Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

ENEA contribution to national programme on SMR/AMR

Mariano Tarantino *Responsabile Divisione Sistemi Nucleari per l'Energia*
Dipartimento Nucleare

ENEA activities on SMRs Technology

In-depth studies for the **characterization of the passive systems modeling from the experimental and computational point of view** including **reliability assessment**.

- Thermal-hydraulic codes validation (TRACE, RELAP, CATHARE)
- Scaling analyses to characterize the code scaling-up capabilities
- Severe Accident Simulations

Participation in **European projects**

PASTELS

works on improving numerical tools to accurately simulate some of the most promising safety passive systems.

TANDEM

develop methodologies and tools to facilitate the safe and efficient integration of SMRs into smart low-carbon hybrid energy systems.

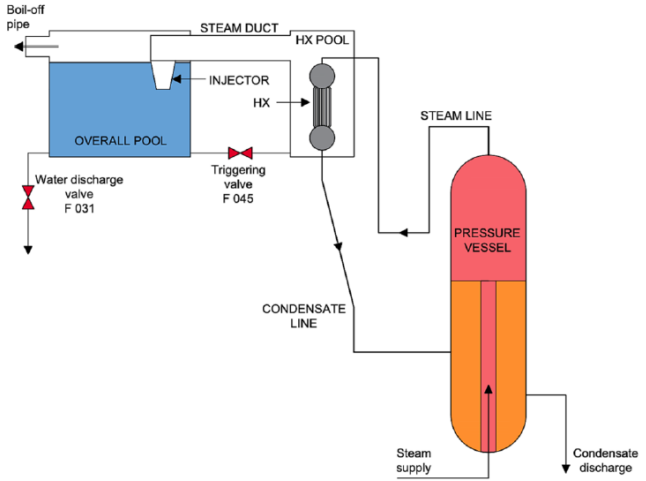
SASPAM-SA

aims to investigate the applicability and transfer of the operating large LWR knowledge to the integral PWR (iPWR).

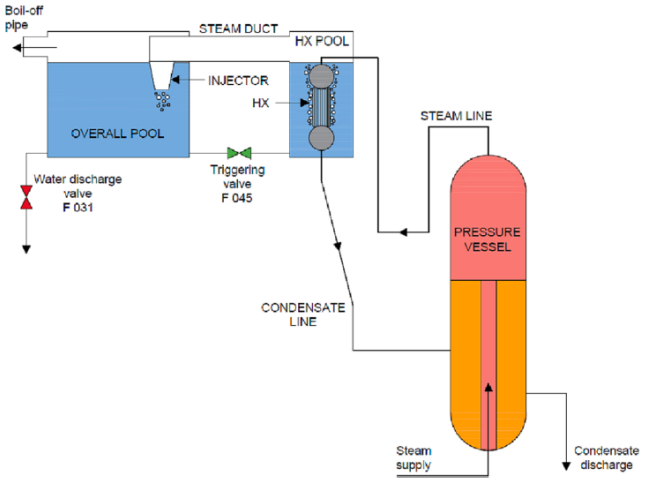
Experimental Facilities: PERSEO (in-Pool Energy Removal System for Emergency Operation)

- Full scale facility located at SIET Laboratories (Piacenza)
- PRIMARY SIDE: Vessel (43 m^3, 13 m height), steam Feed line (10 in), condensate Drain line (6 in), full scale model of SBWR IC heat exchanger (two cylindrical headers and 120 vertical pipes (5 cm OD, 1.8 m average length)
- SECONDARY SIDE: HX pool (29 m^3) and Overall Pool (173 m^3, 5.8 m height) connected at the bottom by a liquid line (0.2 m ID) and at the top by a steam duct (1.1 m ID) ending with an injector flowing into the Overall Pool about 1.3 m below the water level

Passive system not in operation



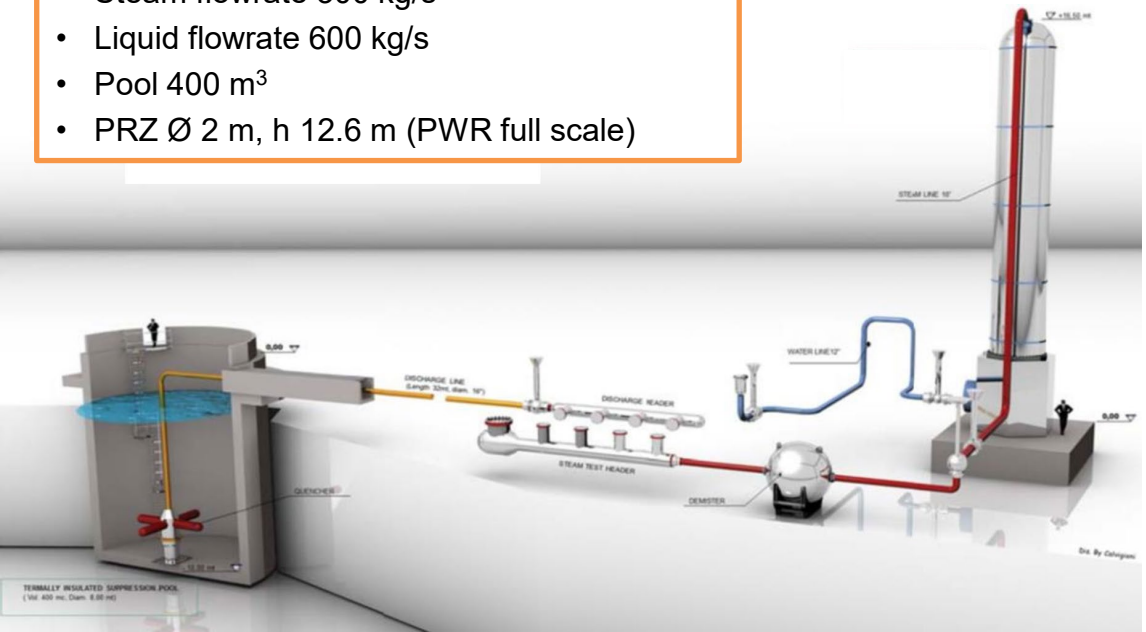
Passive system in operation



VAPORE Facility

Designed for full-scale thermal-mechanical and fluid-dynamic tests on components and systems feeded by saturated water or steam.

- Power 1.4 MW
- Pressure 18 Mpa
- Steam flowrate 300 kg/s
- Liquid flowrate 600 kg/s
- Pool 400 m^3
- PRZ Ø 2 m, h 12.6 m (PWR full scale)



Examples of past experiences

- Safety valves and spargers of Montalto di Castro NPP
- Depressurization system of WH AP600

Activity planning

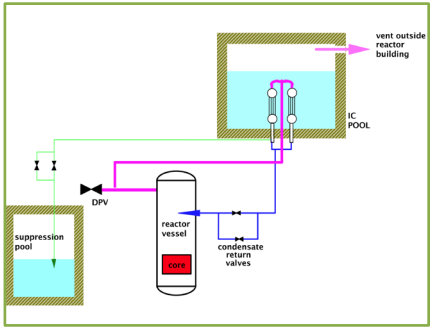
- 2000 stop of operations
- 2025-2027 facility refurbishment and uprating up to 3 MW, funded by MASE
- 2027 sparger test

Experimental support at SIET for safety assessment of SMR

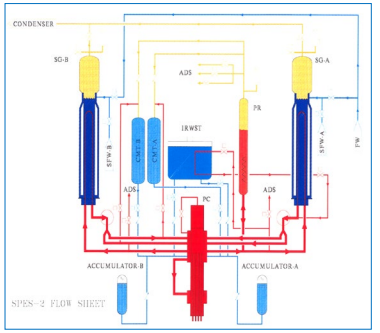
The SIET company has been involved in several experimental campaigns in the last tree decades:

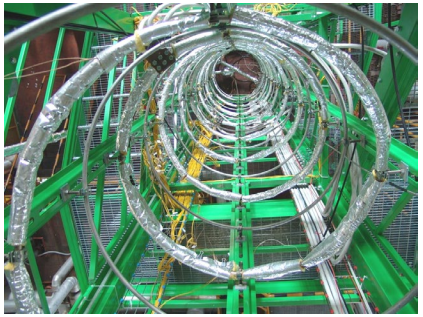
- **SPES2** (1992 - 1994): Integral Test Facility for WEC AP-600 simulation. Full T-H conditions, Volume and power scale ~1/400; Full height.
- **GEST-PANTHERS** (1994 - 1996): Isolation Condenser qualification for GE-SBWR at full scale and full T-H conditions.
- **SPES3-IRIS** (2005-2011): helical coil testing and Integral Test facility design and partial construction

PANTHERS-IC

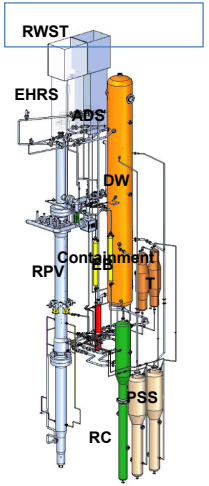


SPES2





Helical coils



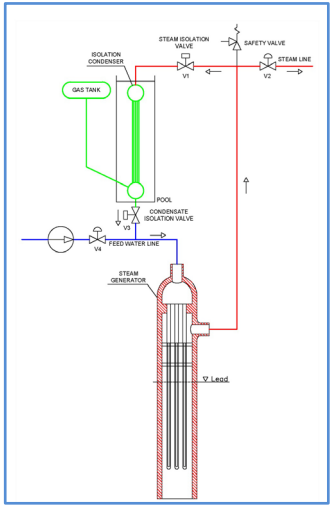
SPES3

Experimental support at SIET for safety assessment of SMR

- **NuScale Power** TF1 and TF2 (2011 – 2015 and 2020 - 2024): helical coil testing and helical coil steam generator mock-up characterization at full scale (reduced number of tube row) and full T-H conditions.
- **NuScale Power** TF3 (2017 - 2024): Helical coil steam generator mock-up at full scale (reduced number of tube row), cold conditions, for Fluid Induced Vibrations investigation.
- **HERO and HERO-2** (2015 - 2017): Testing of bayonet tubes for Liquid Metal Reactor Steam Generator.
- **SIRIO facility** (2018 - 2021) and PIACE European project (2019 – 2022): Testing of a passive “anti-freezing” system for a DHR in Liquid metal cooled reactors and in LWRs.

TF3

TF2 under construction



PIACE

Experimental support at SIET for safety assessment of SMR

ELSMOR European Project H2020 (2018-2023)

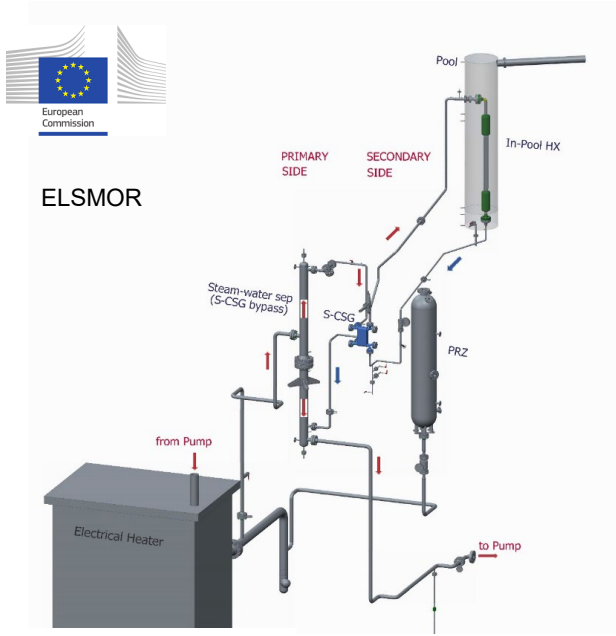
Towards European Licensing of Small MOdular Reactors

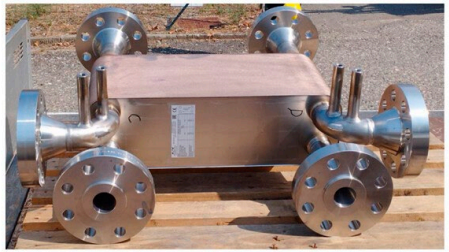
ELSMOR aimed to create methods and tools for the European stakeholders to assess and verify the safety of light water SMRs to be deployed in Europe.

In the frame of the improvement of the European experimental infrastructures, **SIET designed, built and operated a facility to test an innovative DHRS based on a plate-type heat exchager in a reduced elevation natural circulation loop for the E-SMR (Nuward type).**

Several tests were executed for system performance verification:

- tests at different primary side temperatures;
- test at different filling ratios of the secondary side;
- tests with non-condensable gas in the secondary side;
- tests with different pressure drops in the piping, primary and secondary side;
- tests with different levels and temperatures in the HX-Pool;
- tests with two-phase conditions in the primary side (steam in the Separator).





EAGLES

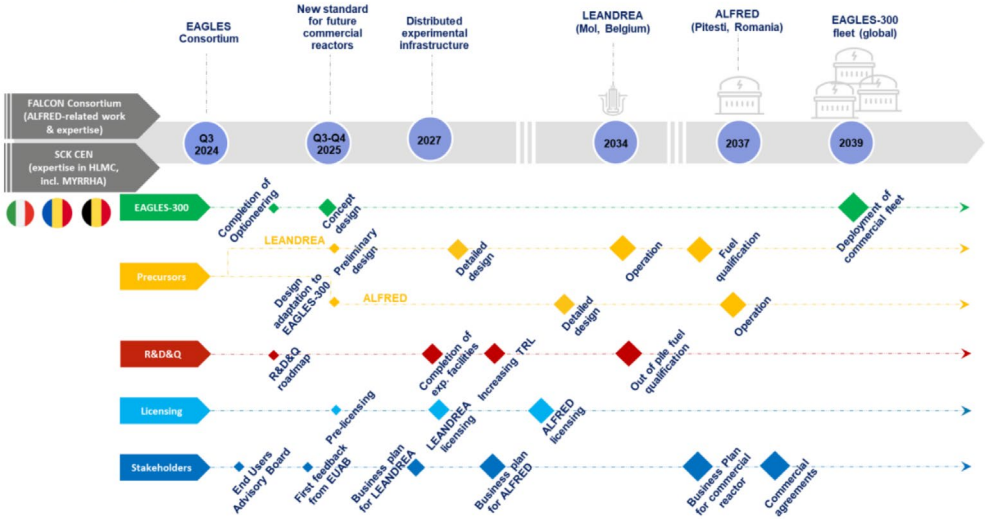
EAGLES

- Competitive economics
- Proven passive safety features
- Sustainable closed fuel cycle
- High temperature heat
- Customers oriented
- Commercial fleet deployment by 2040

ansaldo nucleare | ENEA | RATEN | sck cen Belgian Nuclear Research Centre

- **EAGLES-300 Technology:** land-based medium size Lead-cooled Fast Reactor for electrical and thermal output, fueled with MOX in a closed cycle
- **EAGLES Consortium (established on 16-Jun-2025):** gathering Ansaldo Nucleare (IT) as industrial leader, ENEA (IT), RATEN (RO), SCK CEN (BE)
- **Last year achievements:** identification of design options, setup of IAEA EBP for licensing harmonization (with FANC, CNCAN, ISIN), public tenders for experimental infrastructure launched in Romania and Belgium, engagement with Romanian supply chain, export control requests started
- **2030s Major Milestones:** setup of an End-User Advisory Board (2025), experimental infrastructure completed (2028), LEANDREA COD (2034), ALFRED COD (2037), EAGLES-300 commercial deployment (2039)

Technological Roadmap



ENEA

ALFRED and FALCON Consortium

Under Construction (22 M€)

The **largest pool facility in the world**, for large-scale components testing in representative co

ATHENA

ChemLab

A broad-scope laboratory on the chemistry of HLMs and materials science

A hot facility to characterize radioisotopes behavior in Lead under accident conditions

Meltin'Pot

ELF

A pool facility for long-term experiments, to characterize the components and systems

HELENA-2

A loop facility for full-scale testing and complete thermal-hydraulic characterization of fuel and absorber assemblies

Hands-ON

A facility devoted to the testing and qualification of systems and procedures for the handling of core elements

Funding secured (> 100 M€)

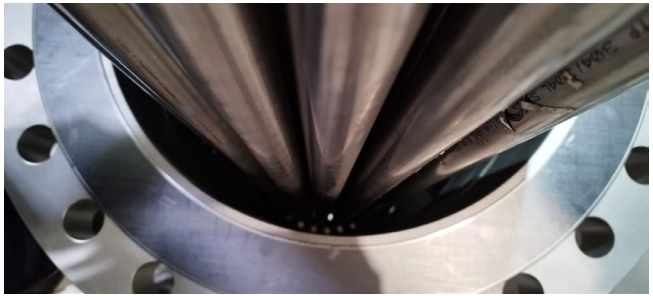
ATHENA Facility

the first step of ALFRED experimental infrastructure

- 2.21 MW Core simulator
- Full height bayonet tube heat exchanger
- Main Vessel hosting 800 tons of lead

Experiments to be performed:

- Fuel assembly performance
- Chemistry control in large pools
- SGTR



newcleo

REACTOR DESIGN:
Small Modular (SMR) + Lead-cooled Fast Reactors (LFR) = AMR
*new*cleo is working to design, build, and operate Gen-IV Advanced Modular Reactors (AMRs) cooled by liquid lead

FUEL MANUFACTURING:
Mixed Uranium Plutonium Oxide (MOX)
MOX and Fast Reactors allow the multi-recycling of nuclear waste into new fuel with no new mining for generations

INTRINSICALLY SAFE power production
COMPETITIVE energy cost
CIRCULAR nuclear waste recycling

€570 million of private funds
~€70 million revenues in 2024

French first **licensing stage completed** for the reactor in **Chinon** and the fuel production facility in **Nogent**

Selected by **France 2030** and the **European Industrial Alliance on SMRs**

1,100+ EMPLOYEES GLOBALLY

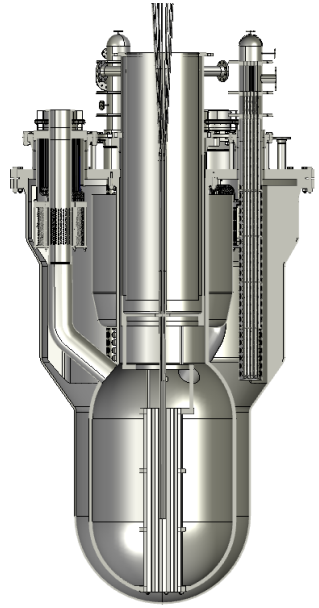
30+ YEARS of leadership in Lead Technology

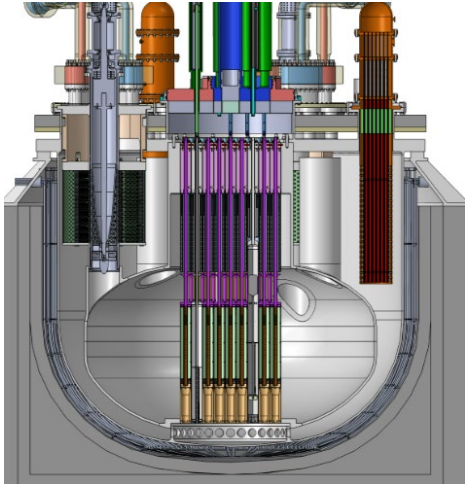
23 PATENTS

Highly specialised EPCM capabilities

FUCINA ITALIA · S.R.S. · RUTSCHI

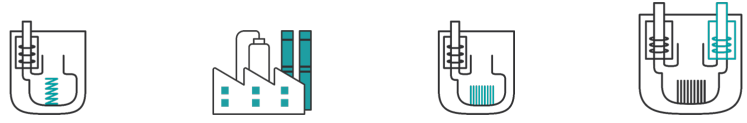
PRECURSOR





LFR-AS-30

newcleo's plan-to-market



R&D and Precursor	MOX production	LFR-AS-30	LFR-AS-200
2026 Several R&D and qualification facilities, and a **10 MW non-nuclear reactor** with turbo-generator (Precursor) built in ENEA-Brasimone	**2030** **FR-MOX production facility**, starting from available (separated) material in France	**2031** **30 MWe** nuclear irradiation reactor with core outlet at 440°C and later 530°C in France	**2033** **200 MWe FOAK**, also for non-electrical uses (e.g. cogeneration and chemicals production)
Design, manufacturing and operation in progress	**Basic Design** in progress **Licensing** in progress for both facilities		**Basic Design** in progress **UK Licensing** started in 2024

Ongoing M&A Acquisition programme

ENEA – *new*cleo Agreement

16 March 2022

*new*cleo signs agreement with ENEA to develop safe and innovative nuclear systems

Press releases

Download

*new*cleo's Generation-IV reactors to be built outside of Italy.
*new*cleo, the clean and safe nuclear technology company developing innovative reactors, signed today an agreement for the development of safe and innovative Generation-IV nuclear systems with ENEA, the Italian national agency for new technologies, energy and sustainable economic development.

DATA STAMPA

la Repubblica BOLOGNA

17-MAR-2022
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Accordo Enea-Newcleo per studiare i nuovi reattori di quarta generazione

Nucleare, 50 milioni al Brasimone

di Marco Bettazzi

Nuova linfa al Brasimone. Grazie a un accordo annunciato ieri tra Enea e la società Newcleo con sede a Londra, sulle sponde del lago sull'Appennino bolognese si studieranno nuovi reattori nucleari di quarta generazione che poi verranno realizzati fuori dall'Italia. Un investimento da 50 milioni che porterà all'assunzione di 25-30 ingegneri.

Ed è un'altra boccata d'ossigeno per la montagna, dopo la conclusione felice della vertenza Saga Coffee, il rilancio delle Terme di Porretta e gli investimenti legati al Pnrr. Questa volta si parla di energia nucleare, ovvero quello di cui si occupava il centro Enea prima del referendum del 1987. Da allora il Brasimone, dove lavorano una settantina di persone, si è specializzato in altri ambiti di ricerca come la fusione nucleare e lo studio dei metalli fluidi. Newcleo invece è una start up che fa ricerca sull'energia costituita nel 2021 da Stefano Buono, imprenditore e fisico italiano che ha lavorato per 10 anni col premio Nobel Carlo Rubbia al Cern e ha poi creato un'altra start up, venduta nel 2018 a Novartis per 3,9 miliardi di dollari.

La centrale del Brasimone

In base all'accordo Enea e Newcleo investiranno al Brasimone, che tra i comuni di Camugnano e Castiglione dei Pepoli conta 400 ettari di superficie e 17 diversi edifici. Verranno rinnovati impianti e laboratori per realizzare un prototipo elettrico di reattore raffreddato al piombo, senza l'uso di materiali radioattivi o combustibile nucleare. Per 50 milioni di investimenti, appunto, e un team di 25-30 ingegneri che lavoreranno "in pianta stabile per circa 10 anni", spiegano Enea e Newcleo.

«Collaboreremo per garantire la produzione di energia elettrica in sicurezza e a lungo termine in impianti da realizzarsi all'estero – spiega Gilberto Dialuce, presidente di Enea – ma con ricadute rilevanti di investimenti e occupazione a livello locale».

«Lavorando insieme a Enea e investendo nelle strutture del Brasimone – spiega invece Buono – contribuiremo all'avanzamento della ricerca in Italia». Esultano le istituzioni locali. «È la più grande operazione di rilancio di un sito strategico per il Paese», conclude l'assessore regionale Vincenzo Colla.

Objective of the Agreement: PRECURSOR (electric LFR prototype) at the ENEA Brasimone Research Centre

ENEA – *new*cleo Agreement

CAPSULE
operational since December 2023

Facility to test various kinds of steel, bare and coated, in stagnant lead under oxygen-controlled concentration, essentially between 10^{-8} - 10^{-6} wt %; temperatures span between 450 - 750 °C

CORE
200 kW
operational in March 2024

Loop-type facility to test various kinds of steel, bare and coated, in fluent lead under oxygen-controlled concentration, essentially between 10^{-8} and 10^{-6} wt %; temperature in the corrosion test section 650 °C and velocity 1 m/s; in the erosion test section the temperature is 520 °C and the velocity 10 m/s.

It will also be used to test the effectiveness of cold traps and mechanical filters

OTHELLO
2 MW
operational in 2026

Loop-type facility with a Fuel Pin Bundle Simulator and a mock-up of *new*cleo Steam Generator with three full length tubes. It will be used to test a Fuel Pin Bundle Simulator to validate thermal-hydraulic computer codes, to appreciate the consequences of partial inter-pins obstructions, to check the risk of fluid induced vibrations.

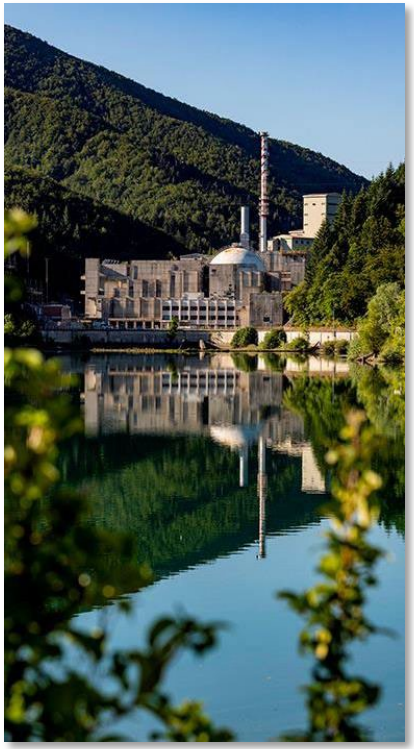
Also, to test the behaviour, both lead side and water/steam side, of the Steam Generator

PRECURSOR
10 MW
operational in 2027

Pool-type integral test facility with an electrical resistors bundle, and three Steam Generators at a thermal reduced scale, and the associated turbine-generator set. It will be used to test the global behaviour of the plant in stationary and transient mode, the inset of lead flow both in hot and cold plenum and of possible stagnant zones, the effectiveness of the DHR system, test various mechanisms as the control rods

MANUT
conceptual phase

It is a “cold” facility to test the fuel hanging and handling systems as well as the rotating plugs operation during refuelling campaign. This facility is just at a first conceptual draft.



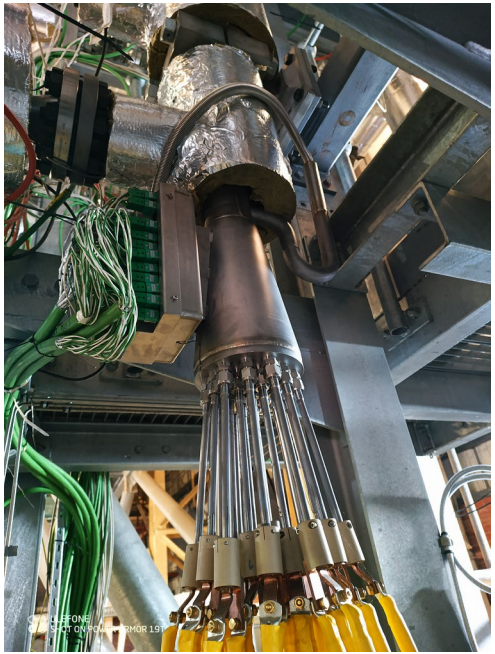
Westinghouse LFR: AMR Phase 2 Program (UK)

ANSALDO Nuclear

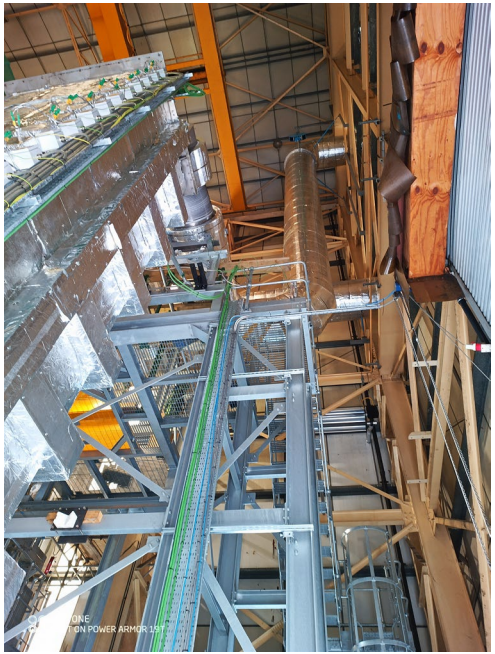
- The VLF is a Pb loop test facility to be used for testing key components of the Westinghouse LFR, e.g.,
  - Fuel bundle mockup
  - Primary heat exchanger
- The PHRF is a test facility simulating the Westinghouse LFR's Passive Heat Removal System (PHRS)

Westinghouse

- Lead Freezing test rig
- Heat exchanger failure testing
- High Temperature Lead Corrosion Test

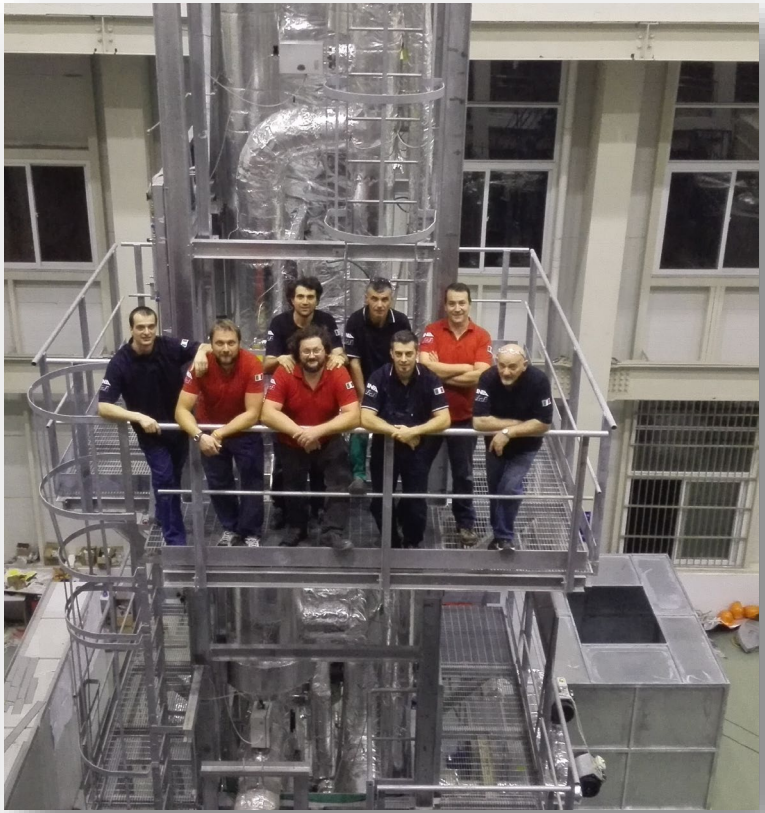


VLF



PHRF

FDS Team (CASHIPS – China)



FDS Team (CASHIPS – China)

- **CLEAR-S Pool**
  - LBE pool (300°C – 400°C)
  - MCP @ 220 kg/s , 2,5 bar
  - CS (7 FPS) @ 2,5 MW
  - DWBT HX @ 100 bar

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