (TBD) [9] was prepared until 2014, with a chapter 11 on criticality safety. Chapter 11 contained a substantial information source, a database, on criticality safety in transport. The intention was to discuss the format and contents, as well as to update the contents with other available information and to maintain the database continuously. The actual format to support this was not established. In the summer of 2017, after having the previous chapter 11 removed for some time, chapter 11 was completely replaced by a different type of document [10], basically a historical view with limited TB. The 2014 and 2017 versions of Chapter 11 have probably not been reviewed by criticality safety specialists. Different interpretations and opinions need to be discussed and concluded, before a formal technical basis can be obtained. A true technical basis for criticality safety in transport, whatever the format, is needed more than ever.

The TTEG, with its WG, has demonstrated that essentially all issues raised by members need support from an established TB, not just recollections from memories. The results of discussions should support a confirmation or update of the existing TB. Para. 685.3 in [7], e.g., refers to events less severe than the test conditions. The TB, as specified in the 2014 version of the TBD [10], originates in fire test interpretations, and answers, almost perfectly, the questions in 2018 by a TTEG member on this issue (cf. IAEA fire test).

A brief summary of most issues, discussed by the WG and TTEG on Criticality since June 2017, is presented in Table I. The purpose of Table I is to demonstrate the need for a TB database and the use of the TTEG to support improvement and maintenance of such a database. It touches on most issues discussed by the Criticality WG, but there are others. Some issues are discussed in this paper and in [3].

Table I. Relationship between TTEG or WG discussions and a structured technical basis

IAEA TRANSSC Criticality Safety Working Group and Technical Expert Group	
Issue	Consistency between SSR-6 and TB? / Comments
Fundamentals, objective, scope for SSR-6	
Technical Basis Document	No / To be discussed. Essential for SSR-6
Fundamental Principles of Criticality Safety - Transport	No / To be discussed. Lacking from SSR-6
Objectives and scope of SSR-6	No / To be discussed
Criticality probability and consequences (risk) covered	No / In TB but not in SSR-6 objectives
Subcriticality need no demonstration, credible scenario	No / Examples have been discussed
Is criticality then "allowed"?	Yes / It is not allowed (§673(a))
Maximum Credible Accident (MCA 1961) = para. 673(a)	Yes / Does not require CA approval
Maximum fission energy release in criticality accident	Yes / From 1960. Needs revision
Safe transport scope – Operations outside transport	No / §106. Only external transport (§107)
Safety support from operations outside transport	Yes / Pre-shipment, fabrication controls
Safety support to operations outside transport	Yes / Loading/unloading, emergencies, etc.
Subcriticality of water-reflected containment vessel	Yes / In 1966 Mod. 1 to Regulations [11]
Containment system, replacing containment vessel	Yes / To cover multiple containments
Single fuel rod cladding as containment system	No / To be discussed.
Confinement system, replacing containment system	No / Incorrect definition
List of criticality safety features	No / In ISO-1709 [12] but no TB for SSR-6
General criticality safety requirement for transport (what to do - objective)	
Subcriticality: Normal and credible abnormal conditions	No / General, not only design (Section VI)
Distinction between safety and technical/administrative	No / Residual, actual transport risk §673(a)
Uncertainties: Large number of unknown parameters	No / General, not only design (Section VI)
Detailed operational provisions during transport (how-to-do practical operations)	
570(e) CSI limits for large freight containers on ships	No / To be discussed
Code for fissile exception in transport document?	Not in TB / perhaps clear now?
Open or closed large freight containers on ship	Not in TB / Discussion in WG
Unlimited CSI for large freight containers onboard ships	No / Discussion in WG
Pre-shipment operations, administrative controls (how-to-do preparations)	
Mixing different package designs for fissile material	Yes / SSG-26 recommends caution
Need for UN number for IP-1, e.g. to apply para. 674(a)	No / Lack of UN number is a problem
Application of para. 417(f) based on design para 606	Yes / Discussion on implementation is of interest
Is "fissile material" correct in para. 832?	Yes / F/FISSILE/fissile material are different
§417(f) "FISSILE" exception, not requiring approval	No / Basis in §606, approval in §806
Design (how-to-do design)	
Minimum external dimension of 10 cm	Yes / Basis from 1961 and later
10 cm cube and birdcage design	Yes / WG member found figure in 2014 TB
Consistency between subcriticality limits (e.g. 45 g ^{235}U)	Yes / Such efforts are clearly made
Criticality safety at low temperatures	Yes / Implementation has been lacking
Air transport. High-speed impact. Moderation issue	Yes / Limits Maximum Credible Accident
IAEA fire test – Less than maximum conditions	Yes / Discussed in the WG
Washed UF_6 cylinder with more than 3.5 g ^{235}U	New issue, extension of current TB
Rounding down of small CSI value to zero	Yes / N "effectively infinite" = "very many"

The Technical Basis Document (TBD) will be the subject of a work programme in the Secretariat and each TTEG will be invited to contribute to its future development. Access to the existing TBD will be given to each TTEG. TRANSSC will approve revision to the TBD content arising from the work programmes of the TTEGs [2]. The TBD has been on the agenda for recent TRANSSC meetings and, in its 38th meeting (June 2019), the future of the TBD will be decided. The plans by IAEA are consistent with the approach presented here. If accepted by TRANSSC, the Criticality TTEG can make a significant contribution.

A QUESTIONNAIRE TO SHARE ABOUT NATIONAL PRACTICES FOR ASSESSMENT OF PACKAGES FOR FISSILE MATERIAL

Objective of this questionnaire

The requirements for the safe transport of radioactive materials are essentially identical between different countries, since they are mainly derived from the international regulations of the IAEA (SSR-6). However, the designer approaches to criticality safety analysis of a package design for fissile material and its associated assessment by the Competent Authority (CA) may be dependent on the country, for example, the acceptance criteria can vary from one country to another.

The objective of this questionnaire is to provide an overview of practices in different countries to improve understanding of the different approaches used for criticality assessment of package designs for fissile material. Perhaps, this questionnaire will help to harmonize our practices on some subject and to show when requirements in SSR-6 or SSG-26 need modification.

Part 1 of this questionnaire contains closed questions whilst Part 2 contains open questions that encourage further comments and explanation.

This questionnaire is intended to provide an opportunity for representatives from Competent Authorities and other organizations to share their methodologies and/or experience and to further extend the knowledge and understanding of the criticality safety assessment of package designs for fissile material. This is particularly important for package designs that require multilateral approval for international shipments and national shipments in a country other than that in which the package design for fissile material was originally designed and approved for use.

This questionnaire will be discussed during TRANSSC 38th (June 26-28th 2019) and might be completed for delivery before TRANSSC 39th. In this case, the completed questionnaire should be returned before TRANSSC 40th and the conclusions should be presented at TRANSSC 41th and could be the subject of a report from the Criticality WG or Criticality TTEG.

Part 1: Closed questions

These questions have to be answered only by yes or no. If there is a need to elaborate on an answer, these topics are also considered in the open questions, where it is possible to elaborate on the answer.

The project of these closed questions is the following:

Q1.1. Do you have, in your organization, specialists dedicated to the criticality-safety assessment of a package design for fissile material?

Q1.2. During the assessment of a package design for fissile material, do you have technical exchanges/meetings with the licensees?

Q1.3. Do you have exchanges with other specialists (mechanical, thermal…) whose conclusion might modify the hypotheses considered in criticality safety assessments?

Q1.4. In the conclusion of an assessment, can you request changes in the scope of a future revision of the safety analysis report for the next renewal process or of a future application to the licensees (for example, a new content), while still approving the current application?

Q1.5. During the assessment of a package design for fissile material, do you perform independent criticality safety calculations?

Q1.6. Are calculations performed using old codes or libraries accepted if validation exists?

Q1.7. Do you require to define the confinement system in the application?

Q1.8. Is the current notion of confinement system (SSR-6, para. 209) convenient for you?

Q1.9. Are you aware that the confinement system was introduced and accepted by IAEA in 1996 to separate the intentions of the previous containment system for subcriticality of an individual fissile package (primarily neutron reflection) and containment of radioactive contents?

Q1.10. Are the operations of loading/unloading of fissile materials inside packagings assessed in the framework of an application for transport approval?

Q1.11. SSR-6 contains requirements that are intended for non-transport operations, e.g. emergency response, loading and unloading radioactive material contents into (and from, respectively) packagings, training, measurements of burnup, etc. The current scope of SSR-6 (para. 106) includes operations for which SSR-6 provides safety and other operations (previous sentence) that may affect transport safety or whose safety may be affected by transport. Can the SSR-6 para. 106 be made clearer to separate the two types of requirements (either for external transport or for non-transport operations, associated with external transport but for which safety is covered by other regulations)?

Q1.12. Is burn-up credit applied for the transport of irradiated fissile material?

Q1.13. Do you accept applications written in languages other than your native language or English?

Q1.14. Do you support the idea of future questionnaires, each on one or more specific issues, identified and prepared by the TTEG, and expected to lead to essential improvements of the Regulations, if formally covered by a proposal by a Member State and approved by TRANSSC?

Part 2: Open questions

Open questions are divided into 6 parts. The project of these open questions is the following:

QUESTION 2.1: Organization of a criticality-safety assessment

Q2.4.a) What is the outcome of your assessment for a national application and a foreign application (for example, a document summarizing the technical assessment and possible requests for future changes or analyses)?

Q2.4.b) If you do not have criticality safety specialists dedicated to assessment of package designs for fissile material in your organization, who performs the criticality-safety assessment?

Q2.4.c) If you have technical exchanges/meetings with the licensees during the assessment of a package design for fissile material, please describe this type of exchange (conference calls, e-mails, etc.).

Q2.4.d) If you have exchanges with other specialists (mechanical, thermal…) during the assessment of a package design for fissile material, please describe this type of exchange (conference calls, e-mails, etc.).

Q2.4.e) At the end of an assessment, do you request the licensees to revise the scope of a future revision of the safety analysis report or in a future application for package design approval; please give examples of typical requests.

QUESTION 2.2: Criticality calculations

Q2.2.a) If you perform criticality safety calculations during the assessment of a package design for fissile material, what is the typical extent of these calculations: is it the same calculation specifications as submitted by the licensees for approval of the package design for fissile material or calculations with different hypotheses?

Q2.2.b) Which calculation methods (computer codes and nuclear data) do you use for your criticality safety calculations?

Q2.2.c) Paragraph VI.5 of the Guidance proposes the following formula for the admissible criteria:

$k_{eff} + n\sigma \leq 1.00 - \Delta_{km} - \Delta_{ku}$, where,

- Δ_{ku} is an allowance for the calculational bias and uncertainty;
- Δ_{km} is a required margin of subcriticality;
- k_{eff} is the calculated value obtained for the package or array of packages;
- n is the number of standard deviations taken into account (2 or 3 are common values);
- σ is the standard deviation of the k_{eff} value obtained with Monte Carlo analysis.

What are the usual values considered for Δ_{km} for:

(i) isolated package under normal conditions of transport (NCT) and under NCT+accident conditions of transport (ACT) ? or

(ii) packages in array under NCT and under NCT+ACT?

How is Δ_{ku} estimated? What requirements are imposed on the validation of the calculation method used in the safety analysis report? What is the value of Δ_{ku} when validation of the calculation method is not available?

QUESTION 2.3: Hypotheses after NCT and ACT

Q2.3.a) What are the typical hypotheses considered in criticality safety analysis that you assess after the NCT and ACT tests (mechanical, thermal, …):

- For the fuel assemblies (expansion of the fuel rod array, displacement of the assemblies or a fraction of rods (differential sliding of rods), the number of fuel pins considered to rupture, the release fraction of a ruptured fuel rod, the relationship between fuel assembly burnup and the number of fuel rods assumed to rupture, the assumed release fraction from a ruptured fuel rod, dispersion of fissile material outside the fuel rod cladding, …)?

- For other fissile contents (position of the content, water in-leakage and distribution of moderation within fissile material, moderation by melted polyethylene, …)?
- For the packaging (material deformation, burned resin, dehydration of the material, …)?

Q2.3.b) Which behaviour of the fissile materials, contents or packaging is considered if the test results leave some degrees of freedom? Do assumptions based on realistic behaviour under actual transport conditions apply or is it the worst theoretical configuration that is assumed? Do the SSR-6 requirements always apply unconditionally (even beyond theoretically possible), or is some informed combination in between acceptable?

QUESTION 2.4: Presence of hydrogenated materials

Q2.4.a) How do you take into consideration the presence of hydrogenous material in a criticality safety analysis? How are hydrogen-rich materials (e.g., polyethylene) considered in the calculation models when their position and degradation (melting for example) under accident conditions of transport are not defined in the safety analysis report?

Q2.4.b) Are partial flooding scenarios (water entering or exiting the fissile package) analysed/assessed based on dynamic water levels or models reflecting a steady state?

Q2.4.c) What are the subcriticality configurations studied for a fissile package with multiple high standard water barriers as per paragraph 680 (a) (for example a limited or unlimited quantity of water in the package that maximises system reactivity by acting as distributed moderation within the fissile material (a limited quantity will require justification in the safety analysis report), fuel assembly deformation determined by the deformation of the packaging structure that is quantified in the safety analysis report, release fraction from ruptured fuel pins, etc.)?

QUESTION 2.5: Concept of confinement system

Q2.5.a) In the application of the Regulation, how do you interpret the concept of the confinement system in the § 209, 501, 681 and 838 of SSR-6?

Q2.5.b) Do you support the original (mid 1960s) intent of subcriticality of the water-reflected containment system? The original intent is known (and still expressed in that way in the national U.S.A. regulations) and there was no intention of change with the introduction of the confinement system in 1996.

Q2.5.c) How do you interpret the requirement to have a water-reflected confinement system (para. 681) with, or in some cases without, water in leakage (para. 680), inside a subcritical fissile package design (para. 682) when the confinement system is not the complete package?

Q2.5.d) Is a list of essential criticality safety features useful in the application and the certificate of approval needed? If so, is a specific definition (other than "confinement system") needed?

QUESTION 2.6: Other questions about applications for transport of fissile material

Q2.6.a) Which regulations apply to criticality safety of operations of loading/unloading of fissile materials into/from a packaging (also who, when, …)?

Q2.6.b) How are the criticality safety demonstrations of the various licensees aligned? How consistent are the criticality safety demonstrations of the various licensees (e.g., do they typically follow CA-issued or international guidance, or do they develop independent methods?)

Q2.6.c) Do you accept analyses of applicants showing deltas in k_{eff} due to several (different) effects that are added up in order to get the "maximum k_{eff}" ($K_{eff,max} = K_0 + \Delta K_1 + \Delta K_2 + \Delta K_3$) instead of modelling the superposition in a single calculation?

Q2.6.d) Can the "permission" not to assess all possible permutations of a large number of parameters in para 676.2 of the next version of the Advisory Material SSG-26 be interpreted in such way, that even a k_{eff} just above the criteria is acceptable if it only occurs with a vanishingly small probability?

Para 676.2: *Where the number of possible parameters is very large the probability of them all achieving their most reactive value during normal or accident conditions of transport may be vanishingly small. In such cases it may not be necessary for a criticality safety assessment to assess all possible permutations provided the Competent Authority is satisfied that criticality safety has been adequately demonstrated.*

Q2.6.e) If burn-up credit is applied for the transport of irradiated fissile material, what are the main hypotheses considered in the criticality safety demonstration and how is the fuel irradiation characterised (profile of burn-up, maximal burn-up, etc.)?

Is it required that the burn-up should be demonstrated by direct measurements or is it acceptable to use other data (for example, burnup history of fuel assembly)? In this case, how are long-cooled irradiated fuel assemblies considered?

Q2.6.f) How do you use the information inside the transport document from paragraph 546(j) (is all these information items useful, do you control it, etc.)?

Q2.6.g) Do you allow the transport of different fissile materials within the same Group in a consignment? And if so, are criticality assessments additional to the design requirements of SSR-6 required?

Q2.6.h) Some package designs exploit the maximum k_{eff} accepted by the CA. On the other hand, calculations performed by another party (such as the CA during their assessment) naturally show differences to the results shown by the applicant. How does the CA deal with cases where their results (but not those of the applicant) violate the maximum k_{eff} accepted?

CONCLUSIONS

Since TRANSSC 34th (July 2017), the Criticality WG has met for two days, just before each TRANSSC meeting. These two days allow information exchange on several subjects and in different ways:

- for low temperature issues, the WG share the results of recent and on-going studies, carried out in different countries;
- for the transport of empty cleaned and washed UF_6 cylinders, the WG discusses and finds a solution to this issue (an additional fissile exception based on contamination level of internal surfaces);
- the WG discusses about the technical basis of the concept of preventing entry of a 10 cm cube and the association with "birdcage" designs.

Moreover, the exchanges during these 2 days generally conclude on the need to establish the technical basis of each provision of SSR-6. Indeed, without such technical basis, requirements of the regulations can be misinterpreted (for example, the concept of confinement system). IAEA has for almost ten years made large efforts to find the technical basis for the Transport Regulations. The TTEG background is to a large extent justified by the need for a complete and continuously updated technical basis database. The procedure for doing this will be decided by TRANSSC in 2019.

In addition, the designer approaches to criticality safety analysis of a package design for fissile material and its subsequent assessment by the CA may vary between different countries. A questionnaire has been proposed by this WG to provide an overview of practices in different countries to improve understanding of the different approaches used for criticality assessment of package designs for fissile material. Perhaps, this questionnaire will help to harmonize our practices on some subject and to show when requirements in SSR-6 or SSG-26 need modification.

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