JAERI-M
93-082

JAERI FUEL CLEANUP SYSTEM (J-FCU) STAND-ALONE TRITIUM TEST AT THE TSTA

—J-FCU TRITIUM TEST WITH FULL IMPURITIES ON FEB., 1992—

March 1993

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編集兼発行　日本原子力研究所
印　　刷　日立高速印刷株式会社

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(Received March 8, 1993)

JAERI designed, fabricated, and installed the JAERI Fuel Cleanup System (J-FCU) as a subsystem of simulated fusion fuel loop at the TSTA. The main function of the J-FCU is to purify and to recover hydrogen isotopes from simulated plasma exhaust while exhausting tritium free impurities. J-FCU has been in tritium test since March, 1991. Ceramic electrolysis cell (CEC) was replaced with its spare on January 1992.

The stand-alone tritium test was performed with full impurities (N_2, CQ_4 and Q_2O etc.) on February, 1992. Main purpose of this test was to evaluate the J-FCU total integrity & function with full impurities after replacing CEC. During this test, plugging of Cold Trap (CT) occured twice and about 500 Ci of tritium exhausted to the Tritium Waste Treatment system (TWT). The safety interlock of the J-FCU acted well, so operation was carried out safely.

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This report describes the detail results of the above test and discuss its functions and difficulties.

Keywords : Fusion, Fusion Fuel Cycle, Tritium, Fuel Cleanup, TSTA, Palladium Diffuser, Ceramic Electrolysis Cell, Cold Trap, J-FCU

JAERI-M 93-082

J－FCU（JAERI－燃料精製捕集装置）のTSTAにおける単独トリチウム試験 －種々の不純物を添加した単独トリチウム試験結果（1992年2月）－

日本原子力研究所那珂研究所核融合工学部

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（1993年3月8日受理）

原研は日米核融合研究協力協定AnnexⅣに基づき，米国ロスアラモス国立研究所のトリチウムシステム試験施設（TSTA）において核融合炉燃料ループの実証試験を行っている。J－FCU（JAERI－燃料精製捕集装置）は，TSTAのメインサブシステムとして，原研が設計，製作し，1990年にTSTAに据え付けたものである。その機能は，模擬プラズマ排ガス中の水素同位体を精製捕集しトリチウムを含まない不純物のみを排出することにある。本装置は1991年3月よりトリチウムの使用を開始している。

このトリチウム試験の一環として，種々の不純物を添加したJ－FCUの単独トリチウム試験が1992年2月におこなわれた。本試験中，2度のコールドトラップの閉塞が生じ，数100Ciのトリチウムをトリチウム排気ガス処理設備（TWT）に排出したが，その他の安全運転上の問題はなかった。

本報告書は，上記試験の詳細結果をまとめたものであり，システムの健全性と現状の問題点についても議論する。

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I. INTRODUCTION

In June 1987, the Japan Atomic Energy Research Institute (JAERI) and the United State Department of Energy (DOE) signed a collaborative agreement (originally 5 years), Annex IV to the Japan/U.S. Agreement on Fusion Energy, regarding development of technology for fusion-fuel processing. Under this agreement, JAERI and DOE have continued joint operations and experiments on fusion-fuel processing technology with the Tritium Systems Test Assembry (TSTA) at the Los Alamos National Laboratory (LANL) [1-2].

JAERI designed and fabricated the JAERI Fuel Cleanup System (J-FCU) as a subsystem of simulated fusion fuel loop at the TSTA under this international collaboration, and installed J-FCU at the TSTA on March, 1990 [3-5]. The main function of the J-FCU is to purify and to recover hydrogen isotopes from simulated plasma exhaust while exhausting tritium free impurities. J-FCU was tested with deuterium for a year after installation [6]. J-FCU has been in tritium test from March, 1991 [7].

During tritium test, some internal leak was obtained at the Ceramic electrolysis cell (CEC), so it was replaced with a spare CEC on January, 1992. After this replacement, a J-FCU stand-alone tritium test was carried out with full impurities simulated plasma exhaust on Feb., 1992. This report describes the detail result of this test and discuss its functions and difficulties.

II. PLAN FOR THE JAERI FUEL CLEANUP SYSTEM STAND ALONE TRITIUM TEST WITH FULL IMPURITIES

This test plan describes the stand alone testing of the JAERI Fuel Cleanup System (JFCU) with full impurities. In 1991, three tests of the JFCU were performed with gram levels of tritium and important data was obtained. A problem with brazing between the ceramic cell and metal base on the Ceramic Electrolysis Cell (CEC) was found and its complete solution is under consideration. The spare CEC was installed and system modifications were made to alleviate the CEC problem. During the first tritium run in 1991, a small humidity spike was detected at the outlet of the Cold Traps (CTs) of the JFCU during the periodic switching of the CTs. Incomplete regeneration of small molecular sieve beds (JMSB#3~5) at the outlet of the CTs is a suspected cause of this problem. Therefore, new JMSBs will be installed. This is the first test after replacement of the CEC and JMSBs.

1. PURPOSE

The main purposes are :

1) to re-check the total integrity and function of the JFCU with full impurities (CH_4 and NH_3) addition and

2) to check the spare CEC and new JMSBs function after replacement.

2. CONFIGURATION

The test will be conducted as a stand alone run of the JFCU. JFCU flow is shown in Appendix I.

Tritium stored in Zirconium-Cobalt Bed 1 (ZCB1) and adsorbed in JFCU Catalytic Reactor 1 (JCR1) (1~2 gram) will be used; no other tritium will be added to the JFCU. Some amount of D_2 (~20 NL) will be added to the JFCU. Methane and Ammonia will be added as simulated impurities; however, the amount of these impurities will be limited to a minimum. "External" CT regeneration mode will be selected and about 6 NL/min He and tritium-free impurities will be exhausted to the Tritium Waste Treatment system (TWT).

The spare CEC (CEC B), new JMSBs and some mass flow meter/controllers will be installed. New interlocks (alarm and "scram" signal from MDAC) will be set using the water decomposition current of CEC as the monitored variable. Alarms from differential pressure of CEC tubes, dew point of CEC inlet, and CT regeneration flow rate will be also set in the JFCU SAFETY program at the MDAC.

3. SUBSYSTEM REQUIRED

The MDAC will archive data from the JFCU. CEC current and O_2 concentration at the inlet to JCR1 will be monitored by MDAC and used to send a "scram" command (= JFCU pause) if these variables exceed safety limits. Oxygen concentration at the input to the JCR1 is

also controlled through MDAC. Safety subsystems TWT that will process exhaust from the JFCU, SEC, TM, VEN, House VAC, PEV, MDAC, and UTIL (high and low pressure nitrogen, chilled water, helium, liquid nitrogen, and regular/emergency and UPS electric power) should be operational. Major tritium operations in other TSTA subsystems during this testing will not occur. After this test, the amount of tritium and deuterium used for the tests will be measured for inventory if needed.

4. PRESONNEL

T. Hayashi and J. W. Barnes will coordinate the test. All the JAERI members and TSTA staff and operators are involved in the testing. TSTA operators, those who are qualified to operate JFCU, shall conduct all JFCU operations with the close collaboration of JFCU-qualified staff. Notification of any operations or system adjustments of any kind, must be conveyed to the operator. The qualified JFCU operators are R. Wilhelm, M. King, and W. Harbin. Qualified staff of JFCU are T. Hayashi, M. Inoue, and J. Barnes. A personnel assignments plan is attached (Attachment I). Usual shift change meetings will be held at 0730, 1530, and 2330.

5. TIME

The main part of this test will require 5 days, around-the-clock operation including 4 night shifts. The operation of JFCU apparatus will start in the week on Feb. 3, 1992, however this date may change if the equipment is not ready.

Main schedule is as follows;

Day1** operations:	*Component heating up and cooling down.
	*System evacuation and zero adjustment of sensors.
	*Regeneration of ZCB1(Q_2 to RT2) and Supply D_2 to RT2 if needed.
Day2** operations:	*establish the "stand-by" mode.
	*non-impurity operation start, if possible, start impurity injection.
Day3** operations:	*impurity addition operation.
	During night shift, depending on the impurity injection start time, * start the shut down and dry-up operation.
Day4** operation:	*CEC cooling down start, depending on the dry up situation.
Day5 operation:	*Only watch the cooling down situation.

** full shift (24 hr) staffing required.

Before this test, initial preparation should be completed (refer to 7.1). Inventory check of ZCB1 will be planned after this test.

6. POSSIBLE HAZARDS

Approximately 1~2 grams of tritium are stored in ZCB1 and adsorbed in JCR1, will be used in the test. GB leak checking (refer GB leak check procedure # TTA-TP-117-07, current revision) and process tritium leak checking shall be conducted before this test. Situations that may lead to large losses of tritium to TWT will initiate interlocked shutdown by JFCU-PC (JFCU pause). In most emergency conditions, all tritium can be recovered by the ZCB1 and/or stored in the JFCU safely. When system safety limits are exceeded, the JFCU SAFETY program at MDAC will send "alarm" and "scram" signals to the JFCU, as mentioned above.

Other potential hazards are related to, high and low temperature at the components, high pressure gas, possible combustible mixtures, and loss of cooling water or electric power. All these hazards are monitored, alarmed and/or interlocked.

7. OUTLINE

7.1 Preparation

Before test, we should complete following preparations;

a) Installation of CECB,

b) Installation and check out new potentiostat,

c) JMSB3, 4 and 5 Installation, leak testing and electrical testing,

(All OMEGA temp. controllers should be checked concurrently.)

d) Modify JFCU safety program (TTA-SP-121-18, current revision) and test,

e) O2 sensor's fuel cell changing and calibration,

f) GC re-calibration and sampling program discussion,

g) Some MKS flow meter sensor replacement,

h) GB helium leak checking (TTA-TP-117-07, current revision) and JFCU process tritium leak checking .

i) Check quantity of gas cylinders that are planned to use and its lines to the JFCU.

7.2 Test

On the first day of the test, (refer to TTA-DTP-118-15, current revision, for detailed procedures)

1) JFCU computer will be started after memory is cleared. New potentiostat input voltage will be set and turned on.

2) JFCU component heating (Palladium Diffuser (PD), JCR1, and CEC) and Refrigerator (REF), process line heating, and CEC cooling water flow will start after checking the heating/cooling parameters listed in Appendix II.

3) Other setting parameters on the JFCU-PC will be checked as listed in Appendix III. (It is changeable, depending on the JFCU situation.)

4) All valve positions checked and indicated local on the pin board.

5) calibration of O2 monitors.

6) final regeneration of JMSBs purging by He.

7) start system evacuation after CEC pressures are checked and after CEC and O2 sensors are isolated. Do not open HV556 (CEC O2 line evacuation valve) After rough evacuation (~ < 30 Torr), isolate JCR1.

8) CTs cooling start.

9) Zero calibration of pressure sensors and mass flow meters/controllers.

10) JFCU safety program start and Helium addition in the recovery loop of the JFCU.

11) start ZCB1 regeneration using Scroll+BP pumps and hydrogen isotopes gases stored in the RT2 as regeneration operation procedure refer to TTA-TP-118-16, current revision. (check the cooling water flow of ZCB1 and that of CEC.)

12) after almost complete regeneration, isolate ZCB1 and turn off heater of ZCB1.

13) CT cycle start and watch the JMSBs temp. cycle. (no regeneration flow)

14) watch CEC temp. increasing curve and CEC differential pressure. (no flow)

The second day, process test will start,

1) check "heating mode" established and the system pressures, and open CEC isolation valves.

2) to establish stand by mode, check hand valves.

3) set "stand by" on JFCU-PC

4) check "stand-by mode" established. (AVs and Pumps)

5) check/select CT regeneration to "External" and JCR1 dilution to "Internal"

6) check pressure of CEC O2 side and start O2 supply to JCR1; supply He to CTs for regeneration. (check AV415, AV414, AV412, AV430, AV431)

7) Original potentiostat input voltage set up.

8) Supply D2 (a few 100 cc/min) to the RT1 from cylinder until RT2 pressure is about 750 torr.

9) Then, connect RT2 to RT1 (recycle).

10) set up "normal OP. mode = UNIT" on the JFCU-PC. And check the JFCU pressure and flow situation. If needed, adjustments will be made to stabilize the system. If needed another D2 addition will also be done to stabilize system.

11) GC sampling/analysis program (type 1), that are discussed before test, will start.

The third day,

1) If the system works well, addition of minimal methane (less than 100 sccm) impurity will be tested.

2) GC sampling/analysis program (type 2), that are discussed before test, will start.

3) Excess hydrogen isotopes will be recovered with the ZCB1 manually, if needed.

4) When enough data is obtained (about 4 hr), stop CH4 addition, and addition of minimal ammonia (less than 50 sccm) impurity will be tested.

5) GC sampling/analysis program (type 2), that are discussed before test, will start.

6) When enough data is obtained (about 4 hr), stop NH3 addition.

7) start recovery of hydrogen isotope gases (in RT2) to ZCB1 and start dry-up operation.

The fourth day,

1) continue the dry-up operation.

2) when system dewpoint is low enough, stop O2 addition and change CT regeneration mode to "INTERNAL".

3) stop CT cycle , manually heat all CTs and JMSBs, and set REF of CTs to "OFF".

4) when system dry up is complete, original potentiostat turn "OFF" and MBP "OFF".

5) CTs and JMSBs heaters off and CEC cool down program start

6) isolate ZCB1 and Scroll + BP turn off.

The fifth day,

1) isolate CEC and O2 monitor, residual gas in the process that is virtually tritium free is pumped by PEV to TWT. After rough pumping, isolate JCR1.

2) isolate main loop of JFCU and evacuate only the main loop of JFCU by TMP.

3) turn off heater of PD JCR1.

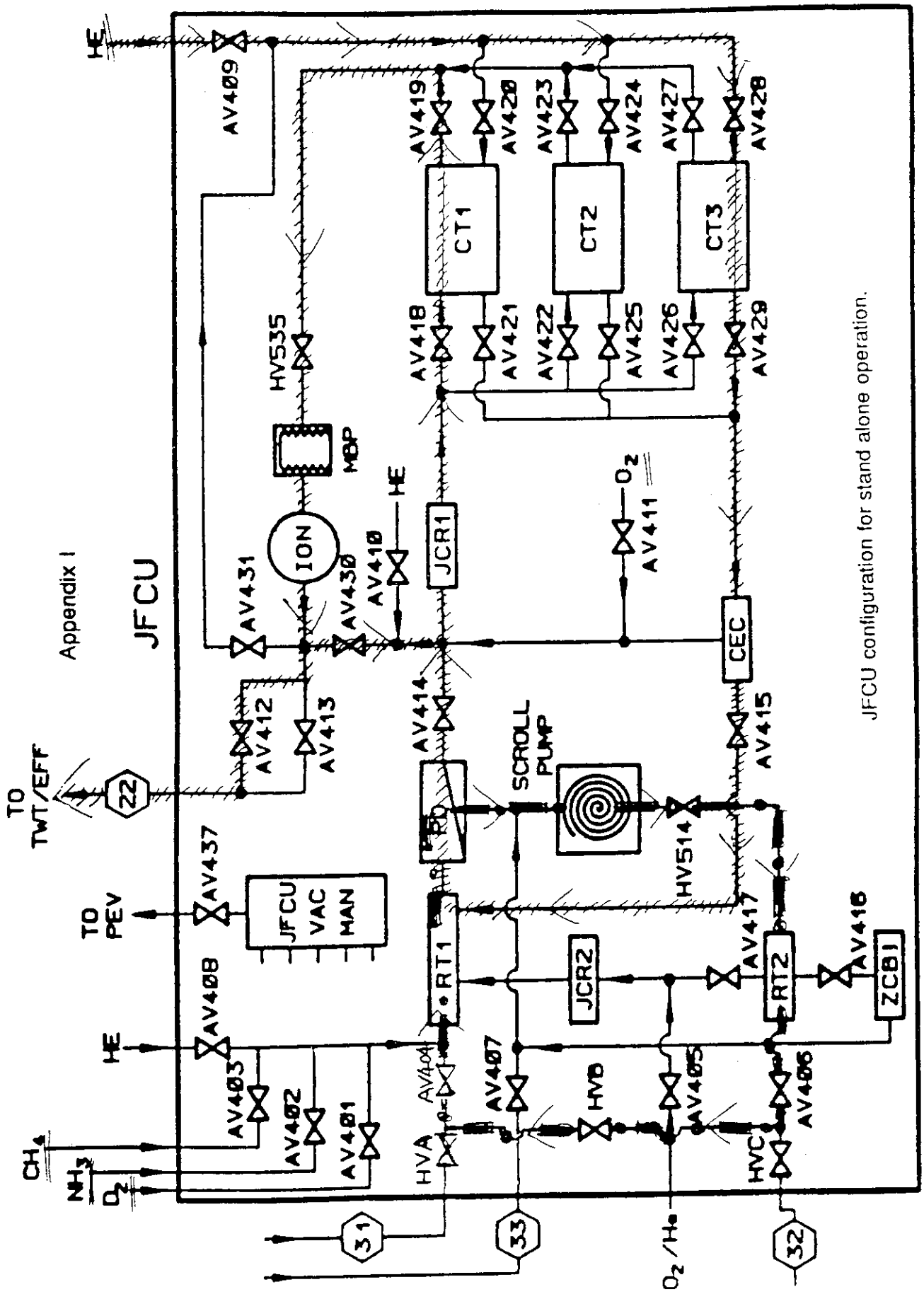
4) if cooling water is needed for CEC B, set the flow at a minimum for safety.

7.3 Inventory

If needed, after this run, ZCB1 will be regenerated completely (TTA-TP-118-16, current revision). Tritium inventory will be measured by mass spectrometer.

8. DATA

Data will be recorded in the JFCU computer. Monitoring at MDAC and archiving will also be done. A lab notebook for the JFCU will be used for the formal logging of the operations. Major configurations and "trends" will be printed out. GC data will stored on a floppy disk in the JFCU-GC computer. This procedure and documentation generated from this test/run shall be maintained in accordance with the Records Control Procedure TTA-QP-10, current revision.


Appendix I
JFCU
JFCU configuration for stand alone operation.
HE
AV409
AV419
AV420
AV423
AV424
AV427
AV428
CT1
CT2
CT3
AV418
AV421
AV422
AV425
AV426
AV429
HV535
MDP
ION
AV431
AV430
AV410
JCR1
HE
O2
AV411
CEC
AV412
AV413
AV414
AV415
SCROLL PUMP
RD
HV514
TO TWT/EFF
Z2
TO PEV
AV437
JFCU VAC MAN
RT1
JCR2
RT2
AV417
AV416
ZCB1
AV408
HE
AV403
AV402
AV401
AV404
AV407
HVB
AV405
AV406
HVA
HVC
CH4
NH3
O2
Z1
Z3
O2 /H2
Z2

Appendix II - 1

CT1~3L

Pattern No. 1
Copied from 1

STEP No.	0	1	2	3	4	5	6	7	8	9
SET TEMP(K)	163.0	163.0		233.0		343.0		343.0		0.000
SET TIME(Hr)		00:00	00:01	00:05	00:00	00:10	00:00	00:29	-0:00	-0:00

CT1~3U

Pattern No. 2
Copied from 2

STEP No.	0	1	2	3	4	5	6	7	8	9
SET TEMP(K)	163.0	163.0		313.0		323.0		343.0		343.0
SET TIME(Hr)		00:00	00:01	00:05	00:00	00:10	00:00	00:29	00:00	-0:00

CEC

Pattern No. 3
Copied from 3

STEP No.	0	1	2	3	4	5	6	7	8	9
SET TEMP(K)	273.0	1023.		873.0		673.0		273.0		0.000
SET TIME(Hr)		16:00	72:00	04:00	00:30	04:00	00:30	08:00	-0:00	-0:00

JCR1

Pattern No. 4
Copied from 4

STEP No.	0	1	2	3	4	5	6	7	8	9
SET TEMP(K)	273.0	773.0		773.0		0.000		0.000		0.000
SET TIME(Hr)		02:00	00:00	-0:00	-0:00	-0:00	-0:00	-0:00	-0:00	-0:00

Appendix II - 2

JCR2

Pattern No. 5
Copied from 5

STEP No.	0	1	2	3	4	5	6	7	8	9
SET TEMP(K)	273.0	473.0		473.0		0.000		0.000		0.000
SET TIME(Hr)		01:00	00:00	-0:00	-0:00	-0:00	-0:00	-0:00	-0:00	-0:00

PD

Pattern No. 6
Copied from 6

STEP No.	0	1	2	3	4	5	6	7	8	9
SET TEMP(K)	273.0	573.0		573.0		0.000		273.0		273.0
SET TIME(Hr)		01:00	00:30	-0:00	-0:00	-0:00	-0:00	-0:00	-0:00	-0:00

ZCB1~3

Pattern No. 7
Copied from 7

STEP No.	0	1	2	3	4	5	6	7	8	9
SET TEMP(K)	273.0	623.0		648.0		673.0		673.0		0.000
SET TIME(Hr)		01:00	00:30	00:06	00:30	00:06	01:00	-0:00	-0:00	-0:00

Appendix III - 1

Table Alarm and Interlock set points

at JFCU-PC ⟷ MDAC

Identification		Set point				ALARM	INTERLOCK	
	LOW	L	H	HH	HIGH			
PRA-RT1		750				Y		
			850			R		
					850	R	PAUSE	
PRCA-RT2		700				Y		
			950			Y		
PRCA-PDEX			850			Y		
PRA-ZCB1EX			950			R	HEATER OFF	
					950	R		
PRCA-ZCB2EX		750				Y		
			850			Y		
PRA-SCROLIN			10			Y		
PRCA-ISSIN			750			Y		
				850		R		
					950	R	PAUSE	
PRCA-JFCUEX		750				Y		
			850			Y		
PRA-TMPEX			20			Y		
					20	Y	TMP STOP AV473 SHUT	
PDRA-CEC		-500				Y		≥-50 Torr R alarm
			-50			Y		≧0 Torr R
					500	R	PAUSE	
RRA-TOTWT			50			Y		
				100		R		
					1000	R	PAUSE	
ORA-JCR1IN			5			Y		>10% R alarm + PAUSE
ORCA-JCR1EX		0.1				Y		
HLRA-CTEX				197		Y		
HLRA-CECEX				313		Y		
VLRA-WECE				12		Y		
PRCA-JFCUEX								1000 R alarm
ILR -WECE								>8A PAUSE
FRC -CECIN								<6 ULH Ralarm

Appendix III - 2

JFCU-PC | MDAC

Identification		Set point				ALARM	INTERLOCK	
	LOW	L	H	HH	HIGH			
TLRCA-PD Control Temp. = 573 K	523	523	553	733	733	R Y	PAUSE HEATING MODE HEATER OFF	
TLRCA-JCR1 Control Temp. = 773 K	723	723	753	873	873	R Y	PAUSE HEATING MODE HEATER OFF	
TLRCA-CT1~3U 163 ~ 343 K			193	373		Y	CT CYCLE	
TLRCA-CECIN			343			Y		
TLRCA-CECA ~ F Control Temp. = 1073 K	823	823	873	1093	1093	R Y	PAUSE HEATING MODE HEATER OFF	
TLRCA-JCR2		423	623		623	Y Y Y	HEATER OFF	
TLRCA-JCR2EX			333			Y		
TLRCA-ZCB1			723		723	Y Y	HEATER OFF	
TLRCA-ZCB2			723		723	Y Y	HEATER OFF	
TLRCA-ZCB3			723		723	Y Y	HEATER OFF	
HLR-CEC IN								>35°C Y (308K) >40°C R (313K) alarms

ATTACHMENT I
Shift Assignment

	Shift A 0730-1530	Shift B 1530-2330	Shift C 2330-0730
Test Dir.	Anderson	Bartlit	
JFCU	JAERI*/Barnes	JAERI*	JAERI*
JFCU Operator	Wilhelm	King	Harbin
Facility Operator	Jenkins	Hamerdinger	Harbin
TWT	Nasise		
ETC	Carlson	King	
PEV, H-VAC	Nasise		
UTIL	Carlson		
MDAC	Cole/Miller		
UPS	Miller		

Notes:
1 All others will be divided between all shifts and subject to call as needed.
2.Some personnel on Shift A & B may shift hours between shifts (with the cognizance of the TD) depending on specific activities under way.

JAERI Team Shift Assignment

Day		Ab (7:30-19:30)	bC (19:30-7:30)
2/3	Mon	Hayashi, Inoue Hirata	Nakamura
2/4	Tue	Hayashi Hirata	Inoue Nakamura
2/5	Wed	Hayashi Hirata	Inoue
2/6	Thu	Hayashi Nakamura	Hirata
2/7	Fri	Hayashi, Inoue Nakamura	

Ⅲ. TEST RESULTS

1. SUMMARY

The tritium testing of the JAERI Fuel Cleanup system (JFCU) after replacing Ceramic Electrolysis Cell (CEC) was performed safely with gram level of tritium. Non-impurity fuel processing operation was performed for several hours and fuel processing operation with a few % of methane was demonstrated for 2 hours safely. During these fuel processing operations, "External" Cold Trap (CT) regeneration line was selected and Catalytic Reactor (JCR1) dilution line was not used. The stream to the Tritium Waste Treatment (TWT) system was almost constant at about 5.1 Nl/min (almost all He gas) and its tritium level was lower than 50 Ci/m3 except the short period after CT2 plugging.

The plugging of CT2 occurred twice and about 550 Ci of tritium exhausted to Tritium Waste Treatment system (TWT) just after the melting of 1st plug. At the 2nd plug, JFCU interlock system acted to shutdown (pause mode) the JFCU and no exhaust of tritium was detected. Because of this trouble and its recovery, ammonia addition was not performed.

At the last stand alone test of JFCU, small amount of humidity spike at the outlet of CTs was detected when each CT was changed periodically (once per an hour). However, no humidity spike was detected during this test. New installed small molecular sieve beds (JMSB3~5) at the outlet of CTs worked well. Also new installed CEC decomposed water well.

Almost all tritium was recovered in the Zirconium Cobalt Bed (ZCB1) of JFCU and minor tritium exhausting (less than 50 Ci) was detected in the TWT for the JFCU process evacuation at the shut down operation.

Before and after this test, ZCB1 was regenerated and its inventory was checked.

Through these operations, operators and staff gained good experiences from the JFCU tritium run.

2. PURPOSE

The main part of this test was performed during February 3 - 7, 1992.

The purposes of this run were :

1) to re-check the total integrity and function of the JFCU with full impurities (CH_4 and NH_3) addition and
2) to check the spare CEC and new JMSBs function after replacement.

Tritium inventory of Zirconium-cobalt bed (ZCB1) before and after this run would provide information on the tritium adsorption in the new installed components as well as the JFCU system inventory.

3. CONFIGURATION

The test was conducted as a stand alone run of the JFCU. Figure 3-1 illustrates the major flows of JFCU under this test.

Tritium stored in ZCB1 and adsorbed in JFCU Catalytic Reactor 1 (JCR1) (1~2 gram) were used; no other tritium was added to the JFCU. About 15 Nl of D2 was added to the JFCU. Methane was added as a simulated impurity. "External" CT regeneration mode was selected and about 5 NL/min He and tritium-free impurity were exhausted to the TWT.

The spare CEC (CEC B), new JMSB3~5 and a mass flow controller (JCR1BYP) were installed. New interlocks (alarm and "scram" signal from MDAC) were set using the water decomposition current of CEC as the monitored variable. Alarms from differential pressure of CEC tubes, dew point of CEC inlet, and CT regeneration flow rate were also set in the JFCU SAFETY program at the MDAC. Other safety systems were used in support of the test.

4. OPERATIONS

Main operation logs were summarized in the APPENDIX I.

4.1 Preparations

Following items were completed before this test.

a) Installation of CECB,

b) Installation and check out of new power supply for CEC,

c) JMSB3, 4 and 5 installation, electrical testing and regeneration,
(All OMEGA temp. controllers were checked.)

d) Modify JFCU safety program (TTA-SP-121-18, current revision) and test,

e) O2 sensor's calibration,

f) A part of GC re-calibration and sampling program setting,

g) MKS flow controller sensor (JCR1BYP) replacement,

h) GB helium leak checking (TTA-TP-117-07, current revision) and JFCU process tritium leak checking.

i) Check quantity of gas cylinders that were planned to use and its lines to the JFCU.

Voltage of new power supply for CEC was set to 0.5 V before starting CEC heating. Then, all components were heated and cooled to operation temperature during the day 1 (Feb.3). All valve positions were checked. Zero adjustments of all flow meters/controllers and pressure sensors were carried out on Feb.3. A part of GC analysis calibration and oxygen monitor calibration were also performed on Feb.3.

On the night of Feb.3, tritium stored in the ZCB1 was supplied to Reservoir tank 2 (RT2) heating up ZCB1 to 723 K. This gas in the RT2 (~350 torr) was sampled for inventory check.

At the 3:00 o'clock on Feb.4, new power supply failed. Another power supply was prepared and supplied 0.2 V in the morning on Feb.4.

4.2 Non-impurity operation

Following the "Detail operation procedure for JFCU" (TTA-TP-118-15, R0) and test plan of this run (TTA-TP-118-19, R0), valves situation and components heating/cooling and pumps situation were checked. " Heating Mode" has been established at the morning of day 2.

Before starting non-impurity operation, JFCU computer was hung up during trending on the VAX GPX II. Finally, JFCU application software should be re-boot using mechanical button after PD and CEC heating control change ("remote" to "local"). In spite of this hang up, JFCU was controlled safely. O2 monitor calibrated again and a fuel cell of the outlet of JCR1 was replaced. It was found that O2 flow could not be controlled by MDAC. So, O2 flow controlled by manual pressure adjustment of the supply cylinder regulator.

Then, Metal bellows pump (MBP) was turned on, O2 and He supply started and recovery loop pressure (~ 600 torr) and flow (He : 5 Nl/min and O2 : 0.13 Nl/min) were adjusted. D2 addition (0.1~0.2 Nl/min) started to increase RT2 pressure. CEC potentiostat was turned on .

After RT2 pressure increase to 650 torr (added amount of D2 about 17 NL), circulation of RT2-RT1-PD-Scroll+BP was started. The system pressure and flow rate were adjusted to stabilize the system, however, 1st CT2 plugging occurred (19:30 on Day 2). This plug melted when CT2 inlet piping temp. was heated to 550 K from 450 K (indication on the JFCU-PC), however, about 550 Ci of tritium was exhausted to TWT at this melting. The following reason (scenario) was suspected ;

1) CT plugged, however, He and O2 were supplied continuously,
2) RT1 and RT2 pressure increased to ~ 830 torr (at that time, pressure of JFCU exhaust was controlled at 600 torr but no flow.),
3) When the plug melted, system pressure stabilized quickly to ~ 600 torr,
4) A surge of tritium through JCR1 occurred for which there was insufficient O2 for complete oxidation,
5) Tritium gas that did not react in the JCR1 was exhausted to TWT.

At the next CT changing after plug melting, TSTA scram signal (CEC current > 8A) was sent to JFCU from MDAC and JFCU was placed in "pause".

From the Day 3 (Feb.5) morning, operation started as following to resume non-impurity operation ;

1) MBP turned on and circulated gas around JCR1 using internal JCR1 dilution line to recover tritium to CT in this section,
2) took sample from #5 sample location and check tritium elimination,
3) O2 sensor calibration and a fuel cell of the inlet of JCR1 was replaced and He/O2 purged again to check O2 sensor,
4) RT2 isolated and check CEC line pressure (open AV415),
5) open AV414 during continuous purge,
6) open Av409 and close AV410 (started CT regeneration He supply),

7) System pressure (PDEX press control 700 torr) and flow adjusted again,
8) CT cycle operation started,
9) " JFCU Safety program "OFF", CEC potentiostat "ON" and "JFCU Safety program "ON",
10) wait and watch dryup situation of CT plugged water,
11) RT2 pressure decreased to 750 torr (from 800 torr) evacuating gradually to ZCB1,
12) circulation RT2-RT1-PD-Scroll+BP started again (16:00 on Day 3),
13) D2 addition started again to make the above circulation flow. (about 4 NL D_2 addition)

GC sampling analysis program was started after making circulation of RT2-RT1. Sampling points were #2,#3,#5.

This operation was continued until 20:00 on Day 3.

4.3 Impurity operation

After some preparation for impurity injection, methane (CH_4) supply was started to JFCU-RT1 (30 ml/min)(20:15 on Day 3). GC sampling points were changed to #4, #5 in order to check the methane combustion situation.

CH_4 supply was stopped at 22:15.

After stop CH_4 addition, CEC differential pressure reversal alarm was sent from MDAC, that DP-CEC went over +30 torr from -120 torr in a short period, and then JFCU was set to "pause mode" by the interlock of ISSIN pressure, which located at the return line from RT2 to RT1.(23: 30) After much consideration of this situation (morning time on Day 4), it was found that the reason was CT2 plugging. Continued addition of helium pressurized the plugged system and triggered the shutdown. To make sure that CEC cells were not broken, gas sample from RT1 was taken and analyzed by laser-raman spectroscopy. Therefor, ammonia addition could not be performed.

4.4 Tritium recovery

4.4.1 main-loop (RT-2)

After analysis of RT1 gas, that there was no O_2, all hydrogen isotopes in the JFCU-RT2 were recovered by Zirconium cobalt bed (ZCB1), operating pumps continuously. Then, gas in the RT1 was circulated through ZCB1 using PD bypass line and BP. After a few hour circulation and isolation of RT2, the gas in the RT2 was evacuated to TWT evaluating the tritium amount in the gas. Tritium amount evacuated to TWT was about 45 Ci.

4.4.2 recovery loop dry up operation

After RT2 gas evacuation, dry up operation (internal circulation in the recovery loop) was started using "Internal" CT regeneration line. No He addition, no O_2 addition, and no exhaust to TWT were performed. Hydrogen isotope gas generated by water decomposition in the CEC was purified and recovered to RT2 continuously. This dry up operation were continued for a total of 12 hrs until Day 5 morning. All hydrogen isotopes in the RT2 was recovered by ZCB1. Residual gases in the recovery loop (almost all Helium) was circulated

through ZCB1 for a few hours and then evacuated to TWT through ZCB1. Less than 5 Ci of tritium detected in the TWT at that time.

4.5 Inventory check

When ZCB1 was regenerated and hydrogen isotopes was released to RT2 on the Day 1-2, gas sample in the RT2 was taken and analyzed by laser-raman spectroscopy and by mass spectroscopy.

After this test, ZCB1 was regenerated again for inventory check, following the detail test plan (TTA-TP-118-16, current revision). This isotopic component was measured by mass spectrometer.

5. RESULTS (part I : Component Performance)

5.1 Palladium diffuser

During this test, Palladium diffuser (PD) temperature was controlled at 573 K. Except for a period of rapid large pressure fluctuation (delta-P = ~ 200 torr) such as CT plug - melting, PD function was expected. Total amount of purified hydrogen isotopes* was about 275 Nl. (225 Nl at non-impurity operation (included dryup operation) and 50 Nl at impurity operation). Purification ratios** (Recovery at the PD) were more than 96 % at non-impurity operation and more than 97 % at impurity operation. Feed flow rate was 5.1 ~ 11 Nl/min and its hydrogen concentration** was 1 ~ 51 %. Impurities (CH_4 (and water) : 0.3 ~ 0.6 %) did not effect to PD function during this run. However, the purification was a little worse than that of JFCU-ISS run (Oct. '91) as shown in fig. 5-1-1. Differences around PD between JFCU-ISS run and this JFCU stand alone test were; 1) the amount of impurities (CH_4 and water) during this test was larger, 2) the isotopic composition of this test was lighter (less tritium), 3) PD bleed flow rate of this test was larger, and 4) hydrogen concentration in the feed flow of PD of this test was lower. There is a small possibility that the impurities effect PD function. Isotopic composition of hydrogen also effect but lighter composition would be easier to pass through PD. Therefor, large bleed flow and low hydrogen gas concentration in the feed (low partial pressure of hydrogen isotopes in the PD feed) could cause the above PD function difference.

* : calculated by the integration of "jfcu-f-vactpu" under RT1-2 circulation and " jfcu-p-rt2" under dryup operation.

** : calculated from the GC data.

5.2 Catalytic reactor

During this test, catalytic reactor (JCR1) was controlled at 773 K. All hydrogen isotopes and methane were completely oxidized by the JCR1 if there was enough oxygen. No tritiated species were found at the outlet of CT under the stabilized condition by GC and by tritium monitor of JFCU. CH_4 combustion efficiency was also measured by GC.*

When the CT plugging occurred, about 550 Ci of tritium was exhausted to the TWT. However, comparing with the 1 gram run, reaction during this run should be done more complete, because the gas speed in the JCR1(~ 5.1 Nl/min) during this test was slower (1/3 ~ 1/4). Therefore, this tritium release was caused by insufficient Oxygen. The oxygen control program by MDAC did not work. So, its flow rate (120 ~ 170 sccm) was controlled manually by pressure adjustment of the O2 supply cylinder regulator.

* : CH4 concentration at the inlet of JCR1 was about 0.5 % and product CO2 conc. was also about 0.5 %.

5.3 Cold traps

During the stable condition, Cold Traps (CTs) collected almost all moisture and were regenerated completely and periodically by using Helium gas from outside cylinder(~ 5 Nl/min). Trapping factor was more than 10^4 under stabilized conditions. Total collected water amount* in each CT within a trapping period was about 0.25 mol(/hr) under non-impurity operation and was about 0.35 mol(/hr) under impurity operation. Differential pressure of CTs was not controlled at this time. Its differential pressure was about 40 torr (CT1,CT3) and about 60 torr (CT2) under stabilized condition. Feed flow rate of CTs was about 5 Nl/min because JCR1 dilution line was not used. (It was same flow rate of JCR1.)

CTs' + JMSBs' water collection performance was as effective as the last cold testing. Small humidity spikes at the CT changing time were not found. JMSBs worked well, because new JMSBs were replaced and regenerated completely. Temperature controller cable for JMSB was also repaired.

However, CT2 plugging occurred twice. This plug was worst problem during this test. 1st plug was melted when CT2's inlet piping heater temp. was increased to 600 K(indication on JFCU-PC). The amount** of hydrogen isotopes, trapped at CT before the plug formed, was 0.26 mol (1st plug) and 0.34 mol (2nd plug), even though design value of each CT water trapped was 0.78 mol/hr. The inlet humidity of CT was 320 K DewPoint (KDP) (1st) and 325 KDP (2nd) at the plugging (design value was ~ 297 KDP (~ 2 % water vapor) as a mean value). During the last test (1 gram run on June 1991), each CT could trap water more than 0.8 mol/hr, however, inlet humidity of CTs was always below 300 K because JCR1 dilution flow (~> 10 Nl/min) diluted this humidity effectively. Refer figure 5-3-1 and 5-3-2. The use of JCR1 dilution flow means that flow through JCR1-CT increases and reaction time of oxidation-trapping decreases. There is some possibility of lack of oxidation-trapping, however, the use of JCR1 dilution flow could be one solution for CT plugging. Further testing will be planned for check CT function.

* : calculated from the mean values of "jfcu-i-wece", "jfcu-hum-cecin", jfcu-hum-cecex", and "jfcu-hum-jcr1ex".

** : calculated from RT2 pressure increase after dryup of this plug.

5.4 Ceramic electrolysis cell

The ceramic electrolysis cell (CEC B) was controlled at 1023 K. Potential between the inside and outside of cell tubes was controlled to be 1.2 - 1.4 Volt by the reference electrode of potentiostat ("jfcu-v-rece"). Differential pressure between the inside and the outside of cell tubes was roughly controlled within - 50 ~ - 200 torr manually. During applying potential to the cells, the differential pressure was nearly constant (non-decomposition of water) or increasing (water decomposition), in spite of CEC B cell leaks Oxygen that leaked from O_2 side to process side was recovered effectively back to the O_2 side. New power supply was installed and input ~ 0.2 volt between RE2 and ground in order to avoid the brazing disconnect problem.

In the non-impurity operation, moisture from regenerated CTs about max 0.2 mol/hr* was decomposed by CEC. In the impurity operation, moisture about 0.3 mol/hr was decomposed. Because operational current of CEC was restricted to 8A (TSTA-scram setting), there was some limit of decomposition function.

During this test, CEC function was better because the line of CT regeneration was set to "external". This mean that CEC was not affected by excess oxygen from JCR1 as the CT regeneration line was set to "internal".

If we want to decompose desired water (0.78 mol/hr), total coulomb required are about 150000 C/hr (0.78 x 96480 x 2). The mean current of CEC is 8.3 A (150000 / 3600 / 5).

CECB has a little leak of order of 10-3 ~ 10-2 Acc/s. This leak did not increase at the high temperature (1023 K) and after this run. However, further periodical watching of this leak should be planned including to make sure that a little voltage input between RE2 of each cell and the ground is effective or not.

* : calculated from the mean value of "jfcu-i-wece".

5.5 Gaschromatographs

Sampling program and analysis program (type I and II) worked automatically. Several samples at the sampling points #2, #3, #4, #5 were taken periodically. The peaks, that were missed to calculate by the GC during the run, were recalculated manually after the run. All results of GCs were shown in APPENDIX II.

A CO_2 peak was not detected at normal pressure (100 torr) sampling during the impurity addition in the GC2. At the last sampling, a small peak of CO_2 was detected but its calculation indicates 0.2 %. Low (~0.5 %) CO_2 conc. is difficult to detect due to its low sensitivity. However, STD gas CO_2 (its conc. is about 2 %) was detected. It may need more injection time (>2 hr) to stabilize CO_2 conc for GC analysis.

JFCU staff and operators became familiar to JFCU-GC program timer and analysis (calibration) program. However, when they want to take samples manually at the off-nornal situation, there was some mistake caused by the lack of GC's hand valves setting checks.

Basically, GC function is well if columns' activation (aging) are completed. Therefore, GC sampling/analysis situation should be watched if some probrem happens or not.

During this test, the retention times of each species at GC2 fluctuated even if the carrier gas flow was constant. Retention time can fluctuate a little as a result of sampling gas pressure (Sample with higher pressure has longer retention times.). However, the fluctuation in this test would be caused by less aging of columns because sampling pressure was almost constant. Before this test, GC columns were activated for about 8-9 hours at 473 K, however, GC2 columns more aging time would be needed because for CEC decontamination gas analysis. Recommended GC molecular sieves columns aging condition is more than 48 hours at 513 K and that for chromosolve 103 is more than 24 hours at 473 K. (recommended from Mr. Tsujii (YANACO))

5.6 Zirconium cobalt bed

During the hydrogen supply/recovery operation, dry up operation, and inventory check operation, the zirconium cobalt bed (ZCB1) worked well. Almost all hydrogen isotopes were recovered safely and quickly. The amount of tritium that exhausted to TWT during shut down operation was less than 50 Ci. Almost all stored hydrogen isotopes was released by regeneration of ZCB1.

6. RESULTS (part Ⅱ: Total System Performance)

6.1 System performance

As described above, all components were operated safely during this operations. Non-impurity fuel processing operation was performed for 6 hours and fuel processing operation with about 1 % order of methane was performed for 2 hours safely. In order to decompose the residual moisture, dry-up operation was continued for 13 hrs.

During these fuel processing operations, "External" Cold Trap (CT) regeneration line was selected and Catalytic Reactor (JCR1) dilution line was not used. The stream to the Tritium Waste Treatment (TWT) system was almost constant about 5.1 Nl/min (almost pure Helium gas) and its tritium levels was lower than 50 mCi/m^3 under the stabilized condition.

CECB, that was a most important maintenance item and has still some leak, worked safely with careful operation using differential pressure and JFCU SAFETY program.

No humidity spike at the outlet of CTs was detected (It means that new installed JMSBs worked well.), however, CT (No.2) plugged twice and significant tritium exhaust to the TWT was detected just after the 1st plug melted because of insufficient O_2 around the JCR1. The amount of water that plugged the CT was less (about a half) of the designed value of water trapped in the CT. The main reason for this plug could be considered 1) high humidity concentration at the inlet of CTs and 2) some lack of CT regeneration. So, it would be needed to control low humidity at the inlet of CTs and to regenerate CTs completely. In order to avoid

the tritium exhausting to the TWT, improvement of O_2 control and stabilization of system pressure fluctuation should be considered.

The interlock system of JFCU was worked well. However, the pause level setting of RT1 pressure should be set closer to PD bleed control pressure (about + 50 torr larger than PD bleed control press.), specially when the "External" line for CT regeneration is selected. This setting will activate JFCU pause soon when CT plug occur.

6.2 Tritium recovery and Inventory

The volume of initially supplied hydrogen isotopes from ZCB1 was about 13 Nl, including 1.3 g tritium measured by mass spectrometer. This result by mass spectrometer was equal to that of Nov.'91 (after 10 grams run). The initial supplied D_2 from gas cylinder was 21 Nl. In the impurity operation, injected CH_4 volume was about 3.5 Nl (total). So, the volume of recovered H_2 from CH_4 was about 7 Nl. Total amount of hydrogen isotopes supplied to JFCU was about 41 Nl.

After this run, ZCB1 was regenerated again. Recovered gas amount was 36.5 Nl and tritium was 1.85 grams.

There is a little difference between estimated total gas volume and recovered one. However, there is a possibility that regeneration was not completed and/or that RT2 pressure indication of >1000 torr had some uncertainty, because pressure sensor range is 0 -- 1000 torr and the volume of RT2 is 30 Nl. In order to check correct inventory of ZCB1, it had better to regenerate again using LIO-PC. We used recovery loop of JFCU with tritium (~ 35 isotopic %) in the JFCU-ISS run and then did not used until this test. Tritium isotopic % in this run was about 20 % finally, as shown in the result of mass analysis. Therefore, the increase of tritium inventory of ZCB1 after this run means that the residual tritium in the JFCU, ex. adsorbed in JCR1, was recovered by exchange between H,D,T. Comparing with mass analysis results before and after this run, recovered tritium amount after this run increased 0.55 gram and tritium isotopic % decreased about a half. If total residual hydrogen isotopes in the JFCU was constant before and after this run, about more 0.55 grams of tritium would be remained in the JFCU.

6.3 System improvements

In order to watch the CEC differential pressure between inside and outside of cells, the connection location of differential pressure gauge was moved to the inside of the CEC isolation valve. Therefore, CEC leak situation can be watched anytime even if the CEC is isolated from the JFCU.

Replaced JMSBs and repaired controllers worked well. Therefore, no humidity spike at the outlet of CTs was detected. Before this run, JMSBs were regenerated for several hours at 573 K while evacuating them. This pre-regeneration might also be effective to eliminate humidity spike.

During this run, the stability of mass flow meter/controllers (MF/MFC) sensors' zero was much improved. Comparing with the last run, only MFC-JCR1BYP (flow controller) was replaced and the others were same. During this run, the temperature around MFC in the JFCU-GB was measured several times. It was about 300 K (before heating) and about max. 315 K (after heating). There was no data of temp. in the JFCU-GB at the last run, however, this run's temp. might be lower because of the winter season and might be much less effective to fluctuate MF/MFC zero-baseline.

6.4 Difficulties and problems

6.4.1 CT plugging and its effect to system

The greatest problem of this run was the CT2 plugging. CT plugging itself was a problem and also made system pressure fluctuation because He gas for CT regeneration was supplied continuously in spite of CT plugging situation. This is a potential problem when the "external" CT regeneration line is selected. During stand alone run, hydrogen isotopes in the RT2 circulate back to the RT1. Therefore, when CT plugged, the above excess He flowed to not only the RT1 but the RT2. This situation is not a problem for safety, however, it is still a problem for operation under stand alone run selecting "external" CT regeneration.

6.4.2 O_2 control

Next difficulty was that O_2 flow could not be controlled by the MDAC, though it was controlled completely at the 1 gram run (June '91). Manual O_2 flow control using the 2nd pressure of the cylinder regulator is a still problem when system pressure fluctuates. O_2 sensor also has some instability when it uses for a long time. To make sure its stability, it needs to be calibrate periodically. It is better to plan to replace fuel cell before big run.

6.4.3 JFCU SAFETY program

JFCU SAFETY program was improved to use the CECB safely. For safety concern, it is useful, however, it had better to turn off this program at the following short period;
1) evacuation the inlet line of the JCR1 because MDAC calculate O_2 conc using pressure of JCR1 inlet line, 2) just when turning power of CEC potentiostat ON because CEC current fluctuates at this period. As described in 5.4, we need to consider again the limit of CEC current for improvement of CEC function within the safety concern.

6.4.4 Computer hang up

The JFCU computer hung up twice during this run. At the 1st time, mouse could not operate while trending data on the VAX GPX II (main computer). At the 2nd time, application program stopped when the cable between VAX GPX II and color printer was disconnected. In both cases, JFCU system was under safety situation, though operator could not access to JFCU through MMI. In future, we must consider the solution to prevent this hung up.

6.4.5 Other

It was found that CEC current fluctuated after turning on the power of potentiostat and at the no electrolyte (low humidity) situation. The response time adjustment of the potentiostat might be effective to stabilize the current fluctuation.

Though CECB worked well and its leak rate did not change before/after this run, there was a possibility to break cells. During this run, cell break possibility was suspected at the 2nd CT plugging. If the cell brakes, large amount of hydrogen-oxygen mixture might be made in the RT1 and RT2. Concerning a possibility of the cell breaking, it is better to reduce O2 conc. in the O2 jacket of the CEC.

7. CONSIDERATIONS AND IMPROVEMENT FOR FUTURE TEST

In order to perform future JFCU test more successfully and more safely, the following items should be considered.

1) Improvement of CT plugging

As discussed above, the main reason of plugging would be high humidity at the inlet of CTs, longer resistant time due to lower flow rate and some lack of regeneration. Therefor, more than 5 Nl/min of JCR1 dilution flow should be used for decreasing humidity. In order to complete regeneration, regeneration temp. changing (up to 363 K from 343 K) and increasing regeneration flow should be considered. Because CT2 piping heater was found to be loose after this run, it should be fixed tight. The heating situation at the upper flange of CTs in the cover should be checked. It had better to check and evaluate again after the above improvement until the loop run.

2) O2 control

O2 flow should be controlled by the MDAC. Therefore, program and signal wiring should be checked again. Hopefully, O2 conc. control should also be improved by re-considering MDAC program and testing.

3) Safety concern

In order to avoid hazardous hydrogen-oxygen mixture, even if the CEC cell breaks, it is better to fill inert gas (He) to O2 jacket of the CEC initially. Therefor, temporary piping to supply He in the CEC O2 side should be installed. O2/He or Ar supply line, that have not been used, could be useful for the above modification.

Interlock setting of RT1 pressure should be adjusted to a close value (maybe + 50 torr) of PD bleed control pressure. JFCU SAFETY program should also adjust depend on the consideration above.

4) JFCU application software and hard disk memory increasing

JFCU application software have some mistakes on the graphics and its memory for accumulation of data is small (less than a week of capacity). So, new application software will be made and sent to TSTA this march. Hard disk (RD50) has been requested through Mr Steven Cole. At the same time of the above software installation, it had better to install the

latest version up of GKS (basic graphic software). There is a possibility to exist some bugs in the GKS & VMS (system software).

5) Others

Some mass flow meters/controllers (MF/MFC) did not read properly. Therefore, it needs to check. There are MFC-NH3 and MFC-ISSIN. During this run, stability of MF/MFC was well enough. However, it might be better to have a system to cool GB atmosphere forcibly.

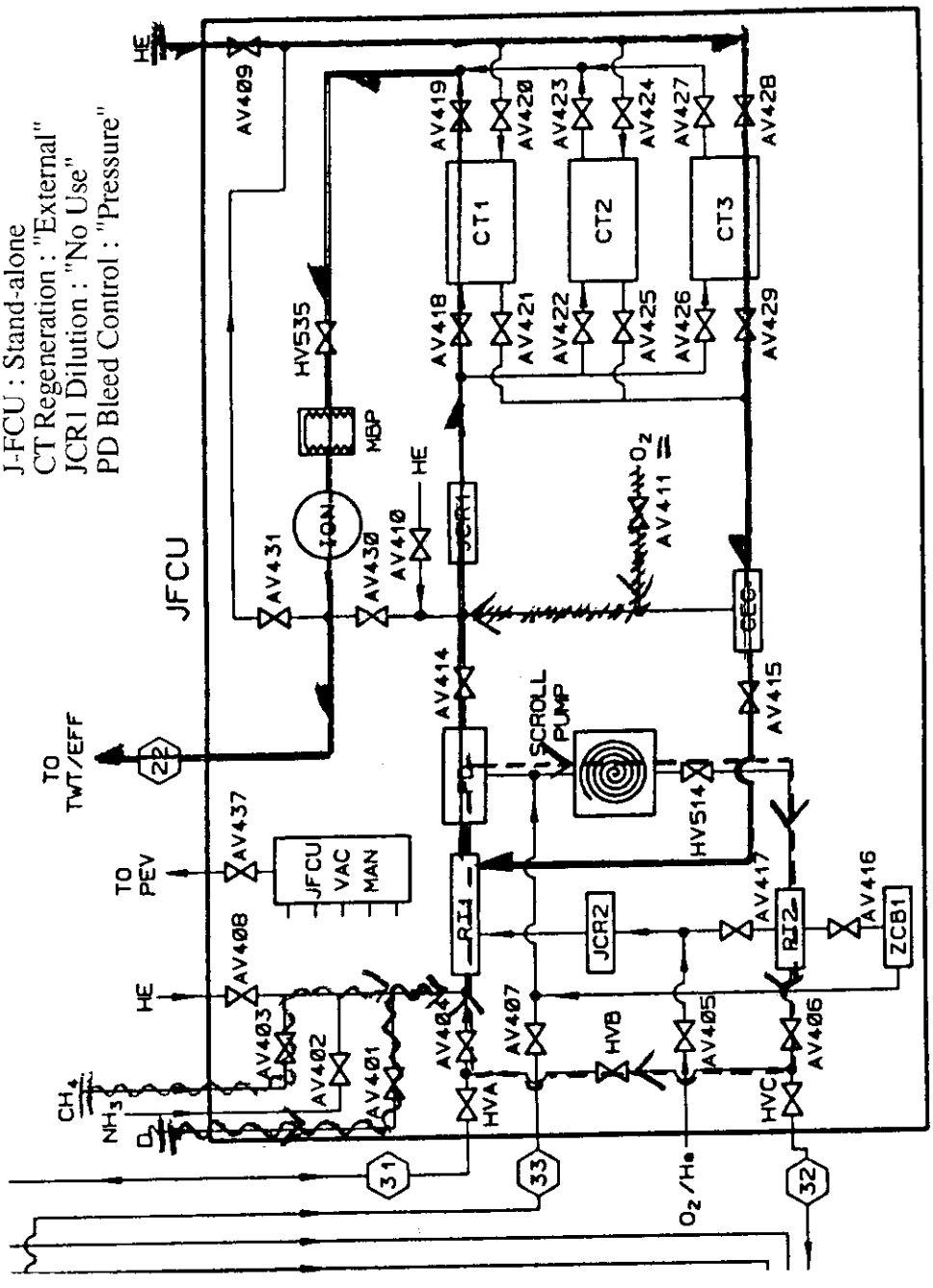


Fig. 3.1 JFCU configuration

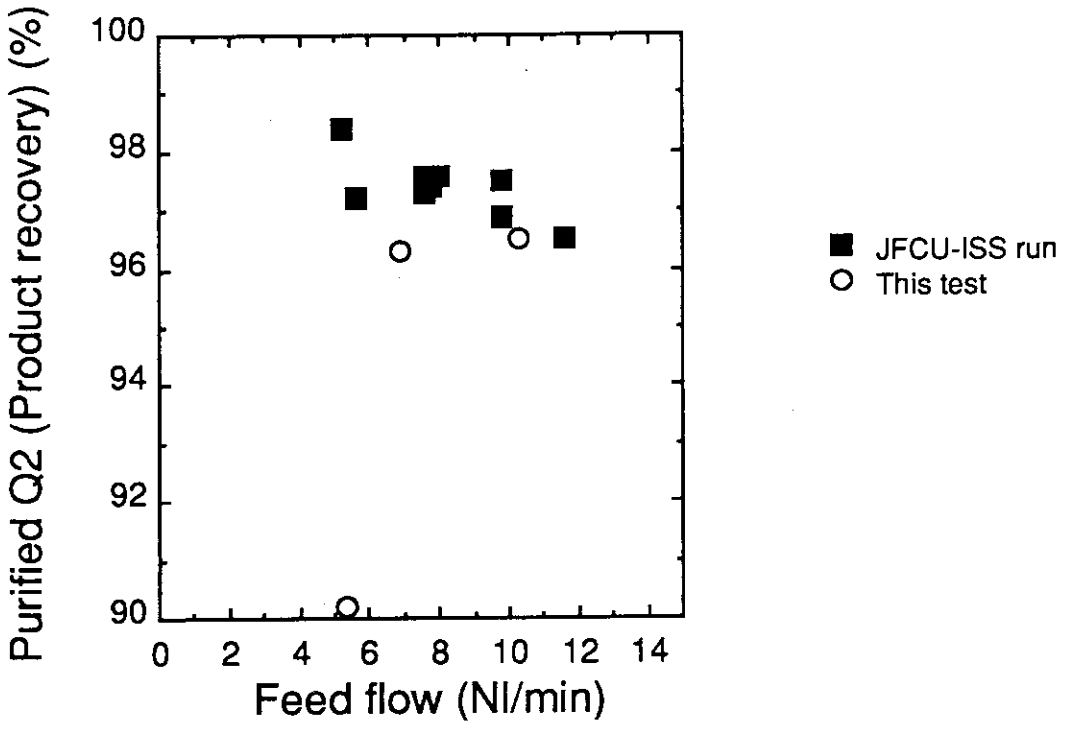


Fig. 5. 1. 1 Hydrogen isotopes gases (Q_2) purification percent in the Palladium Diffuser as a function of the feed flow rate.

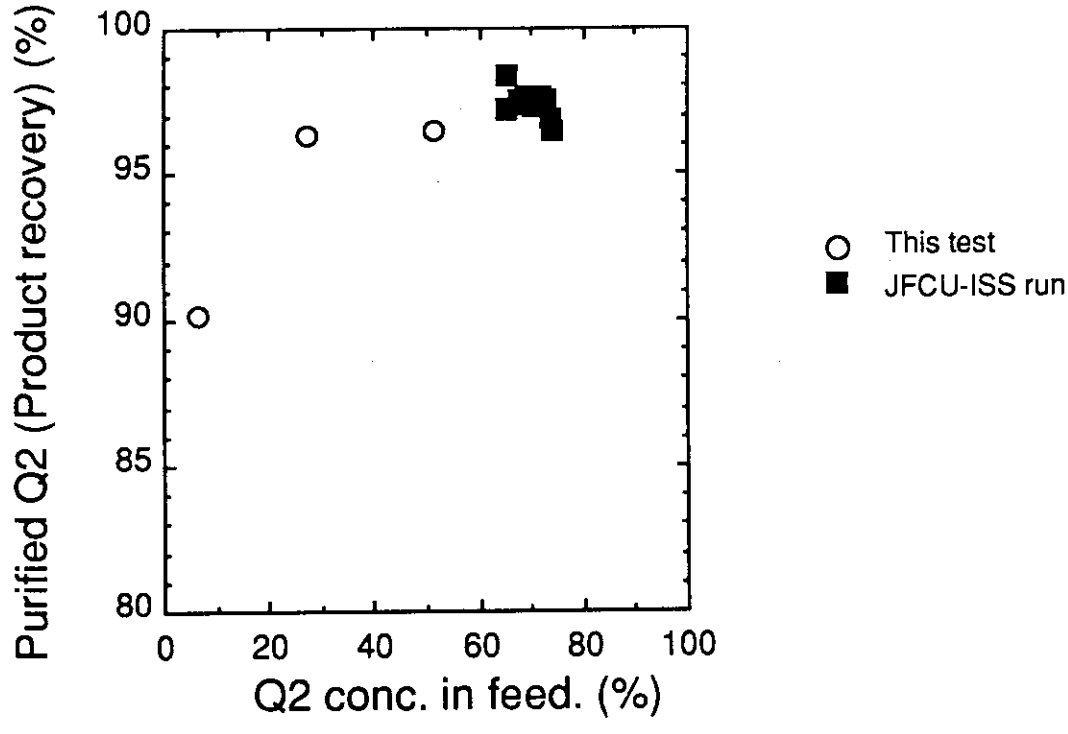


Fig. 5. 1. 2 Hydrogen isotopes gases (Q_2) purification percent in the Palladium Diffuser as a function of the Q_2 conc. in the feed gas.

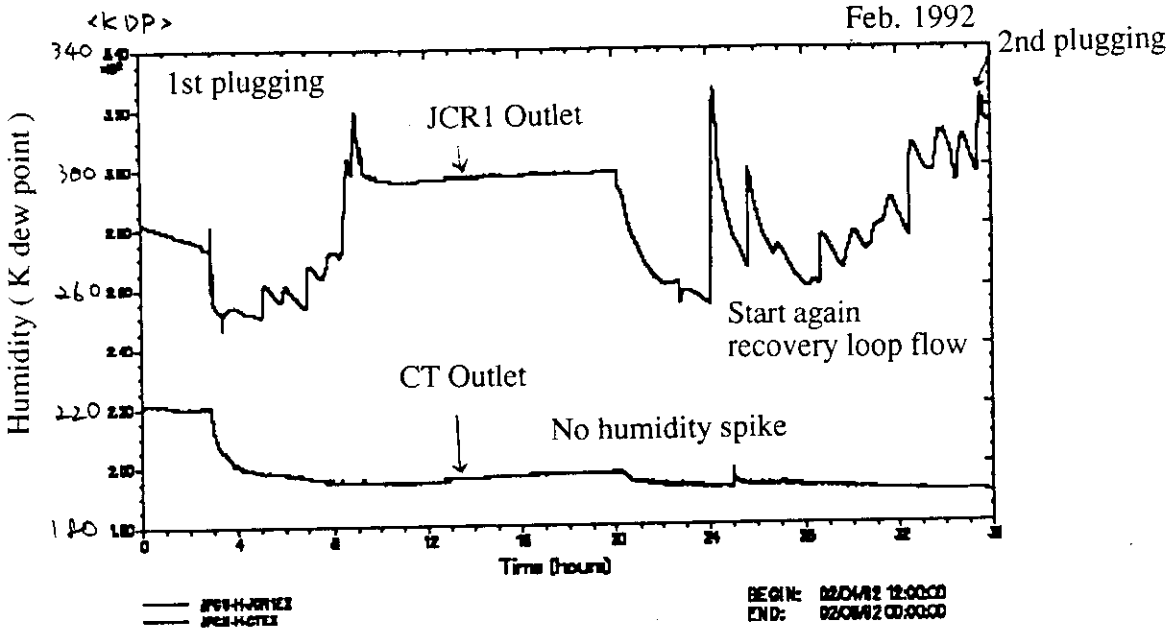


Fig. 5. 3. 1 Humidity fluctuation in the JFCU during this test.

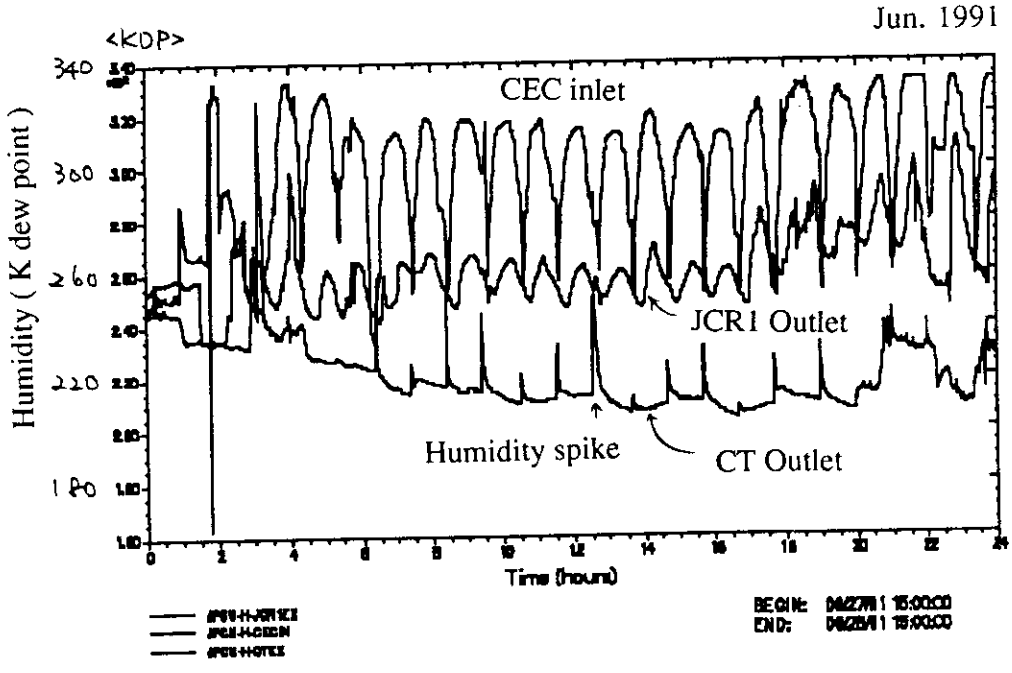


Fig. 5. 3. 2 Humidity fluctuation in the JFCU during the 1gram run.

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APPENDIX I

JFCU operation log.

Day and Time		Explanation
-------Jan.31		- Installation of CECB and its wiring check, - Installation and check out new power supply for CEC, - JMSB3, 4 and 5 installation, electrical testing and regeneration, - Modify JFCU safety program and test, - O2 sensor's calibration, - GC column aging, A part of re-calibration, and program timer setting, - MKS flow controller sensor (JCR1BYP) replacement, - GB helium leak checking and JFCU process tritium leak checking. - Check quantity of gas cylinders and its lines to the JFCU.
Feb.3,	08:00	- JFCU computer memory cleared. - new power supply for CEC turn on
	08:30	- JCR1 and PD heater turn on, CEC heater turned on.
	09:00	- Adjustment of CEC cell differential pressure (-55 torr) - Refrigerator(REF) turn on.
	10:00	- All valve positions checked.
	10:30	- PEV start for GC calibration.
	11:00	- TMP turn on and evacuation of vacuum jackets of PD and JCR1. - CT cycle operation set to "reset"
	13:30	- CEC heater No.D 's temp. measuring span factor adjust.
	14:00	- Mass flow meters/controllers zero calibration. - O2 in the CEC O2 jacket evacuation (~3L) to adjust differential press.
	16:00	- flow meter calibration and span adjusting
	17:00	- Oxygen monitors calibration.
	17:30	- CEC-DP adjusting - set small sample bottle for inventory check
	18:00	- JFCU system evacuation except CEC and O2 sensors - TSTA SCRAM coming for wrong calculation of O2 conc. by MDAC. - TMP turn on and Scroll-BP turn on
	19:00	- pressure sensors zero calibration
	20:00	- ZCB1 heating start, hydrogen gas was stored in the RT2 by pumps
	20:30	- CT cycle operation start.
Feb.4	00:00	- GC calibration with ammonia
	01:00	- CEC-DP adjusting
	03:00	- new power supply for CEC burned out.
	04:00	- CEC-DP adjusting
	05:30	- CEC-DP adjusting
	06:30	- CEC-DP adjusting
	08:00	- another new power supply installed and turn on
	08:30	- ZCB1 heating up to 723 from 673 K - re-setting ZCB1 alarm parameters
	09:30	- JFCU computer hang up (mouse operation)
	10:30	- recover of the JFCU computer hung up
	11:30	- take sample from RT2 for inventory check
	13:30	- prepare for recovery loop flow of JFCU
	14:30	- TSTA SCRAM coming for wrong O2 calculation at the line evacuation - O2 sensors re-calibration
	18:00	- O2 sensor's fuel cell replacement (JCR1 outlet) - prepare recovery loop flow
	18:30	- start D2 addition

	19:00	- Potentiostat "on".
	20:00	- connect RT2 to RT1
	20:45	- CT2 plugging
		- CT2 plug melting
		- TWT-LPR tritium monitor high up
	23:00	- TSTA SCRAM coming by CEC current high just after CT switching
		- potentiostat change to stand-by mode.
		- Isolate RT2 from RT1 and Scrol + BP turn on
		- hold this situation to the next morning
Feb.5	03:00	- CEC-DP adjusting
	08:00	- start internal circulation of JCR1 line
		- take sample by GC from #5 twice (no tritium indication in Ion chamber)
		- start purge O2 sensors with He using JCR1 He dilution line to TWT
		- O2 sensor's fuel cell replacement (inlet of JCR1) and calibration
	11:00	- huddle
	11:30	- start preparation for recovery loop flow
		- CEC line pressure check
		- system pressure check and adjustment
		- start He supply from CT regeneration line
		- He and O2 flow adjustment
		- system pressure re-adjustment
		- CT cycle operation "start" again
		- JFCU SAFETY program off
		- potentiostat turn on
		- JFCU SAFETY program on again
	12:30	- watching this situation
	16:00	- RT2 pressure decrease (~ 50 torr) by evacuate a little to the ZCB1
		- connect again RT2-RT1
	17:30	- to make RT2-RT1 flow, start D2 addition stepwise
	19:30	- stop D2 addition
		- GC sampling program start
	20:15	- start CH4 addition
	22:15	- stop CH4 addition
	23:30	- alarm CEC-DP reversal
		- JFCU pause by P-ISSIN interlock setting
		- potentiostat set stand-by
		- Isolate CEC from JFCU
		- turn off JCR1 heater
		- GC sampling around RT1 gas
		- hold this situation
Feb.6	08:00	- start CEC cooling
		- check JFCU situation to decide the next step
	10:00	- extended huddle
	11:00	- take sample from RT1 and analyses by raman
	12:00	- re-heating up of CEC
	14:00	- found no O2 in the RT1
	16:00	- start recover hydrogen gas in the RT2 and RT1 to ZCB1 by circulation
	18:00	- stop recovery and start evacuation RT2 gas to TWT thru ZCB1
	21:00	- start dry up operation by internal circulation and heating up JCR1 again
		- CT cycle start and potentiostat on
	23:00	- CEC-DP adjusting
Feb.7	06:00	- CEC-DP adjusting
	08:00	- stop dryup operation

- CEC cooling down start
- RT2 recovered hydrogen gas recovered to ZCB1
- potentiostat off , CT cycle reset
- circulation recovery loop flow thru ZCB1

14:00 - start system evacuation to TWT thru ZCB1
16:00 - JCR1 and PD heaters off
18:00 - JFCU data log file save to MT
18:30 - set CEC cooling flow minimum
Feb. 10 08:00 - REF stop
- cooling flow stop

APPENDIX II

GC analysis results

Non-impurity operation

Time		Feb.4 22:09	Feb.5 09:52	13:29	14.53	18:20	19:53
Sampling # and Species							
#2	Q2	51.2	27.5	9.1	1.0	2.6	6.7
#3	Q2	3.6	1.4	---	---	---	0.7
#5	O2	3.7	2.5	1.7	1.7	3.0	3.5
	Ion ch.	---	---	---	---	---	---

Impurity operation

Time		Feb.5 22:06	22:37	23:09
Sampling # and Species				
#4	O2	2.1	2.0	2.3
	CH4	0.3	0.4	0.5
#5	O2	1.6	1.3	1.2
	CO2	---	---	0.2
	Ion ch.	---	---	---

Q : H, D, T
--- : Not Detected