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Review of recent japanese activities on tritium accountability in fusion reactors

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HIGHLIGHTS

- Review of Japanese tritium-safety research is given from several viewpoints.
- The keywords are tritium accountability and self sufficiency.
- Tritium-relating history, tritium facilities and legal regulation are introduced.

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ABSTRACT

After introduction of Japanese history or recent topics on tritium (T)-relating research and T-handling capacity in facilities or universities, present activities on T engineering research in Japan are summarized in short in terms of T accountability on safety. The term of safety includes wide processes from T production, assay, storing, confinement, transfer through safety handling finally to shipment of its waste. In order to achieve reliable operation of fusion reactors, several unit processes included in the T cycle of fusion reactors are investigated. Especially, the following recent advances are focused: T retention in plasma facing materials, emergency detritiation system including fire case, T leak through metal tube walls, oxide coating and water detritiation. Strict control, storing and accurate measurement are especially demanded for T accountability depending on various molecular species. Since kg-order T of vaporable radioisotope (RI) will be handled in a fuel cycle or breeding system of a fusion reactor, the accuracy of <0.1% is demanded far over the conventional technology status. Necessity to control T balance within legal restrictions is always kept in mind for operation of the future reactor.

1. Introduction (general topics on tritium)

Tritium (T) accountability is the most important issue from viewpoints of fusion reactor safety. T is strictly controlled as fusionable nuclear materials and vaporable radioisotope (RI). Although T atom emits only weak beta ray lower than 18.6 keV, HTO molecule is easily incorporated in human body through breathing or eating and is exchanged with water in cells. According to the ICRP publication 71 [1], HTO incorporated in human body is exhausted to its outside with half residual time of around 10 days. In order to keep in mind T safety, the U.S. T research group published a handbook named "tritium handling and safe storage" in 1999 [2], which provides guidance from the receipt of T source, assay and storing through handling to shipping of T waste. Each T-handling laboratory in U.S. is required to satisfy the accountability of <3.5 TBq (0.01 g) in the full facilities as the DOE-control laboratory. Canada also published a similar handbook for T-handling facilities [3]. Heavy water reactors in Canada produce at a rate of around 2 kg/year T, and T is recovered from D_2O moderator for safety. In our Japan a manual to analyze T in several materials or in atmosphere was published previously from Japanese government [4]. However, recent information to handle a large amount of T aiming at development of fusion reactors is not included in it.

T in a fusion reactor will be present in various forms such as gas (T_2, HT, DT), liquid water (T_2O, HTO, DTO), tritiated methane (CT_4, CT_3H and so on) and other T chemical compounds or organically bound T (OBT) along with liquid solution or tritide in metals or alloys. For examples, T_2 gas is stored in a bed packed with depleted uranium (U) or ZrCo alloy particles, where its tritide form is expressed as UT_3 or $ZrCoT_3$. They absorb T_2 gas at room

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Table 1
T-handling facilities in Japan and handling capacities. Original data in ref. [8] have been modified slightly.

Institute or university T-handling laboratory	Daily allowed usage	Annual allowed usage
Japan Atomic Energy Agency (JAEA)	9.25 PBq	740 PBq
University of Toyama	8.0 TBq	560 PBq
Kyushu University	3.7 GBq	18.5 GBq
Nagoya University	3.7 GBq	370 GBq
Shizuoka University	3.7 GBq	80 GBq
University of Tokyo (Yayoi Lab)	50 GBq	50 GBq
Institute of Laser Engineering, Osaka University	30 TBq	1 PBq
BA IFERC Rokkasho	3.7 TBq	29.6 TBq

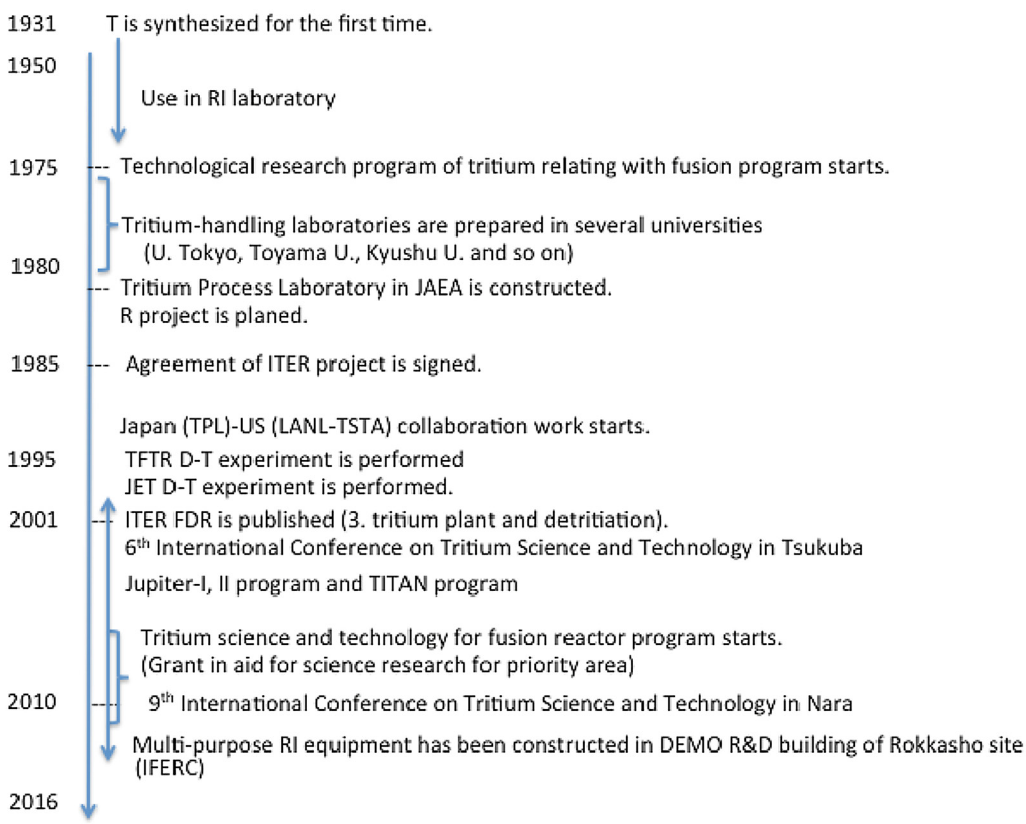

Fig. 1. History of T-relating topics in Japan.

temperature and release it around at 400 °C. In storing or handling T, attention should be paid to at least two facts unique to T that (i) beta decay occurs with the half decay time of 12.3 year, which means annual 5.63% T conversion to He^3 and (ii) T atoms are easily exchanged with H ones adsorbed on container surfaces.

Japanese researchers have been studying various engineering issues related with T accountability using tritium process laboratory (TPL) in Japan Atomic Energy Agency (JAEA), which has daily usage capacity of 9.25 PBq/day (26 g). BA research laboratory in Rokkasho International Fusion Engineering Research Center (IFERC) has a capacity of 3.7 TBq/day and T-handling laboratories in several universities has capacities of 3.7 GBq/day–8 TBq/day (around 0.1Ci– 200 Ci/day) as summarized in Table 1. The law concerning prevention from radiation hazards in Japan, on the other hand, decides the maximum permissible concentration in wastewater is <60 Bq/cm^3 and that in air exhaust is <70 Bq/cm^3 for HT and <5 mBq/cm^3 for HTO, which values are set to be radiological dose lower than 1 mSv/year according to the ICRP recommendation. The difference in Derived Air Concentration (DAC) between HT and HTO comes from the fact that the radiation hazard of HTO is 25,000 times higher than HT [5]. All those tritiated compounds are measured correctly and controlled lower than the specified concentration or amount.

Although RI including T has been handled in several universities also in Japan before the World War II since T atom was synthesized by the D-D nuclear reaction for the first time in 1931, the technological research program of T relating with fusion program started actually in 1975 [6] as seen in the history table of Fig. 1. Specially designed T-handling laboratories started constructed in several universities since 1976. Daily T handling amounts in universities at present are in an order of GBq-TBq. TPL was constructed in the JAEA Tokai site in 1982. The Reacting Plasma Project (R project) was planed at 1980 in National Institute for Fusion Science (NIFS) [7]. Since then, T activities in Japan have increased year by year, and a lot of papers and proceedings have been published. International Conference on Tritium Science and Technology was held two times in Japan (6th Tsukuba 2001, 9th Nara 2010). The program of T science and technology for fusion science Grant-in-Aid for Scientific Research on Priority Area of Ministry of Education, Culture, Sports, Science and Technology (MEXT) was conducted from 2006 to 2011, and a lot of publications are given in the home page [8]. A lot of Japanese research activities are continued in various

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