Proposal to return to intent and replace confinement system with subcritical system

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Subcritical system

Intended to be subcritical, a separable assembly of one or more *containment system(s)* including *fissile material*. Applies to an individual package containing one or more *subcritical systems*. Additional components in the *packaging* or in the contents may be required (e.g. structural, spacing, neutron absorption) for a *subcritical system* containing multiple *containment systems*. 
681. Each *subcritical system* shall remain subcritical under the following conditions:

(a) The complete *package* shall have been subjected to accident conditions of transport

(b) The *subcritical system* shall be reflected by 20 cm of water or such greater reflection as may be present in the outer *packaging*

(c) Reliance on prevention of water in- or outleakage shall be specified.
A purpose is to provide an easily verifiable (transparent) subcritical system for support of package design, site operation, emergency and inspection.

Interaction between subcritical systems and between different system is not covered.

Containment, as required for subcriticality, is not covered by the containment system. The subcritical system is something else. Escape of fissile material is treated separately.
Subcritical system - More

- No impact on structure of Regulations.
- 680. Unchanged (water moderation)
- [680 and 681 could be exchanged since the special features is a later step]
- 682. The package shall be subcritical, accounting for para. 680 [but not 681], under routine, normal and accident conditions
- Subcritical system and containment system are different, but with common specifications
Transport, site and emergency

• The IAEA Transport Regulations apply to transport of complete packages
• The Regulations do not cover safety during site operations, emergencies, inspections.
• It is argued that subcriticality of a specific state of an inner container is a technical requirement, not a safety requirement
• Subcriticality of the whole package, under accident conditions, is a safety requirement
Subcriticality versus safety

• Until 1973, subcriticality of the containment vessel was required by the Regulations.
• This information is valuable in criticality safety control during transport, emergencies, inspections and at nuclear sites.
• Before 1973, the complete package, including interaction control and administrative controls, was designed to preserve criticality safety.
Subcriticality versus safety-2

• After 1973, the subcriticality requirement of the containment [vessel] was removed.
• The subcriticality requirement was replaced by specifications for the containment system.
• Strange: 20 cm water around the containment systems (could be many) is not possible.
• In 1996, if the confinement system remains within the packaging after the tests, 20 cm of water surrounding the package is sufficient.
5.1.1. The packaging shall be such that the radioactive materials cannot readily escape and for this purpose the container shall be leak-proof and securely closed by a positive fastening device.

- A shield is an external packaging constituent
- Fire, shocks and water require protection
- Changes in temperature and pressure
- Corrosion (+ decontamination needs)
Safety factors 1964

- C-5.3.1.1 Where mass is the controlling nuclear safety factor, the permissible value shall not exceed 80 % of the critical mass;
- where dimension is the controlling nuclear safety factor, the permissible value of each controlling dimension shall not exceed 92 % of the respective critical dimension;
- Clarified in Modification No 1 in 1966.
C-5.3.2.1. (i) with the material within the containment vessel:

• the most reactive configuration and moderation foreseeable under the conditions of (a) above;

• close full water reflection of the containment vessel or such greater reflection of the containment vessel as may additionally be provided by the surrounding material of the packaging,
608. The package shall be sub-critical by an adequate margin under the conditions specified in para. 607, … a [e.g. 80 % of mass] (a) with the material within the containment system:

(i) the most reactive configuration and moderation foreseeable under the conditions of para. 607

(ii) close full water reflection of the containment system … or such greater reflection …
213. *Containment system* shall mean the assembly of components of the *packaging* specified by the designer as intended to retain the *radioactive material* during transport.

209. *Confinement system* shall mean the assembly of *fissile material* and *packaging* components specified by the designer and agreed to by the *competent authority* as intended to *preserve criticality safety*. 
Confinement system definition

• The term “confinement”: No bearing on criticality. Confinement of radioactive materials, of fusion plasma, of pigs, etc.
• Fissile material ≡ fissile nuclides (only $^{235}\text{U}$ in diluted material) from 1985 until 2009.
• Agreed to by the competent authority: Why emphasize this? Multilateral validation of something so vague (really, just wrong)?
• Intended for individual package only
Criticality safety or subcriticality

- Preserve criticality safety: Requires protection against accident conditions, human factor, interaction, etc.
- In transport, significant protection is obtained from packaging components surrounding the “inner container” together with administrative controls.
- At nuclear sites and during emergencies, other protection may be needed.
Reasons for change in 1996

• Difficult to find source text. An IAEA CSM, with very limited participation, appears to have created the text "on-the-fly".

• Informal 1993-1994 report from UK CA (copied by author 2001) had some problem background: The containment system definition was not sufficient for criticality.

• UK solution: Change containment system definition or introduce new concept.
• The national USA regulations (CFR 71) have not adopted the confinement system – subcriticality of the containment system is retained and practiced when applicable
• The clad of fresh fuel is often defined as the containment system. There are more than 500 such rods in a PWR package – Criticality safety needs more specifications
• The change in 1996 was intended to be editorial, clarifying. There was no indication of any need to change the intent

• After 1996, a very large variety of definitions of confinement systems was observed (some without any fissile material)

• Today, some definitions may contain five pages of specifications.

• In general, the full package is needed
SSG-26 Advisory Material

• The Advisory Material in 2012:
  • 209.1: “the confinement system maintains criticality control whereas the containment system prevents leakage of radioactive material” [both statements incorrect]
  • 681.1: “during routine loading operations, or subsequent to an accident” [Not transport]
  • 681.2: “routine conditions of transport.” “may be removed from the packaging” [=]
Multiple subcritical systems?

- The purpose of the subcritical system is to have some easily specified system that is typically handled on its own outside the package.
- Large modern packages for unirradiated fissile material contain well separated positions for inner containers. These are handled individually outside the package. Each inner container is a subcritical system.
Conclusions

• The original intent has been lost completely
• Para. 681 is not applied (CA conclusions a few years ago at IAEA CSM)
• Definition is so strange that it hurts the credibility of the IAEA Regulations
• A perception that subcriticality of a state means preserving safety is dangerous!
• The proposal has support in IAEA origins, is clearly practical and provides transparency