Profile LFR-71

DELTA

USA

GENERAL INFORMATION

NAME OF THE FACILITY	DEvelopment of Lead Alloy Technical Applications
ACRONYM	DELTA Loop
COOLANT(S) OF THE FACILITY	Lead-Bismuth
LOCATION (address):	Los Alamos Neutron Science Center (LANSCE), Los Alamos National Laboratory, Los Alamos, NM 87545
OPERATOR	Los Alamos National Laboratory
CONTACT PERSON (name, address, institute, function, telephone, email):	S. A. Maloy, Los Alamos National Laboratory, Los Alamos, NM 87545, + 1 505 667 9784, maloy@lanl.gov

STATUS OF THE FACILITY	standby
Start of operation (date):	5 December 2001

MAIN RESEARCH FIELD(S)

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

TECHNICAL DESCRIPTION

Description of the facility

The DELTA loop was designed to study the long-term corrosive effects of liquid lead-bismuth eutectic (LBE) on structural materials at temperatures up to 500°C [1]. The DELTA loop supports LBE materials corrosion property research and thermal-hydraulic studies in LBE for fast reactors, accelerator systems, and investigation on LBE flow in future spallation target designs. <u>Design/Performance Parameters:</u> Up to 3.54 m/s LBE velocity in 2.54” diameter test section (test section length ~3 m), up to 100°C □T between heater section and heat exchanger exit for mass transport study, up to 550°C operation in the test section, gas injection system for oxygen control, capable of free convection flow in test section of 45 cm/s, all 316L construction, functional for LBE thermal-hydraulic component tests (targets, HX's, etc.), and robust and safe to operate. Adjustable operating parameters: Pump speed, tank levels, loop temperature, oxygen concentration.

Acceptance of radioactive material

No

Scheme/diagram

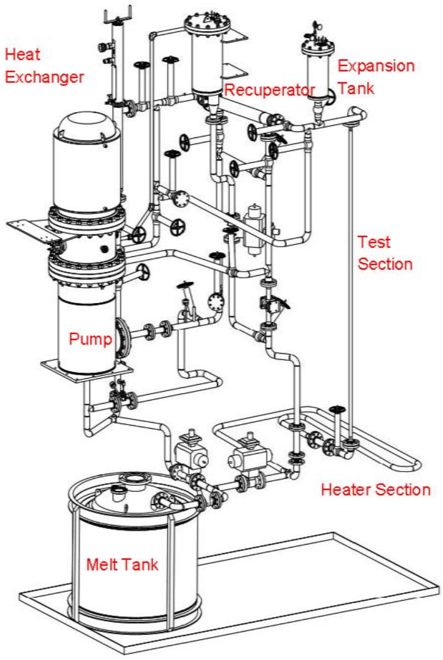

FIG. 1. Scheme of the DELTA facility

3D drawing/photo

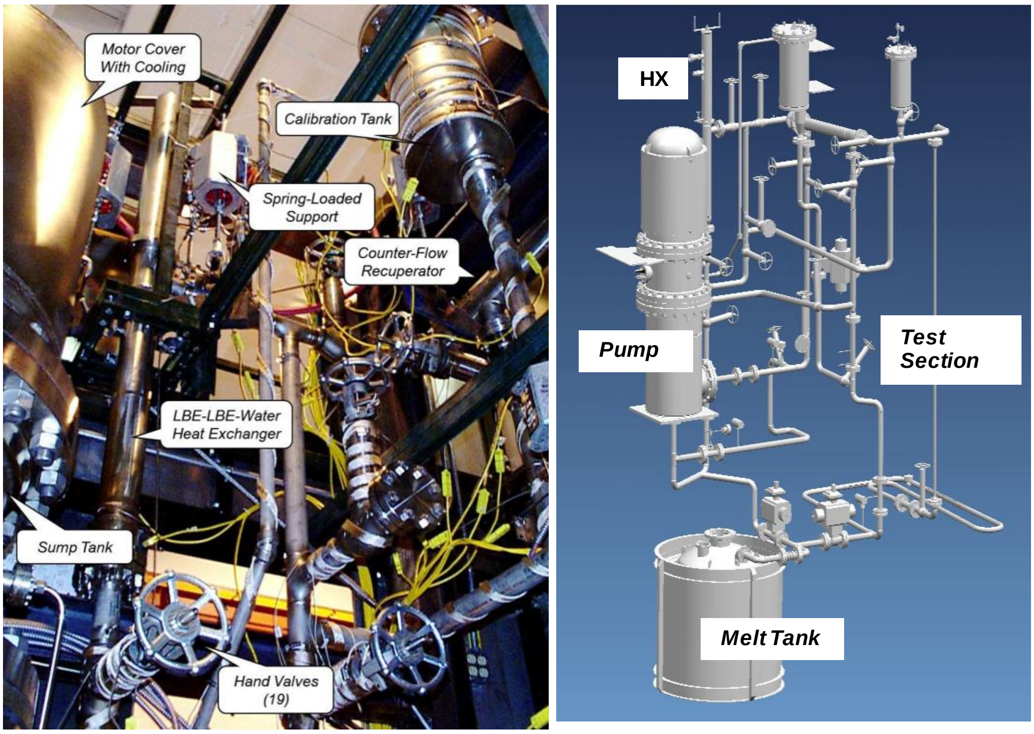

FIG. 2. View of the DELTA facility (left) and its 3D drawing (right)

Parameters table

Coolant inventory	Approximately 1/2 m^3
Power	50 kW
Test sections	
TS #1	*Characteristic dimensions* 5 cm diameter, 3 m length
	Static/dynamic experiment Dynamic
	Temperature range in the test section (Delta T) 100^oC
	Operating pressure and design pressure MAWP 100 psi (0.7 MPA)
	Flow range (mass, velocity, etc.) 5+ m^3/hr
Coolant chemistry measurement and control (active or not, measured parameters)	Active oxygen control, % by weight. Measured O_2, controlled by gas injection of H_2 or O_2.
Instrumentation	Pressure, temperature and flow rate at appropriate locations, liquid level in vessels

COMPLETED EXPERIMENTAL CAMPAIGNS: MAIN RESULTS AND ACHIEVEMENTS

* Steel Corrosion Tests in High-Velocity Flowing Lead-Bismuth Eutectic in LANL DELTA Loop [2-4]: An experimental campaign was launched to study the central role of corrosion resistance on steels exposed to LBE flowing at 3.54 m/s. This research highlights effects of chemical composition (such as the beneficial addition of Cr, Al, Si), microstructure (form and size of the steel grains) and surface modification with materials (as-received and polished conditions). Corrosion/erosion tests on steels were performed aiming at: 1) developing a better understanding of flow velocity and high-temperature effects on LBE corrosion properties, and 2) extending the corrosion tests beyond the traditional flow-rate limit of 2 m/s. LBE velocity was maintained constant (at 3.54 m/s) during the whole experiment. Dissolved oxygen levels were initially at saturation, but then they were reduced to acceptable range for duration of the test, with an average value of 2.3×10^{-5} wt.% (maximum $\sim 8 \times 10^{-4}$ and minimum $\sim 2 \times 10^{-8}$ wt.%). LBE was flowing at an average temperature of ~ 488^{o}C. In total, 144 thin corrosion test coupons (35 x 8 x 1mm) were tested in these experiments. The materials selection included conventional steels candidate for heavy-liquid metal (HLM) cooled reactors, such as 12 Cr F/M HT-9, Russian EP823 (11.7 Cr) engineering steels, and innovative steels such as new high temperature functionally graded composites (FCG), as well as oxide dispersion strengthened (ODS) FeCrAl alloys, namely, MA956 (20Cr-4.5Al) and PM2000 (20Cr-5.5 Al), and FeCr and FeSi model alloys for fundamental research studies in view of future data validation for computer simulation modelling. Candidate accident tolerant fuel (ATF) alloys for light water reactors (LWRs) cladding such as the Kanthal series steel and Alkrothal 3, were also part of the test matrix. Several steels were selected that have been proposed for fuel cladding, heat exchangers and structural materials in ADS and lead-cooled fast reactors (LFRs), such as T91 or austenitic steel 316L for vessel and in-vessel components. In general, high flow-rate LBE corrosion test results revealed that oxide layers appear to be stable after exposure to high velocity LBE flow with several materials opening the possibility for increased LBE coolant flow velocity in reactor designs, e.g. ATF alloys, such as Fe-Cr-Al-rich APM steel, and innovative FGC composites. Results obtained from these corrosion tests will contribute to build a database for the development of empirical correlations essential to accelerate the progress in materials research and reactor deployment. Long-term corrosion studies are needed to provide valuable information to engineers that need to determine margins and operating constraints for structural components in LBE coolant.

* Dissolution Kinetics of Lead-Oxide (PbO) in LBE: Experiments were performed at LANL DELTA Loop in the frame of collaboration with SCK•CEN, Belgium, on lead oxide mass exchanger dissolution in LBE. The R&D focus is on solid lead-oxide packed-bed mass exchangers (PbO MX) for oxygen control in LBE-cooled reactors. Oxygen concentration at the outlet of the PbO MX was measured for different conditions using a potentiometric oxygen sensor, and the dissolution rate was determined for five different temperatures. The temperature dependence of the dissolution rate was then determined and the experimental data was used to validate a numerical model [5,6]. The research is part of a thesis work aiming to develop numerical models for oxygen mass transfer in LBE cooled nuclear

systems, and to predict oxygen distribution in the primary system of the 50-100 MWth accelerator-driven system MYRRHA during normal operation, and also transient conditions such as commissioning, starting-up and shutdown of the reactor, and some accidental conditions like failure of the oxygen supply system, or blockage of flow.

PLANNED EXPERIMENTS (including time schedule)
none

TRAINING ACTIVITIES
* Oxygen control and corrosion experiments and general training in loop system and procedures [7]: Oxygen control by direct mass transfer, loop restart, design and implementation of gas flow controller, expansion tank refurbish, LabView software upgrade and software alterations, computer hardware upgrade, DELTA loop modifications (oxygen sensors, gas switch, drain line check valve, etc.).

* LBE loop analysis and scanning electron microscopy (SEM) studies [8]: Design and components specification of a modified LBE loop, computer fluid dynamics analysis of convection and developed flow, and scanning electron microscopy analysis of model alloy specimens of previous 666h corrosion tests conducted at low LBE velocity (2 m/s) and high temperature (450^{o}C).

REFERENCES (*specification of availability and language*)

1. LI N., “Lead-bismuth eutectic (LBE) coolant technology development at Los Alamos National Laboratory”, Report LA-UR-00-5129, Los Alamos National Laboratory (October 2000).
2. CARO M., WOLOSHUN K., RUBIO F., MALOY S.A., CIONEA C., ROSE C.G., HOSEMANN P., “Steel Corrosion Tests in Flowing Lead-Bismuth Eutectic in LANL DELTA Loop”, Materials and Fuels for the Current and Advanced Nuclear Reactors III, Structural Materials I, LA-UR-14-20842, TMS Annual Meeting, February 16-20, 2014.
3. CARO M., WOLOSHUN K., NELSON A. T., RUBIO F., MALOY S., “Heavy Liquid Metal Corrosion of Structural Materials in Advanced Nuclear Systems”, JOM Corrosion and Environmental Effects - Corrosion in Energy Production, (August 2013).

4. CARO M., WOLOSHUN K., RUBIO F.V.,. MALOY S.A, “Material selection ofr the lead-bismuth corrosion and erosion tests in DELTA Loop”, Report LA-UR-13-22282, Los Alamos National Laboratory (March 2013).
5. MARINO A., LIM J. KEIJERS S., VAN DEN BOSCH J., DECONINCK J.,. CARO M, WOLOSHUN K., RUBIO F., MADRID M., MALOY S., “Oxygen control in lead-bismuth eutectic cooled reactors”, LA-UR-12-23519, Rio Grande Symp on Advanced Materials (October 2012)
6. MARINO A., LIM J., KEIJERS S., VAN DEN BOSCH J., DECONINCK J., “Numerical modelling of oxygen mass transfer from PbO spheres packed bed to liquid lead bismuth eutectic: A venturi-type PbO mass exchanger”, Nucl. Eng. Des. 265, 576 (2013).
7. RUBIO F. V., “DELTA Loop Refurbish and Operations, June 2012 -June 2013”, Post Baccalaureate Report, LA-UR-13-25272, (June 2013).
8. WARD M., WOLOSHUN K., CARO M., ”DELTA Loop Repair, Corrosion Test Results, and Analysis, July 2013 – September 2013”, Summer Internship Closeout Report, (priv. comm. 2014).