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TESTS OF THE JAERI FUEL CLEANUP SYSTEM WITH DEUTERIUM AT THE TRITIUM SYSTEMS TEST ASSEMBLY

— JFCU Stand Alone Deuterium Test —
— JFCU Stand Alone Deuterium Test 2 —

March 1993

Satoshi KONISHI, Shigeru O'HIRA*[1], Takumi HAYASHI
Masahiko INOUE*[2], Tetsuo WATANABE*[3], Yuji NARUSE
Kenji OKUNO, J. W. BARNES*[4], W. HARBIN*[4]
J. R. BARTLIT*[4] and J. L. ANDERSON*[4]

日本原子力研究所
Japan Atomic Energy Research Institute

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J.R. BARTLIT*4 and J.L. ANDERSON*4

Department of Fusion Engineering Research
Naka Fusion Research Establishment
Japan Atomic Energy Research Institute
Naka-machi, Naka-gun, Ibaraki-ken

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A plasma exhaust processing subsystem, JAERI Fuel Cleanup (JFCU) was fabricated in Japan, as a major subsystem of the TSTA loop under the US-Japan collaboration program. This process is based on some Japanese developed components, and designed to meet TSTA requirements to interface existing TSTA loop. Following the installation at the TSTA in early 1990, stand-alone deuterium tests of the system were performed to verify the function of the process and the integrity of the system. Functions of all the components were satisfactory and system response in the operation were obtained. Some problems were found on the monitoring and control system.

Keywords: Nuclear Fusion, Tritium, Deuterium, TSTA, Fusion Fuel Cycle, palladium, Solid Electrolyte, Electrolsis Cell, Catalyst, Cold Trap

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*1 Attached to the Science and Technology Authority
*2 Mitsubishi Heavy Industries, Inc.
*3 Kawasaki Heavy Industries, Inc.
*4 Los Alamos National Laboratory

ＴＳＴＡ用原研製燃料精製システムの重水素試験
－ＪＦＣＵ単体重水素試験 －
－ＪＦＣＵ単体重水素試験２－

日本原子力研究所那珂研究所核融合工学部
小西　哲之・大平　茂[*1]・林　巧・井上　雅彦[*2]
渡辺　哲郎[*3]・成瀬　雄二・奥野　健二・J.W.BARNES[*4]
W.HARBIN[*4]・J.R.BARTLIT[*4]・J.L.ANDERSON[*4]

（1993年３月８日受理）

原研は日米協力協定AnnexⅣに基づいて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模擬試験を共同で行っている。その一環として原研が設計，制作してＴＳＴＡに設置した燃料精製システムの総合的な機能の検証を目的として単独重水素試験を行った。各コンポーネントは設計通り作動し，システム全体としての水素の精製機能と，不純物処理機能が確認された。また，定常運転に加え，起動，停止および非常停止操作におけるシステム全体の挙動に関する知見が得られた。酸化反応器への酸素添加量制御など，測定，制御システムに起因する過渡特性に問題が発見された。

那珂研究所：〒311-01　茨城県那珂郡那珂町大字向山801-1
*1　科学技術庁出向中
*2　三菱重工業㈱
*3　川崎重工業㈱
*4　ロスアラモス国立研究所

Contents

目　　次

I. Introduction

Annex IV to the Implementing Arrangement between the Japan Atomic Energy Research Institute and the United States Department of Energy on Cooperation in Fusion Research and Development was signed in June 1987 for the joint research on the fusion fuel processing technology. Under this agreement, JAERI and DOE jointly fund and operate the Tritium Systems Test Assembly (TSTA) at the Los Alamos National Laboratory , that is a working prototype of a fuel processing loop for a fusion reactor.

In the second phase of the collaboration, a complete plasma exhaust processing subsystem was designed and fabricated by JAERI for the test in the TSTA fuel loop. The apparatus of the JFCU was installed in early 1990 in the TSTA and a number of tests without tritium were performed since then. The purposes of the tests are; to evaluate the performance of components and integrated system, to uncover possible problems, improve, and optimize the system for processing simulated plasma exhaust, to verify the safety features and interlocks, to accumulate necessary information and experience for initiation of tritium operation, and to establish operation procedures, train operators, and be familialized with the behavior of the system. This report describes the outline of the cold tests of the integrated process of the JFCU(JAERI Fuel Cleanup System) performed for above purpose. The results of the modifications to the previously uncovered problems were verified.

II. Test Plan TTA-TP-118-06

PLAN FOR THE JAERI FUEL CLEANUP SYSTEM STAND ALONE DEUTERIUM OPERATION

1. Purpose

This test plan describes the outline of the cold testing of the integrated process of the JFCU(JAERI Fuel Cleanup System). Since the acceptance in March 1990, minor problems were corrected and the tests on some of the components were conducted. Modifications to the oxygen concentration control and cold traps are still in progress. The major purpose of this test is to evaluate the total function of the system that purifies and recovers hydrogen isotopes while rejecting impurities to exhaust . No tritium is used. The effectiveness of the modifications to the oxygen control system and cold traps will be verified.

Another major purpose is training and familiarization of TSTA/JAERI personnel in JFCU operation. Actual operation of equipment will be conducted by TSTA facility operators. Procedures and other operating documents will be used. Experience gained during operation will be used to revise documentation.

Data and other information needed for the safety appraisal will be obtained during this test.

2. Configuration

The test will be conducted as a stand alone run of the JFCU. Temporary piping for impurities and utilities will be provided as shown in the figure 1. No process piping is connected between JFCU and TSTA main loop or safety systems. A tribodyne pump is used for vacuum service. A metal bellows pump and a flow controlling bypass valve will be used to simulate the ISS/TPU that circulates ca. 6 liter/min of deuterium through the RT1-PD-SCROL-RT2 loop. Outlet of this temporary pump should be protected against overpressure. Process and vacuum exhaust, and nitrogen exhaust from the refrigerator are sent to stack through the portable ventilation ducts.

3. Subsystem Required

No TSTA subsystems are required to conduct the test except for MDAC and UTIL. High and low pressure nitrogen, chilled water, helium, liquid nitrogen, ventilation and electric power both from regular and UPS source are needed. Normal operations and maintenance of the TSTA subsystems during this testing may be conducted. MDAC will monitor and log the JFCU data. The MDAC archive function will be tested. Oxygen concentration at the JCR1 will also controlled through MDAC.

4. Personnel

S. Konishi and J. W. Barnes will coordinate the test. All the JAERI members and a number of TSTA staff, operators are involved in the testing. TSTA operators will conduct the operation. Shift work for one day is needed. Personnel assignment is shown in the attached table 1.

5. Time

The test is scheduled for the week of June 4 or 11. Approximately one day each is required for heating and cooling of the components. Operating personnel will be needed in regular work time during these periods. After the start up, 1 and a half days of continuous run followed by a "pause" at night will be tested. Tentative schedule is attached.

6. Possible Hazards

No tritium will be used in the test. Potential hazards are related to, high and low temperature at the components, high pressure gas, possible combustible mixtures, water, and electric power. All the major hazards are monitored and alarmed and/or interlocked.

7. Outline

Cold trap packing and the oxygen control system will be modified as determined by prior testing. The total performance of the JFCU will be tested in both round-the clock and run-and-stop operation. Purification of deuterium, oxidation of impurities, trapping and decomposition of water, and gas analysis by the GC system will be tested. System deuterium throughput, deuterium concentration in the bleed, conversion efficiency at the catalytic reactor, trapping efficiency at the cold traps, and capacity of the electrolysis cell are of concern. Supply and recovery of deuterium will be done with the ZCB1.

The detailed procedure is attached.

7.1 Preparation

All the set points for interlocks and alarms will be checked before the tests.

Utilities will be hooked up.

The JFCU apparatus will be filled with helium.

Gas Chromatographs will be turned on.

Prepare utilities, i.e., nitrogen, liquid nitrogen, He, O_2 and D_2, and vacuum. Leave the Scroll pump oil circulation running.

7.2 Start up/Heating/Cooling

Activate the computer.

Evacuate the system and backfill the downstream with helium. (Be sure to isolate oxygen probes) Keep scroll pump and palladium diffuser under vacuum.

Turn on the heaters of JCR1, PD, process piping, and CEC, start Freon Refrigerator and cold traps.

Set operation mode and alarm settings and interlocks.

Open both sides of the electrolysis cell to the atmosphere. When heated, purge out the oxygen side with pure O_2.

Heat ZCB1 for supply of deuterium.

Establish Stand-by mode.

7.3 Continuous Unit Operation

Start pumps. Supply D_2 to the loop from the ZCB bed.

Start Unit operation mode. Supply impurities. Start GC analysis.

Test flow control to simulate the return from ISS.

Operate stably for more than 24 hours.

Shut down system.

7.4 Pause

Stop impurities, then oxygen supply. Close all the boundary valves.[#1].

Stop scroll pump and isolate PD1-RT1-Scroll pump loop.

Stop cold trap cycle and turn off potentiostat.

#1 Supply of He, CH_4, O_2, AV401- 411, outlet to TWT(temporary room)AV412, 413, internal subloops, AV414 and 415, D_2 recovery to ZCB1 AV416.

This PAUSE mode can be attained by the "pause" switch
Observe if the system can be stopped safely and stably.

Restart

Restart Unit operation mode.
Start cold trap cycle, oxygen supply and potentiostat.
Supply impurities. Start GC analysis.

7.5 Shut Down／Deuterium Recovery

Stop impurities. Recover pure deuterium by the ZCB1. Continue to operate cold traps and the electrolysis cell.
Stop oxygen supply. Regenerate all the cold traps until dried out.
Continue to electrolyze moisture in the system.
Circulate the gas through the bed to remove deuterium.
Turn off the potentiostat.
Turn off pumps. Cool down system.
Regenerate the ZCB1 after the complete shut down.

8. Data

Data will be recorded in the JFCU computer. Monitoring at MDAC and archiving will be tested Major parameters of interests are to be entered in the check list attached to the procedure. A lab notebook for the JFCU will be used for the formal logging of the operation. Detailed procedure will be checked and modified during the operation. Valve settings are printed out for future use. A number of variables will be printed out by computer after some analysis aided by the software installed in the JFCU computer.

Table 1. Test Schedule and Personnel Assignment

SCHEDULE

date	Subject	Status at night
6/11 Mon	Preparation, start heating	cooling water, heater program running
6/12 Tue	Stand by-Unit mode	round-the clock
6/13 Wed	Unit Operation-Pause	Pause, components active
6/14 Thu	Unit Operation-shut down	ditto
6/15 Fri	Hydrogen recovery, Shut down	CEC cooling, water

PERSONNEL ASSIGNEMENT

JAERI

Day	Ab 7:30 - 20:00	bC 19:30 - 08:00	Bc 13:00 - 24:00	regular
6/11 Mon				All
6/12 Tue	Konishi	Inoue, Watanabe	Ohira	
6/13 Wed	Konishi			Ohira
6/14 Thu				All
6/15 Fri				All

TSTA

On 6/12, M. King is assigned B and R. Jenkins is C.

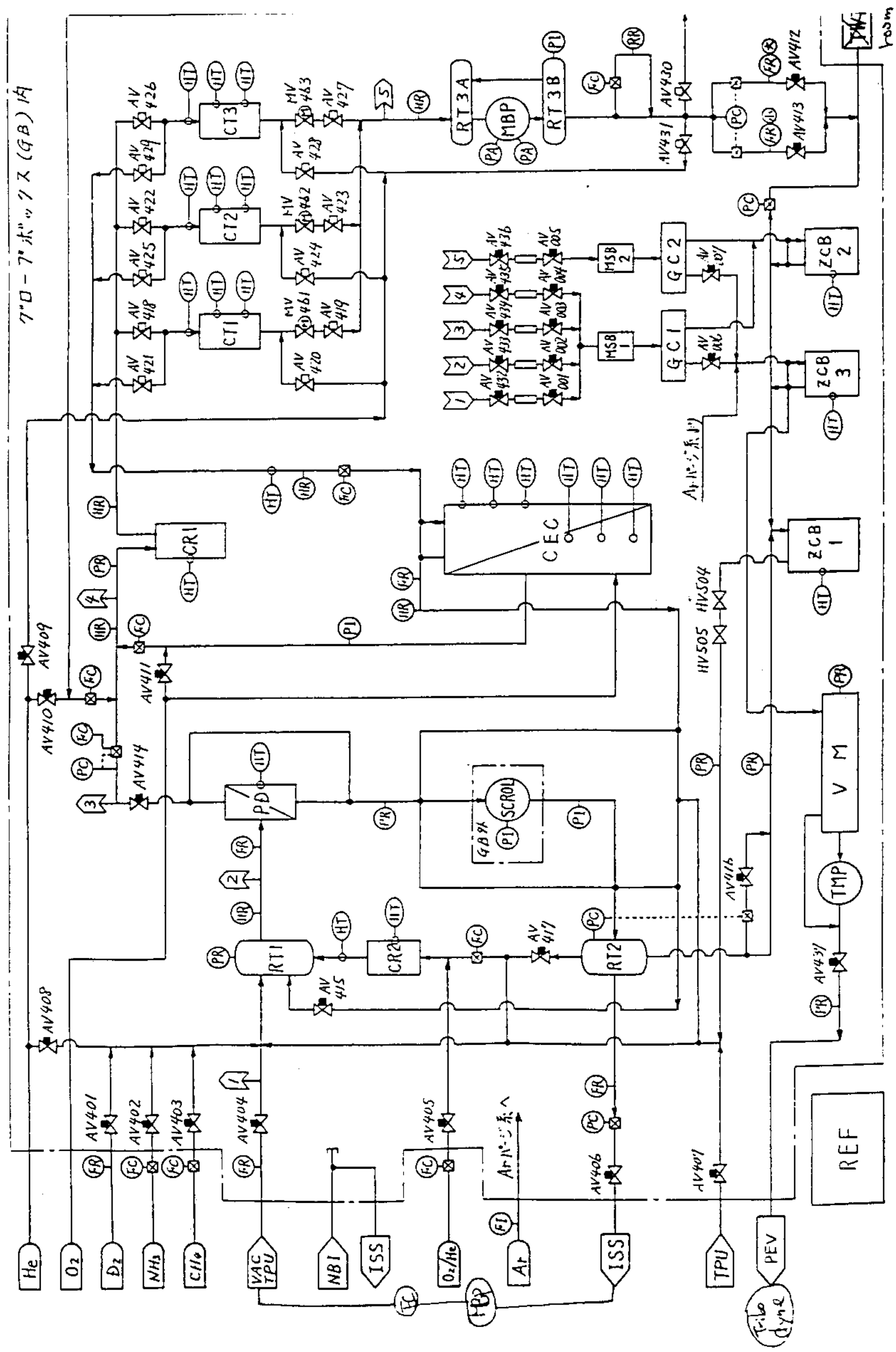


Fig. 1 Configuration of the JFCU Plumbing for the Test

Ⅲ. Test Results

TRITIUM SYSTEMS TEST ASSEMBLY
TEST RESULT

JAERI FUEL CLEANUP SYSTEM
STAND ALONE DEUTERIUM OPERATION 1

To be attached to the Test Plan TTA-TP-118-06, R0

1. Outline

This report describes the summary of the result of the cold testing of the integrated process of the JFCU(JAERI Fuel Cleanup System), planned in the test plan TTA-TP-118-06 and performed in the period of June 11 to 15.

The major purpose of this test was to evaluate the total function of the system that purifies and recovers hydrogen isotopes while rejecting impurities to exhaust . The effectiveness of the modifications to the oxygen control system and cold traps were tested. Operating procedure of the JFCU attached to the test plan was verified and corrected during the test.

2. Configuration

The test was conducted are shown in the figure 1 in the test plan.. No process piping is connected between JFCU and TSTA main loop or safety systems. A tribodyne pump was used for vacuum service. A metal bellows pump was used to circulate ca. 6 liter/min of deuterium through the RT1-PD-SCROL-RT2 loop in lieu of ISS.

3. Test result

The total performance of the JFCU was tested in both round-the clock and run-and-stop operation. Purification of deuterium, oxidation of impurities, trapping and decomposition of water, and gas analysis by the GC system were done. System deuterium throughput, deuterium concentration in the bleed, conversion efficiency at the catalytic reactor, trapping efficiency at the cold traps, and capacity of the electrolysis cell were measured. Supply and recovery of deuterium were done with the ZCB1.

The print out of the trend is attached.

3.1 Operation

3.1.1 Startup

All the components except for the temperature controller for the electrolysis cell started well. Temperature controller was found to have wrong internal setting and was fixed later. The cell was operated at 580°C in the test.

Supply of deuterium from the ZCB1 was successful.

3.1.2 Normal Operation

Continuous operation of the process was successfully performed for 25 hours with a few short pauses. Little difficulty was experienced in controlling and operating the system. Pressures in RT2 was kept relatively low, due to the poor compression of deuterium at the scroll pump. Gas chromatograph was not not operated skillfully and failed to leave meaningful data. This needs further familiarization and adjustment.

JFCU computer (DEC, VAX-GPX) was known to have a"bug" that causes system down. This problem was experienced twice in the run. Updating the OS is needed.

3.1.3 Pause/Restart

Manual "PAUSE" and restart was tested to experience intermittent operation and to test the condition for the holding shift. System was kept stable and safe during the PAUSE status, with deuterium and water kept in the process. It was possible to leave the process unattended in this status, but it will be questionable if we can do this with tritium. System was restarted readily and smoothly.

It is strongly suggested, if we can choose the timing, to stop the processing in the last several minutes of a cold trap cycle.so that we will leave no cold traps that have vapor in it. One can start the next cycle with a precooled dry trap. Written procedure should prevent operator to "RESET" the cold trap cycles, instead of to "STOP". Procedure for unexpected interlocked "PAUSE" will also have to be determined in the DTP.

3.1.4 Hydrogen recovery and shut down

Recovery of gaseous hydrogen was quite successful and easy. But recovering hydrogen from moisture in the process took longer than expected and we could not dry the process completely. . For the future inventory purpose, it will be enough fo dry the process down to the dew point lower than ca. 273K, where no liquid water is expected to remain. However, it is desirable to keep the process as dry as possible when shut down.

3.2 System function and performance

3.2.1 Deuterium purification and bleed control

Purification of deuterium and bleed flow control went well at the diffuser. Since there was no control on the flow rate from the process outlet to ISS(simulated by a metal bellows pump), the product flow rate was not steady. It was mainly due to lack of compression of deuterium by the scroll pump. When the pressure of RT2 was carefully kept high, it was possible to maintain the product flow rate in the range of 6~8 liter/min. This result possibly suggests that the PD could process the deuterium at the designed throughput with acceptable mixing of deuterium into the bleed. Further testing is needed with a booster pump for the Scrol pump.

3.2.2 Conversion at JCR1

Oxygen concentration control was temporary performed by a Brooks flow controller (non-tritium compatible) and MDAC logic. The control logic worked reasonably, but the stability of the oxygen concentration was not good. More improvement was needed fo the control. Oxygen monitor at the outlet of the reactor, ORCA-JCR1EX indicated insufficient oxygen several times.

Conversion of combustible species seemed to be acceptable, however the GC analysis could not verify the result.

Identification of peaks in the GC spectra was not successful. Further familiarization in the operation is needed.

3.2.3 Cold Traps

Cyclic operation of cold traps went quite well in both continuous and Pause-Restart operation. Regeneration of the traps was completed in each one hour cycle at the regeneration temperature of 90°C. No plugging was observed.

When regeneration was unexpectedly stopped, it was needed to extend regeneration cycle to dry it completely.

Humidity spikes at the outlet of the trap were still observed when the traps were switched despite the effort to modify the inner structure. Detailed consideration and improvement was reported elsewhere. Rough estimation indicates that order of 10 Ci/day will be discharged to TWT if the carried over humidity is DTO.

Flow controller for regeneration (FRC-CECIN) was sometimes pegged and real flow rate decreased. It is suspected that the flow transducer reads high when it is wet. Change of the location of the flow controller was suggested.

3.2.4 Electrolysis Cell

The cell decomposed water extremely well although it was operated at the temperature far below the designed condition. If the electrolysis capacity was not sufficient, water would accumulate in the process, and finally incomplete regeneration of cold traps would occur. Amount of water trapped in the CTs indicated in the trend of HLR-CECIN suggests no increase of water. No. 10 cell did not indicate any sign of current.

The potentiostat was not used for the voltage control, for the cell was operated at the maximum voltage, 10V most of the time due to the low operation temperature.

Humidity reading at the outlet of the cell was usually higher than the inlet. The probe was suspected to be wrong.

4. Chronology

6/11	17:06	CEC heaters turned on
6/12	09:02	Process evacuated
	09:48	Evacuation completed
	11:50	Freon supplied to cold traps
	12:01	CT regeneration heater turned on
	14:38	Cold trap cycle started
	14:43	Scrol pump started

	14:45	Potentiostat turned on
	14:52	ZCB1 heater turned on, D_2 supplied.
	16:15	ZCB1 heater turned off
	16:19	Bleed opened to JCR1
		Flow to simulated ISS maintained over 6 liter/min.
	17:03	CT regeneration set to External
		Normal operation continued
	23:50	JFCU computer system down
6/13	00:51	processing restarted
	05:30	JFCU computer system down.
	06:50	Processing restarted.
	08:19	CT program stopped to complete regeneration.
	08:51	D_2 recycle to the inlet stopped to recover D_2 from water.
	09:25	CT cycle resumed.
	11:50	D_2 recycle started.
		System stabilized.
	13:14	CH_4 supplied.
	15:58	"Pause" set manually.
6/14	07:56	Restarted.
	10:50	CH_4 supply stopped.
	10:55	D_2 recycle stopped.
	11:22	D_2 recovery at ZCB1 started.
	11:25	O_2 supply stopped. Electrolysis continued.
	16:56	Manual "PAUSE".
6/15	10:05	Dry out operation restarted.
	14:08	All CTs heated.
	15:58	Potentiostat set to 0V. Electrolysis stopped.
	16:00	Gas circulation stopped.
	16:05	CEC cool down started.

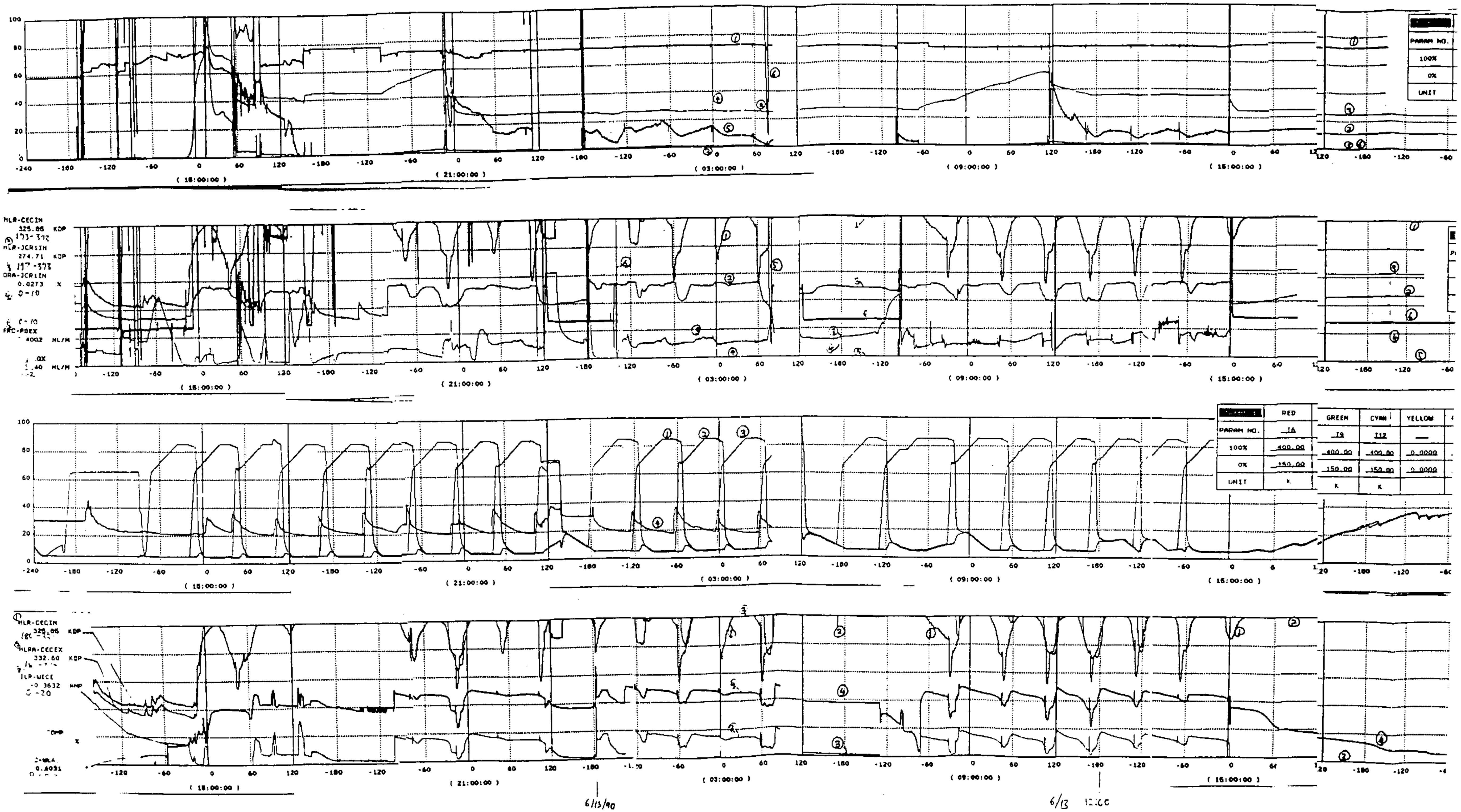
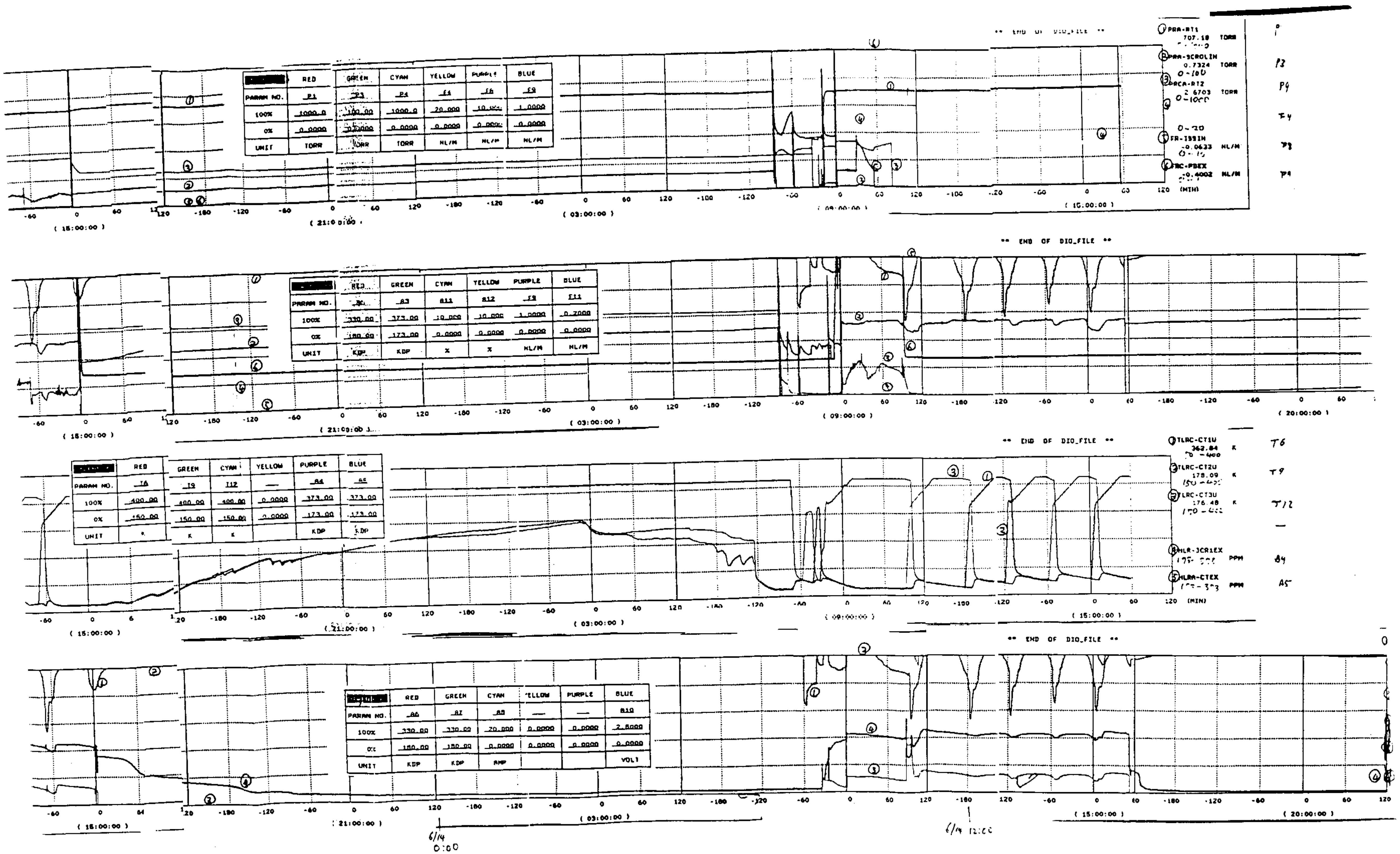


Fig. 1 Trend of the Major Variables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PRA-SCROLIN 0.7324 TORR
PRCA-RT2 2.6703 TORR
FR-1591N -0.0623 NL/M
FRC-PBEX -0.4002 NL/M
TLRC-CT1U 362.84 K
TLRC-CT2U 175.09 K
TLRC-CT3U 176.48 K
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HLRA-CTEX PPM
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GREEN
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YELLOW
PURPLE
BLUE
6/14 0:00
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IV. Test Plan2 TTA-TP-118-10

PLAN FOR THE JAERI FUEL CLEANUP SYSTEM STAND ALONE DEUTERIUM OPERATION 2

1. Purpose

This test plan outlines cold testing of the integrated JFCU(JAERI Fuel Cleanup System)process. Since the cold run in June 1990, most of the problems were corrected and the tests on the major components were completed. The purpose of this test is to evaluate the total function of the system that purifies and recovers hydrogen isotopes while rejecting impurities to exhaust . No tritium is used. The effect of the addition of the metal bellows pump to the Scroll pump inlet will be tested with the simulated fluctuation of the flow from the ISS. Improvement of efficiency in trapping moisture by the molecular sieve beds added to the cold traps will be verified. The newly installed CEC will be operated as a part of the system. The operation will include some tests of the safety-related functions of the JFCU, that will be demonstrated as a part of the preoperational appraisal scheduled in January 1991.

Another major purpose is training and familiarization of TSTA/JAERI personnel in JFCU operation. Actual operation of equipment will be conducted by TSTA facility operators. As the Operation Readiness Review of the JFCU is approaching, this operation will finalize the training and accreditation of the personnel in JFCU operation.

2. Configuration

The test will be conducted as a stand alone run of the JFCU. No process piping is connected between the JFCU and TSTA main loop or safety systems. An Alcatel pump is used for vacuum service. A metal bellows pump and a flow controlling bypass valve will be used to simulate the ISS/TPU that circulates ca. 6 liter/min of deuterium through the RT1-PD-SCROL-RT2 loop. Process and vacuum exhaust, and nitrogen exhaust from the refrigerator are sent to the stack through the portable ventilation ducts.

3. Subsystem required

The MDAC will archive data from the JFCU. The test may include emergency shutdown from the MDAC if the software is available. Oxygen concentration at the

JCR1 may also be controlled through MDAC. No other TSTA subsystems are required to conduct the test except for the UTIL. High and low pressure nitrogen, chilled water, helium, liquid nitrogen, ventilation and electric power both from regular and UPS source are needed. Normal operations and maintenance of the TSTA subsystems during this testing may be conducted.

4. Personnel

S. Konishi and J. W. Barnes will coordinate the test. All the JAERI members and a number of TSTA staff, operators are involved in the testing. TSTA operators will conduct the operation. Personnel assignments will be announced.

5. Time

The test is scheduled for the week of Dec. 10 following the CEC electrolysis test. Approximately three days will be required to conduct the test. Cooling of the components will be done during the weekend. Operating personnel will be needed in regular work time during this period. Some overtime work will be needed depending on the progress of the test. Test will start with an 8:15 briefing every morning. A tentative schedule is attached.

6. Possible hazards

No tritium will be used in the test. Potential hazards are related to, high and low temperature at the components, high pressure gas, possible combustible mixtures, water, and electric power. All the major hazards are monitored and alarmed and/or interlocked.

7. Outline

Oxygen control system is expected to be fixed prior to testing. Molecular sieves at the outlet of the CTs will be ready, except for the programmed regeneration. JMSB3, 4 and 5 will be regenerated manually. Separation of deuterium from impurities at the nominal throughput, as well as under simulated supply fluctuations from the ISS will be tested. Oxidation of methane impurity, trapping and decomposition of water, and gas analysis by the GC system functions will be tested. System deuterium throughput, deuterium concentration in the bleed, conversion efficiency at the catalytic reactor, trapping efficiency at the cold traps, and capacity of the electrolysis cell will be determined. Deuterium will be supplied from an external source and recovered with the ZCB1.

7.1 Preparation (12/10)

All the set points for interlocks and alarms will be checked before the tests.

Utilities will be connected.

Gas Chromatographs will be turned on and the carrier gas will be supplied.

Prepare utilities, i.e., nitrogen, liquid nitrogen, He, O_2 and D_2, and vacuum. Leave the Scroll pump oil circulation running.

CEC, JCR1, PD and process piping will be heated for the CEC tests.

Purge the oxygen side or the cell with pure O_2.

Connect a circulation pump(rubber diafragm) between the "VAC-TPU" and the "ISS".

7.2 Start-up/Heating/Cooling (day 1)

Make sure that the JFCU computer has sufficient memory space#1 . If not, store the log files in a tape and delete unnecessary files.

Evacuate RT1-PD-SCROL-RT2 and vacuum jackets. Isolate PD, SCROL and RT2.

Purge JCR1-CT-CEC-RT1-PD(feed side) with helium.

Start heating of the CEC, JCR1 and PD.

7.3 Continuous Unit Normal Operation (day 2)

Start Freon Refrigerator and cold trap cycles.

Set operation mode and alarm settings.#2

Establish Heating mode.

Establish Stand-by mode.

Start pumps. Supply D_2 to the RT1-PD-SCROL-RT2 loop from the bottle.

#1 Memory space can be checked by the @DEV_ST_LOOP macro on the GPX. Start operation with at least 15% of memory(85% occupied).

#2 Modes settings are; DILUTION-INTERNAL, REGENERATION-EXTERNAL, PDBLEED-PRESSURE, and UNIT loop mode.

Start Unit operation mode. Supply impurities. Start GC analysis.

When the pressure in the RT2 becomes greater than PRA-RT1, start "UNIT" operation. (Fig.1)

Operate the system stably for several hours.

Regenerate the JMSB-3,4,5 by hourly manual switching.

7.4 Pause (day 2 evening)

Stop impurities, and oxygen supply. Close all the boundary valves#3 .

Stop scroll pump and isolate PD1-RT1-Scroll pump loop.

Stop cold trap cycle and potentiostat.

Observe if the system can be stopped safely and all the variables stable.

Scroll pump may be left ON and isolated manually.

Restart (day 3)

Reset the "PAUSE" switch.

Start cold trap cycle, oxygen supply and potentiostat.

Supply impurities. Start GC analysis.

Restart normal operation mode.

Change mode to "LOOP".

Simulate fluctuation by the ISS using circulation pump(Rubber diafragm)#4

7.5 Interlocked Shutdown (12/13)

Activate PAUSE mode by the "pause" switch.

Test the "PAUSE" switch activating by the interlocks#5 .

Shut down the JFCU by setting "JFCU_CS_SCRAM" to "ON" from MDAC.

#3 Supply of He, CH_4, O_2, AV401- 411, outlet to TWT(temporary room)AV412, 413, internal subloops, AV414 and 415, D_2 recovery to ZCB1 AV416.

#4 Change the flow rate FR-VACTPU to 2 liter/min and hold for 10 min.
Watch the change in the pressure and flow rate in the JFCU process.
Then, change that to 10 liter/min and hold for ten min.
Repeat and change the flow rate and.or frequency when needed.

#5 RT2 pressure will be raised by closing AV406. Some other interlocks such as JCR1 temperature low will be tested.

7.6 Shut Down/Deuterium Recovery (day 3,4)

Stop impurities. Isolate PD(Permeated side)-SCROL-RT2. (Close AV406).

Recover pure deuterium to ZCB1. (fig.2)

Continue to operate cold traps and the electrolysis cell.

Stop oxygen supply30 min after methane is stopped..

When leaving on the day3, Stop Potentiostat and the circulation pump.

Restart Circulation pump and potentiostat. (day 4)

Heat all the cold traps and MSBs when they are almost dried out(HLR-CECIN~273KDP).

Continue to electrolyze moisture in the system.

Circulate the gas through ZCB1 to remove deuterium when necessary. (Fig. 3)

Turn off the potentiostat.

Turn off pumps. Cool down system.

Pump out the process.

8. Data

Data will be recorded in the JFCU computer. Monitoring at MDAC and archiving will be tested Major parameters of interests are to be entered in the check list attached to the procedure. A lab notebook for the JFCU will be used for the formal logging of the operations. Major configuration will be printed out. Detailed procedure will be checked and modified during the operation. Valve settings are printed out for future use. A number of variables will be printed out by computer for analysis aided by the software installed in the JFCU computer.

Table 1. Schedule of the Test

SCHEDULE

day	date	Subject
1	12/10 Mon	preparation, CEC test(covered by TTA-TP-118-09)
	12/11 Tue	CEC test
2	12/12 Wed	Steady Operation-Pause
3	12/13 Thu	ISS simulation Operation-Emergency Stop
4	12/14 Fri	Hydrogen recovery, Shut down. CEC cooling.

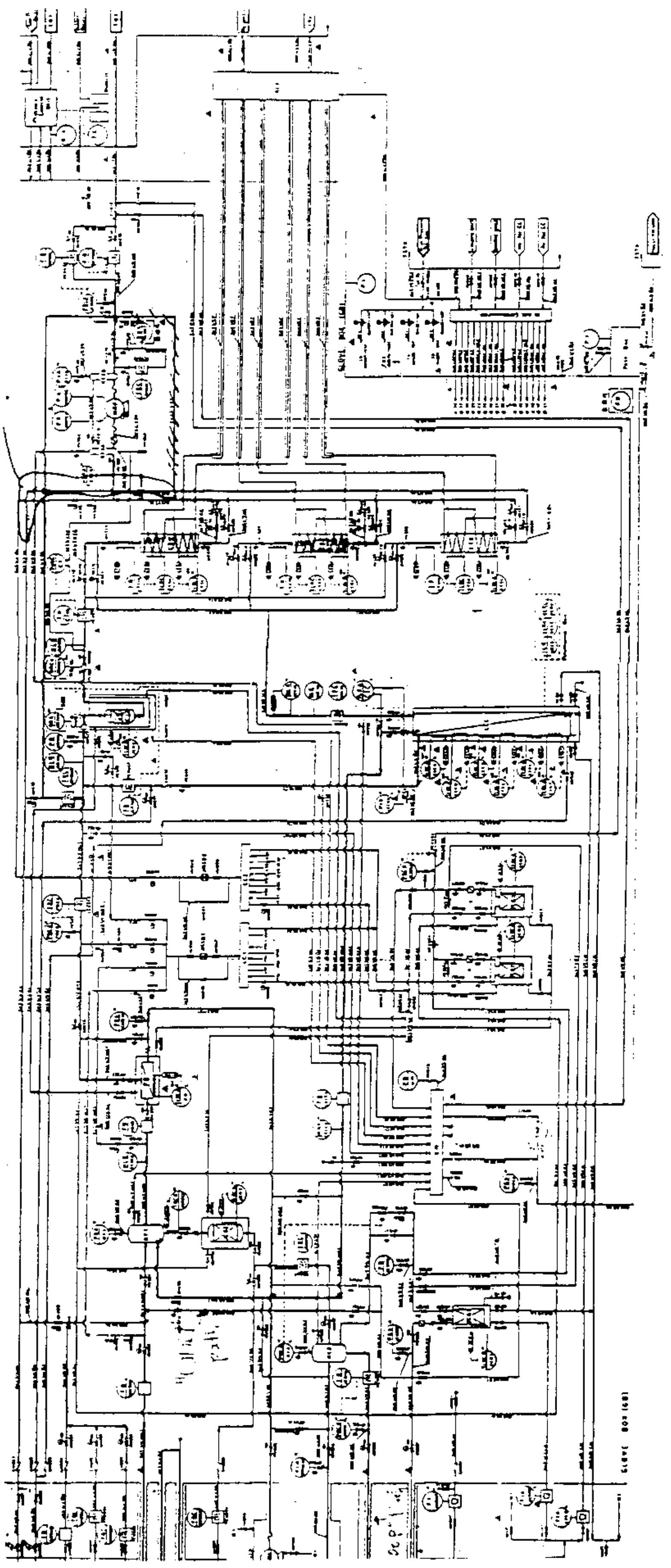


Fig. 1 Unit Operation

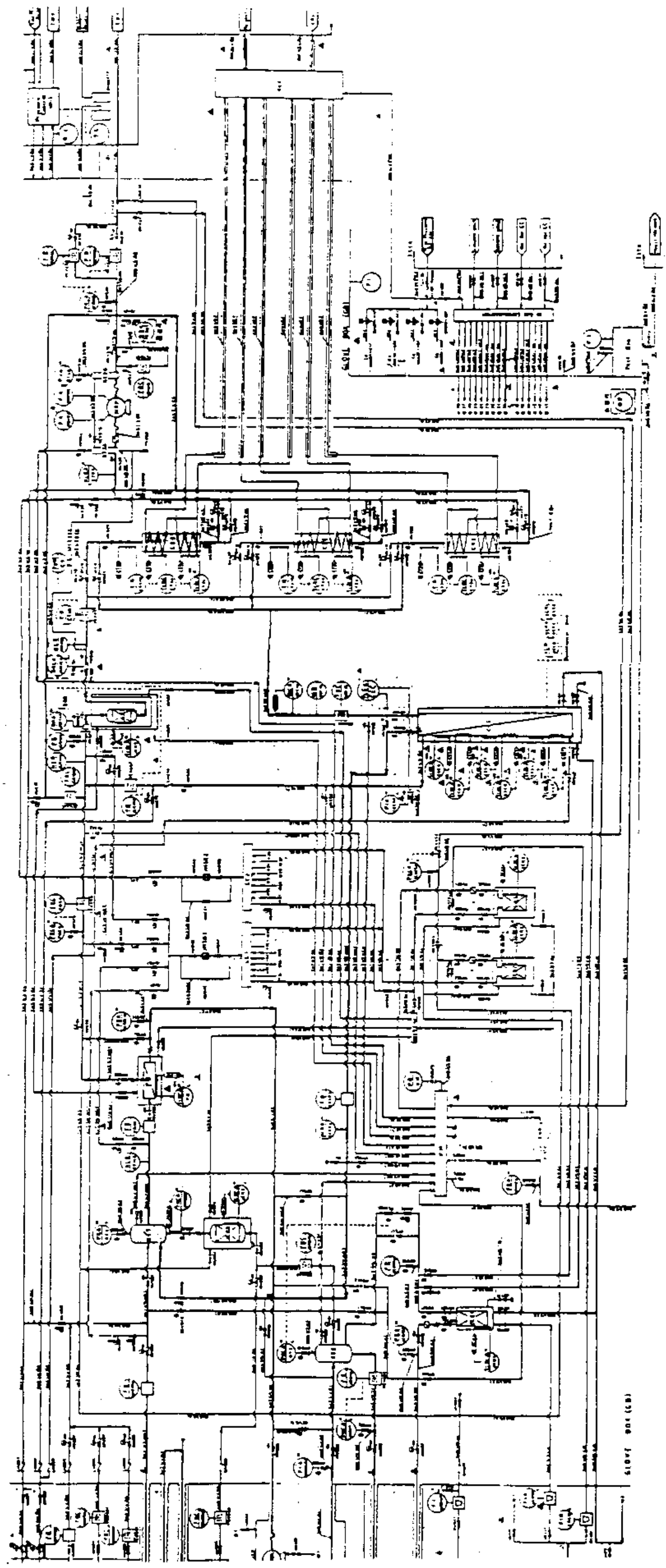


Fig. 2　D2 Recover

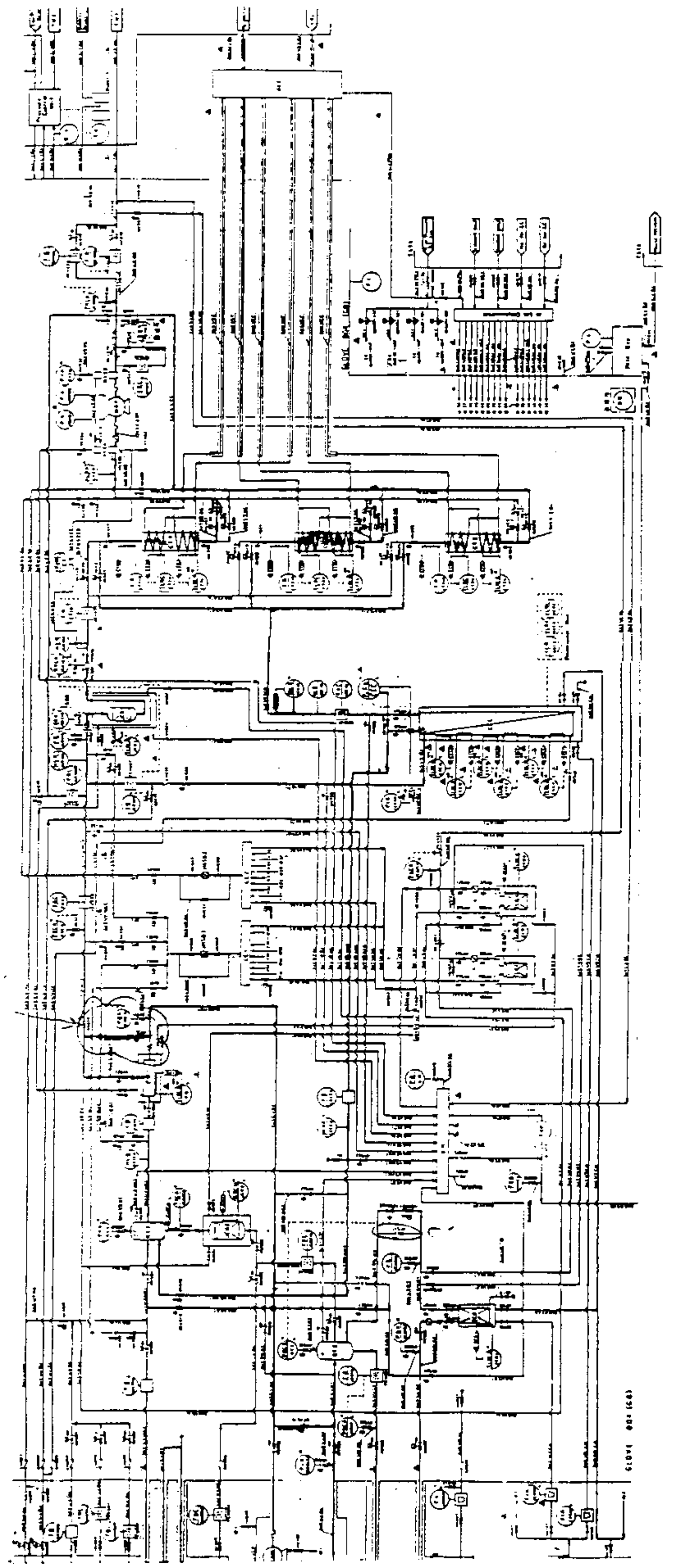


Fig. 3 System Shutdown

V. Test Results 2

TRITIUM SYSTEMS TEST ASSEMBLY

TEST RESULT

JAERI FUEL CLEANUP SYSTEM
STAND ALONE DEUTERIUM OPERATION 2

To be attached to the Test Plan TTA-TP-118-10, R0

1. Outline

This report describes the summary of the result of the cold testing of the integrated process of the JFCU(JAERI Fuel Cleanup System), planned in the test plan TTA-TP-118-10 and performed in the period of Dec. 18 -21.

The major purpose of this test was to evaluate the total function of the system that purifies and recovers hydrogen isotopes while rejecting impurities to exhaust . All of the problems found in previous tests have been corrected. The effectiveness of the modifications to the oxygen control system and addition of small molecular sieve beds to cold traps were tested. The CEC was replaced. Operating procedure of the JFCU attached to the test plan was verified and corrected during the test. This test was the last deuterium run before the first tritium test.

2. Configuration

The test was conducted with the JFCU configured as shown in the figure 1 in the test plan.. No process piping is connected between JFCU and TSTA main loop or safety systems. An Alcatel pump was used for vacuum service. A metal bellows pump was installed at the discharge side of the Scroll pump. The flow controller for regeneration of the cold traps was moved to the inlet of the traps. Small molecular sieve beds were installed at the exit of cold traps so that minor moisture failed to be captured by the traps could be prevented. Regeneration of the beds were controlled manually synchronized with the one hour cold trap cycles. The CEC was replaced with more reliable one that has glass seal on the ceramic-ceramic joints with enhanced strength at elevated temperature. Deuterium was supplied from external source and recovered at the ZCB1.

3. Test result

Purification of deuterium, oxidation of impurities, trapping and decomposition of water, and gas analysis by the GC system were tested. Methane was used as impurity.

The print out of the trend is attached.

3.1 Operation

3.1.1 Startup

All the components started well. Temperature controller that had a trouble in June run was fixed and verified to operate.

3.1.2 Normal Operation

Continuous operation of the process was successfully performed. "Hang" problems were experienced on the JFCU computer. Some macros to deal with this problem will be needed. Difficulty in controlling flow rates in the process was fixed. Oxygen concentration control was successful. Attempt to simulate TP1-ISS was failed due to a large leak on the rubber membrane pump used to simulate TP1. Operation of GC showed a progress since June run. Results of the GC analysis (attached) seemed reasonable. Flow controller for methane showed an oscillation. It will be replaced.

3.2 System function and performance

3.2.1 Deuterium purification and bleed control

Purification of deuterium and bleed flow control went well at the diffuser. Addition of a metal bellows pump between the scroll pump and RT2 was successful to maintain an adequate compression of deuterium from the permeated side of the diffuser to the RT2. However, we could not verify that this compression was maintained with the designed 6 liter/min of throughput in this run. (This was done in an independent component test.) The result indicates that this purification loop will meet TSTA loop requirement with deuterium. Question on the matching with ISS/TP1 was not answered yet.

3.2.2 Conversion at JCR1

Oxygen concentration control was performed by a fixed MKS controller with the MDAC logic. The control of the oxygen concentration at the outlet of the JCR1 was successful. Flow meter reading was 1/4 of the correct value. Some of range parameter on the MKS signal conditioner should be corrected. It was found that the control was not fast enough to compensate a very fast change in hydrogen or methane concentration in the stream. No serious problem is anticipated as long as no sudden change in the flow rate of the bleed happens.

Conversion of combustible species was good. No carbon monoxide generation or insufficient oxygen problem occurred. Obtained result of GC analysis was reasonable.

3.2.3 Cold Traps

Humidity spikes at the outlet of the trap in switching were completely removed. When cold traps were operated, humidity at the outlet decreased steadily. It will take very long time to dry out that part of the process completely and the hygrometer reading reaches equilibrium, that is expected to be around 170K. Regeneration of JMSB3, 4 5 seems completed during the one hour cycle. Accumulation of moisture in the beds will not occur.

Flow controller for regeneration (FRC-CECIN) was moved to the regeneration inlet. No difficulty in controlling regeneration flow was encountered.

3.2.4 Electrolysis Cell

The new CEC worked well. We did not worry about the differential pressure across the cell. It seems that the electrolysis capacity was sufficient to decompose water supplied from the regenerating traps. No accumulation of water in the loop was observed.

A problem was found in the voltage control in P-stat mode of the operation of the potentiostat. New circuit installed to observe and record the current on each ceramic cells was suspected. It was possible to operate the system with CV(Constant Voltage) mode, but it is preferable to operate in P-stat mode. Some electrical check will be needed on the potentiostat-CEC circuit.

4. Chronology

12/17	16:45	CEC heaters turned on
12/18	14:25	PD and JCR1 heated
12/19	09:44	Cold trap cycle started
	09:55	MBP turned on for circulation
	10:03	CT regeneration heater turned on
	12:42	Stand-by mode turned on
	12:54	Scroll pump turned on
	13:07	D_2 supply started.
	13:25	D_2 supply stopped
	15:22	CH_4 addition started.
	16:51	Normal operation mode off
	16:53	CH_4 , He stopped. Process Paused.
12/20	08:59	Metal Bellows pump started for circulation.
	09:05	CT cycle started.
	09:15	Scroll pump started.
	09:36	CH_4 addition started..
	09:44	Interlocked pause
	10:32	CT cycle restarted.
	10:34	SCROL restarted.
	11:03	CH_4 supply restarted.
	14:41	CT cycle stopped.
	15:51	Freon Ref. stopped.
	15:54	All CTs regenerated.
	16:59	Regeneration stopped.

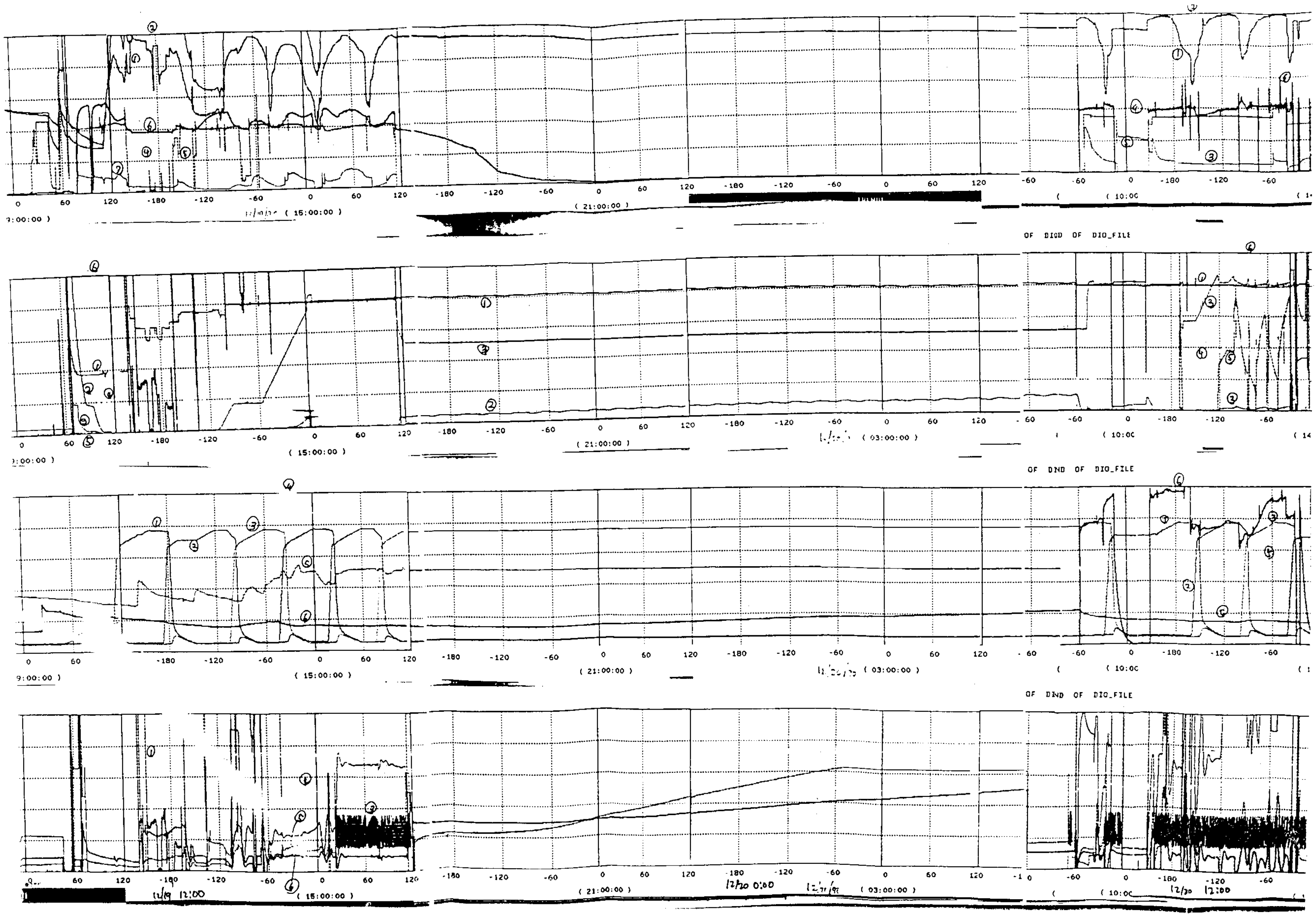
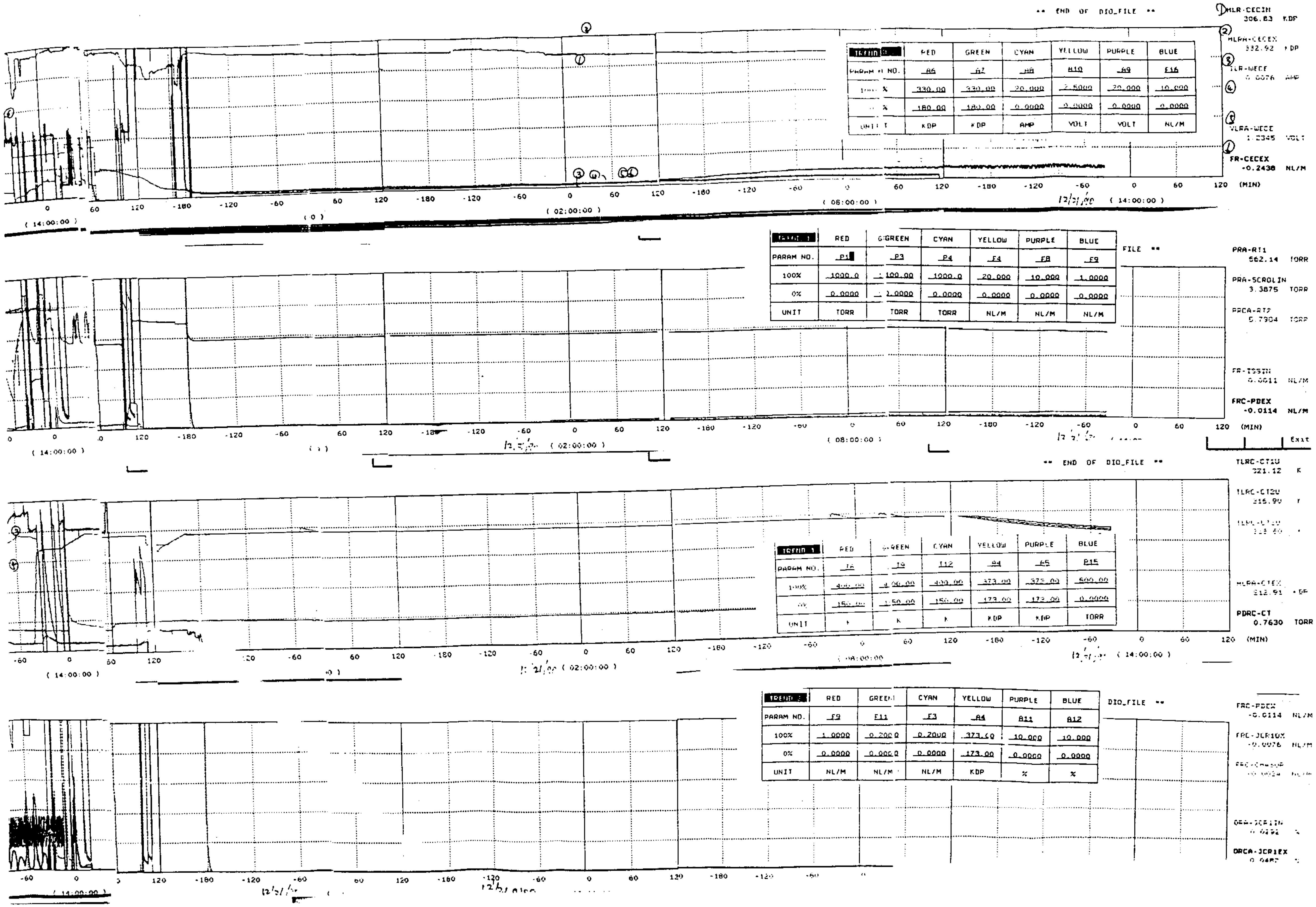


Fig. 1 Trend of the Major Variables


** END OF DIO_FILE **
MLR-CECIN 306.83 KDP
MLRA-CECEX 332.92 KDP
VLRA-WECE 1.2345 VOLT
FR-CECEX -0.2438 NL/M
(14:00:00)
(02:00:00)
(08:00:00)
(MIN)
PRA-RI1 562.14 TORR
PRA-SCROLIN 3.3875 TORR
FRC-PDEX -0.0114 NL/M
TLRC-CT1U 321.12 K
PDRC-CT 0.7630 TORR
ORCA-JCR1EX

JFCU COLD RUN (DEC.1990) GC DATA

SP#3

TIME	H2	O2	N2	CH4
12/19/1990				
13:43	0.0000	0.0000	0.0000	0.0000
14:29	0.4618	0.0000	0.0000	0.0000
16:07	0.0000	0.0000	0.0000	0.4532
12/20/1990				
9:41	0.0000	0.1314	0.1787	0.5106
11:16	0.0000	4.4030	19.5508	0.2328
12:32	6.2110	0.2095	1.1810	0.4170

SP#4

TIME	H2	O2	N2	CH4
12/20/1990				
10:19	0.0000	2.6808	0.0000	0.0000
11:53	0.0000	1.2901	0.0805	0.0125
13:10	1.0122	1.0000	0.0000	0.0152

SP#5

TIME	O2	N2	NH3
12/19/1990			
13:43	0.3043	0.0000	0.0000
14:29	0.3886	0.0000	0.0000
15:27	0.8637	0.1847	0.0000
16:07	0.4080	0.0000	0.0000
12/20/1990			
9:41	0.7840	0.0000	0.0000
10:19	0.4884	0.0072	0.0000
11:16	3.3571	18.2864	0.0824
11:53	1.1939	0.8658	0.0000
12:32	1.1900	0.0718	0.0000
13:10	0.9102	0.0000	0.0000

VI. Conclusion

In the cold tests described above, JFCU worked as designed throughout the procedures. Major modes of the system, either normal or off-normal conditions, were verified. Some problems were found on the components and instrumentations. They need further improvements and modifications. Software interface between the TSTA main computer system and the JFCU computer was not completed yet. Procedure to supply and recover tritium was tested. Another major purpose of training and familiarization of TSTA/JAERI personnel in JFCU operation was accomplished. It should be noted that most of the operations of the JFCU was done by the TSTA operators under training according to the detailed manual, while JAERI personnel provided maximum assistance as operation supervisors. The obtained experiences are reflected in the modification and addition on the operation manual.

Apendix Procedure of the JAERI fuel cleanup system stand alone deuterium operation

1. Purpose

This document describes the procedure of the cold testing of the integrated process of the JFCU(JAERI Fuel Cleanup System). The function and performance of the components and the system will be studied without tritium.

Another major purpose is training and familiarization of TSTA/JAERI personnel in operation. Actual operating procedure for each equipments will be conducted and experienced by TSTA facility operators. This procedure will be checked during the experiment and be modified.

2. Schedule

date	Subject	Status at night
6/11 Mon	Preparation, start heating	cooling water, heater
program running		
6/12 Tue	Stand by-Unit mode	round-the clock
6/13 Wed	Unit Operation-Pause	Pause, components active
6/14 Thu	Unit Operation-shut down	do.
6/15 Fri	Hydrogen recovery, Shut down	CEC cooling, water

3. Personnel Assignement

S. Konishi and J. W. Barnes coordinate the test. Operators will have maximum opportunity to gain experience of the operation of the JFCU as assigned by TSTA management. Round-the-clock operation is scheduled on the second day of the experiment. Following is the assignement of the personnel.

JAERI

Day	A	B	C	regular
	7:30 - ?	15:30 - 23:30	23:30 - 07:30	7:30 - 17:00
6/11 Mon				All
6/12 Tue	Konishi	O'Hira	Inoue	Watanabe
6/13 Wed				SK, SO, TW
6/14 Thu				All
6/15 Fri				All

TSTA

6/12 B and C to be assigned.

4. Procedure

4.1 Utility preparation

4.1.1 Check that air valves for N_2 gas, cooling water and liquid nitrogen are ready to use.

i) **Adjust following gas regulater. (about 0.5 kg/cm^{2}G)**

• He gas regulater	RV-901
• O_2 gas regulater	RV-902
• D2 gas regulater	RV-903
• GC standard gas (1)regulater	RV-909
• GC standard gas (2)regulater	RV-910
• GC He gas regulater	RV-911
• GC Ar gas regulater	RV-912

4.1.2 Check that the tribodyne pump is connected to the manifoled to the PEV.

4.2 Evacuation

4.2.1 Operate valves

In accordance with test flow sheet-1, lineup valves. (Refer valves list-I- no.1)

4.2.2 Start tribodyne pump.

Wait until PRA-TMPEX pressure decreases.
Open turbo molecular pump exit valve AV-437, turn "ON" TMP(PC) and start TMP.
After evacuation, close HV034, 035, 072, 073, 549~555, HV507, AV417.
AV437 may be left open for GC analysis.

4.3 Heating the components

4.3.1 Check that temperature control patterns and set points for each component.

Temperature control program for the regeneration of the cold traps may be changed.

4.3.2 Purge JCR1-CT-CEC with He

i) **Isolate RT-1, PD, Scrol and RT2.**

This portion of the system remains under vacuum.

ii) **Purge He from AV408.**

Close HV 001, open AV408, slowly open HV001, then
Check HV507, 510, AV404, 406, 415, 417 closed. HV577, 527, 528, 578, HV540, 545 in this sequence.
Open HV053 to purge out the room.
Stop purging after several minutes.

iii) **Isolate electrolysis cell.**
Close HV540, 541, Open 545, 053 to open the process side of the cell to the room.
Open HV542 and valve to atosphere to open the oxygen side.

iv) **open both side of the cell to the room.**
Now both side of the cell are at the same pressure. Watch for the differential pressure PDRA-CEC.

4.3.3 Start heating.
(Heater operation panel on the PC)

i) **Pd diffuser heater**
ELB-01 Breaker "ON" - Power control panel CP
H-PD Contactor "ON" - PC
TLRCA-PD Temp. controller "RUN" - PC

ii) **Cold trap upper heater (I) - (3)**
ELB-09, 11, 13 Breaker "ON" - CP
H-CT1U-CT3U Contactor "ON" -PC
H-CT1U-CT3U Temp. controller "RUN" -PC

iii) **Cold trap lower heater (1) - (3)**

ELB-I0,12,13	Breaker	"ON" CP		
H-CT1L-CT3L	Contactor	"ON"	PC	
H-CT1L-CT3L	Temp. controller		"RUN"	PC

iv) **Cold trap entrance piping heater (1) (3)**

ELB-24	Breaker	"ON" CP	
H-CT1IN-CT3IN	Contactor	"ON"	PC

v) **Electrolysis cell heaters (A) - (F)**

ELIB-03-08	Breaker	"ON" CP		
H-CECA-CECF	Contactor	"ON"	PC	
TLRCA-CEC	Temp. controller	"RUN"		PC

Open the following valves to supply He to the system. Wait until the system inside pressure approaches about 800 Torr. Close valves to stop He supply.

It takes 14 hours to heat the cell to 973K.

vi) **Electrolysis cell entrance piping**

ELB-21	Breaker	"ON"	CP
H-CECIN	Contactor	"ON"	PC

vii) **Catalytic reactor (1) heater**

ELB-02	Breaker	"ON"	CP
H-JCR1	Contactor	"ON"	PC
TLRCA-JCR1	Temp. controller	"RUN"	PC

4.3.4 Warm up Scroll pump

i)**Check cooling water is flowing.**

(There is no flow indication.)

ii) **Turn "ON" SCROL STAND-BY(PC) to start oil pump.**

iii) **Wait until "STAND-BY OK" lamp turns on.**

It takes 6 mint to 1 hour.

4.5 Cold traps preparation

i) **Set freon refrigerator control panel (REFP) temperature controller (TLC-REF) at -115°C.**

ii) **Open HV-4 and AV-7 to supply LN2.**-in REFP
(Check vacuum in the insulation and transfer tube. Evacuate when necessary.)

iii) **Select "LOCAL"** -REFP
Wait until TLC REF temperature approaches about 80°C.

iv) **Turn "ON" refrigerator to start freon circulation. -REFP**
Wait until the temperature of the cold traps (1) to (3), TLRC-CT1U to CT3U, TLRC-CT1L to CT3L goes down to -105°C.

v) **Turn operation selector to "REMOTE".** - REFP

vi) **Check the CT timer setting(pc) as follows**

CT TIMER		TIME	CT TIMER		TIME
Each Cycle Period	TM01	60 min	AV-CTEX	TM08	3 min
AV-CTIN OFF-	TM02	2 min	(R)	TMO9	4 min
ON -	TM03	0min	MV	TM10	20min
AV-CTEX OFF-	TMO4	2min	FREON	TM11	2 min
ON -	TMO5	1min	FEED	TM12	11 min
AV-CTIN OFF	TMO6	3min			
(R) ON -	TMO7	4min			

vii) **Set CT CYCLIC OPE to "START"** -PC

Turn CT heater Contactors ON -PC

Check CT heater programs "RESET" -PC, heater operation

Turn REF "ON" -PC, heater operation

Set CT CYCLE "Start" -PC, Component operation

4.6 Selecting operation mode

4.6.1 Set JFCU operating condition and mode selection -PC

i)OPERATION MODE "LOOP"

ii) CT REGENERATION "INTERNAL"

iii) DILUTION "INTERNAL"

iv) PD BLEED CTRL "PRESSURE"

v) STAND-BY MODE "OFF

vi)NORNAL OPE.MODE "OFF"

vii) PAUSE "RESET"

viii)INTERLOCK "ON"

4.6.2 Set pressure and flow rate settings
-PC, Set points panel
i)Pd diffuser exit pressure PRCA - PDEX 720 torr
ii) JFCU exit pressure PRCA -JFCUEX 800 torr
iii) Cold trap pressure drop PdRC - CT 300 torr
iv)Catalytic reactor (I) bypass flow rate FRC-JCRIBYP 20 Nl/min
v)Electrolysis cell inlet flow rate FRC-CECIN 5.6 Nl/min

(Note that Values given above may be changed so that the system will be operated stably.)

4.6.3 Check all the pressure／flow rate controllers in "REMOTE" position -IP

4.7 Establish Stand-by Mode

4.7.1 Start Circulation by MBP
i) Check valve HCV-575is fully open, AV414 and 415 open.
MBP bypass has to be open when started
Turn On the MBP -PC and slowly close the HCV-575.
Check pressure/ flow control of the system.

4.7.2 Establish "STAND-BY" mode.
i)Check all the components at the operation temperature.
ii) Turn "ON" STAND-BY mode - PC, mode setting
Metal bellows pump starts.

4.7.3 Start SCROL.
i)Check Scroll bypass valve HCV574 open, PRCA-RT2 and PRA-SCROLIN indicate vacuum.
Check AV 406 closed.

ii) Turn On the SCROL - PC
Open HV512.

4.7.4 Supply Oxygen to the system
i) Check pressure difference across the cell is within the limit.
ii)Set O2 regurator 0.2 kg/cm2 G, -valve rack
Open HV-002 -valve rack,
open HV-544 -process
Check cell pressure

4.7.5 Start Potentiostat -IP, Potentiostat
i)LOCAL-REMOTE, "REMOTE"
ii)CV-P-STAT, 'P-STAT'
iii)LIMITER "5V"
iv)Set potential WE-RE 1.0V -PC, Setting

4.8 Normal Operation Mode

4.8.1 Supplying D2

i)Open HV504, 505, 508
Check HV507, HV521, 522, AV416, HV517 closed.

ii)Flow cooling water.

iii)Turn on the ZCB1 heater -PC
iv)Run the TCRCA-ZCB1 program -PC
v)Wait until RT2 pressure PRCA-R2 to exceed RT1 pressure PPA-RT1.
(approximately 860torr)
RT2 is filled with D2 from the bed.
Turn OFF the heater and isolate the ZCB1.
If the D2 seems insufficient, add from the external bottle as follows,

vi) Open D2 supply valve HV-003 and D2 supply valve AV-401.
Open HV 575 and Close AV414 and 415.
Supply D2 at about 500 Ncc/mim.
Watch PRCA-RT2 and stop.
Open AV414 and 415.

vii). Stop D2 supply.
Turn off the heater H-ACB1 - PC.
Watch PRCA-RT2 and TLRCA-ZC1. When both begin to go down, close HV504, 505, 508.

4.8.2 Unit operation mode

i) Check that gas chromatographs are ready to operate.
Use tribotine pump to evacuate sample line.
Discharge carrier gas into the room from PCV-454, by-passing ZCBs.

ii) Open AV-414 and 415 to connect hydrogen purification system and recovery system.

4.8.3 Turn "NORMAL OP. MODE ON" -PC

Adjsut system pressure and flow rate so that system be operated at the set flow rate and pressure.
Run gas chromatograph program to start analysis.
System exhaust (to TWT) begins to flow out.
Change Potensiostat voltage when needed.

4.9 Loop Operation Mode Test

4.9.1 Loop Mode

i) Set "LOOP" mode -PC

Close HV-501.
Open VAC/TPU supply valve AV-404 and AV-406
Slowly open HV-501.

ii)Turn on the metal bellows pump and set the flow rate at 6 l/min.

Slowly close metal bellows pump bypass valve HV-915 for circulation.
Operate the system continuously and stably until 6/13 afternoon.
Add D2 when necessary.

iii)Add CH4 to the system.

Close HV005. - Valve stand.
Set FRC-CH4Sup to 50cc/min. -PC
Open HV005 slowly. -Stand
Change flow rate when necessary.

4.9.2 Pause

i)Intentional "PAUSE"

Wait regeneration of a cold trap in the cycle is completed.
Stop cold trap cycle at 50~59 min in the 60 min cycles when neccesary.
Activate "PAUSE" switch -PC, CP
Immediately close HV512 AND HV501 to isolate the scroll pump..
Boundary valves close. (AV403, 404, 406, 409, 411, 412 or 413, 414, 415, 416)
Check on PC..
Pumps stop. Turn off the temporary metal bellows pump.
Stop oxygen supply by MDAC control.
Turn off the potentiostat voltage. -IP.
GC analysis continues. Sampling stops. Stop computer at the GC panel when calculation is completed..

ii)Check CH4, O2 stopped.

Close cylinders and regulaters when leave.

iii)Check components ready to run.

All the heaters ON.
Freon REF running.

System securely stops in this mode.

4.9.3 Restart

i)Turn "NORMAL OP. MODE - not used in this test.

System starts to run Loop mode.
Start GC.
Start impurities.

ii)Manual Restarting

"RESET" the pause mode.
Open MBP bypass HCV575, start MBP.
Open AV412, 414, 415 and 409. to start circulation of He.and slowly close HCV575.
Open AV411 and start oxygen supply from the MDAC.
"START" cold trap cycle. **NEVER HIT 'RESET'** -PC
Turn On the potentiostat. -IP
Start Scrol pump and Open HV512 and AV406.
When PRCA-SCROLIN goes down and stabilized,
Open AV404, slowly open HV501 to restart D2 circulation.
and, Check bypass is open and Start temporary MBP. Slowly close the bypass.

When system is stabilized, open AV403 and HV005 to start CH4.
Open AV416 for excess hydrogen storage.

4.10 Shut Down

4.10.1 Stop Normal Operation

i)Stop impurity(CH4) and wait for 5 min.

continue to run system.
Close AV404, Stop metal bellows pump and open the bypass.

4.10.2 Recover D2 at ZCB1

i)Recovering Pure D2

Close AV416, check HV517, 507, 508 closed, HV522, 521 open.
Open HV504, 505,549 and evacuate the ZCB1 for a few minutes.
Close HV549, 505 and 504. Open HV517.
D2 in the RT2 is recovered. D2 in the system is slowly recovered through the palladium diffuser.

4.10.3 Stop oxydation

i)Stop O2 supply

Continue GC analysis. Residual D2 decreases.
Set oxygen control at the MDAC to zero.
Close AV409 and 412. Open AV431 to select "INTERNAL" regeneration.

ii) Wait HLR-JCR1EX decreases to ca.250K.

Electrolysis and cold trap regeneration continues.

4.10.4 Stop CT cycle
i) CT CYUCLE "RESET" -PC
ii)Close HV4 and AV7 -REFP
iii)Stop LN2 Supply.
iv)Heat CT1, 2,3 -PC
wait until HLR-CECIN decreases and stailized.
System is dried out by electrolysis of residual water.

4.10.5 Stop Electrolysis
i) Set Potentiostat voltage to 0V -PC
ii)Turn "Off" the Potentiostat. -PC, IP

4.10.5 Stop Flow
i) Continue GC analysis until D2 will not be detected.
(ii)Circulate the gas throuigh the ZCB1 when needed.)
iii) Open HCV-575, Close AV414, 415.
iv)Stop MBP -PC

Isolate ZCB1 by Closing HV-517, 521 and 522.
v)Stop SCROL pump. -PC

4.10.6 Evacuation (This may not be conducted)
i)Isolate Osxygen Monitor Probes.
ii)Close HV577,527,528,578,421,425,429,545,541,544.
iii)Open HV549~554, 557 to evacuate the process.

4.10.7 Cooling Components
i) Turn off the contactors and heaters of the following components -PC
PD, JCR1, CT1~3, CECIN
ii)Cool down the CEC
Set Controller "COOL DOWN" -PC
iii)Open both sides of the cell to the room.
iv)Turn off the Heaters for the cell.
H-CECA~F

Valve List 1 - Evacuation -

Valve No.	position O/C	Action A/Chk	Valve No.	position O/C	Action A/C	Valve No.	position O/C	Action A/C
HV001	C		HV073	O				
HV002	C		HV074	C		HV519	C	
HV003	C		HV075	O		HV520	C	
HV004	C		HCV081	O		HV521	C	
HV005	C		HCV082	O		HV522	C	
HV006	C					HV523	O	
HV007	C		HV101	O		HV524	C	
HV008	O		HV102	O		HV525	O	
HV009	O		HV103	C		HV526	O	
HV010	O					HV527	C	
HV011	O							
HV012	C		HV111	O		HV528	C	
HV013	C		HV112	O		HV529	O	
HV014	C		HV113	O		HV530	O	
HV015	C					HV531	O	
HV016	C		HV117	O		HV532	O	
			HV118	O		HV533	O	
HV031	C		HV119	C		HV534	O	
HV032	C		HV120	O		HV535	O	
HV033	C		HV121	O		HV536	O	
HV034	O		HV122	O		HV537	O	
HV035	C		HV123	C		HV538	O	
HV036	O		HV124	O		HV539	O	
HV037	C		HV125	O		HV540	C	
HV038	C					HV541	O	
HV039	C		HV501	O		HV542	C	
HV040	C		HV502	O		HV543	O	
HV041	C		HV503	O		HV544	C	
HV042	O		HV504	C		HV545	C	
HV043	C		HV505	O				
HV044	O		HV506	O		HV547	C	
HV045	O		HV507	O		HV548	C	
HV046	O		HV508	O		HV549	V	
HV047	O		HV509	C		HV550	V	
HV048	C		HV510	C		HV551	V	
HV049	O		HV511	O		HV552	V	
HV050	O		HV512	O		HV553	V	
HV051	C		HV513	O		HV554	V	
HV052	C		HV514	O		HV555	V	
HV053	C		HV515	O		HV556	C	
			HV516	O		HV557	C	
HV071	C		HV517	O		HV558	O	
HV072	C		HV518	O		HV559	O	

Valve No.	position O/C	Action A/Chk	Valve No.	position O/C	Action A/C	Valve No.	position O/C	Action A/C
HV560	O		AV412	C				
HV561	O		AV413	C				
HV562	O		AV414	O				
HV563	C		AV415	O				
HV564	C		AV416	C				
HV565	C		HV417	O				
HV566	C		AV418	O				
HV567	O		AV419	O				
HV568	C		AV420	O				
HV569	C		AV421	O				
HV570	C		AV422	O				
HV571	C		AV423	O				
HV572	O		AV424	O				
			AV425	O				
HCV573	C		AV426	O				
HCV574	O		AV427	O				
HCV575	O		AV428	O				
HCV576	O		AV429	O				
			AV430	O				
HV577	C		AV431	O				
HV578	C							
			AV437	V				
			HV901	C				
			HV902	C				
			HV903	C				
AV401	O		HV904	C				
AV402	O		HV905	C				
AV403	O		HV906	C				
AV404O		HV907	C					
AV405	C		HV908	C				
AV406	O		HV909	C				
AV407	C		HV910	C				
AV408	C		HV911	C				
AV409	C		HV912	C				
AV410	C		HV913	O				
AV411	C							