

# TEX-MOX DESIGN UPDATES SUMMARY OF THE WORK 2022

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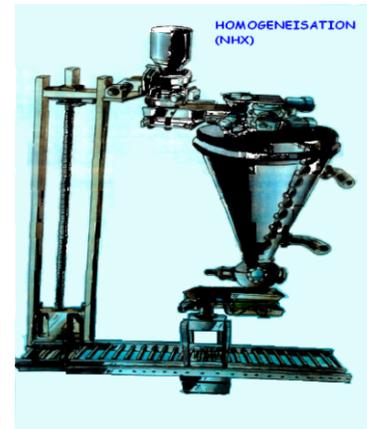
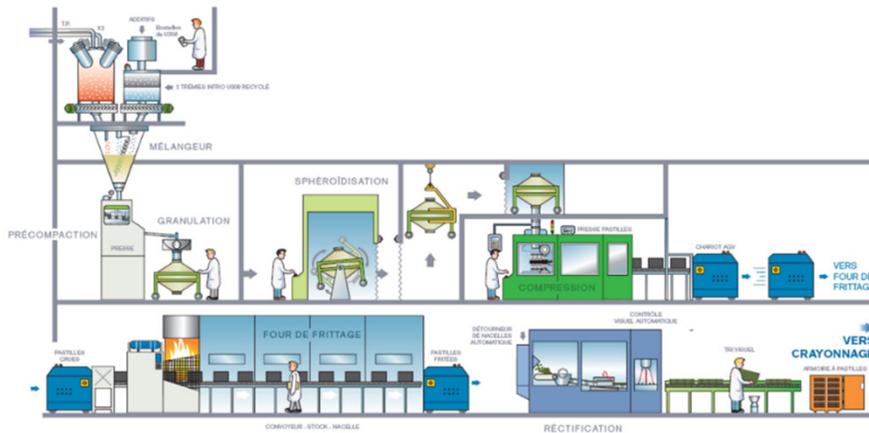
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## Motivation

Main motivation for TEX-MOX :

Validation of U, Pu and U+Pu in intermediate energy spectra



For fuel fabrication and criticality safety issues, moderator quantities are very low  
In many units, only the powder humidity (few %) is considered

➔ Majority of configurations are in the intermediate energy spectra

## Motivation

Needs for  $^{238}\text{U}$ ,  $^{235}\text{U}$ ,  $^{239}\text{Pu}$ ,  $^{240}\text{Pu}$ ,  $^{241}\text{Pu}$

Unfortunately, there is a lack of good quality experimental data for these isotopes and energy spectra.

- Consequence: a 2000 pcm bias is considered in the upper safety limit (USL)  
Huge impact on the production by limiting the mass allowed or the Pu content in French MELOX facility
- Is 2000 pcm bias enough to bound the lack of validation?
- The TEX Pu results highlighted C-E 1000 pcm bias with JEFF 3.1.1 just for  $^{239}\text{Pu}$

This experimental needs were identified by NEA/WPNCS SG5:

- $^{238}\text{U}$  and  $^{240}\text{Pu}$  are 1<sup>st</sup> priority
- $^{239}\text{Pu}$  and  $^{235}\text{U}$  are 2<sup>nd</sup> priority

## Motivation

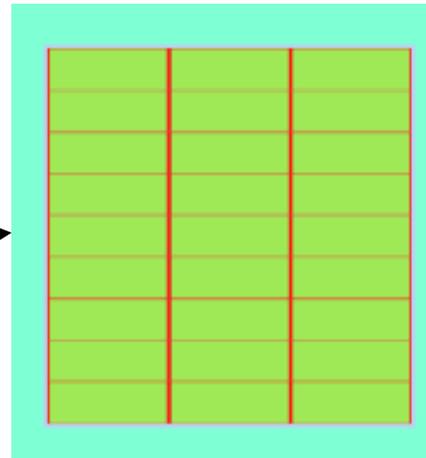
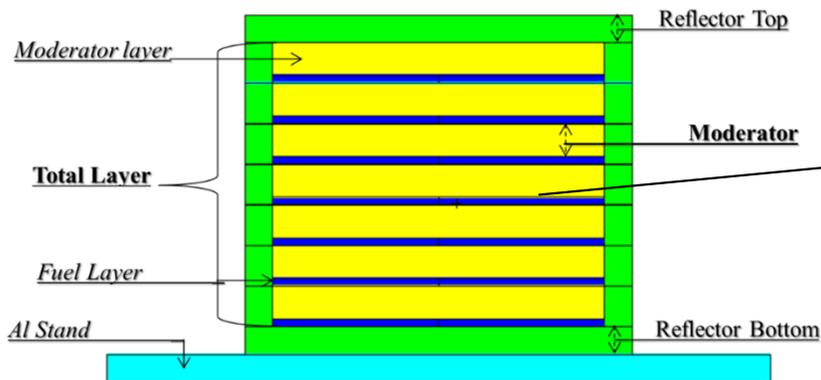
**TEX HEU and Pu are already useful to improve NCS.  
TEX MOX experiments would help confirm and complete results from TEX-Pu**

- IRSN provide TEX MOX experiments design and provide materials
- For the CED-1 of TEX MOX, IRSN considered all fissile plates available and proposed an optimized design (maximization of sensitivities)
- CED-1 was reviewed by LLNL and LANL
- CED-2 will detail 5 designs and will treat of thermal and radiation shielding issues

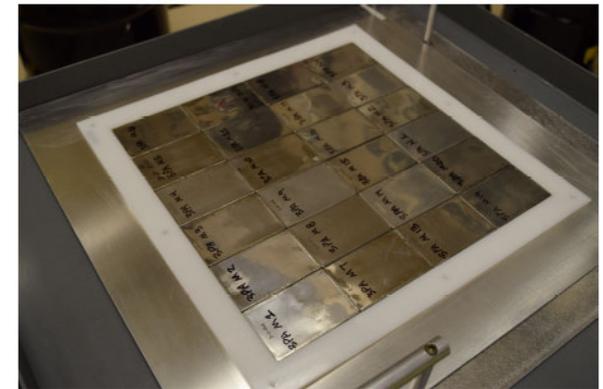
## What is TEX MOX ?

TEX-MOX: 5 experiments  
a stack of fuel layers:

- assembled in two parts
- with varying:
  - Polyethylene HD thickness between the fuel layers from 0 to 3 cm
  - number of fuel layers (10 - 30)



1 layer : 27 6" PUMN plates



Example of similar fuel plates

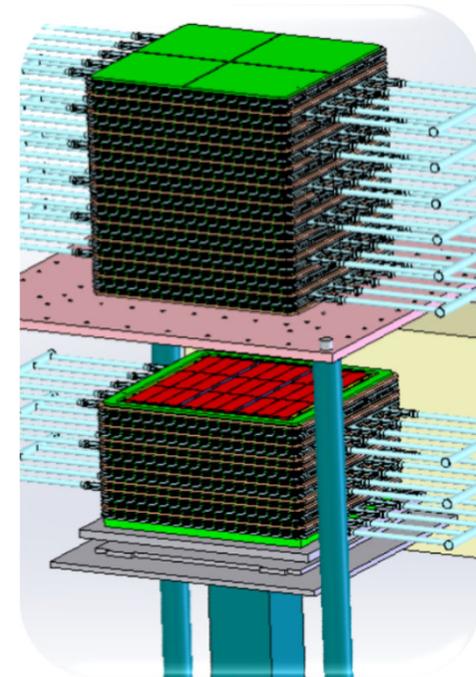
Pu-U-Mo-NUMEC plates already available @ NCERC

Pu (wt%of U+Pu)	U235 (%wt of U)	Pu240 (%w of Pu)
28.8	0.2	11.6

## work performed on TEX-MOX, in 2022

### Design constraints:

- Keep the geometry simple (rectangles)
- Temperature to be as low as possible
  - Quality of benchmark (TEX-Pu) @45°C instead of 20°C → bias of +100 pcm
  - Minimize the deformation due to thermal expansion (alu + PE + fuel)
  - Maximum of 65°C:
    - PEHD starts to lose its “strength”, VICAT softening temperature ~85°C, minus safety margin of 20°C
- Delta T (in the PE and fuel) vertical and horizontal (main problem is vertical) to keep as low as possible < 15°C
- No additional material if possible
- Respect load limitations
- Dimension supporting plate of PLANET machine to support the load
- Minimize additional structures: space optimization (reduce operational time) → ∩ radiation dose



## work performed on TEX-MOX, in 2022

Main difficulty with TEX-MOX : **HEAT**

Indeed, PUMN plates emit a non-negligible amount of power

One plate → ~0.9W

One layer → ~23W

Worst configuration (30 layers) → ~690W

Added to the use of PEHD, which is pretty good for thermal insulation

**Risk of melting PEHD and/or huge thermal gradient**

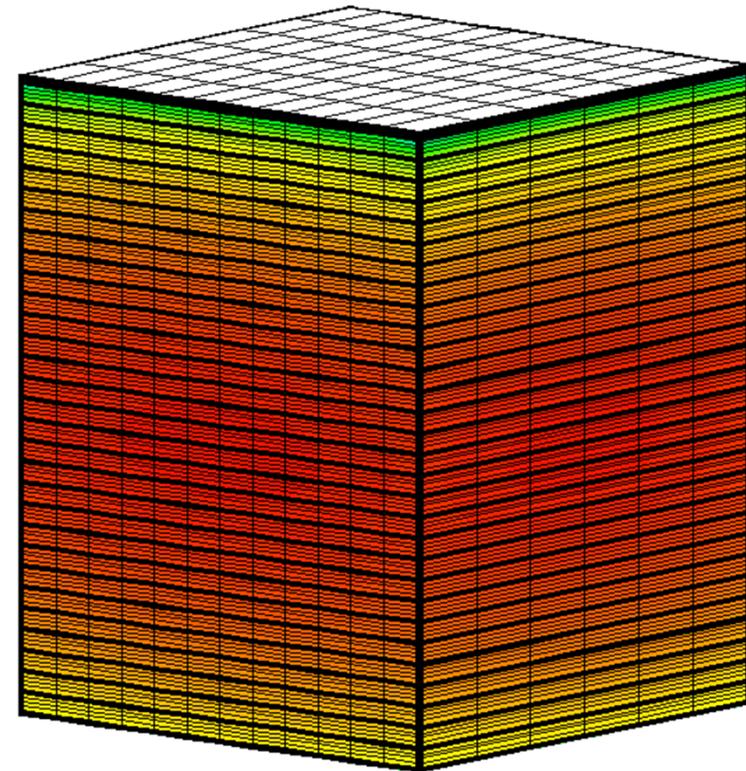
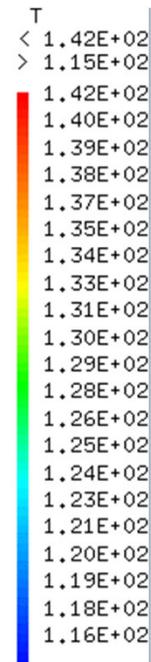
## work performed on TEX-MOX, in 2022

calculation performed with CFD code CAST3M

Thermically worst configuration (obtained for an intermediate spectrum)

30 layers without any heat extraction

T max= 142 °C  
Thermal gradient  $\approx$  30 °C

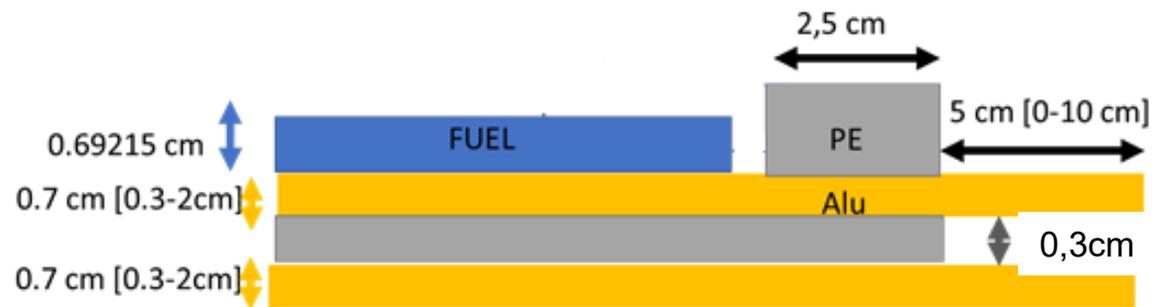


## work performed on TEX-MOX, in 2022

Thermically worst configuration:  
30 layers with heat extraction  
by addings fins in aluminum

Parametric study on

- # of fins per layer
- width of fins
- thickness of fins



Best thermal results (with still a critical configuration w/o losing neutronic qualities) :

T max= 68 °C

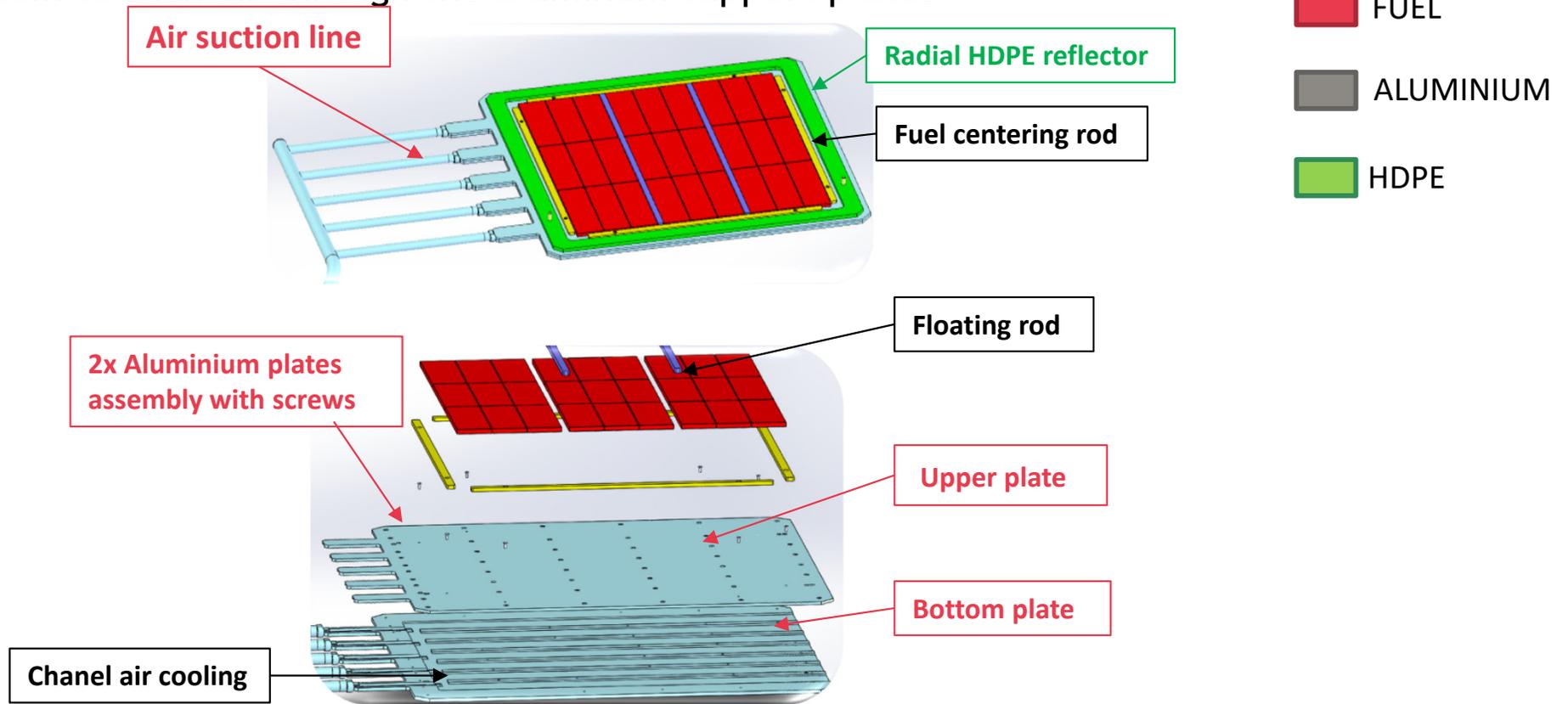
Thermal gradient around 21 °C

**Better but still not good enough!**

**→ Proposal of an air forced system by IRSN**

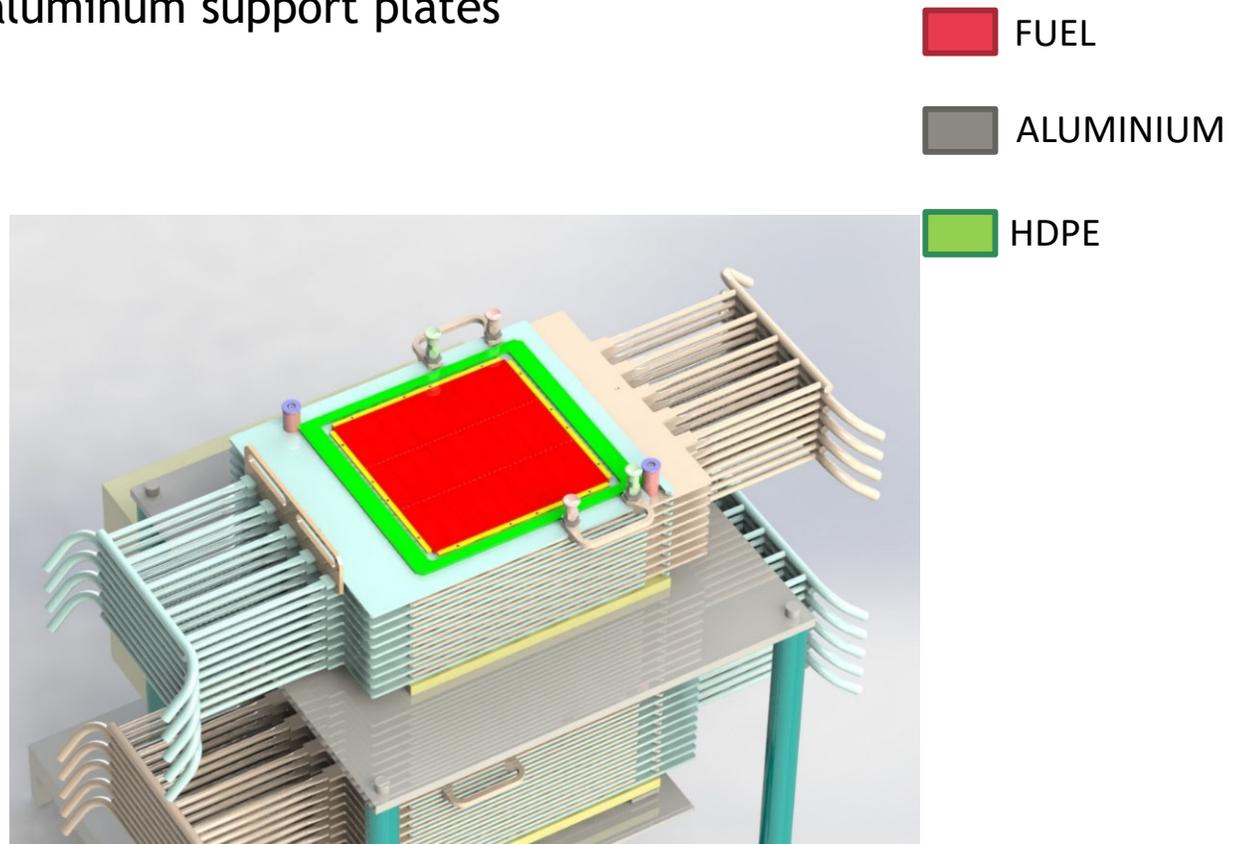
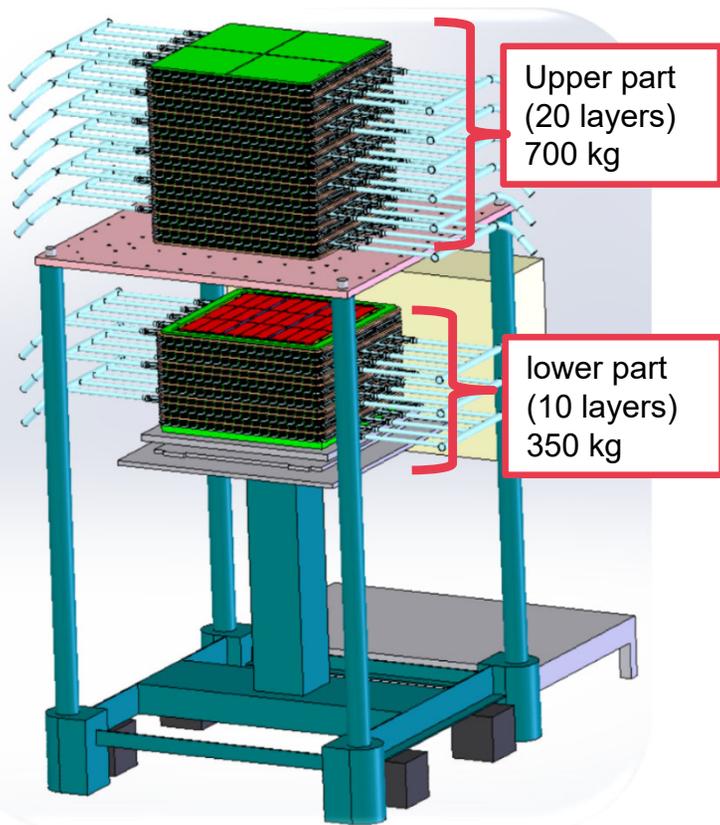
## work performed on TEX-MOX, in 2022

Results of collaboration with engineering department of IRSN :  
A system to suck air through the aluminum support plates



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## Pros and cons

### Pros :

- thermally stable system, no thermal gradient in space
- Easier to get various configurations (with different moderator thicknesses) with same heat parameters

### Cons:

- Adding weight on PLANET system
- More difficult to handle
  - Increase of dose exposure?
- Risk of failure of the system
  - Melting of PEHD on PUMN plates
- Necessity to validate:
  - cooling performance
  - industrialization and manufacture of cooling plates,
  - assembly of the plates in two parts

## Current status

Air forced system presented to LLNL, LANL & SNL on 01/12/2023.

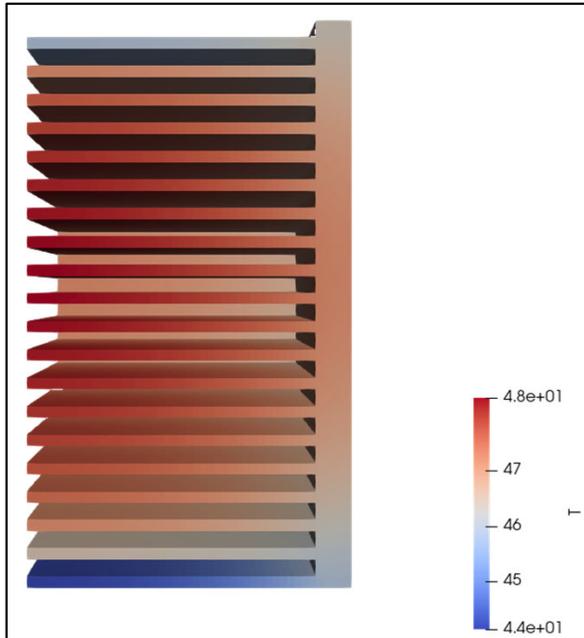
Discussions on the absolute necessity of an air forced system  
(agreement on the complexity of this system and better to avoid it)

We all agreed to perform other thermal assessments on passive system

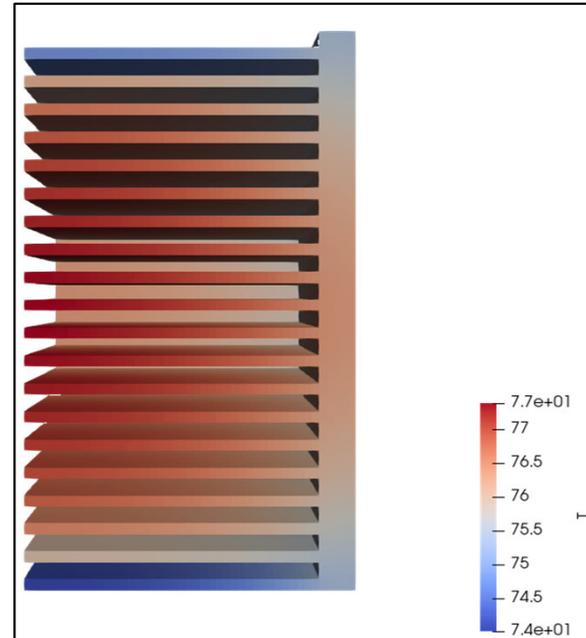
- From both sides (LANL & IRSN)
- To be sure of the absolute necessity of an air forced system

## Current status

Complimentary thermal calculations (w/o fins) by IRSN (with room temp. 0°C)



$H = 10 \text{ W/m}^2\cdot\text{K}$



$H = 5 \text{ W/m}^2\cdot\text{K}$

Thermal gradient : 3-4°C,  
whatever is the *convective heat transfer coefficient* considered

But even with minimal heating  
of +44°C, → could lead to +64°C  
(depends on room temp.)

→ Huge uncertainty on the h value. Whatever h value is, the temp. stays high.  
This solution is risky w/o mock-up demonstration.

## Work to be performed in 2023

1. Passive system : CFD calculations for 20 fuel layers (upper part) of TEX-MOX ( $T_{\max} < 65^{\circ}\text{C}$  and  $\Delta T < 15^{\circ}\text{C}$ )
  1. Still needs to check/confirm different parameters
  2. A discussion with LANL and LLNL to be done
2. Active system :
  1. Creation of a mock-up device
  2. Analysis of the cooling failure -> measurements of the dynamic behavior on the mock-up and CFD calculations
3. Proposal of 5 experimental designs (by extension different spectra) by optimization of:
  1. Moderator/reflector
  2. # of fuel plates + layers
4. Radiation protection calculation
5. Experimental uncertainty and bias estimation
6. Writing of the CED-2 report,
  1. after all previous points completed
  2. and active/passive cooling system chosen

**Thank you !**