Profile LFR-41

CIRCE SGTR

ITALY

GENERAL INFORMATION

NAME OF THE FACILITY	CIRculation Eutectic
ACRONYM	CIRCE
COOLANT(S) OF THE FACILITY	Molten lead-bismuth eutectic
LOCATION (address):	Italian National Agency for New Technologies, Energy and Sustainable Economic Development, C.R. ENEA Brasimone, Italy
OPERATOR	ENEA
CONTACT PERSON (name, address, institute, function, telephone, email):	Ing. 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	Designed, it is partially under construction and partially in procurement phase
Start of operation (date):	2015

MAIN RESEARCH FIELD(S)

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

TECHNICAL DESCRIPTION

Description of the facility

CIRCE facility aims to LBE natural circulation investigation, LBE coolant enhanced circulation by gas injection system, thermal-hydraulic characterization of the fuel assembly, thermal-hydraulic behaviour of the target unit, performance of the secondary loop, instrumentation immersed in LBE and material corrosion in the pool with flowing LBE of controlled dissolved oxygen activity.

It is composed by three main vessels: the largest LBE pool worldwide S100 in which the experiments are carried out, the storage tank S200 that hosts the whole amount of LBE when

the facility is not operational and the small intermediate vessel S300 that is adopted during the filling and draining phases of S100.
The main tank S100 is made of AISI 316L. The bottom and cylindrical shell (without the cover) have an overall height of 8500 mm, the external diameter and the thickness are 1200 and 15 mm, respectively. The maximum LBE inventory is almost 90000 kg, the foreseen available amount of LBE for the experimental campaign execution is about 70000 kg.
CIRCE S100 is designed to host different test sections hung to the cover vessel. In the frame of SGTR experiment, a new cover vessel is built to support the dedicated test section aiming to characterize the Steam Generator Tube Rupture (SGTR) event in a relevant configuration for MYRRHA reactor. The experiment also foresees the assessment of the tube rupture propagation, damping effect of the surrounding structures, safety-guard devices, steam dragged into the main flow path and the investigation of the solid impurity formation and filter qualification, as a consequence of the SGTR phenomenon.
The SGTR test section is designed to perform four SGTR experiments in a relevant configuration for MYRRHA reactor.
3D view of test section is shown in Figure 1 and one 2D vertical and horizontal sections are depicted in Figures 2 (it is out of scale because it is enlarged five times to make a more detailed description of the SGTR-TS possible) and 3, respectively.
In the Figures the centrifugal pump is highlighted by the letter “A”. This component is able to provide a mass flow rate of ~50 kg/s at a LBE pressure head of ~4 m. The pump discharge “A1” is connected by a flexible tube (not depicted in the figures), aiming to solve geometric inconsistencies, with “B1” tube that supply LBE driving fluid to the jet pump “C”, composed by the convergent “C1”, mixing “C2” and divergent “C3” regions (Figure 2). The cylindrical component “B” constitutes the suction chamber into which the LBE enters from the CIRCE lower plenum through the bottom opening “B2”, which is sized to simulate the pressure drop occurring in the reactor core. Opening “B2” is therefore called core simulator.
The LBE flows upwards through the jet pump to provide the needed higher mass flow rate. At the jet pump exit (upper position) a Venturi flow meter “D” is placed. It has the task to provide mass flow rate feedback information, allowing the centrifugal pump velocity regulation in order to reach the desired LBE flow rate. Downstream, a filtering section “E” is set and the total LBE mass flow rate passes through it. This component aims to quantify the pollution produced by the SGTR event. The reduction of pressure drops along the component “E” led to choose a filtering section composed by filtering planes that do not close the whole horizontal section (Figure 2). Above, a perforated tube “F” having the same inner and outer diameter of the filter “E” is welded. The “F” component accomplishes the task of horizontally distributing the injected LBE, as it is carried out by the barrel component of MYRRHA design. The LBE reaches the separator component “G”, composed by a cylindrical shell closed at the bottom by a round plate (two small holes assure the correct execution of the draining phase). The separator defines a separate pool from the main CIRCE LBE melt. The component “G” performs the task of the MYRRHA diaphragm, in which the main coolant enters flowing upwards through the core and barrel openings, isolating the upper hot plenum from the lower cold plenum. Analogous behaviour is carried out by the separator. However, a crucial difference that needs to be remarked consists in the thermal equilibrium of the LBE melt in any position inside the CIRCE vessel.
Indeed, the melt temperature is set equal to the LBE inlet temperature in the PHX, which is 350°C. Such a decision aims to execute SGTR tests in the most severe conditions, which would cause, thus, higher and faster water vaporization.
The separator component hosts four SGTR-TSs “H”. Each of these test sections is composed by an external 6 inch tube ~5 m long, hosting a tube bundle of 31 tubes. Water flows upwards

into the central tube and the surrounding ones are dummy tubes. The SGTR-TS aims to simulate a portion of the PHX of MYRRHA system.
The SGTR-TS connects the LBE contained into the separator to the melt into the CIRCE pool, analogously to the MYRRHA PHX connecting the hot and cold plenum. The outgoing LBE from the SGTR-TSs is available to be sucked by the centrifugal pump and jet pump suction chamber "B2", so that the system works continuously.
The LBE flows from the separator into the SGTR-TS passing through vertical openings "H1". The LBE flows downwards into 6 inch tubes "H", shell side of the tube bundle, and goes out from a free radial opening "H3" performing the task of the PHX LBE outlet regions.
The overall LBE mass flow rate, outgoing from the perforated tube, has to feed one SGTR-TS at a time, where the test is ongoing. Therefore, a closure system constituted by sliding valves "J" is adopted to allow to the whole LBE stream to flow through one of the four SGTR-TSs.
The experimental campaign foresees to perform four experiments, in the frame of which the rupture of the four water tubes "H5", one for each SGTR-TS, is caused at two different heights (bottom and middle). The rupture of the water tubes is obtained by hydraulic devices that catch and pull up "K" the tubes, from the outside of the cover vessel. The positions in which the ruptures occur are precisely defined by the reduced tube thickness obtained by a circumferential notch performed by machine tools.
Figure 3 shows the horizontal sections A-A and B-B defined in Figure 2. In the section on the left, the upper part of the facility is viewed from the bottom, in which the four SGTR-TSs "H", top plate "N" and the centrifugal pump "A" are shown. The section B-B depicts the four SGTR-TSs "H" and respective spacer grids, the filtering section "E", the separator "G" and the centrifugal pump "A".
In Figure 3 two red lightings mark the position where the ruptures are scheduled to be performed.
The ratio between the cover gas and LBE volume of SGTR-TS implemented into CIRCE vessel is set coherently to the value of the same design parameter of MYRRHA reactor.

Acceptance of radioactive material

No

3D drawing

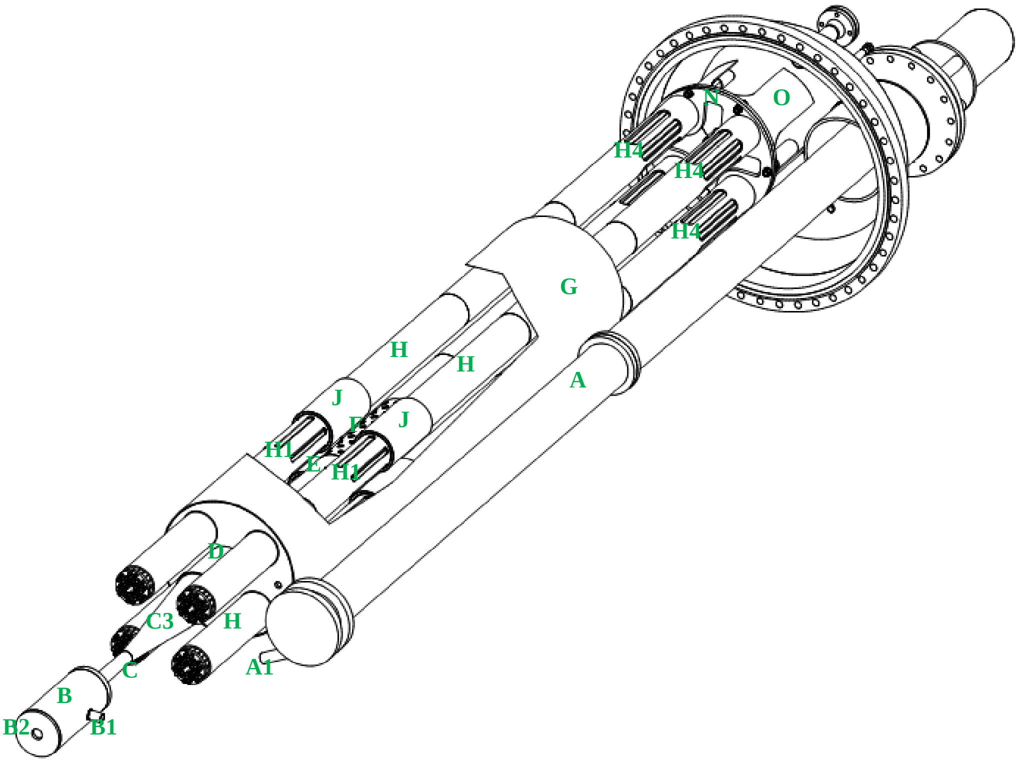

FIG. 1. SGTR test section, 3D bottom view

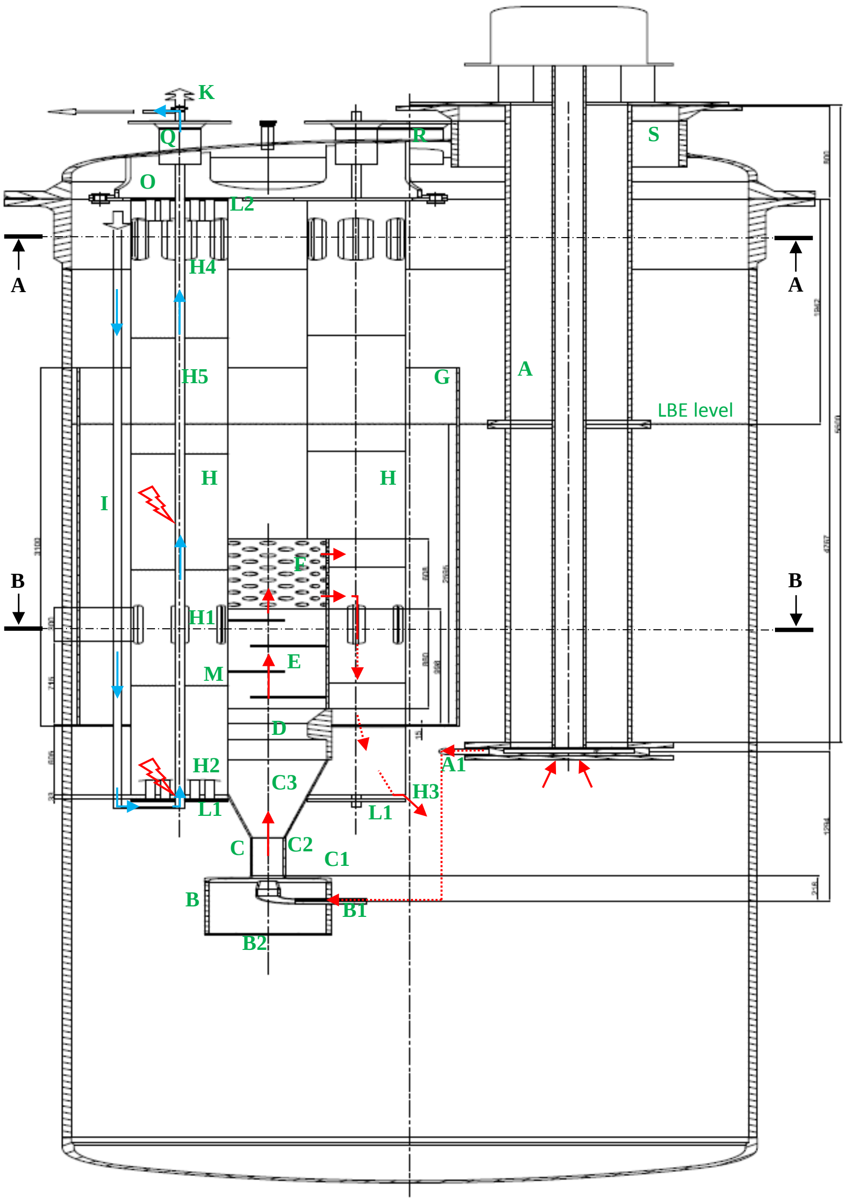

FIG. 2. CIRCE and SGTR test section, 2D vertical section
(out of scale: height conserved, width enlarged 5 times)

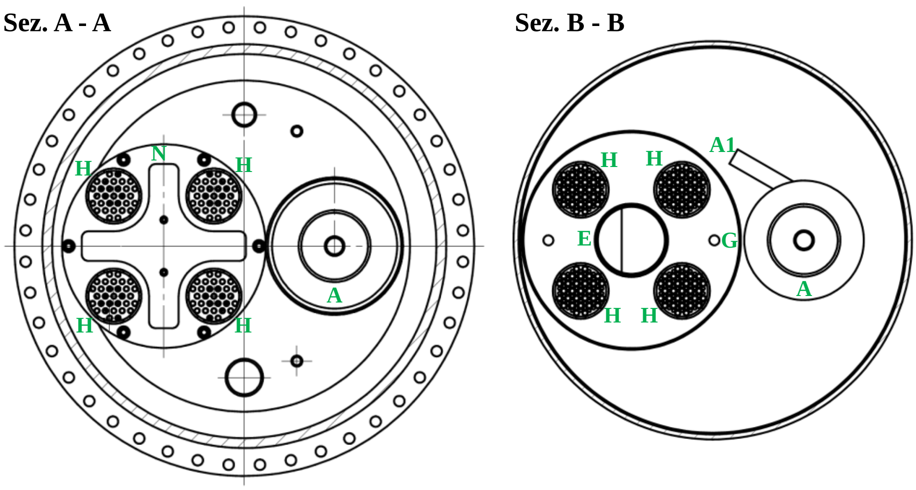

FIG. 3. CIRCE vessel and SGTR-TS horizontal sections A-A and B-B

Parameters table

Coolant inventory	Max LBE inventory 90000kg
Power	30 kW
Test sections	
TS #1	*Characteristic dimensions* Outside diameter 1200 mm Overall height 8500 mm
	Static/dynamic experiment Dynamic
	Temperature range in the test section (Delta T) 150°C, water injected at 200°C into LBE pool at 350°C
	Operating pressure and design pressure Operating pressure 50 kPa (gauge) Cover design pressure 800 kPa (gauge) Vessel design pressure 1600 kPa (gauge)
	Flow range (mass, velocity, etc.) LBE mass flow rate 50 kg/s and water mass flow rate 0.05 kg/s
Coolant chemistry measurement and control (active or not, measured parameters)	The configuration of CIRCE facility, aiming to investigate the water-LBE interaction following an SGTR event, is not involved in the technology development of coolant chemistry. One filtering device is installed at the jet pump exit section and the adoption of an extractive oxygen gas analyser is foreseen for on-line monitoring of the oxygen content in the cover gas.
Instrumentation	Thermocouples, fast pressure transducers, flow meters (Venturi nozzle), bubble tubes, strain gauges and resistivity probes.

COMPLETED EXPERIMENTAL CAMPAIGNS: MAIN RESULTS AND ACHIEVEMENTS

None

PLANNED EXPERIMENTS (including time schedule)

The experimental campaign foresees the execution of four SGTR tests. Each one of which requires the reaching of the planned boundary conditions. The activation of the pulling system causes the water tube rupture and consequently the water injection into the LBE region starts. The injection lapse of time is of the order of magnitude of seconds, aiming to limit the pressure increase in S100. The tests are foreseen to be performed in a period of time that could be evaluated to be almost one month in 2015.
The four tests are foreseen to be executed performing the water tube rupture near the lower tube plate (two tests) and at the average position between two spacer grids (two tests).

TRAINING ACTIVITIES

Training activities could be agreed with ENEA Brasimone RC for the operation of the experimental campaign under the supervision of ENEA qualified staff.

REFERENCES (*specification of availability and language*)

1. PESETTI; "SGTR Large Scale Test Section Design and Preliminary Pre-Test Analysis"; ENEA report, Ref. CI-D-R-082, 31 March 2014.