

## UPDATED RULES FOR MASS LIMITATION IN NUCLEAR PLANTS

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### Introduction

In some nuclear facilities where plutonium or uranium are processed, nuclear criticality safety is achieved by exercising control over the mass and the distribution of all fissile materials, including or not a limitation of moderation.

For many of them, criticality safety assessment is based on recommendations established by the former French CSIA “Atomic plants safety commission”, created to propose rules for such evaluation. The aim of these recommendations, dating from the years 1966 to 1971, was to provide practical easy rules for plant operators [1], [2] and [3]. These rules derived from data obtained while using old calculation codes.

The aim of the present study is to perform new calculations using recent criticality codes (standard route or reference route of CRISTAL package [4]), in order to firm up the recommended mass limits.

### Actual French rules

The recommendations presented in tables 1 and 2 deal with:

- the maximum allowable mass of fissile materials per package when a « double loading » is possible and considering a minimum of 30 cm between packages (edge to edge),
- the maximum allowable mass of fissile materials per package when a « double loading » is impossible and considering a minimum of 60 cm between packages (edge to edge),
- the maximum allowable mass of fissile isotopes when beryllium, graphite, heavy water or lead are present in a plant which process very little quantities of these isotopes without any limitation of moderation.

### Parameters studied

Calculations are performed to assess the impact of classical parameters such as:

- the type of external moderation between fissile material masses,
- the effect of the fissile material density,
- the presence of different reflectors.

Moreover, this study takes into account other parameters which had not been considered in the previous studies:

- the impact of a double loading of fissile material on the K effective value,
- the effect on the K effective value of a non-homogeneous repartition of moderation in the fissile material.

Then, the present status of the calculation codes qualification for dry or semi-dry fissile materials has been updated.

### Conclusion

The final objective of this article is to propose new formulations for recommended practical rules, based on an updated justification. These proposed rules are built to be easy to apply, but using and non-ambiguous formulation, to avoid any mistake in the practical use.

### REFERENCES:

[1] Décision CSIA N° 66-216 (July 6, 1966)

[2] Décision CSIA N° 68-304 (March 6, 1968)

[3] Décision CSIA N° 71-402 (December 15, 1971)

[4] J.M. Gomit, P. Cousinou, Alain Duprey, “The new CRISTAL criticality-safety package”, ICNC’99, Versailles, France (September 20-24, 1999)

**Table 1 - Usual recommended mass limits of uranium and plutonium**

Uranium

Moderation area	$0 < H/Pu \leq 2$	$2 < H/Pu \leq 20$	$H/Pu > 20$
Possible double loading (separated by 30 cm)	10 kg of U	2.5 kg of U	0.35 kg of U
Impossible double loading (separated by 60 cm)	16 kg of U	4 kg of U	0.6 kg of U

Plutonium

Moderation area	$0 < H/Pu \leq 2$	$2 < H/Pu \leq 20$	$H/Pu > 20$
Possible double loading (separated by 30 cm)	6 kg of Pu in oxide form (maximum of density)	2 kg of Pu *	200 g of Pu *
	2.5 kg of metallic Pu ( $\alpha$ or $\delta$ phase)		
Impossible double loading (separated by 60 cm)	10 kg of Pu in oxide form (maximum of density)	3.4 kg of Pu *	350 g of Pu *
	5.2 kg of metallic Pu ( $\delta$ phase)		
	4 kg of metallic Pu ( $\alpha$ phase)		

\*for Pu in any form (oxide, metallic  $\delta$  ou  $\alpha$ )

**Table 2 - Handling of small quantities of fissile isotopes**

Mass limits of fissile isotopes $M_i$ ( $m_i \leq M_i$ )		
Fissile isotope	LF1	LF2
$^{239}\text{Pu}$	0.375 kg	0.150 kg
$^{233}\text{U}$	0.375 kg	0.150 kg
$^{235}\text{U}$ if $^{235}\text{U}/\text{U} > 6\%$	0.600 kg	0.150 kg
$^{235}\text{U}$ if $1\% < ^{235}\text{U}/\text{U} \leq 6\%$	1.2 kg	0.150 kg

Mass limits of other materials	
LM1 if only one of these materials is present	LM2 if several materials are present
Beryllium 5 kg	5 kg if beryllium is present
Graphite 30 kg	30 kg if no beryllium
Heavy water 50 kg	50 kg if nor beryllium and graphite
Lead 200 kg	

Mixing rule:  $\sum m_i/M_i + m^*/12 \text{ Kg} \leq 1$  \*  $m = \text{mass of } ^{235}\text{U}$  in uranium enriched less than 1% if it is present

	configuration	Actual rule for fissile isotopes
I	Building containing only uranium with $^{235}\text{U}/\text{U} \leq 1\%$	Maximum of 1.5 tonne of enriched uranium bars – No limit for depleted or natural uranium
II	Building containing fissile isotopes and other materials (masses less than LM1 or LM2)	Maximum mass defined by LF1 for the building and using mixing rule
III	Building containing fissile isotopes and other materials (with at least one mass greater than LM1 or LM2)	Maximum mass defined by LF1 for the building and in addition: <ul style="list-style-type: none"> <li>- maximum mass defined by LF2 in any room</li> <li>- maximum mass defined by LF1 in rooms where other materials are less than LM1 or LM2</li> <li>- maximum mass defined by LF1 in rooms where other materials can't constitute a containment for fissile isotopes with internal dimensions less than 1 meter in any direction</li> </ul>