Nitrogen Hot Trap Design and Manufactures for Lithium Test Loop in IFMIF/EVEDA Project*)

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The lithium target facility of IFMIF (International Fusion Materials Irradiation Facility) consists of target assembly, lithium main loop, lithium purification loops, the diagnostic systems, and remote handling system. Major impurities in the lithium loop are proton, deuterium, tritium, 7-Be, activated corrosion products and the other species (C, N, O). It is very important to remove nitrogen content in lithium loop during operation, in order to avoid the corrosion/erosion of the nozzle of lithium target for the stable lithium flow on the target assembly. Nitrogen in the lithium can be removed by N hot trap using Fe-5%Ti alloy at temperatures from 400 to 600°C. In this study, the specification and the detailed design were evaluated, and the component of N hot trap system was fabricated.

Keywords: IFMIF, IFMIF/EVEDA project, Li purification, nitrogen hot trap, Fe-Ti alloy

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1. Introduction

In parallel to the International Thermonuclear Experimental Reactor (ITER) program, the Broader Approach (BA) activities [1, 2] are being implemented by the European Union (EU) and Japan (JA), aiming at the early realization of the fusion energy. The BA activities comprise the International Fusion Materials Irradiation Facility/Engineering Validation and Engineering Design Activities (IFMIF/EVEDA) [3, 4], the International Fusion Energy Research Center (IFERC) [5], and the Satellite Tokamak [6] started from 2007 in the joint program. The main function of the IFMIF is to generate the intense fusion neutrons by injecting the deuteron beams accelerated to high energy onto the liquid lithium flow at 250°C. Guiding the lithium flow with a speed of 15 m/s along the concave back plate is required to increase the pressure in the lithium flow by centrifugal force, to avoid boiling by the heat input about 1 GW of the deuteron beams [7] and to remove heat by the lithium flow circulation under the lithium purification controls by N hot trap, H hot trap, and cold trap [8–10].

According to the IFMIF design requirement, hydrogen isotope content in the liquid lithium in the target facility of the IFMIF is required to be less than 10 wppm, and tritium content in the liquid lithium is especially required to be less than 1 wppm. Each of the other element (C, N, and O) contents in the liquid lithium is required to be less than 10 wppm. The solubility of both oxygen and carbon in lithium is so low, less than 10 wppm around 200°C, and their concentration in lithium can be controlled by a cold trap. On the other hand, the solubility of nitrogen and hydrogen in lithium is large even at around the melting point of lithium; therefore, both elements should be removed from the liquid lithium chemically with other traps, which are so called hot traps. The related recent activities of lithium purification studies were reported in the references [8–18], and the content of the lithium test facility of IFMIF have been reported in the references [8, 9, 19–27].

This paper presents a design and the evaluation of a nitrogen hot trap for removing nitrogen in Li loop in the IFMIF/EVEDA project.

2. Specification, Design and Manufacture of N Hot Trap System

In Table 1, main specification of purification system and the related ones in the EVEDA Li test loop is summarized. Considering the experimental conditions and output in previous nitrogen trap experiments on hot trapping by Fe–Ti alloy, the temperature of the lithium would be better to be increased to the range from 400°C to 600°C. Thermal convection is not suitable as the driving force because

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Table 1 Main specification of purification system and the related ones in EVEDA Li test loop (ELTL) .

Required Item	Required Condition
Impurity Content	< 10 wppm (each C, N, O)
Hydrogen Isotopes Content	< 10 wppm (< 1 wppm:T)
Erosion/corrosion thickness:	
-Nozzle and back wall,	< 1 μm /year
-Piping, container, etc.	< 50 μm /30 years
Inlet Temperature of Li	250°C (nominal)
Li inventory in EVEDA Li test loop	5 m^3 (~2.5 tons)
Temperature of N hot trap	400 - 600 °C
Internal volume of the container of N hot trap	0.07 m^3
Design pressure of the container	From -0.1 to 0.75 MPaG
N trap material	Fe-5Ti alloy, pebble (0.16 mm in diameter.in average (0.10-0.22 mm)), 95 kg, 20 ℓ in volume
Flow rate in main loop	37.5 ℓ/s (50 ℓ/s at Max.)
Entrance of N trap system from main loop of ELTL	About 10 ℓ /min in max.
Pipes size of Main loop	8B Sch20: 1.2 m/s(37.5ℓ/s), 1.5 m/s(50 ℓ/s) , 4B Sch20: 4.2 m/s(37.5ℓ/s), 5.6 m/s(50 ℓ/s)
Thickness of pipe	8B: 6.5 mm, 4B: 4.0 mm, 2B: 3.5 mm, 1B:3.0 mm (Sch20)
Pipe of N trap system	1B Sch40

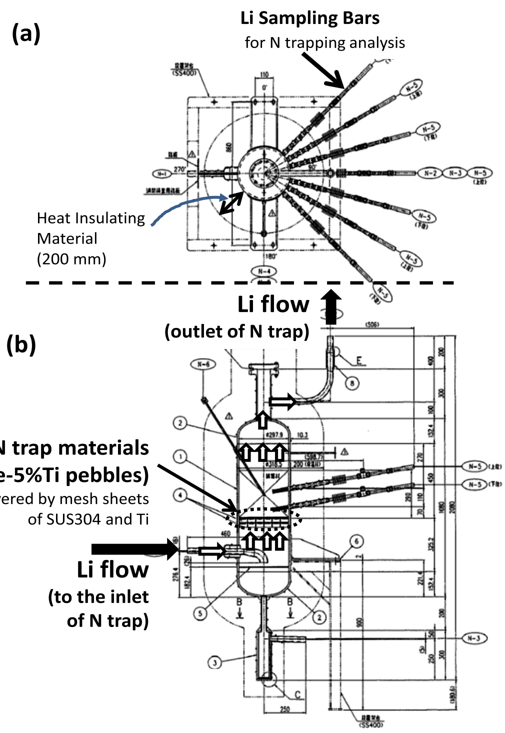

Fig. 1 Schematic image of nitrogen hot trap, showing lithium flow. Top view (a) and side view (b).

the temperature difference in the loop may seriously affect the trapping behavior. The shape of the trapping material installed in the loop shall be a pebble of Fe-5Ti alloy, approximately 0.16 mm in diameter, which is adopted as N hot trap in EVEDA Li test loop (ELTL). The designed N hot trap has a pebble bed column and seven Li sampling bars as given in Fig. 1.

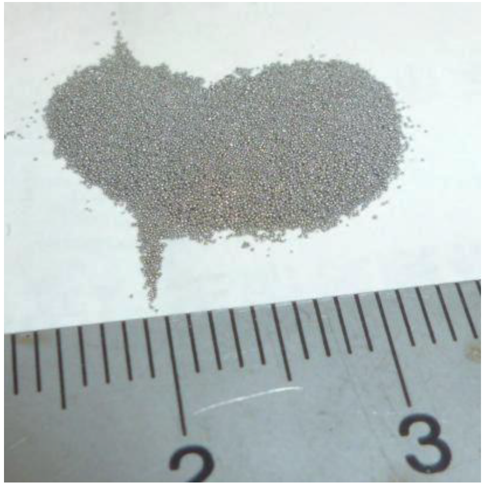

Fig. 2 The getter material of Fe-5at%Ti alloy pebbles.

Table 2 Specification of getter material.

Item	Specification
Getter material	Fe-5at%Ti
Getter material weight	95 kg
Space volume of getter material	12 L
Diameter of getter pebble	0.16 mm in average
Total surface of the getter	460 m^2

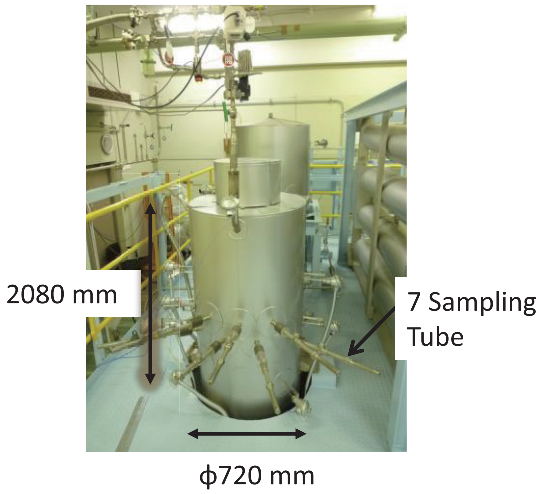

Fig. 3 Manufactured N trap with 7 sampling tube.

The getter material of Fe-5at%Ti alloy pebbles in the nitrogen hot trap is shown in Fig. 2, and the average diameter of the pebble was 0.16 mm. The specification of getter material in the nitrogen hot trap is given in Table 2. The nitrogen hot trap was fabricated in a frame work of the validation test. The picture of the manufactured N hot trap is shown in Fig. 3, and the temperature of the nitrogen hot trap can be controlled from room temperature to about 600°C.

Nitrogen impurity in the lithium can be removed by N hot trap using Fe-Ti alloy at temperatures ranges from 400

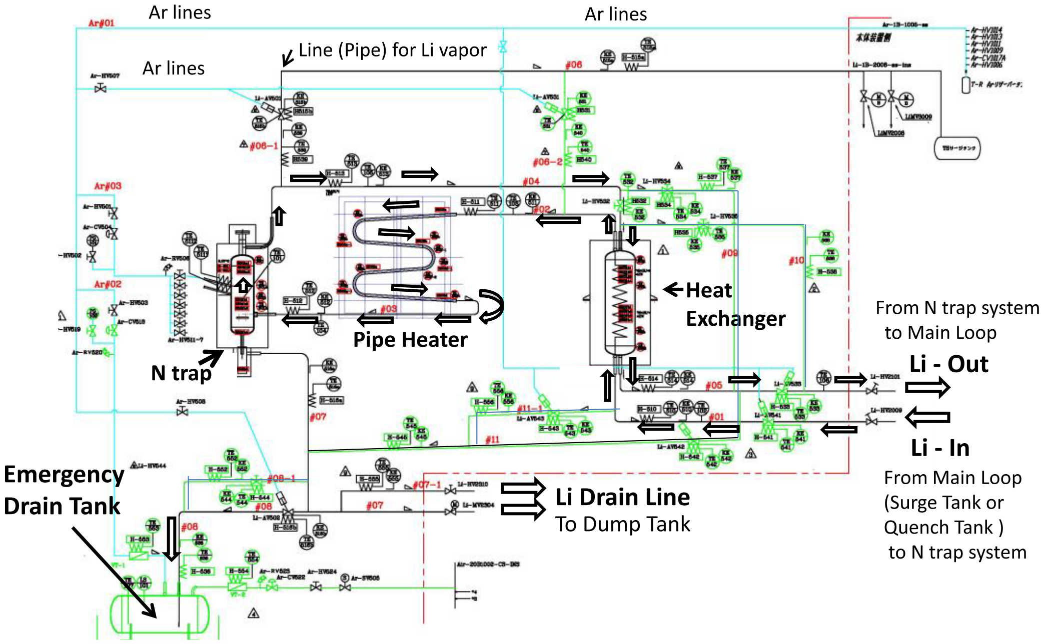

Fig. 5 Schematic diagram of nitrogen trap which is a case of connection with Li test loop.

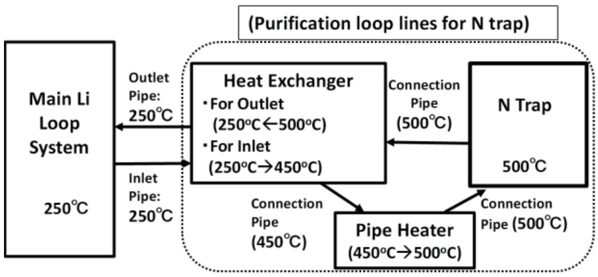

Fig. 4 Conceptual layout and system operation conditions for the nitrogen hot trap, heat exchanger, pipe heater, and the main Li loop system operated at 250°C.

to 600°C. An example of the operation condition of N hot trap system is shown in Fig. 4, and it is controlled by heat exchanger, pipe heater, and N hot trap. The design of the vessel and pipes of N hot trap is evaluated by the analysis of materials properties such as creep, creep-fatigue and corrosion. The nitrogen content in lithium loop during operation should be controlled to avoid the corrosion of the nozzle of lithium target under less than about a hundred ppm. Li inlet pipe conducted from main loop to N trap system is unique line.

The lithium passing rout from inlet pipe to outlet pipe is shown in the schematic diagram of nitrogen trap in a case of the Li test loop as given in Fig. 5.

3. Summary

This paper evaluated a specification and the design of a nitrogen hot trap for removing nitrogen impurity in Li in the IFMIF/EVEDA project. The nitrogen hot trap was fabricated in a frame work of the validation test. Nitrogen in the lithium can be removed by N hot trap using a Fe-5at%Ti alloy at temperatures from 400 to 600°C. The design of the vessel and pipes of N hot trap was evaluated by the analysis of materials properties such as creep, creep-fatigue and corrosion. The nitrogen content in lithium loop during operation should be controlled to avoid the corrosion/erosion of the nozzle of lithium target under less than about 10 - 30 wppm. The specification evaluation, the detailed design, and the component's manufacturing of N hot trap system were carried in the EVEDA project.

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