PRELIMINARY DESIGN OF TRITIUM CLEANUP SYSTEM FOR THE LARGE HELICAL DEVICE

Y. SAKUMA, H. YAMANISHI, T. UDA and H. HIRABAYASHI
National Institute for Fusion Science
Furo-cho, Chikusa-ku, Nagoya 464-01, Japan

At the National Institute for Fusion Science, we are planning to carry out DD experiments using the Large Helical Device, in the near future. The device will generate a small amount of tritium, as a fusion product. In order to remove it from the exhaust, we have designed a tritium cleanup system based on a new concept. This system is mainly composed of a palladium permeater, a decomposer and hydrogen absorbing alloys. It could perfectly recover the tritium without oxidizing it.

1. Introduction

When DD experiments using deuterium are carried out in a nuclear fusion experimental facility, tritium is bound to be generated, though the amount may be slight. Here at the National Institute for Fusion Science, we are planning to carry out DD experiments as a second stage program for the Large Helical Experimental Device (referred to as a "LHD" hereafter). The world's largest helical device is now under construction. The completed LHD will have a major radius of 3.9m and utilize superconducting coils to generate its magnetic field. The main goal of the project are the demonstration of currentless state plasma operation and the achievement of reactor-relevant plasma parameters.

Since the disposal of generated tritium within the Laboratory is our policy, it is necessary to develop a tritium cleanup system. To recover tritium discharged from the experimental facility, it is usual to employ a system (referred to as "wet system" hereafter) by which the entirety of gas including tritium is converted to water vapor by catalytic oxidation so as to adsorb the vapor by a molecular sieve. However, it is not rational to

deliberately convert the discharged tritium from the elemental state into water vapor, the latter one affects human body 15,000 times more strongly. Besides, in the wet system the device generally tends to become in size. In view of this, we have developed a tritium cleanup system (referred to as "dry system" hereafter) by which the elemental tritium is fixed directly to hydrogen absorbing alloys which have not so far been developed at any other place.

2. DESIGNING

Because of the LHD exhaust composition is unclear, we assumed it as shown in table 1. The device will at most generate 430GBq of tritium a year. We assumed all of the tritium would be exhausted during normal operation (DD experiment) and discharge cleaning operation. This means the device will exhaust 430GBq of tritium during normal operation and will also exhaust 430GBq of tritium during discharge cleaning operation. In table 2 we showed design conditions of the exhaust of the LHD.

Table 1 Assumption of LHD exhaust

Operating condition		Normal operation	Discharge cleaning
Flow rate [Nm^3/hr]		0.1404	1.4400
Composition [Nm^3/hr]	He	0.0014	1.4400
	H_2, HD, D_2	0.1359	
	HT, DT	4.27×10^{-9}	3.17×10^{-7}
	H_2O, HDO, D_2O	0.0003	
	HTO, DTO	8.84×10^{-12}	
	CH_xD_y	0.0028	
	CH_xD_yT	1.77×10^{-10}	
Pressure [Pa]		1.3	1.3
Temperature [℃]		20	20
Activity [MBq/Nm^3]	HT, DT	1.50×10^{4}	1.07×10^{4}
	HTO, DTO	3.1	
	CH_xD_yT	30.9	

Table 2 Tritium concentration of the outlet of the cleanup system with the legal regulation level [kBq/Nm^3]

	Q_2	Q_2O
Dry system	1.4	64.9
Wet system	0.3	0.0
Regulations		
Labo. air	2.0×10^{10}	7.0×10^{5}
Exhaust air	9.0×10^{7}	5.0×10^{3}

Q means one of hydroigen isotopes; H,D,T.

The main constituent of the exhaust of the experimental facility for DD experiments is deuterium, but there are also mixed a trace of helium and its tritium compounds and a variety of impurities. It is an easy task to remove elemental hydrogen isotopes, namely, protium, deuterium and tritium (referred to simply as "hydrogen" hereafter), from the mixture of hydrogen and helium if one employs hydrogen absorbing alloys. However, it will no longer be a simple matter if there are mixed water vapor, Methane and the like even in a small amount. Such impurities are actually included in the exhaust of a fusion experimental facility. We have completed a conceptual design for a tritium cleanup system in which a nonvolatile getter (decomposer) material is employed to let it adsorb carbon and oxygen generated by the decomposition of these impurities caused by the decomposing material. And hydrogen absorbing alloys employed to let it adsorb the elemental hydrogen, where these materials may be stored or disposed of as deemed necessary.

We have examined the case where titanium is used as a hydrogen absorbing alloy and Zr_3Al_2 is used as a nonvolatile decomposing material. For titanium is has a low equilibrium hydrogen pressure and is inexpensive[1] and there is an available report as to the decomposing material's action on methane[2]. The result of design, of a dry tritium cleanup system as shown in Table 2, for the exhaust system in the LHD revealed that the outlet concentrations are 0.0kBq/m^3 for water vapor tritium and 0.3kBq/m^3 for elemental tritium. In contrast to the outlet concentrations of the wet system previously designed are 64.9kBq/m^3 for water vapor tritium and 1.4kBq/m^3 for elemental tritium. So that it is obvious that the dry system is far more advantageous from the viewpoint of safety.

The comparison of the dry system and the wet system is shown in Table 3. The flow chart of the system is shown in Fig.1. The flow rates, the temperatures and the tritium concentrations at each part are shown in Table 4. The table (a) is in the case of normal operation and (b) is in the case of discharge cleaning operation.

3. CONCLUSION

A tritium cleanup system by which the elemental tritium is fixed directly to absorbing alloys have been developed. It could perfectly recover the tritium from the exhaust of the Large Helical Device.

References

1) W.M.Muller. J.P.Blackledge and G.G.Libwitz, Metal Hydrides, Academic Press, New York and London (1968)

2) H.Heimbach, H.R.Ihle and C.H.Wu, Removal of Nitrogen and Methane from Hydrogen by Metal Getters, Fusion Technology 1984, Vol.1, 421-426 (1984)

Table 3 Comparison of dry and wet tritium cleanup systems

Item	Dry system	Judg.	Wet system	Judg.
Waste amount	~800kg-alloy/yr, 60L×8	△	~320kg-water/yr	○
Storage space of waste	~30m^2×4m/yr Storage in two layer	△	~16m^2×4m/yr Storage in 5m^3 vessels	○
Treatment of impurities	Reduction by nonvolatile getter Few data for methane treatment	?	Oxidation by palladium catalyst	○
Safety	Gas phase waste is safer than liquid phase Can be treated as solid except fire and broken at the same time	○	Waste vessels have to be strong	△
System cost	Flow rate is 1/100 compered with wet system Vacuum line is needed	○	Air has to add in order to oxidize hydrogen	△
Concentration of tritium in treated gas	Can be evacuated directly cf. Table 2	○	Can not be evacuated directly cf. Table 2	△
Utilities	Electricity Cooling water Hydrogen Vessels of hydrogen absorbing alloy	○	Electricity Cooling water Humidifying water Pressurized air	○

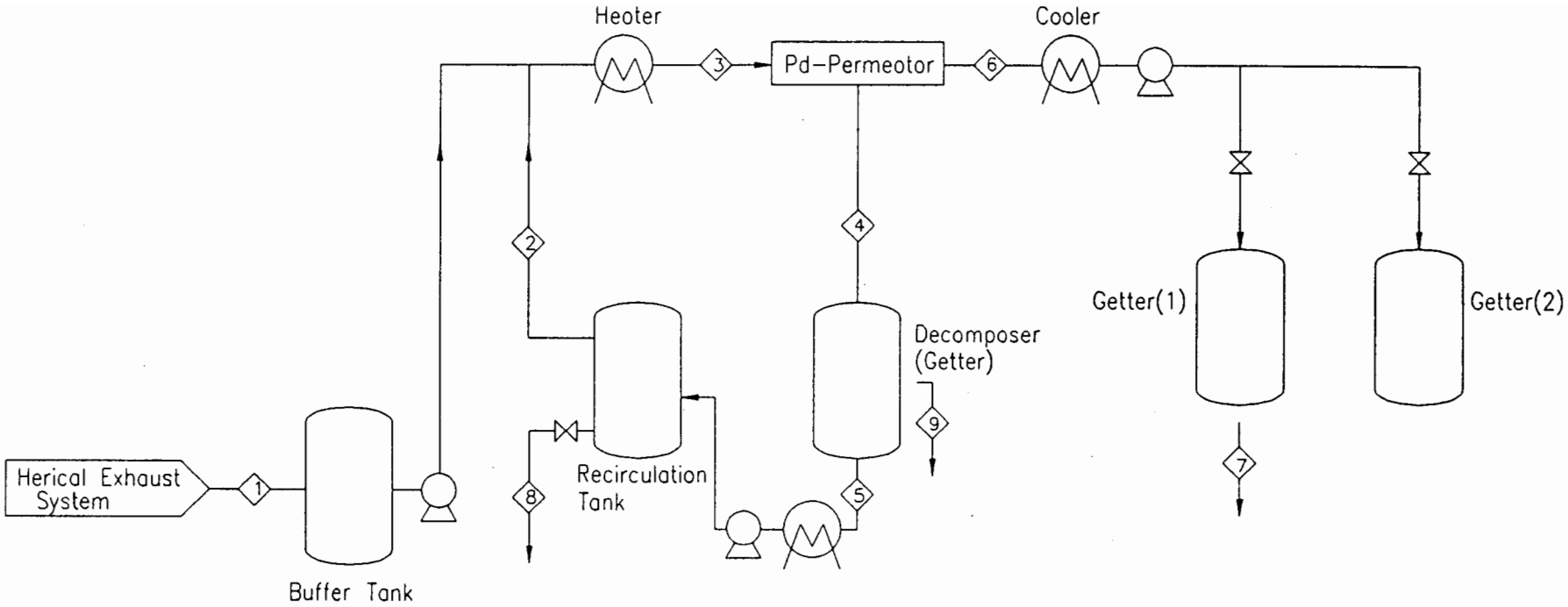

Fig.1 Flow chart of the tritium cleanup system

Table 4 The flow rates, the temperature and the tritium concentaration at each part of the system
(The numbers are corresponding to the numbers in Fig.1.)

(a) In the case of normal operation

Number in Fig. 1		1	2	3	4	5	6	7	8	9
Item		LHD exhaust	Recirculation gas	Permeator in	Permeator out	Decomposer out	Refined gas	Getter (Waste)	Exhaust gas	Getter (Waste)
Flow rate [Nm^3/hr]		0.1404	0.2633	0.4037	0.2620	0.2648	0.1418	1.42×10^{-10}		
Composition [Nm^3/hr]	He	0.0014	0.2500	0.2514	0.2514	0.2514	1.42×10^{-10}	1.42×10^{-10}		
	H_2, HD, D_2	0.1359	0.0133	0.1492	0.0075	0.0134	0.1418			
	HT, DT	4.27×10^{-9}	6.03×10^{-10}	4.87×10^{-9}	2.44×10^{-10}	6.07×10^{-10}	4.63×10^{-9}			
	H_2O, HDO, D_2O	0.0003		0.0003	0.0003					
	HTO, DTO	8.84×10^{-12}		8.84×10^{-12}	8.84×10^{-12}					
	CH_xD_Y	0.0028		0.0028	0.0028					
	CH_xD_YT	1.77×10^{-10}		1.77×10^{-10}	1.77×10^{-10}					
He discharge [Nm^3/batch]									0.0112	
Getter [kg/yr]								727.8		57.5
Pressure [Pa]		1.3	7.0×10^{4}	7.0×10^{4}	7.0×10^{4}	6.5×10^{4}	1.3	1.0×10^{-4}	7.0×10^{4}	
Temperature [℃]		20	70	450	450	600	450	20	70	
Activity [MBq/Nm^3]	HT, DT	1.50×10^{4}	61.6	561.0	44.1	61.6	1515.5		2.61×10^{-4}	
	HTO, DTO	3.1		1.1	1.7					
	CH_xD_YT	30.9		10.8	16.6					

(b) In the case of discharge cleaning operation

Number in Fig. 1		1	2	3	4	5	6	7	8	9
Item		LHD exhaust	Recirculation gas	Permeator in	Permeator out	Decomposer out	Refined gas	Getter (Waste)	Exhaust gas	Getter (Waste)
Flow rate [Nm^3/day]		1.4400	0.1000	2.5400	1.5400	1.5400	1.0000	1.54×10^{-9}	1.4400	1.000
Composition [Nm^3/day]	He	1.4400	0.100	1.5400	1.5400	1.5400	1.54×10^{-9}	1.54×10^{-9}	1.4400	1.0000
	H_2, HD, D_2		1.43×10^{-9}	1.000	2.20×10^{8}	2.20×10^{8}	1.000		2.06×10^{-8}	
	HT, DT	3.17×10^{-7}	4.53×10^{-16}	3.17×10^{-7}	6.97×10^{-16}	6.97×10^{-16}	3.17×10^{-7}		6.52×10^{-16}	
	H_2O, HDO, D_2O									
	HTO, DTO									
	CH_xD_y									
	CH_xD_yT									
He discharge [Nm^3/batch]										
Getter [kg/yr]								71.9		
Pressure [Pa]		1.3	7.0×10^{4}	7.0×10^{4}	7.0×10^{4}	6.5×10^{4}	1.0×10^{-6}	1.0×10^{-6}	7.0×10^{4}	
Temperature [℃]		20	70	450	450	600	450	20	70	
Activity [MBq/Nm^3]	HT, DT	1.07×10^{4}	2.20×10^{-4}	6.06×10^{3}	2.20×10^{-4}	2.20×10^{-4}	1.54×10^{4}		2.20×10^{-4}	
	HTO, DTO									
	CH_xD_yT									