

DESIGN OF TEX-MOX CRITICAL EXPERIMENTS VARYING NEUTRON SPECTRUM

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Need for new experiments

The International Criticality Safety Benchmark Evaluation Project (ICSBE) includes a limited number of critical experiments representative of MOX fuel with low moderation. Furthermore, their quality is questionable. This work proposes a set of critical experiments with varying neutron spectra that should contribute to nuclear data validation for this kind of configurations. This series of independent experiments can be performed on the PLANET machine at NCERC (National Criticality Experiments Research Center) in the USA using available uranium-plutonium fuel plates. Due to the decay heat emitted by the fuel plates, a dedicated thermal-mechanical design of the assembly has been defined to fit all the experimental constraints.

Neutronics design

Two types of fuel plates are used in this series of experiments: PUMN (Pu-U-Mo plates manufactured by Numec Corporation) and to a lower extent PUMH (similar to PUMN with High 240Pu content) plates. The fuel plates are disposed in a fuel layer on an aluminum supporting plate. The moderator polyethylene layer of a variable thickness is inserted in between the fuel layers to fine tune the neutron spectrum.

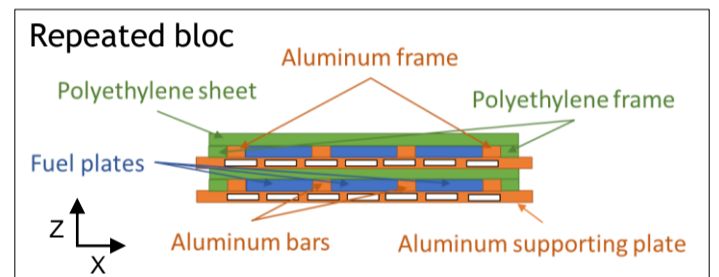
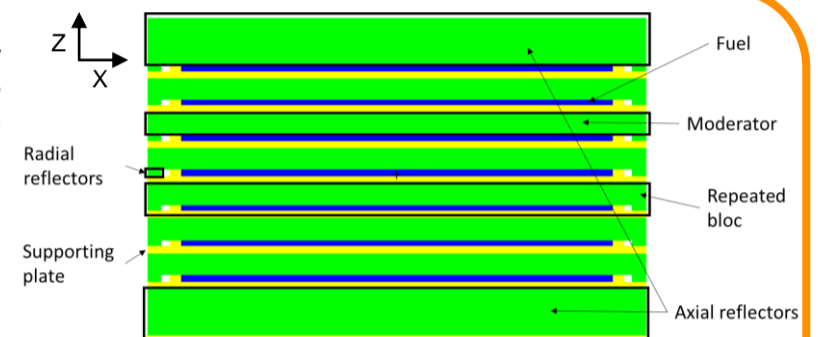
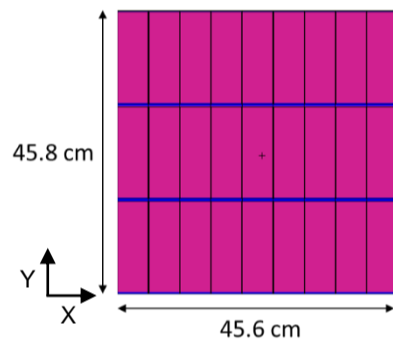


Table I. Fuel plates characteristics calculated for 2025

	PUMN	PUMH
TOTAL Fuel mass [g]	668.9	669.5
Pu/TOTAL [%w]	27.7%	32.7%
Am/TOTAL [%w]	0.4%	1.6%
Pu239/Pu [%w]	87.9%	70.8%
Pu240/Pu [%w]	11.7%	27.2%
Pu241/Pu [%w]	0.1%	0.5%
U/TOTAL [%w]	69.3%	63.1%
U235/U [%w]	0.3%	0.3%
U238/U [%w]	99.7%	99.7%
Mo/TOTAL [%w]	2.5%	2.5%
Decay Power [W]	0.85	2.06

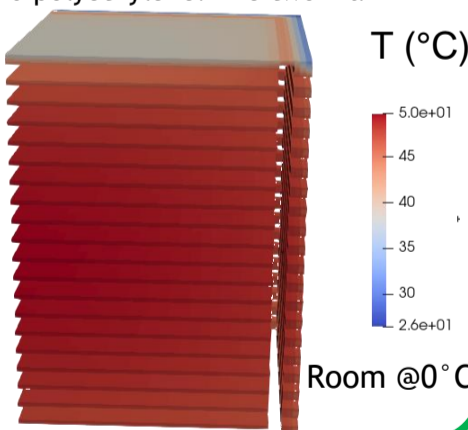
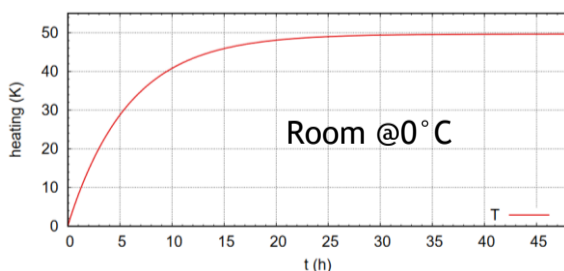


27 6"-long fuel plates composing a fuel layer

Thermal calculations

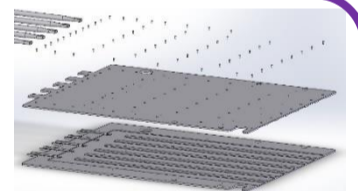
The temperature have a high impact on the k_{eff} , due mainly to expansion of materials and Doppler broadening of the main actinides. If the experiment is performed at 60°C and it is intended to constitute a benchmark at 20°C, then the simplification bias may reach 500-600 pcm. To maintain a good quality benchmark, the critical assembly will be actively cooled. Nevertheless, for safety reasons the polyethylene temperature should never reach the softening temperature for high density polyethylene (85°C), even when the cooling fan fails.

Thermal simulations were performed using CALIF3S. The fuel stack is constituted of 20 superimposed fuel plates surrounded by aluminum and polyethylene. The two main mechanisms are the radiative heat transfer (leading to a heat exchange coefficient of 6.4 W/(m².K) for polyethylene) and natural convection (1.5-4 W/(m².K)).

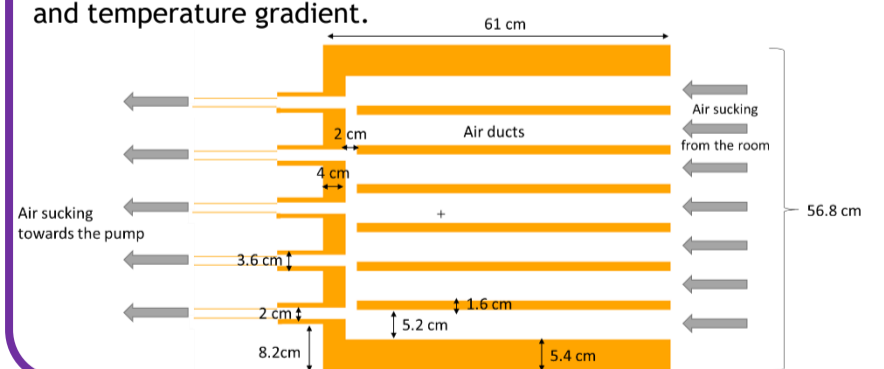


Cooling system

The proposed cooling system is based on the air sucking within the aluminum supporting plate through air channels, that will be connected to tubes, that lead to collectors. The collectors can then be connected via flexible pipes to the air pump. All elements near the assembly are composed exclusively in aluminum. The idea is to partially replace the supporting plates by the cooling plates, in a compromise between a simple execution of the experiment and a low temperature and temperature gradient.



Each aluminum plate will be fabricated through screwing of two initial plates.



Conclusion and prospects

These experiments correspond to IER (Integral Experimental Request)-296 of U.S. Department of Energy Nuclear Criticality Safety Program (NCSP), that could be performed at National Criticality Experiments Research Center (NCERC) in the next years. The final design of the proposed experiments is detailed in the final design report that will be finalized end of 2023.

Series of experiments:

- I. Thermal
- II. Intermediate - PUMN only
- III. Intermediate - PUMH & PUMN
- IV. Fast
- V. High temperature

References

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- [3] Brovchenko M., Salmon R., IRSN preliminary design for Thermal/epithermal Experiments with MOX fuel (TEX-MOX) - CED-1 report for the nuclear criticality safety program of the DOE, Rapport n° IRSN/2022-00508.
- [4] CALIF3S. Collaborative development environment, IRSN, <https://gforge.irsnn.fr/#/project/calif3s>.