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Status of Development of Lithium Target Facility in IFMIF/EVEDA Project

IFMIF/EVEDA事業におけるリチウムターゲット施設開発の現状

Eiichi Wakai, Hiroo Kondo, Takuji Kanemura, Yasushi Hirakawa, Tomohiro Furukawa, E. Hoashi[1], S. Fukada[2], A. Suzuki[3], J. Yagi[4], Y. Tsuji[5], T. Yokomine[6], Serizawa[1], K. Nakaniwa, Y. Ito, H. Tanaka, M. Sugimoto, S. Ohira, J. Knaster, et al.

若井栄一, 近藤浩夫, 金村卓治, 平川康, 古川智弘, 帆足英二[1], 深田智[2], 鈴木晶大[3], 八木重郎[4], 辻義之[5], 横峯健彦[6], 中庭浩一, 伊藤譲, 田中浩, 杉本昌義,大平茂,ﾌｫｱﾝ･ﾅｽﾀｰ[7],他

Directorate of Fusion R&D, Japan Atomic Energy Agency
2-4, Shirakata-shirane, Tokai-mura, Nakagun, Ibaraki 319-1195, Japan
1)Osaka Univ., 2)Kyushu Univ.,3)Univ. Of Tokyo,4)NIFS,5)Nagoya Univ.,6)Kyoto Univ.,7)IFMIF/EVEDA project team

原子力機構 核融合研究開発部門IFMIF照射・試験施設開発Gr 〒319-1195 那珂郡東海村白方白根2-4
1)阪大, 2)九大, 3)東大, 4)核融合研, 5)名大, 6)京大, 7)IFMIF/EVEDA事業チーム

The EVEDA (Engineering Validation and Engineering Design Activity) Lithium Test Loop (ELTL) with the world's highest flow rate of 3000 L/min was succeeded in generating a 100 mm-wide and 25 mm-thick free-surface lithium flow steadily under the IFMIF operation condition of a high-speed of 15 m/s at 250°C in a vacuum of 10^{-3} Pa by the design development and optimization of operation condition. Recent related the engineering validations including lithium purification, lithium safety, and remote handling technique and the engineering design of lithium facility were also evaluated and the main contents were summarized. These results will advance greatly the development of an accelerator-based neutron source to high energy and high-density as an important key technology for development of fusion reactor materials.

1. Introduction

Fusion reactor materials development needs a high energy and high-density neutron source to simulate the neutrons generated by fusion reactions. IFMIF evaluation has successfully passed through all needed key steps as below:

(1) Conceptual Design Activity (CDA) phase in 1996: It was performed as a joint effort of the EU, Japan, RF and US.

(2) Conceptual Design Evaluation (CDE) report in 1998: The contents were conducted towards a design simplification and cost reduction.

(3) The Conceptual Design Report (CDR) in 2004: It was evaluated and summarized by a committee of EU, Japan, RF, and US.

(4) The final Phase of EVEDA (engineering validation and engineering design activities) within BA activities from 2007: As an efficient risk mitigation exercise, it is conducting to face the construction on cost and schedule timely with the world needs for a fusion relevant neutron source.

The objective of International Fusion Materials Irradiation Facility (IFMIF) is to generate high intensity neutrons, which are similar to fusion neutrons with 14 MeV, by injecting the CW deuteron two-beams with a current of 250 mA (125 mA x 2) accelerated to high energy onto the 260 mm wide and 25 mm thick free-surface lithium flow with a velocity of 15 m/s at 250°C under the vacuum of 10^{-2} to 10^{-3} Pa. Guiding the liquid lithium along the concave back plate at a speed of 15 m/s is required to increase the pressure in the lithium flow by centrifugal force, to avoid boiling by the heat input of the deuteron beams, and to remove heat by the lithium flow circulation. A flux of neutrons of ~10^{18} $m^{-2}s^{-1}$ is generated in the forward direction with a broad peak at 14 MeV.

2. Engineering Validation of Lithium Facility

In the engineering validation of lithium facility [1-4], there are several subjects as shown in Fig. 1.

In LF01 (Construction, operation and tests of ELTL), ELTL was designed and constructed in

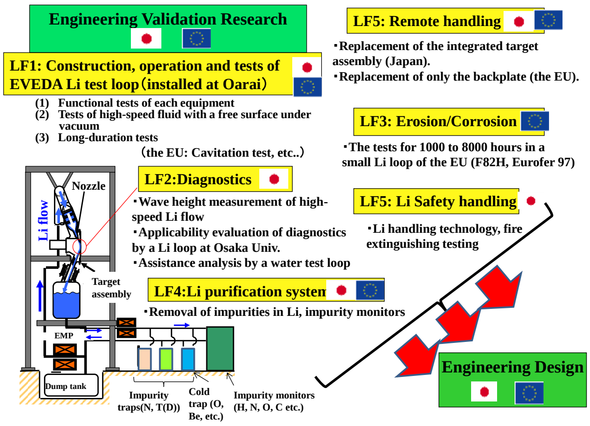

Fig. 1: Engineering validation and design of lithium facility in the IFMIF/EVEDA.

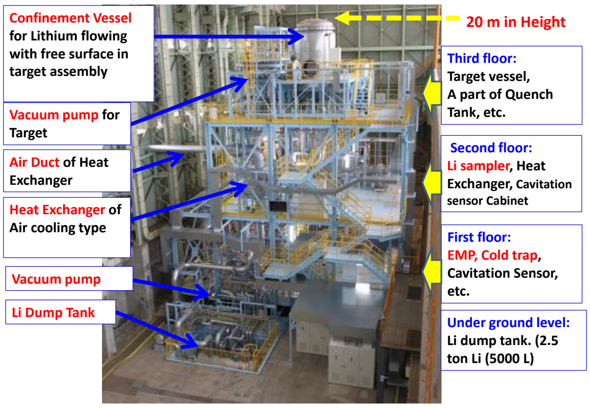

Fig. 2: EVEDA lithium test loop.

November 2010 in order to examine the engineering validity of the prototype of a Li target facility of the IFMIF as shown in Fig. 2. Based on (i) design and high accuracy machining of flow channel and back-plate with concave geometry, which guide and stabilize the high speed lithium jet with free surface by centrifugal force, (ii) evaluation of pressure to prevent the occurrence of cavitation in electro-magnetic pump, and (iii) optimization of operation flow condition and nozzle's cleaning, it was succeeded in generating a 100 mm wide and 25 mm thick free-surface lithium flow along a concave back plate steadily under the IFMIF operation condition of 15 m/s at 250^{o}C in a vacuum of 10^{-3} Pa. The height of 20 m was needed to prevent the occurrence of cavitation in the electro-magnetic pumps.

In LF02 (Diagnostics for lithium flow with free surface), a contact-type liquid level sensor and non-contact probe method by laser-based distance meter were developed to measure the thickness of lithium flow, and the averaged deviation of wave height in the square area shown in Fig. 1 was evaluated as about 1.0 mm by the laser type. Applicability evaluation of diagnostics was also performed by a Li loop at Osaka Univ. Assistance analysis of flowing behaviors by a water test loop is also conducting.

In LF03 (Erosion/corrosion), ENEA Lifus-6 lithium loop for the erosion/corrosion test is being constructed, and it is under operation from around October 2014. The tests for 1000 to 8000 hours will be checked in a small Li loop of the EU (F82H, Eurofer 97)

In LF04 (Li purification), purification systems with Y trap to reduce hydrogen up to 1 ppm, and Fe-Ti trap to reduce nitrogen up to 16 ppm were evaluated, and hydrogen monitor such as Ti coated with Fe (Pd, Ta, W) is also under developing.

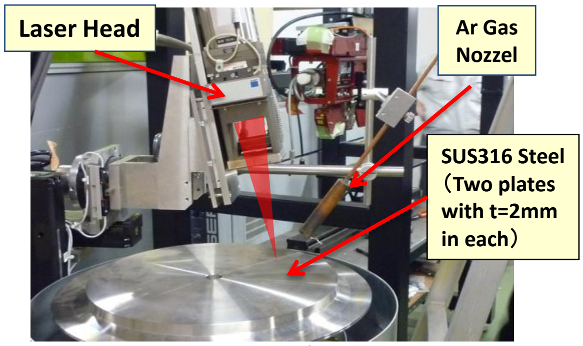

Fig. 3: Validation tests of the welding and cutting by a fiber laser.

In LF05 (Remote handling, Li safety), fiber-laser welding and cutting technique were developed in two plates of 316L steel with 2 mm-thickness for each plate as the remote handling technique, as given in Fig. 3. Lithium safety handling was also evaluated for fire-extinguishing of lithium, chemical reaction of lithium leakage, and lithium removal from the components and chemical analysis of lithium impurities.

3. Engineering Design of Lithium Facility

In ED03 (Engineering design of lithium target facility), the design was summarized on June 2013 [4]. The intermediate IFMIF engineering design was produced by all teams of IFMIF/EVEDA project. The main modifications from CDR are described as below:

(1) Alvarez-type Drift Tube Linac replaced by a superconducting RF Linac: Reduction in beam losses and operation costs.
(2) Configuration of the test cell changed the irradiation modules have no more a shielding function: Improved irradiation flexibility and the reliability of the remote handling equipment.
(3) Quench Tank of the Lithium loop re-located outside the test cell: Reduction of tritium production rate and simplification of maintenance processes.
(4) Maintenance strategy modified: Allowing a shorter yearly stop of the irradiation operations and a better management of the irradiated samples.

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