§75. Study of an Installation of the Tracer-Encapsulated Solid Pellet (TESPEL) Injector on QUEST for Measuring Various Physical Quantities

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A Tracer-Encapsulated Solid Pellet (TESPEL)[1, 2] has been originally developed in the National Institute for Fusion Science (NIFS) for diagnosing precisely an impurity transport in magnetically-confined high-temperature plasmas. The TESPEL is, simply stated, a double-layered impurity pellet. In general, the TESPEL consists of a polymer as an outer shell and a tracer impurity as an inner core. The significant advantages of the method by using the TESPEL is summarized as follows: 1) a tracer impurity source can be localized 3-dimensionally, 2) the amount of the tracer impurity deposited inside the plasma can be known precisely, 3) various elements (solid only right now) can be loaded into the TESPEL. Nowadays, owing to these advantages, the TESPEL has been utilized extensively also for investigating the transport of heat and high-energy ions, and for studying atomic-molecular processes.

The Q-shu University Experiments with Steady-State Spherical Tokamak (QUEST) was built at the Advanced Fusion Research Center, Research Institute for Applied Mechanics, Kyushu University. The final goal of the QUEST project is to achieve a steady-state plasma with a high beta value (< 10 %) under controlled plasma-wall interactions. To this end, the experiment for a plasma start-up by using a radio frequency (RF) heating has been performed in QUEST. In this experiment, damage to the vacuum vessel wall of QUEST by high-energy ions, which are considered to be existed outside a last-closed flux surface (LCFS), becomes a problem. Therefore, it is an urgent issue in QUEST to evaluate absolute amount of such high-energy ions that exists around the LCFS. In this regard, we proposed to use the TESPEL injection as probes to evaluate the absolute amount of the high-energy particles outside the LCFS. When the TESPEL is injected during such a RF plasma start-up, the ablation process of the TESPEL will be accelerated by collisions with the high-energy particles. Thus, the absolute amount of the high-energy particles can be evaluated from the comparison between calculated and experimentally obtained temporal evolutions of the TESPEL ablation. In addition, when given the TESPEL injection through the different poloidal locations, the spatial distribution of the high-energy particles can be also estimated, even roughly. The purpose of this study is to design the injector of the TESPEL for QUEST.

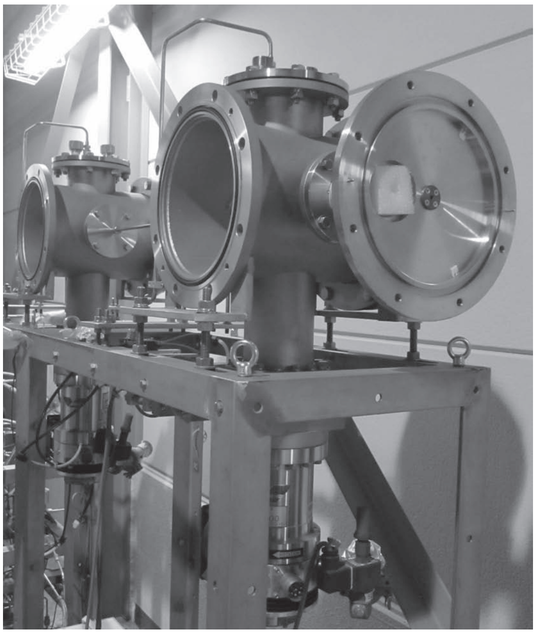

Fig. 1. Photo of the vacuum vessels of the hydrogen pellet injectors, which had been developed in Kyushu University. Since these are currently longtime out of use, these will be diverted to the TESPEL injection system for QUEST.

At the beginning, we determined the size and targeted velocity of the TESPEL for QUEST. The maximum size of the TESPEL will be around 1 mm, which is based on an experience of the TESPEL injection experiments on NSTX spherical tokamak at the Princeton Plasma Physics Laboratory in the United States of America. And then the targeted velocity of the TESPEL will be several hundred m/s, which is almost the same as that for LHD. A basic design of the TESPEL injector for QUEST is almost the same as that for the LHD, which consists of the TESPEL injection system and the differential pumping system. Here, in the TESPEL injection system, a pneumatic pipe gun method is adopted for the pellet acceleration. And then, the differential pumping system is essential for preventing the high-pressure gas for the acceleration from penetrating into the vacuum vessel of QUEST. The differential pumping system in the TESPEL injector for QUEST will have more than three stages, which is more than that for LHD. This is because an ultra-fast electromagnetic shutter valve, which is used for interrupting the flow of the acceleration gas from an injection part of the system for LHD, will not be used in QUEST from a standpoint of cost-saving. In order to make cost saving further, the differential pumping system will cannibalize the vacuum vessels of the hydrogen pellet injectors, which had been developed in Kyushu University, as shown in Fig. 1.

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1) Sudo, S.: J. Plasma Fusion Res. **69** (1993) 1349.
2) Sudo, S. and Tamura, N.: Rev. Sci. Instrum. **83** (2012) 023503.