§ 10. Computer Simulation of the Processing of Tritium in Exhaust Gas from the LHD

Kawano, T., Sakuma, Y.,
Kabutomori, T. (The Japan Steel Works Ltd.),
Shibuya, M. (JGC Corporation)

The development of a tritium cleanup system has been proceeding over the last few years based on a new concept. A significant characteristic of the system is that the tritium is removed from the exhaust gases in the form of hydrogen molecules. The system essentially consists of three components: a hydrogen separator, a decomposition-processing vessel and a hydrogen-absorbing vessel. Of these components, the decomposition-processing vessel carries out the conversion of tritium from the various chemicals in which it occurs into tritium gas. The system includes two additional important components: a buffer tank and a circular pump, which are necessary for practical operation. To investigate the performance of the system, we have used computer-based simulation. The performance of the cleanup system will be strongly dependent on the selection of these component devices. Table 1 shows the component devices we selected in the present study. In the simulation, the exhaust gas for processing in each batch was assumed to be 1 Nm^3, to contain 1 GBq of tritium and to be made up of 90% hydrogen, 5% methane and 5% helium and we examined the partial pressures of hydrogen, methane, a both-sum pressure (hydrogen + methane) and a total-sum pressure (hydrogen + methane + helium).

Table 1 Selection of component devices

Components devices	Selection
① Hydrogen separator	Hydrogen purifier: JLS-30E (Jpn Pionics)
②Hydrogen-absorbing vessel	Manufacturing: Titanium
③Decomposition-processing vessel	Manufacturing: ZrNialloy
④ Circler pump	Scroll vacuum pump: PV-12 (Normetex)
⑤ Buffer tank	Not specified: 6 m^3

Fig. 1 was obtained as a result of the simulation. The figure shows the changes in the partial pressures of hydrogen, methane and helium. A 'both-sum' pressure and a 'total-sum' pressure are also shown in Fig. 1. The partial pressure of hydrogen decreases rapidly, and the rate of this decrease is faster than that for the methane. This means that the hydrogen-separating capacity is sufficiently large and the partial pressure of hydrogen never increases although the process of methane decomposition is generating hydrogen. The change in the partial pressure of hydrogen is characterized by a marked change in the trend at an elapsed time of about 2.1 hours. This corresponds to the time at which one cycle of gas processing had been completed, and suggests that the curve of hydrogen partial pressure is a composite of two curves, one attributable to hydrogen separation and the other to methane decomposition. The first half of the curve, i.e., the part before this completion of one cycle, is dominated by the hydrogen that was initially contained in the gas being processed. The later half is dominated by the hydrogen that has been generated by methane decomposition. The curve of the both-sum pressure thus follows that for the partial pressure of hydrogen over the first two hours and then almost exactly corresponds to the curve for the partial pressure of methane. It is noteworthy that almost all of the hydrogen which had initially been contained in the exhaust gas was removed within one cycle. After that, the curve for the pressure of hydrogen reflected the generation of hydrogen by methane decomposition.

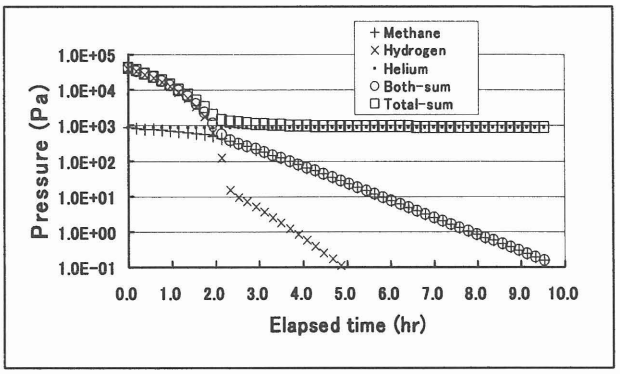

Fig. 1 Changes in the partial pressure of hydrogen, methane, helium, the sum for both and the total pressure.

The curve for total pressure also has a marked change of trend. This change appears at almost the same elapsed time (about 2.1 hours) as that at which the partial pressure of helium became dominant over the total-sum pressure. This was because the hydrogen and methane were being removed by the loop of separator and decomposition processes while the helium remained as it was not affected by these processes. It is important to note that the total pressure did not exceed atmospheric pressure (1×10^5 Pa), since this demonstrates that the tritium would not leak from the system to the environment outside the system.

The Japanese law on radiation protection places a limit of 5×10^{-1} Bq/cc on the concentration of tritium in a working place which is a controlled area. We thus discuss the point at which the concentration of tritium in the gas being processed falls below this limit. After processing of the gas has made sufficient progress, the helium occupied almost 100% of the process gas. This is because the initial volume of helium is retained in the mixture during the whole period of processing, although the volumes of hydrogen and methane decrease. This leads us to the assumption that all of the tritium that is not yet removed is contained in the 50 Nl of helium when the tritium concentration has reached the limit. At this time, the radioactivity of the tritium in the helium gas is 25000 Bq, which corresponds to a both-sum pressure of 0.40 Pa. This pressure was realized about 8.7 hours after the start of processing, as is indicated in Fig.1. Consequently, it is possible to envisage a situation in which the exhaust gas generated in a DD-plasma experiment is accumulated in a buffer tank during the daytime and the tritium is removed from the gas in a batch process carried out at night, commencing on the same day. The cycle of a plasma experiment in the daytime and the batch process of removing tritium at night may be repeated as a daily routine under the gas conditions described.