MHI's Activities on Tritium Technology

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MHI has been developing tritium technology for more than 20 years, mainly in the following fields concerning thermonuclear fusion reactors.

1 Isotope separation system by cryogenic distillation.

2 Fuel clean up system by palladium permeation and electrolysis cell method.

3 Tritium recovery system from the blanket by palladium permeation method.

4 Blanket materials, mainly the development and charactarization of Li ceramic.

5 Tritium removal system by tritium oxidation catalysis.

Based on the tritium technology recenthy attained through the above developments, MHI has built a tritium treatment installation where MHI can treat 2.2×10^{12}Bq(6Ci) of tritium per year.

1.Introduction

MHI has been researching tritium treatment technology in developing fission reactors, fuel cycle processes and fusion reactors.

As for tritium technology in fusion reactors, MHI has mainly participated in the development of a fusion reactor fuel cycle system, blanket materials, and the tritium removal system.

Tritium gas flow mainly consists of the following three flows.

FIG. 1 shows the concept of hydrogen isotope flows in a thermal fusion reactor system.

(1) Tritium fuel cycle process flow

Tritium from the fuel storage system is supplied to the fusion reaction vessel by the gas puffing system and the ice pellet injection system, recovered from the reaction vessel, transferred to the fuel cleanup system, enriched by the isotope separation system and recovered in the storage system.

(2) Fusion blanket circulating flow

Tritium is generated in the blanket and recovered by the blanket tritium recovery system, enriched by the isotope separation system and stored in the fuel storage system.

(3) Tritium flow concerned with tritium removal systems

Tritium, in various states kinds of exhausted gas, is recovered from the tritium treatment equipment are recovered by the tritium recovery system.

Tritium released to the atmosphere is removed by the gas cleanup systems.

MHI has participated in almost all the developments of the systems and equipment concerned with the tritium flows mentioned above.

However, MHI's main concern has been with the developments of the fuel pellet injector, the fuel cleanup system, the isotope separation system, Li ceramics as blanket material and the tritium removal system.

This paper introduces several results of these developments.

Recently MHI has built a tritium treatment facility to develop tritium applied technology.

At present the facility is used for the fabrication of pulsed neutron generators.

This paper also introduces the concept of the facility.

2.Tritium fuel cycle process

2.1 Isotope separation system

MHI, based on the fundamental concept of JAERI, designed and constructed an experimental isotope separation system for the tritium process laboratory of JAERI(1985-1987).

MHI also assisted JAERI to design a Japanese plan for an isotope separation system for an experimental reactor(1988-1996).

FIG. 2 shows an example of the design for the experimental reactor.

The design was conducted using an isotope separation system design code developed by MHI.

The isotope separation system consists of combining of a distillation column and a hydrogen isotope equilibrator.

The first column separates hydrogen from deuterium and tritium and the second column separates deuterium from 70% enriched tritium.

2.1 Fuel cleanup system

MHI, based on JAERI's fundamental idea, designed and constructed an experimental fuel cleanup system at the tritium process laboratory of JAERI(1986-1987) and another at TSTA in Los Alamos(1989) for the collaborative experiments between JAERI and the Los Alamos laboratory.

MHI also assisted JAERI to design a Japanese plan for a fuel cleanup system for an experimental reactor(1989).

FIG. 3 shows the concept of the cleanup system for the experimental reactor.

Hydrogen gas isotopes are separated from impurities using a palladium diffuser 1, and the hydrogen oxide in the impure gas is reduced to hydrogen gas using a ceramic electrolysis cell.

The hydrogen gas generated there is separated by a palladium diffuser 2.

Methane, in the impure gas from the diffuser 2, is oxidized by a catalyst reactor to CO_2, Q_2O (Q means H, D or T).

Q_2O is trapped in a cold trap and other impurities are sent to the tritium removal system.

Q_2O in the cold trap is recycled to the ceramic electrolysis cell.

3. Fusion blanket

3.1 Blanket tritium recovery system

MHI assisted JAERI to design a Japanese plan for the blanket tritium recovery system for an experimental reactor.

FIG. 4 shows the concept of the blanket tritium recovery system for the experimental reactor.

The blanket is assumed to contain Li_2O pebbles as a tritium breeder.

Helium gas is circulated between the blanket and the blanket tritium recovery system.

Hydrogen gas from the isotope separation system (specially arranged to enrich the recovered tritium from the blanket) is added to He gas at the inlet of the blanket to accelerate the release of tritium from the Li_2O pebbles.

Q_2O in He gas flow from the blanket is trapped in a molecular sieve bed and the dried He gas containing hydrogen and tritium gas is compressed to a cryogenic molecular sieve bed and cooled with liquid nitrogen.

Tritium with hydrogen is adsorbed in the cryogenic molecular sieve bed and He gas is recycled to the blanket.

The cryogenic molecular sieve bed is heated periodically and desorbed tritium hydrogen mixed gas is sent to the palladium diffuser by a vacuum pump, permeates the palladium diffuser and is then sent to the isotope separation system where hydrogen gas is separated from tritium and recycled to the He gas flow at the inlet of the blanket.

2.2 Compatibility of blanket structure materials with Li ceramics

MHI has developed a fabrication method for various kinds of Li ceramics to supply them for neutron irradiation testing at JAERI.

In addition, MHI, proceeded with a series of cold tests to characterize Li ceramics, such as compatibility tests, mass transfer tests and thermal cycle tests for Li ceramics and Be.

Following are the results of the compatibility tests between Li ceramics(mainly Li_2O)and a stainless steel(mainly PCA) blanket structure.

FIG.5 shows the apparatus for the compatibility tests.

He gas was circulated between a moisture generator and the reaction component, a temperature controlled vacuum vessel in which the test samples were inserted.

Samples for the compatibility tests were arranged using a sandwich method .

After exposing a sample to the circulating He gas, the structure material and the Li ceramic of the sample were separated and analyzed individually using SEM, EPMA, XD, ICP, IMA, etc.

Table 1 shows the concentrations of the structure material elements in Li ceramics after exposure .

At temperatures under 550 ℃ the concentrations of elements in Li_2O changed little and had similar concentrations as the original samples. At 650℃ however, the concentration of Fe greatly increased and at 750℃ Ni also increased.

For structure materials, testing, reaction layers were observed by SEM, OM, EPMA, IMA and the crystal forms of these layers were analyzed by XD.

Structure material tensile strength tests were also carried out.

After 500 hrs of exposure to a PCA/Li_2O sample in circulating He gas at 750℃, with a moisture level of 200ppm, the decrease in strength of PCA was about 10% after 200 hrs remained seemed fairly stable thereafter.

Based on these compatibility tests, it is recommended that Li_2O be placed in the blanket at the temperatures under 550℃ with a moisture level under 200ppm.

However the compatibility tests did not include tests on the effect's of radiation, that can occur in the actual blanket.

4. Tritium removal system

In 1995, MHI started research and development for a tritium removal system using oxidation catalysis and a molecular sieve bed.

FIG. 6 shows the representative data of oxidation coefficients for Pt and Pd on Al_2O_3 pellets for tritium gas These were estimated using the following formula on the experimental data.

$K=(Q/V)\ln(Co/C)$

K(1/min):oxidation coefficient

Q(NL/min):gas flow rate

V(L):volume of catalysis

Co(ppm):tritium concentration at the inlet of the oxidation reactor

C(ppm):tritium concentration at the outlet of the oxidation reactor.

FIG. 7 shows the oxidation coefficients for CH4.

The oxidation coefficient of Pd is higher than that of Pt.

5. MHI tritium treatment facility

MHI has a radiation controlled area at Omiya City, where MHI can work with many kinds of radioactive isotopes.

There, MHI performed several tests involving tritium removal.

In these tests, the amount of tritium was less than 100mCi annually.

During the last year, MHI completed a tritium treatment facility where a maximum of 6 Ci of tritium can be tested per year.

At present the facility is used for the manufacturing of pulsed neutron generators.

The neutron generator emits neutrons by D-T fusion reaction induced by the collision of accelerated deuteron or triton with deuteron or triton in the target.

Deuterium and tritium mixed gas is supplies from a reservoir made with hydrogen absorption metal and an electric heater.

MHI will continue to develop application technology for the pulsed neutron generator.

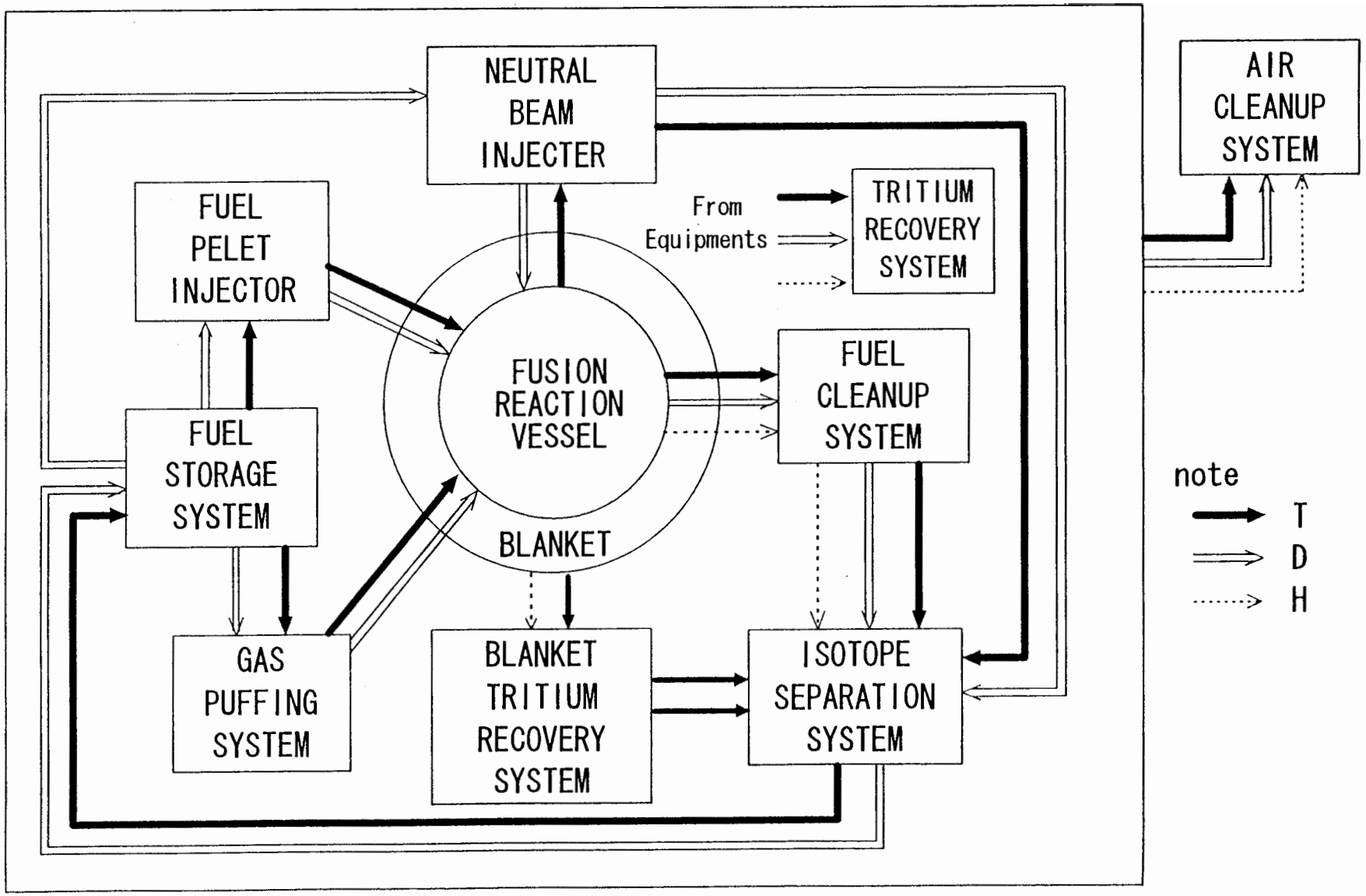


FIG.1 Concept of Hydrogen Isotopes Flows in Thermal Fusion Reactor System

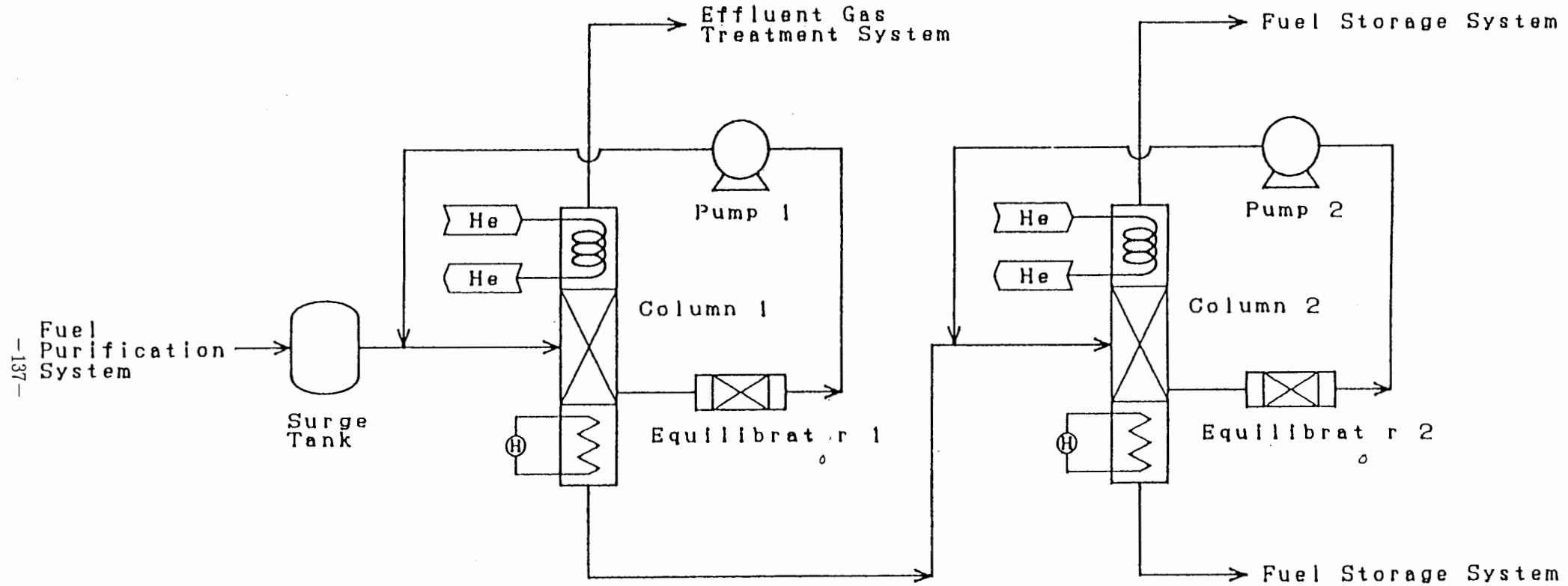


FIG.2 Isotope Separation System Concept

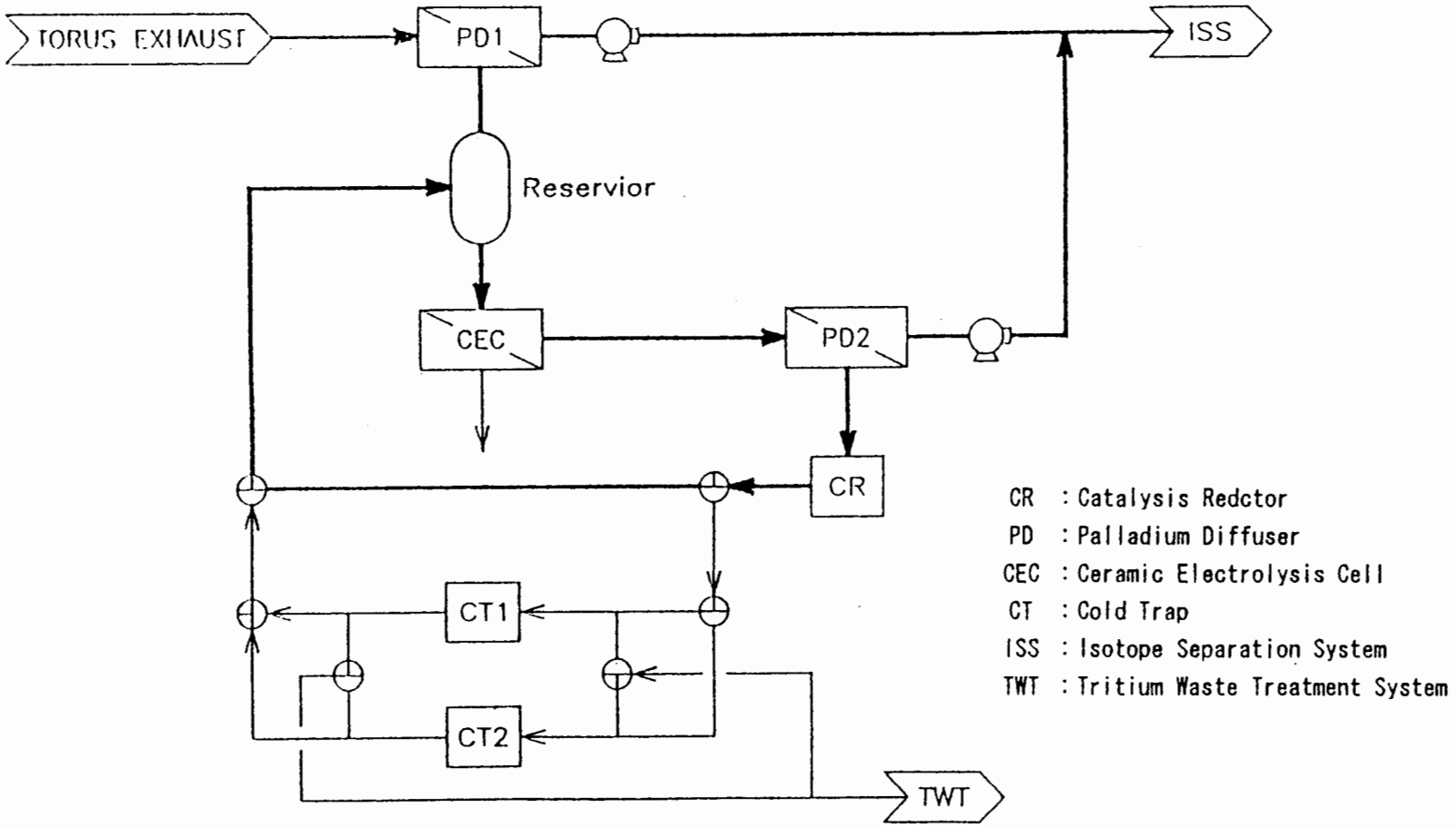


FIG.3 Fuel Cleanup System Concept

MSB : Molecular Sieve Bed
CMSB : Cryogenic MSB
Pd : Palladium Diffuser

ISS : Isotope Separation System
TWT : Tritium Waste Treatment System
LWT : Low Level Waste Treatment System

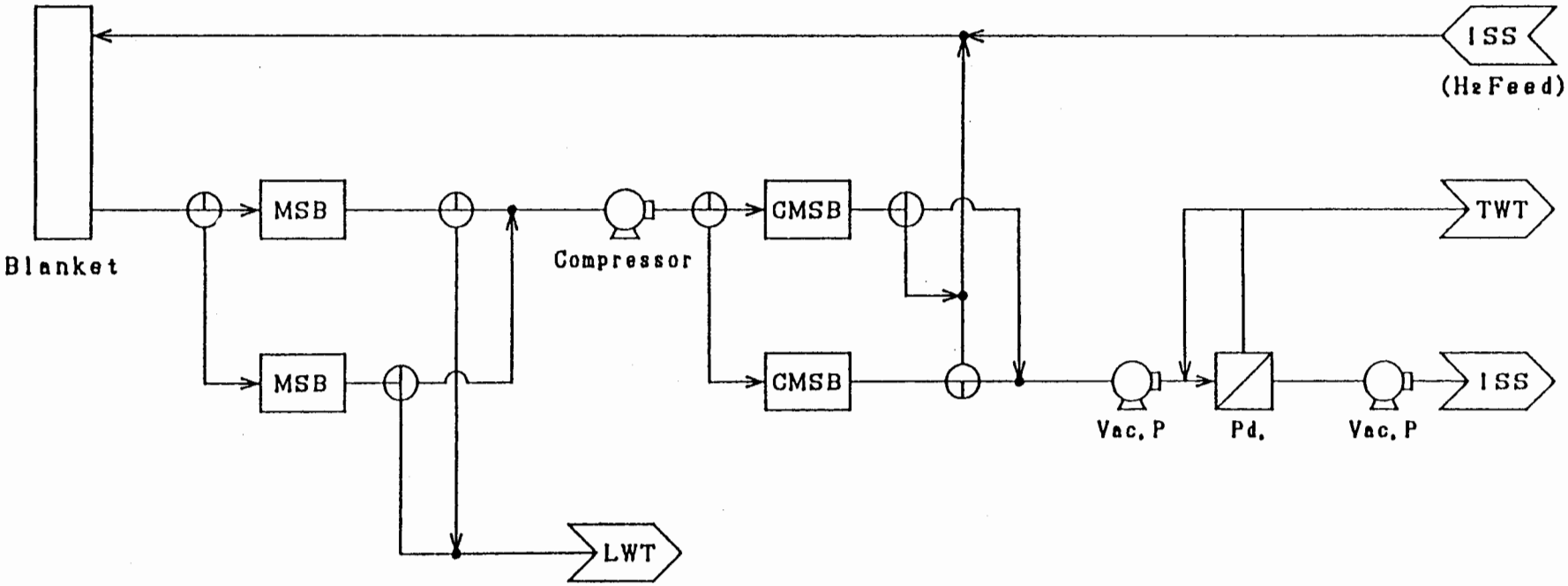
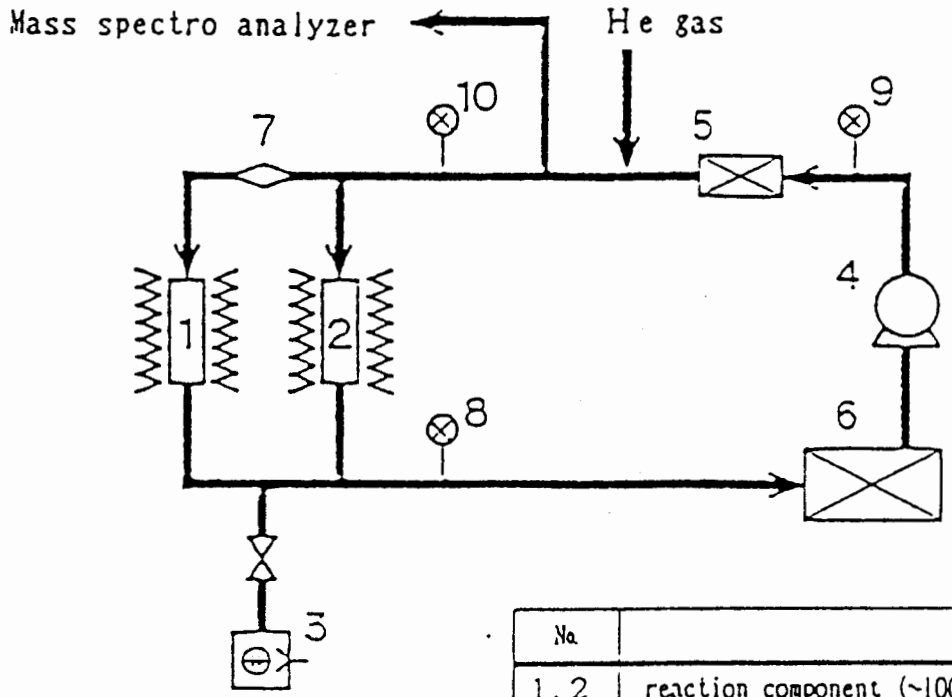


FIG.4 Blanket Tritium Recovery System Concept



No.	
1, 2	reaction component (~1000°C)
3	turbo molecular pump
4	circular pump (~5 ℓ/min.)
5	adsorption bed
6	moisture generator (0.5~1000ppm
7	helium gas devider
8, 9, 10	hygrometer sensor

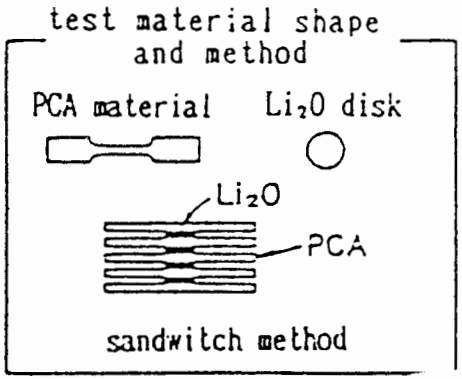


FIG.5 Compatibility Tests Aparatus Concept

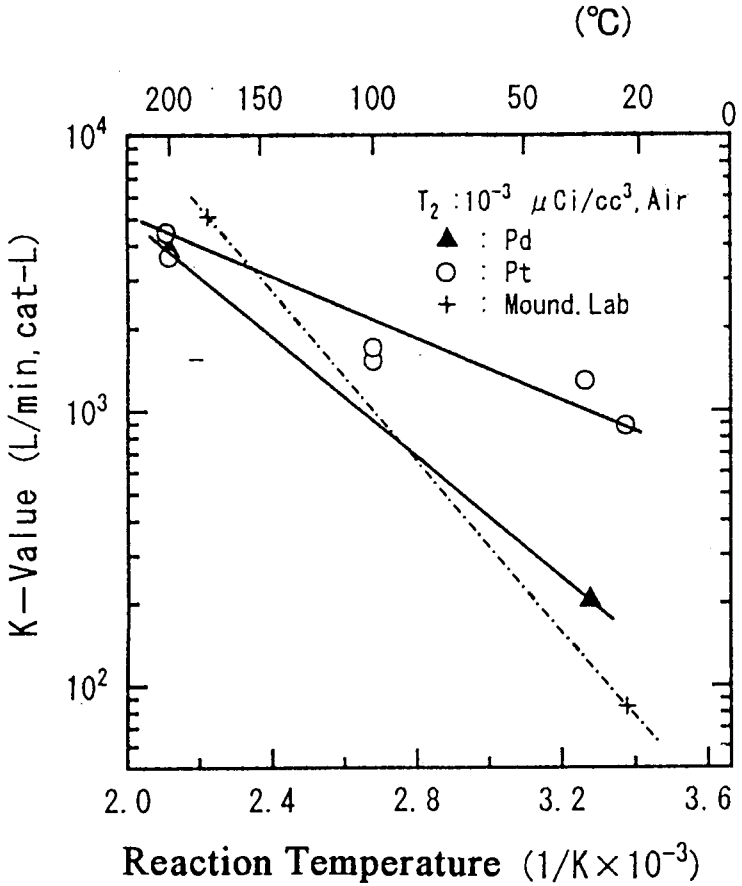


FIG6. Tritium oxidation coefficient of Pd and Pt catalyst

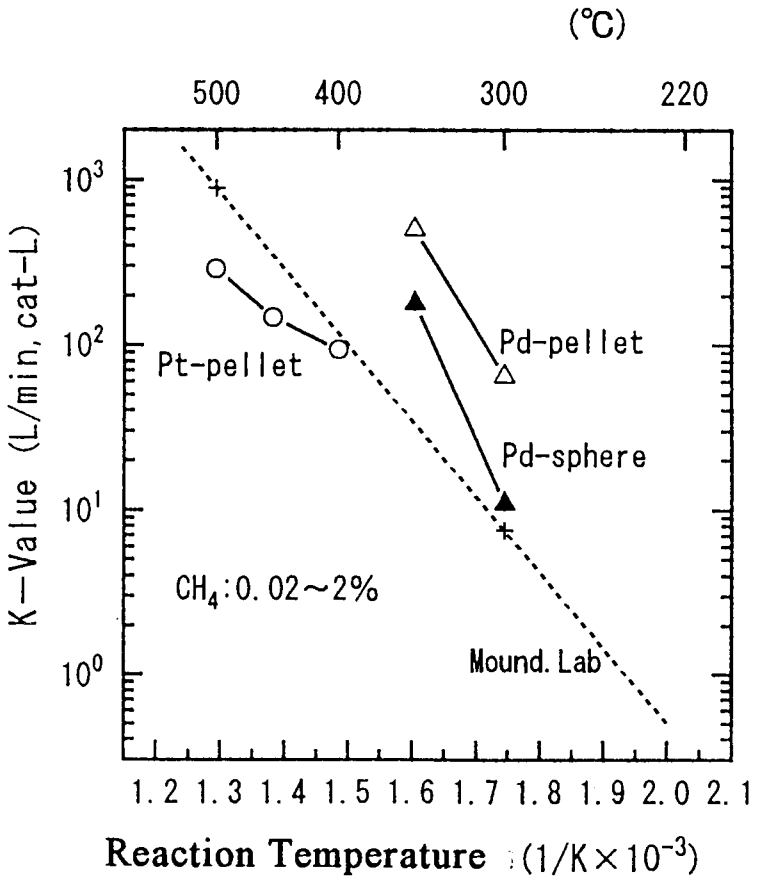


FIG7. CH_4 oxidation coefficient of Pd and Pt catalyst

TABLE1 Metal Element Concentrations in Li Cermics after exposure to He flow

Materials	Test time (Hr)	Test temp. (℃)	Water (ppm)	Elements (ppm) Fe	Ni	Cr
Li_2O Reference	——	——	——	32	1.9	2.7
Li_2O/PCA	50	750	200	4569	7.2	*1 ND
Li_2O/PCA	100	750	200	13784	37.5	ND
Li_2O/PCA	150	350	200	33.0	3.3	4.5
		450		34.1	4.3	4.6
		550		26.0	2.0	3.3
		650		640	3.6	2.9
		750		33100	50.0	5.1
Li_2O/PCA	150	750	2000	19233 (20%)	3483 (3.1%)	33.9 (1.8%)
Li_2O/PCA	500	750	1	7200	89	38
Li_2O/PCA	500	750	200	47600	82	3.1
Li_2O/SUS316	50	750	200	3984	41.2	ND
Li_2O/SUS316	100	750	200	15760	368	ND
Li_2O/SUS316	150	350	200	28.4	2.7	3.5
		450		31.0	2.5	3.7
		550		44.2	2.9	3.3
		650		471	26.3	9.3
		750		15480	691	52.9
Li_4SiO_4/PCA	150	750	200	1741	26.6	3.3
Li_2ZrO_3/PCA	150	750	200	30.5	5.5	0.4

* 1 N.D Non Detect