Profile LFR-46

NACIE-UP

ITALY

GENERAL INFORMATION

NAME OF THE FACILITY	NACIE-UP
ACRONYM	NAtural CIrculation Experiment UPgrade
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. Ivan Di Piazza, ENEA UTIS-TCI C.R. Brasimone 40032 Camugnano (Bo) Tel. +39 0534 801 248, Researcher of Thermal Fluid Dynamic and Facility Operation Laboratory ivan.dipiazza@enea.it
STATUS OF THE FACILITY	In operation
Start of operation (date):	2014

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

NACIE-UP is a rectangular loop which allows to perform experimental campaigns in the field of the thermal-hydraulics, fluid-dynamics, chemistry control, corrosion protection and heat transfer and to obtain correlations essential for the design of nuclear plant cooled by heavy liquid metals.

It basically consists of two vertical pipes (O.D. 2.5”), working as riser and downcomer, connected by two horizontal pipes (O.D. 2.5”). The whole height of the facility is around 8 meters, while the horizontal length is close to 2 meters. In the bottom of the riser a prototypical wire-spaced fuel pin bundle simulator (FPS), with a maximum power of 235 kW, is installed. A proper heat exchanger is placed in the upper part of the downcomer. A

secondary side, working with pressurized water at 16 bars, an air cooler and a pump allows to perform long transients till thermal equilibrium.
NACIE-UP is made in stainless steel (AISI 304) and can use both lead and the eutectic alloy LBE as working fluid (about 1600 *kg*, 160 *l* in the updated configuration). It has been designed to work up to 550°C and 10 bar. The P&ID of the facility is shown in Figure 1; a picture of the primary side is shown in Figure 2. The difference in height between the center of the heating section and the center of the heat exchanger, denoted by *H*, is around 5 m and it is very important for the intensity of the natural circulation. In the riser, an argon gas injection device ensures a driving force to sustain forced convection in the loop. Finally the facility consists of an ancillary gas system which provides the cover gas in the expansion tank, and a fill&drain system to allow the right operation of the loop.
The facility includes:

- ✓ The Primary side, filled with LBE, with 2 ½" pipes, where the main new components and instruments will be placed:
- ✓ A new Fuel Pin Simulator (19-pins) 250 *kW* maximum power;
- ✓ A new Shell and tube HX with two sections, operating at low power (5-50 *kW*) and high power (50-250 *kW*);
- ✓ A new low mass flow rate induction flow meter (0-3 *kg/s*) FM101;
- ✓ A new high mass flow rate induction flow meter (3-15 *kg/s*) FM102;
- ✓ 5 bubble tubes to measure the pressure drops across the main components and the pipes;
- ✓ Several bulk thermocouples to monitor the temperature along the flow path in the loop;
- ✓ The Secondary side, filled with water at 16 bar, connected to the HX, shell side. It includes a pump, an air-cooler, by-pass and isolation valves, and a pressurizer (S201) with cover gas;
- ✓ An ancillary gas system, to ensure a proper cover gas in the expansion tank, and to provide gas-lift enhanced circulation;
- ✓ A LBE draining section, with ½″ pipes, isolation valves and a storage tank (S300);

The ancillary gas system is practically identical to the previous configuration of the NACIE facility and does not have significant upgrade. It has the function to ensure the cover gas in S101 and to manage the gas-lift system in the riser (T103) for enhanced circulation regime.
The primary system is ordinary filled with liquid LBE and it is made by several components, pipes and coupling flanges.

The FPS consists of 19 electrical pins with an active length L_{active} = 600 *mm*. The whole length (L_{total} = 2000 *mm)* includes the *non-active* length and the electrical connectors region. The pin have a diameter D = 6.55 *mm*, and the maximum wall heat flux will be close to 1 MW/m^2. The pins will be placed on an hexagonal lattice by a suitable wrapper, while spacer grids will be avoided thanks to the wire spacer. This fuel pin bundle configuration is relevant for the MYRRHA's core thermal-hydraulic design. The test is instrumented with 67 thermocouples monitoring wall temperatures, bulk temperatures in different ranks of subchannels at different heights. The heat transfer coefficient can be also characterized in the specific wire-wrapped geometry.

Acceptance of radioactive material
No

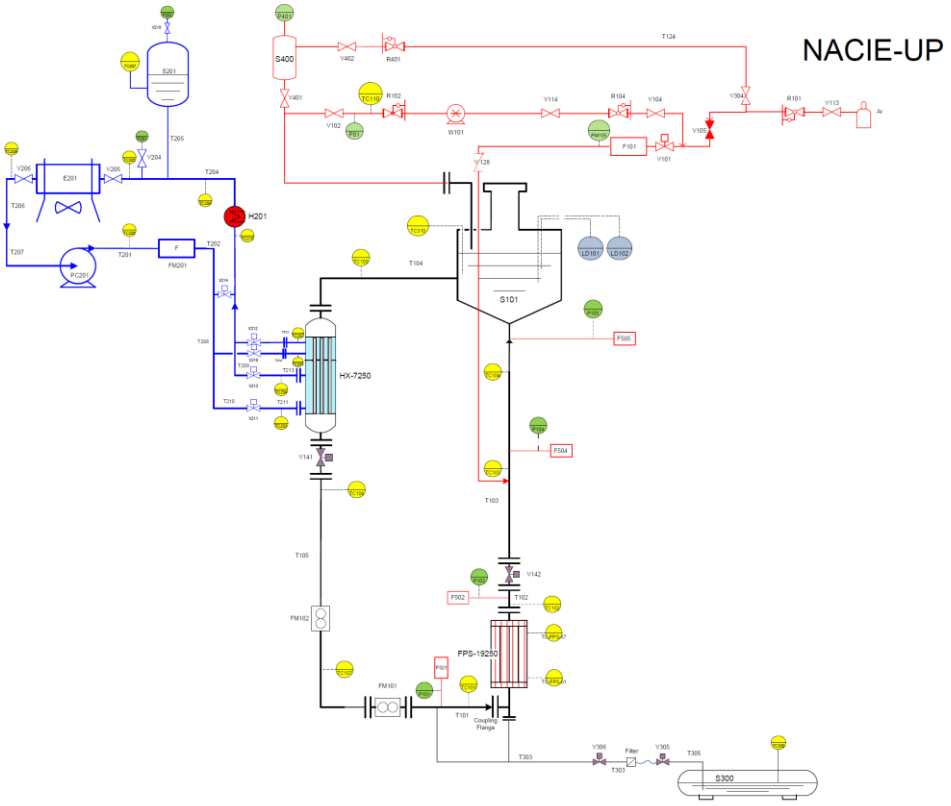

FIG. 1. P&ID of the HLM facility NACIE-UP.

FIG. 2. Primary Side of NACIE-UP loop.

Parameters table

Coolant inventory	Max LBE inventory 2200 kg
Power	235 kW
Test sections	
FPS	*Characteristic dimensions* Outside pipe diameter 60 mm Overall height 2200 mm Active length 600 mm Difference in height between FPS and HX 5 m
	Static/dynamic experiment Dynamic
	Temperature range in the test section (Delta T) 150°C trough the FPS
	Operating pressure and design pressure Operating Pressure 8 bar (gauge) Design pressure 10 bar (gauge)
	Flow range (mass, velocity, etc.) 0-7 kg/s maximum velocity in the fuel bundle of about 1 m/s
Coolant chemistry measurement and control (active or not, measured parameters)	
Instrumentation	Thermocouples, pressure transducer, Gas injection system, Induction

	flow meters.

COMPLETED EXPERIMENTAL CAMPAIGNS: MAIN RESULTS AND ACHIEVEMENTS

Some experimental campaigns with a simpler FPS and components were carried out on NACIE before the upgrade from 2007 to 2012. In particular, the experiment for the DEMETRA EC project must be recalled. The induction flow meter to be used in the NACIE-UP configuration was tested in 2013 by several circulation tests.

The new NACIE-UP will be filled and tested for the first time in November 2014.

PLANNED EXPERIMENTS (including time schedule)

The next experimental campaign to be completed within 2014 was designed in order to describe the thermal-hydraulic behavior of the MYRRHA FA during a Loss of Flow Accident (LOFA) with the coast-down of the main circulation pump.
That accident can be *protected* (PLOFA) if control rods can be inserted and the neutronic multiplication stops. In that case only the decay heat must be evacuated depending on the burn-up level, and at maximum 7% of the power should be considered in this case.
The accident is *unprotected* (ULOFA) if the control rods cannot be inserted and the full power must be evacuated.
Heat transfer during a LOFA is driven by the inertia of the fluid during the pump coast-down and the onset of natural circulation due to the difference in height between the heat source and the heat sink.
As a consequence of a LOFA, a stationary natural circulation flow rate will be established in a characteristic time which depends on the specific geometry of the system under consideration and on the geometry of the bundle.
To simulate the fuel pins, an electrically heated rod bundle has been specifically designed and provided by THERMOCOAX for this purpose.
The main difference between the MYRRHA bundle and the NACIE-UP bundle is the number of ranks and pins: 7 ranks and 127 pins for MYRRHA against 3 ranks and 19 pins for NACIE-UP. This difference in the number of pins is not relevant for the convective heat transfer in the sub-channels because side, corner and central sub-channels can be monitored in the 19 pin bundle and basic phenomenology is the same as in the MYRRHA bundle.
Detailed information on wall and bulk temperatures with subchannel velocities up to half of the nominal in MYRRHA bundle will be collected during the experimental campaign and the coolability of the bundle will be assessed.
Experiments of foot blockage are also possible by operating a valve close the FPS.
All these experimental data will validate System TH and CFD codes for HLM.
The study of the internal blockage in a grid-spaced ALFRED-like bundle test section is also foreseen by proper test sections.

TRAINING ACTIVITIES

Training activities can 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. PIAZZA I. DI, TARANTINO M., AGOSTINI P., GAGGINI P., POLAZZI G., FORGIONE N., MARTELLI D., NACIE-UP: An heavy liquid metal loop for mixed convection experiments with instrumented pin bundle, Proc. HLMC-2013, Obninsk, Russia.
2. FORGIONE N., MARTELLI D., DEL NEVO A., DI PIAZZA I., Coupled Simulation of the NACIE Facility using the RELAP5 Thermal System Code and the CFD Ansys FLUENT Code, Proc. HLMC-2013, Obninsk, Russia.
3. PIAZZA I. DI, MARTELLI D., Experimental circulation tests on a prototypical inductive flow meter with the NACIE loop, ENEA Report NA-T-R-029, 2013.