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Validation of IFMIF liquid Li target for IFMIF/EVEDA project

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HIGHLIGHTS

- The EVEDA Li Test Loop (ELTL) is a major Japanese activity for the validation of the Li target facility for the IFMIF in the IFMIF/EVEDA project.
- This study demonstrates a stable Li target that satisfies the IFMIF design conditions (250 °C, 15 m/s, 10^{-3} Pa).
- We used a laser-based method to verify that the Li target was adequately stable.
- Cavitation upstream of the Li target was examined and a startup pressure was determined.

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ABSTRACT

A liquid-Li free-surface stream flowing at 15 m/s under a high vacuum of 10^{-3} Pa is to serve as a beam target for the planned International Fusion Materials Irradiation Facility (IFMIF). The Engineering Validation and Engineering Design Activities (EVEDA) for the IFMIF is implemented under the Broader Approach. As a major activity for the Li target, the EVEDA Li test loop (ELTL) was constructed by the Japan Atomic Energy Agency. The present study demonstrates a stable Li target that satisfies the IFMIF design conditions (250 °C, 15 m/s, 10^{-3} Pa) and presents the procedure for operating the Li target which consists of seven stages. We used a laser-based method to verify that the Li target is adequately stable. In addition, we examine cavitation occurring during startup of the Li target, and consequently, determine the appropriate startup pressure.

1. Introduction

The International Fusion Materials Irradiation Facility (IFMIF) is an accelerator-based D^+-Li neutron source designed to produce an intense high-energy neutron flux for testing materials. To deliver such a capability, two 40 MeV deuteron beams with a total current of 250 mA are injected into a liquid-Li free-surface stream (hereafter, referred to as the Li target) flowing at 15 m/s. Since 2007, the Engineering Validation and Engineering Design Activities (EVEDA) for the IFMIF has been implemented under the Broader Approach (BA) Agreement. See Ref. [1] for the recent activities of the IFMIF/EVEDA project.

The EVEDA Lithium Test Loop (ELTL), which simulates the Li target and purification system envisaged for the IFMIF, is the main Japanese activity for the Li target system of the IFMIF/EVEDA project. The ELTL was designed in 2008 and 2009 (see, e.g., Ref. [2]), and the construction was completed in February 2011 at the Oarai site of the Japan Atomic Energy Agency [3]. Because of the Great East Japan Earthquake, the operation was suspended for 16 months to allow for repair and inspection. A validation phase started in September 2012. Our previous reports present preliminary tests of Li target operations in the design-velocity range of 10–20 m/s [4]. For these tests, we used the laser-probe method to measure the Li target [5].

Following these preliminary experiments, we achieved a stable Li target under the IFMIF conditions, which stipulate a Li temperature and velocity of 250 °C and 15 m/s, respectively, under a high vacuum of 10^{-3} Pa. Since then, we have improved the previous procedure [4] for operating the Li target, and we present this new procedure in this paper. We also discuss the appearance of the flowing Li target, its stability, and cavitation that occurs during the operation.

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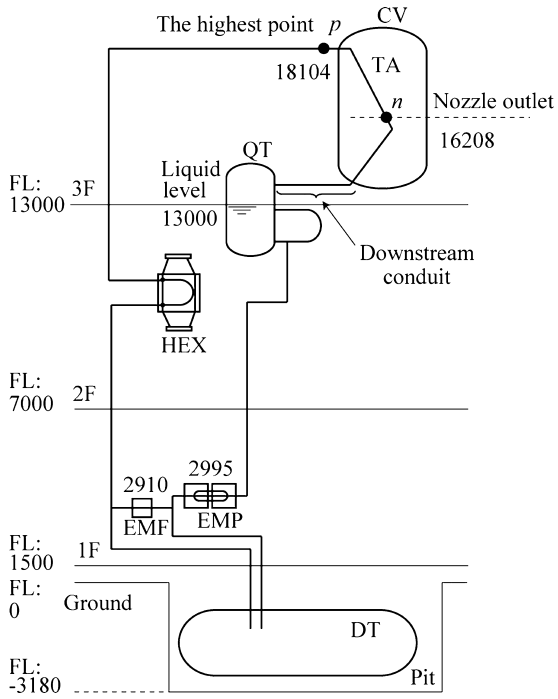

Fig. 1. Schematic of ELTL main loop.

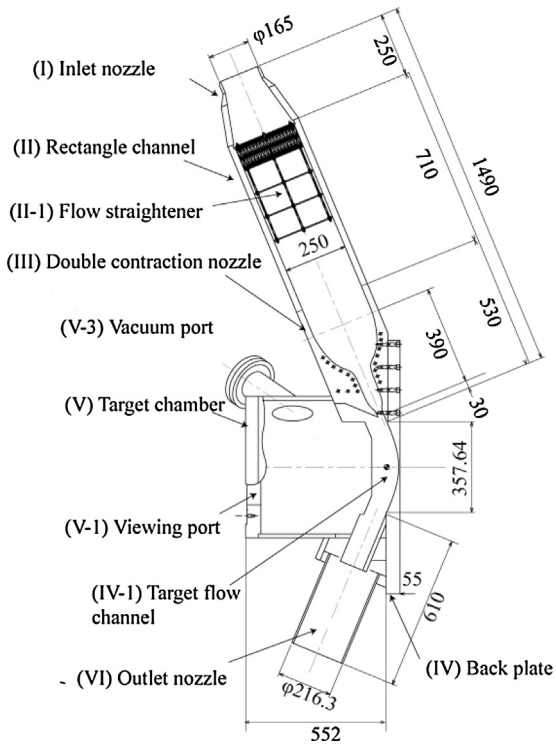

Fig. 2. Target assembly structure.

2. Experimental facility and conditions

2.1. Experimental facility and instrumentation

Fig. 1 shows a schematic of the main loop of the ELTL, whose Li inventory is 5.0 m^3 and which has a platform size of roughly $20 \times 20 \times 20$ m^3 consisting of three floors. For each floor level (FL), Fig. 1 indicates the nominal liquid level (13 000), the highest level (18 104), and the outlet level of the Li target (16 208) in mm above ground level (0).

The main Li loop is designed to supply an adequate flow of liquid Li (maximum flow rate is 0.05 m^3/s, which is 3000 L/min) at the appropriate temperature (operational temperature range is 250–350 °C), to the target assembly (TA), in which the flowing Li target is produced. The main loop essentially consists of 6-inch Li circulation pipes made of AISI type-304 stainless steel, the TA, a quench tank (QT), an electromagnetic pump (EMP), an electromagnetic flow meter (EMF), and a heat exchanger (HEX). The TA is installed in the confinement vessel (CV). The tanks are connected to an Ar-gas system and vacuum pumps to evacuate the system and control its pressure. The 5.0-m^3 Li is stored in a dump tank (DT) during a shutdown.

Fig. 2 illustrates the TA, whose major components are the flow straightener (II-1), double-contraction nozzle (III), and back plate (IV) [2]. Li flows into the double-contraction nozzle and forms the Li target, whose velocity, thickness, and width are 20 m/s (maximum), 25 mm, and 100 mm, respectively, along the concave back plate. The Li target can be observed and measured through the viewing port (V-1).

The instrumentation used in this facility is listed in Table 1. The Li temperature is measured at three positions in the QT and at the inlet and outlet of the HEX by thermocouples. The volumetric flow rate was measured by the EMF (Sukegawa Electric Co., Ltd.), installed in the main-loop as shown in Fig. 1, and the mean velocity of the Li target was calculated by dividing the flow rate by a cross-sectional area of the nozzle outlet of 25 mm in depth and 100 mm in width. Gaseous pressure in the TA, which equals pressure in the QT as well as surface pressure of the Li target, was measured by a pressure gauge (PTU-S, Swagelok Company) or a vacuum gauge

Table 1
Instrumentation used in this study.

	Instrument	Model, supplier	Major specifications
Temperature	Thermocouple	Type K, Okazaki Manufacturing Company	Standard/Class: JIS C 1605-95 (*)/Class 2, tolerance: ±2.5 °C, error: −0.5 °C (at 300 °C)
Flow rate (velocity)	Electro-magnetic flow meter (EMF)	Sukegawa electric Co., Ltd.	Range: ±3000 L/min, accuracy (1σ): ±27.9 L/min
Pressure	Pressure gauge	PTU-S, Swagelok Company	Range: −0.1 to 0.3 MPa-G (gauge), accuracy: ±0.5% FS (full scale)
	Cold-cathode Pirani gauge	M-360CP-SP/N25, Cannon Anelva Corp.	Range: 5×10^{-7}–1×10^{5} (Pa), accuracy: ±30% RD (reading)
Residual gas mass spectrum	Quadrupole mass spectrometer (QMS)	M-201QA-TDM, Canon Anelva Corp.	High-sensitivity type (a secondary electron multiplier)
Target flow	Digital camera	D800 (Lens: AS Nikkor 28–300 mm), Nikkon	Number of pixels: 36.3 M
	Laser-probe	Laser-distance meter, Optical Comb, Inc.	Measurement distance: 1.5–3 m, precision: a few tens μm

(*) JIS: Japanese Industrical Standerd

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