XFR R&D Needs:

X: SFR, LFR, GFR

Topic 5

- **Topic 5: Safety** and Instrumentation

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- Identification of ‘instrumentation for safety’ R&D needs importance by number of crosses in the table of the following slide.
  - o X -> low
  - o XX -> Medium
  - o XXX -> High

Safety and Instrumentation								
Item			**SFR Needs**	**LFR Needs**	**GFR Needs**	**Synergies**		
Growth FA blockage			X	XXX	X	**yes, ECFM, TC, DND (SFR&LFR)**		
Fission gas release (Detection)			XX	X	X	**yes, Mass spectrometry, CRDS**		
Residual power measurements			XX	XX	X	**yes through instrumentation principle**		
Reactivity control			X	XXX	XX	n detection		
DHR			XXX	XXX	XXX	different techniques		
Freezing of coolant			not for prima	XXX	na			
Bubles (steam/gas)er in coolant			X	X	na	for instru. Principle		
Lost fuel elements								
Correct core loading			XXX	X	X	Instrumentation for Identification		
Accident initiator								
Coolant sloshing			X	X	na	Modelling & methodology		
Coollant Leak detection								
		Local	X	na	X	for LFR&SFR ?		
		Global	X	X	X	for LFR&SFR ?		
Fuel-Coolant-Interaction			XXX	XX	?	Modelling work		
SGTR phenomenology			X	X	XX	no		
Degraded core			XXX	XXX	XXX	Use of facilities		
Core catcher design			XXX	na	XXX	Facility for qualification		
Pressure boundary			na	na	XXX	no		

- Identification of the synergies :
  - Some synergies can be found on instrumentation development between the projects. Sometimes the synergies are only partial (same measurement principle or method for some of them, however the implementation of the technical solutions will be different)
  - On some important safety R&D needs, it is difficult to identify synergies (the topics to be addressed are the same, but the technical development is completely different)

LFR R&D Needs:

X: SFR, LFR, GFR

Topic 5

- **Topic 5: Safety** and Instrumentation

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Main priorities for LFR Topic 5

1. Molten lead is corrosive as well as might erode structural materials
2. Accumulation of corrosion products might lead to coolant blockages
3. Lead has high freezing point (327°C) with a potential for coolant solidification
4. Large specific weight of lead and its quantities in the primary pool might, in case of external excitations, challenge structural integrity or functionality of systems or components
5. Large quantities of coolant in the main vessel of pool LFRs may lead to complex flow patterns and interactions between the coolant and structures
6. Loss of core geometry (core compaction) might lead to a positive reactivity insertion and power increase
7. Ruptures of steam generator tubes might lead to over-pressurization of the primary side, sloshing and steam/water entrainment resulting in a positive reactivity insertion
8. Lead density reactivity coefficient might be positive in some core regions
9. Lead vapors are chemically toxic
10. Lead is optically opaque

Main priorities for LFR Topic 5

Reactivity Control

- Corrosion/erosion as well as irradiation promoted corrosion might lead to a potential degradation of control/safety rods
  - Corrosion/erosion might impair control/safety rods movement or damage core support structures leading to reactivity transient in case of their failure.
  - Further R&D is necessary on structural material behavior and its degradation mechanisms in molten lead and irradiation environment
- Excessive concentrations of dissolved oxygen in the coolant
  - Excessive oxygen concentrations might lead to the formation of solid oxide particles resulting in blockages impairing or deteriorating the operation of the rods
  - Further R&D is necessary on oxygen control strategy in pool type reactors
- Innovative design of control rods driven by buoyancy
  - Further R&D is necessary on design and qualification of innovative CR designs

Main priorities for LFR Topic 5

Decay Heat Removal

- Corrosion/erosion
  - Corrosion/erosion might lead to the formation and deposition of corrosion products and formation of solid particles, which could form FA or heat exchanger blockages
  - Further R&D is necessary on structural material behavior in molten lead and irradiation environment (to prevent and manage produced corrosion products)
- Coolant freezing / solidification
  - Coolant freezing / solidification might lead to the formation of blockages impairing coolant flow
  - R&D shall be performed aiming at establishing if coolant solidification is a safety issue or not (prevention and mitigation measures for accidental solidification)
- Innovative design of passive decay heat removal systems (e.g., isolation condensers for ALFRED LFR)
  - Further R&D is necessary to qualify the innovative designs of passive DHR systems, in particularly regarding the degree and stability of established natural convection flow

Main priorities for LFR Topic 5

Potential Core Disruptive Accident Initiators

- Gas/steam ingress into the core
  - High lead and LBE boiling point makes coolant boiling highly unlikely
  - Gas/void might appear in the core as a consequence of gas release from ruptured fuel pins or steam generator tube leakages/ruptures
  - SG with double walls makes unlikely the event of concomitant wall break, however phenomenology related to lead-water/steam interaction (incl. degree of steam entrainment, pressure wave propagation, management of over-pressurization and possible containment bypass, etc.) has to be addressed
- Total Instantaneous Blockage (TIB) of one FA
  - TIB of one FA without scram has the potential to initiate fuel melting. Melting may propagate to neighboring FAs potentially resulting in fuel disruption, even if the reactor is subsequently shutdown
  - Sudden and complete flow blockage is prevented by a FA design solution involving multiple inlet openings
  - Any other blockage caused by the deposition of a material is gradual and can be monitored by the detection of an increase of the outlet coolant temperature of each FA. It has to be demonstrated that the blockage can be detected ,at the FA outlet, before cladding rupture would occur
- Loss of core geometry (core compaction)
  - Coherent external force excitation (e.g., earthquakes) leading to large fluid / structure interactions (incl. sloshing) can lead to core compactions
  - Due to the high density of lead, the response to large external excitations needs to be carefully considered. Further R&D and qualification efforts are necessary regarding prevention/mitigation measures to be implemented on the level of FA (e.g., distance pads to prevent the compaction) and on the level of reactor building structures (e.g., 2D isolators).

Main priorities for LFR Topic 5

Phenomenology of Core Disruptive Accidents

- Fuel Coolant interaction
  - Further R&D is necessary on thermodynamic and chemical interaction of solid and molten fuel with cladding and the coolant
- Fuel dispersion (sinking or/and floating)
  - Core catcher is currently not considered since only cases with the floating fuel in lead/LBE have been evaluated up to now. For these, a core catcher would not be effective. However, further R&D is necessary to understand severe accident phenomena (fuel sinking or/and floating), which will serve as a basis for the development of severe accident management strategies and corresponding mitigation measures. The impact on integrity and functionality of components, such as SGs/HXs, needs to be carefully considered.
- Source term predictions (retention of fission and activation products)
  - Further R&D is necessary on behaviour of fission and activation products (I, Cs, Po, ..) in lead
- Water – fuel-cladding-lead interactions & concrete-lead interactions
  - The injection of water is being considered as an ultimate Severe Accident Management measure through flooding of the reactor cavity between main and safety vessels
  - Further R&D is necessary on water – fuel-cladding-lead interactions and concrete-lead interactions (relevant in case of reactor vessel rupture)

Main priorities for LFR Topic 5

1. Behavior (incl. corrosion/erosion) of structural material in lead and irradiation environment
2. Oxygen control strategy
3. Qualification of innovative components (control rods, passive DHRs, etc.)
4. Lead chemistry control, purification from impurities / corrosion products
5. Lead – water/steam interaction (SGTR)
6. Coolant freezing (safety issue ?)
7. Internal Fuel Assembly flow blockage
8. Fuel coolant interactions
9. Fuel dispersion in lead (sinking, floating)
10. Source term predictions (retention of fission and activation products)
11. Development and qualification of appropriate modeling tools for the above tasks