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REDUCTION OF HYDROCARBON IMPURITIES IN 200 L/H

HELIUM LIQUEFIER-REFRIGERATOR SYSTEM

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ABSTRACT

A cryogenic system with the capacity of 200 l/h or 500 W at 4.4 K has been operated to develop the superconducting conductors and coils for the LHD. The system has contributed in various superconducting technologies along with the dc 75kA power supply and 10 MN mechanical testing machine, and completed the basic R&D works of the LHD. On the way of operating the cryogenic system, impurity densities of hydrocarbon gases in circulating helium gas became much larger than the expected values for this cryogenic system, so that the densities of some impurity gases were carefully monitored in reference to the operational conditions of circulating compressor by using a gas chromatography. Impurity gas densities of oxygen, nitrogen and ethane increased obviously, when the output capacity of the compressor was reduced. In a two-stage oil injected compression system with a variable stroke mechanism for a first stage, a reduction in the capacity of the first stage leads to a larger compression ratio for the second stage, and the temperature of the injected oil becomes higher. The production of the impurities in the helium might be caused by cracking a part of injected oil in the compressor. The compressor, therefore, was reconstructed such that the injection oil is supplied sufficiently and the compression ratio division becomes even for each stage. It was confirmed that the impurities are not produced now after modification.

Keywords : cryogenic system, impurities, hydrocarbon gases, circulating
compressor, lubricating oil

INTRODUCTION

The Large Helical Device (LHD) [1], [2] is a heliotron type fusion experimental device and it consists of fully superconducting coils with the total stored magnetic energies of 1.6 GJ. It is not easy to fabricate such large coils so that the R&D program to develop the superconducting (SC) conductors and winding technologies for the LHD was started in 1989. For the program, the SC magnet test facilities including the 8 Tesla split coil for the SC short samples test and four SC R&D magnet tests, the 10 MN mechanical testing machine, a dc 75 kA power supply systems have been fabricated [3]-[6]. A helium liquefier-refrigerator system with the capacities of 200 l/h and 500 W at 4.4 K, was also constructed in 1990 [7], [8].

After 1500 hours operation of the cryogenic system, impurity densities of hydrocarbon gases and hydrogen became much larger than the base values in the system. These impurities had introduced some operational troubles into the cryogenic system, e.g. unstable rotations of the turbines, or a choke of the delivery tube from the cold box to LHe storage tank and other very low temperature (< 40 K) region of the system. We examined various cases and confirmed that these impurities must be produced by the circulating compressor.

This paper describes the survey of the impurities, the modifications of the circulating compressor and the result by these improvements.

CRYOGENIC SYSTEM

Figure 1 shows a flow diagram of the cryogenic system. The system consists of a helium liquefier-refrigerator (buffer tanks, circulating compressor and cold box), a liquid helium (LHe) storage tank, a heat-exchanger of the supercritical helium (SHe), recovery system (gas bag, recovery compressor and recovery tank) and a gas purifier unit. An operation as a refrigerator, a liquefier or both functions are available in this system. Helium gas compressed by the circulating compressor is fed to the cold box and is cooled in seven heat-exchangers with two turbo expanders and J-T valve. The cold helium from the cold box is supplied to the LHe storage tank of 10 m^3, cryostat for the 10 MN mechanical testing system and the superconducting magnet (SCM) test stands through the distribution box and the transfer tubes. When testing the magnets of the cable-in-conduit conductor, the SHe heats exchanger unit with a mass flow rate of 50 g/s at 4.5 K is connected to this cryogenic system. The pure boiled helium from the 10 MN mechanical test stand and the SCM test stands are warmed by the heater up to atmospheric temperatures and are returned directly to the circulating compressor. On the contrary, the cold impure gas is turned back to the recovery system and is purified by the purifier unit.

The main specification of this cryogenic system is listed in Table 1. Including the cool down operation of the cold box in the final stage, the system is designed for full automatic operation. It was confirmed that the system is able to produce 250 l/h of liquid helium or a refrigeration of 600 W at 4.4 K as a maximum capacity.

SURVEY OF HYDROCARBON IMPURITY GASES

An averaged operation time per year of the circulating compressor is approximately 2500 hours, and the accounted time up to the present is more than 5500 hours. After 1500 hours operation, we had some troubles caused by the impurities. e.g. unstable rotations of the turbines indicating that the ices of impurities had choked the narrow passage of the labyrinth seal. It was suspected that these troubles must be caused by the hydrocarbon gases, and that such hydrocarbon gases are produced by the circulating compressor.

The densities of some impurity gases in a simple flow circuit from one of the buffer tanks to the circulating compressor were carefully monitored in reference to the operational conditions of the compressor by using a gas chromatography. This testing flow circuit diagram is shown in figure 2. Two gas chromatographies were prepared for measuring them ; one was used to measure hydrogen and hydrocarbon at the point A, B and C, and the other for hydrocarbon etc. at point D that is shown in figure 2.

Figure 3 and figure 4 show the measured densities of hydrocarbon and hydrogen gases in the test flow circuit, when the strokes of the slide adjusting valve for controlling discharge capacity of the compressor are selected to 0%, 50% and 75%, respectively. Though the output capacities were changed, the densities of oxygen, nitrogen and ethane gases did not increase in this flow circuit. On the contrary, methane, ethylene and hydrogen gases increased obviously, when the output capacity of the compressor was reduced. Methane, ethylene and hydrogen gases show the increase of 0.27 ppm, 0.25 ppm and 0.44 ppm, respectively, that values are normalized by the delivery volume of the circulating compressor during an hour. It is recognized that the densities of methane and ethylene at the measured point A, B, and C are nearly equal to the densities of them at point D.

MODIFICATION OF CIRCULATING COMPRESSOR

The circulating compressor was dismounted, and was inspected carefully into its element. The rotors, bearing units and inner surface of the casing were not damaged, but foreign substance such like tar adhered to the edge of the male rotor and its opposite surface of the casing in the second stage.

In a two staged compressor system with a cascade connection, reduction of output capacity of the first stage leads to a large compression ratio for the second stage. Applying an adiabatic model, the temperature of the discharge gas of the second stage, T_{out}, may be expressed as,

$$T_{out} = T_{in} C^{\frac{k-1}{k}}. \tag{1}$$

Where, T_{in} is a temperature (K) of the suction gas at the second stage, C for a compression ratio, k for a specific heat ratio of the helium gas (k=1.66). When we assume T_{in} is equal to 65 degree in the unload operation (stroke of 0 % and C of 7.0), T_{out} becomes about 460 degree. Although the actual temperature will be much lower due to the heat capacity of the injected oil, it is inferential that a part of lubricating oil may be cracked, if the oil does not cooled sufficiently. These assumptions will support the results as shown in figure 3 and figure 4, that the impurities increase when the output capacity is reduced to the small values (stroke 0 % and 50 %).

Thus, the production of the impurities in the cryogenic system might be caused by cracking a part of lubricating oil in the circulating compressor of the second stage. The circulating compressor, therefore, was reconstructed :

(1) the lubricating oil is supplied sufficiently and uniformly inside the casing space, and (2) even if the output capacity is selected from unload to full load, the compression ratio division becomes even for each stage.

After modification, the compressor system was tested again in the same flow circuit shown in figure 2. Where, another buffer tank was used in this test, because the hydrogen and hydrocarbon gases contaminated the buffer tank at the above mentioned loop test. Figure 5 gives the measured impurities in the test flow circuit, when both the strokes of the slide adjusting valves of the compressor are controlled at the same range, to 0 %, 50 % and 100 %. It is clearly seen that the impurity gases of methane ethylene and hydrogen are not produced in the system except the initial residue.

REDUCTION OF IMPURITIES IN THE SYSTEM

A purifier unit, consisting of a molecular sieve with the room temperature and activated carbon with the liquid nitrogen temperature is equipped in this cryogenic system. A purifier unit is designed to reduce the oxygen or nitrogen level below 1 ppm, when the input mass flow rate of a helium is 150 m^3/h including the impurities of 1000 ppm. Impurity densities of hydrocarbon gases in the cryogenic system were measured much larger than the base values for the liquefier operation, so that the reductions of them were curried out by using the purifier unit and the cold trap of the liquid nitrogen temperature in the cold box. The flow diagram is shown in figure 6. First, impure helium gas in the buffer tanks was purified by the simple flow circuit among the buffer tanks, circulating compressor and the purifier unit. Secondary, the whole liquid helium in the LHe storage tank was heated up, and its evaporated gas was turned back to the recovery system. Impure helium gas was purified, and was delivered to the pure buffer tanks. Finally, pure helium gas was liquefied, and was stored in the LHe tank again, to balance the inventories of the gas and liquid.

In these operations, impurities were monitored continuously by the gas chromatography. Figure 7 and figure 8 give the measured impurity densities at the point A, B, C and point E (shown in figure 6). We started to operate the purification unit to remove impurities in the buffer tanks at the time of 120 hr, and started to use the nitrogen trap in the cold box at the time of 240 hr, respectively. The final tuning of the discharge pressure, the flow rate of cooling water and a bypass valve are carried out in the period from 150 hr to 220 hr in parallel with purification operation. This adjusts may affect the increase of impurity. The slight increase of ethylene gas at the time of 170 hr is due to the adjustment of the slide valve of the circulating compressor. As shown in figure 7 and figure 8, reduction of not only hydrocarbon gases but also hydrogen is evident, when the purifier unit in the cryogenic system is in operation.

After the modification of the circulating compressor, it has been operated more than 4000 hours. During this period, there is not any troubles caused by the above mentioned impurities in the cryogenic system.

SUMMARY

A cryogenic system including a helium liquefier-refrigerator with the capacity of 200 l/h or 500 W at 4.4 K was operated for more than 5500 hours from March 1991 to June 1993 in order to test the SC R&D conductors, magnets, and the supporting structures for the LHD. The production and reduction of the hydrocarbons and hydrogen in the cryogenic system are described in this paper. The results are summarized as follows :

(1) It was found that these impurities are produced by cracking of a part of lubricating oil in the circulating compressor, operated under a higher compression ratio in the second stage, typically during unload operation.

(2) The compressor was reconstructed so that the lubricating oil was supplied sufficiently and the compression ratio division became even for each stage. These reconstructions were found effective to keep the pure helium gas in the cryogenic system.

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REFERENCES

[1] O. Motojima et al, "Physics and engneering design studies on the Large Helical Device", Fusion Engineering and Design, Vol.20 (1993) pp.3-14.

[2] O. Motojima et al, "Engineering design study of superconducting Large Helical Device", Plasma Phys. Controlled Nucl. Fusion Res., Washington, Vol.3 (1990) pp.513-523.

[3] T. Mito et al, "Short sample test of full-scale superconducting conductor for Large Helical Device", IEEE Trans. on Magn., Vol.28, No.1 (1992) pp.214-217.

[4] K. Takahata et al, "Experimental results of the R&D forced-flow poloidal poil (TOKI-PF)", Fusion Engineering and Design, Vol.20 (1993) pp.161-167.

[5] M. Sakamoto et al, "Stress analysis of the module coil (TOKI-MC) as an R&D program for the Large Helical Device", Fusion Engineering and Design Vol.20 (1993) pp.181-185.

[6] S. Yamada et al,"Characteristics of a dc 75 kA power supply in the superconducting magnet test facilities", Fusion Engineering and Design, Vol.20 (1993) pp. 201-209

[7] J. Yamamoto et al, "A cryogenic system for the superconducting magnet test facility", Advances in Cryogenic Engineering, Vol.37,Part A (1992) pp.755-762.

[8] J. Yamamoto et al, "Superconducting test facility of NIFS for the Large Helical Device", Fusion Engineering and Design, Vol.20 (1993) pp.147-151.

Figure Captions

Figure 1. Schematic flow diagram of the cryogenic system.

Figure 2. Simple test flow circuit for the survey of the impurities.

Figure 3. Measured impurity gas densities at one of the buffer tanks (Point D).

Figure 4. Measured hydrogen gas densities at the suction and discharge lines of the circulating compressor (Point A, B and C).

Figure 5. Measured impurities at modified compressor (a) and one of the buffer tanks (b) .

Figure 6. The flow diagram for the reduction of the impurities in the cryogenic system.

Figure 7. Measured impurities at the point A and point C.

Figure 8. Measures impurities at the point E and point B.

Table 1. Specifications of the cryogenic system.

Unit	Specifications
Cold Box	
capacity	200 l/h or 500 W (at 4.4 K)
number of turbines	two gas bearing turbines
number of heat-exchangers	seven, 1st one for L-N_2
Circulating Compressor	
type	oil lubricated 2-stage SRM compressor
flow rate & output pressure	2500 m^3/h, 15.5 kg/cm^2
Liquid Helium Storage Tank	
volume	10 m^3
Buffer Tanks	
volume	300 m^3
operating pressure	15.5 kg/cm^2
Helium Gas Recovery	
gas bag	100 m^3
compressor	reciprocating type, 150 m^3/h,
recovery tank	18kg/cm^2, 100 m^3
Purifier Unit	
input impurity	below 1000 ppm
output impurity	below 1 ppm (N_2, O_2)
capacity	150 m^3/h
SHe Heat-Exchanger Unit	
flow rate	50 g/s (at 4.5 K)

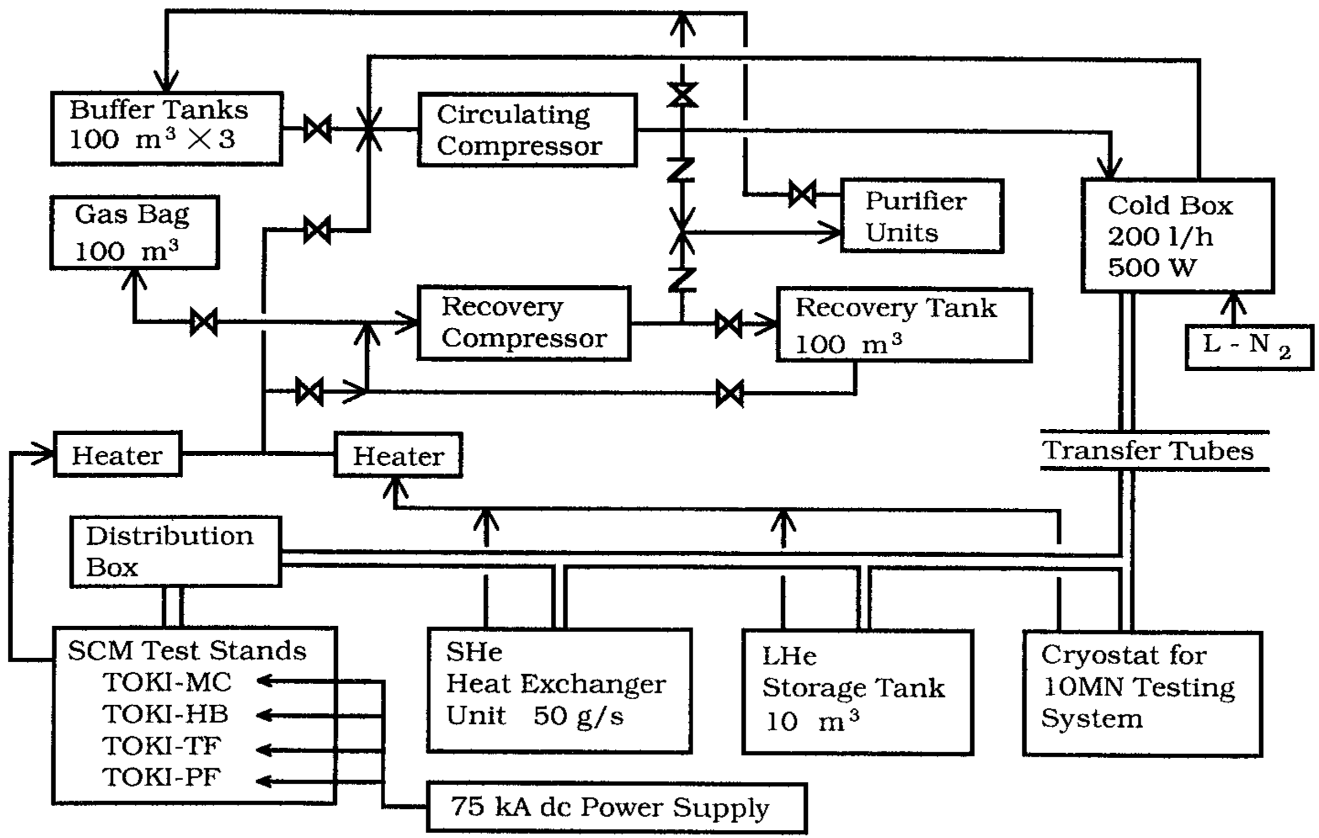

Buffer Tanks
100 m^3 × 3
Circulating
Compressor
Purifier
Units
Cold Box
200 l/h
500 W
Gas Bag
100 m^3
Recovery
Compressor
Recovery Tank
100 m^3
L - N_2
Heater
Heater
Transfer Tubes
Distribution
Box
SCM Test Stands
TOKI-MC
TOKI-HB
TOKI-TF
TOKI-PF
SHe
Heat Exchanger
Unit 50 g/s
LHe
Storage Tank
10 m^3
Cryostat for
10MN Testing
System
75 kA dc Power Supply

Fig. 1.

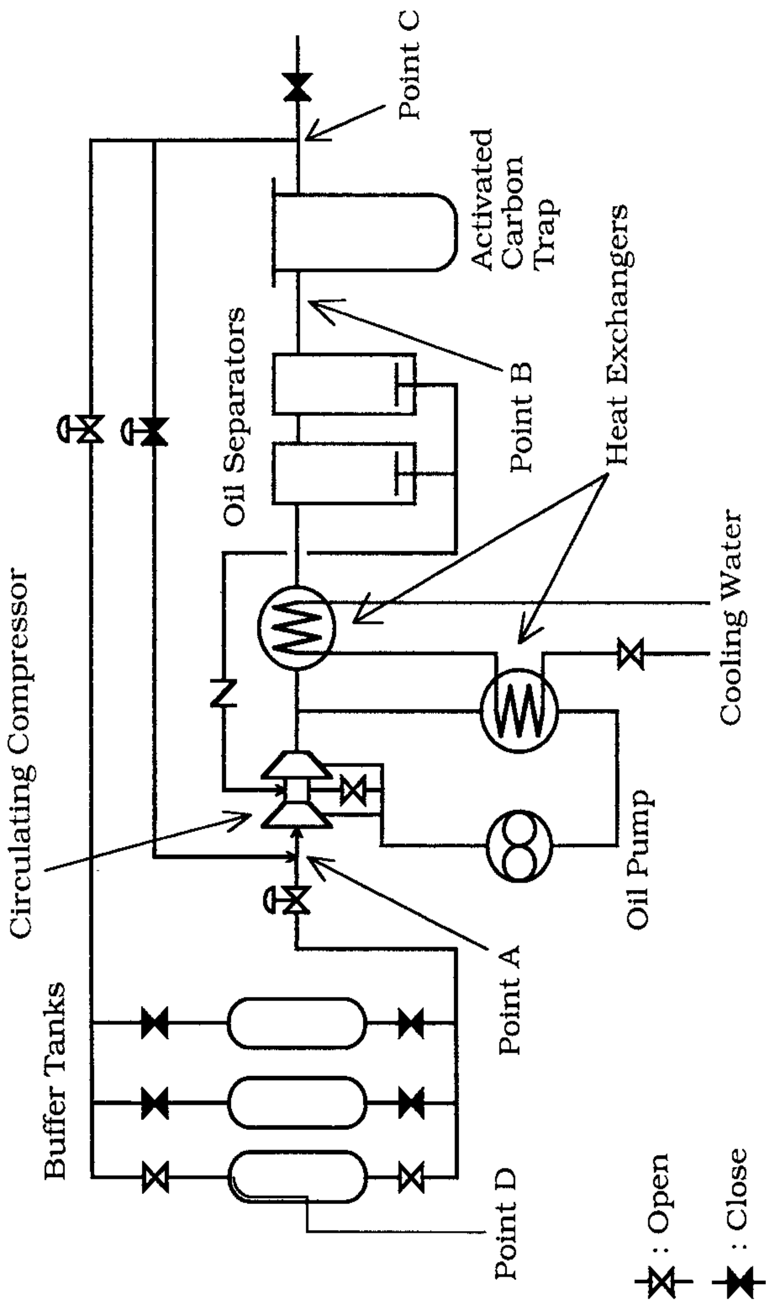

Point C
Activated
Carbon
Trap
Heat Exchangers
Oil Separators
Point B
Circulating Compressor
Cooling Water
Cooling Water
Oil Pump
Point A
Buffer Tanks
Point D
: Open
: Close

Fig. 2.

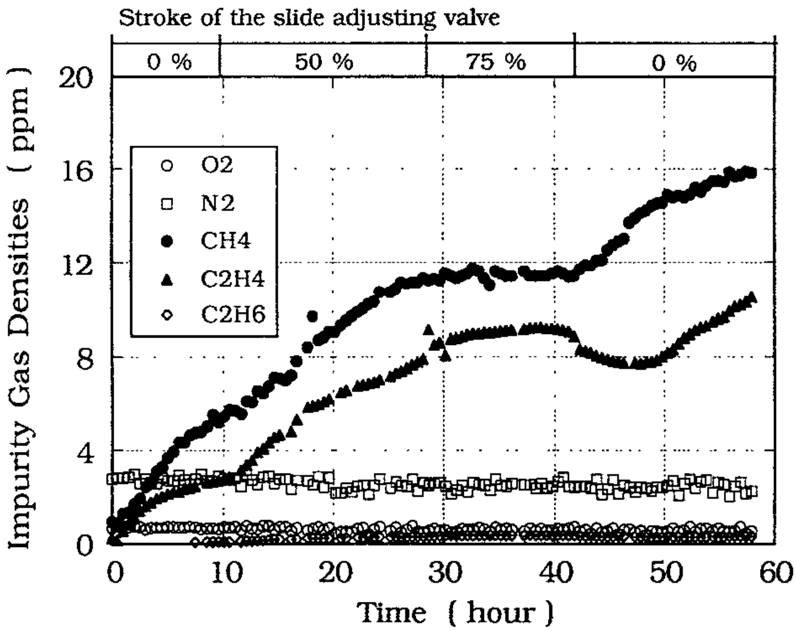
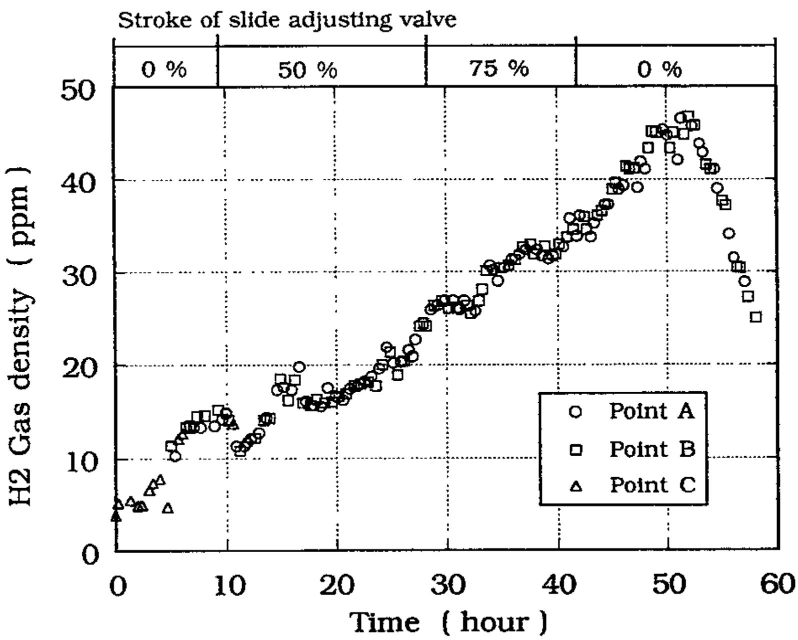

Stroke of the slide adjusting valve
0 %
50 %
75 %
0 %
Impurity Gas Densities (ppm)
20
16
12
8
4
0
O2
N2
CH4
C2H4
C2H6
0
10
20
30
40
50
60
Time (hour)

Fig. 3.



Stroke of slide adjusting valve
0 %
50 %
75 %
0 %
H2 Gas density (ppm)
0
10
20
30
40
50
60
Time (hour)
Point A
Point B
Point C

Fig. 4.

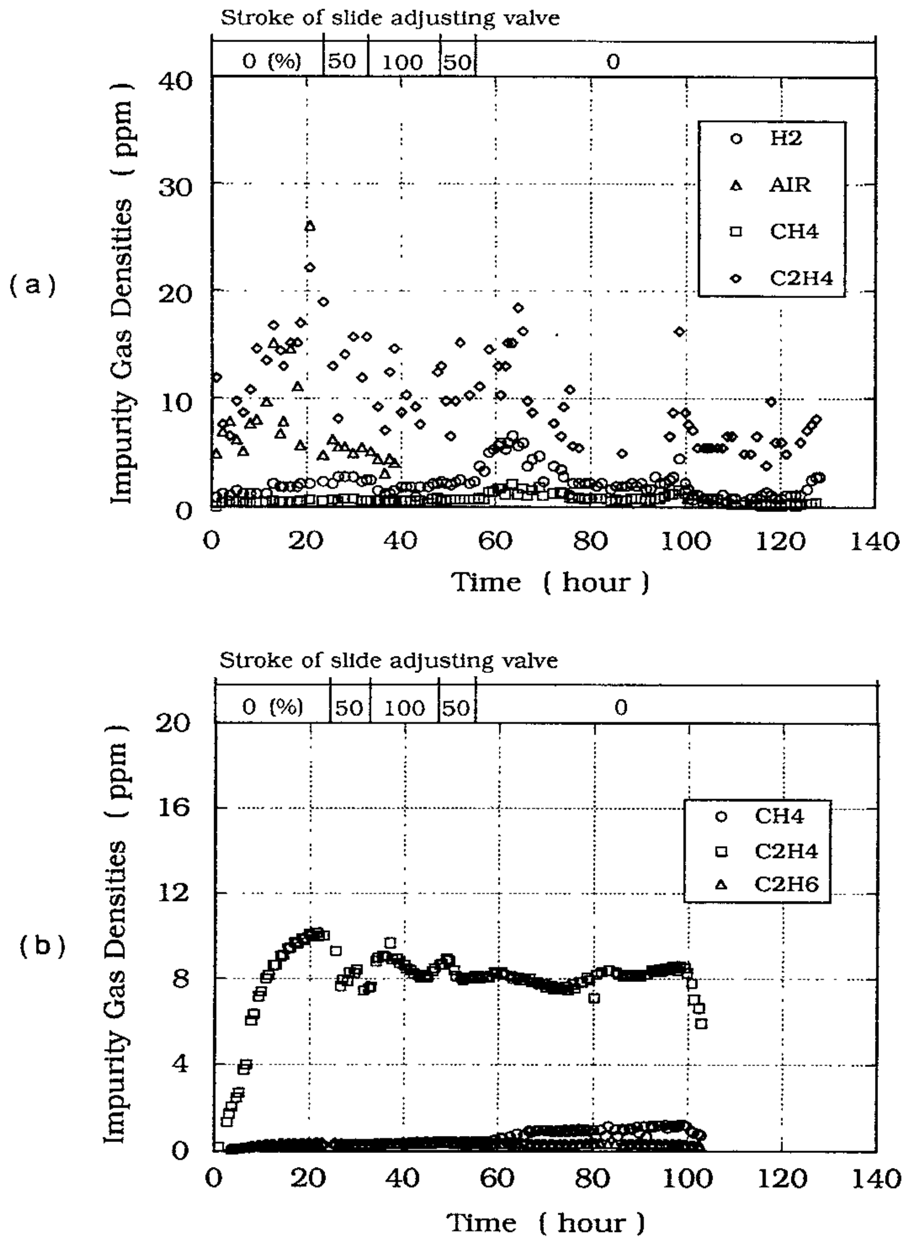
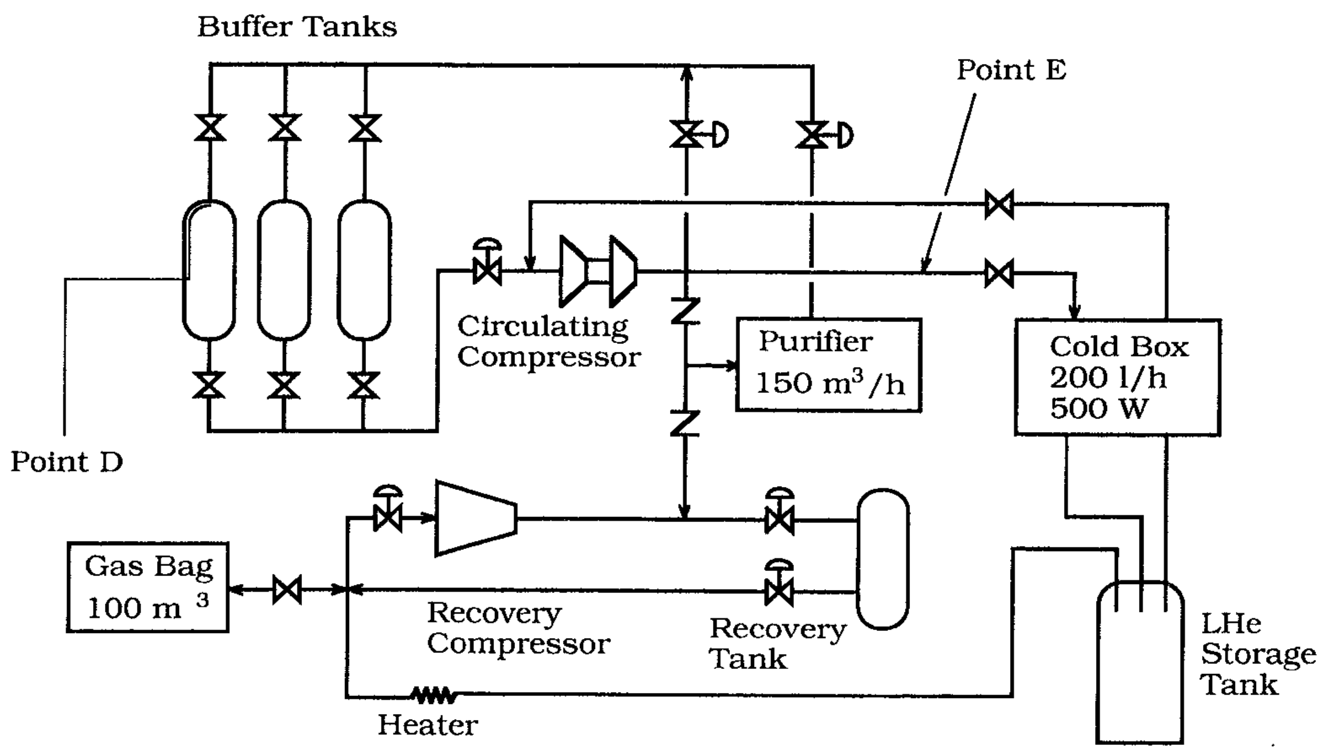

(a)
Stroke of slide adjusting valve
0 (%)
50
100
50
0
Impurity Gas Densities (ppm)
0
10
20
30
40
H2
AIR
CH4
C2H4
0
20
40
60
80
100
120
140
Time (hour)
(b)
Stroke of slide adjusting valve
0 (%)
50
100
50
0
Impurity Gas Densities (ppm)
0
4
8
12
16
20
CH4
C2H4
C2H6
0
20
40
60
80
100
120
140
Time (hour)

Fig. 5.



Buffer Tanks
Point E
Point D
Circulating Compressor
Purifier
150 m³/h
Cold Box
200 l/h
500 W
Gas Bag
100 m 3
Recovery Compressor
Recovery Tank
LHe Storage Tank
Heater

Fig. 6.

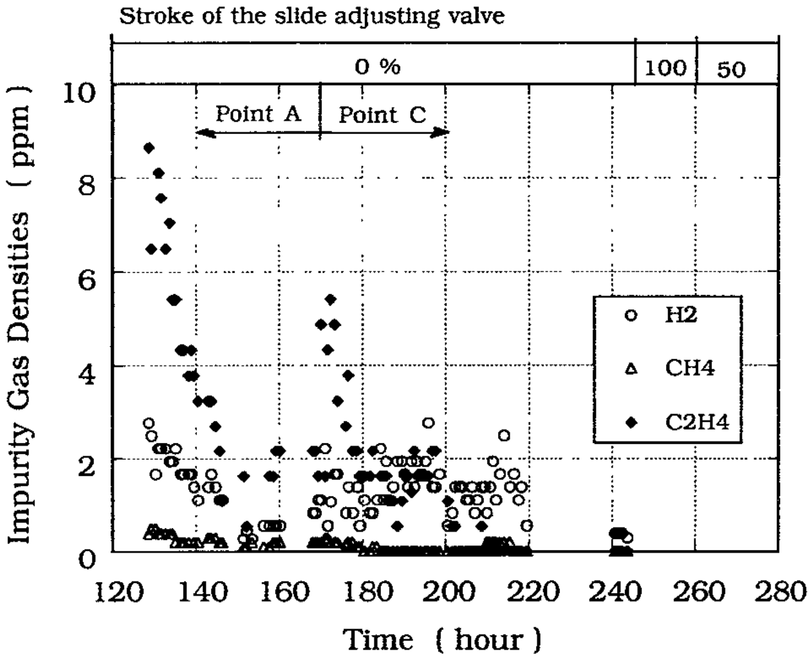

Stroke of the slide adjusting valve
0 %
100
50
Point A
Point C
H2
CH4
C2H4
Impurity Gas Densities (ppm)
0
2
4
6
8
10
120
140
160
180
200
220
240
260
280
Time (hour)

Fig. 7.

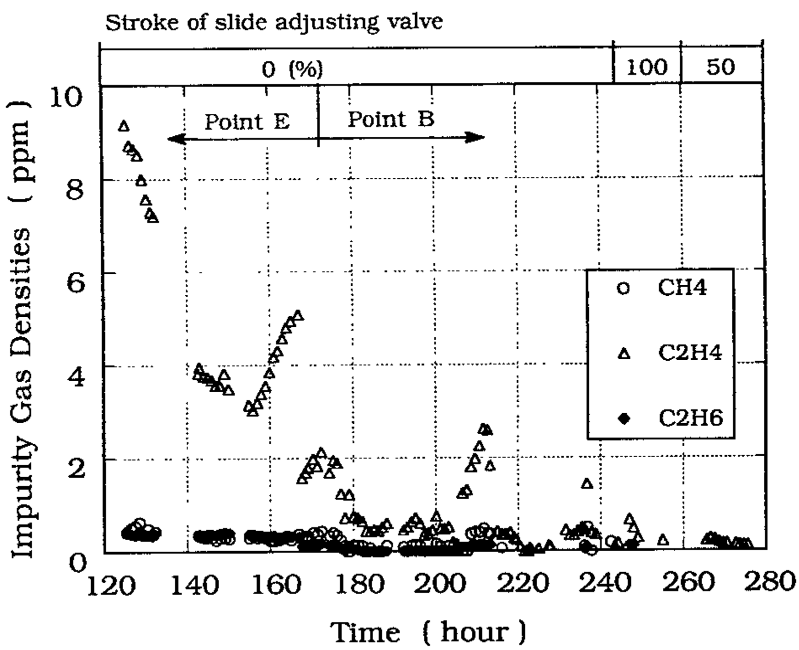

Stroke of slide adjusting valve
0 (%)
100
50
Point E
Point B
CH4
C2H4
C2H6
Impurity Gas Densities (ppm)
0
2
4
6
8
10
120
140
160
180
200
220
240
260
280
Time (hour)

Fig. 8.

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NIFS-253 S. Sudo, Y. Tomita, S. Yamaguchi, A. Iiyoshi, H. Momota, O. Motojima, M. Okamoto, M. Ohnishi, M. Onozuka, C. Uenosono, *Hydrogen Production in Fusion Reactors,* Nov. 1993

NIFS-254 S. Yamaguchi, A. Iiyoshi, O. Motojima, M. Okamoto, S. Sudo, M. Ohnishi, M. Onozuka, C. Uenosono, *Direct Energy Conversion of Radiation Energy in Fusion Reactor,* Nov. 1993

NIFS-255 S. Sudo, M. Kanno, H. Kaneko, S. Saka, T. Shirai, T. Baba, *Proposed High Speed Pellet Injection System "HIPEL" for Large Helical Device* Nov. 1993

NIFS-256 S. Yamada, H. Chikaraishi, S. Tanahashi, T. Mito, K. Takahata, N. Yanagi, M. Sakamoto, A. Nishimura, O. Motojima, J. Yamamoto, Y. Yonenaga, R. Watanabe, *Improvement of a High Current DC Power Supply System for Testing the Large Scaled Superconducting Cables and Magnets*; Nov. 1993

NIFS-257 S. Sasaki, Y. Uesugi, S. Takamura, H. Sanuki, K. Kadota, *Temporal Behavior of the Electron Density Profile During Limiter Biasing in the HYBTOK-II Tokamak*; Nov. 1993

NIFS-258 K. Yamazaki, H. Kaneko, S. Yamaguchi, K.Y. Watanabe, Y.Taniguchi, O.Motojima, LHD Group, *Design of Central Control System for Large Helical Device (LHD)*; Nov. 1993