CERCA 01 : A New Safe Multidesign MTR Fresh Fuel Transport Cask

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Abstract

CERCA, a subsidiary company of FRAMATOME ANP, manufactures fuel for research reactors all over the world. To comply with customer requirements, fabrication of Material Testing Reactors elements is a mixed of various parameters. World-wide transportation of elements requires a flexible cask which accommodates different designs and meets international transportation regulations. To be able to deliver most of fuel elements, and to cope with non-validation of casks used previously, CERCA decided to design its own cask. All regulatory tests were successfully performed. They completely validated and qualified the safety of this new cask concept. No matter the accidental conditions are, a 5 % ΔK subcriticality margin is always met.

1. Introduction

CERCA manufactures fuel for research reactors all over the world. To comply with customer requirements, design and fabrication of Material Testing Reactors elements may be composed of various configurations such as uranium enrichment (LEU, MEU and HEU), uranium quantity, fuel alloy (Al, Si, Zr, …) or geometry (square, cylindrical, …). World-wide transportation of these elements requires a flexible cask which accommodates those different designs and meets the international transportation regulations. To be able to deliver most of fuel elements, and to cope with non-validation of casks used previously, CERCA decided to design and handle manufacturing of its own cask.

During all the phases of the cask design, emphasis has been put on the criticality safety aspects to comply with international requirements. Keeping in mind the large range of geometry of MTR fuel elements, three inner baskets have been designed to accommodate this aspect : two for large elements, and one for six "classical" MTR elements.
As fuel integrity is the main criticality safety viewpoint, emphasizes were put on the mechanical behaviour of the fuel geometry during the regulatory tests of dropping and punching. To ensure the fuel integrity, a thick stainless steel inner shell is added between the shock absorbers and the inner fuel basket. The neutron absorber as well as its thickness were carefully chosen in order to keep a reactivity level as low as possible to meet the criticality safety criterion even after regulatory mechanical and thermal tests.

Criticality safety evaluations have been performed following two situations :

- One large fuel element with a robust skeleton is placed inside the inner basket ; thanks to the cask concept, no fuel damage can occur. This complies with RHF and FRM2 fuel elements.
- Six "classical" MTR elements, with a more simple structure around the fuel, are placed inside an inner basket ; even if some tests showed that their simple structure could stand IAEA mechanical tests, a penalizing bounding limit of an homogeneous U metal – Water

mixture accounted for a complete fuel geometry loss. Therefore the content of the cask is defined as a maximum weight of uranium versus the enrichment.

2. Shipping cask design and fissile and material contents

The CERCA 01 cask is a type 3 fissile materials industrial package (IP-3 Fissile).

In view of the great diversity of fuel elements transported and in order to optimise cask capacity, three baskets have been designed. Each basket can easily be installed or removed from the cask and can be used in every cask of the same type.

Cask : This cask has the following features (see figure 1) :

- A cylindrical circular cavity with a net diameter of 543 mm and a net length of 1590 mm,
- A body composed of concentric walls made successively of stainless steel, plywood and stainless steel. This succession of walls ensures good mechanical performance and makes the cask fire-proof,
- the diameter of the ends is 980 mm, the overall length is 2089 mm and maximum weight of a loaded cask with basket and fuel is equal to 1490 kg.

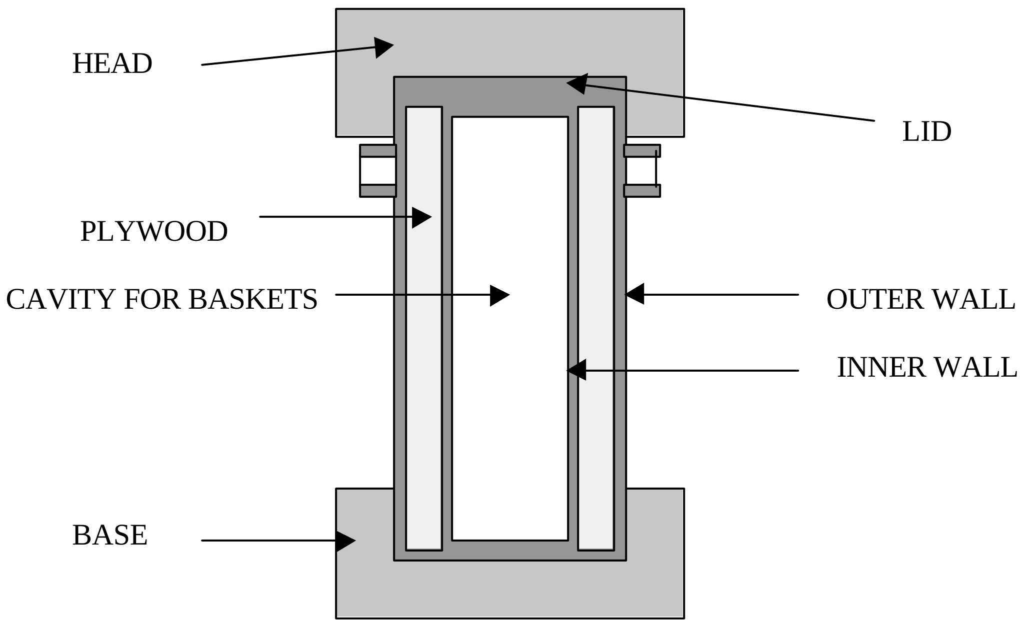


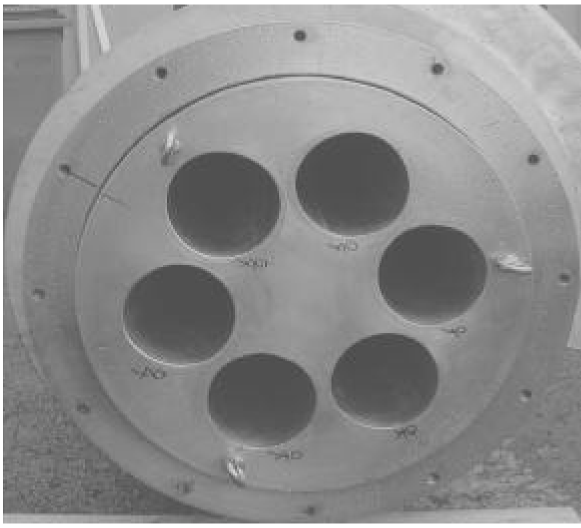
FIGURE 1 : CERCA 01 cask

Baskets : The three inner baskets are the RHF / FRM2 baskets (one element per package) and the multi-compartments basket : this basket is used for «standard» MTR fuel elements, as BR2, HFR, R2, HOR, French reactors ….; 6 fuel elements can be shipped per package (see figures 2 and 3).

The geometrical constraints for fuel elements are diameter and length : respectively 129 mm and 1566 mm maximum.

The baskets present the following features:

- An outer circular cylindrical section, 537 mm in diameter and 1585 mm in total length,
- Neutron absorption for criticality safety is provided by a compound with Boron, placed between the outer section and the compartments provided for the fuel elements.



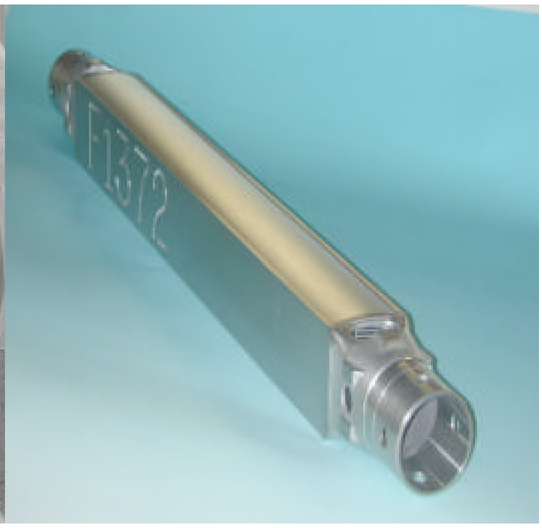


FIGURE 2 : Multi-compartments basket

FIGURE 3 : HFR fuel element

3. Criticality methodology and results

The calculation codes used in this study are recommended, qualified and used by the CEA/IPSN/DPEA/SEC. This system of codes has also been adopted by the whole French industry. It includes tools to describe the inputting, and the two main codes APOLLO 1 and MORET 3.

3.1. Large elements (RHF and FRM2)
The main safety assessments used in the calculations are the following ones :
- the fuel is moderated by water,
- the thickness of the water layer inside the central void region of the fuel element is variable,
- the burnout of 20 mm of neutron absorber material results in its replacement by a vacuum ; the remaining thickness of 30 mm has a chemical composition changed by the fire,
- the total thickness of the energy absorber (made of plywood) is lost,
- 2 x 2 package array for RHF element and infinite array for FRM2 element.

The figure 4 hereafter shows the reactivity variation with the water content inside the inner assembly volume accounting for accidental conditions.

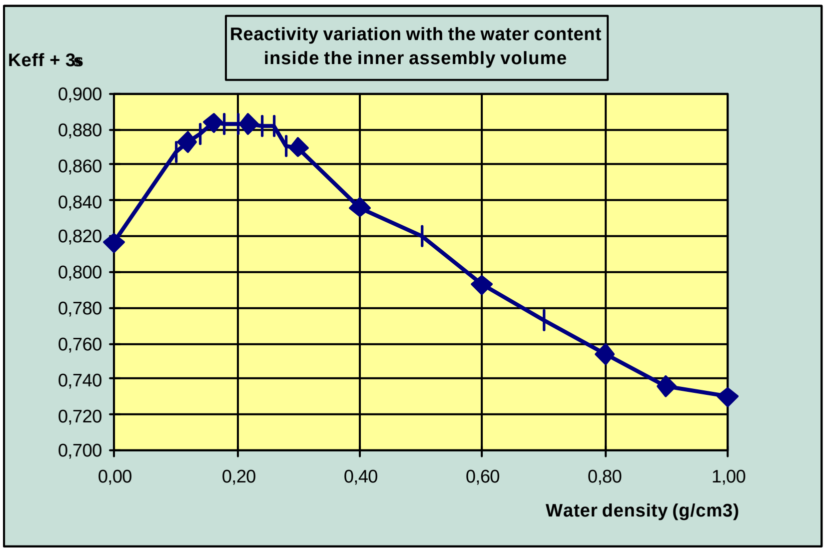


FIGURE 4 :
Reactivity versus water content

3.2. Standard fuel plate elements

In order to study the whole diversity of elements manufactured by CERCA, the following hypotheses are considered :

	U235 enrichment 20 %	U235 enrichment 93,5 %
U235 content per compartment	1200 g	1000 g
U235 content per package	7200 g	6000 g
Core density	10 gU/cm^3	10 gU/cm^3

All different fuel elements alloys are considered as homogeneous metal-water mixtures (at 20% or 93% enrichment of U235), which show upper bounding reactivity assumptions (see figure 5).

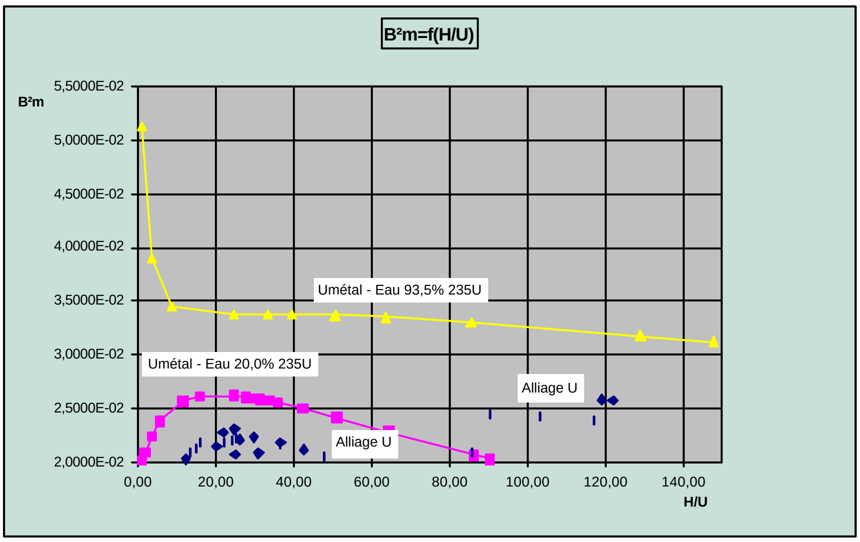


FIGURE 5 :
Criticality assumption : metal-water mixtures bound fuels

As for large elements, the same accidental conditions were applied for the basket with 6 standard fuel elements. Figures 6 and 7 show for the LEU and HEU enrichments the reactivity behaviour versus Uranium content.
The criticality safety criterion is satisfied for an infinite package array for LEU fuel elements and for 12 packages for HEU fuel elements.

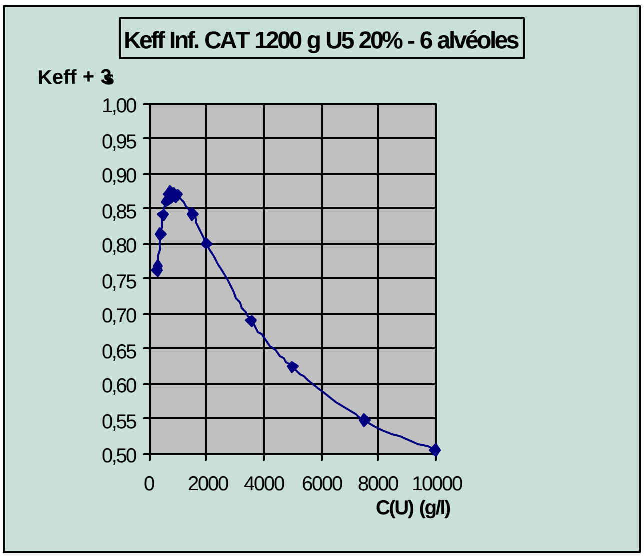


FIGURE 6 :
LEU Fuel Reactivity versus Uranium content

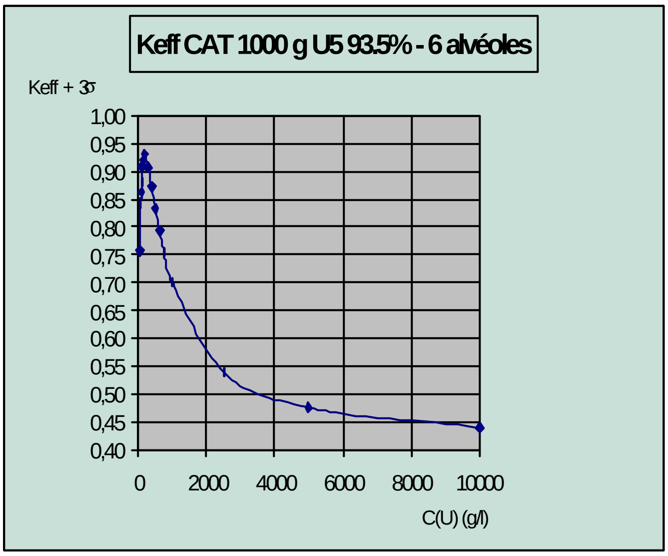
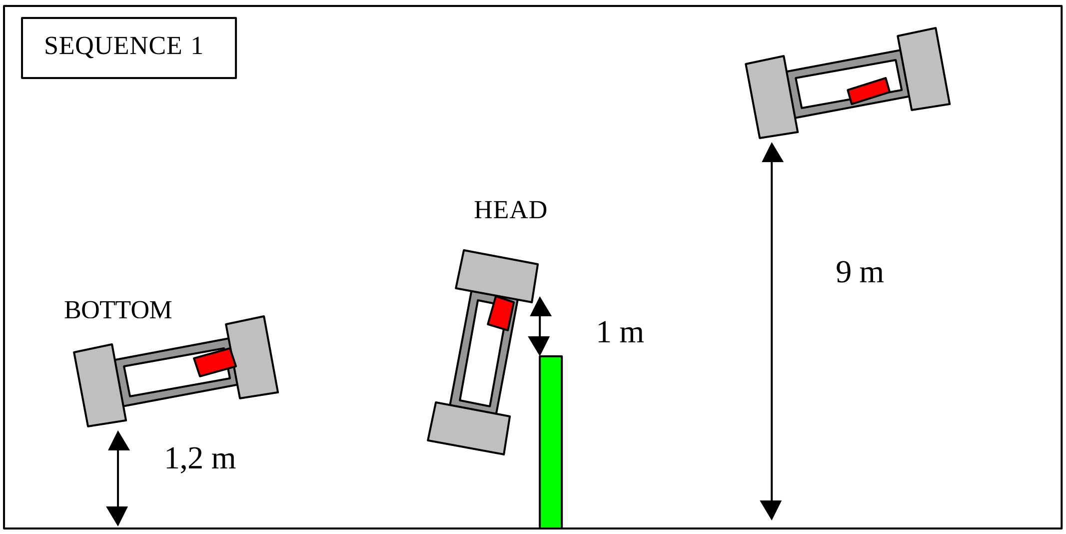


FIGURE 7 :
HEU Fuel Reactivity versus Uranium content

4. Regulatory mechanical tests

Among all safety justifications, mechanical drop and punch tests are of huge importance : their results justify the hypotheses taken into account in criticality and thermal calculations. Because of the fissile type of the cask, it has to withstand drop tests required by regulations pertaining to normal and accident conditions of transport, in accordance with <1> and <2>.
After preliminary mechanical calculations, a program of drop tests was written, agreed by French safety authorities, and finally performed in April 2000. Figure 8 gives the full description of the 7 drops ; the number and order of these drops for the sequences are justified so that the specimen sustains maximum damage ready for fire test and criticality analyses.



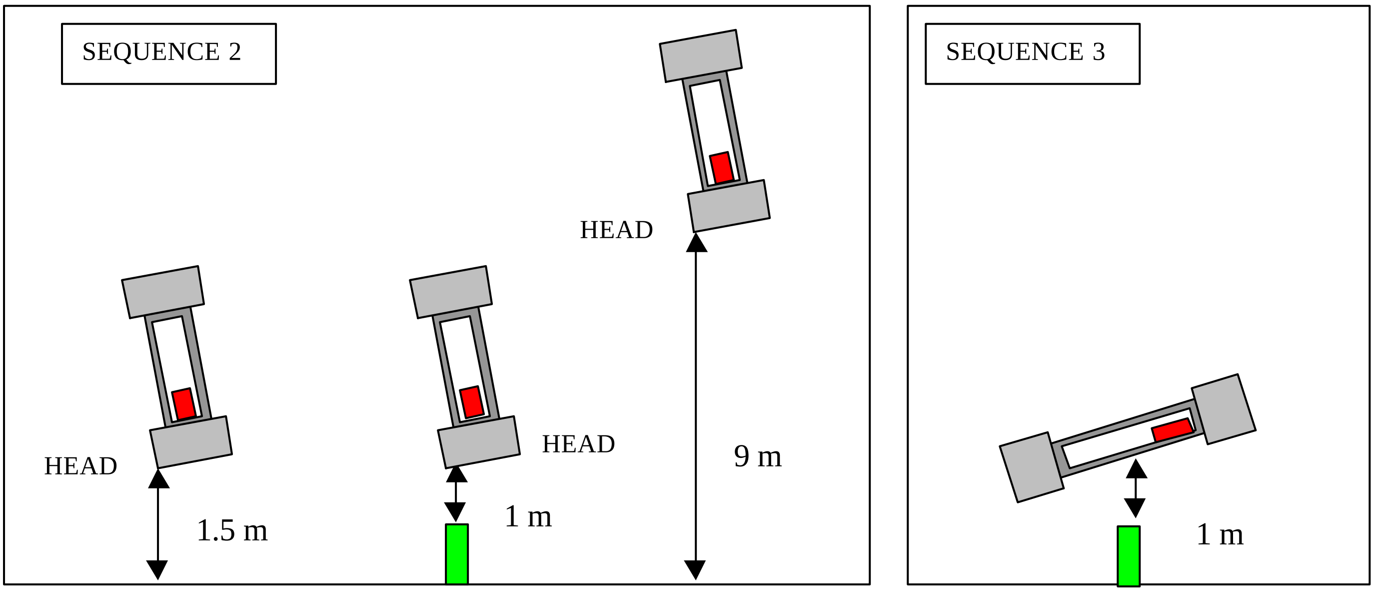
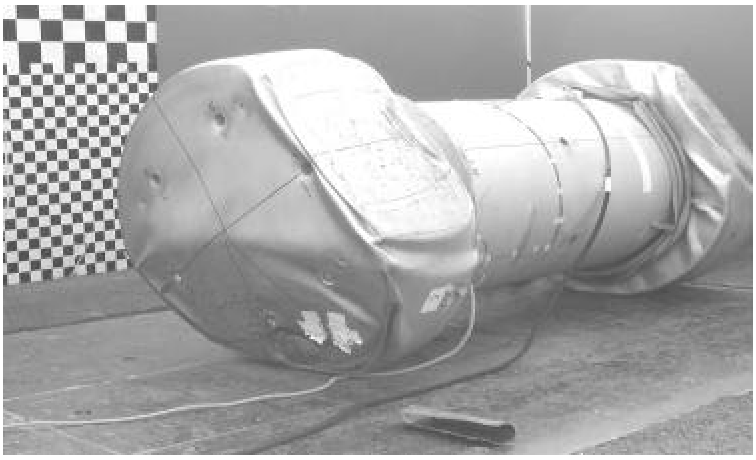


FIGURE 8 : Regulatory drop tests



All results were in accordance with calculations, and validated the hypotheses ; figure 9 shows the specimen after all drops.

FIGURE 9 : Results of drop tests

4. Conclusion

CERCA 01 package was licensed by French safety authorities : first in November 2000 for RHF and FRM2 elements, then in January 2001 for the "standard" elements. Now on the process to be validated all over Europe, this new cask will allow CERCA to meet customers needs on a more flexible and safe ways than before.

References

<1> IAEA Safety Series n°6. Regulation for the safe transport of radioactive materials 1985 edition (revised 1990).

<2> Regulation for the safe transport of radioactive materials: IAEA Safety Standards – ST