Panel on Innovative SMRs: SFRs

Key Features and Comparative Advantage of Sodium cooled Fast SMRs

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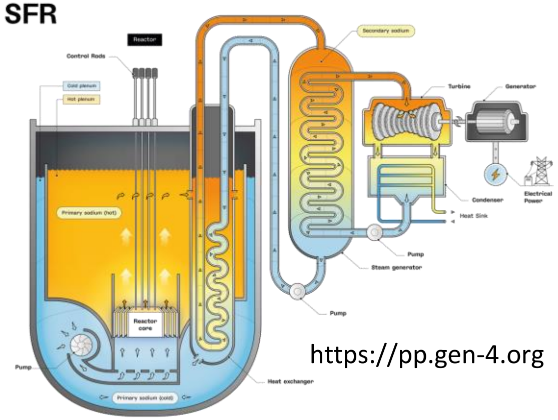
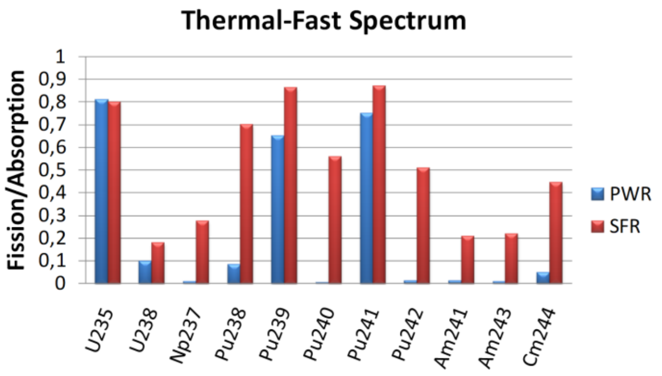
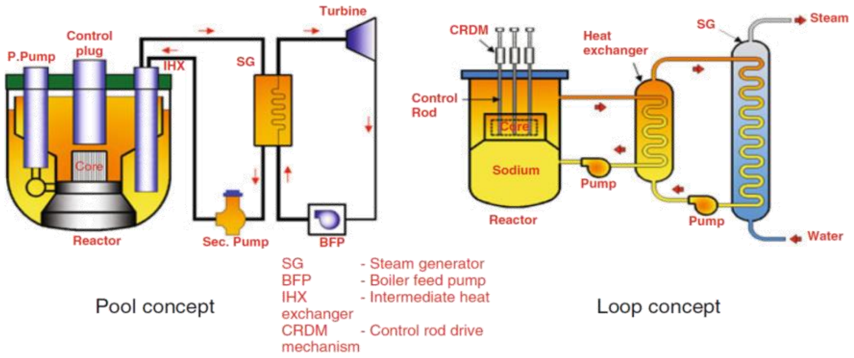


https://pp.gen-4.org

Sodium-cooled Fast Reactors

- **Fast Spectrum:** fuel breeding, less production of minor actinides and the possibility to transmute LWR-spent fuel.
- **Core layout:** cake-shape for enhancing neutron leakage in case of boiling. In SMR-size, it is an inherent safety feature against prompt criticality. (e.g. EBR-II tests)
- **Sodium physical properties:** large margin to boiling, temperatures (350-500/550°C), greater thermal efficiency than LWRs. Metal fluid: EM pumps
- **Heat transfer:** excellent heat transfer properties, high-power density, compact core designs,
- **Reactor layout:** loop or pool designs able to provide safety features depending on the power level (e.g. pool: pumps immersed, no LOCA, high thermal inertia).





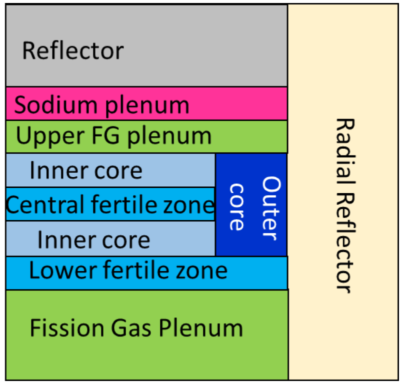
Dan Gabriel Cacuci (ed.), Handbook of Nuclear Engineering, Ch,21. Springer Science+Business Media

Sodium-cooled Fast Reactors

Karlsruhe Institute of Technology

- **Safety reactivity features:** Sodium void and density reactivity. In case of voiding:
  - less neutron capture (positive reactivity)
  - neutron spectrum hardening (positive reactivity)
  - larger mean free path due to neutron leakage increase (negative reactivity)

- **Safety measures:**
  - **Fuel:** axially heterogeneous fuel (central fertile layer increasing neutron flux in upper fissile layer, or shorter fissile zone). Oxide and metal options.
  - **Core:** large sodium plenum at core top (neutron leakages increased); absorbing zone in upper shielding (reducing neutron reflection back to fissile core)
  - **Passive systems:** natural circulation to remove decay heat.
  - **Low-pressure primary system:** near atmospheric.
  - **Na-water interaction:** Intermediate Sodium Loop (primary - power conversion system.)



- **Commercial readiness:** Extensive operational experience world-wide, over 400 reactor-years, 20 reactors. Current projects in China (CEFR), Russia (BN-800) and India (PFBR)

- **Load-following:** temperatures compatible with reasonable-sized intermediate thermal storage systems

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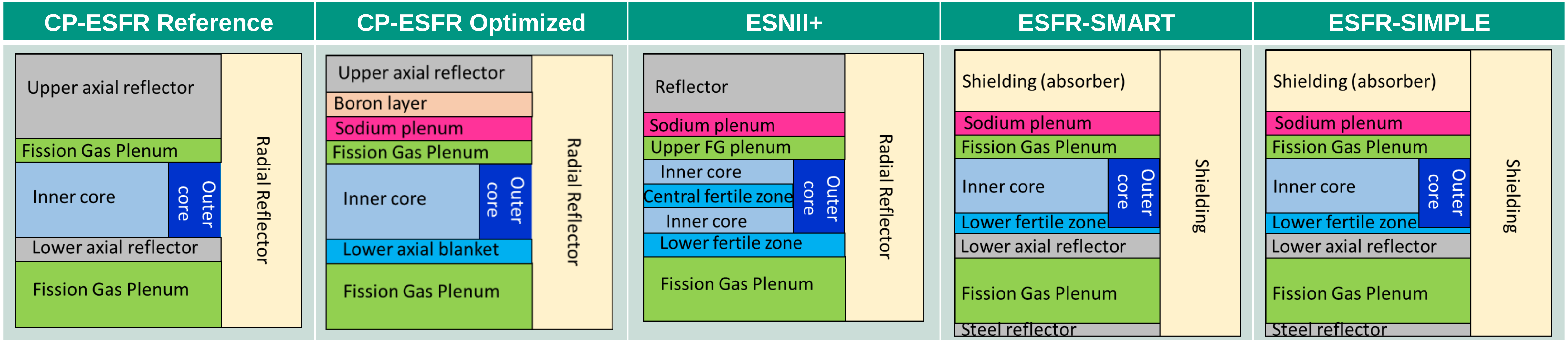
SFR reactor designs in EU projects

	CP-ESFR	ESNII+	ESFR-SMART	ESFR-SIMPLE
Time	2009-2012	2013-2017	2018-2022	2023-2027
Target	SFR	Gen-IV (SFR, LFR, GFR…)	SFR	SFR
Reactor power (MWth)	3600	1500	3600	3600 & SMR
Reactor performance	Minor Actinides transmutation	ASTRID	Improved CP-ESFR reactor	SMR design (oxide) Metal fuel (SFR)
Safety measures	decrease sodium void worth	negative sodium void worth	corium discharge tubes passive SR (Curie-point triggered)	



Comparative Advantage of SFR-SMR

- Fast Spectrum: less production of minor actinides compared to thermal spectrum.
- High coolant temperatures 350-500/550°C: greater thermal efficiency than LWRs
- Low pressure cooling circuits.
- Extensive experience in reactors from small facilities to large reactors (FFTF, EBR, …, Joyo, … PHENIX, Monju, … SUPERPHENIX, BN-800, PFBR …).
- Extensive R&D activities: test reactors, in-pile fuel tests (pin and SA level), two-phase flow, source term, … needed for code validation.

	Sodium	Lead
Heat Transfer	+	-
Natural circulacion	-	+
Neutron activation	+	-
Corrosion in structural materials	+	-
Chemical activation (H2O, O2)	-	+
Intermediate loop needed	-	+
Void reactivity	-	+
Operational experience	+	-

Conclusions

- SFRs and SFR-SMR have great characteristics with respect to fuel performance, core size, thermal cycle efficiency and safety behaviour. The later being the focus of several R&D programmes.

- Medium-size SFR enhancing neutron leakage in case of boiling (inserting negative reactivity) presents even better safety performance.

- Integration of Thermal Energy Storage for providing load-following capability without affecting reactor operation. Coolant temperatures (350-500ºC) allow reasonable TES size.

- Further R&D under collaborative projects are required to continue the enhancement of SMR-SFRs:
  - Experimental tests reflecting the current trends in core designs.
  - Passive systems for Decay Heat Removal
  - Integration of Molten Salts Loops (Na-MS HX)