Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2015

Development of a Portable Fusion Neutron Generator

Byung-Hoon Oh*[1], Sang-Ryul In[1], Jeong-Tae Jin[1], Cheol Ho Lee[2], Dae-Sik Chang[1], Doh-Yun Jang[1]
[1]*Korea Atomic Energy Institute, 111 Daedeok-daero 989, Yuseong-gu, Daejeon, Korea*
[2]*Department of Nuclear Engineering, Hanyang University, Seoul 133-791, Korea*

**Corresponding author: bhoh@kaeri.re.kr*

1. Introduction

Recently the need of movable neutron generator is expanded very fast especially for explosive material detection, nuclear weapon detection, and high quality radiography [1]. For this purpose commercial ones, fast neutron yield from 10^7 to 10^{11}, are supplied by several companies and research groups around the world. But internally the following limits make it difficult to develop the related application systems by domestic companies and/or research groups.

- Limited life time
- High price
- Frequent trouble

Not only to remove these limits but also to find out new internal application fields, it is necessary to develop our own domestic neutron generators. With the related technologies earned during fusion related researches, we did start to develop movable neutron generators from small one to big one, which could cover different fusion neutron yields. In this presentation the design and initial experimental results on the developed small neutron generator with a final target of 10^8 n/s of 14 MeV neutrons, will be summarized.

2. Design of a Portable Neutron Generator

Generally, a movable neutron generator is composed of an ion source, an accelerator or beam extractor, a target, and a fuel controller. Depending on neutron strength of the generator, different type ion sources should be used. For a high flux neutron generator an added accelerator tube is needed to increase the beam energy higher than 200 keV. Getter is usually used as a fuel controller for a portable one, but for a high flux one vacuum pump and gas feeding system should be introduced. As a target, a drive-in target is generally used, but for a very high flux one gas target is needed because of the heat load on the target.

2.1 Penning Ion Source

Penning ion source [2] is a low current ion source, but it is simple and stable in a low power operation condition. Therefore a penning type ion source is suitable to be used in a portable neutron generator, and we select this type as an ion source. Fig. 1 shows the designed prototype neutron generator including ion source and vacuum pumping system for the test of developed components for a portable one such as ion source, feedthru, getter, and drive-in target. The penning ion source is designed to be operated continuously in an arc power of less than 1 Watt.

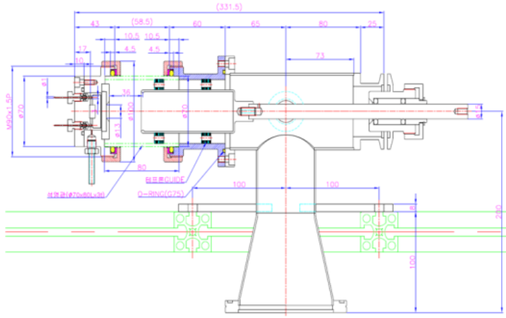

Fig. 1. Prototype of a portable neutron generator to test the developed components.

2.2 Drive-in Target

Fig. 2 shows the expected neutron yields depending on the energy of the incident particle. The drive-in target is a solid target for a mixed fuel beam such as D and T. 14 MeV neutrons are produced from the DT (D+T→n(14.1)+ ^{4}He(3.5)) interactions of impinged fast D and/or T ions with T and/or D atoms embedded in the lattice of the target material. Drive-in target is designed and fabricated by titanium coating (2 μm) on a 30 mm copper disc.

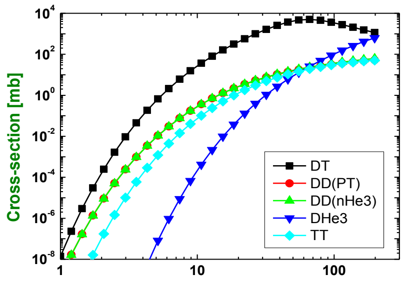

Fig. 2. Major fusion reaction cross-sections as a function of the beam energy, where the target is fixed. [3]

2.3 High Voltage Feedthru

To be an effective neutron generator in a view of ratio of the input power to the neutron yield, the beam energy should be higher than 70 keV as shown in Fig. 2. A feedthru is designed to cover the stable beam higher than 100 keV and fabricated.

2.4 Getter Pump

The D/T gas recycles in sequence through the ion source, target, and getter as described in Fig. 3. Before saturation of the target with D/T gases, there is practically no desorption from the target, and the getter acts only as a gas supplier. After saturation, at the steady state, there is a net flow of D/T gas from the target, according to the beam current subtracted with the diffused flow into the bulk of the target and the loss in fusion reactions.

The pumping speed of the getter depends on the surface area and the specific pumping speed (roughly 0.01 L/s·cm^2 for hydrogenous gases). The pumping rate of the getter whose area is 8 cm^2 is in the range of 10^{-4} mbar·L/s. Some absorbed molecules are associatively desorbed from the getter, and at the steady state the desorption rate makes a quasi-balance with the pumping rate. The minute difference between them corresponds to the net loss of D/T gas in the target.

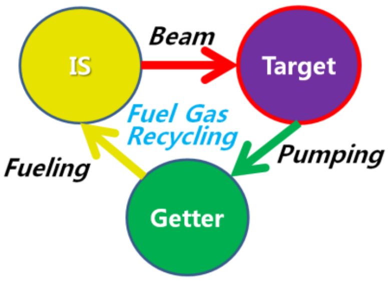

Fig. 3. D/T gas recycles in a portable neutron generator.

3. Experimental Results

3.1 Summary of Fabrication and Experimental Results

The prototype neutron generator is fabricated as shown in Fig. 4, and at this moment beam extraction experiments with hydrogen beam is being made to test ion source and high voltage feedthru. Also to check the characteristics of the commercially available getter material, test block of Fig. 5 is attached to the prototype, and the fuel recycle characteristics has been measured. More detailed experimental results will be summarized at the presentation.

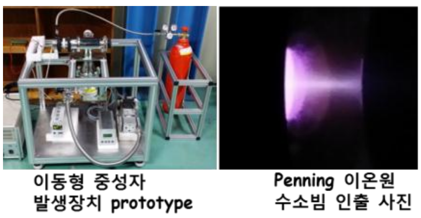

Fig. 4. Photo of the fabricated prototype and extracted beam.

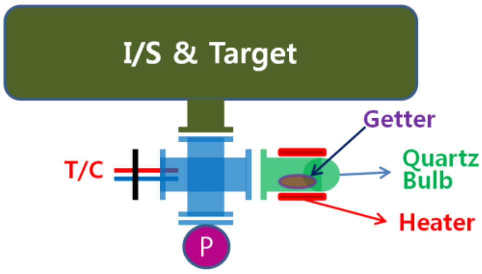

Fig. 5. Layout of getter test system.

3.2 Future Plan

At this moment we are preparing a test to check the characteristics of a drive-in target. To do this, a room with neutron shielding is necessary. And as the shielding room be fixed, the experiments on fast neutron generation and measurement will be executed by injecting deuterium beams on a drive-in target. After finishing the test, all of the experimental results on the developed components will be upgraded and combined together as a portable neutron generator.

And applying similar technologies and process a high flux DD neutron generator of the order of 10^{11} n/s will be designed and developed.

4. Summary

A prototype neutron generator to check the developed components of the planned portable fusion neutron generator is fabricated, and the characteristics of the components are being tested.

REFERENCES

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