Profile LFR-48

SIRIO

ITALY

GENERAL INFORMATION

NAME OF THE FACILITY	Sistema di rimozione della potenza di decadimento per reattori nucleari innovativi "Decay heat removal system for innovative nuclear reactor"
ACRONYM	SIRIO
COOLANT(S) OF THE FACILITY	Pressurized Water
LOCATION (address):	SIET - SOCIETA' INFORMAZIONI ESPERIENZE TERMOIDRAULICHE, VIA NINO BIXIO 27/c, 29121, Piacenza (Italy).
OPERATOR	ENEA - Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Italy
CONTACT PERSON (name, address, institute, function, telephone, email):	Dr. Gustavo Cattadori, SIET, NINO BIXIO 27/c, 29121, Piacenza (Italy), Tel. 39 0523 329011, Chief Operating Officer, cattadori@siet.it Dr. Mariano Tarantino, ENEA UTIS-TCI C.R. Brasimone 40032 Camugnano (Bo) Tel. +39 0534 801 262, Head of Thermal Fluid Dynamic and Facility Operation Laboratory, mariano.tarantino@enea.it
STATUS OF THE FACILITY	Under Design
Start of operation (date):	2016

MAIN RESEARCH FIELD(S)

	Zero power facility for V&V and licensing purposes
X	Design Basis Accidents (DBA) and Design Extended Conditions (DEC)
X	Thermal-hydraulics
	Coolant chemistry
	Materials
X	Systems and components
X	Instrumentation & ISI&R

TECHNICAL DESCRIPTION

Description of the facility

The Decay Heat Removal System (DHRS) is a fundamental passive safety system allowing the decay heat removal from the reactor core during accident conditions by means of heat transfer to an atmospheric water pool in natural circulation mode. One of the challenges of the system design consists of avoiding the lead freezing in the steam generator due to an excess of cooling. Accordingly to that, a DHRS which allow controlling the heat transfer rate by injecting uncondensable gas in the system has been proposed and conceptualized.
The DHRS [1], proposed by Ansaldo Nucleare, is a passive heat removal system operating on the basis of physical phenomena such as steam condensation and natural circulation. It has been designed to avoid the lead freezing in the LFR.
A simplified scheme of DHRS is reported in Figure 1. The system mainly consists of:

- a steam generator (SG);
- an in-pool condenser (Isolation Condenser);
- a non-condensable gas tank;
- a steam and a feed water line each equipped with isolation valves.

The condenser consists of two headers and sixteen tubes installed in an atmospheric pool full of water; the upper (steam) header is connected to the SG outlet through the steam line while the lower (condensate) header is connected to the steam generator inlet through the feed water line. The noncondensable gas tank is connected to the lower header of the IC.
In normal operation condition of LFR the IC system (condenser and gas tank) is filled with non-condensable gas at 110 bar and it is isolated upstream and downstream, respectively, from the SG steam line and feedwater line through the isolation valves, V1 and V3 respectively, kept closed.
As a consequence of a reactor accidental event (e.g. station blackout) both the plant feed water and the steam line valves, V2 and V4 respectively, are automatically closed. The SG pressure increases up to the pressure set point (190 bar,a) for the opening of the steam isolation valve (V1). The steam enters the IC, "pushes" the non-condensable in the gas tank and condenses along the IC tubes. When the pressure inside the IC is equal to the pressure in the SG the condensate isolation valve (V3) opens and a natural circulation occurs providing heat transfer from the SG to the water of the IC pool. In the long period, when the power removal capacity of the IC exceeds the LFR decay power, the pressure of the system (SG+IC) decreases; at this time the non-condensable gases flow back from the tank into the IC tubes so decreasing its condensing capacity. As consequence the pressure remains almost constant and the system is able to control the temperature of the lead at the SG output. Concerning the SG, which has particular features coupled to the DHRS, it consist of the SG proposed for the ALFRED reactor [2]. Figure 2 shows the conceptual design and the geometrical characteristics of one of these tubes. Each bayonet tube is composed by four coaxial tubes: slave, inner, outer and outermost tube, respectively. The molten lead wets the outermost tube (diameter 31.73 mm) for about 6000 mm from the bottom. The space between the outermost tube and the outer tube (diameter 25.4 mm) is filled with helium and high conductivity particles. The feed water flows through the slave tube (diameter 9.52 mm), moves downwards through the inner tube (diameter 19.05 mm) and goes back upwards into the gap between the inner and outer tubes where boiloff occurs due to heat transfer from lead side.
The SIRIO facility, conceptualized and scaled down by ANSALDO NUCLEARE, SIET, ENEA and SRS, includes the following components/systems:

- steam generator
- condenser
- condenser pool
- gas tank and relevant feeding system
- gas tank/IC connection lines
- feed water circuit
- automatically operated isolation valves
- safety valves
- IC/SG connecting piping
- instrumentation and data acquisition system
- auxiliary systems

A schematic P&ID is reported in figure 3.

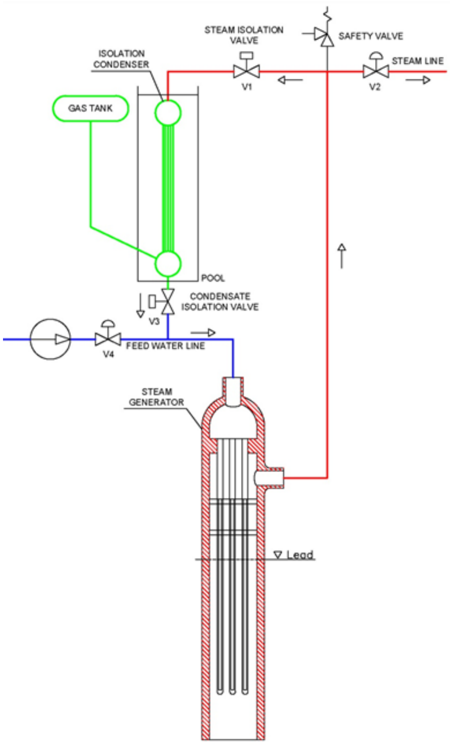

FIG. 1. Simplified scheme of Decay Heat Removal System

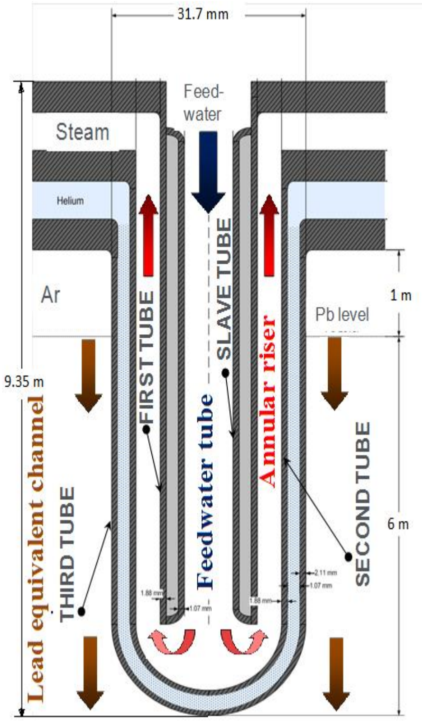

FIG. 2. Double Wall Bayonet Tube Steam Generator scheme

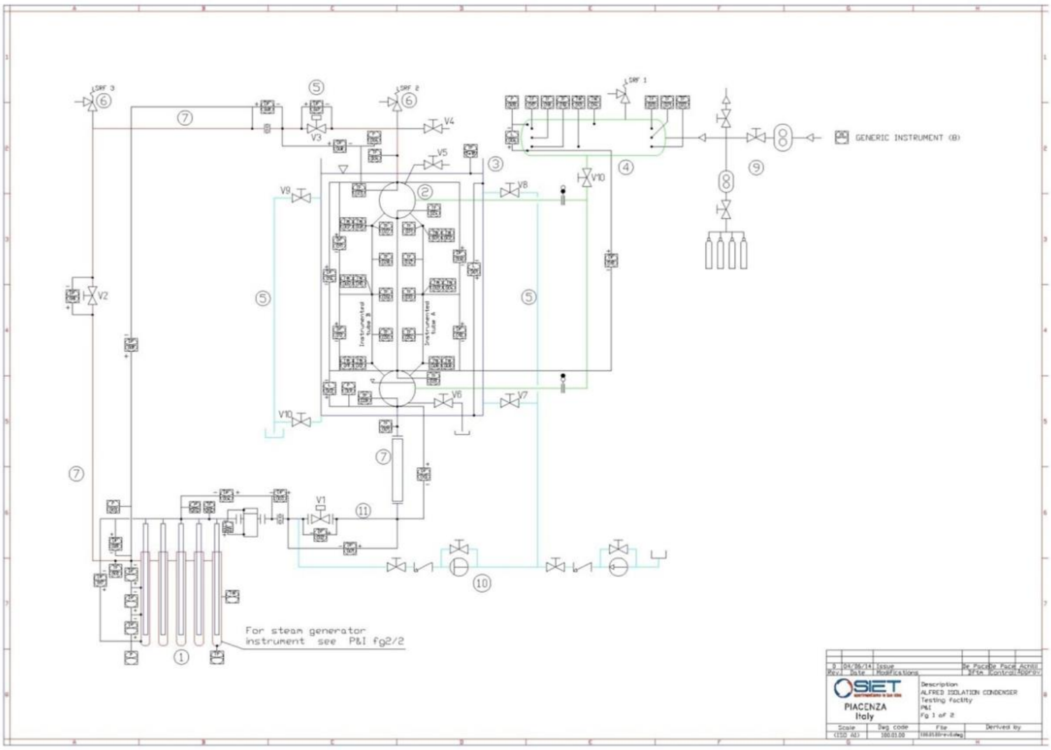

FIG. 3. P&ID of the SIRIO facility

Acceptance of radioactive material

No

Parameters table

Coolant inventory	Pressurized water. Inventory not avalaible.
Power	70 kW for each Bayonet Tubes. Minimum 7 bayonet tubes are considered.
Test sections	
DWBT	<u>*Characteristic dimensions*</u> Number of coaxial tubes per bayonet: 4 Length: 9.35 m P/D (triangular array): 1.42 Slave tube Outside diameter: 9.52 mm Thickness: 1.07 mm Length: 5.35 m Inner tube Outside diameter: 19.05 mm Thickness: 1.07 mm Length: 9.35 m Outer tube Outside diameter: 25.4 mm Thickness: 1.83 mm Length: 8.05 m Outermost tube Outside diameter: 31.75 mm Thickness: 2.11 mm

	Length: 7.0 m Lenght of exchange: 6.0 m Steam Generator Plena Argon plenum height: 1.0 m Helium plenum height: 0.8 m Steam plenum height: 0.8 m
	Static/dynamic experiment Dynamic
	Temperature range in the test section (Delta T) 335°C-450°C on the steam side
	Operating pressure and design pressure Operating Pressure → 180 bar (gauge)
	Flow range (mass, velocity, etc.) 0.0473 kg/s for each bayonet tube.
Coolant chemistry measurement and control (active or not, measured parameters)	NONE
Instrumentation	Thermocouples, pressure transducer, mass flow meters.

COMPLETED EXPERIMENTAL CAMPAIGNS: MAIN RESULTS AND ACHIEVEMENTS

None. The engineering design of the facility is ongoing. To be completed by 2015.

PLANNED EXPERIMENTS (including time schedule)

The test matrix test will be detailed during the commissioning phase (2016).
It is foreseen an extensive experimental campaign aiming to investigate the behavior of the isolation condenser employed on ALFRED (DEMO LFR).

TRAINING ACTIVITIES

Training activities can be agreed with ENEA for the operation of the experimental campaign under the supervision of ENEA/SIET qualified staff.

REFERENCES (*specification of availability and language*)

1. DE PACE O., ACHILLI A., BOTTI S., CATTADORI G., “Feasibility study on the experimentation of a Decay Heat Removal System (DHRS) for Lead Fast Reactors (LFR)”, SIET internal document, identification code 02321RT14, september 2014.
2. DEL NEVO A., TARANTINO M., ROZZIA D., FORGIONE N., SCALETTI L. “ALFRED-SGBT. Preliminary Characterization by the HERO Test Section”, Report RdS/PAR2013/040, September 2014