LEADER
Lead-cooled European Advanced DEmonstration Reactor

RELEVANT FIGURES AND GRAPHS FOR LEADER PROJECT

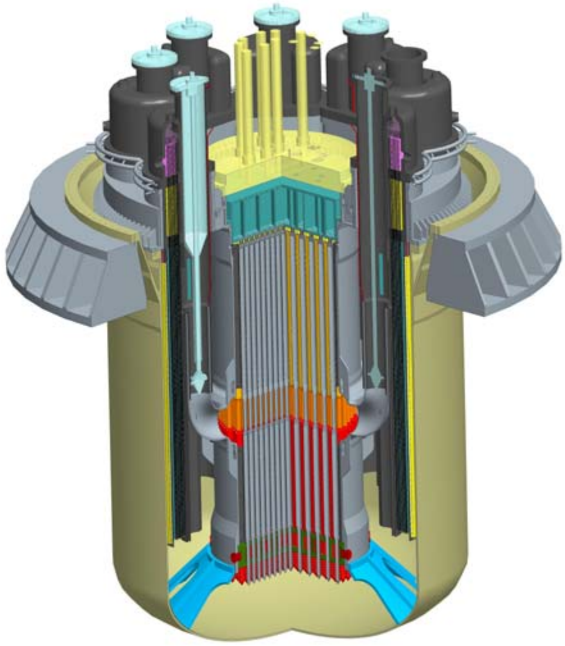

Figure 1: ALFRED 3D sketch

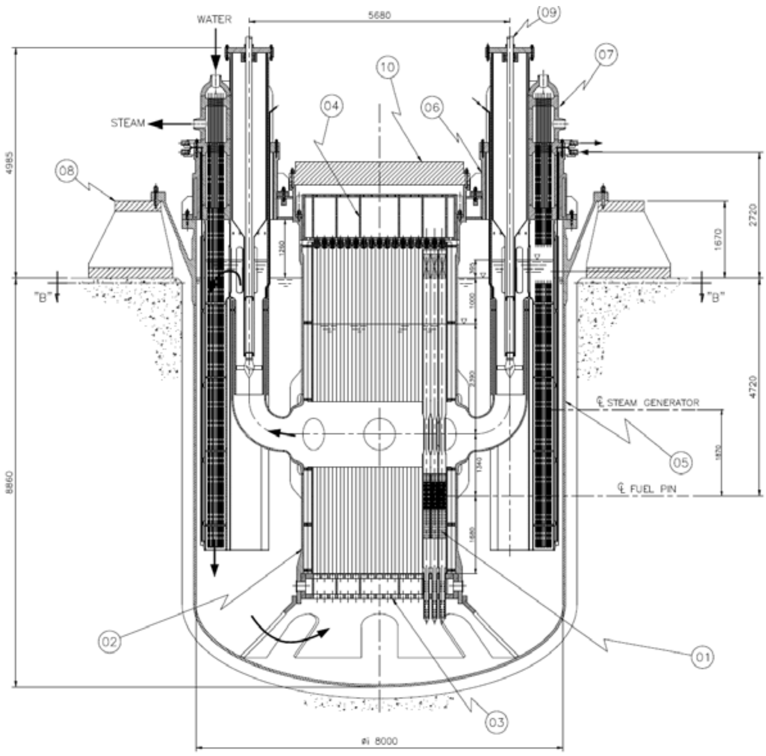

Figure 2 - Reactor block vertical sections: 01) Fuel assembly ;02) Inner vessel;03) Core lower grid; 04) core upper grid; 05) Reactor vessel; 06) Reactor cover; 07) Steam Generator; 08) Vessel support; 09) Primary pump; 10) Reactor FAs cover)

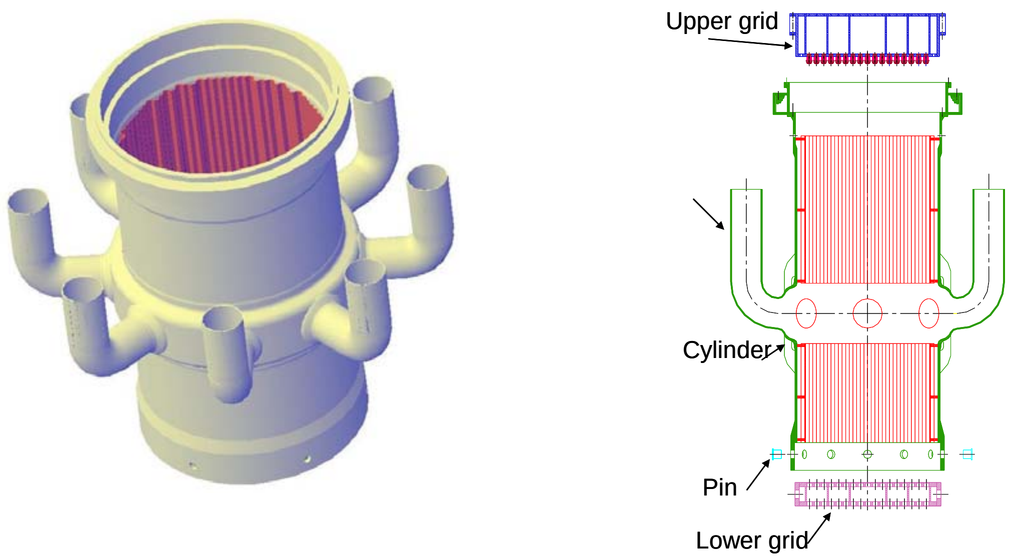

Figure 3: Inner Vessel: 3-D sketch and axial section with FAs inside

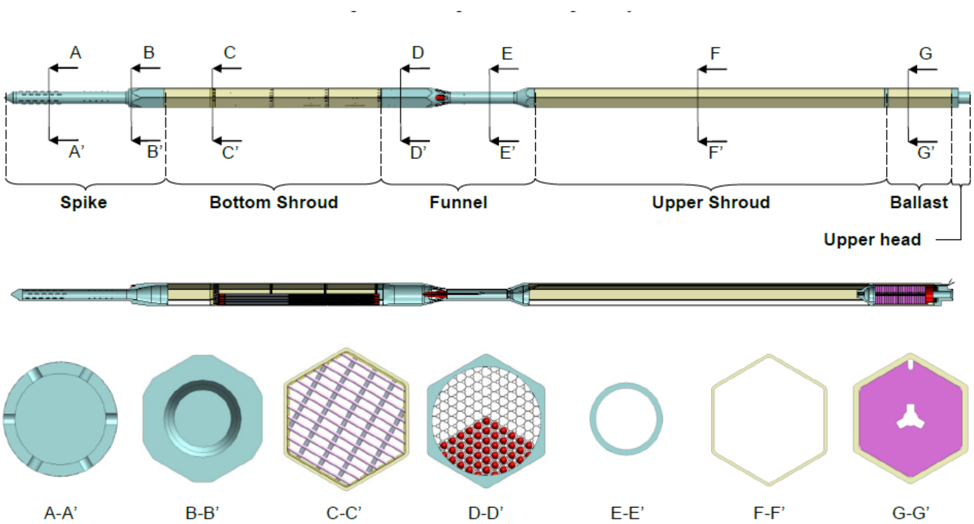

Figure 4: Fuel Assembly geometry

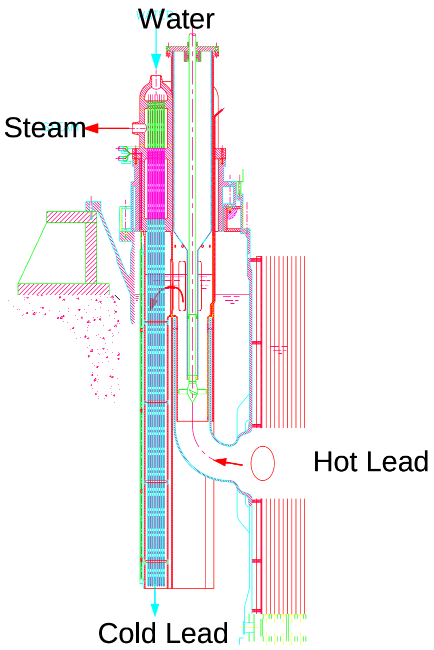

Figure 5: Inner Vessel, Primary Pump and Steam Generator coupling scheme

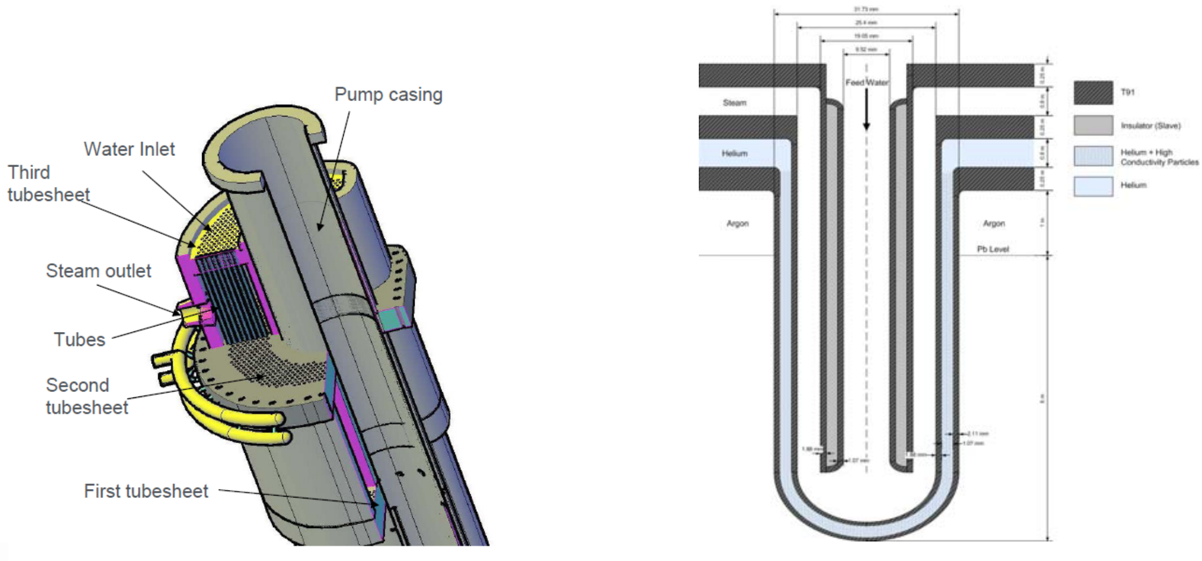

Figure 6: 3D scheme of SG and bayonet tube configuration

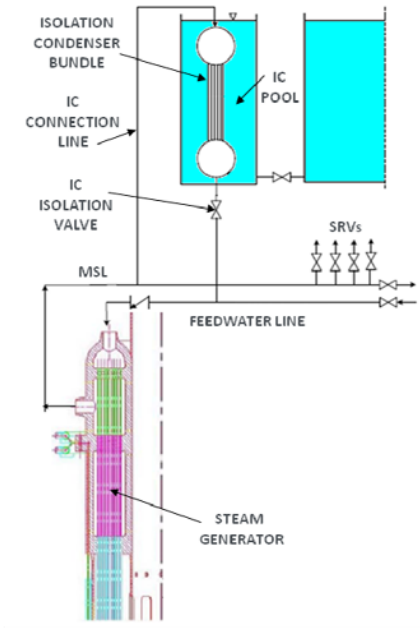

Figure 7: Isolation condenser

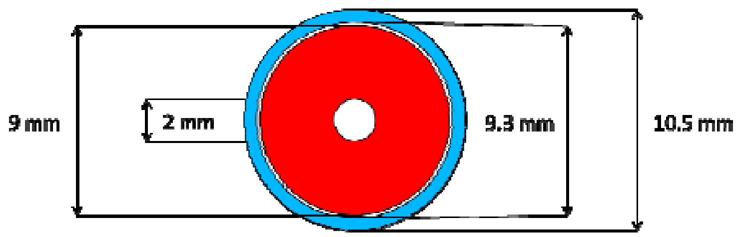

Figure 8. ALFRED fuel pin cross-section.

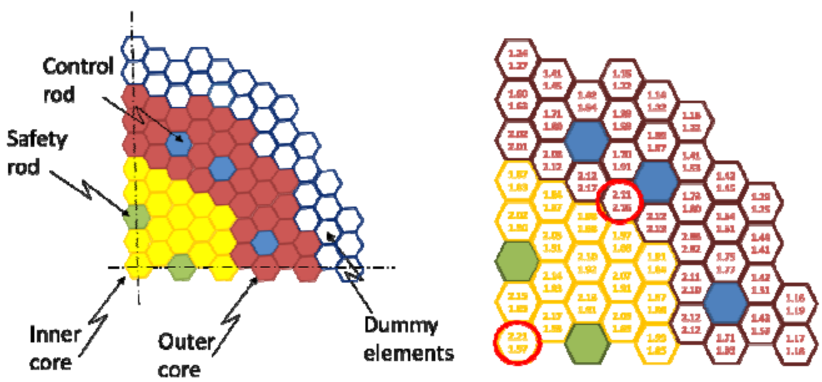

Figure 9. Final ALFRED core configuration (left) and BoC (upper value) and EoC (lower value) power (in MW) per FA distribution (right).

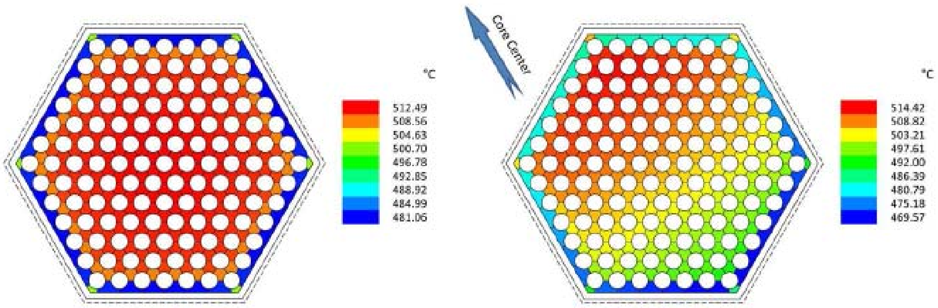

Figure 10. Coolant outlet temperature distribution among the sub-channels of the most powerful FAs:on the left the central one; on the right the one in the outer core region.

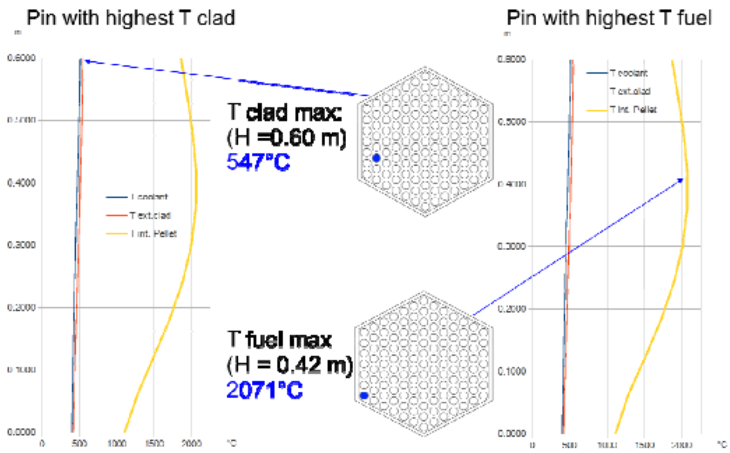

Figure 11. Axial temperature profiles in the hottest pins of the most powerful FA.

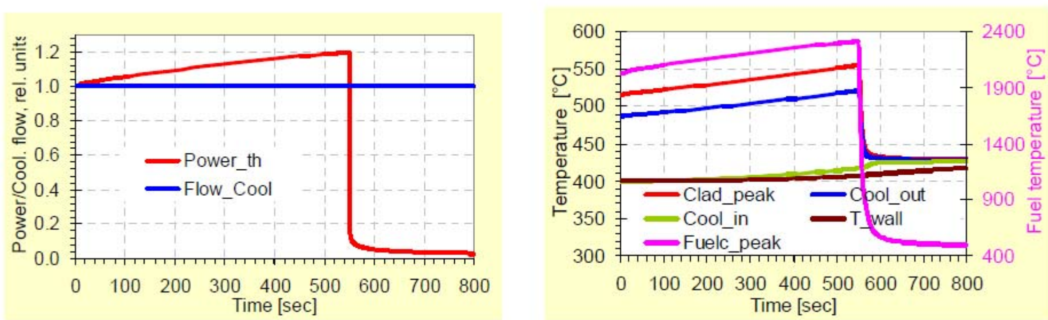

Figure 12. Evolutions of reactor power and primary coolant flowrate (left), and peak fuel, clad, coolant and vessel wall temperatures (right) with time for BOC as calculated by SIM-LFR (KIT)

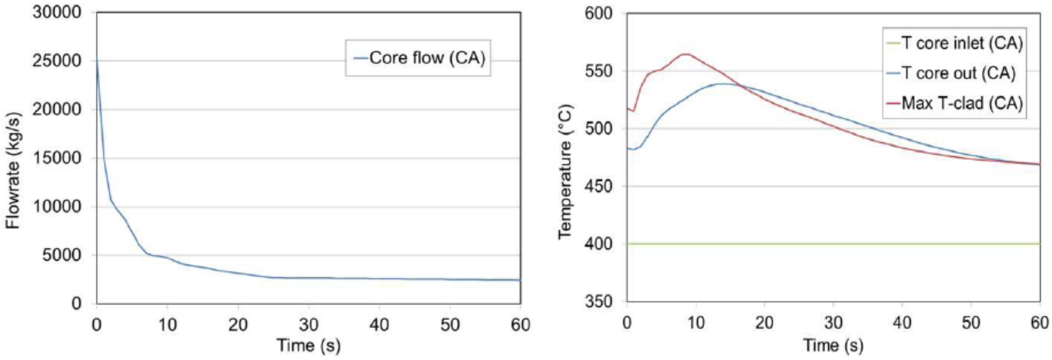

Figure 13. Evolution of active core mass flowrate (left) and core temperature (right) as calculated by CATHARE (CEA) in the short term

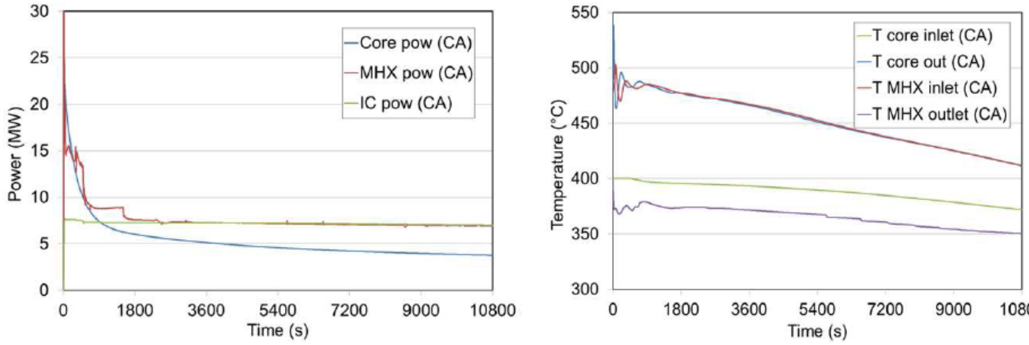

Figure 14 Evolution of core decay, MHX and DHR-1 (IC) powers (left) and primary lead temperatures (right) as calculated by CATHARE (CEA) in the medium term

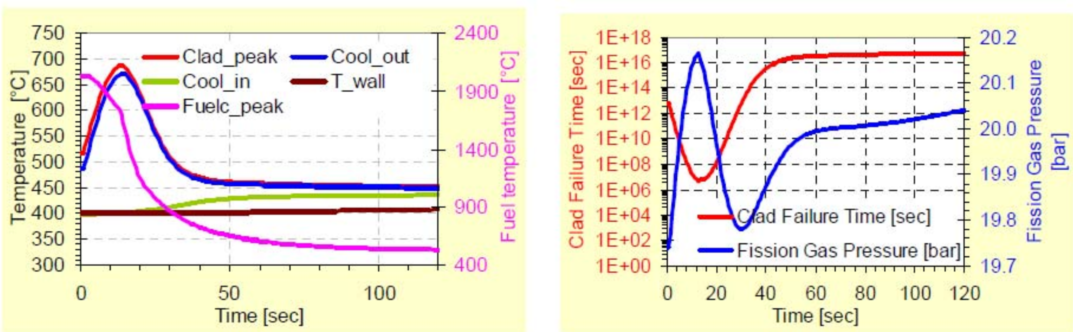

Figure 15. Evolutions of peak fuel/clad/coolant/vessel wall temperatures (left) and peak pin fission gas pressure and clad failure time (right) with time for EOC as calculated by SIM-LFR (KIT); Case (70% flow area blockage and reactor trip delayed by 10 sec)

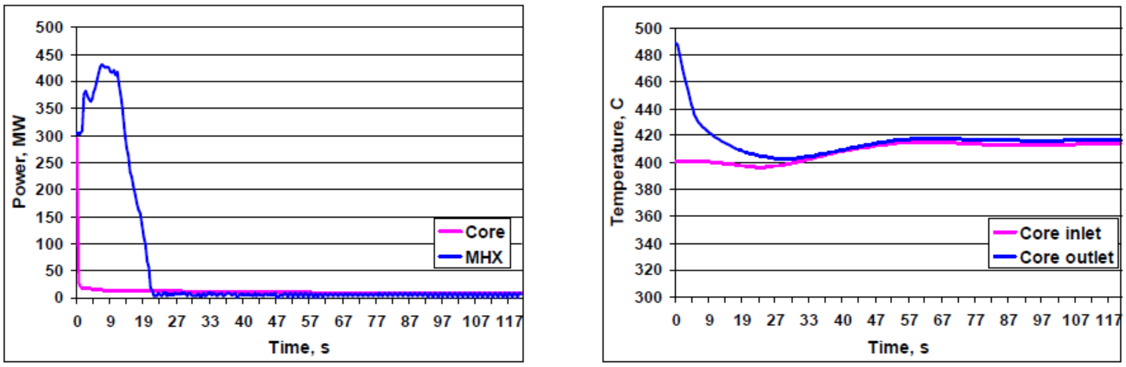

Figure16. Evolutions of core/SG powers (left) and core inlet/outlet temperatures (right) with time in short-term time scale as calculated by TRACE (PSI)

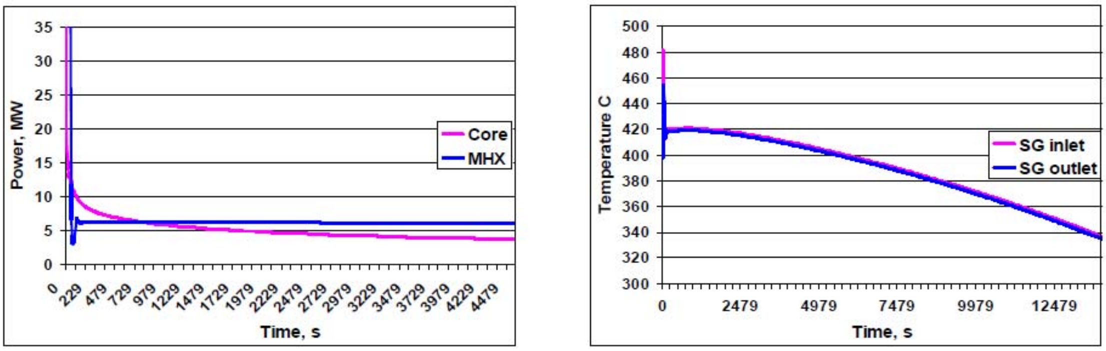

Figure 17. Evolutions of core/SG powers (left) and core inlet/outlet temperatures (right) with time in long-term time scale as calculated by TRACE (PSI)

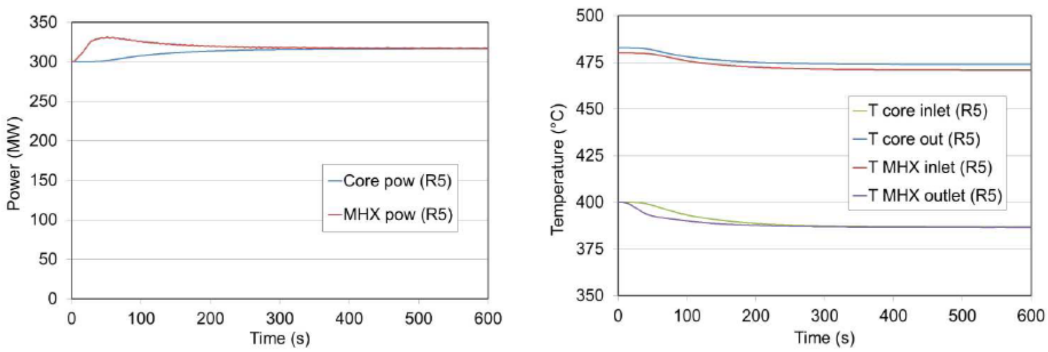

Figure 18. Evolution of core and MHX powers (left) and primary lead temperatures (right) as calculated by RELAP5 (ENEA)

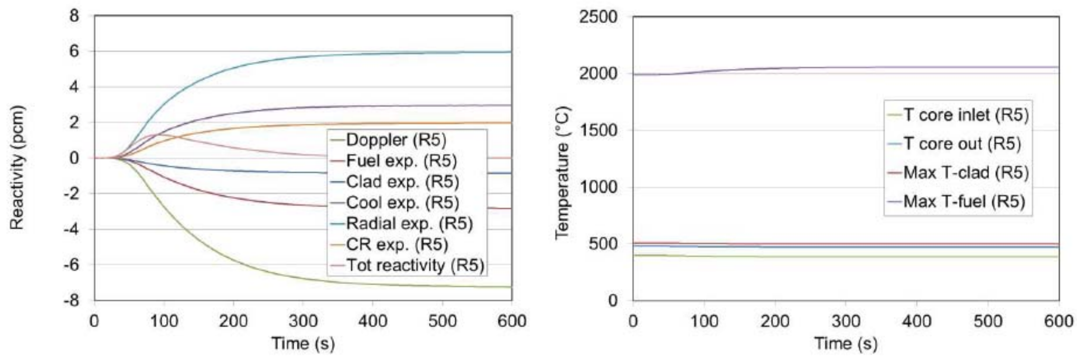

Figure 19. Evolution of total reactivity and feedbacks (left) and core temperatures (right) as calculated by RELAP5 (ENEA)

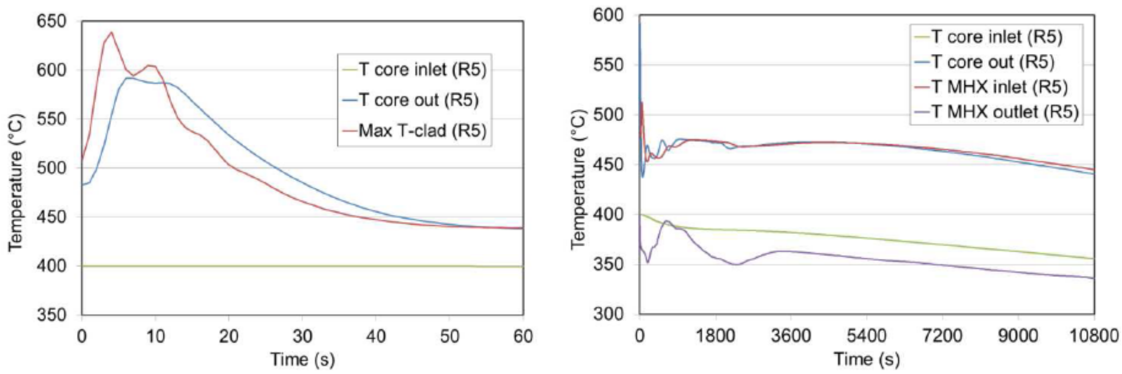

Figure 20. Evolution of core temperatures in the short term (left) and primary lead temperatures in the long term (right) as calculated by RELAP5 (ENEA)

Components	Material	Min./Max Temp. Normal Operation (°C)	Max. Lead velocity (m/s)	Max. Radiation damage (dpa/y)	Max. Radiation damage (dpa)
Reactor Vessel	AISI316L	380÷430	0.1	< 10^{-5}	0.0002
Inner Vessel	AISI316L	380÷480	0.2	0.1	2.1
Steam Generator	T91/AISI316L	380÷480	0.6	< 10^{-5}	0.0001
Primary Pumps	MAXTHAL (Ti_3SiC_2) Coated T91 or SS (Aluminized, Ta)	380÷480	10	< 10^{-5}	0.0001
FA Clad FA Structures	15-15Ti /T91 Aluminized	380÷550 380÷530	1 2	- -	100/200 100/200
Dummy Assemblies	T91	380÷480	0.01	-	100/200
Refueling Equipment	AISI316L	380÷480	0.2	0.02	0.3
DHR Heat Exchanger	T91	380÷430	0.2	< 10^{-5}	0.0001

Table 1. Materials and conditions for the different reactor components of ALFRED and ELFR

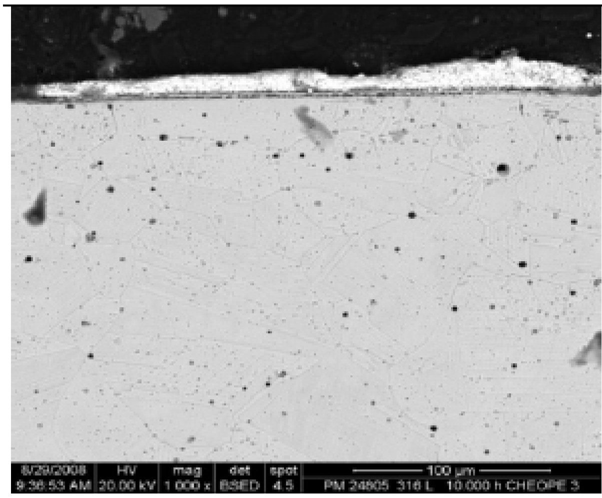

Fig 20a) 316l after exposure in Pb (10-6wt% oxygen) at 550°C for 10,000h

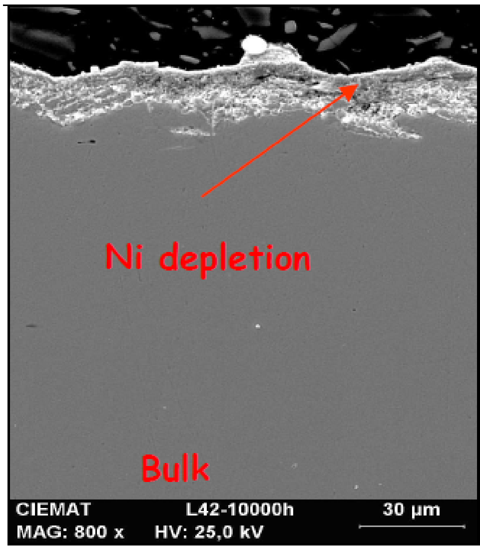

Fig 20b) 316L after exposure in LBE (10-8wt% oxygen) at 450°C for 2000h

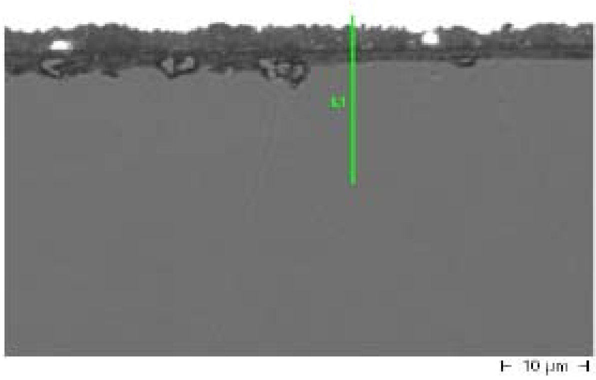

Fig. 21a) SEM cross section of 15-15 Ti stabilized steel after 2000h exposure at 480 °C

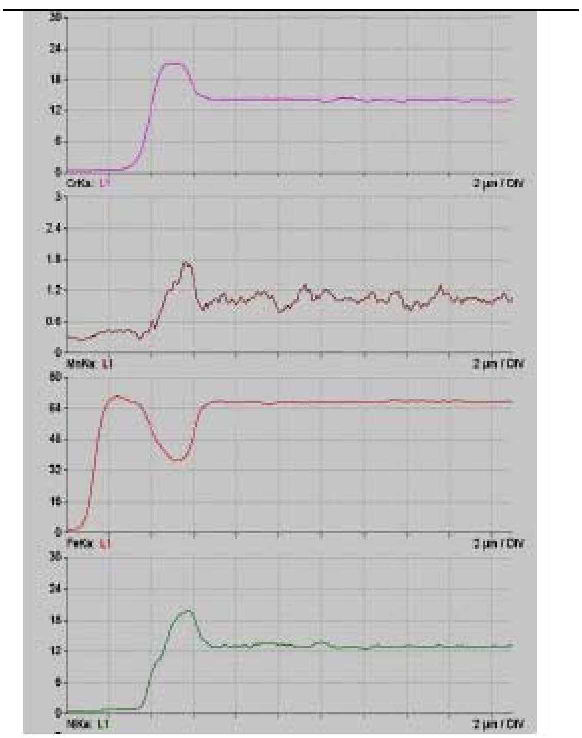

Fig. 21b EDX line scan at line depicted in Fig 21a

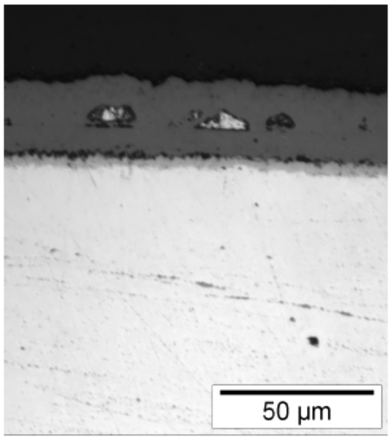

Fig. 22a Oxide scale formed at T91 steel in PbBi at 480°C

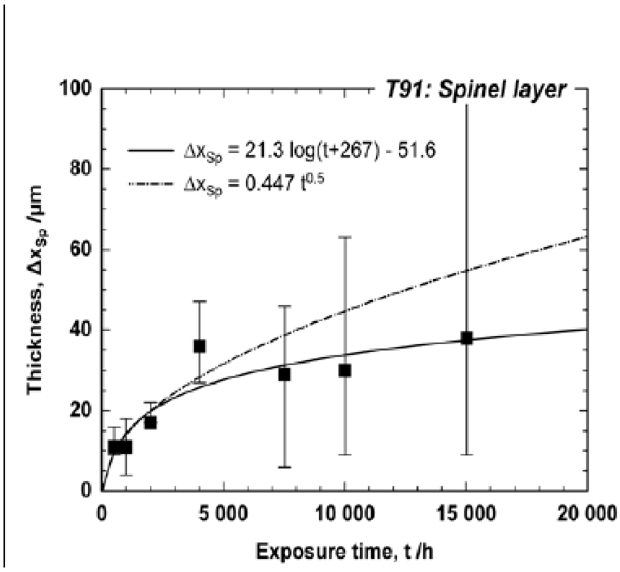

Fig. 22b T91 oxidation as function of time at 550°C

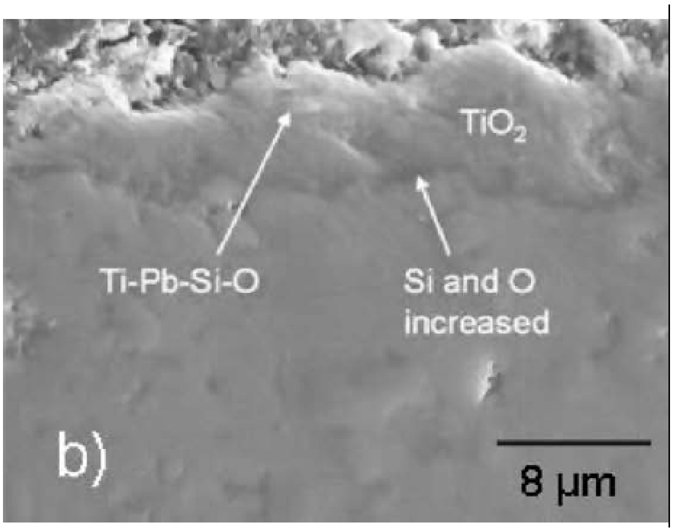

Fig. 23a Maxthal after exposure to Pb at 750°C –formation for thin protective oxide scales

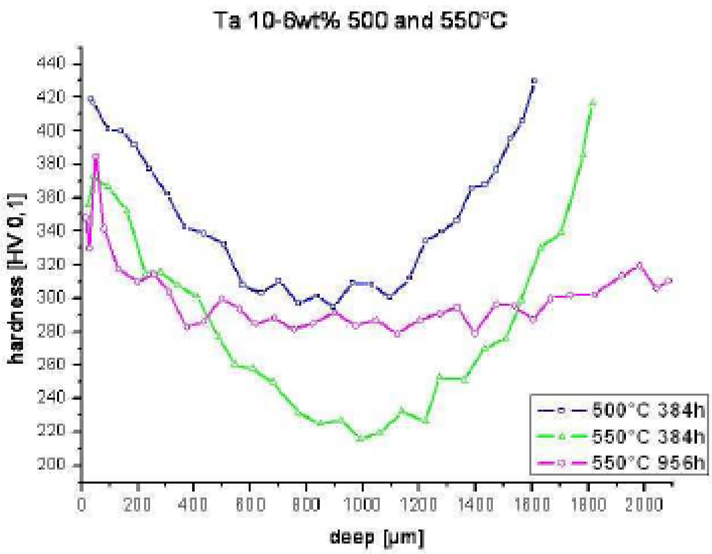

Fig. 23b Hardness increase by oxygen diffusion

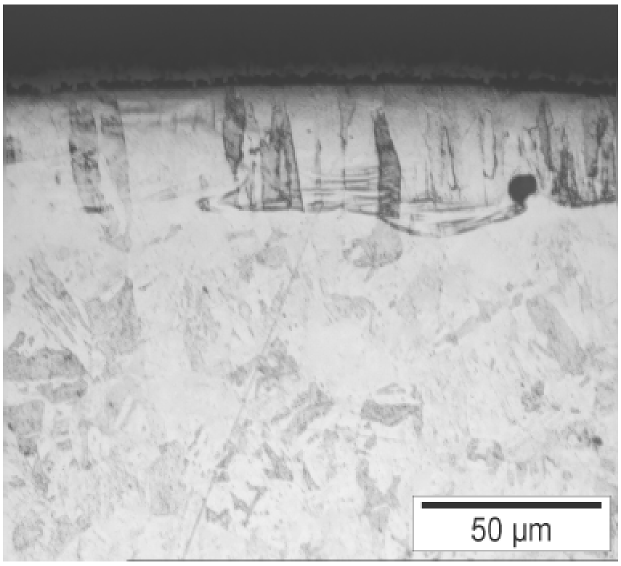

Fig. 24a: Surface alloyed f/m Steel T91 – perfect metallic bonding

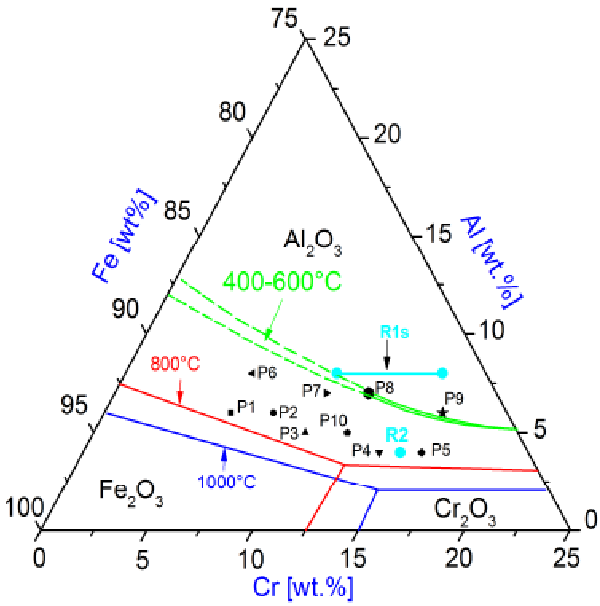

Fig. 24b: FeCrAl oxide map derived from experiments in Pb

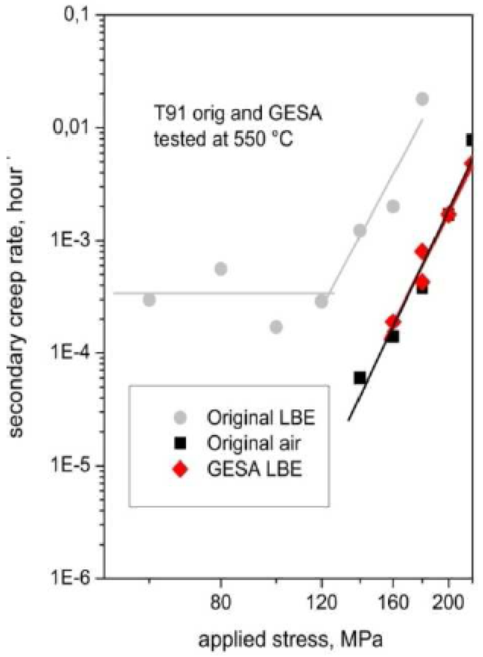

Fig. 25a Secondary creep rate in LBE and Air-threshold stress

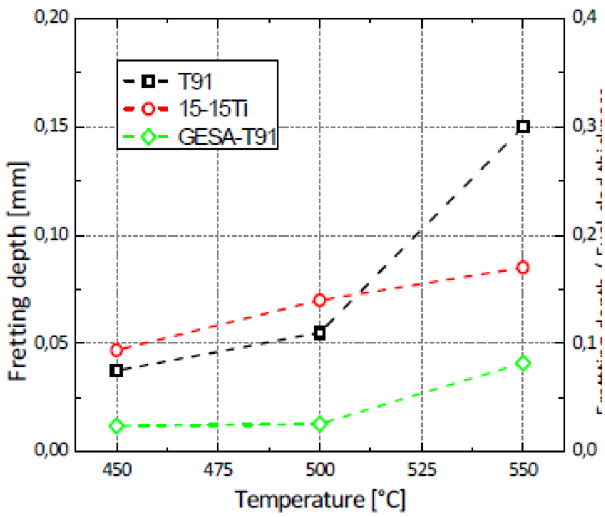

Fig. 25b fretting damage as function of temperature

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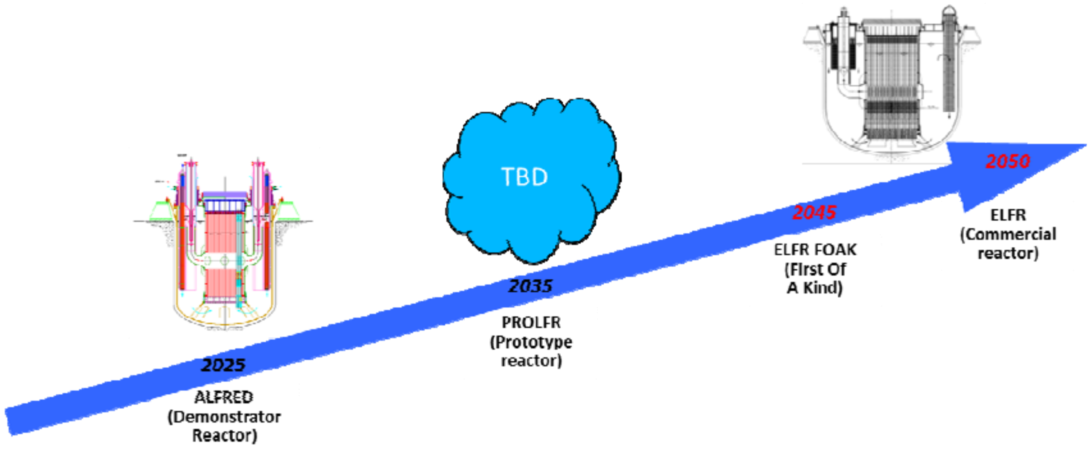

Figure 26. LFR Roadmap towards industrial deployment

Figure 27. Facilities for LFR technology development

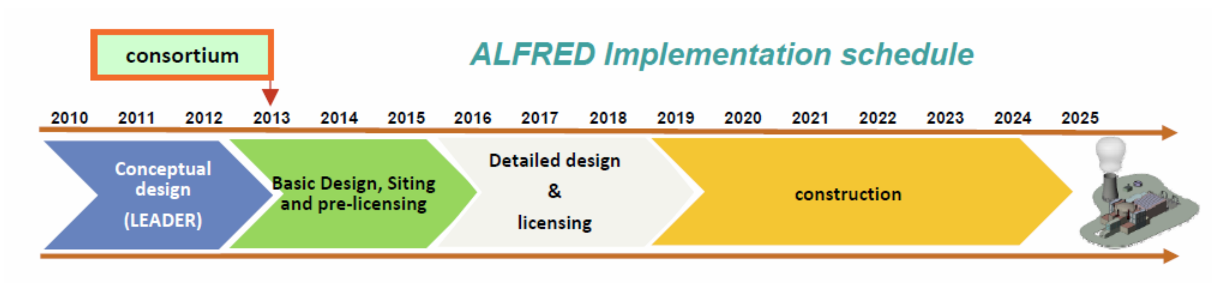

Figure 28. ALFRED Implementation schedule

Parameter	Unit	ALFRED	ELFR
Thermal power	MW	300	1500
Electric power	MW	~125	~625
FA concept	-	Closed hexagonal	Closed hexagonal
Fuel type	-	MOX	MOX with equilibrium Pu and MA
Fuel enrichment	%	< 30	equilibrium one
Maximum fuel temperature	°C	≈ 2000	2000
Peak BU	MWd/kg-HM	100	100
Clad material	-	15-15 Ti	T91
Maximum clad temperature	°C	550	550
Coolant inlet temperature	°C	400	400
Coolant outlet temperature	°C	480	480
Coolant velocity	m/s	1.4	1.5
Primary pressure drops	bar	1.5	1.5
Maximum cladding temperature in ULOF	°C	750	750
Secondary cycle	-	superheated steam	superheated steam
Steam pressure	bar	180	180
Steam temperature	°C	450	450
Cycle efficiency	%	~44	~43
Steam generator concept	-	double-wall bayonet tube	single-wall spiral tube
Seismic dumping devices	-	2D isolators below reactor building	

Table 2. Main plant parameters for ALFRED and ELFR.