WPEC SG 46
Target Accuracy Requirements for Sodium Fast Reactor

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Target Accuracy : Needs and Requirements

- Since 2008 many country projects related to GEN-IV for next generation Fast Reactors have been settled, some closed and some are still living…

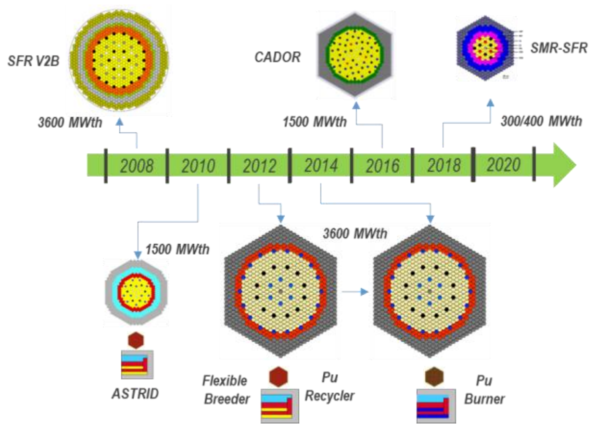
- In France and worldwide, most of the R&D programs on GEN IV reactor were driven by the need of reliable and safe concept that could meet high standards regarding:
  - Safety : toward improved resilience of the core for unprotected transients cases
  - Sustainability : enhanced capability of material multirecycling, including minor actinides
  - Economy : in service inspection as much as possible to reach 90% charge factor

- This requirements can be translated into Target Accuracy Requirements following the needs of enhanced safety margins for both experimental (prototype) or industrial version of theses concepts with reduced uncertainties on the main quantities of interest or figures of merit…

- The update of the High Priority Request List is performed with the help of the PIRT of the relevant core configurations (nominal and transients cases) combined with sensitivity studies

SFR VVUQ : current status of French Cases

- France : since no industrial design is foreseen at near term, the VVUQ process needs to consider all targeted designs with potential improvement regarding GEN-IV (as well as regulatory and industrial) requirements



- Many different objects and configurations :
  - Core power, power density, linear heat rating
  - Burnup up (90 → 170 MWd/t_{HN})
  - Plutonium vectors (WG vs multi-recycled LWR)
  - Plutonium content
  - Neutron spectrum (hard vs very smoothed)

⇨ Need to expand the validation domain compared to solely ASTRID core

⇨ Need to update TAR taking into account the whole set of designs

- Worldwide: we also need to collect and incorporate all needs from any advanced reactor designs:
  - United States: Under the Advanced Reactor Demonstration Program of DOE-NE, TerraPower, LLC will demonstrate 340 – 500 MWe Natrium reactor coupled with thermal energy storage, and Advanced Reactor Concepts, LLC will deliver a conceptual design of 100 MWe SFR. Both reactor concepts adopt metallic fuel targeting high burnup. In addition, DOE-NE is developing Versatile Test Reactor (VTR), a new research reactor capable of performing irradiation testing at much higher neutron energy fluxes.

SFR TAR : prerequistes

- Before proving any new HPRL, and in order to go beyond “expert view”, we need to pay attention to the way new requirements are settled:

Questions related to methodology

- What are the main quantity of interest: we known them for sure…but do we take into account their impact up to transient cases ➔ need to go beyond neutronic to some extent
- What is the level of accuracy needed for the TAR update on those concepts : how uncertainty quantification is related to the method we use to get sensitivity coefficients (implicit effect, core description, numerical methods, EOC vs BOL,…) ➔ toward Best Estimate Plus Uncertainty approach to tackle this

Other questions related to ND uncertainty levels themselves

- Is there a consensus on the state of the art on (co)variance data ?
- The need of improvement is always related to a specific covariance matrix…how to deal with diversity ?
- Is it worth defining TAR if reference cross sections are greater than twice the variance ?
- Is it worth refining for ever if no experimental data is available to confirm (1% on fission for Cm244) ?

Targeted Quantities of Interest :uncertainty levels

- At a very general stage, requirements related to uncertainty level on quantity of interest or figures of merit need to be iterated and agreed among participants (which was not the case in the 2008 exercise…)

Quantity of Interest	Core state	PIRT	Target	ASTRID COMAC	Contributor to uncertainty
Criticality	BOL	All	300* pcm	650 pcm	Pu, U, MA, Na,..
Flux and reaction rate (spatial distribution)	All	Nominal, UTOP	2%	<1%	Pu, U, MA, Na, Fe, O (oxide)
Burnup reactivity change		UTOP	2%	**30%**	**Pu**, U, ***Fission Product***
Kinetic parameter	All	UTOP, UOLF	2-5%*	3.5%	Pu, U, ν prompt and delayed
Reactivity coefficients (Doppler+thermal expansion)	EOC	UTOP, ULOF	5-10%*	**2-20%**	**Pu**, U, Na, **Structural isotopes**
Control rod worth, shutdown margin	BOC	UTOP	5%*	2%	Pu, U, Bore
Decay heat		Nominal, shutdowns	TBD		**Fission Product**, Heavy Nuclei
Damage Rate (DPA)	EOL	Nominal	TBD		Pu, U, **Structural isotopes**
Material Balance	All	Nominal			

- To Be Determined as well as * values: Designer views ? Expert views ? TSO view ?

SFR TAR : the case of ASTRID

- In the frame of the ASTRID project, nuclear data uncertainty propagation has been performed up to transient for:
  - ULOF challenging case : loss of primary pumps (half flow within 10 s)
  - UTOP : reactivity insertion representative of one control rod withdrawal (~1/2 $)
- Specific target requirements for ASTRID need to be merged with ones of other concept and iterated…
- Regarding methodology, the effect of Boltzmann/Bateman coupling on sensitivities was found to be of prime interested for relevant analysis. Here the example for reactivity swing for ASTRID (~800 pcm) : sensitivity and uncertainty COMAC V1 prior (JEFF3.1.1)

	One group sensitivity on $\Delta\rho$		
Isot/reaction	Case	capture	fission
^{239}Pu	Boltz.	-1.668	+3.345
	B&B	-1.560	**-3.702**
^{240}Pu	Boltz.	+0.209	-0.371
	B&B	+1.294	-0.818
^{238}U	Boltz.	-0.425	+0.223
	B&B	**10.132**	+0.182

	Uncertainty (%) per isotope		
Isot/reaction	Case	capture	fission
^{239}Pu	Boltz.	0.747	2.796
	B&B	4.235	1.953
^{240}Pu	Boltz.	*i*1.4524	2.325
	B&B	**5.218**	***i*3.193**
^{238}U	Boltz.	0.900	+0.223
	B&B	**13.939**	+0.182

- Depending of the methodology, efforts need to be focused on different isotope, reaction and energy range !!!

TAR updates

- ❑ For SFR core concept, the 2008 exercises need to be performed once more with up to date core designs, not only focusing on one major one but taking into account a wide panel of GEN-IV candidates : medium and large core size, fuel nature, etc…
- ❑ Relevant core configurations need to treated in the PIRT built-up : nominal and transients cases

- ❑ Analysis must be done using a Best Estimate approach both for the core description and sensitivity methodology to avoid any misleading conclusions or trends…
- ❑ Structural and Fission Product need to be included in the analysis
- ❑ To do we propose to rely on NEA UAM SFR exercises which aims at doing the relevant job for several selected cores:
  - ❑ Medium size metallic fueled core (ABR-like)
  - ❑ Large oxide core, medium ASTRID-like core

➔ too short for next SG26 meeting but worth waiting for international agreed analysis and recommendations

- ❑ Other SFR core design could also by added…

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