2nd International Summer School on
Early-deployable Small Modular Reactors (2024)

SIET
sperimentiamo le tue idee

Experimental support at SIET for safety assessment of LWR and SMR

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27 June, 2024
Lario Lake, Lecco, Italy

Content

- The SIET company
- Business areas
- Overview of SIET facilities capabilities and main characteristics
- SIET facilities application for SMR testing
- Conclusions

SIET location

SIET company

- Established in 1983 by ENEA & CISE with the primary purpose of carrying out safety tests on components and systems of Nuclear Power Plants
- Based in Piacenza (Italy) in the buildings of a dismissed power station

Current Shareholders:

ENEA
ENEL Innovation Hubs
Tectubi Raccordi
Politecnico di Milano
Ansaldo Energia
Mare Engineering Group

27 Employees

Annual Revenues = 3 ÷ 4 M€

SIET building

SIET BUSINESS AREAS

THERMAL - HYDRAULIC TESTING [Core Business]

R&D and Experimental Qualification of Nuclear Power Plant Components and Systems
(e.g.: Integral Facilities, Heat Removal Systems, Emergency Core Cooling Systems, etc.)

ENGINEERING

Design of Experimental Facilities (including Instrumentation & DAS)
Use of Relap-5 Code to support SIET experimental activities and facility design

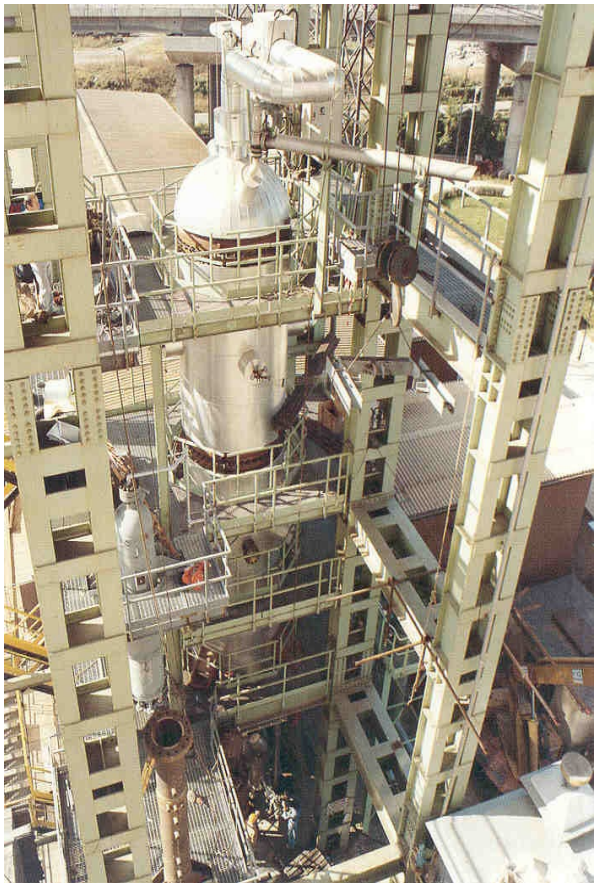
INSTRUMENT CALIBRATION SERVICES

Calibration Laboratories at SIET (pressure, temperature, flow-rate, dimensions, etc.)
to support experimental activities and provide calibrations for external customers

PRODUCT CERTIFICATION

SIET is accredited by EU as a Certification Body for thermal-hydraulic devices to be used on industrial & civil hydraulic systems (e.g.: Thermostatic Radiator Valves)

SIET FACILITY CAPABILITIES



GEST facility vessel (45 m^3)

The on-site availability of large capacities in terms of Power and Fluids for experiments allows SIET to test Large Scale LWR components and systems at nominal operating conditions

Saturated Steam [40 kg/s, 7 MPa]

Water [200 kg/s, 17 MPa, 330 °C]

Power [10 MW]

Laboratory Area [≈10.000 m^2, 30 m elevation]

Infrastructures and energy potential for TH experiments certainly unique in Italy and rare to find worldwide.

SIET "NUCLEAR-GRADE" QUALITY ASSURANCE AND CERTIFICATIONS

SIET Laboratories have a nuclear quality assurance culture in place conforming to:

- ASME NQA-1-2008 with 2009 Addenda
- 10 CFR 50 Appendix B
- 10 CFR 21

In 2013 SIET passed an NRC inspection with no findings

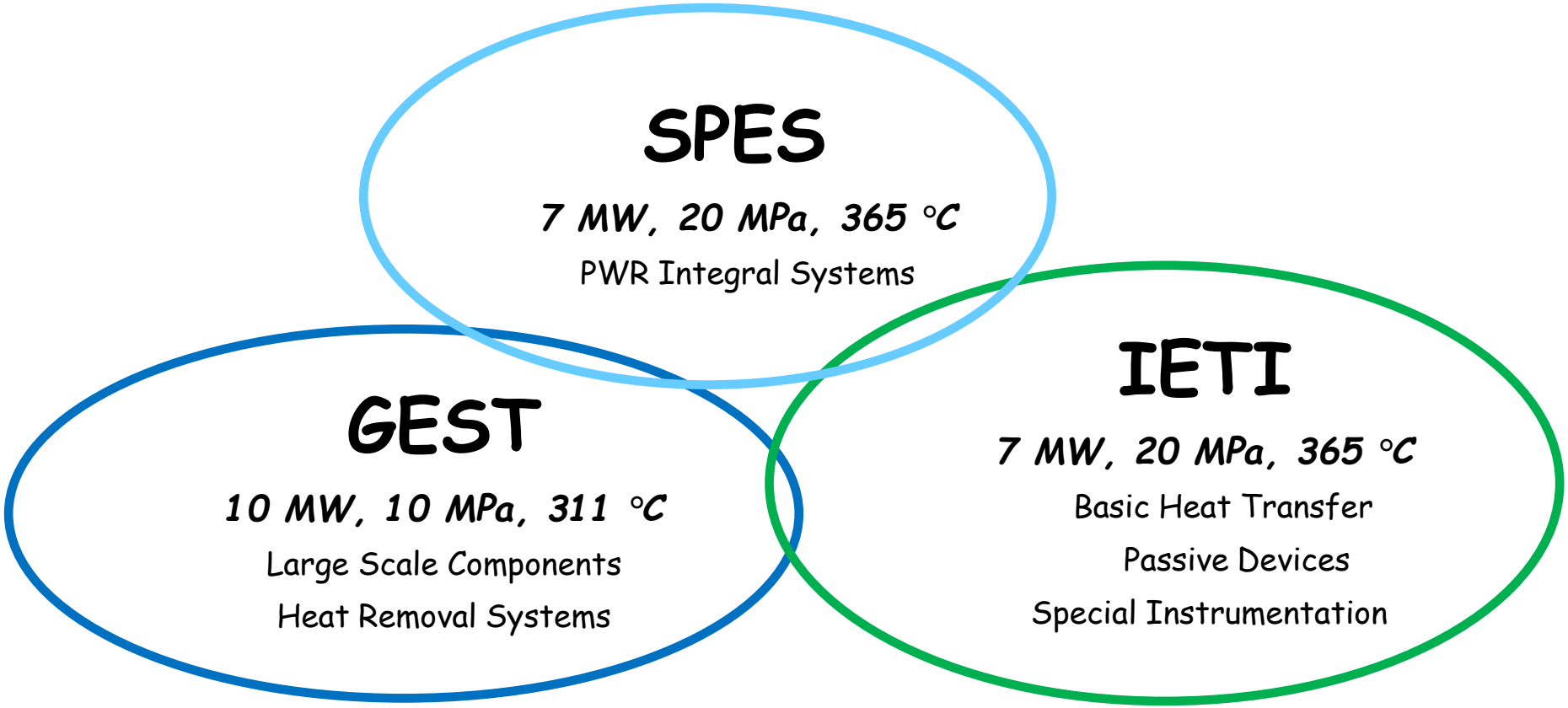
In July 2019, NRC successfully performed a surveillance audit during SGFIV Modal testing

In May 2023, NRC performed a surveillance audit during TF2-DWO testing

SIET is recognized by CEN (European Committee for Standardization) as "Test House" & "Empowered Certification Body"

SIET is recognized by ACCREDIA, the Italian Accreditation Body both as Testing and Instrumentation Calibration Laboratory

SIET EXPERIMENTAL FACILITIES FOR REACTOR SAFETY



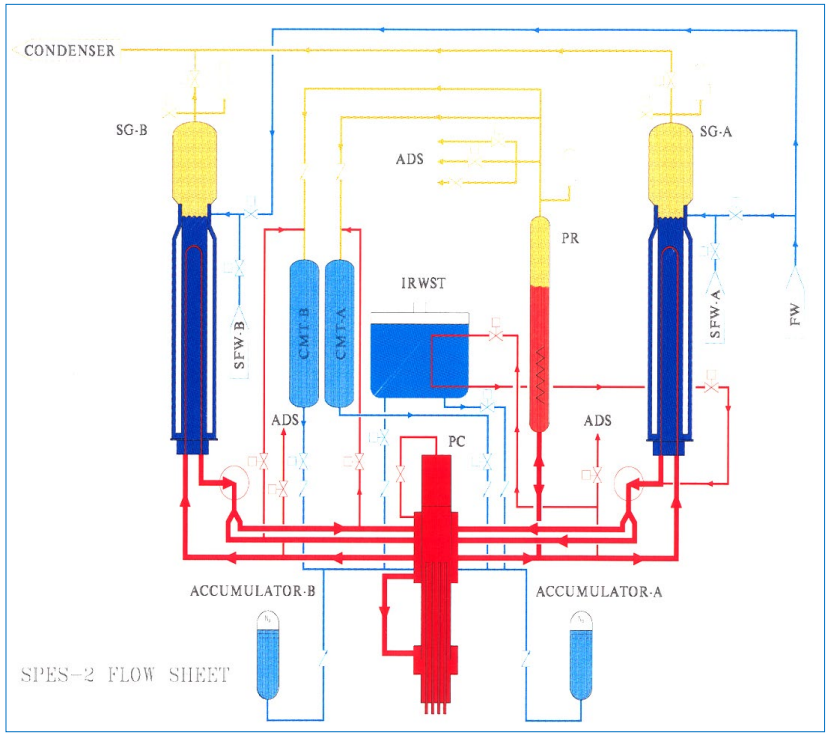
SIET MAIN NUCLEAR RESEARCH PROGRAMS IN THE PAST

In the ‘90s of last century, SIET participated in important international nuclear research programs gaining large experience on test conduction and data analysis.
Two experimental campaigns, among others, are worth to be mentioned for importance:

1) SPES-2 testing which data allowed Westinghouse to obtain the certification of the AP-600 reactor and later that of that of AP-1000;

2) the full-scale experimental qualification of the PCC and IC heat exchangers of the General Electric SBWR.

Experimental certification of AP-600



SPES-2 facility

2-loops PWR

Power: 5 MW

Full pressure/temperature conditions

Full scale elevation

Volume Scaling Factor: 1/395

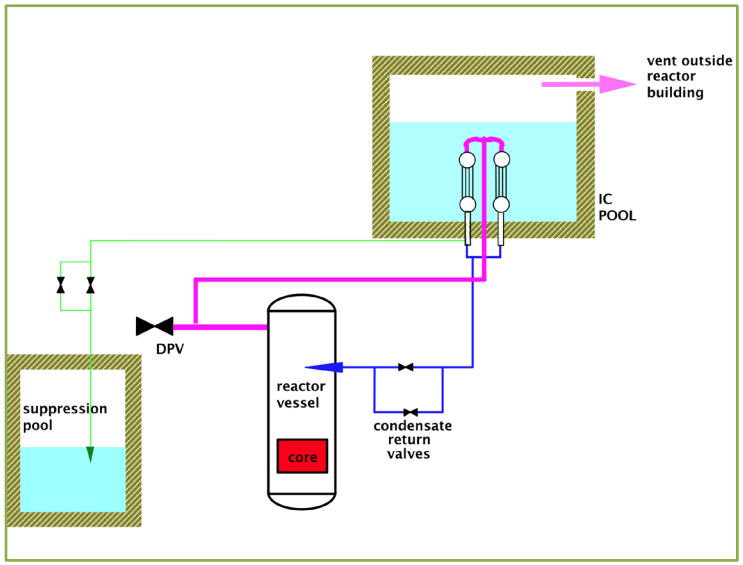
In the frame of an agreement among Westinghouse, Ansaldo, ENEA and ENEL, SIET carried out an experimental program (1992÷1994), that contributed to the AP-600 Reactor Licensing by NRC (1997) and later of AP-1000 (2005).

The program included #15 tests designed to study the AP-600 passive safety system response in the different accident scenarios:

- Range of SBLOCAs at different reactor locations (total of 11 tests)
- Single Steam Generator tube ruptures with passive/active safety systems (3 tests)
- Main Steam Line break transients (1 test)

In 1999 the SPES2 facility was restarted to test a 10-inch equivalent LBLOCA

FULL-SCALE EXPERIMENTAL QUALIFICATION OF THE PCC AND IC HEAT EXCHANGERS FOR THE GE-SBWR



GEST/PANTHERS facility

Heat Rate: 20 MW (IC), 10 MW (PCC)

Full pressure/temperature conditions

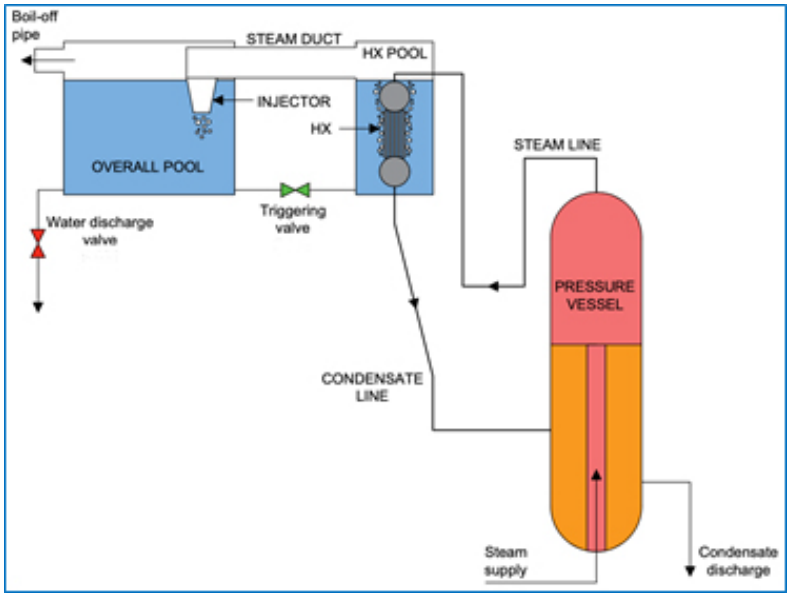
Full scale volumes

In the frame of an agreement among General Electric, Ansaldo, ENEA and ENEL, SIET carried out an experimental program (1994÷1996) to qualified both the GE in-pool Heat Removal Systems

Typical tests performed:

- Steady-state TH performance tests (steam-air mixture for the PCC)
- Non-condensable gas build-up tests, PCC & IC
- Pool water level effect tests, PCC & IC
- Start-up demonstration tests, IC
- Structural cycle tests (normal operation & ATWS), IC

FULL-SCALE EXPERIMENTAL TESTS ON THE PERSEO FACILITY



GEST/PERSEO facility

(in-Pool Energy Removal System for Emergency Operation)

Heat Rate: 20 MW (IC)

Full pressure/temperature conditions

Full scale volumes

In the frame of a program funded by ENEA, SIET carried out a series of tests (2003) to verify the operation of an enhanced in-pool Heat Removal Systems for decay heat removal

Typical tests performed:

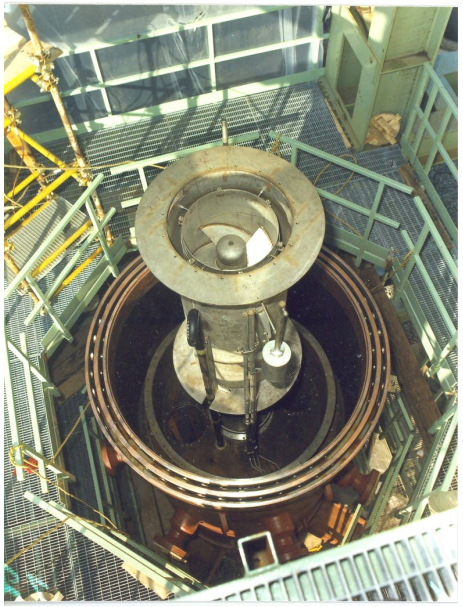
- Integral tests at different thermal-hydraulic conditions in the vessel
- Stability tests at different conditions in the HX pool

In the last few years (2018-2020), PERSEO data were used for an international benchmark exercise of simulations with codes in the frame of an activity of passive systems design and safety assessment by the OECD/NEA/CSNI/WGAMA group.

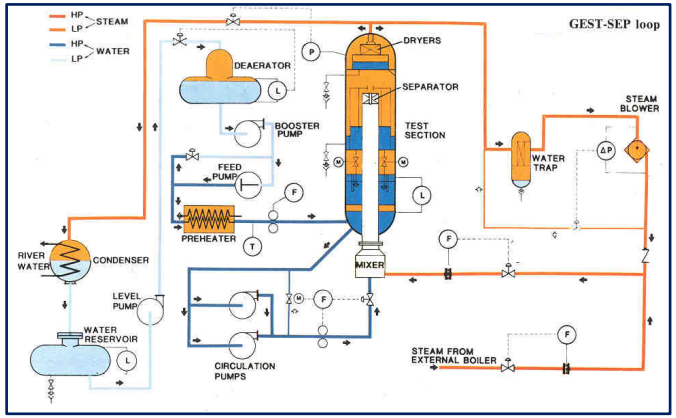
THERMAL HYDRAULIC CHARACTERIZATION OF LWR COMPONENTS

In the early 2000's, many experimental campaigns were carried out:

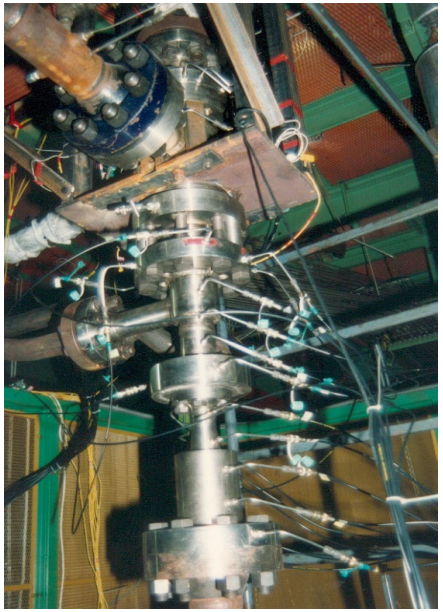
- for the characterization of steam separators/dryers for both PWR and BWR (customers: Westinghouse, Mitsubishi, Toshiba, Doosan);
- for the characterization of steam injectors as non-rotational pumping systems for LWR passive injection systems (customers: Toshiba, EU Projects Synthesis and DEEPSSI).



Installation of a 20-inch Steam-Water separator in the GEST-SEP facility vessel



GEST-SEP facility schematic flow-diagram



Steam injector

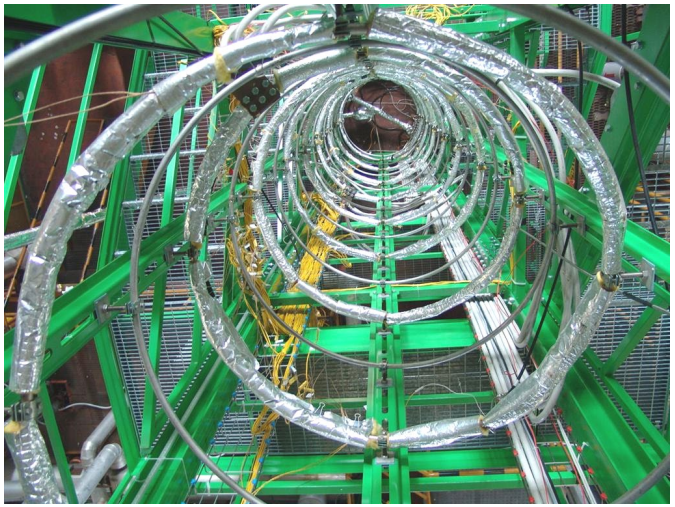
R&D AND TESTING FOR SMALL MODULAR REACTORS (1)

Testing on helical coil Steam Generator tubes

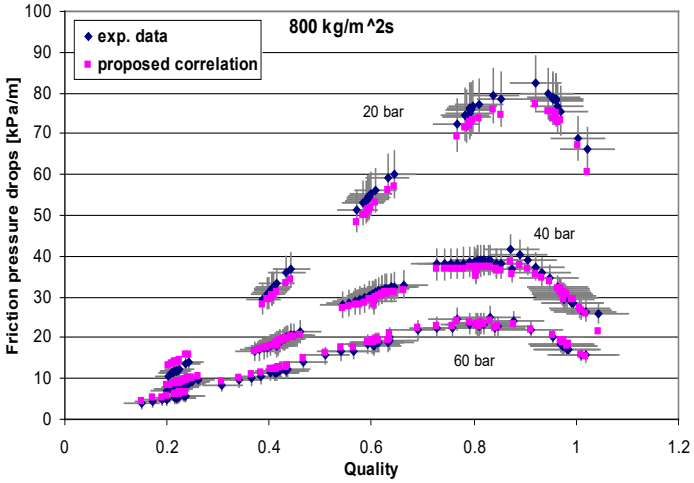
In the frame of the IRIS reactor development (2005-2011), thermo-fluid-dynamic characterization tests were performed on two prototypical helical coils (agreement SIET and Politecnico di Milano).

The experimental program included:

- Heat transfer and pressure drops measurements in steady-state conditions;
- Density Wave Oscillation tests on two tubes in parallel.



Full scale helical coil SG tubes on the IETI facility



Two-Phase flow pressure drops in helical coils

R&D AND TESTING FOR SMALL MODULAR REACTORS (2)

Design, simulation and construction of the SPES3 Test facility for IRIS/SMR simulation

The design of the SPES3 integral test facility was performed in the frame of the IRIS consortium, led by Westinghouse (including industries, universities and research institutes) to simulate all loops and containment compartments of the IRIS reactor (2006-2012).

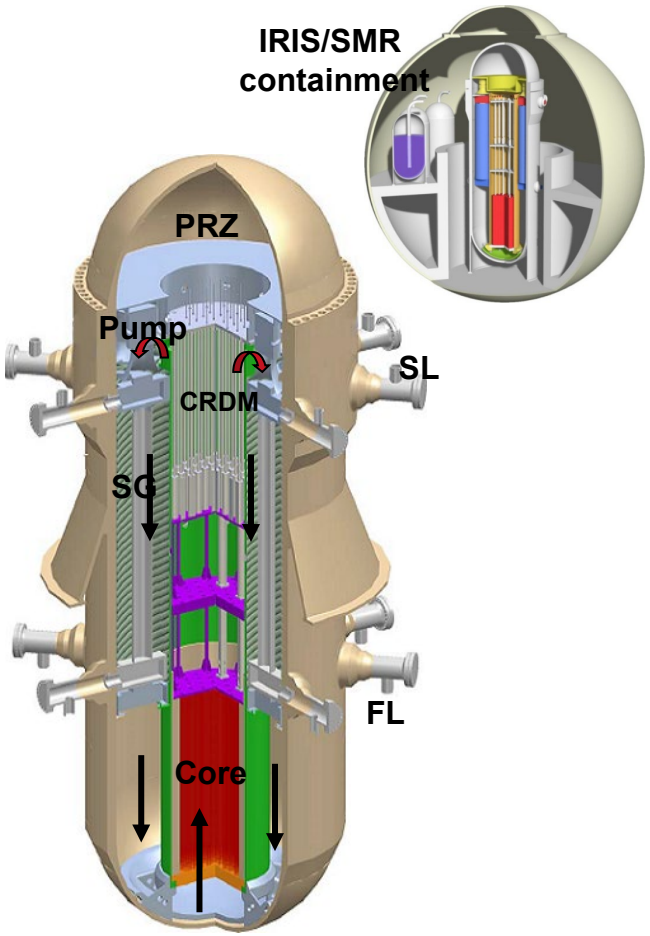
In 2010, Westinghouse left the consortium, but the Italian organizations decided to go ahead with the facility construction for investigating general safety features common to integral type SMRs currently under development in the world (PWR based concepts).

In 2012, following the Fukushima accident, ENEA decided to stop the program when the facility installation at SIET had reached ~60% progress.

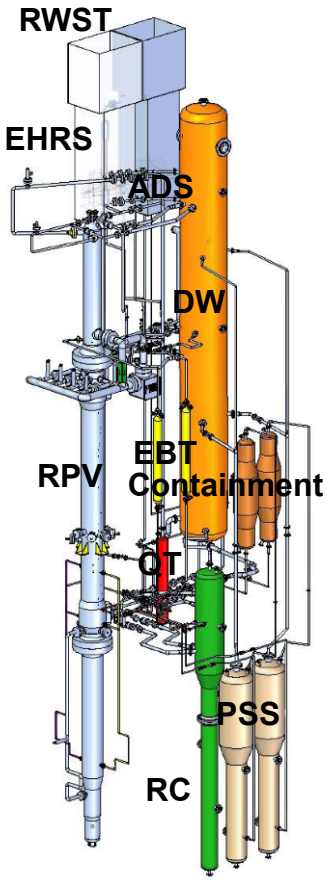
SPES3 facility
Volume scaling factor 1:100
Full elevation
Prototypical thermal-hydraulic conditions
PS and SS design conditions: P: 17.25 MPa; T: 353 °C (saturation)
Containment system design conditions: P: 1.5 MPa; T: 198 °C (saturation).

R&D AND TESTING FOR SMALL MODULAR REACTORS (3)

The SPES-3 Integral Test Facility



IRIS/SMR



SPES-3 layout

SPES-3 facility

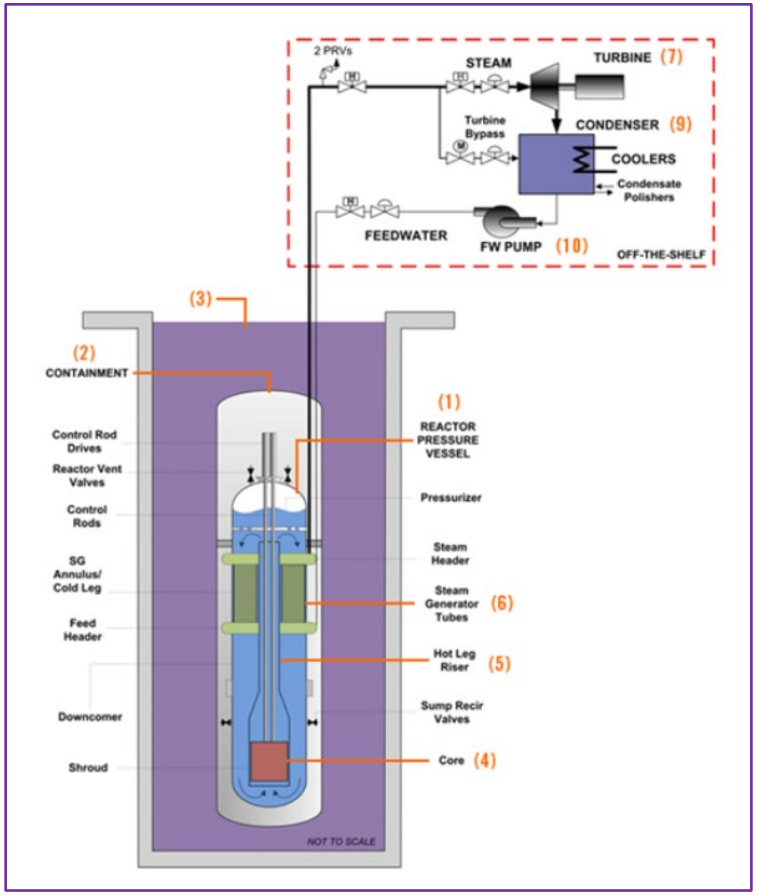
R&D AND TESTING FOR SMALL MODULAR REACTORS (4)

Testing on NuScale Power SMR Steam Generator

In 2012, SIET won an international tender for manufacturing and testing of a prototype of NuScale SMR Steam Generator in the frame of a R&D/Design Certification program co-funded by NuScale and DOE.

SIET designed and performed large scale heat transfer tests on a prototypical SG helical coil bundle on the IETI and GEST facilities (2012-2015). Max. power ~6.5 MW.
Additional high power tests (~8.5 MW) were performed (2021-2023) on an upgraded configuration of the GEST facility to characterize heat transfer and investigate DWOs in a wider range of thermalhydraulic conditions.

Activities for NuScale SMR certification followed-on (2017-2024) with the design and testing of a SG prototypical tube bundle for FIV (Flow Induced Vibration) characterization on a brand new facility.
Tests are ongoing.



NuScale SMR

R&D AND TESTING FOR SMALL MODULAR REACTORS (5)

[NON-PROPRIETARY PHOTOS]

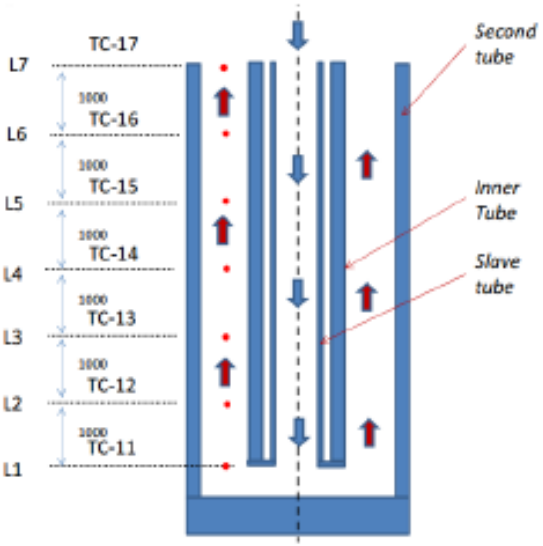
Phases of manufacturing, transportation, installation of the SG mock up

R&D AND TESTING FOR GEN-IV REACTORS (1)

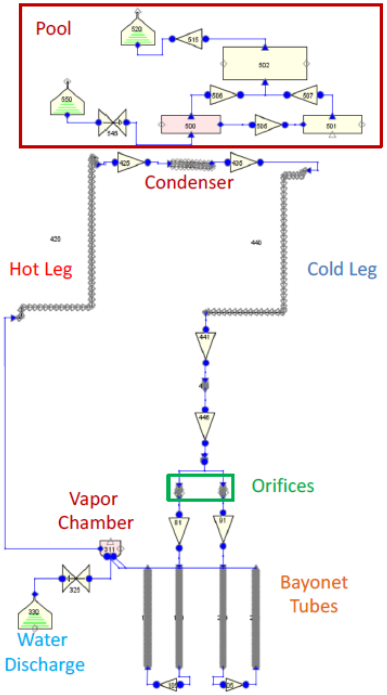
Testing of bayonet tubes for Liquid Metal Reactor Steam Generator (2015-2017)

In the frame of an Italian R&D program on Lead cooled reactors, tests were performed on the HERO facility:

- to characterize the heat transfer and thermal-hydraulic behaviour of a full scale bayonet tube;
- to investigate the effectiveness heat transfer in a Passive Heat Removal System including the bayonet tube in a natural circulation loop with an in-pool heat exchanger.



Bayonet tube scheme



Passive Heat Removal System

HERO testing loop

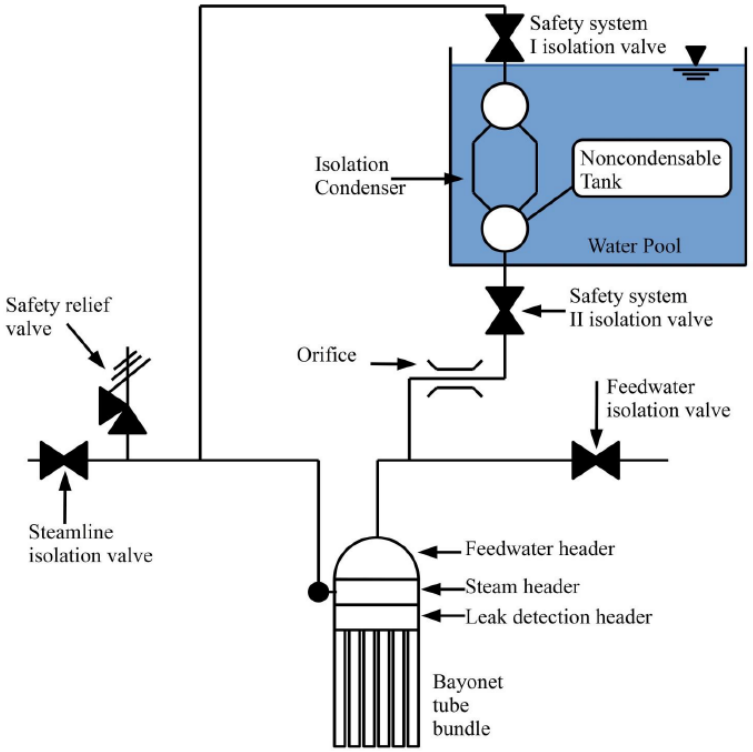
R&D AND TESTING FOR GEN-IV REACTORS (2)

Testing of an "anti-freezing" system for DHR in Liquid metal cooled reactors

The SIRIO facility was designed and built in the frame of an Italian R&D program involving industries (Ansaldo, SRS) and research institutes (ENEA, SIET) (2018-2021).

The main objective was to characterize the self-regulating Decay Heat Removal System (Ansaldo patent) to be installed on the LFR ALFRED (European Technology Demonstrator). In a compromise between decay heat removal from the primary side and avoiding Lead freezing, the system is based on the detrimental effect of non-condensable gases on heat transfer in natural circulation loops.

Prototypical thermal-hydraulic conditions
Power to volume scale 1:47
Full elevation



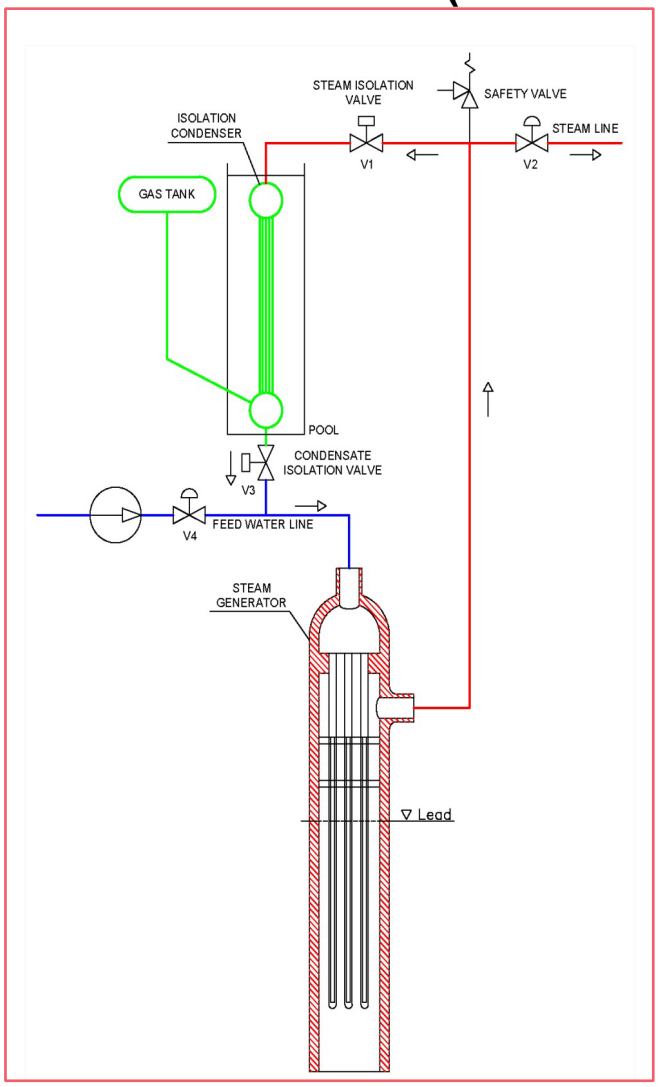
Scheme of the SIRIO facility (DHRS)

R&D AND TESTING WITHIN EUROPEAN PROJECTS H2020 (2019-2022)

PIACE Passive Isolation Condenser

PIACE aimed to support the technology transfer from research to industry in the area of safety of nuclear installations.

The innovative technology of Decay Heat Removal Systems, validated on the SIRIO facility, was scaled-up to demonstrate the operation of the system prototype at conditions relevant for LFRs/ADSs and LWRs.



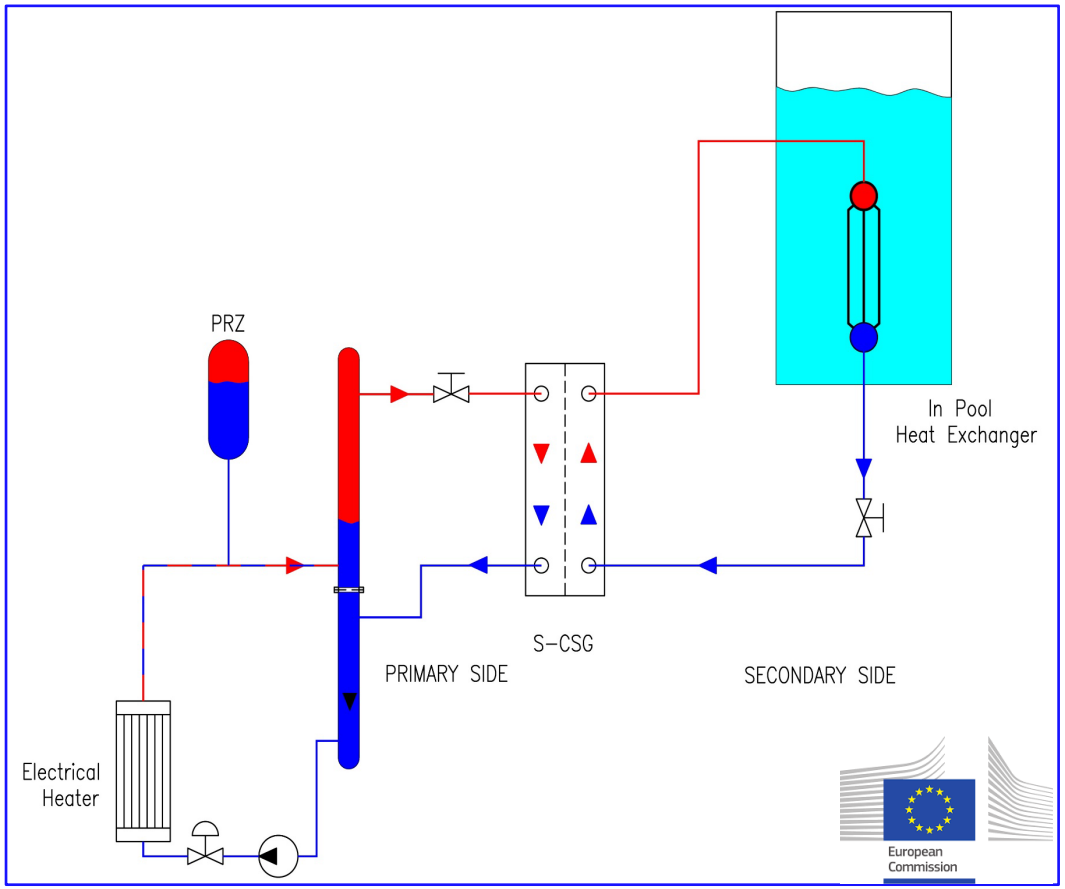
PIACE facility

R&D AND TESTING WITHIN EUROPEAN PROJECTS H2020 (2018-2023)

ELSMOR 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 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).



ELSMOR loops

CONCLUSIONS

This presentation has provided an overview of the SIET company, its expertise and capabilities in designing, building and testing thermal-hydraulic loops aimed at the characterization of systems and components for the safety of nuclear power plants in general and Small Modular Reactors in particular.

Thank you for attention!

Questions

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