Profile LFR-70

TALL-3D

SWEDEN

GENERAL INFORMATION

NAME OF THE FACILITY	TALL-3D
ACRONYM	Thermal-hydraulic ADS Lead-bismuth Loop with 3D flow test section
COOLANT(S) OF THE FACILITY	Lead-bismuth eutectics
LOCATION (address):	Royal Institute of Technology, Stockholm, Sweden
OPERATOR	Division of Nuclear Power Safety
CONTACT PERSON (name, address, institute, function, telephone, email):	Pavel Kudinov, Associate Professor, Division of Nuclear Power Safety Royal Institute of Technology (KTH), AlbaNova University Center SE - 106 91 Stockholm, Sweden Tel: +46 (0)8-5537-8826 Fax: +46 (0)8-5537-8830 E-mail: pavel@safety.sci.kth.se

STATUS OF THE FACILITY	In operation
Start of operation (date):	2014

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

The primary goal of the facility is to provide data for system thermal-hydraulic (STH), computational fluid dynamics (CFD) and coupled STH-CFD codes. The facility can carry out tests in forced, natural and mixed circulation regimes and various transients of safety importance with transitions between different regimes. Design of the facility promotes twoway feedbacks between the local 3D flow phenomena (e.g. thermal stratification, mixing) inside a pool-type test section and the dynamics of the loop system.

The schematic of the installation is shown in the

FIG. *1.* . It incorporates the primary loop with two hot legs and one cold leg, electro-magnetic pump (EMP) installed in the cold leg, the secondary loop, the differential pressure measurement system, pressurized service loop, preheating system, and data acquisition system (the last three elements are not shown in the drawing). Vertical legs are equipped with ball valves for fine tuning of the hydraulic resistances and to provide possibility to adjust or completely stop LBE flow in any leg.

The primary loop operates Lead Bismuth Eutectic (LBE). The secondary loop removes heat from the primary loop and is equipped with automatic temperature control system. Dowtherm RP heat transfer fluid is used as the process media. All facility components that come in contact with LBE are made of 316L stainless steel and are equipped with band, tape or rope type heaters. During the tests only differential pressure measurement system is continuously heated up.

Total electric power is about 80kW, including 27 kW pin-type Main Heater (MH) and 15 kW heater installed at the top part of the 3D test section. The maximum LBE flow velocity is above 5 kg/s in forced circulation and about 0.6 kg in natural circulation in the Heat Exchanger (HX) leg. During transients near stagnant flow can be established in one of the hot legs. The maximum LBE temperature is 460 °C in the hot legs and 350 °C in the cold leg. The secondary loop can be operated at temperatures from 50 to 300 °C. Maximum temperature difference across the heat exchanger is 90 °C. The static pressure at the top is 1.3 bar and at the bottom is 7.8 bar. The maximum head from the EPM pump is 2 bar.

Main thermal-hydraulic characteristics of the loop are provided in Table 1 as a set of dimensionless quantities. The maximum values are provided assuming 5 kg/s mass flow rate and 350 °C LBE flow temperature. The minimum value is taken for stagnant flow at 150°C.

Table 1: Ranges of dimensionless quantities for the main loop

Dimensionless quantity	**Minimum value**	**Maximum value**
$Re = (\rho \cdot \nu \cdot L)/\mu$	0	140 000
$Pr = (C\_p \cdot \mu)/k$	0.020	0.045
$Pe = Re \cdot Pr = (\nu \cdot L)/\alpha$	0	350

The primary loop consists of the sump tank (

FIG. *1.*) used to store, melt and supply LBE into the main loop, 3 vertical legs and 2 connecting horizontal sections. The total height of the facility is about 6.5 m. The distance between the adjacent vertical legs is 0.74 m and the distance between the horizontal sections is 5.83 m; the nominal pipe Inner Diameter (ID) is 27.86 mm.

The Main Heater (MH) leg (left) accommodates (i) the pin-type 27 kW electric heater (outer diameter 8.2 mm, heated length 870 mm) in the lower part (see FIG. 2.), and (ii) the expansion tank at the top. The expansion tank is used to (i) maintain loop pressure during temperature induced deformation of the loop components and LBE volumetric expansion / contraction and (ii) to monitor the LBE level in the loop. The Heat Exchanger (HX) leg (right) has (i) the counter-current double-pipe heat exchanger placed at the top and (ii) the Electric Permanent Magnet (EPM) pump used for forced circulation of LBE. The heat exchanger is the common component for primary and secondary sides. The 3D leg (middle) connects a pool-type 3D test section to the loop (see FIG. 2.). Depending on instantaneous flow characteristics, the LBE inside the test section can undergo thermal mixing or stratification. LBE mass flowmeters as temperature sensitive equipment are located in the cold side of the loop (section below the heat exchanger up to the 3D test section and the main heater). LBE flow temperature around the loop is measured at 23 locations. Differential pressure can be measured around any of the 12 primary loop sections. Oxygen content sensor is installed on top of the cold leg.

Dedicated DAS system is implemented for control of the facility and data recording. It uses Beckhoff hardware and software with LabVIEW interface and control logic. The total number of control and data acquisition channels is 589. Main heater, test section and the heat exchanger are equipped with hundreds of dedicated TCs for exhaustive information on temperature fields.

Acceptance of radioactive material

No

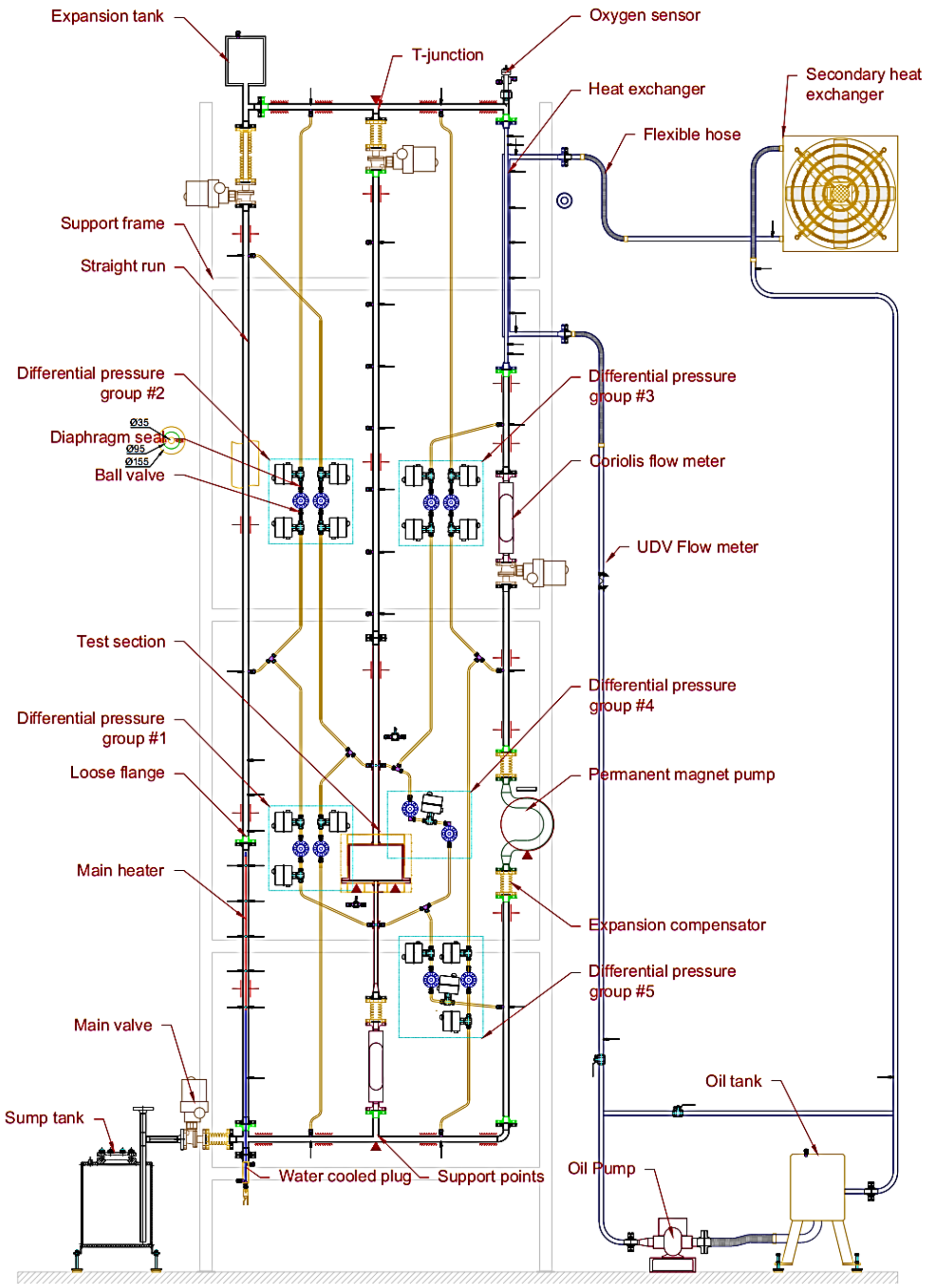

FIG. 1. TALL-3D facility main components

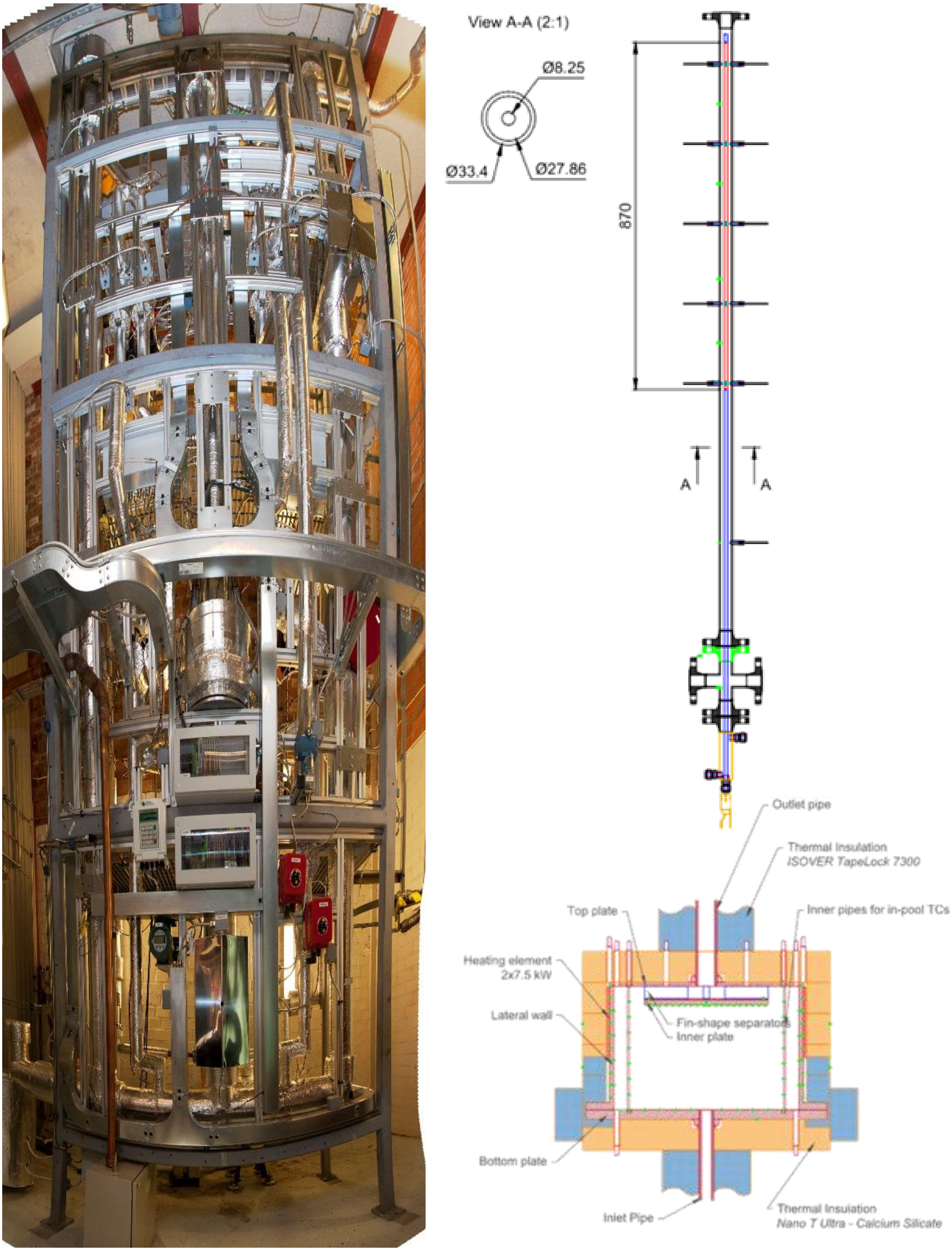

FIG. 2. TALL-3D primary side, pin-like Main heater and pool type Test section

Parameters table

Coolant inventory	LBE inventory ~350-400 kg
Power	80 kW, including Main heater 27 kW and Test section 15 kW
Test sections	
TS #1	*Characteristic dimensions* Ø300 mm, H200 mm
	Static/dynamic experiment Dynamic
	Temperature range in the test section (Delta T) 150-460°C
	Operating pressure and design pressure Operating pressure 7 Bar Design pressure 10 Bar
	Flow range (mass, velocity, etc.) 0-5 kg/s, maximum velocity is 0.187 m/s
Coolant chemistry measurement and control (active or not, measured parameters)	Oxygen measurement
Instrumentation	Thermocouples, Coriolis mass flow meters, differential pressure transducers, level meters

COMPLETED EXPERIMENTAL CAMPAIGNS: MAIN RESULTS AND ACHIEVEMENTS

First experimental campaign was carried out in 2014 in the frame of THINS project, including 2 calibration and 10 transient experiments. The obtained experimental data on loop thermal-hydraulics was successfully used for validation of standalone and coupled CFD and STH codes. Example of the experimental data from forced to natural circulation transient is demonstrated in the FIG. *3.* [9].

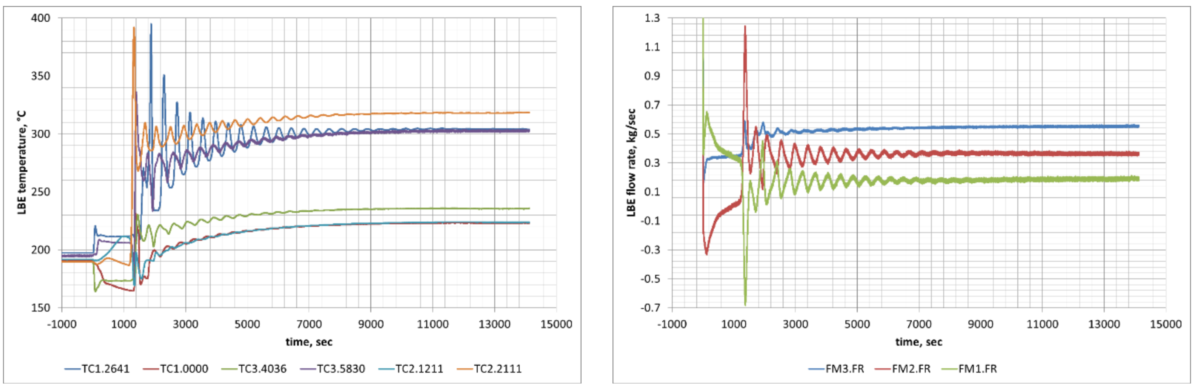

FIG. 3. Forced to natural circulation transient (T02.04) LBE flow temperature (left) and LBE mass flow rate (right)

PLANNED EXPERIMENTS (including time schedule)

In 2015-2018 a series of tests is planned in the framework of EU SESAME project. The tests will include investigation of:

- Loop system thermal hydraulics in different transients for validation of STH codes.
- Mixing and stratification phenomena in a pool for validation of CFD codes.
- Feedback between system thermal hydraulics and 3d effect for validation of coupled CDF-STH codes.
- LBE solidification phenomena and the effect of the flow structure for validation of solidification models.

TRAINING ACTIVITIES

Training activities can be agreed with KTH for the operation of the facility and execution of an experimental campaign under the supervision of NPS qualified staff.

REFERENCES (*specification of availability and language*)

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2. JELTSOV M., KÖÖP K., KUDINOV P., and Villanueva W., "Development of a Domain Overlapping Coupling Methodology for STH/CFD Analysis of Heavy Liquid Metal Thermal-Hydraulics," 15th International Topical Meeting on Nuclear Reactor Thermal Hydraulics, NURETH 15, May 12 to 17, 2013, Pisa, Italy, Paper 466.
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