JAERI - M
88-204

TSTA LOOP OPERATION WITH 100 GRAMS-LEVEL OF TRITIUM

—MILESTONE RUN IN JUNE, 1987—

October 1988

Hiroshi YOSHIDA, Shingo HIRATA[*1], Taisei NAITO[*2]
Toshihiko YAMANISHI, J. L. ANDERSON[*3]
J.R. BARTLIT[*3], R.V. CARLSON[*3], D.O. COFFIN[*3]
R.H. SHERMAN[*3] and R.S. WILLMS[*3]

日 本 原 子 力 研 究 所
Japan Atomic Energy Research Institute

JAERI-M レポートは，日本原子力研究所が不定期に公刊している研究報告書です。
入手の問合わせは，日本原子力研究所技術情報部情報資料課（〒319-11茨城県那珂郡東海村）あて，お申しこしください。なお，このほかに財団法人原子力弘済会資料センター（〒319-11 茨城県那珂郡東海村日本原子力研究所内）で複写による実費頒布をおこなっております。

JAERI-M reports are issued irregularly.
Inquiries about availability of the reports should be addressed to Information Division, Department of Technical Information, Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki-ken 319-11, Japan.

編集兼発行　日本原子力研究所
印　　刷　㈱原子力資料サービス

TSTA Loop Operation with 100 grams-level of Tritium
— Milestone Run in June, 1987 —

Hiroshi YOSHIDA, Shingo HIRATA[*1], Taisei NAITO[*2]
Toshihiko YAMANISHI, J.L. ANDERSON[*3]
J.R. BARTLIT[*3], R.V. CARLSON[*3], D.O. COFFIN[*3]
R.H. SHERMAN[*3] and R.S. WILLMS[*3]

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

(Received September 24, 1988)

The first loop operation tests of Tritium Systems Test Assembly (TSTA) with 100 grams-level of tritium were carried out at Los Alamos National Laboratory(LANL) on June and July, 1987. The tests were one of the milestones for TSTA goal scheduled in June, 1987 through June, 1988.

The objectives were (i) to operate TSTA process loop composed of tritium supply system, fuel gas purification system, hydrogen isotope separation system, etc, (ii) to demonstrate TSTA safety subsystems such as secondary containment system, tritium waste treatment system and tritium monitoring system, and (iii) to accumulate handling experience of a large amount of tritium.

This report describes the plan and procedures of the milestone run done in June and the summary results especially on the safety aspects.

*1 Kawasaki Heavy Industries, Ltd.
*2 Mitsubishi Atomic Power Industries, Inc.
*3 Los Alamos National Laboratory

Analysis of the emergency shutdown of the process loop, which happened in the June run, is also reported. A brief description of the process and safety subsystems as well as the summary of the TSTA safety analysis report is included.

Keywords: Fusion Reactor, Tritium Technology, Fusion Fuel Cycle, Plasma exhaust Gas, Fuel Cleanup, Isotope Separation, Secondary Containment, Tritium Monitoring

100グラムレベルのトリチウムを用いたTSTAループ試験
― 1987年6月のマイルストン・ラン ―

日本原子力研究所那珂研究所核融合研究部
吉田　浩・平田　慎吾[*1]・内藤　大靖[*2]
山西　敏彦・J.L. ANDERSON[*3]・J.R. BARTLIT[*3]
R.V. CARLSON[*3]・D.O. COFFIN[*3]・R.H. SHERMAN[*3]
R.S. WILLMS[*3]

（1988年9月24日受理）

日米核融合研究協力の一環として，原研と米国エネルギー省との間で実規模核融合炉トリチウム技術の開発・実証研究を進めるための「Fusion Fuel Program」の実施協定が昭和62年6月に調印された。本協力研究は，ロスアラモス研究所のトリチウムシステム試験施設を使用して，D－T燃料流量約～2 kg／日のループ試験を行い核融合炉トリチウム燃料のプロセス及びシステム技術の開発を進め，併せて大量トリチウム安全取扱いシステムの実証データの蓄積ならびに同施設の運転経験を取得しようとするものである。

本プログラムは，昭和67年6月までの5ケ年間の協力計画であり，前半の3年間は既存のTSTAを用いた試験，後半の2年間はTSTAの増強が予定されている。原研は，毎年4名のメンバーをTSTAに派遣することができる。

本報では，協力計画第1年目に実施した世界で初めての実規模D－T流量による核融合炉トリチウムシステムの試験結果を説明する。

那珂研究所：〒311－01　茨城県那珂郡那珂町大字向山801－1
＊1　川崎重工業㈱
＊2　三菱原子力工業㈱
＊3　ロスアラモス国立研究所

Contents

目　　次

1. INTRODUCTION

1.1 LAYOUT OF JAERI/TSTA-LANL COLLABORATION

A new collaboration program on fusion tritium technology(Fusion Fuel Program) has been established between JAERI and DOE/LANL (Department of Energy/ Los Alamos National Laboratory) in June, 1987.

This program, which will be conducted for a five-years period, consists of the following phases;

Phase-I : Existing TSTA process loop is operated during the first three years,
Phase-II : TSTA will be upgraded and operated for the next two years.

The objectives of this program are to perform the joint work of planning, experiments and analysis by using TSTA (Tritium Systems Test Assembly; the tritium inventory and circulation flow rate are approximately 100 g-T and 1800 g-DT/day, respectively) at LANL. The goals of this collaboration are to establish a fusion fuel processing technology of practical engineering scale and to demonstrate the safety technology necessary for handling a large amount of tritium.

Table1.1 shows the schedule of the TSTA loop operation in the first year of the Annex IV program. Major features of these operations are (i) to demonstrate TSTA process loop functions with 100 grams-level of tritium for a period of a week, (ii) to upgrade FCU function by incorporating additional processes such as impurity regeneration train composed of a catalytic reactor(CR2), DTO freezer(DTOF) and DTO converter(HMB4 and 5), and (iii) to incorporate compound cryopumps in the TSTA process loop, and (iv) to perform basic cryogenic distillation experiments by using single column and multi-columns of the TSTA-ISS.

1.2 BRIEF DESCRIPTION OF TSTA [Ref. 1]

1.2.1 PROCESS SYSTEMS

The current TSTA process loop(shown in Figure 1.1), is composed of the following sub-systems;

(1) UTB(Uranium Tritide Beds)
Tritium and other hydrogen isotopes storage /supply system with five large uranium beds(UB-1, 2, 3, 4 and 5).

(2) ISS(Isotope Separation System)
Hydrogen isotope separation system with four inter-linked cryogenic distillation columns(I, H, D and T) and a surge tank.

(3) TP3(Transfer Pump system-3)
Transfer pump system with metal bellows pumps(MBPA and MBPB), gas mixer(MX) and hydrogen isotope equilibrator(EQ).

(4) TP1(Transfer Pump system-1)
Transfer pump system with scroll pump(S) and metal bellows pumps(MBPA and MBPB).

(5) FCU(Fuel Cleanup system)
Fuel cleanup system with catalytic reactors(CR1 and 2), cryogenic molecular sieve beds(MSB1 and 2), uranium beds(HMB4 and 5) and tritiated water vapor freezer(DTOF). This system also includes Neutral Beam Interface (NBI) front end composed of cryogenic molecular sieve beds(MSB3 and 4).

(6) LIO(Load-in and Load-out system)
Load-in/Load-out system for tritium by using T_2 shipping containers.

1.2.2 SAFETY SYSTEMS

The major environmental and safety sub-systems of TSTA facility are as follows;

(1) SEC(Secondary Containment system)
The primary process equipment and process lines are doubly contained with secondary containment such as gloveboxes and plastic tubing. The containment is purged with nitrogen gas , and the pressure in the gloveboxes is controlled at approximately atmospheric pressure. Figure 1.2 shows concept of the instrumentation of a typical TSTA glovebox. The purge gas(N_2) is supplied to the glovebox when the tritium level in the glovebox is higher than 1 mCi/m^3.

(2) TWT(Tritium Waste Treatment system)
The tritium waste treatment system treat all tritium-bearing gaseous effluents generated of various subsystems in TSTA. This system is operated either in once-through or recirculation mode as necessary. The exhaust from the TWT is routed to the TSTA

stack after monitoring tritium concentration in the exhaust stream.

The capacity of the TWT compressors are 90 and 25 STP-m^3/hr.

(3) TM(Tritium Monitoring system)

A number of tritium monitors(Stack, Duct, Room, Glovebox, and process) have been installed in the TSTA facility. They perform the following functions; (i) quantitavive determination of stack releases, (ii) monitoring tritium concentrations in room and room-exhaust air, secondary containment atmosphere, and process system lines, (iii) initiation of local alarms and computer-control signals(secondary containments, room or room exhaust ducts) and (iv) initiation of room air isolation and an evacuation alarms.

(4) ETC(Emergency Tritium Cleanup system)

The TSTA main cell contains approximately 3000 m^3 of building atmosphere which would be contaminated with tritium in the event of an accidental release from secondary tritium containments. This system, the emergency tritium cleanup system, has a primary function to detritiate the room air before release to the environment from the TSTA cell after such an accident.

The free air capacity of the primary compressor is $2.5x10^3 m^3$/hr at 0.77atm and 293K.

(5) VEN(Ventilation system)

The ventilation system is divided into two zones. Zone I system provides heating and ventilation for areas(rooms for non-tritium handling) from which tritium will be excluded and is maintained at a slight positive pressure(0.23 Torr) with respect to atmospheric pressure. The Zone II system(shown in Figure 1.3), for the main cell and other tritium handling rooms, is maintained at a slight negative pressure(0.23 Torr) with respect to atmospheric pressure to minimize possible diffusion of tritium to the environment.

The ventilation capacity of the Zone II system is $1.5x10^4 m^3$/hr.

(6) MDAC(Master Data Acquisition and Control system)

The TSTA is a computer controlled system and will not process tritium unless master data acquisition and control(MDAC) is operatonal. This system contains two computer systems (shown in Figure 1.4); the process system consisting of two mini-computers and an interface.

The detail description of above systems is given in Attachment I.

1.2.3 TSTA DESIGN DOSE COMMITMENTS

For TSTA to handle tritium, the following subsystems must be on line: SEC, TM, TWT, ETC, VEN, MDAC, Power and Utilities. Most operations are under total computer control. Based on these operations, the radiation dose to personnel can be maintained less than the TSTA design goal for radiological dose.

Table 1.2 shows the TSTA design dose determined to reduce radiation exposure from tritium to As Low As Reasonably Achievable(ALARA).
The value for occupational exposure is one-fifth of the guide line level(5 rem/yr) in DOE manual(DOE Order 5480.1A Chapter XI), and the nonoccupational dose will be less than 1 mrem/yr at routine environmental tritium release rate of 200Ci/yr(see Attachment II) selected as a design goal for TSTA. The dose for TSTA secretaries and other personnel in adjacent buildings will be less than 500 mrem/yr from TSTA operations.

In four years of operation the total person dose to all TSTA personnels was less than 200 mRem, much less than the goals.

1.2.4 ACCIDENT CONSIDERATIONS

(1) Failure Modes and Effects Analysis

TSTA subsystems have been analyzed with a Failure Modes and Effects Analysis to evaluate the safety features of the design, identify critical failure modes, and recommend alternatives or precautions that will mitigate the effect of failures.

Table 1.3 gives a summary of the effects resulting from representative accidents which have been postulated for TSTA. Table 1.4 shows an expected tritium inventory in TSTA.

Analysis and discussions of the postulated accident and failures for TSTA are described in the TSTA Final Safety Analysis Report[Ref. 1].

(2) Accident Scenarios

(i) Single failure in any secondarily contained subsystem, i.e., release into gloveboxes, will not result in exposures to individuals or release to environment, since the TWT will process the secondary containment atmosphere.

(ii) Double failures in systems which have secondary containment or single failure in a few safety systems with single containment may result in a tritium release into the experimental area. The extent of personnel exposures depends on the tritium concentration in the area, the tritium form(oxide or elemental), and the time required to exit from the area. The exposures for all credible accidents are within the TSTA design goal(25 rem) for accident situations.

Examples of accident scenarios are:

- Glove rupture plus a release in that glovebox
- Rupture of ISS system plus rupture of the vacuum jacket
- TWT low pressure receiver failure.

The release to the environment for the above types of accidents is very small because the ETC is designed to process the contaminated room air. For a postulated release of 100 grams(10^6Ci) of tritium into the facility only 10Ci would be released from ETC to the environment.

(3) Emergency Evacuation Procedures

Evacuation procedures during a TSTA emergency have been established in accordance with the TSTA Quality Assurance Program. Any tritium release to the room atmosphere is quickly picked up by the room monitor, and a local alarm will be given at each of three levels of tritium concentrations measured.

- Low (20×10^{-6} Ci/m^3) ;amber light
- Mid ($100\ 10^{-6}$ Ci/m^3) ;red light, steady sonalert(mutable)
- High($10000\ 10^{-6}$ Ci/m^3);flashing red light, pulsing sonalert

The room evacuation alarm is automatically triggered by the high level alarm.

The stay time in the contaminated room with Mid Level(10^2 - $10^3 \times 10^{-6}$ Ci/m^3) to keep the committed dose below 50 mrem is:

(i) Without protective clothing;
Stay time(min) = 6000/tritium level(10^{-6} Ci/m^3)

(ii) With bubble suits and supplied air;
Stay time(min) = 1200000/tritium level(10^{-6} Ci/m^3)

Re-entry at concentration over 10^{-3} Ci/m^3 requires full protective clothing(bubble suits) and may only be made if accompanied by a second person who is also suited up.

Table 1.1 Schedule of TSTA Operation (June, 1987 - July, 1988)

Mid. June, 1987	:	Integrated loop test with ISS and FCU*1 (100 grams-level T_2)
Mid. July	:	Integrated loop test with ISS and FCU*2 (100 grams-level T_2)
Early October	:	ISS single column test in total reflux and recycle(no FCU, H-D separation)
Early November	:	ISS single column test in total reflux and recycle(no FCU, D-T separation, 60g-T_2)
Early Feburary, 1988	:	Integrated loop test with ISS and FCU*3 (100 grams-level of T_2)
Early March	:	ISS two columns test(no FCU, H-D-T separation, 100 gram-level T_2)
Early June	:	Integrated loop test with ISS, FCU*4 and VAC*5(100 grams-level T_2)
Mid July	:	Loop operation for TSTA Technical Safety Assessment(100 grams-level of T_2)*6

*1 Impurity removal front end : CR1(catalytic reactor to remove O_2) + MSB1 and 2(cryogenic molecular sieve beds to remove N_2 and CH_4).

*2 The same front end as that of Mid. June run.

*3 Back end of FCU is incorporated: Regeneration train with CR2(oxidizes CH_4 from regenerated MSBs) + DTOF(freeze out moisture from CR2) + HMB4 and 5(uranium bed to convert moisture from regenerated DTOF to hydrogen isotope gas).

*4 Front end with a high temperature uranium bed will be incorporated: Impurities such as CT_4 and NT_3 are directely reduced to T_2 through the following reactions; $U + CT_4 \rightarrow UC + 2T_2$, $U + NT_3 \rightarrow UN + 3/2T_2$

*5 Compound cryopump(BNL or LLNL type with charcoal panel is incorporated.

*6 Demonstration for the Technical Safety Assessment of the TSTA

Table 1.2 TSTA design dose commitments

TSTA DESIGN DOSE COMMITMENTS[a]

Condition	Design Objectives	
	Radiation Workers	Public
[b]Normal Operation (mrem/yr)	1000	170
[c]Accident (rem)	25	5

[a]Design dose commitment is the exposure which, under the given conditions, shall not be exceeded in design.

[b]Examples:
- (1) Normal component operation including shutdown, repair, maintenance, and checkout
- (2) Operational occurrences such as leaks, loss of power, and component malfunctions likely to occur once or more during the life of the facility

[c]Examples:
- (1) Very low probability events such as "most intense predicted" natural phenomena
- (2) Major component failure events which are not likely to occur during the life of the facility

Table 1.3 Summary of postulated accidents for the TSTA

Failure	Releasable Inventory Ci	Releasable Inventory Form	Mitigation Method[1]	Release to Stack Ci	Boundary[2] Site Whole Body Dose (mrem)	Whole Body Worker Dose Rate[3] (mrem/min)	Freq
1. a) Rupture or large leak from torus plus loss of SEC	100	DT	A	100	1×10^{-6}	1×10^{-3}	E
			B	1×10^{-3}	7×10^{-7}	1×10^{-3}	E
b) Same as 1a, accompanied by a fire	100	$DTO/HTO/T_2O$	A	100	7×10^{-2}	67	E
			B	1×10^{-3}	7×10^{-7}	67	E
2. a) Rupture of cryopump plus loss of SEC	5.8×10^4	DT	A	5.8×10^4	7×10^{-4}	0.8	E
			B	5.8×10^{-1}	4×10^{-4}	0.8	E
b) Same as 2a, accompanied by a fire	5.8×10^4	HTO/T_2O	A	5.8×10^4	38	3.9×10^4	E
			B	5.8×10^{-1}	4×10^{-4}	3.9×10^4	E
3. a) Rupture of distillation columns to vacuum jacket	9.7×10^5	DT, T_2	C	1	7×10^{-4}	0	E
b) Same as 3a followed by a breach of the vacuum jacket	9.7×10^5	DT, T_2	A	9.7×10^5	1×10^{-2}	13	E
			B	9.7	6×10^{-3}	13	E
c) Same as 3b, accompanied by a fire, release at 50 m	9.7×10^5	D_2O, DTO, T_2O	A	9.7×10^5	6×10^2	6.5×10^5	E
			B	9.7	6×10^{-3}	6.5×10^5	E
4. a) Leakage of transfer lines from NBI and IMS to FCU into secondary containment.	3000	DT, T_2	C	3×10^{-2}	2×10^{-5}	0	E
b) Same as 4a, followed by breach of secondary containment	3000	DT, T_2	A	3000	4×10^{-5}	4.0×10^{-2}	E
			B	3×10^{-2}	2×10^{-5}	4.0×10^{-2}	E
c) Same as 4b, accompanied by a fire	3000	DTO, D_2O, T_2O	A	3000	2	2.0×10^3	E
			B	3×10^{-2}	2×10^{-5}	2.0×10^{-3}	E
5. Aircraft crash into facility	9.7×10^5	HTO	NA	NA	4.7×10^3	NA	E
6. Earthquake total destruction	1.45×10^6	HT	NA	NA	0.23	NA	E
		HTO	NA	NA	11×10^3	NA	E

[1] Mitigation Method

A - Ventilate Experimental Room

B - Process Room Air with Emergency Cleanup System. Release form is tritiated water vapor.

C - Process Contaminated Air with Tritium Waste Treatment System

NA - Not Applicable

[2] This is maximum dose comitment and includes the skin intake. The dose is determined from Fig. B-1. The dose to the skin itself is discussed in Sec. 6.1. Site boundary is 400 m from TSTA. The dose from any tritium which escapes before the room is isolated has been neglected.

[3] Worker dose per minute of exposure. It is expected that personnel will exit from the room in less than 30 seconds. The calculations also assume uniform mixing in the room.

Table 1.4 Expected tritium inventory in the TSTA subsystems

SUBSYSTEM	COMPONENT	INVENTORY[1,2]	FORM
VAC	a. Torus	.01 g	DT
	b. Cryopump	6 g	DT
FCU	HMB's, MSB's	10 g	T_2,DT,DTO
	DTOF	to 30 g	$C(D,T)_4$,$N(D,T)_3$
ISS	a. Total	100 g	T_2,DT
INV	a. TSTA Shutdown	150 g	T_2,DT
	b. TSTA Normal	0.25 g	
TWT	a. Low Pressure Receiver	0.1 g	DT,T_2,HTO,C_xT_y,H_2
	b. Molecular Sieve Drier	4-6 g	HTO
XCS		0.1 g	T_2, HTO
ETC	a. Normal Operation	small or none	
	b. After Spill of X g	X g	HTO,T_2O,DTO

1. The inventory in the piping of TSTA is estimated at 1 g.
2. In some cases the amount of tritium is at its maximum in the system before regeneration or removal for disposal.

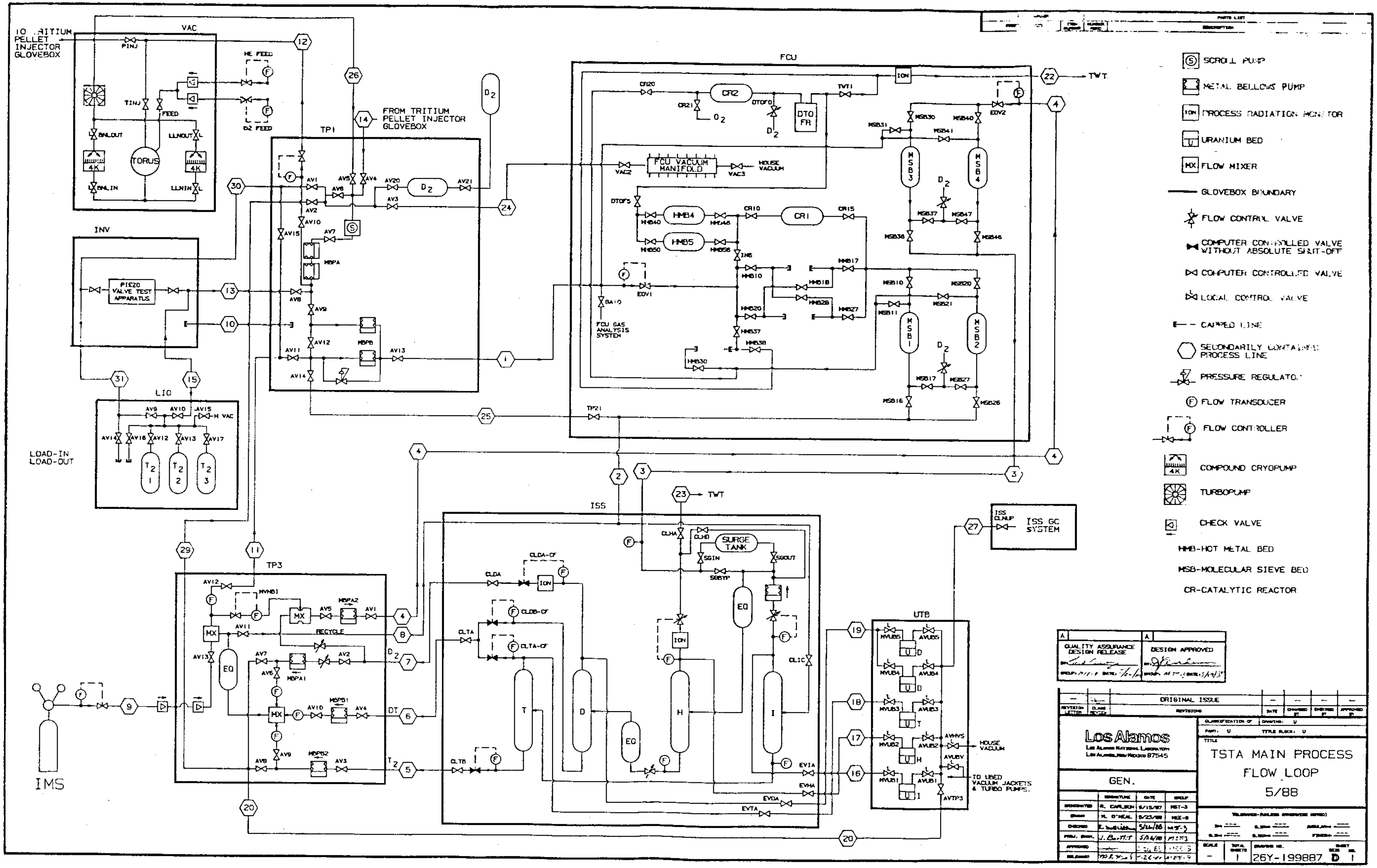


Fig. 1.1 TSTA process loop flow diagram

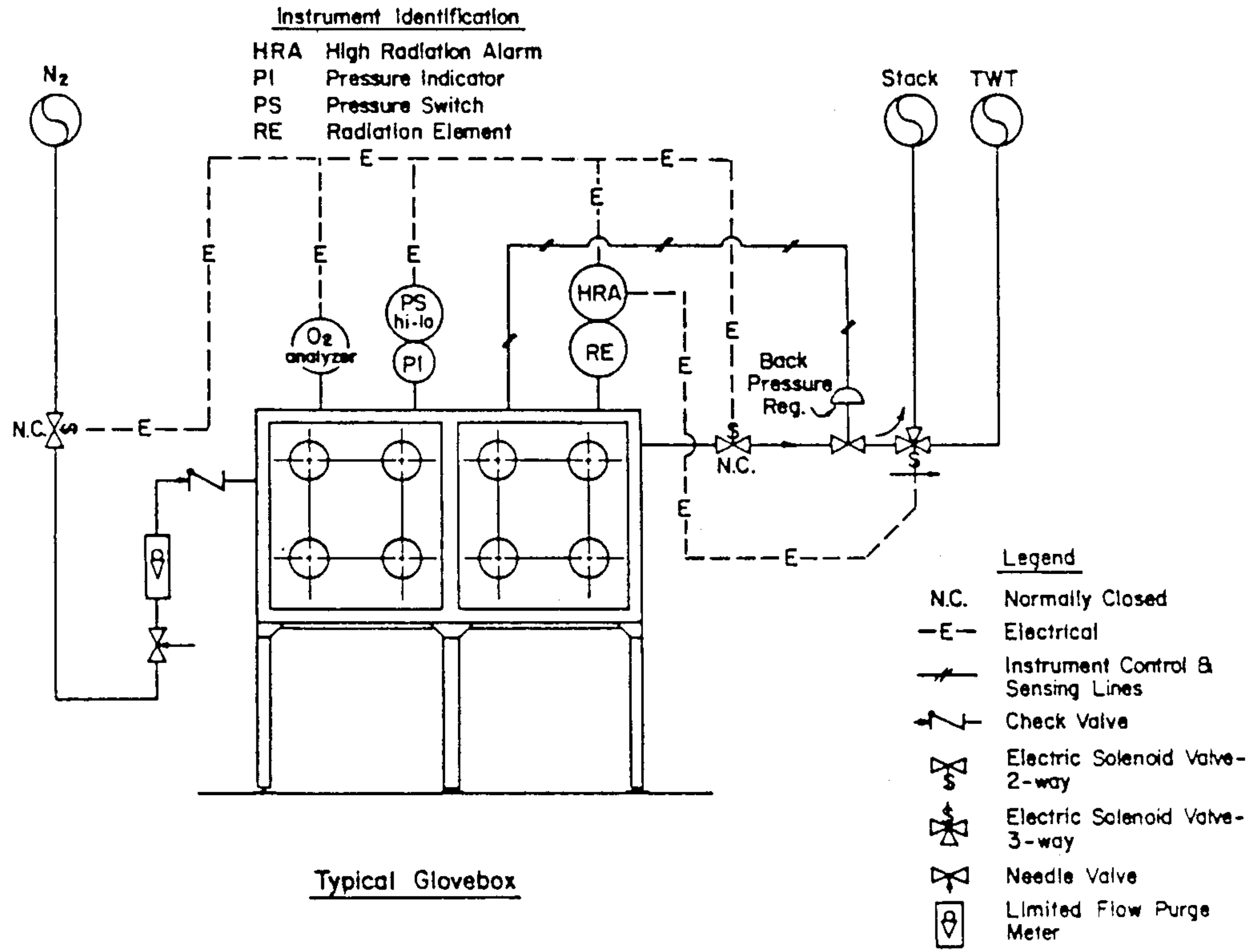


Fig. 1.2 Conceptual drawing of TSTA glovebox control system

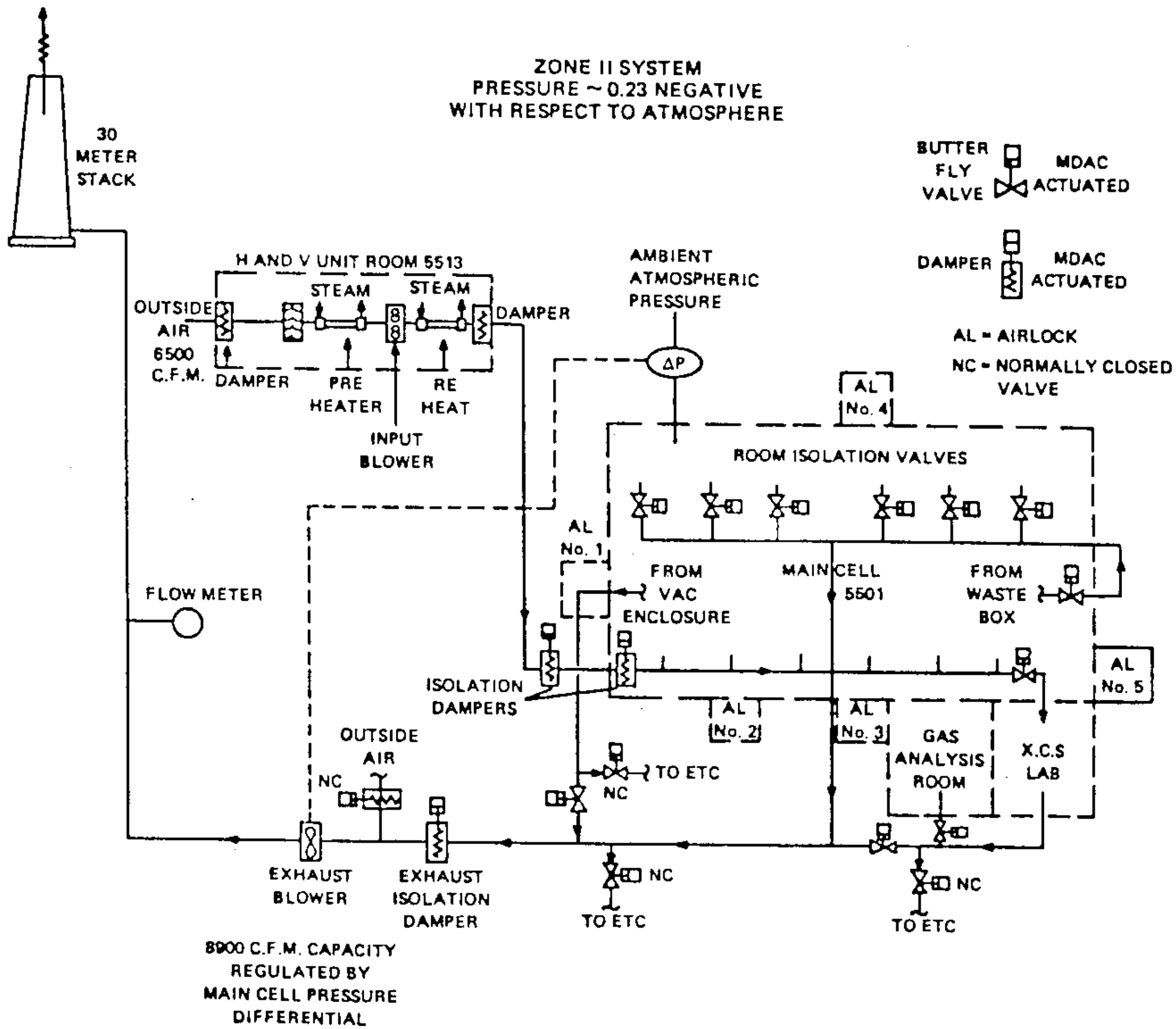


Fig. 1.3 TSTA ventilation system for the tritium area (Zone II)

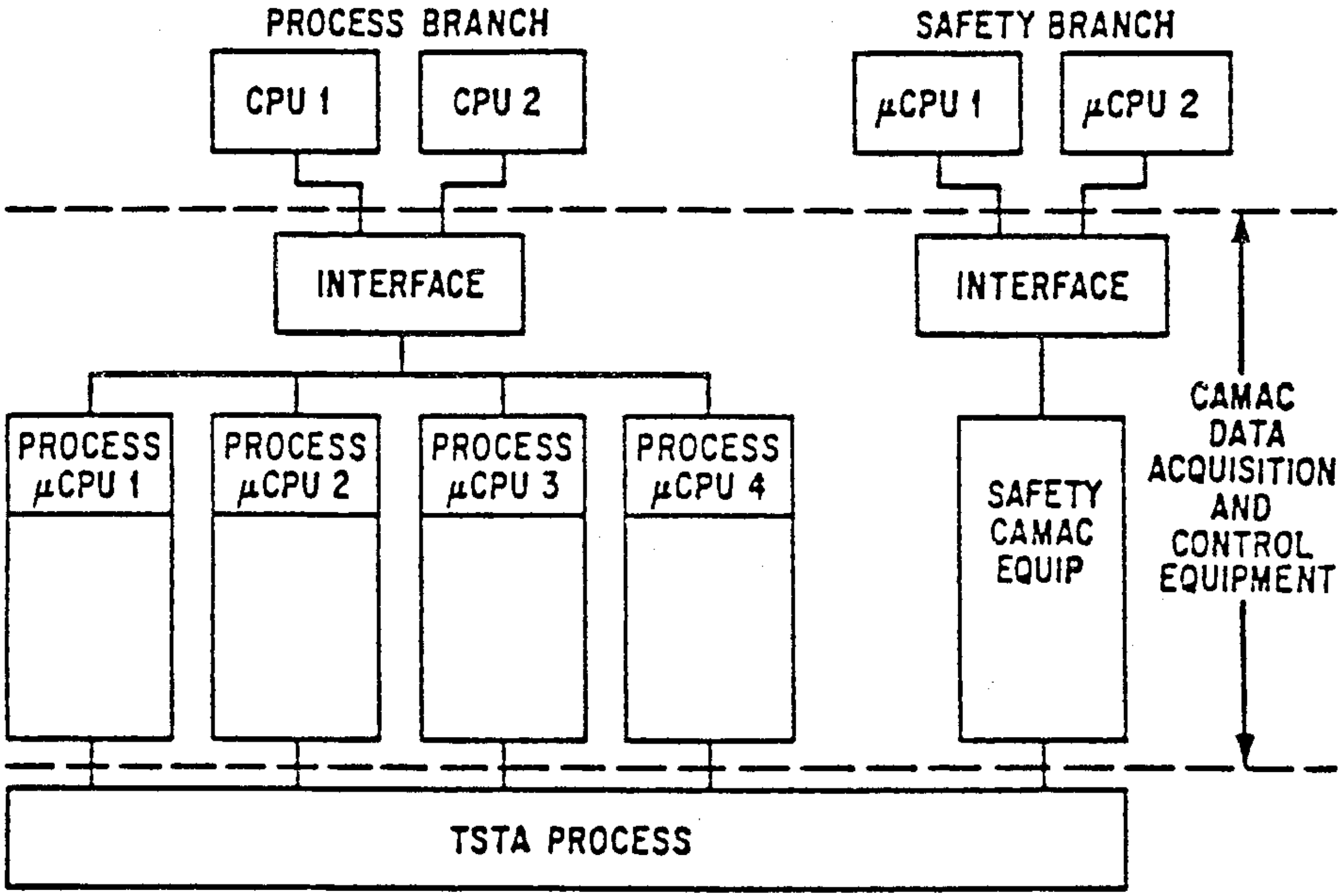


Fig. 1.4 Concept of the TSTA data acquisition and control system(MDAC)

2. TEST PLAN

2.1 OBJECTIVES

The primary objectives for the milestone run in June, 1987 were:

(i) Operate TSTA process loop and safety subsystems with 100 grams-level of tritium,
(ii) Demonstrate impurity (N_2 and CH_4) removal with the FCU front end composed of a catalytic reactor and cryogenic molecular sieve beds.
(iii) Demonstrate NBI(Neutral Beam Interface) flow with cryogenic molecular sieve beds,
(iv) Demonstrate H-D-T and ^{3}He separation with four interlinked cryogenic distillation columns system(ISS),
(v) Gain operating experience with the TSTA.

2.2 CONFIGURATION

The TSTA process loop is configured as shown in Figure 1.1. The system is able to operated in any of the following modes:
- Local,
- Computer manual,
- Computer macro,
- Full computer control.

The ISS is started locally, however the computer manual mode will be tested during the runs.

Process systems used are: LIO, UTB, FCU, IMS(impurity injection system), ISS, GAN(gas analysis system), TP1 and TP3.

Required safety subsystems are: SEC, TM, TWT, VEN, ETC, MDAC, power with EGS(emergency generator set) and UPS(uninterruptable power supply).

Utilities are: House vacuum system, low and high pressure nitrogen gas, cooling water, breathing air, etc.

2.3 SCHEDULE

Both milestone runs were planned to be carried out with continuous staffing(three shifts) of about 25 people(includes four JAERI members).

The time schedule planned for each runs were:

(i) milestone run in June ; June 22(Mon) to at latest July 2(Thu),

(ii) milestone run in July ; July 19(Sun) to July 25(Fri).

The tritium run in June was halted on June 26 as a result of a mechanical failure of the ISS refrigerator which caused a loss of refrigerant(He at 18K) to the ISS. The run in July was a resumption of the June run.

The week prior to each run, the following preparations were done:

- Tritium leak checking of the process systems with a low level of tritium,
- Checking vacuum leak tightness of process components with vacuum jackets,
- Preheating of UTB (UB-1,2,3 and 5) to 475K, UB-4 was in standby for safety. The estimated tritium inventory in the UTB at the June run were:
  - * UB-1 ; 6.5g-T
  - * UB-2 ; 1.5g-T
  - * UB-3 ; 36.3g-T
  - * UB-4 ; 0.0g-T
  - * UB-5 ; 0.0g-T
- Pumping down the ISS vacuum jacket and precooling the ISS system with liquid nitrogen,
- Connection of tritium gas shipping containers(PCs) to LIO.
  - * PC-572 ; 9.84g-T + 24.5% ^{3}He
  - * PC-1100 ; 9.40g-T + 39.5% ^{3}He
  - * PC-1101 ; 9.37g-T + 39.5% ^{3}He
- Additional tritium gas shipping containers
  - * PC-648 ; 9.37g-T
  - * PC-664 ; 9.19g-T

Both gas containers are estimated to contain a similar level of ^{3}He of above PCs.

2.4 TEST PROCEDURES

The following is a brief description of the operations done in the June run. The details are shown in the daily log of June run(Attachment III).

The details of the July run will be described by the separate report.

(1) Tritium loading and ^{3}He stripping

As the first step of the run, loading of tritium from UTB and T_2 gas shipping containers(PCs) was performed. The tritium supply from PCs was done after the start of process loop operation. Because each PC contains about 40% of ^{3}He generated during their storage, stripping procedures of helium were done using two methods. One was separation of He/hydrogen isotopes with the UTB and recovery of ^{3}He from the process loop to PCs through TP1(scroll pump). The other was removal of ^{3}He from process loop with the ISS.

(i) Stripping procedures with UTB are:
- pumping tritium with ^{3}He from the PCs to the process loop through TP1,
- circulate the process gas with ^{3}He through the TP1-FCU-ISS-UTB loop, the UTB will soak up hydrogen isotopes,
- transfer the residual gases in the loop to PCs through TP1,

(ii) Stripping procedures with ISS

Because ^{3}He can be readily separated from D-T in the ISS, and is concentrated at the top of the column H, it can be transferred to the TWT.

(2) Loop operation

Loop operation was initiated after completion of tritium loading from three UBs, which contain approximately 40g-T from previous TSTA operations. During loop operation, the following tasks were planned to be demonstrated:

- Separation of H-D-T with ISS in a stable operation mode,and in line gas analysis to obtain concentration profiles in each column.
- Withdrawal of pure T_2 gas from the column T in the ISS, and loading it to a PC.
- Injection of impurities(N_2 and CH_4) to the loop and removal of them with the FCU cryogenic molecular sieve beds(MSB1 and 2).
- The impurity injection was planned to be periodically performed for 24hrs on each MSB.

(3) Shutdown of process loop

The following ordinary shutdown procedures were planned:

- Unloading contents of the ISS to the UTB and warm up the ISS.
- Circulation of the residual gas in the ISS through the path TP3-TP1-FCU over the UBs to recover the remaining hydrogen isotopes.
- Removal residual gas in the ISS using the TWT.
- Setup line from the FCU to PCs at LIO, and warmup the FCU-MSBs to send the contents to PCs. The remaining gas in the MSBs is pumped out to PCs using the TP1.

3. TEST RESULTS

3.1 RESULTS ON PROCESS SYSTEMS

3.1.1 TRITIUM INVENTORY

In the final stage of this run, the TSTA process loop contained approximately 91 grams of tritium(44g-T from three uranium beds and 47g-T from five tritium gas shipping containers). The following are the steps of inventory increase in the process system:

June 22

- (i) Tritium(19.24g-T) with ^{3}He was loaded from two PCs(PC-572 and 1100) to the process system.
- (ii) Tritium was soaked up on two uranium beds(UB-1 and 3), and ^{3}He(approximately 30 STP-liters) was pumped to the PC-572. The amount of tritium in the UBs(1 and 3).
- (iii) Deuterium with 1.5g-T was loaded from two uranium beds(UB-2 and 5) to the process loop.

June 23

- (i) Tritium in the UBs(1 and 3) was loaded to the loop.
- (ii) Full loop operation with the TP1-FCU-ISS-TP3 path was started after completion of tritium loading.
- (iii) Inventory in the loop increased to 63.5g-T.

June 24

- (i) Tritium(18.56g-T) with ^{3}He was added from two gas cylinders(PC-1101 and 664) to the process loop.
- (ii) Helium(approximately 70 STP-liters) was removed from the top of the ISS column H and routed to the TWT.
- (iii) Inventory in the loop was 82.1g-T.

June 25

- (i) H_2 gas(30 STP-liters) was loaded to the loop to enhance separation of ^{3}He in the ISS.
- (ii) Withdrawal of H_2 with ^{3}He from the top of the column H was performed until the amount of gas withdrawn reached approximately 30 STP liters.
- (iii) Addition of tritium(9.37g-T) from another gas cylinder (PC-648), and stripping of ^{3}He(about 30 STP-liters) from the ISS were done . The total tritium in the loop at this stage reached 91.4g-T.

3.1.2 TRITIUM STORAGE AND SUPPLY SYSTEM(UTB)

The temperature scheme of each uranium bed(UBs) as well as pressures of the FCU, ISS and INV at D-T gas unloading stage(include ^{3}He stripping with the UTB) are shown in Figures 3.1 and 3.2(Abbreviation for all figures in Sections 3 and 4 are listed in Attachment IV). The required time periods for the unloading were:

UB2, connected to the Column H	;	1.5 hrs
UB5, connected to the Column D	;	6 hrs
UB1, connected to the Column I	;	11 hrs

UB3, connected to the Column T ; 7 hrs

The heating time required to increase temperature from 373K to 673K was approximately 3 hrs. Cooling time from 673K to 373K required approximately 1 day.

The temperature characteristics of the UTB during the ISS emergency shutdown is described in Section 4.

3.1.3 FUEL CLEANUP SYSTEM(FCU)

The following operation modes were selected during this milestone run:

(i) He stripping stage with the UTB; The flow path through MSB1 was incorporated with the loop of ISS-UTB-TP3-TP1.

(ii) Full loop operation stage; The NBI flow path ISS-TP3-MSB3-ISS and the ISS-TP3-TP1-MSB1-ISS were operated. Impurity injection was done at this stage, but was halted after approximately 20 min injection due to the ISS emergency shutdown.

(iii) Internal circulation on FCU; The internal loop TP1-MSB1-TP1 was operated after the ISS shutdown to resume impurity removal experiment on the MSB1.

The result of gas analysis(off-line Laser Raman spectroscopic analysis) done at the outlet of the MSB1 are:

Gas composition(%)		Isotopic composition(%)	
HD	0.08	H	0.06
HT	0.05	D	65.55
D_2	42.79	T	34.38
DT	45.33		
T_2	11.66		
N_2	0.09		
CH_4	0.002		

The background data analysed before unloading of the PC-648 on June 25(15:10) are:

Gas composition(%)		Isotopic composition(%)	
HD	0.10	H	0.07
HT	0.04	D	72.18
D_2	52.26	T	27.75
DT	39.02		
T_2	8.09		
N_2	0.49		
CH_4	not detected		

The above results of gas analysis may indicate that a certain amount of nitrogen and methane exist in the outlet stream of the MSB1. There were several sources of the nitrogen such as species bled from the MSB1(this component failed to adsorb nitrogen), contaminant from the sample cell used for the analysis, leak in the plumbing system for gas sampling. The identification of the source of these species failed during this run.

The apparent reduction rate of nitrogen and methane, assuming background of both species in the gas analysis system(FCU-GAN) was less than the detection limit of the Laser Raman spectroscopy, were 0.902 and 0.974, respectively. If these values represent the MSB1 performance there may be a possibility to cause plugging of process flow line operated at low temperature such as the ISS(18-25K). Although this run had to be halted due to the mechanical trouble in the ISS, better gas analysis techniques will be developed for future experiments.

The flow rates of the MSB1 flow path were approximately 7 STP-liters/min and that of the MSB3 flow path(NBI) was larger than the range of the flow meter(5 STP-liters/min). The design values of these flow rates are 15.2g-mol/hr(5.6 STP-liters/min) and 12.0g-mol/hr(4.3 STP-liters/min).

3.1.4 ISOTOPE SEPARATION SYSTEM(ISS)

Cooling down of the ISS with liquid nitrogen and helium refrigerant was started on June 19(Fri) and June 21(Sun), respectively. Operation with full loop operation mode was from June 24(Tue) through 26(Fri).
The time period of the ISS operation with 91g-T was approximately 38hrs, and that period was used to stabilize the ISS.

Figures 3.3 and 3.4 show the pressure variations in each column, and Figures 3.5 and 3.6 the liquid levels during this run.

It can be seen that the liquid levels in column I were likely to exceed the upper limit of the liquid level controller and the levels in the column D and T were unstable. The liquid level of the column H was relatively stable.

In the design of the columns of the ISS, the packed sections as well as the condensers and reboilers of the column I and T are cooled with He refrigerant. The columns H and D have no cooling in the packed sections. Figures 3.7 and 3.8 show the temperatures at the condensers, packed sections and reboilers of the columns D and T. From these figures it can be seen that cooling of the packed section of the column T(and I) was much faster than that of the column D(and H). The rapid temperature decrease on June 22(Figure 3.7) indicates the accumulation of liquefied hydrogen isotope in the column D reboiler began at that time. The steady state pressures, liquid levels and flow balance in each column could not be attained during this run because of failure of the He refrigerator. The first indication of liquid levels in the four columns was observed after unloading of the UTB-5(D_2) in early morning of June 24. The pressures in each column were approximately 800 Torr at that time.

Gas analysis with two ISS gas chromatographs(ISS-GAN) was started(June 23, 22:00).

During this run, 41 samples taken from the top and bottom streams were measured with gas chromatographs. Figure 3.9 shows concentration profiles of typical species in each column.

These profiles resulted from the process unstability as observed in Figures 3.3 to 3.7.

Figure 3.10 and Table 3.1 show the status of the ISS just before the emergency shutdown.

Detailed analysis and discussion of the ISS will be done in a separate report.

3.2 RESULTS ON SAFETY SYSTEMS

3.2.1 GLOVEBOX RADIATION LEVELS

Monitoring of the radiation levels of the gloveboxes was performed through at this run. Figure 3.11 shows the levels in the main process gloveboxes such as FCU-GB1, ISS-GB1, GB2 and GB3, TPU-GB1, and INV-GB1.

(1) Radiation levels in ISS-GB1

For the ISS-GB1 radiation, three major peaks were caused by the leak in the piping of a rupture disk attached to the top flow path of the ISS column I. Because of the difficulty in making a tight connection, a small "hat" was placed on the connection(morning, June 24), and the glovebox purge exhaust was routed through the "hat" to the TWT. The maximum value of the level reached higher than 50mCi/m^3. These off-normal high readings were observed at the conditions of high pressure and concentration of tritium in the column I. The peak on June 26 was caused by the high pressure of the system during the ISS emergency shutdown(loss of the He refrigerant).

Figure 3.12 shows the variation of the radiation level as a function of glovebox gas purge. The radiation level during the first 65hrs was maintained less than 1mCi/m^3 with the gas purge(approximately 1.7 m^3/hr). At a the level less than 0.4mCi/m^3, the purge stream stops by automatically. In the next 30hrs(June 23 - June 24), the purge was stopped several times because the TWT was in recirculation mode to treat the FCU-MSB2 regeneration gas. During that time period the radiation level increased to 55mCi/m^3. The tritium leak rates of both peaks were calculated to be 22 and 5.4mCi/m^3/hr, respectively, and leak rate at the ISS emergency shutdown(June 26) was 22mCi/m^3/hr.

(2) Radiation levels in ISS-GB2

Many peaks higher than the set value of 1mCi/m^3 were observed in Figures 3.11 and 3.13. Most of these tritium leaks occurred during ISS gas analysis. The leak position has been identified to be a connection around a pressure regulator in the gas analysis system(ISS-GAN). The first peak(maximum 23 mCi/m^3) on June 22 occurred during tritium unloading and helium stripping.

(3) Radiation levels in FCU-GB1

Figure 3.14 shows the radiation levels and the history of glovebox gas purge. It is apparent that the radiation levels in the FCU-GB1 was higher(1 - 5mCi/m^3) after unloading of all UBs (tritium inventory in the process loop; 73g-T). On the contrary, no marked peaks of radiation were observed except during the ISS emergency shutdown(June 26). These facts indicate at least a small leak existed in the FCU system, which could not be identified during this run. The offnormal radiation at the ISS emergency(FCU system pressures reached approximately 2000 Torr) is considered to be caused by this unidentified leak.

(4) Radiation levels in ISS-GB3, TPU-GB1 and INV-GB1

Off-normal release of tritium was not observed in these systems during this run.

(5) Relationship between glovebox radiation levels and system pressures

The radiation levels in the gloveboxes were closely related to the process conditions(pressures and tritium concentrations) and the glovebox gas purge scheme. The purge also depends on the status of TWT operation modes. A relationship among these parameters can be seen in the next Figures.

Figure 3.15-3.17 respectively show reboiler heater outputs and pressures of the ISS, and pressures of the FCU at the time period from June 23(10:00) through June 24(16:00). These system pressures varied with the adjustments of the reboiler outputs. The adjustments were performed by manual and/or automatic control modes to stabilize the ISS operating parameters(liquid levels, pressures and flow rates).

Figure 3.18 shows the radiation levels of the ISS-GBs at the same time period. The features of each step of radiation levels are:

Step (I) ;

- Loading of tritium(62g-T) from UB1 and 3 was started under loop operation,
- Loading of D_2 was completed,
- ISS pressure(column I) was approximately 780 Torr,
- GB1 and 2 had been purged with N_2 gas.

The increase of radiation level in the GB1 would be related to the increase of tritium concentration in the column I.

Step (II) ;

- ISS pressure increased to 850 Torr due to the reboiler heater adjustments,
- Glovebox gas purge was halted due to the TWT unavailability(stacking mode was halted),

The rapid increase of radiation level(GB1) depends on the pressure increase and halting of gas purge.

Step (III) ;

- ISS pressure dropped to 500 Torr, which is lower than atmospheric pressure at Los Alamos(approximately 590 Torr).

The plateau of radiation level(55mCi/m^3 for GB1) indicates a tritium leak from the ISS column did not occur in this time period. The decrease of the level can not be explained.

Step (IV) ; - Glovebox gas purge was performed,
- ISS pressure was increased to 830 Torr,

Radiation levels(GB1) was decreased to 3 mCi/m^3 by the glovbox gas purge.

Step (V) ; - ISS pressure was maintained at 780-750 Torr,
- glovebox gas purge was halted,

Increase of radiation levels indicates tritium leak occurred in the GB1 and 2.

Step (VI) ; The radiation levels of both gloveboxes decreased with the gas purge.

3.2.2 TWT CHARACTERISTICS

The tritium waste treatment system(TWT), one of the key systems needed to perform tritium experiments, was operated the entire period of this milestone run.

Figure 3.19 shows the operating temperatures of the TWT recombiner(catalytic oxdizer). The operating temperature varied between 430 C and 510 C. The design temperature(550-600 C) could not be obtained due to unknown difficulties in the electrical circuit of the recombiner heaters. The temperature of 510 C level(on June 23 ,24 and 26) could be attained by operation of the larger compressor(90 m^3/hr) in the TWT recirculation mode. This operation was performed for the purpose of treating exhaust gases including tritiated hydrocarbons such as the FCU-MSB2 regeneration gas(June 23 and 24) and the evacuation gas of the UB2(June 26).

Figure 3.20 shows the radiation levels of inlet and outlet streams of the TWT. The inlet represents the reading of a tritium monitor installed in the TWT low pressure receiver(LPR; pressure of gas stream : 0.3 atm) and the outlet is one of the readings of tritium monitors in the outlet of TWT dryers MSB(A, B, C and D; pressure : 2.8 atm). The inlet radiation level started increasing June 23 and shows many peaks. The major sources of tritium are FCU-MSB2 regeneration and its He purge, ISS gas analysis, and stripping of ^{3}He and H_2 from the ISS column H.

The total amount of tritium of 250 Ci from MSB2 was estimated from the reading of radiation levels , pressures and the volume of the LPR.

The three major peaks of the outlet radiation found on June 23, 24 and 26 were related to the FCU-MSB2 regeneration and the UBs evacuation through the House Vac. The exhaust gases included tritiated hydrocarbon, because the MSB2 was previously used for a methane adsorption experiment and the House Vac system has been contaminated with oil vapor originating from an oil lubricated vacuum pump.

After the purge of the regeneration of MSB2(June 24), the outlet radiation level remained at a high level of 20mCi/m^3 because the TWT-MSBD was saturated with tritiated moisture. The switch from MSBD to MSBA resulted in the rapid decrease (20 mCi/m^3 to 2mCi/m^3) of the radiation level.

Figure 3.21 shows the decontamination factor(DF) determined by normalizing pressures in both streams of inlet and outlet of the TWT. The great drops of the DF on June 23, 24 and 26 were considered to be some elution of unconverted hydrocarbon due to the relatively low temperature of the recombiner(the desirable temperature to oxidize methane is approximately 550-600 C).

The TWT is operated in a recirculation mode when the radiation level is higher than a limit value, and is operated in stacking mode in the range less than 75% of this limit. These functions are actuated either manually or automatically. Figure 3.22 shows the TWT-MSB outlet radiation level and the limit level.

Stacking operation was performed for a short time period on June 23, 24 and 26. The amount of tritium released to the environment (approximately 1.7 Ci) was determined from the reading of the stack monitor(stack flow rate 250m^3/min).

3.2.3 ROOM RADIATION LEVELS

Although several times tritium leaks were observed into the gloveboxes, no offnormal radiation levels in the experimental room (TSTA main cell) occurred during this run(Figures 3.23 and 3.24).

During the ISS emergency shutdown, pressures in the process loop reached approximately four times atmospheric pressure, and offnormal releases of tritium were found in the gloveboxes of the FCU and the ISS. No increase of the room radiation level, however, was detected at the time.

3.2.4 STACK RADIATION LEVELS

Figure 3.25 shows the daily integrated radiation level monitored (with VEN-R-STKI) in the period between June 21 and August 3, 1987. The peak of June 24 corresponded to the FCU-MSB2 regeneration(The peak of July 24 was caused by offnormal release in TSTA out-of-loop facility in the SWD-hood). Because the daily back-ground(approximately 3.5 Ci) represents the noise level of the integrating monitor, the net release to the environment on June 24 can be estimated to be approximately 1.5Ci.

Figure 3.26 shows the stack radiation levels during FCU-MSB2 regeneration. The total release (approximately 1.7Ci) reveals good agreement with the above value determined by the stack monitor. The variation of the radiation levels corresponds to the TWT operation modes, that is, all peaks were found when the operation mode was switched from recirculation mode to stacking mode. Because the stacking operation was performed when the radiation levels(TWT-RAD-RECYCLE) in the TWT outlet stream decreased to approximately $15mCi/m^3$, it can not be the reason for the high radiation levels observed with the stack monitor. To prevent similar releases to the environment, switching the TWT operation mode should be done by checking both monitors in the TWT outlet stream and stack stream.

Figure 3.27 shows the radiation levels of the TWT(RAD-RECYCLE; outlet of MSBs, RAD-RMEX; outlet to stack) and of the stack as well as the status of TWT operations. The source of this radiation was exhaust gas from the UB2 during evacuation to reduce the blanketing effect at UB2. This component was operated to soak up hydrogen isotopes in the ISS column H during the ISS shutdown. As can be seen in this figure, the maximum level in the MSB outlet stream reached to 10^{-5} - $10^{-4}Ci/m^3$ and small amount of tritium was released to the environment when the TWT operation was in stacking mode.

The increase of radiation level at the outlet of the dryers(MSBA) would depend on the conversion rate of tritiated species in the TWT recombiner(maximum 510 C, see Figure 3.19). From the similarity with the FCU-MSB2 regeneration gas(see Figures 3.20 and 3.21), the most probable species is considered to be tritiated hydrocarbon originating from contaminants in the House Vac.

As can be seen from the indication of the TWT operation mode shown in this figure, the operation mode was selected by detecting the radiation levels(TWT-RAD-RECYCLE) in the outlet stream. Although the actual radiation level was as high as $50mCi/m^3$ at the stages (I) and (2), TWT was operated in the stacking mode because the apparent radiation level signal, which varies with the measuring range on the tritium monitor(TWT-RAD-RECYCLE), was less than the level($15-20mCi/m^3$) for the TWT circulation mode. The peak radiation levels observed on the stack radiation monitor(VEN-R-STK) are the result of this improper selection of the TWT operation mode. This problem seems to be a defect of the software program for the tritium monitor signal treatment.

The total amounts of tritium released through the ventilation systems (from June 22 through 28) are estimated as follows:

HTO release (stack bubbler) ; 456 mCi
HT release (stack bubbler) ; 18.4 mCi
Total release (stack monitor); approximately 1.7 Ci

The values of HTO and HT were measured by the TSTA stack bubbler system composed of glycol bubblers and a catalytic reactor (operating temperature 350 C). This system does not measure precisely the amount of tritiated hydrocarbons, because the temperature of the catalytic reactor is not high enough to convert these species.
The total release measured with the stack monitor includes all tritiated species such as HT, HTO and $C(H,D,T)_4$.

Table 3.1 Compositions in the top and bottom streams of the ISS four columns just before the ISS scram

Col-I-Bottom	D_2	2.52 %	measured at 8:06
	DT	71.19	on June 26
	T_2	26.29	
Col-I-Top	D_2	100	measured at 8:56
Col-H-Bottom	^3He	29.98 %	measured at 10:13
	H_2	2.10	
	HD	63.40	
	D_2	4.53	
Col-H-Top	HD	0.56	measured at 10:50
	D_2	99.44	on June 26
Col-D-Bottom	D_2	100 %	measured at 10:34
Col-D-Top	D_2	100	measured at 9:50
Col-T-Bottom	D_2	0.42 %	measured at 8:34
	DT	34.34	
	T_2	65.23	
Col-T-Top	D_2	25.08	measured at 9:27
	DT	70.79	
	T_2	4.13	

Above values are apparent data obtained by gas chromatographic measurements.

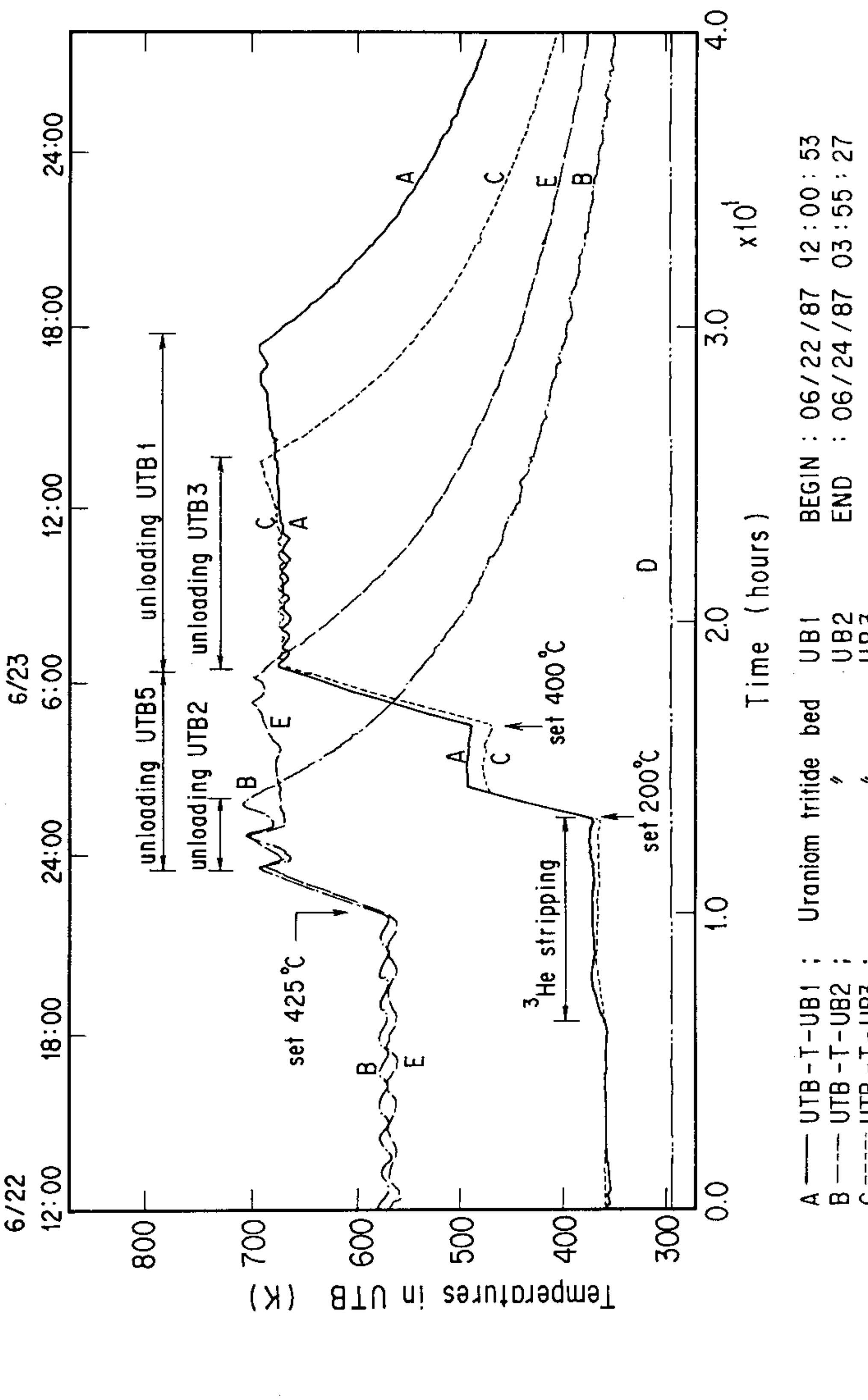


Fig. 3.1 Temperature profiles for the tritium unloading process of the UTB

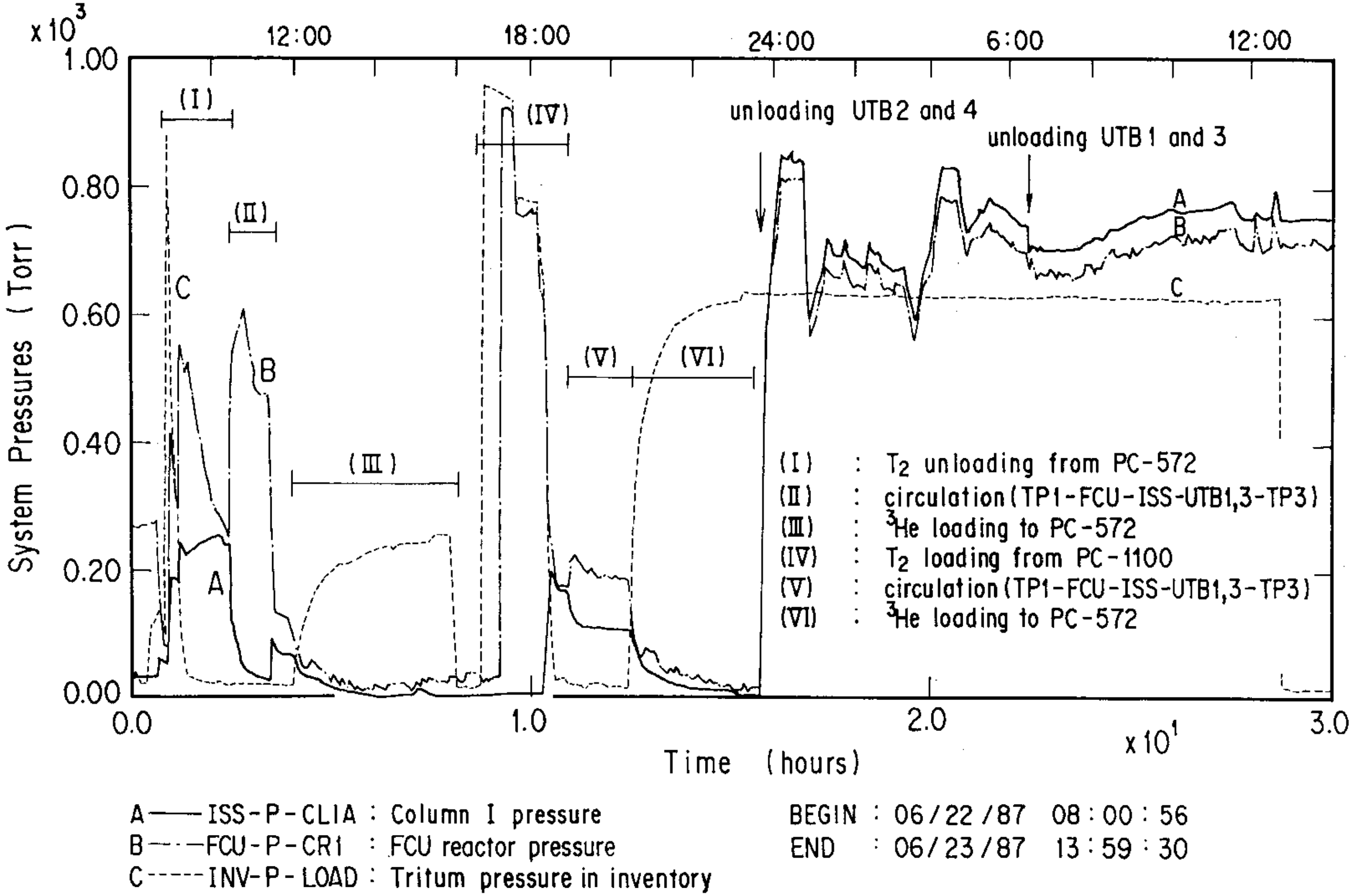
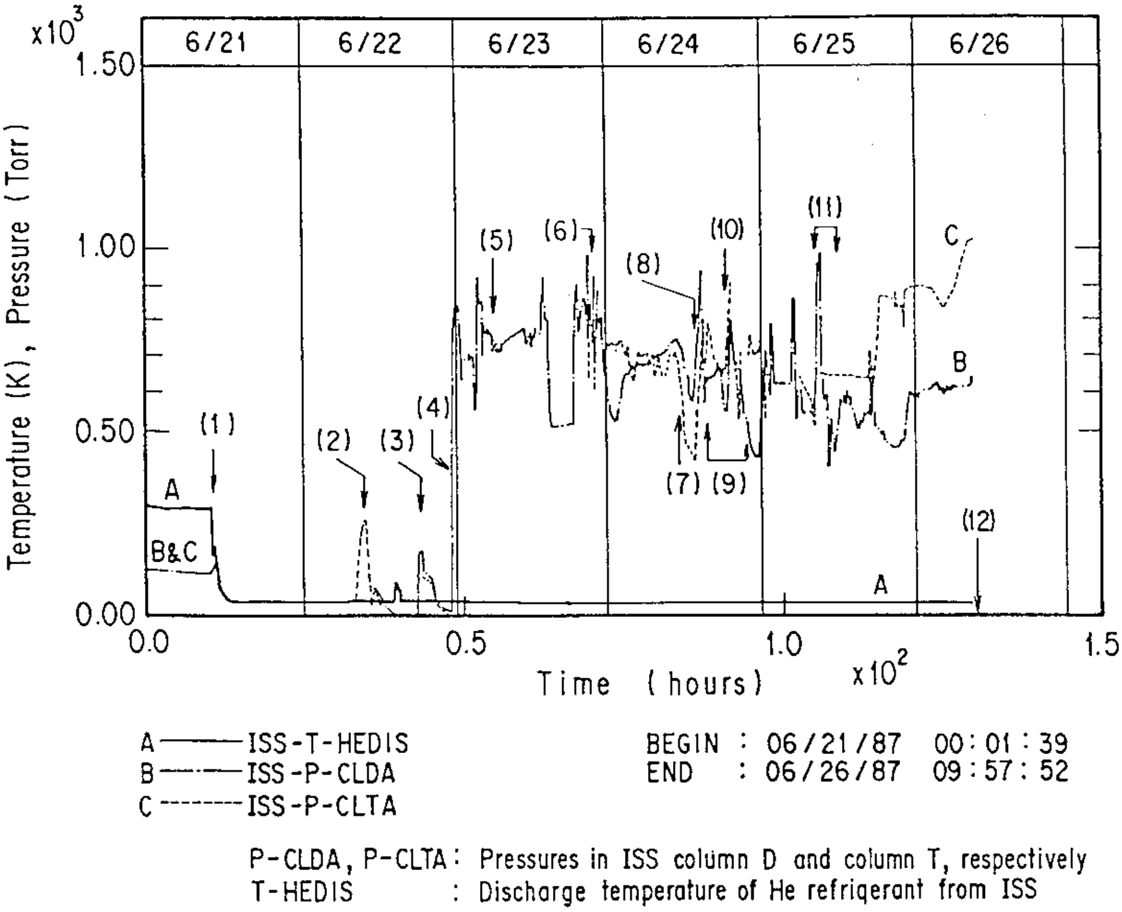
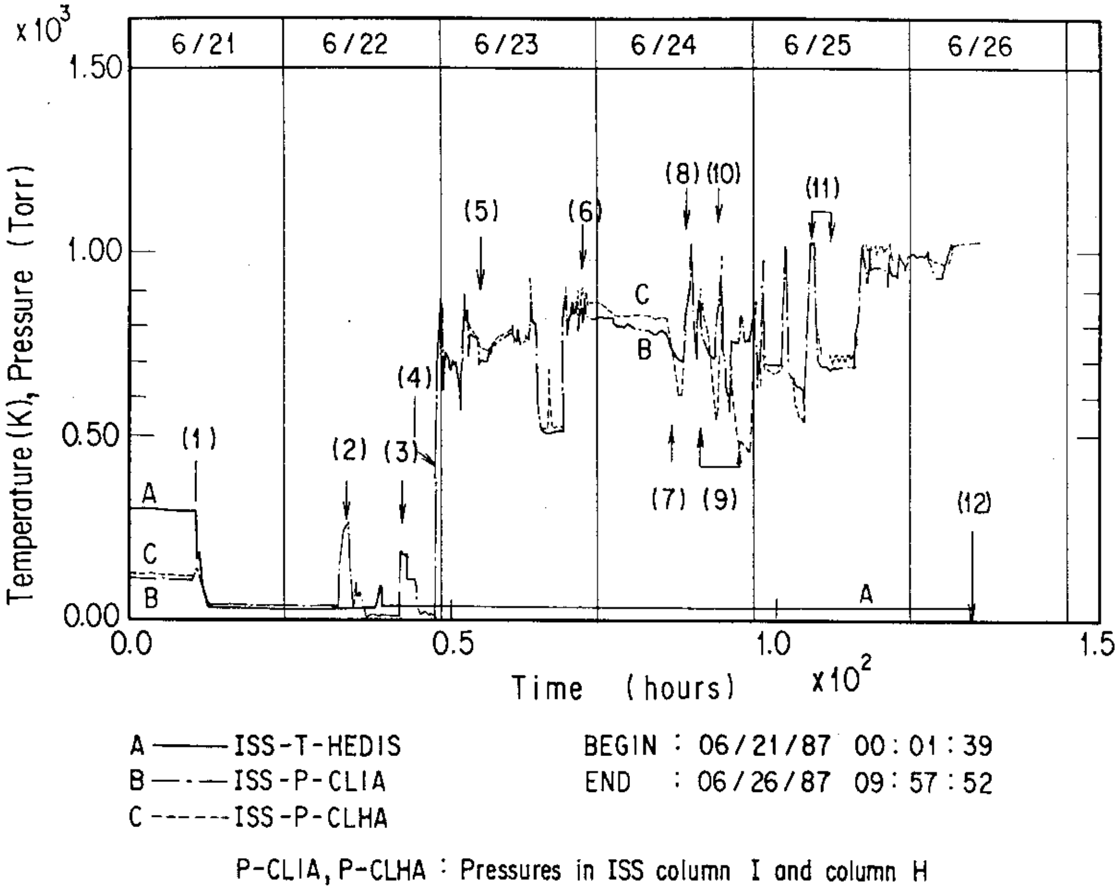


Fig. 3.2 Pressure variations in the ISS, FCU and INV during tritium loading to the TSTA process loop



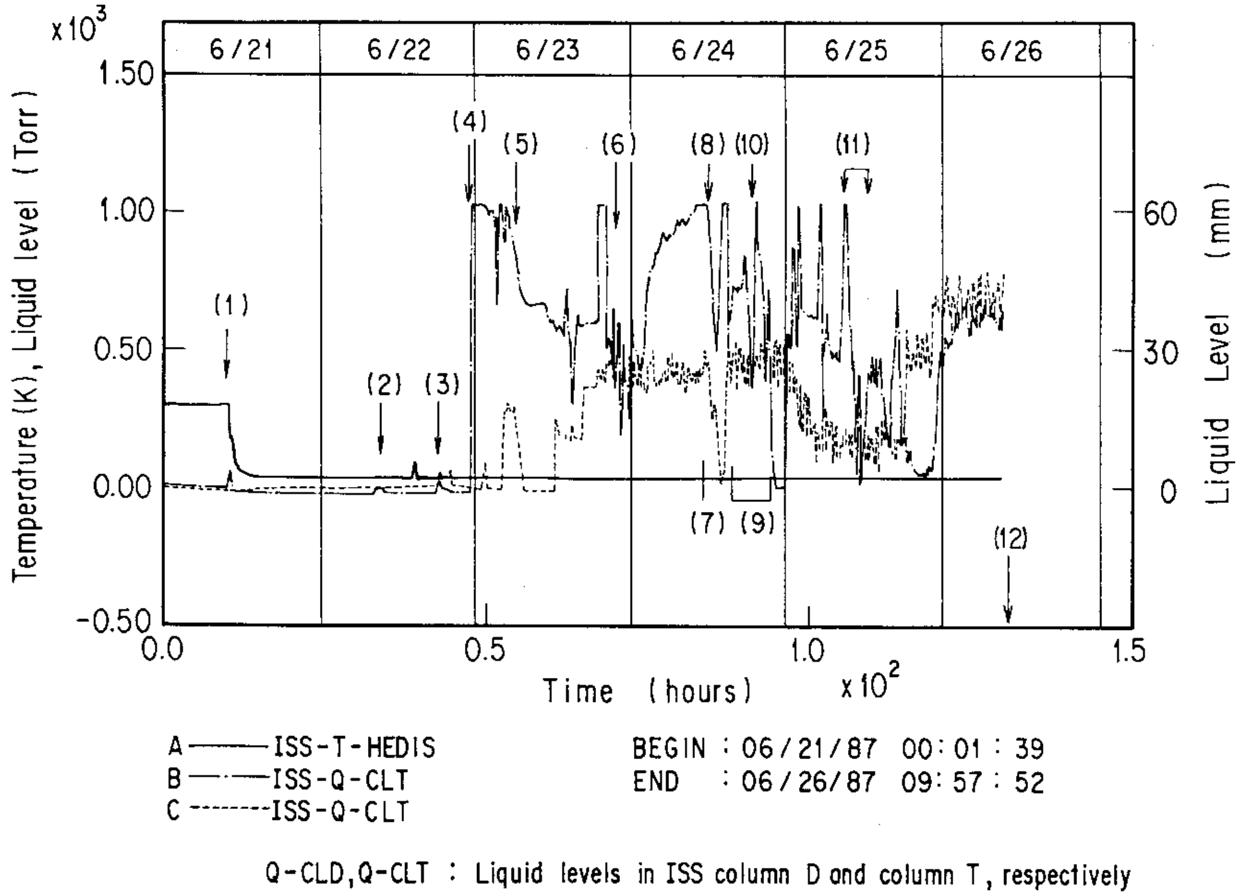
(1) start cooling with He
(2) loading T_2(PC-572) and stripping ^{3}He with UB-1,3
(3) loading T_2(PC-1100) and stripping ^{3}He with UB-1,3
(4) loading D_2 from UB-2,5
(5) unloading UB-1,3
(6) full loop operation with NBR(MSB3)
(7) ^{3}He withdrawal from column H
(8) loading T_2(PC-1101)
(9) ^{3}He withdrawal from column H
(10) loading T_2(PC-664)
(11) H_2 loading and ^{3}He withdrawal from column H
(12) ISS scrammed

Fig. 3.3 He refrigerant temperature and the ISS pressures in the columns D and T



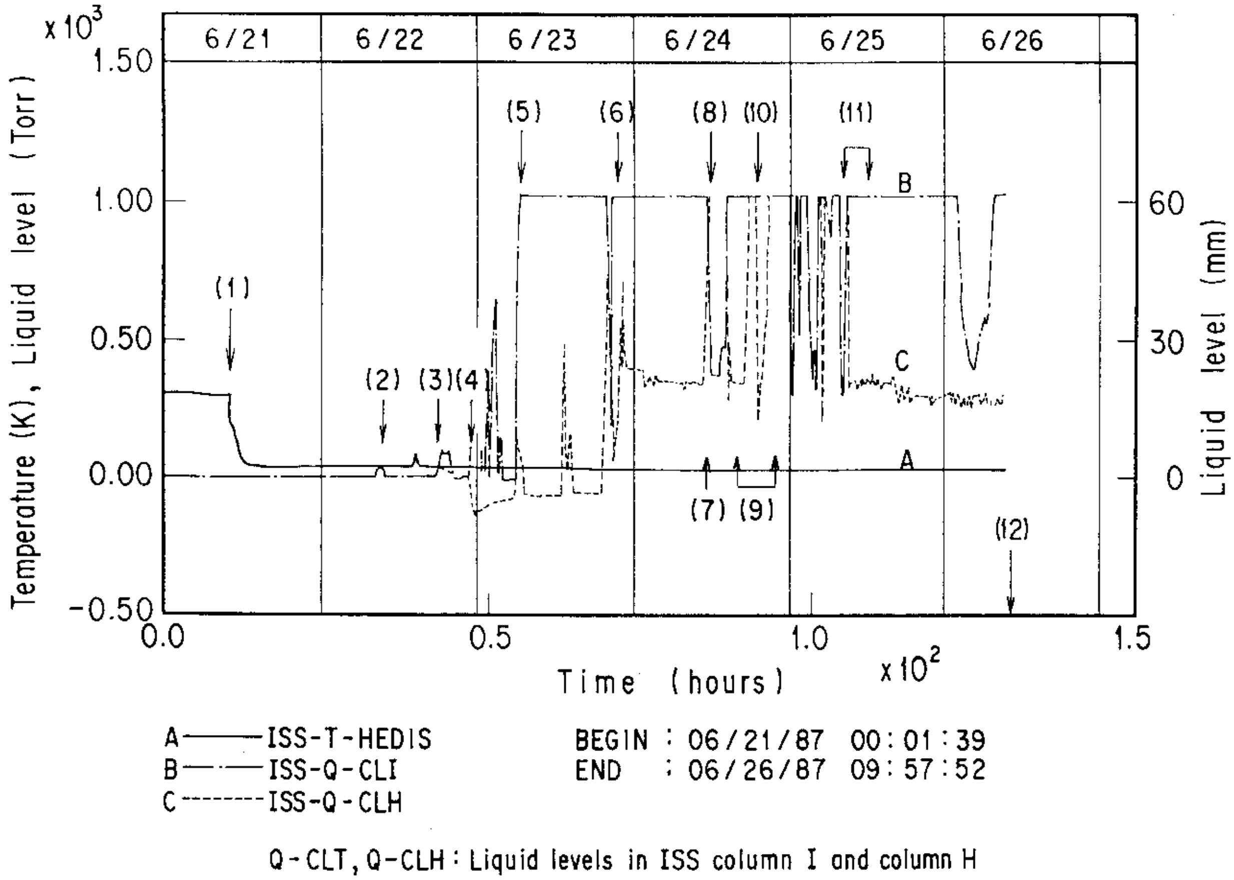
(1) start cooling with He
(2) loading T_2(PC-572) and stripping ^3He with UB-1,3
(3) loading T_2(PC-1100) and stripping ^3He with UB-1,3
(4) loading D_2 from UB-2,5
(5) unloading UB-1,3
(6) full loop operation with NBR(MSB3)
(7) ^3He withdrawal from column H
(8) loading T_2(PC-1101)
(9) ^3He withdrawal from column H
(10) loading T_2(PC-664)
(11) H_2 loading and ^3He withdrawal from column H
(12) ISS scrammed

Fig. 3.4 He refrigerant temperature and the ISS pressures in the column I and H



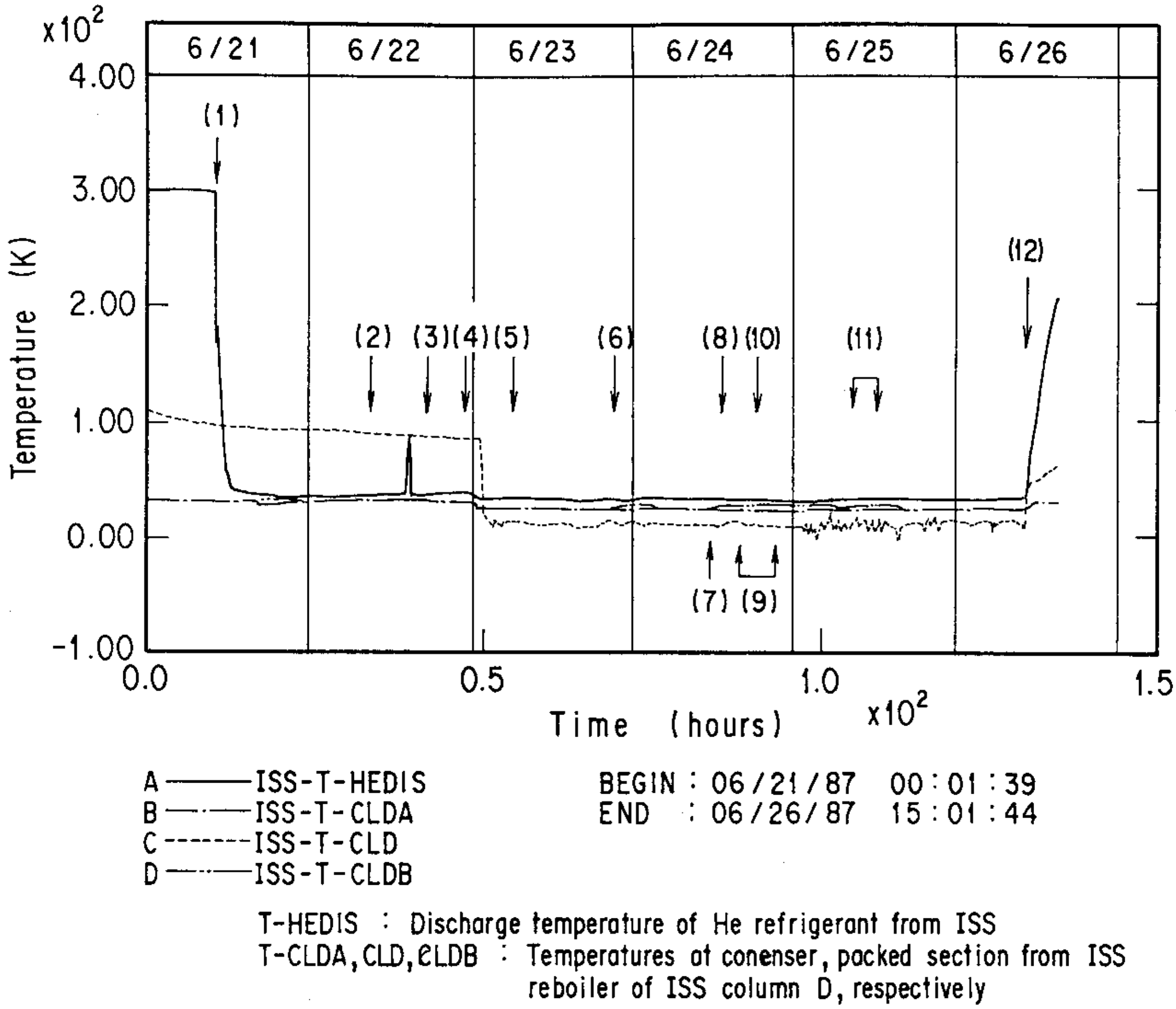
(1) start cooling with He
(2) loading T_2(PC-572) and stripping ^{3}He with UB-1,3
(3) loading T_2(PC-1100) and stripping ^{3}He with UB-1,3
(4) loading D_2 from UB-2,5
(5) unloading UB-1,3
(6) full loop operation with NBR(MSB3)
(7) ^{3}He withdrawal from column H
(8) loading T_2(PC-1101)
(9) ^{3}He withdrawal from column H
(10) loading T_2(PC-664)
(11) H_2 loading and ^{3}He withdrawal from column H
(12) ISS scrammed

Fig. 3.5 He refrigerant temperature and the ISS liquid levels in the column D and T



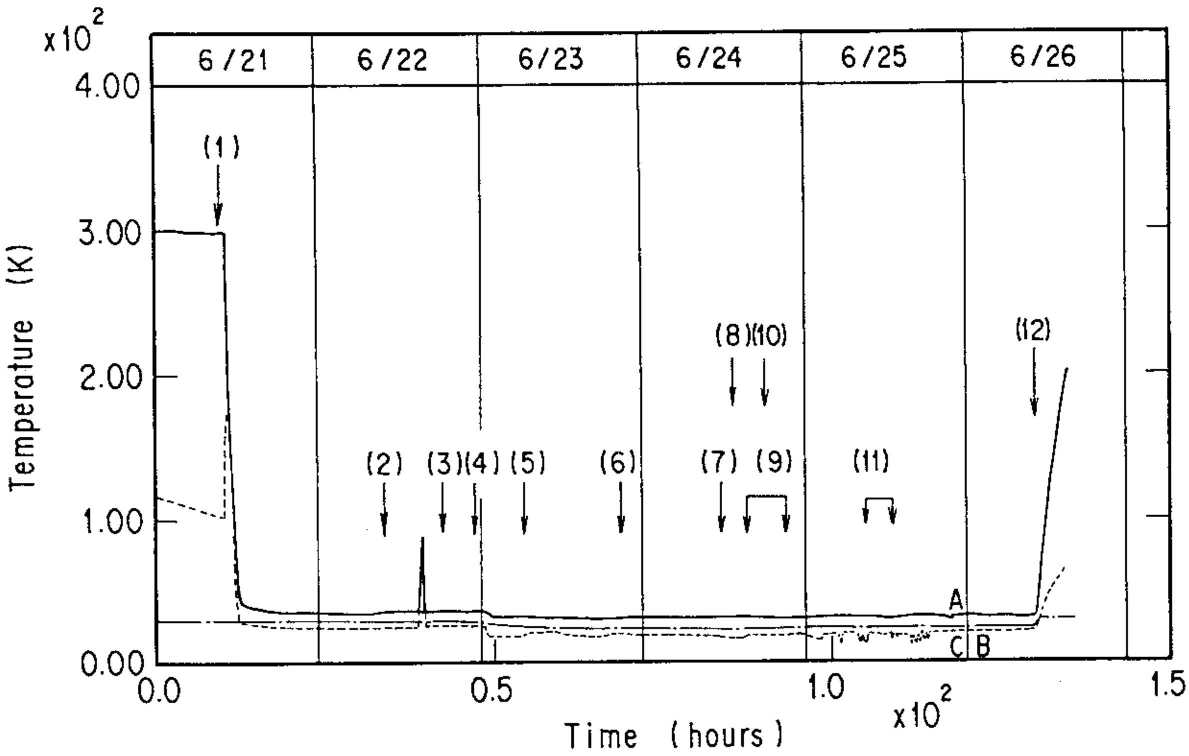
(1) start cooling with He
(2) loading T_2(PC-572) and stripping ^3He with UB-1,3
(3) loading T_2(PC-1100) and stripping ^3He with UB-1,3
(4) loading D_2 from UB-2,5
(5) unloading UB-1,3
(6) full loop operation with NBR(MSB3)
(7) ^3He withdrawal from column H
(8) loading T_2(PC-1101)
(9) ^3He withdrawal from column H
(10) loading T_2(PC-664)
(11) H_2 loading and ^3He withdrawal from column H
(12) ISS scrammed

Fig. 3.6 He refrigerant temperature and the ISS liquid levels in the column I and H



(1) start cooling with He
(2) loading T_2(PC-572) and stripping ^3He with UB-1,3
(3) loading T_2(PC-1100) and stripping ^3He with UB-1,3
(4) loading D_2 from UB-2,5
(5) unloading UB-1,3
(6) full loop operation with NBR(MSB3)
(7) ^3He withdrawal from column H
(8) loading T_2(PC-1101)
(9) ^3He withdrawal from column H
(10) loading T_2(PC-664)
(11) H_2 loading and ^3He withdrawal from column H
(12) ISS scrammed

Fig. 3.7 He refrigerant temperature and the ISS column D temperatures in the condenser, packed section and reboiler



A —— ISS-T-HEDIS
B —·— ISS-T-CLTA
C ------ ISS-T-CLT
D —··— ISS-T-CLTB

BEGIN : 06/21/87 00:01:39
END : 06/26/87 15:01:44

T-CLTA,CLT,CLTB : Temperatures at condenser, packe dsection and reboiler of ISS column T, respectively

(1) start cooling with He
(2) loading T_2(PC-572) and stripping ^3He with UB-1,3
(3) loading T_2(PC-1100) and stripping ^3He with UB-1,3
(4) loading D_2 from UB-2,5
(5) unloading UB-1,3
(6) full loop operation with NBR(MSB3)
(7) ^3He withdrawal from column H
(8) loading T_2(PC-1101)
(9) ^3He withdrawal from column H
(10) loading T_2(PC-664)
(11) H_2 loading and ^3He withdrawal from column H
(12) ISS scrammed

Fig. 3.8 He refrigerant temperature and the ISS column T temperatures in the condenser, packed section and reboiler

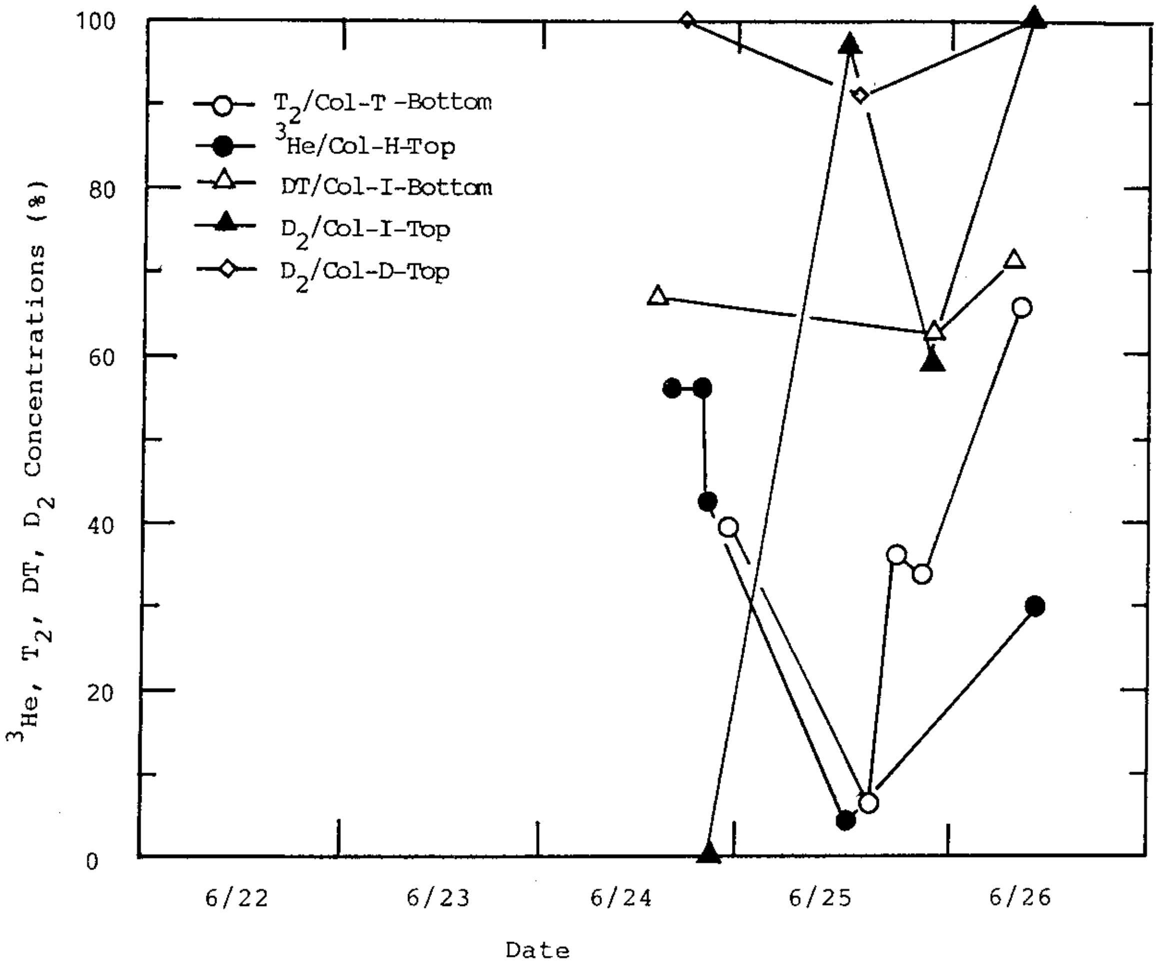
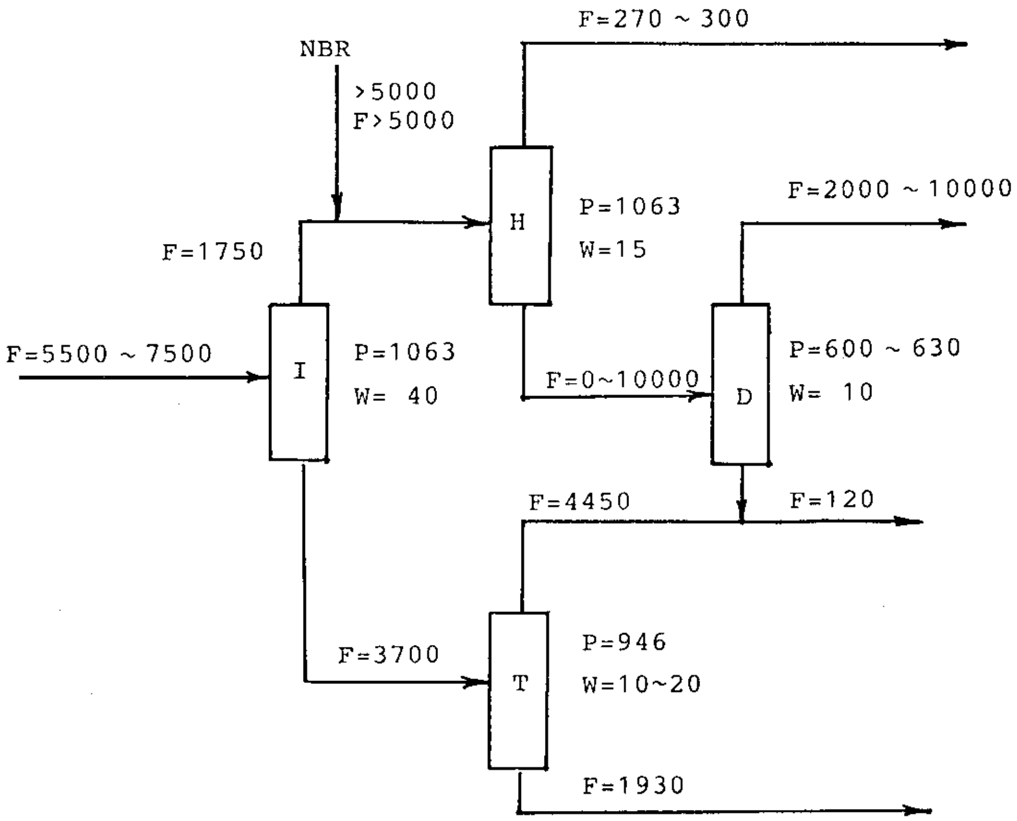


Fig. 3.9 Concentration distribution of ^{3}He, T_2, DT and D_2



F : Mass flow rates(SCM-H_2)
P : Pressures(Torr)
W : Output of reboiler heaters
NBR: Flow from Neutran Beam Return path

Fig. 3.10 ISS status at 2hrs before shutdown
Valuses in the figure represent apparent data on the ISS instruments (at 8:25, June 26)

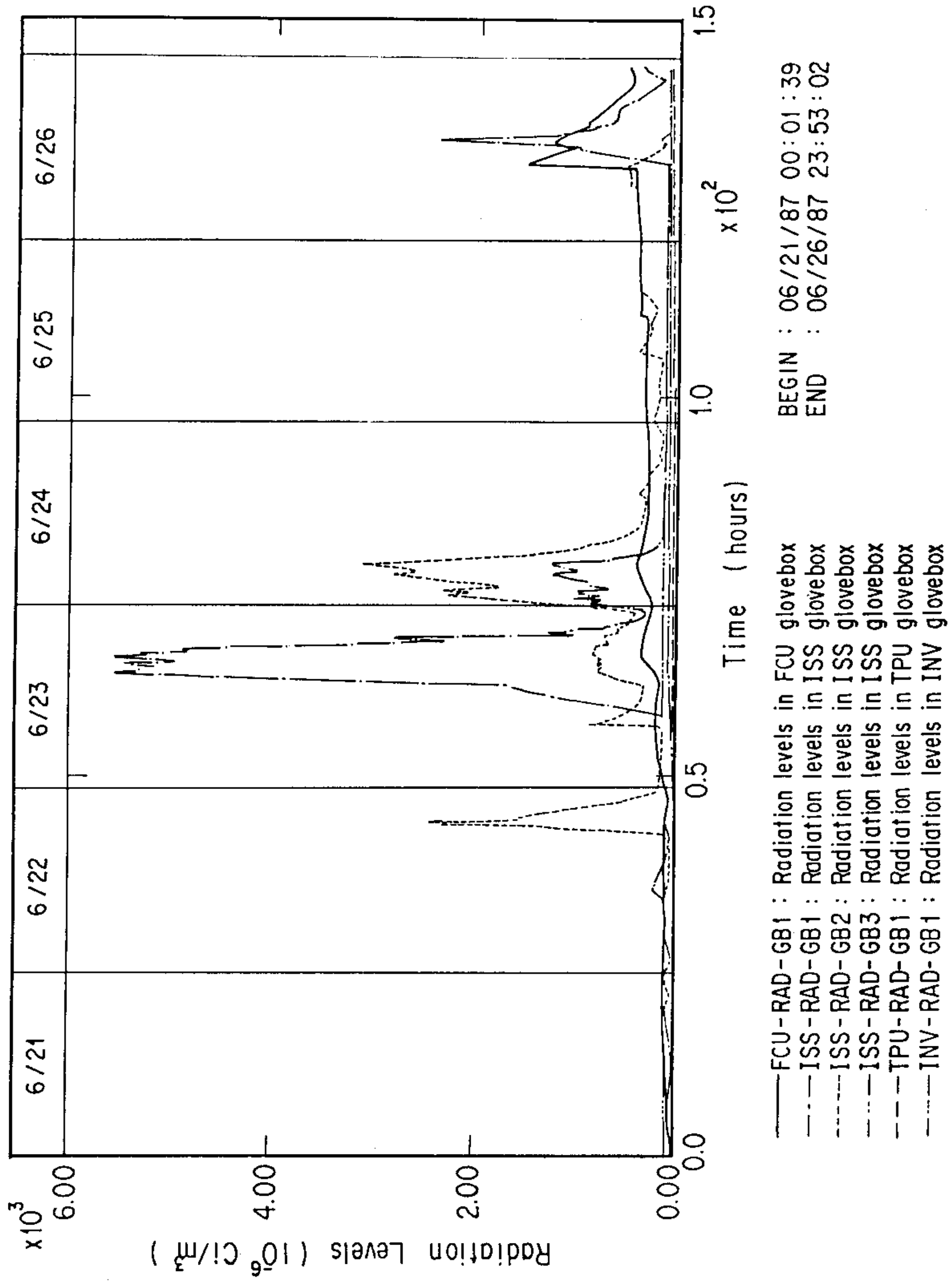


Fig. 3.11 Radiation levels in the gloveboxes

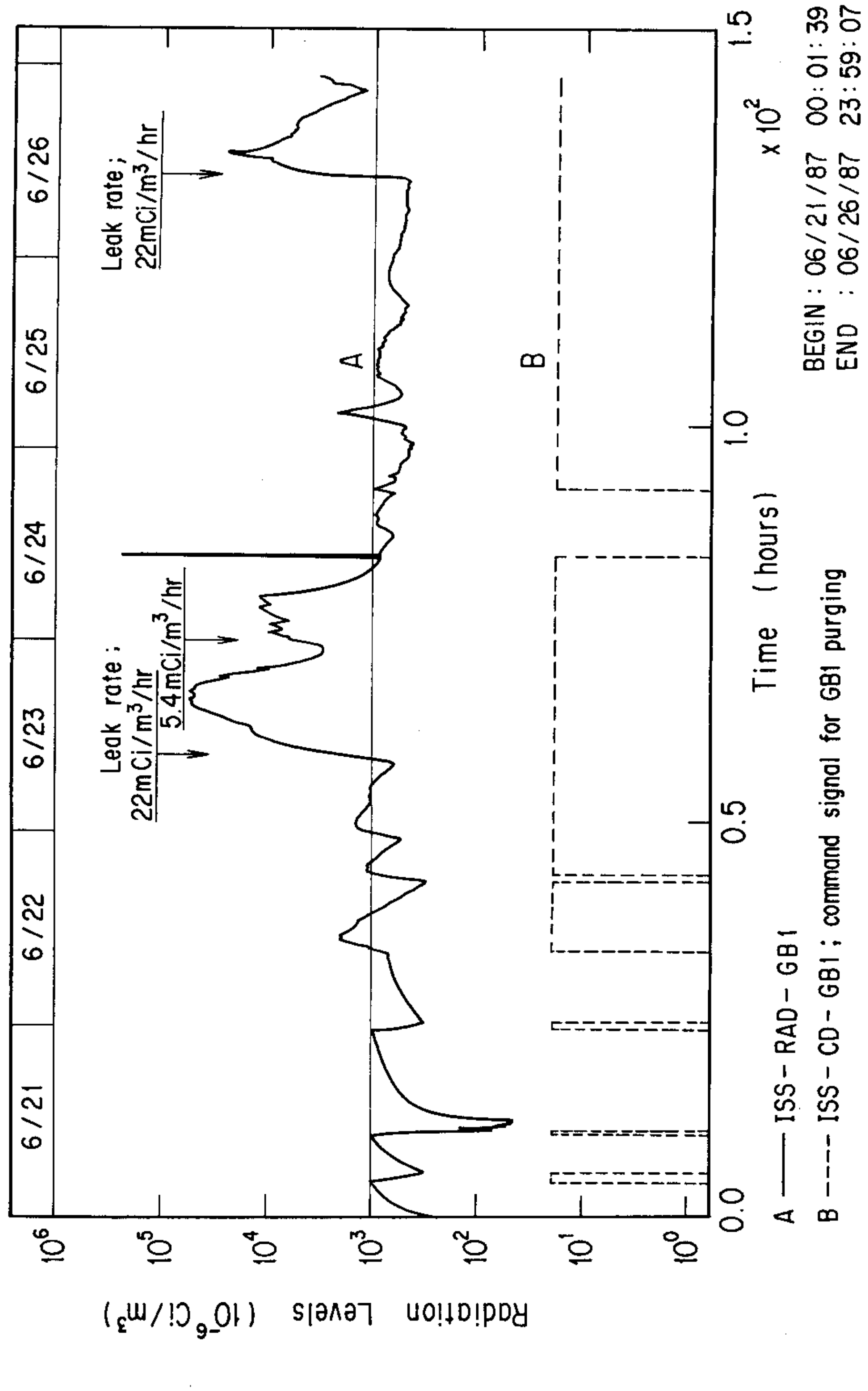


Fig. 3.12 Radiation levels in the ISS glovebox(GB1)

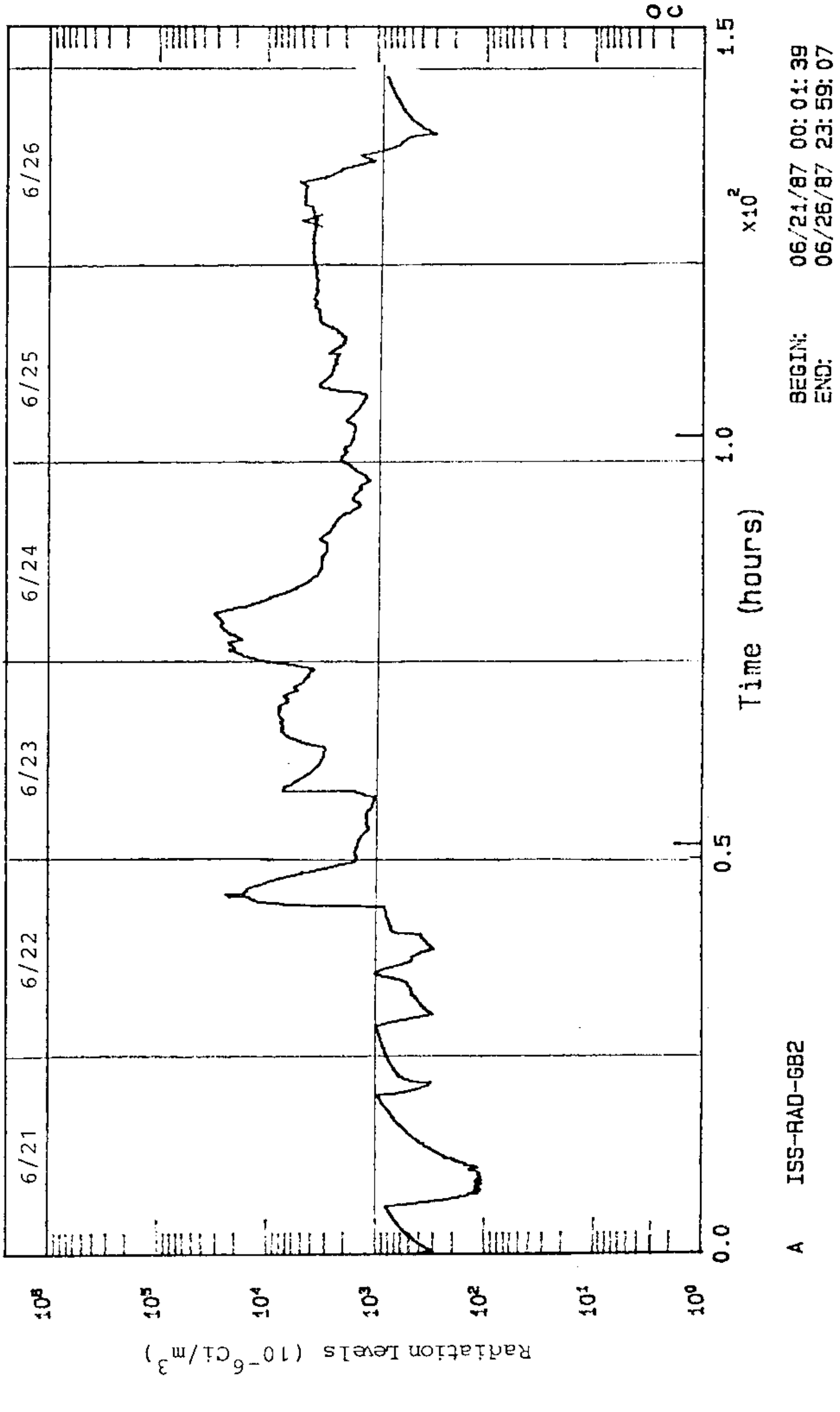


Fig. 3.13 Radiation levels in the ISS glovebox(GB2)

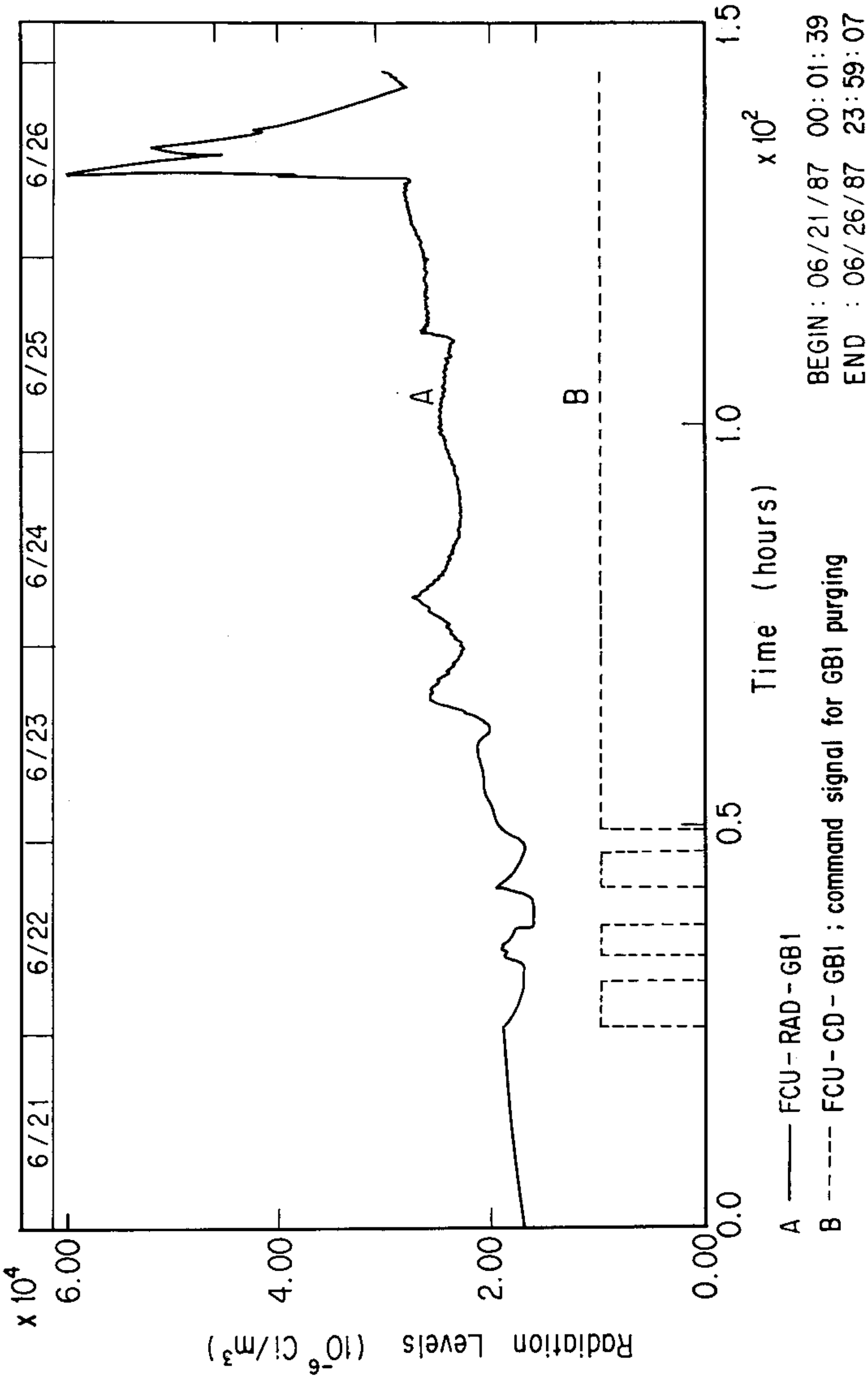


Fig. 3.14 Radiation levels in the FCU glovebox(GB1)

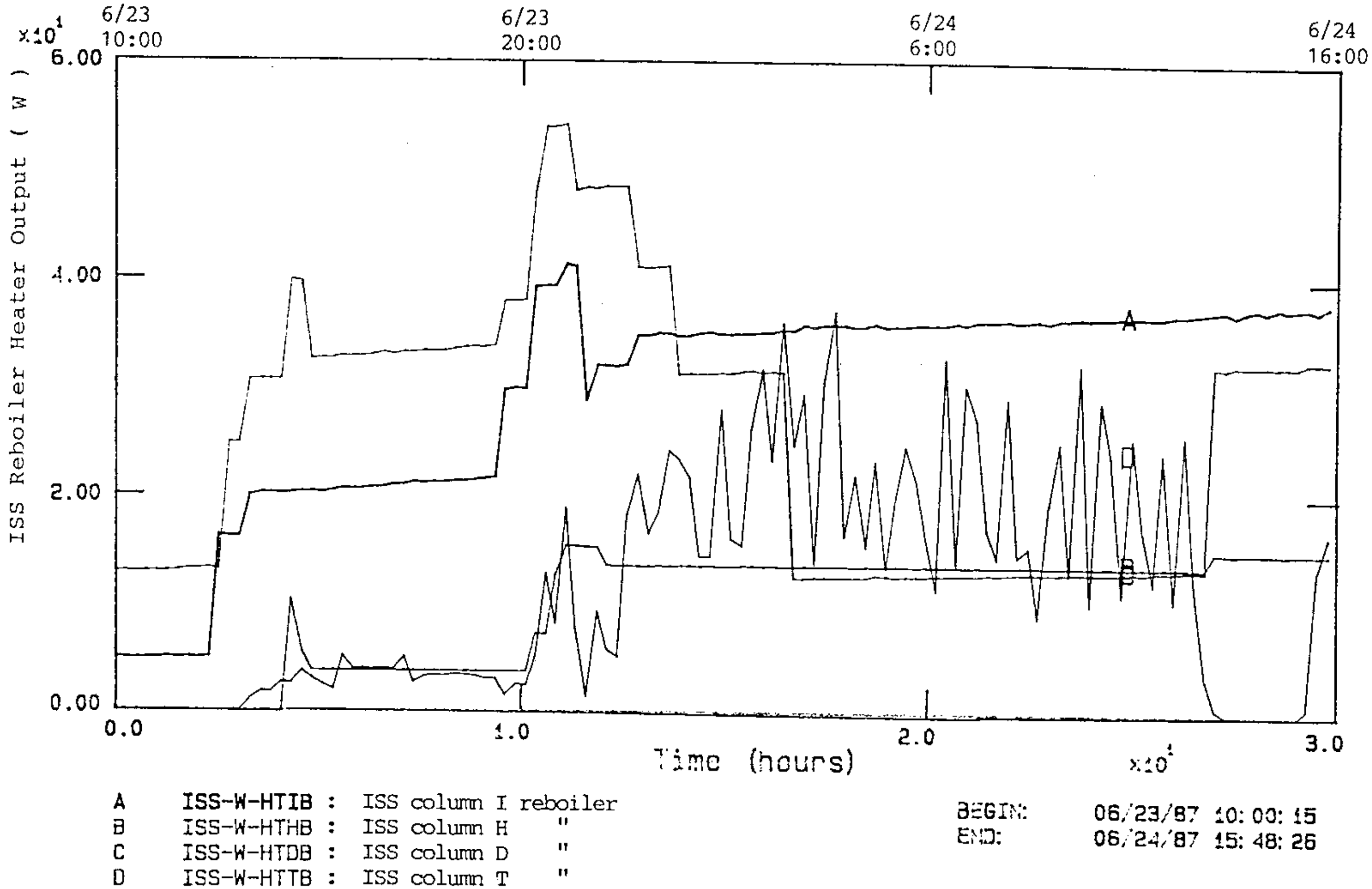
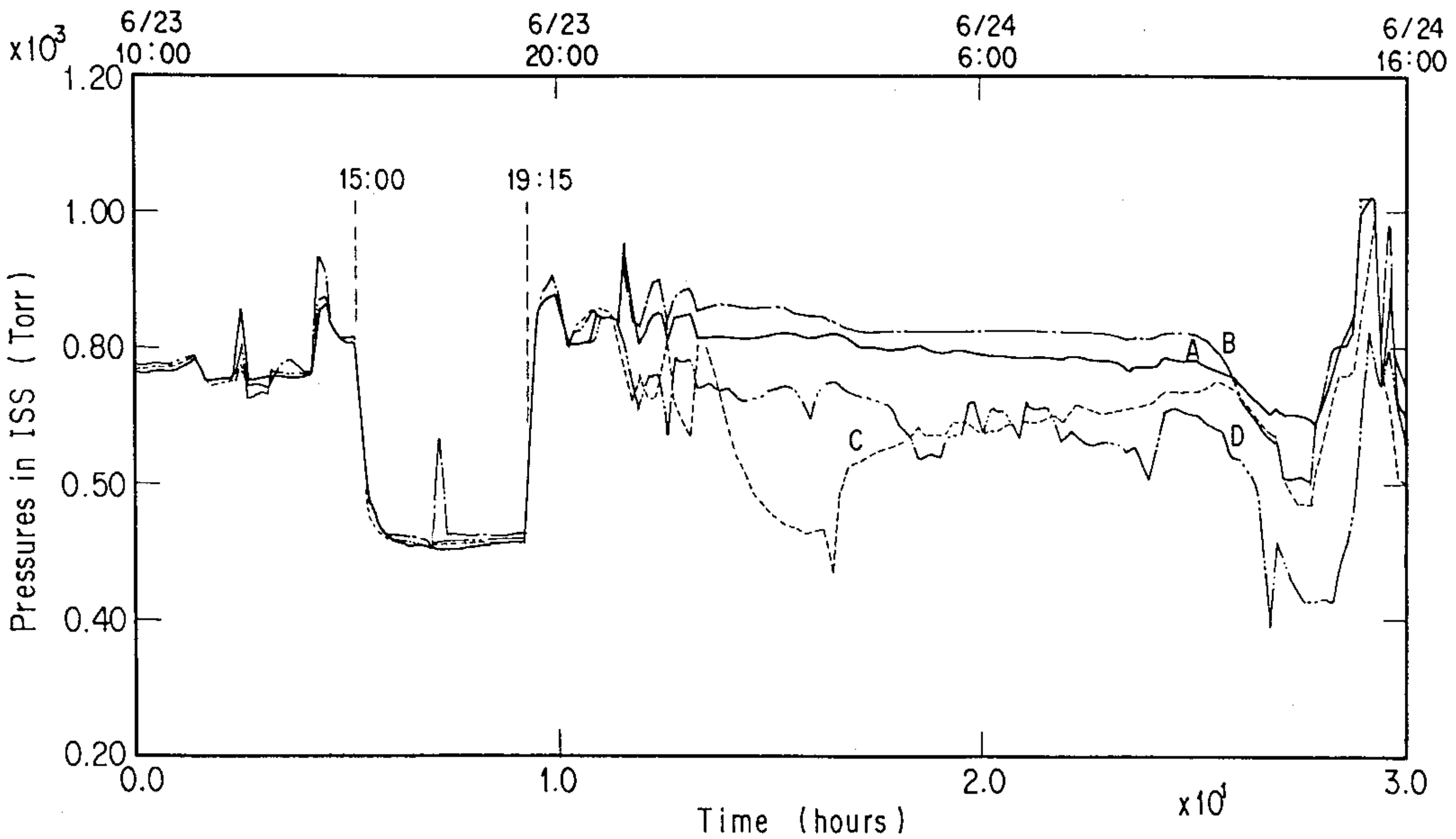


Fig. 3.15 Reboiler heater output of the ISS four columns



A —— ISS-P-CLIA : Pressure in column I
B —·— ISS-P-CLHA : Pressure in column H
C ---- ISS-P-CLDA : Pressure in column D
D —··— ISS-P-CLTA : Pressure in column T

BEGIN : 06/23/87 10:00:15
END : 06/24/87 15:58:31

Fig. 3.16 Pressure variations of the ISS four columns

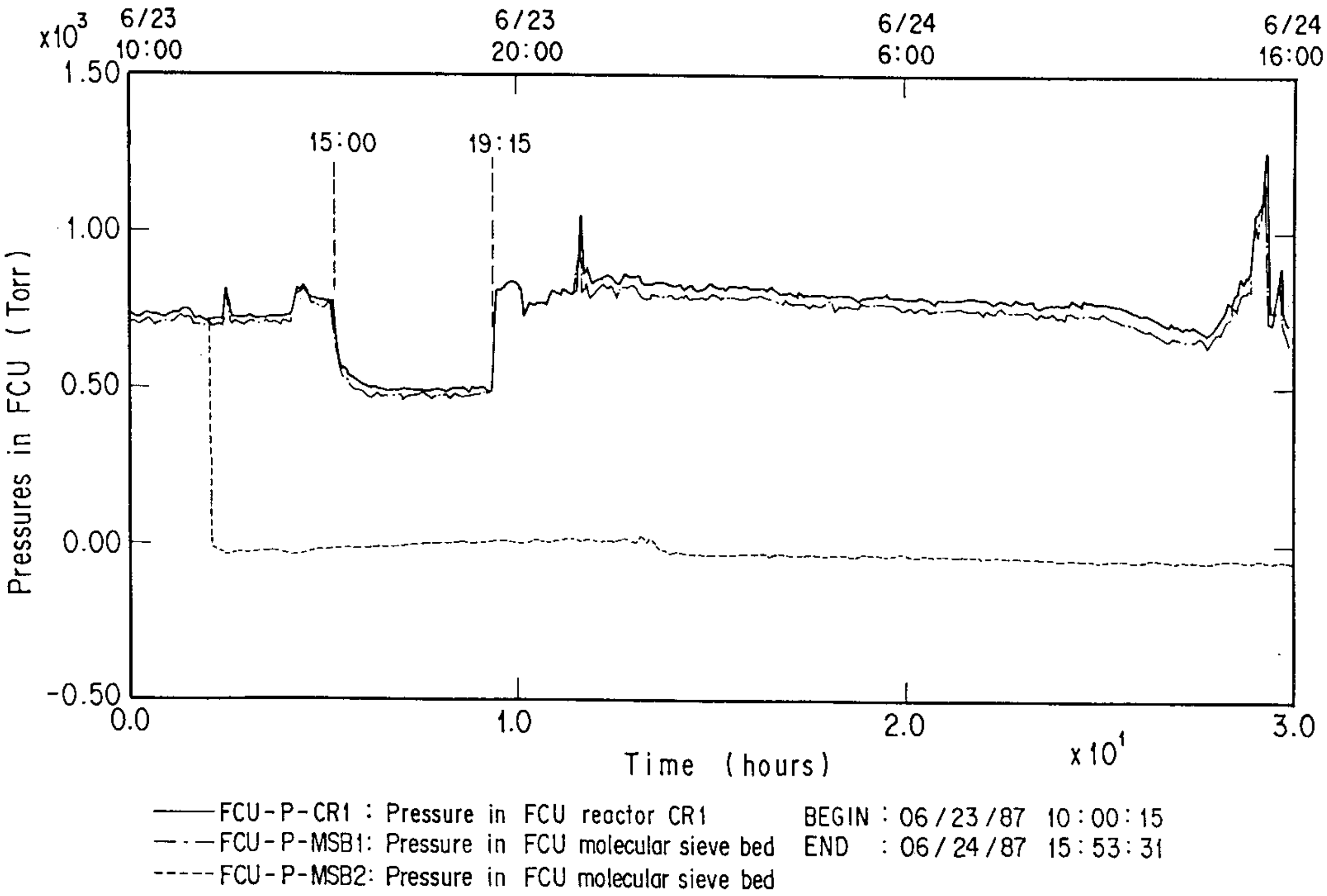


Fig. 3.17 Pressure variations in the PCU catalytic reactor(CR1) and molecular sieve beds(MSB1,2)

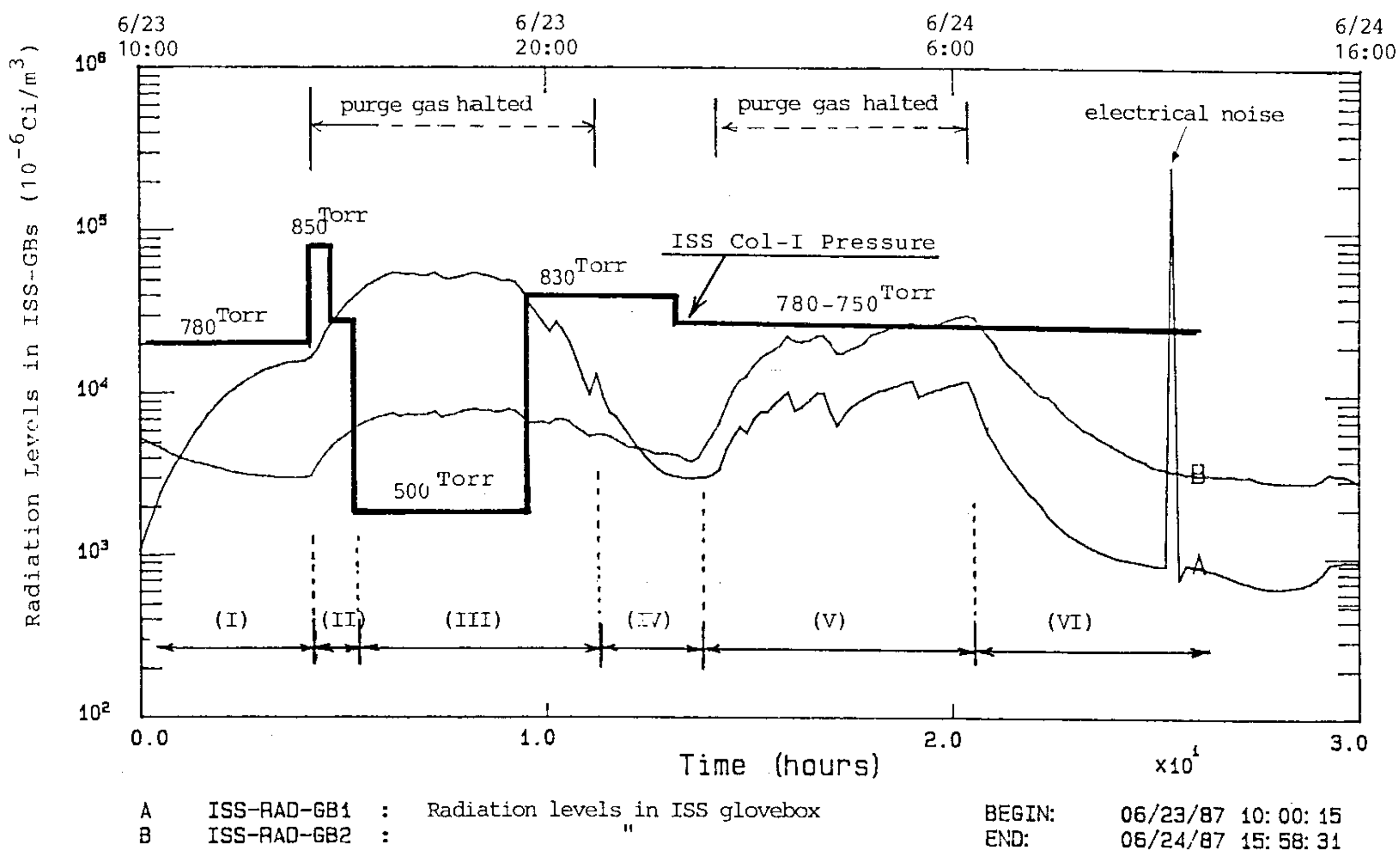


Fig. 3.18 Relationship between radiation levels in the ISS gloveboxes(GB1,2) and ISS process pressures in column I

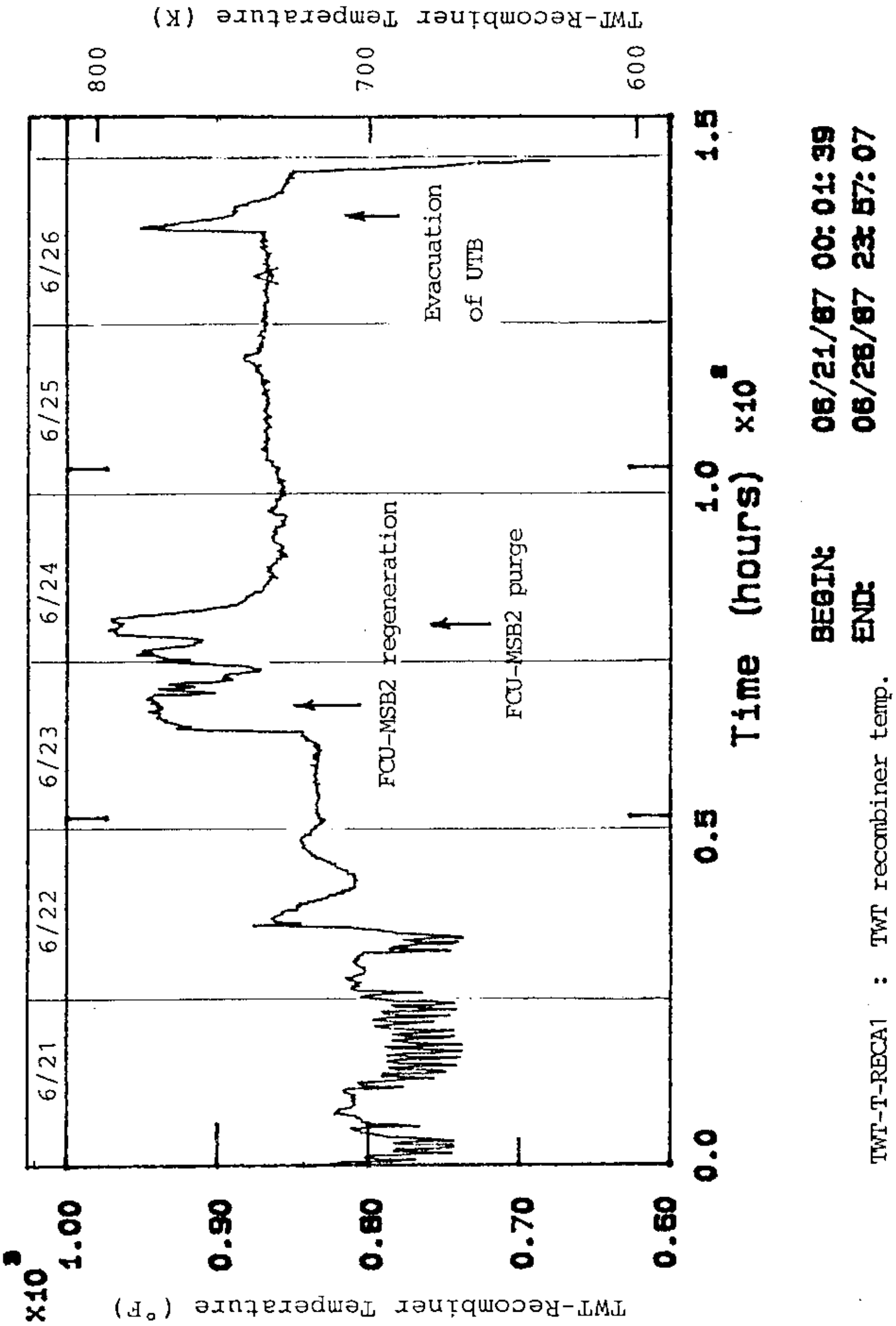
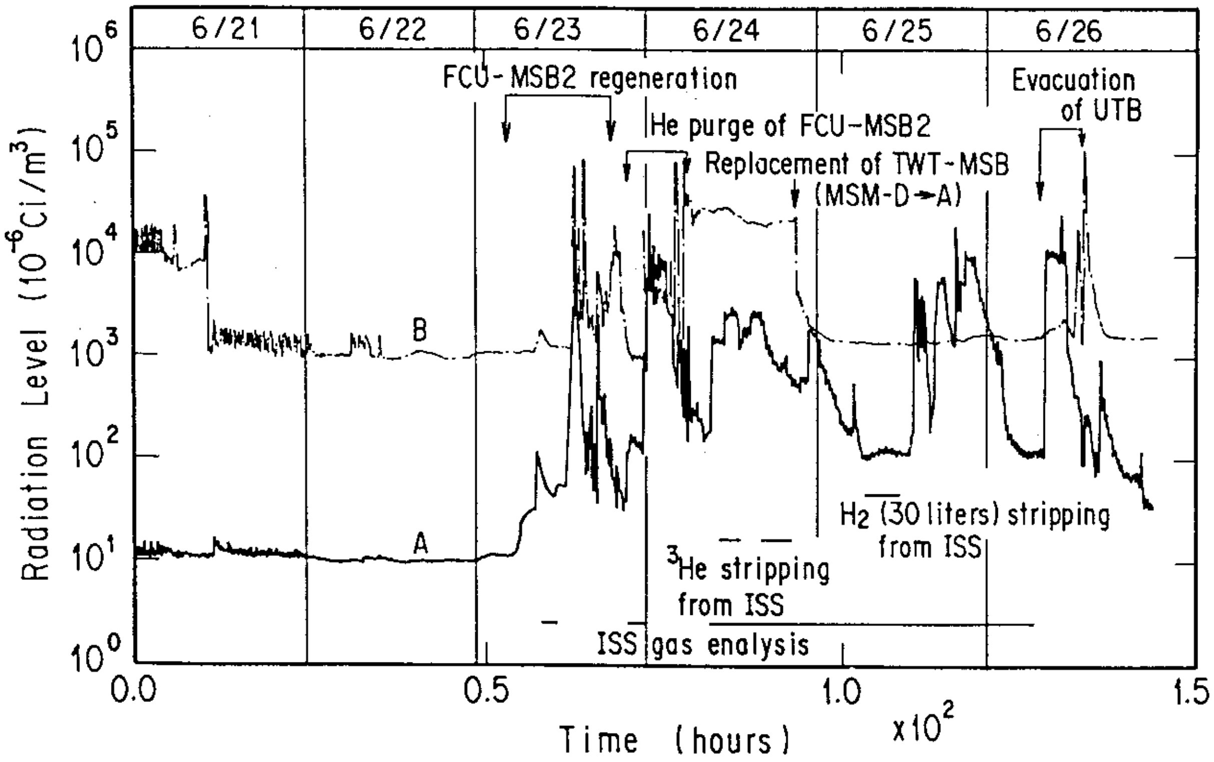


Fig. 3.19 Operating temperature of the TWT recombiner



A ——— TWT-RAD-LPR
B —·— TWT-RAD-RECYCLE

BEGINE : 06/21/87 00:01:39
END : 06/26/87 23:57:07

TWT-RAD-LPR : Radiation levels in TWT inlet receiver
TWT-RAD-RECYCLE : Radiation levels in TWT outlet

Fig. 3.20 Radiation levels in the TWT low pressure receiver(RAD-LPR) and outlet of the TWT dryers(RAD-RECYCLE)

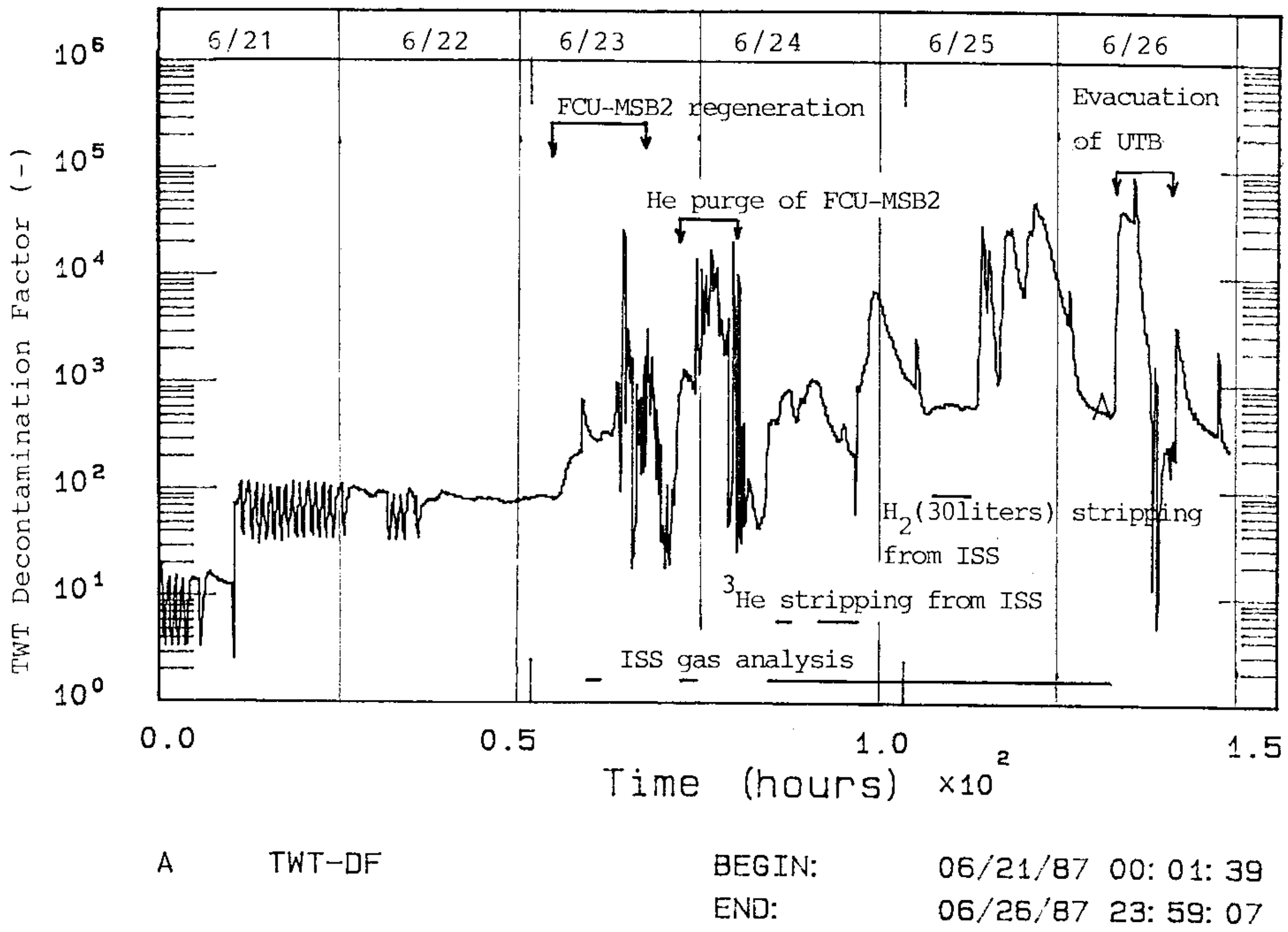


Fig. 3.21 Variations of tritium decontamination factor in the TWT

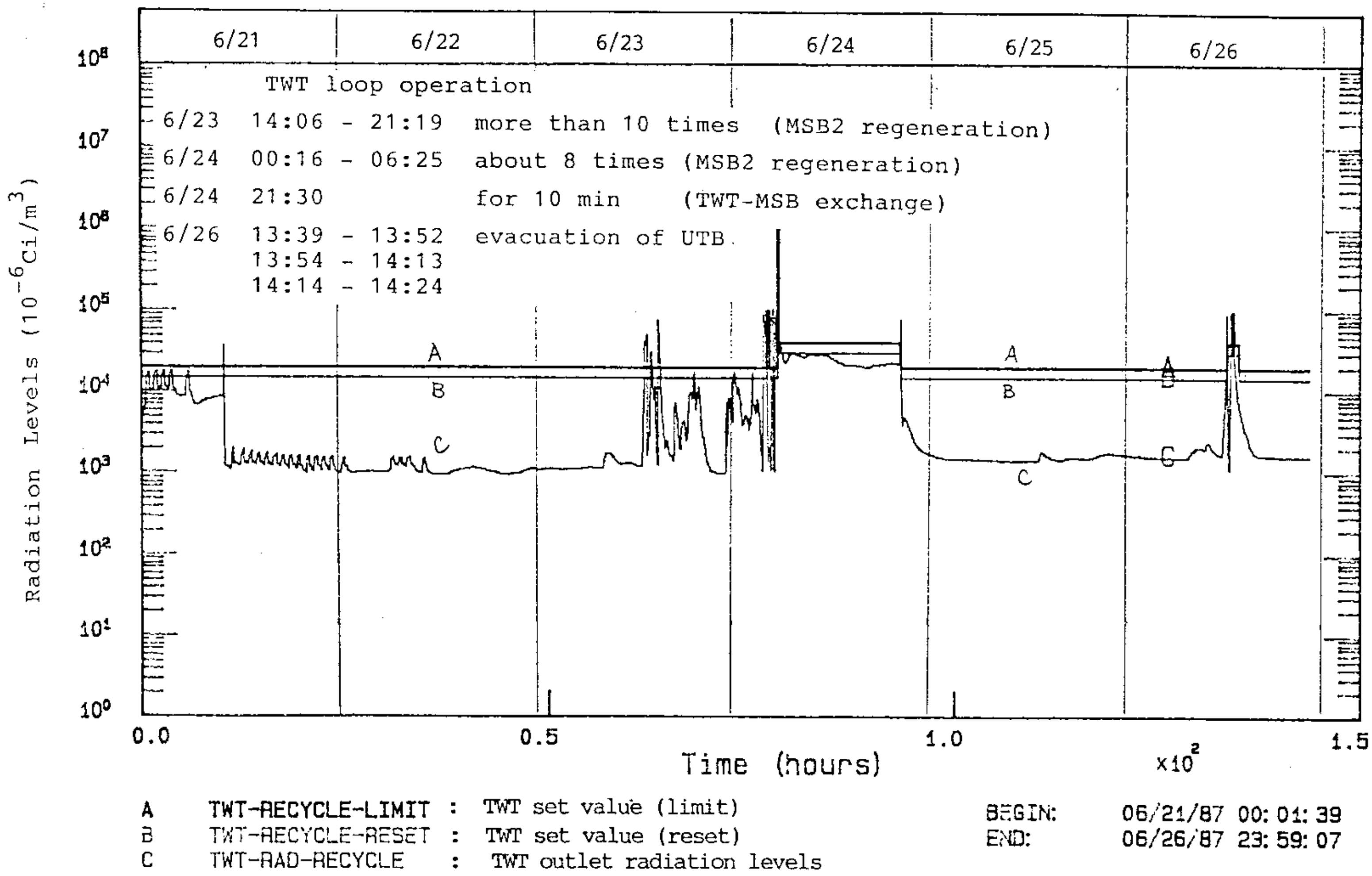


Fig. 3.22 Status of the TWT operation and the radiation levels

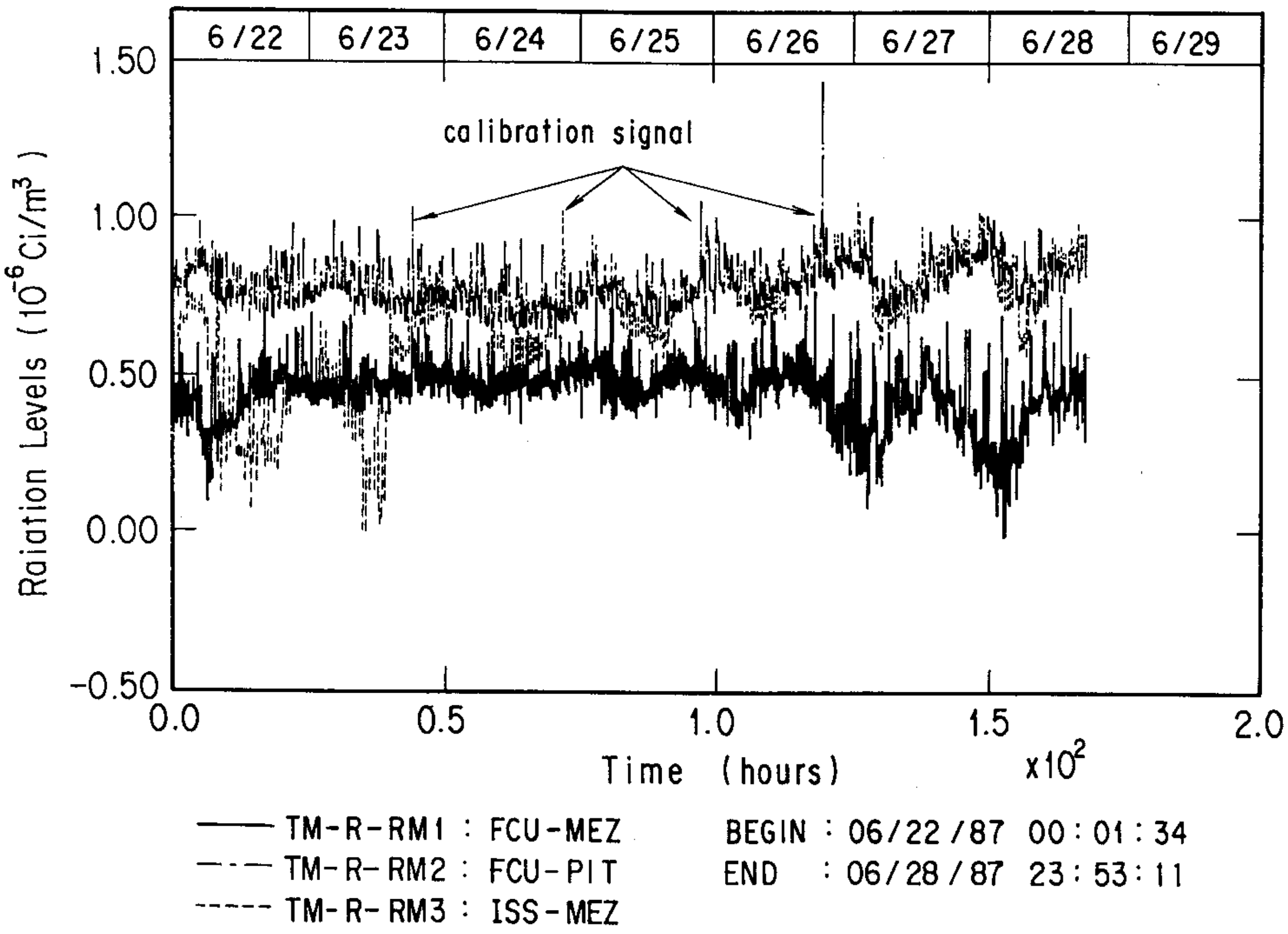


Fig. 3.23 Radiation levels at the key locations of the TSTA experimental room

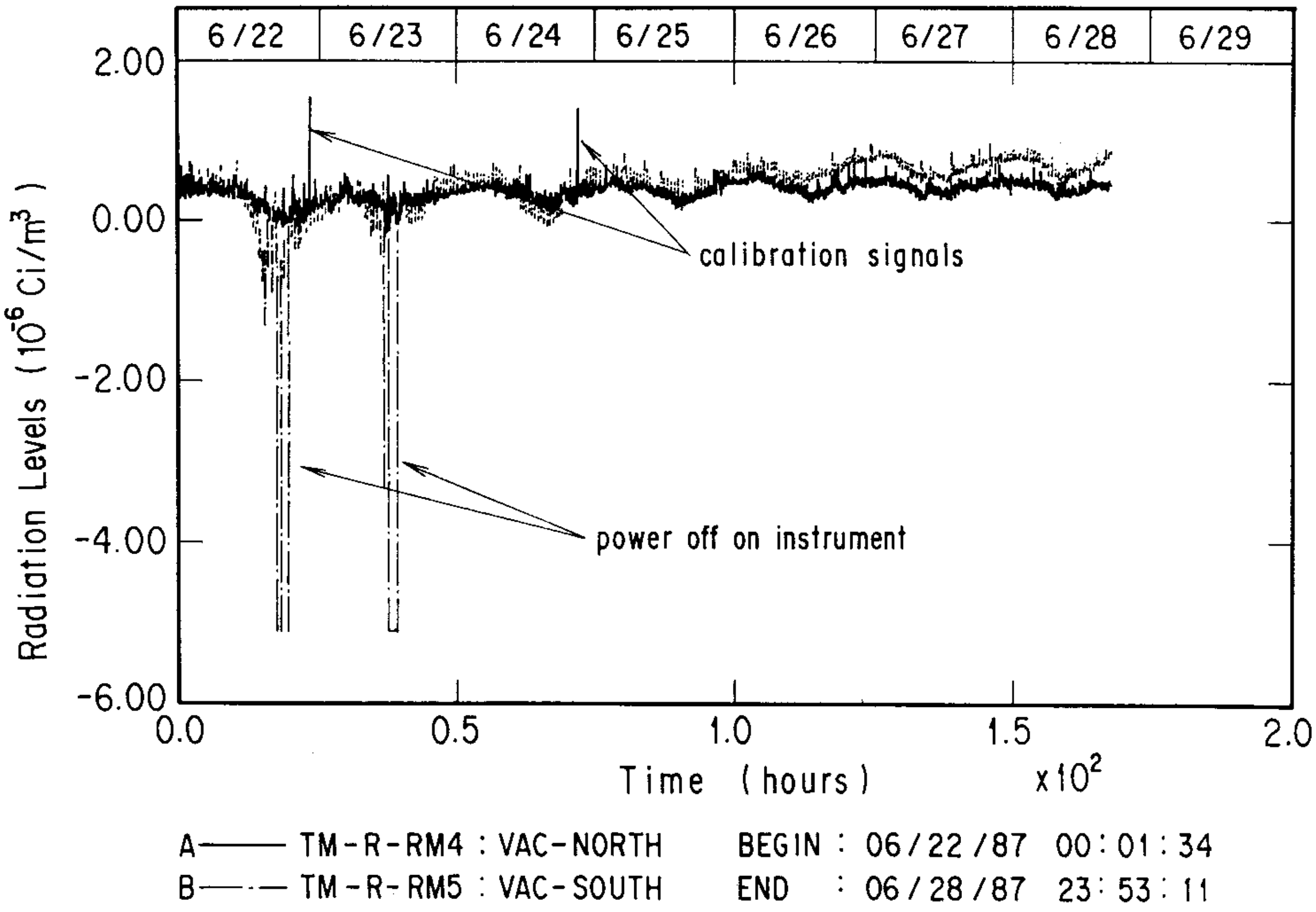


Fig. 3.24 Radiation levels at the key locations of the TSTA experimental room

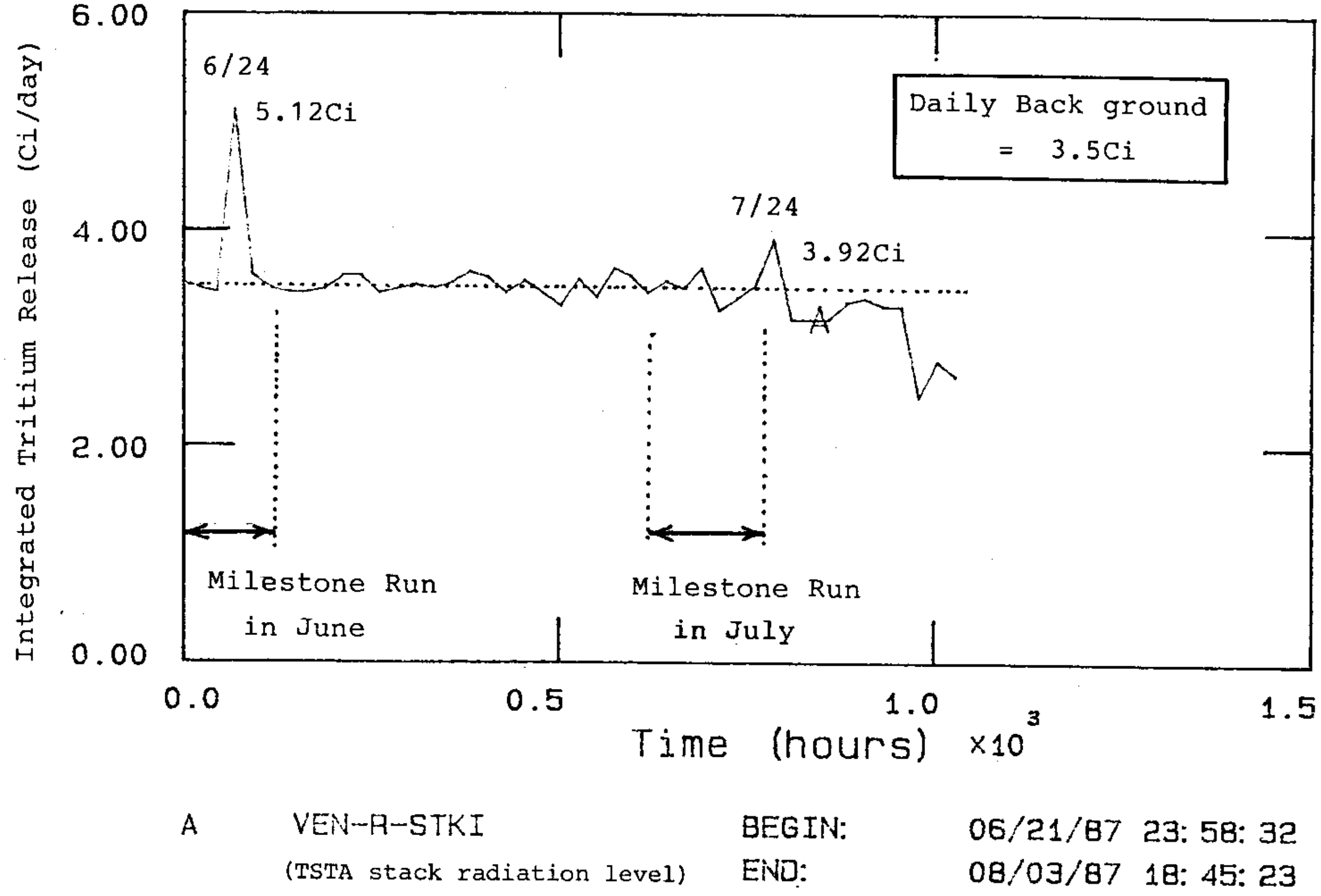


Fig. 3.25 Variations of the TSTA daily integrated stack radiation levels

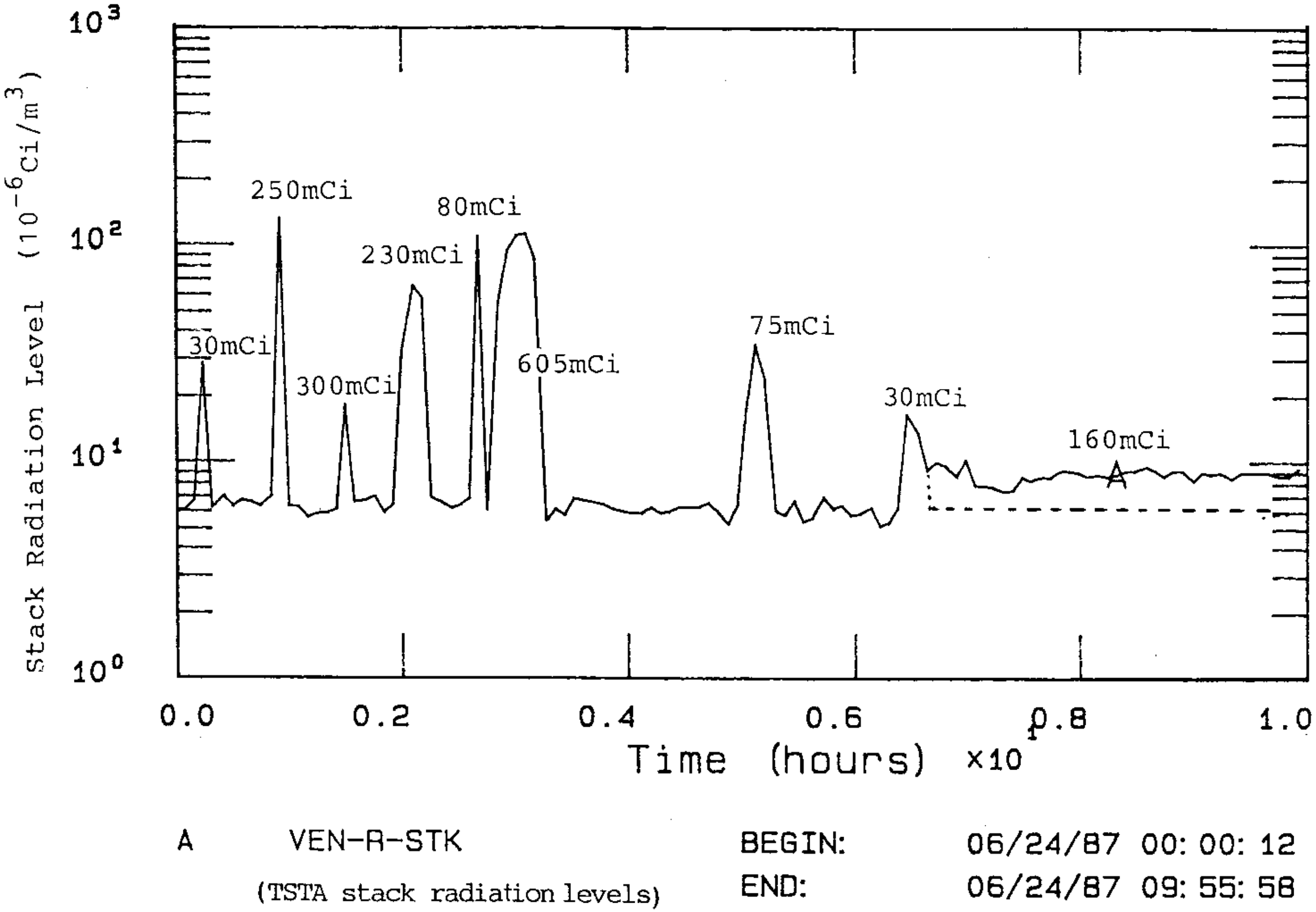
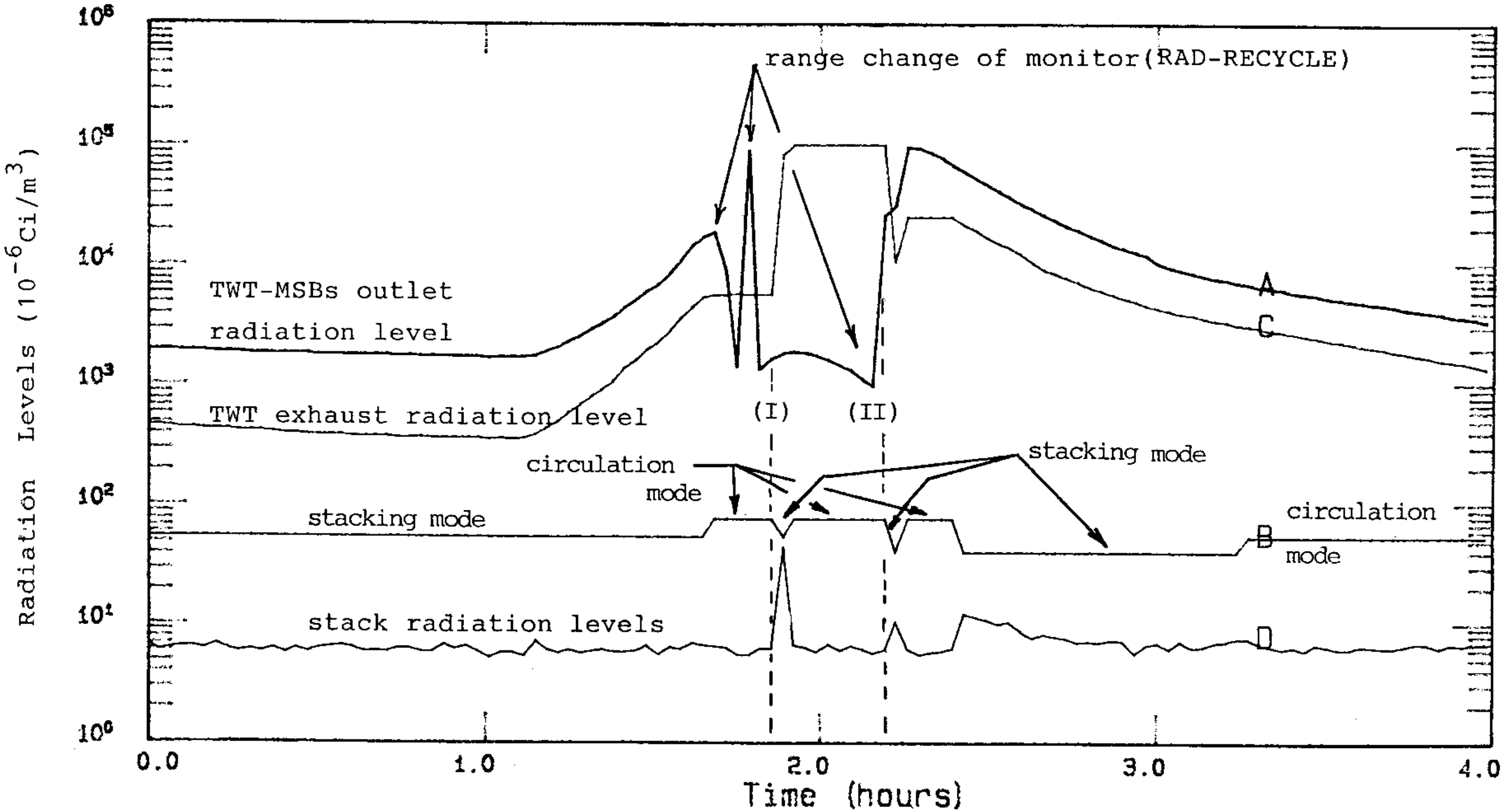


Fig. 3.26 Radiation levels on the TSTA stack monitor during FCU molecular sieve(MSB2) regeneration



A	TWT-RAD-RECYCLE	: Radiation levels in TWT outlet
B	TWT-STATUS	: TWT operating mode
C	TWT-RAD-RMEX	: Radiation levels in TWT outlet
D	VEN-R-STK	: TSTA stack radiation levels

BEGIN: 06/26/87 12: 00: 30
END: 06/26/87 15: 59: 21

Fig. 3.27 Relationship between radiation levels of the TWT exhaust stream and the TWT operation mode

4. SUMMARY OF ISS EMERGENCY SHUTDOWN

4.1 GENERAL PROGRESS OF THE EMERGENCY

This milestone run was unavoidably halted at around 10:40 of June 26 because of failure of the helium refrigerator(break of an expansion engine shaft) followed by loss of refrigerant for the ISS.

The log on the ISS and other related process systems are shown in Tables 4.1 and 4.2, and Figure 4.1, respectively.

The major procedures done by manual and computer control at the emergency situation were:

(i) Efforts to maintain helium refrigeration power.
(ii) Automatical scram of gas circulation (stopped TP3) by MDAC control program(scram macro).
(iii) Emergency dumping of process gas in the ISS to all UBs by manual scram program.
(iv) Isolation of ISS from other process system except UTB.
(iv) Stop FCU impurity injection experiment. The experiment was resumed without ISS for a short period after completion of the emergency shutdown of the ISS.
(v) Check out of radiation levels of the glovboxes, room area monitors and stack monitor.
(vi) Maintain functions of safety subsystems such as MDAC, TWT and necessary utilities (liquid nitrogen for FCU experiment).

Figures 4.2, 4.3 and 4.4 show refrigerant temperatures at the inlet and outlet of the ISS, and pressures and flow rates of hydrogen isotope streams at TP3. Figures 4.3 and 4.4 indicate that the process loop operation was scrammed at 10:38. This scram was actuated by detecting high discharge pressure(higher than 2000 Torr) at TP3. The flow variations(Figure 4.4) of the TP3-F-DIS(column I inlet stream), and the TP3-F-D_2(column I bottom stream) are considered to reflect the function of the column D pressure controller as well as the column I liquid level controller. The flow rates at the inlet and top of the column D are controlled by both controllers.

4.2 ISS CHARACTERISTICS

The ISS was under loop operation, in which the major process parameters such as pressures, temperatures, flow rates and liquid levels of each column were controlled at their desirable conditions. This affected column characteristics during the ISS shutdown.

Figure 4.5 shows pressure variations of the four columns at several stages in the ISS emergency situation. The time and operation done at each stage are:

(1) 10:00 ---- Temperature increase of He refrigerant began.

(2) 10:38 ---- Process gas circulation was stopped by automatic scram on the TP3.
(3) 10:41 ---- H-D-T gas in the ISS was manually dumped to UTB.
(4) 11:02 ---- ISS interconnecting flow control valves were opened to equalize the pressure of all columns.

The pressures on columns I and H continued to increase after the stage(3) operation (hydrogen isotopes mixture in the ISS was dumped to the five uranium beds UBs), and reached approximately 2.8atm. On the contrary the pressure of column D connected to the two uranium beds(UB3 and 4) rapidly decreased to approximately 200 Torr, and the column T pressure shows complex behavior. By the stage(4) operation, pressures of all columns were equalized and high pressures of the column I and H dropped to approximately 1.3atm.

Figures 4.6 and 4.7 show temperatures at the condensers and the packed sections of four columns, respectively. Figure 4.8 shows the liquid levels in the reboilers of columns. In Figure 4.6, the condenser temperatures of columns I and H increase monotonically, and reached maximum range(30K) of the instruments within 15min after the beginning of temperature increase on He refrigerant, but that tendency in column D is not so simple. The temperature decrease observed on the column D (Figure 4.6) was attributed to the rapid pressure decrease in the column D(Figure 4.5). The temperature change in the packed section of the column D indicates that most of the liquid in this section vaporized at around 11:02.

From Figure 4.8, we can estimate the time of disappearance of reboiler liquids in each column. The times are 10:40 - 10:50 for the column D and I, and 11:00 - 11:10 for the column H and T. The equalization of column pressures(Figure 4.5) would enhance vaporization of liquids in the column H and T. Some irregularities due to electrical or mechanical troubles on the instruments of the columns D and I occurred at 11:04.

The amount of hydrogen isotopes in the ISS was estimated as fololws:

Col-I	;	18.5 g-mol
Col-H	;	9.2 g-mol
Col-D	;	30.5 g-mol
Col-T	;	11.4 g-mol

4.3 UTB AND TWT CHARACTERISTICS

During the rapid decrease of the cryogenic helium refrigeration power for the H-D-T distillation system(ISS), we could quickly shutdown the ISS, which is one of the TSTA emergency modes, with use of the UTB.

Figure 4.9 shows the UTB characteristics during the emergency recovery of H-D-T mixture in the ISS. Marked temperature increases due to the exothermic reaction (heat of formation of uranium hydrides) were observed on UB1, 3, 4 and 5. The differences in the rate of increase and the maximum temperature would depend on the rate and amount of hydrogen absorption on each bed. Isotope effects on these parameters can not be found because isotopic mixing among the columns occurred during the ISS emergency situation. The temperature on UB2 indicates this bed did not work effectively. It was the expected phenomenon at UB2, because it is connected to column H containing ^{3}He separated from D-T species. The inactive gas over the uranium bed is likely to prohibit hydrogen absorption under non-flow stream conditions. This phenomenon, known as the blanketing effect, is considered to be caused by a boundary layer of inactive gases formed in the vicinity of the uranium powder surface.

Figures 4.10 shows the ISS pressure and the UB2 temperature after removal of residual gas by evacuating the UB2. It is apparent that this treatment reduced the blanketing effect and enhanced the hydrogen absorption on the UB2.

Figure 4.11 shows the inlet(low pressure receiver) and outlet(outlet of molecular sieve dryer) radiation levels in the TWT. The outlet radiation level increased to approximately 15mCi/m^3 by the first evacuation of UB2 done at around 13:00, but no increase occurred during the second evacuation. The residual gas in UB2 would include methane and nitrogen regenerated from FCU-MSB1. Both species were supplied to MSB1 during the impurity injection experiment. A major part of the methane was removed from UB2 during the first evacuation, raising the outlet radiation level because of the relatively low conversion rate of methane in the TWT recombiner(the operating temperature was less than 510 C). As shown in this figure, the TWT inlet radiation level increased due to ISS gas analysis, but change in the outlet level is negligibly small. This fact indicates that the exhaust gas routed through the House Vac from the ISS-GAN was not accompanied by tritiated hydrocarbons, which will increase the radiation level in the TWT outlet stream as can be seen in the of FCU-MSB regeneration(June 23). In the case of pumping the ISS-GAN exhaust gas, contamination with tritiated hydrocarbon in the House Vac would be considered to be very small because of the very small throughput of ISS-GAN exhaust gas.

4.4 RADIATION LEVELS IN GLOVEBOXES AND ROOM

Figures 4.12 show radiation levels of the process gloveboxes at the time period around the ISS emergency situation . It is apparent that offnormal tritium releases occurred in the two gloveboxes(ISS-GB1 and FCU-GB1,) but their radiation levels varied with the operating mode of the TWT as well as process gas pressures in the ISS and the FCU. For example, the changes of radiation levels in stages(2)-(3) and (3)-(4) correspond to glovebox purge operation. In the former stage, glovebox purge gas is halted to meet the requirement of TWT recycle operation, and in the latter stage glovebox is purged with N_2 gas(1.7m^3/hr). The purge gas is routed to the TWT while it is operated in the stacking mode.

The radiation level in ISS-GB2 observed after stage(2) operation reveals that the offnormal tritium leak at the ISS gas analysis system(ISS-GAN) stopped after the termination of the gas analysis. The other glovebox radiation levels were kept as low as of 1mCi/m^3(normal control level).

The offnormal release in all gloveboxes that occurred on June 27 is discussed later.

Figures 4.13 and 4.14 show room radiation levels measured at six strategic places of the TSTA main cell for 24hrs on June 26. No indication of offnormal release of tritium into the room is observed in the entire time period.

Table 4.1 Log on ISS and He-refrigerator (Local)

Time	Observations and Procedures	Notes
~10:30	-Pressures on ISS start increasing	
	-Supply temperature on He-refrigerator starts increasing	Set value=18.3K
	-Engine speed on He-ref. starts decreasing	Tried to increase engine speed
10:35	-He temperature = 22.4K (still increasing)	
	-Engine speed = ~70 rpm (set value = 110 rpm)	
10:37	-Engine speed still decreasing	
	-Pressures of Refrigerator	He ref. operation;
	PI37(engine outlet)=175psi	-Comp.#1 starts when
	PI39(He supply) = 75psi	PI37 drops to 50psi
	PI33(comp. outlet) =225psi	-Comp.#2 starts when
	PI38(comp. inlet) = 6psi	PI33 drops to 180psi
10:40	-Pressures in ISS	Pressures at 8:25
	Column I = ~36psi(~1900Torr)	-Col. I=1063Torr
	Column H = ~37psi(~2000Torr)	-Col. H=1063Torr
	Column D = ~14psi(~ 900Torr)	-Col. D= 630Torr
	Column T = ~35psi(~1900Torr)	-Col. T= 946Torr
	-ISS shutdown procedures were in the control room(MDAC) and ISS local panel	
	10:40:54 Open ISS-EVIA	By opening valves on each column , process gas was recovered by uranium beds(UTBs)
	10:40:55 Open ISS-EVHA	
	10:41:06 Open ISS-EVDA	
	10:41:12 Open ISS-EVTA	

Table 4.1 (continued)

Time	Observations and Procedures	Notes
10:45	-He refrigerator engine stopped	engine shaft broken
11:00	-Valves inter columns were closed	
11:24	-ISS was isolated from other process systems except UTBs	
12:41	-Valves on ISS and UTBs were operated (close/open) to evacuate residual gas	
13:27	in UTBs(reduction of blanketing effect)	

Situation of ISS heater controllers

Positions		10:00	11:00	14:00
He-refrigerant heater	for Col-I pressure control	0 W	0 W	0 W
"	of Col-I packed section	0	0	0
"	for Col-I liquid level control	42	42	0
reboiler heater	for Col-H pressure control	0	0	0
He-refrigerant heater	for Col-H liquid level control	15	15	0
"	for Col-D pressure control	7	7	0
reboiler heater	for Col-D liquid level control	11	11	0
He-refrigerant heater	for Col-T pressure control	4	4	0
"	of Col-T packed section	0	0	0
reboiler	for Col-T liquid level control	15	0	0

Table 4.2 Log on Other Systems (MDAC control)

Time	Observations and Procedures	Notes
10:38	ALARM on MDAC : TP3-MBPA stopped	High discharge pressure (exceeds 2000Torr)
10:39	Stop impurity injection to FCU by closing TP3-AV13 (manually on MDAC)	
10:40:01	ALARM on MDAC : TP1-MBPB stopped	High discharge pressure (exceeds 2000Torr)
10:40:09	TP-3 was scrammed by MDAC computer macro	
10:40:54	Shutdown ISS by unloading procedures on ISS-UTBs	
10:41:12		
10:45	He-refrigerator engine stopped by itself	
10:45:01	ALARM on MDAC : TP1-MBPB stopped	High discharge pressure
10:50:02	ALARM on MDAC : TP1-MBPB stopped	High discharge pressure

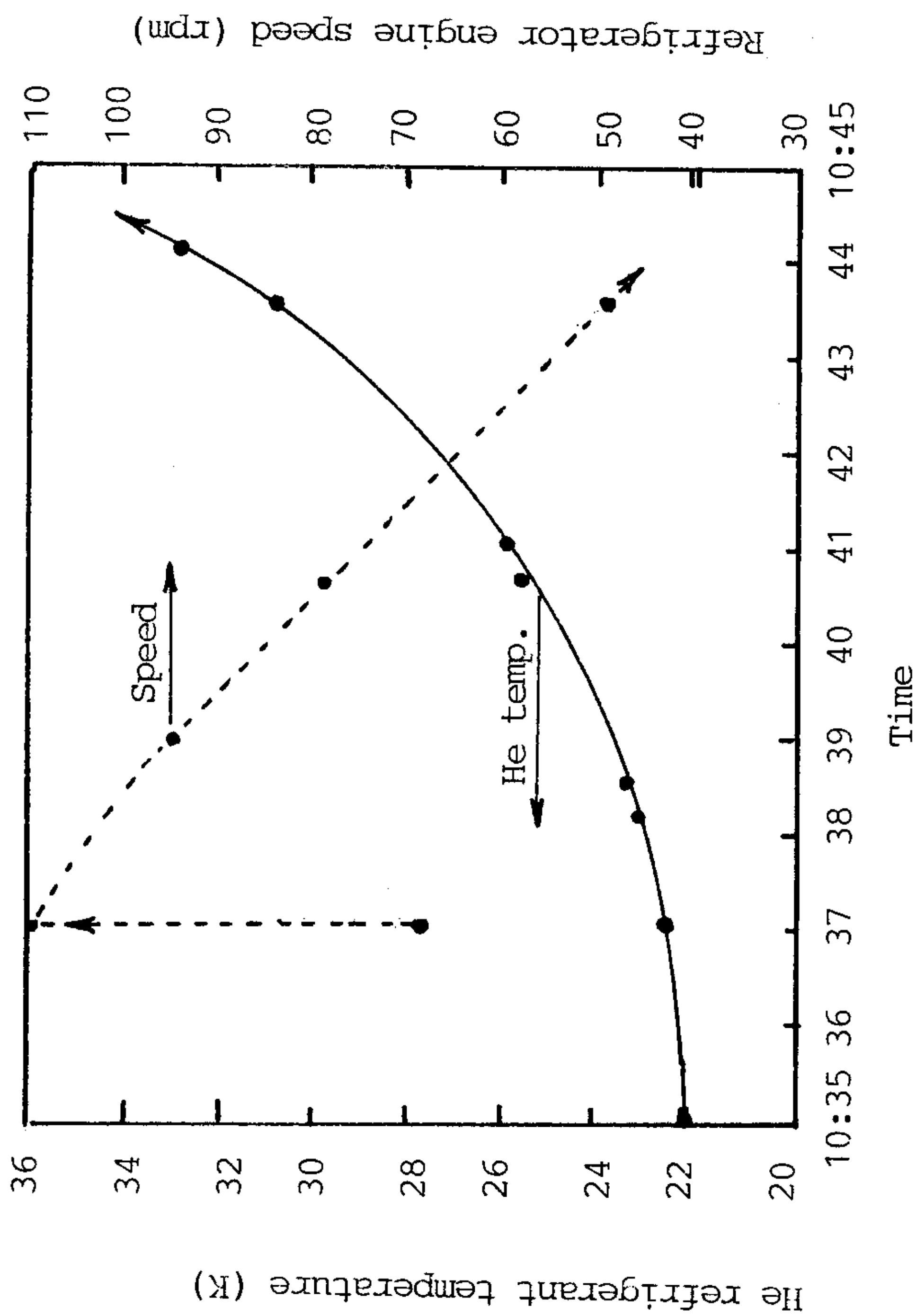


Fig. 4.1 Status of the He refrigerator (expansion engin speed and He temperature) at the ISS emergency situation

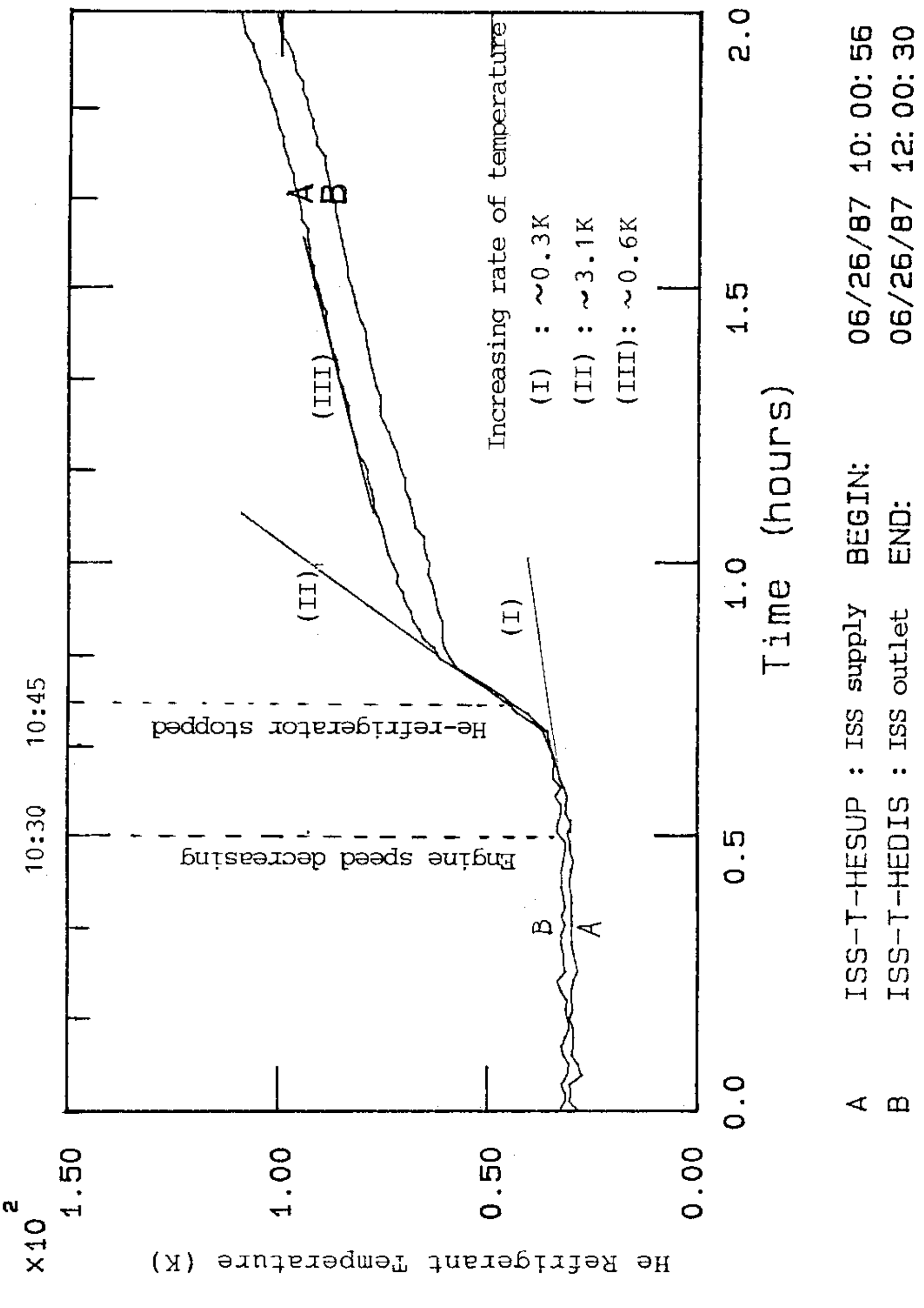


Fig. 4.2 He refrigerant temperatures at the ISS emergency situation

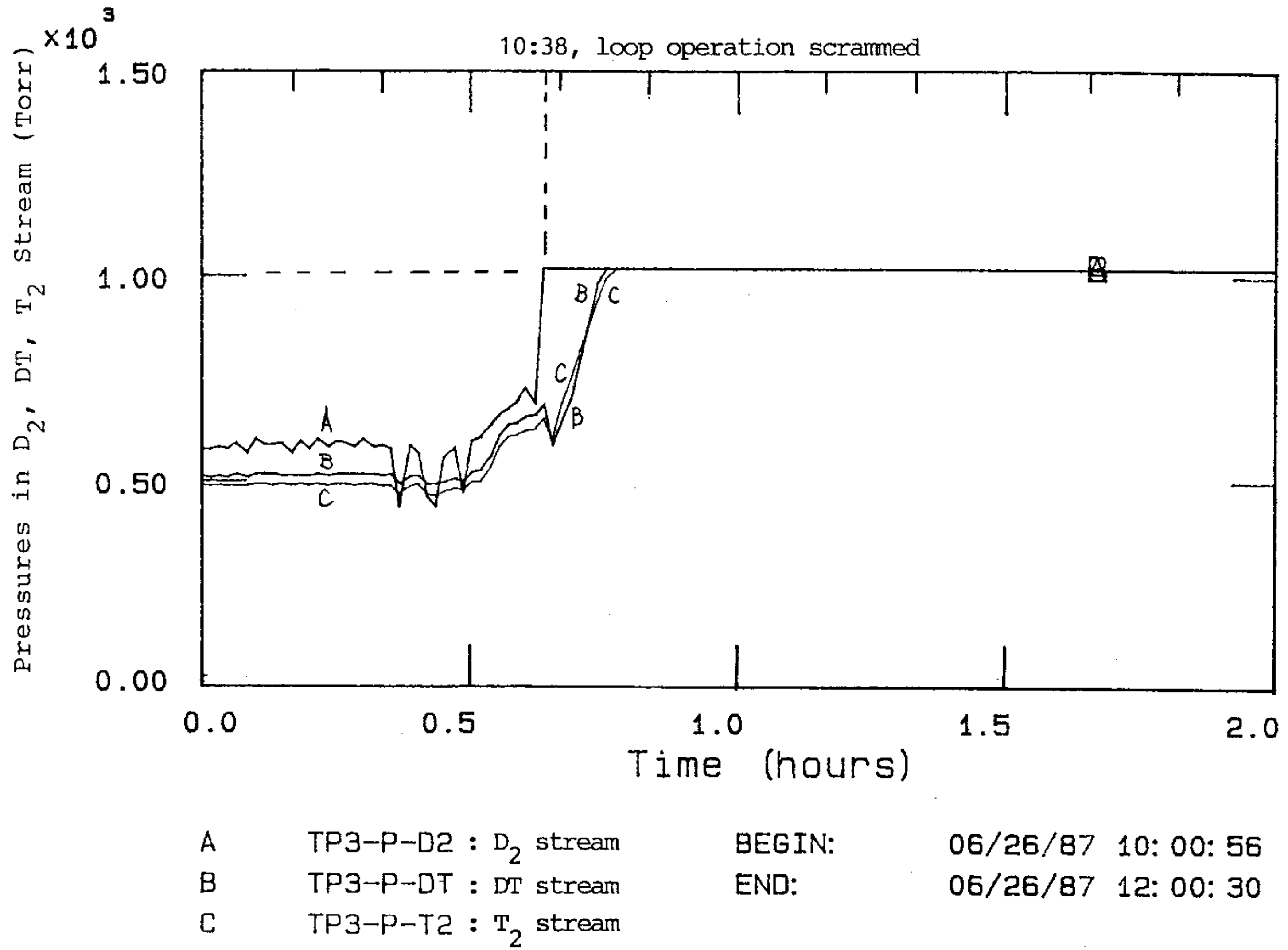


Fig. 4.3 Pressures of the D_2, DT and T_2 streams from the ISS at the ISS emergency situation

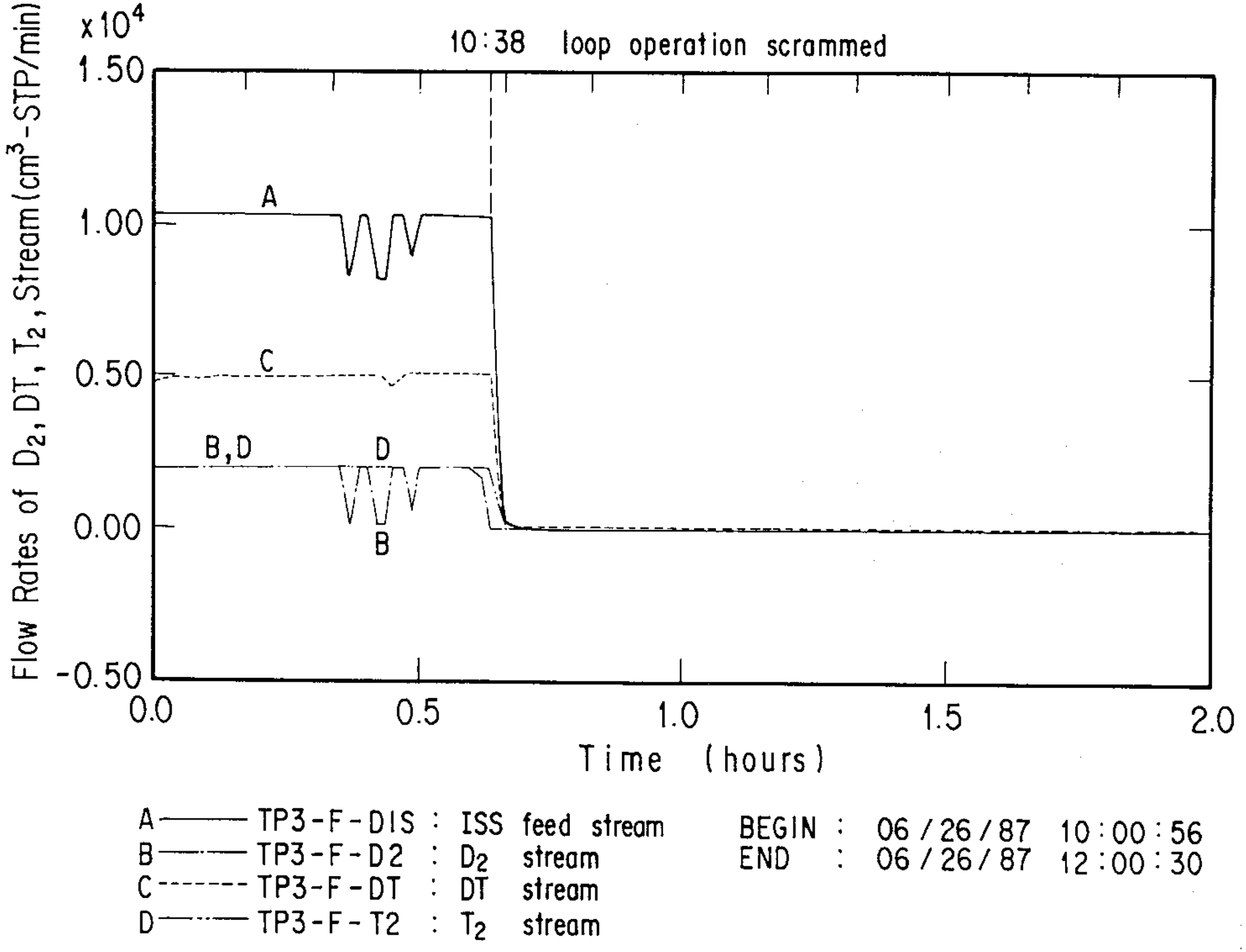


Fig. 4.4 Flow rates of the D_2, DT and T_2 streams from the ISS, and the TP3 discharge flow rate at the ISS emergency situation

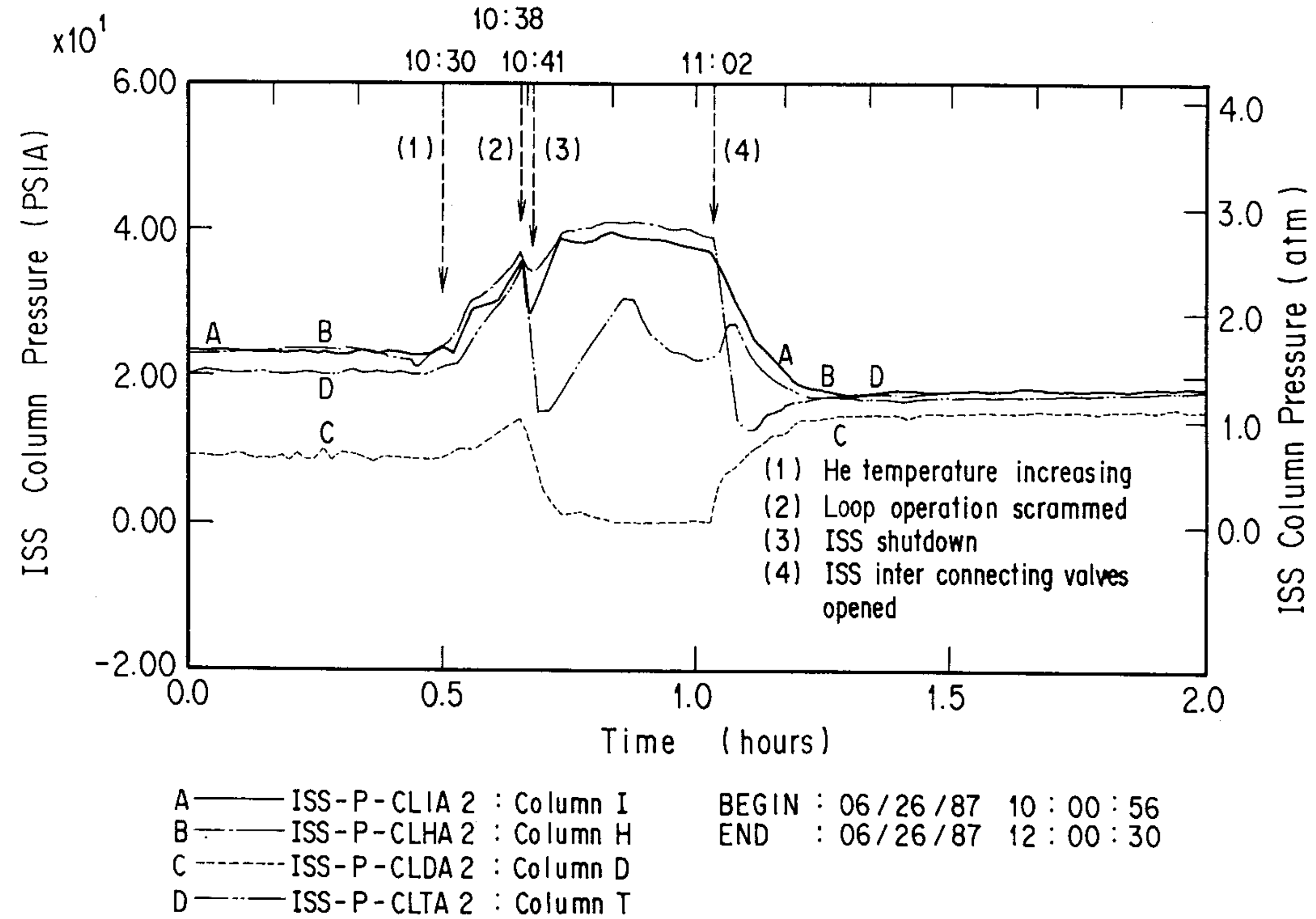


Fig. 4.5 Pressures of the ISS four columns at the ISS emergency situation

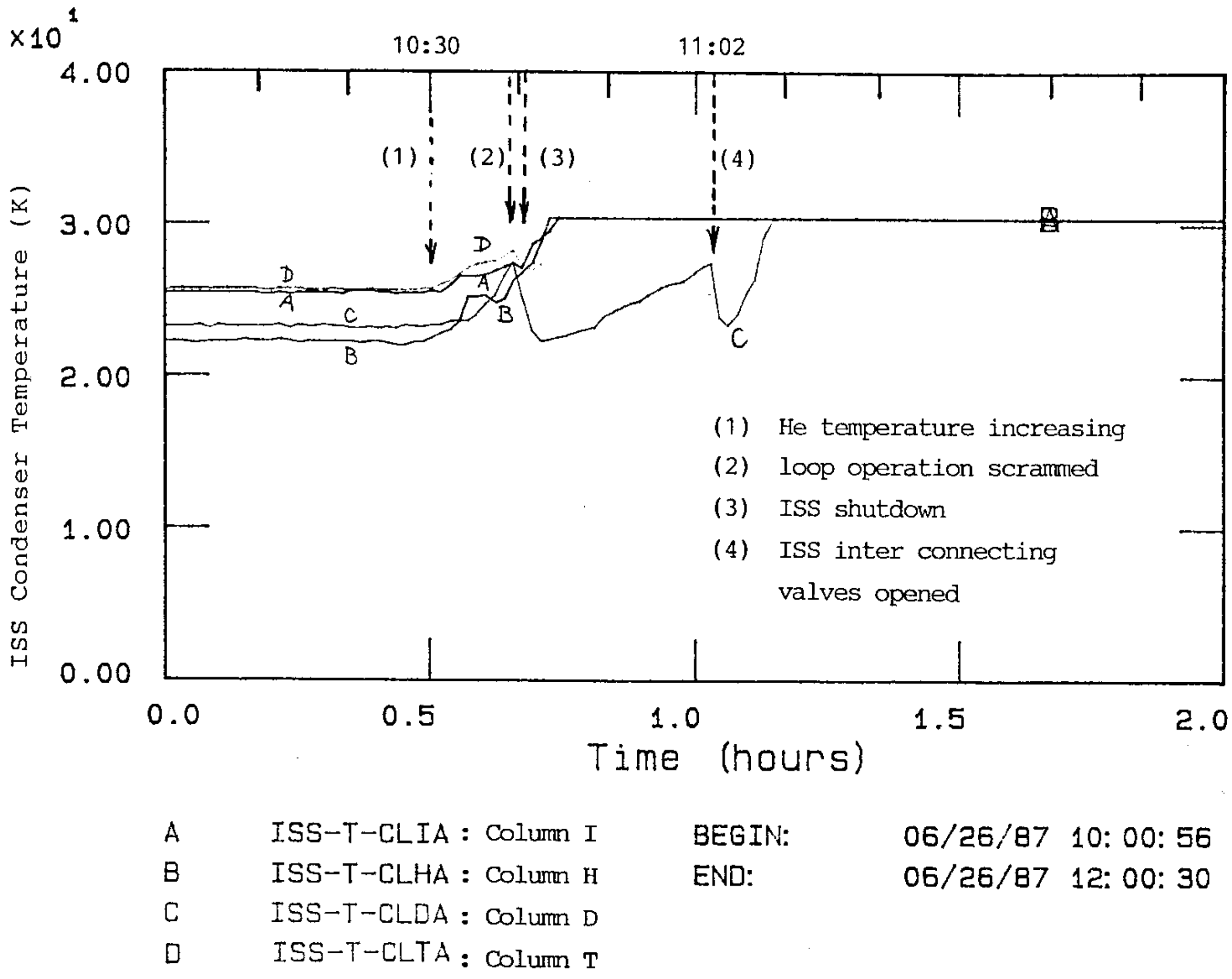


Fig. 4.6 Temperatures of the ISS column condensers at the ISS emergency situation

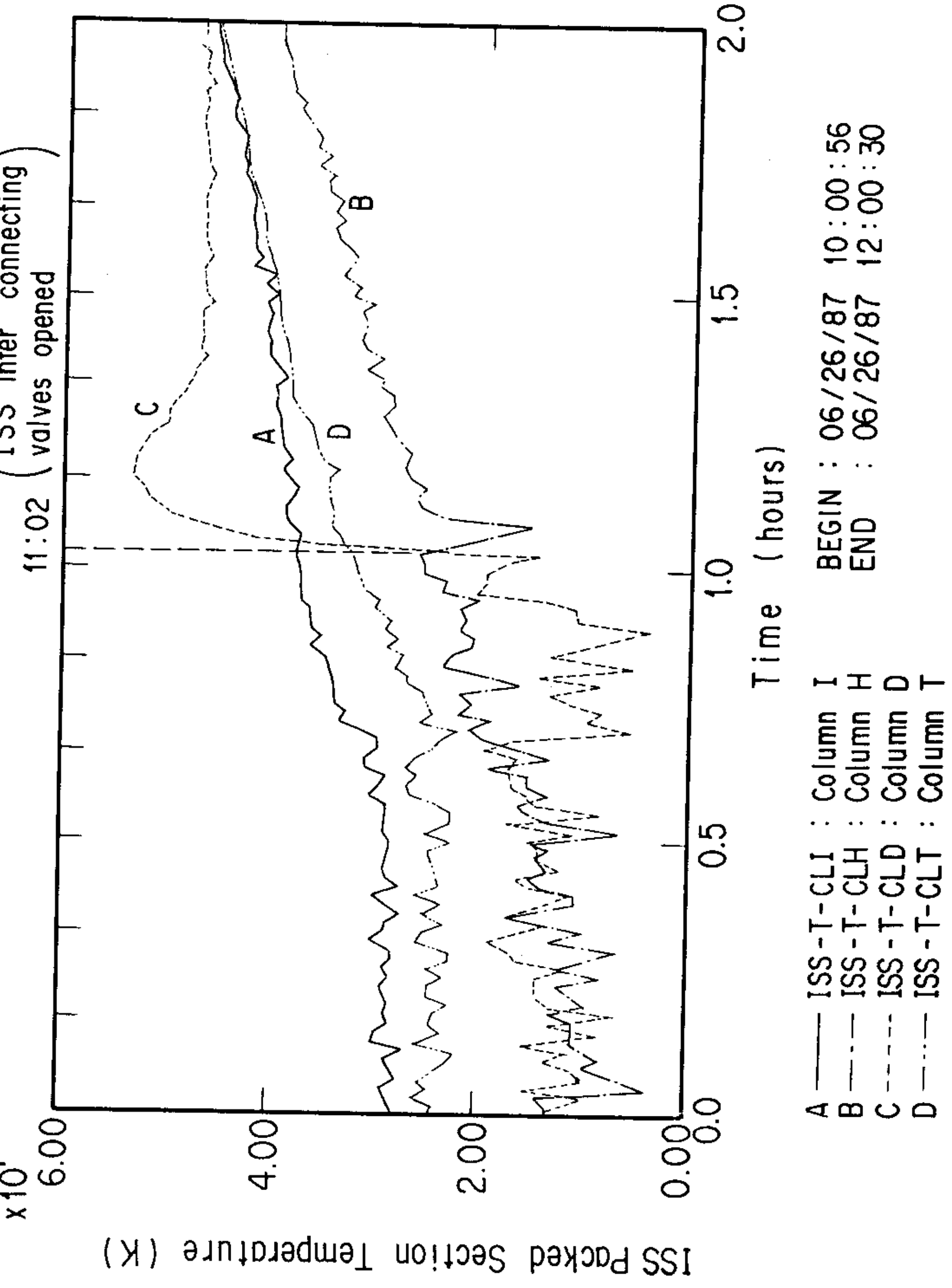


Fig. 4.7 Temperatures of the ISS column packed sections at the ISS emergency situation

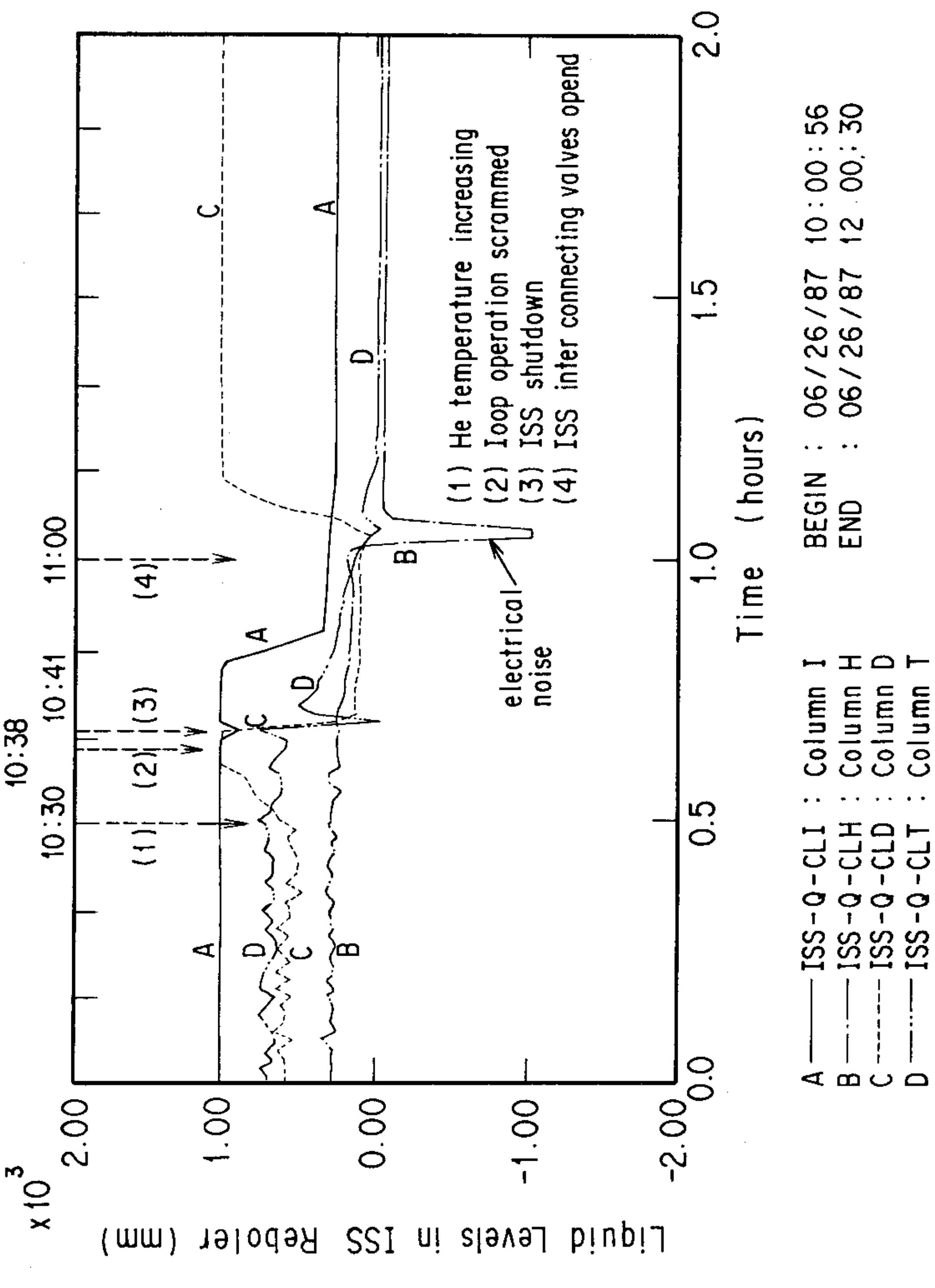


Fig. 4.8 Liquid levels of the ISS four columns at the ISS emergency situation

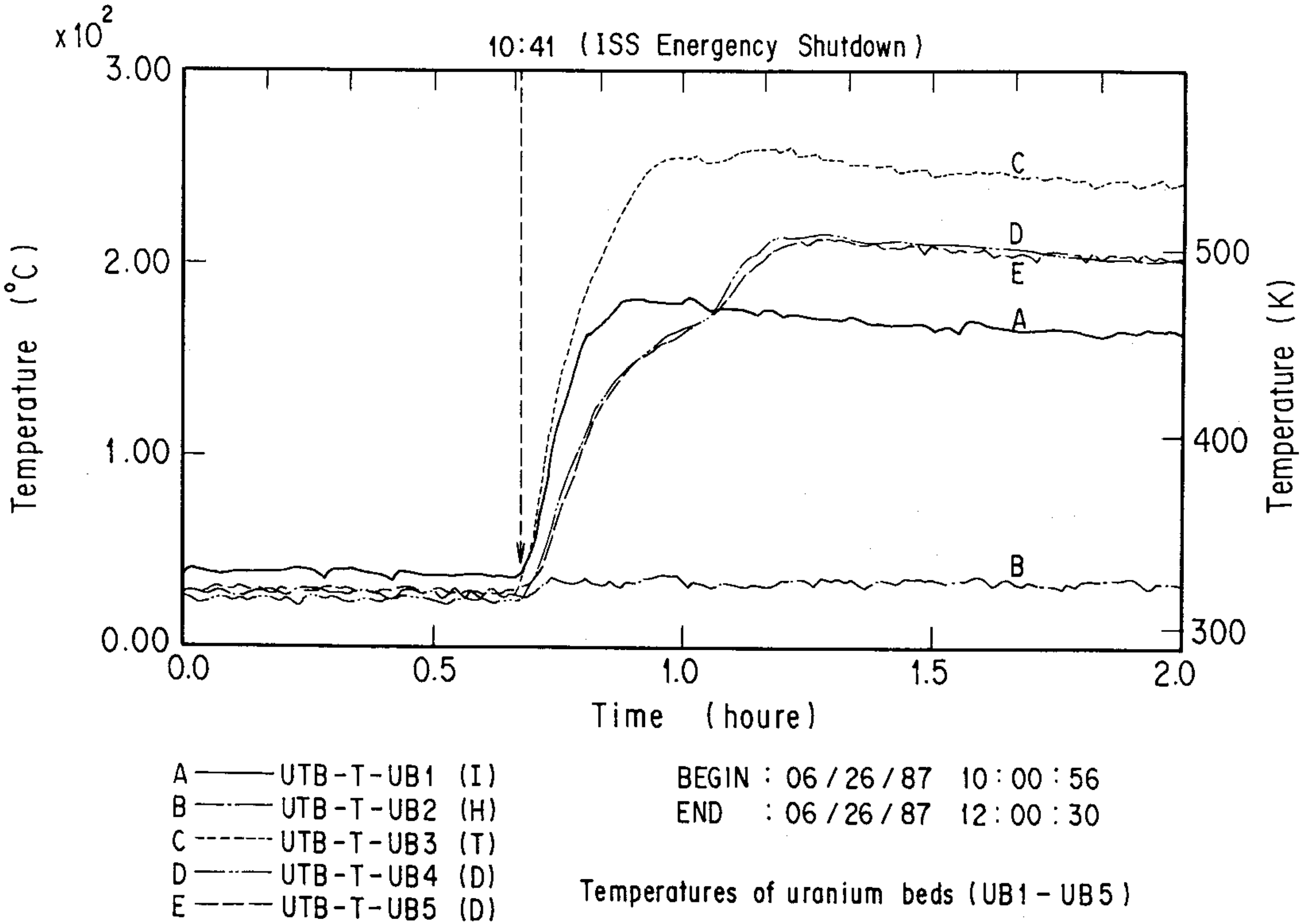


Fig. 4.9 Temperature variations of the UTB at the emergency scram of the ISS

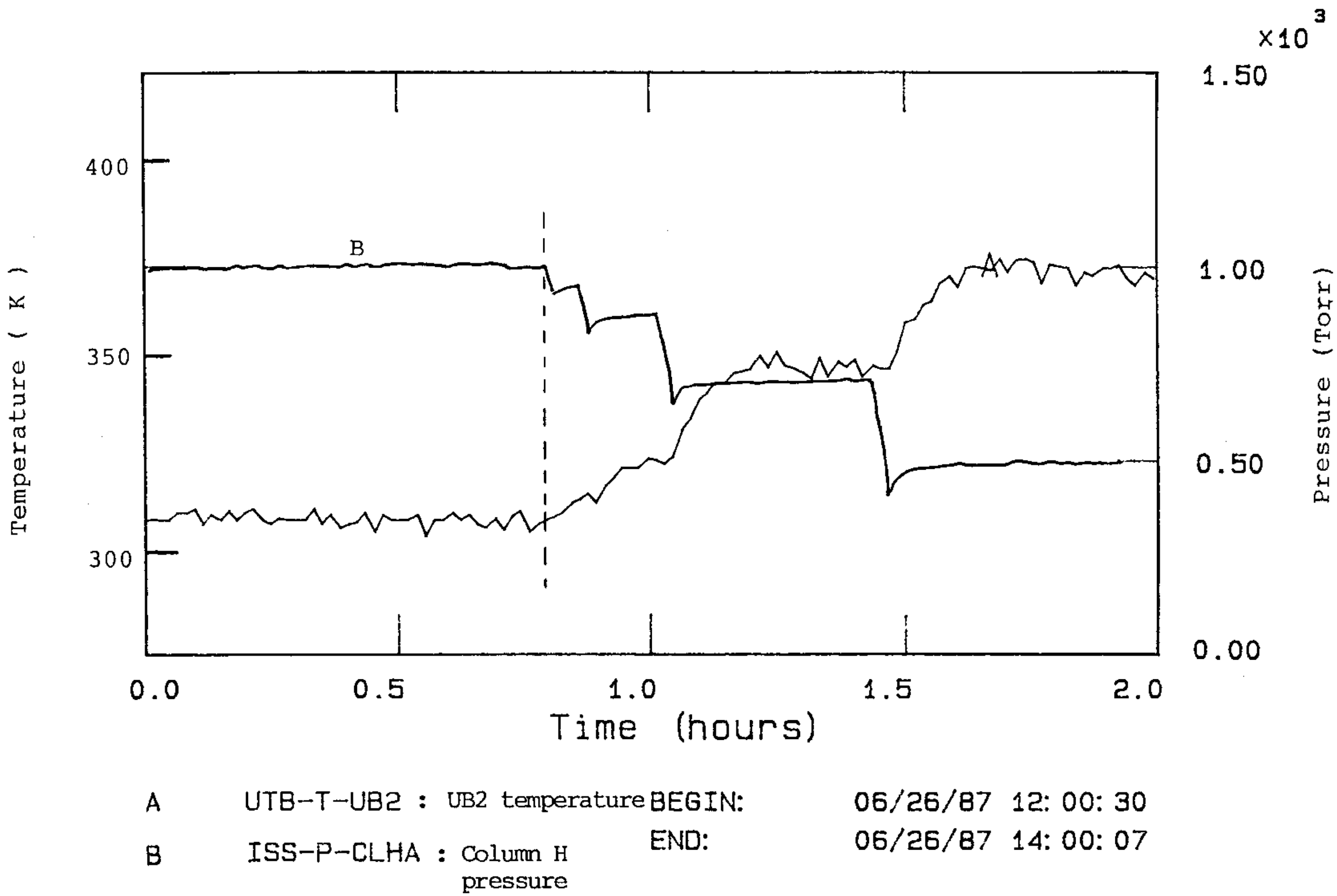


Fig. 4.10 Relationship of the residual gas pressures in the column H and the temperature change of the UB2

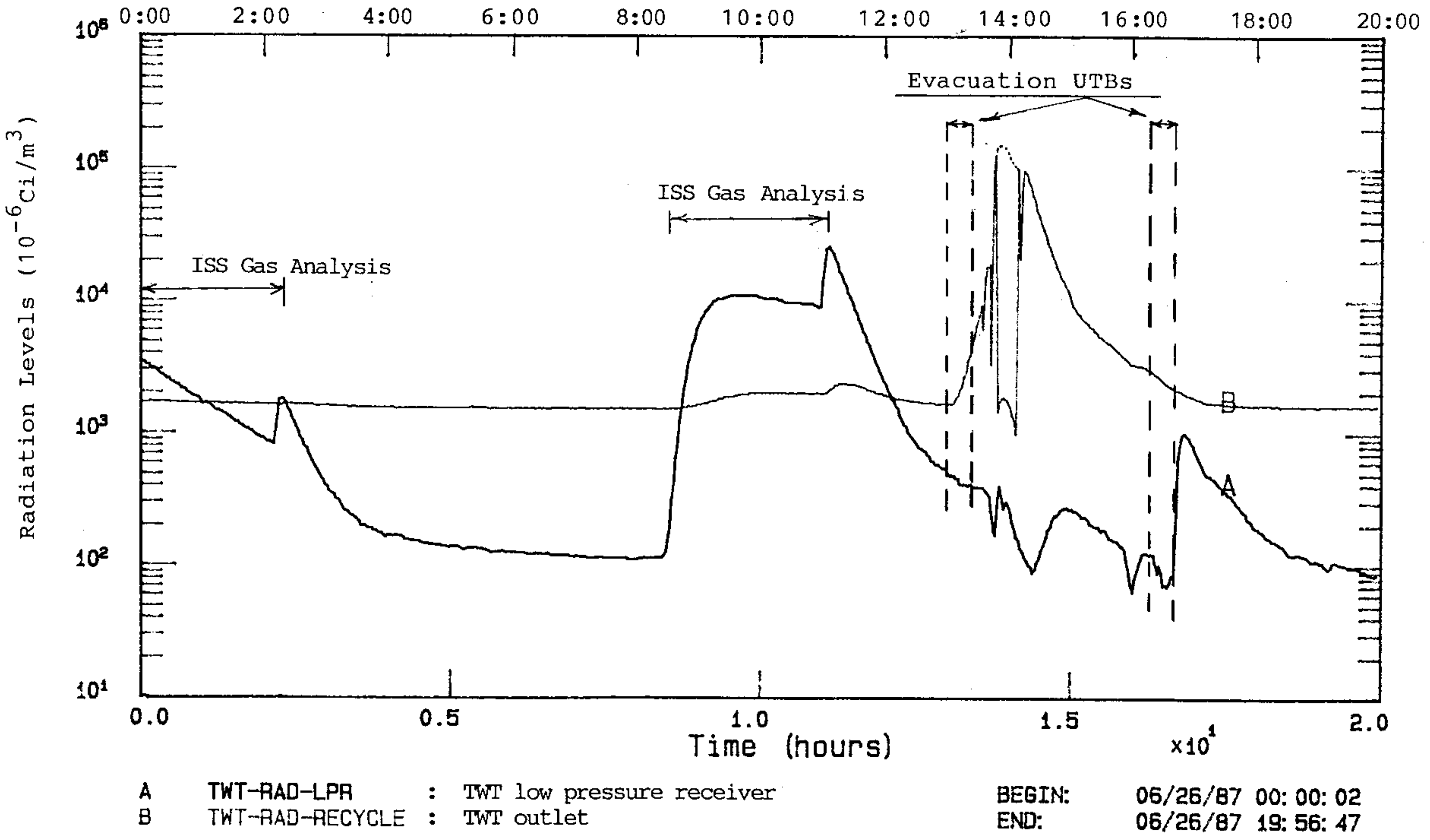
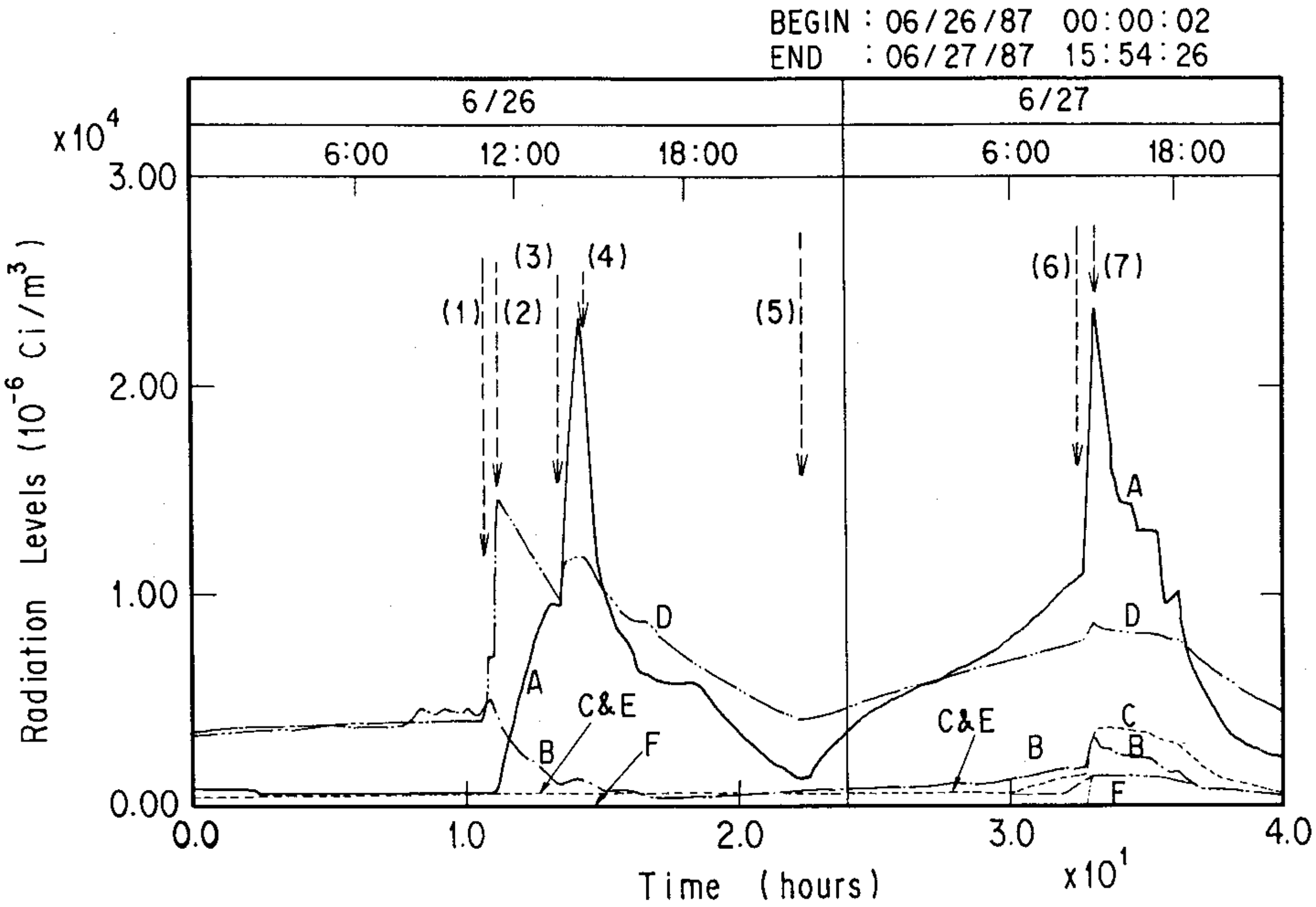


Fig. 4.11 Radiation levels in the inlet and outlet streams of the TWT



A ——— ISS-RAD-GB1
B —·— ISS-RAD-GB2
C - - - - ISS-RAD-GB3
D —··— FCU-RAD-GB1
E — — — TPU-RAD-GB1
F —·-·— TPU-RAD-GB2

(1) High pressures at ISS emergency / ISS shutdown
(2) TWT stacking mode with purging gloveboxes
(3) TWT recycle mode without purging gloveboxes
(4) TWT stacking mode with purging gloveboxes
(5) TWT recycle mode without purging gloveboxes
(6) TWT scrammed due to high temperature of cooling water
(7) TWT stacking mode with purging gloveboxes

Fig. 4.12 Offnormal radiation levels in the SEC-gloveboxes at the ISS emergency situation and at the finishing work on the June run

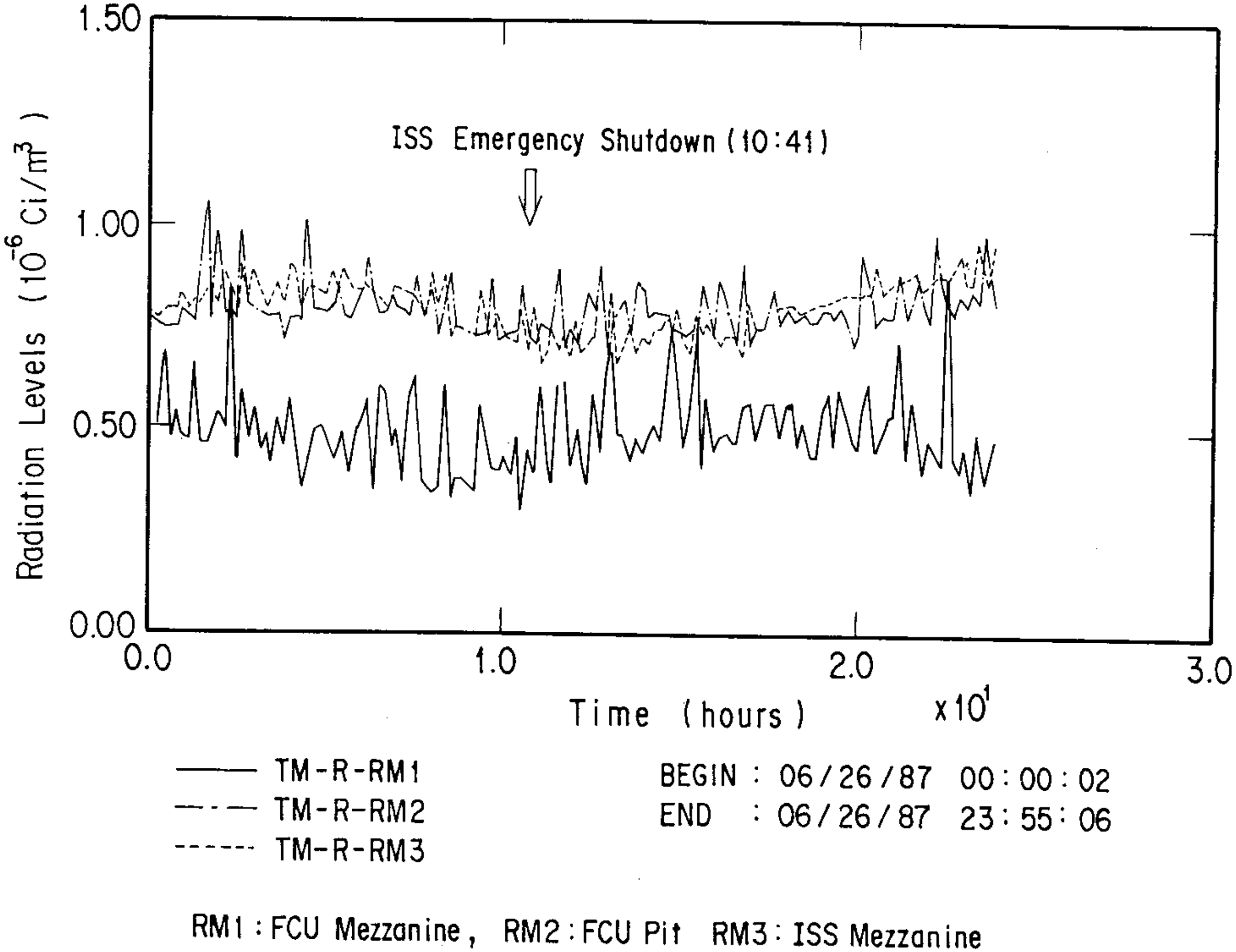


Fig. 4.13 Radiation levels at the key locations of the TSTA experimental at the ISS emergency situation

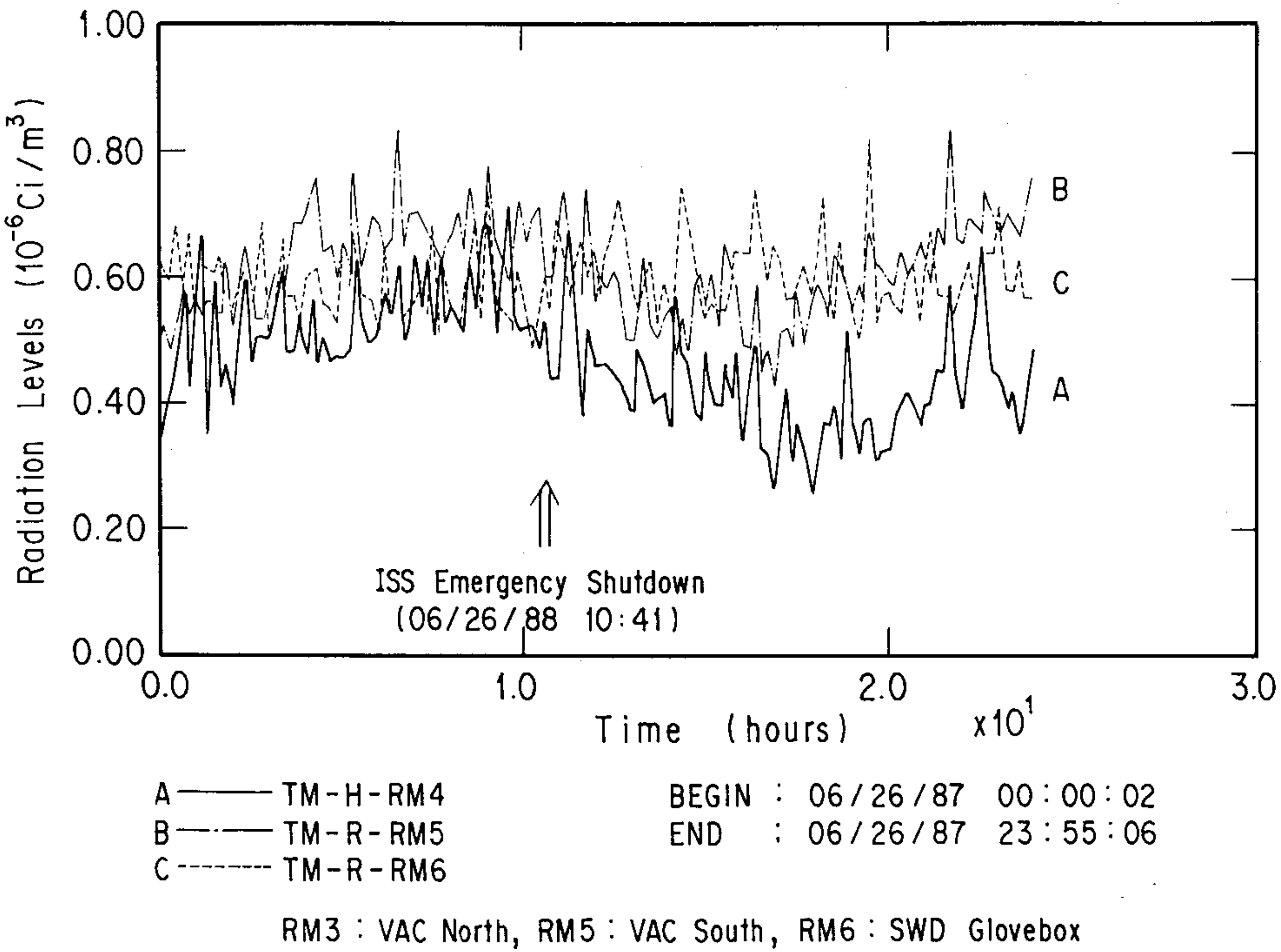


Fig. 4.14 Radiation levels at the key locations of the TSTA experimental room at the ISS emergency situation

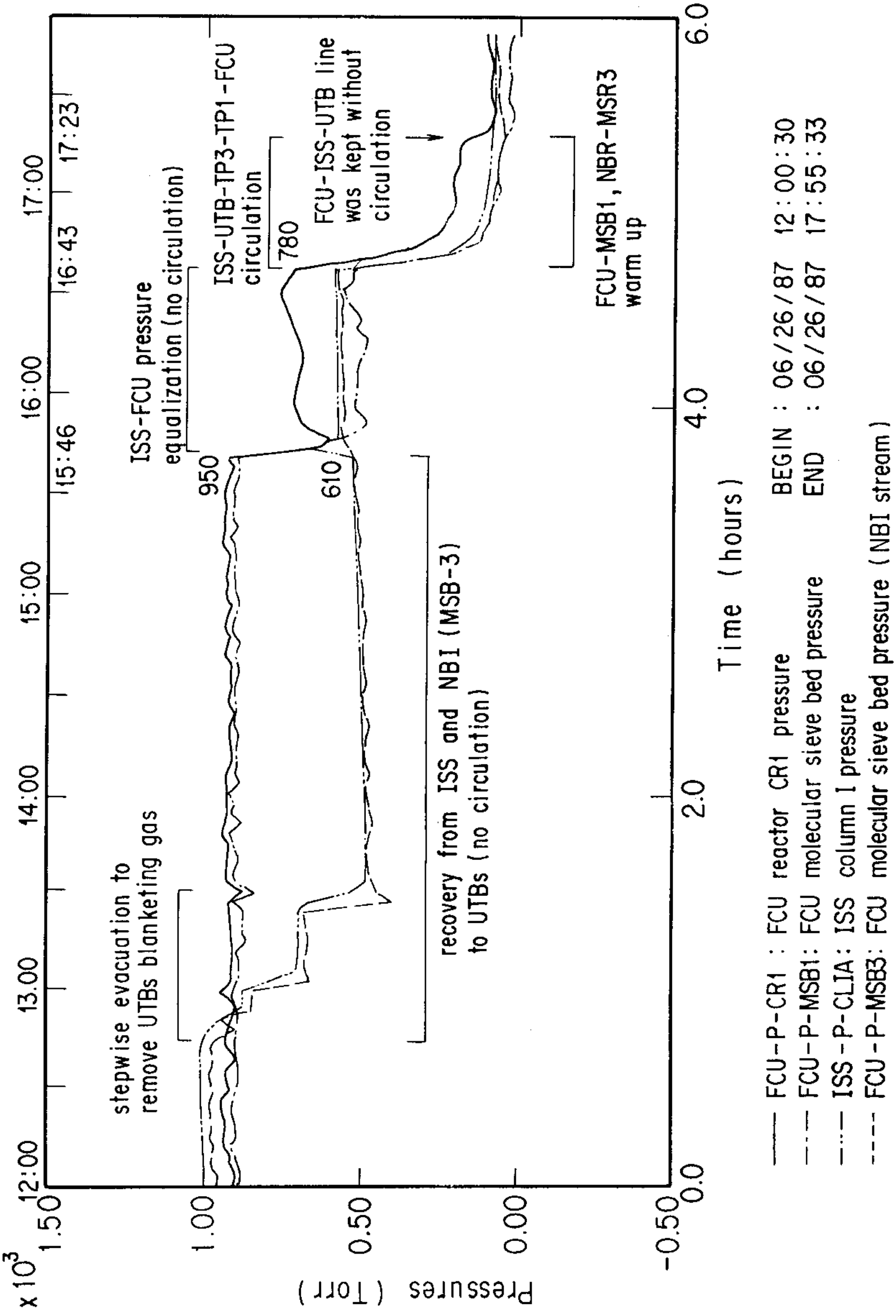


Fig. 4.15 Pressure variations in the FCU and ISS during process gas recovery operation

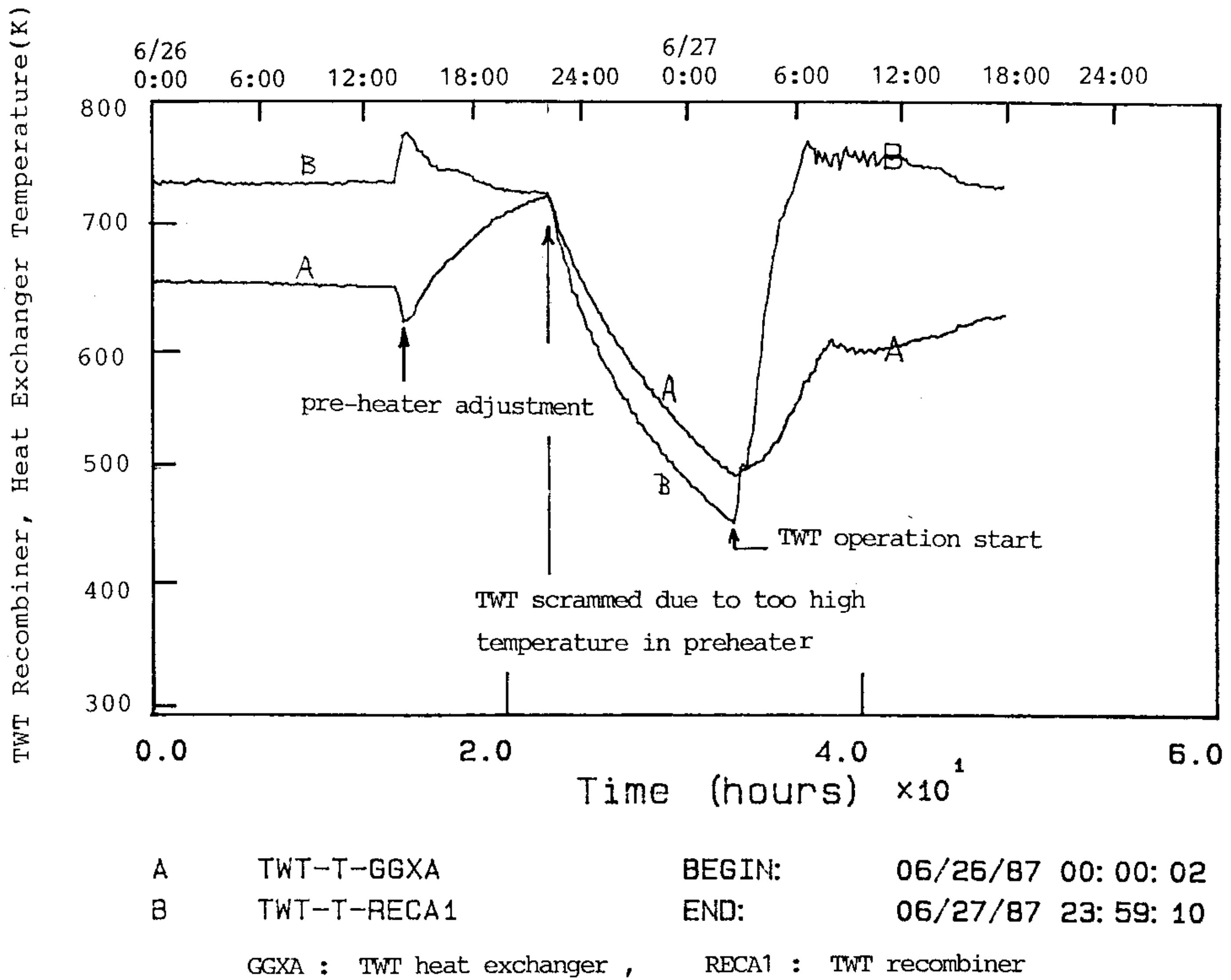


Fig. 4.16 Temperature variations of the TWT recombiner and heat exchanger(pre-heater) at the scram

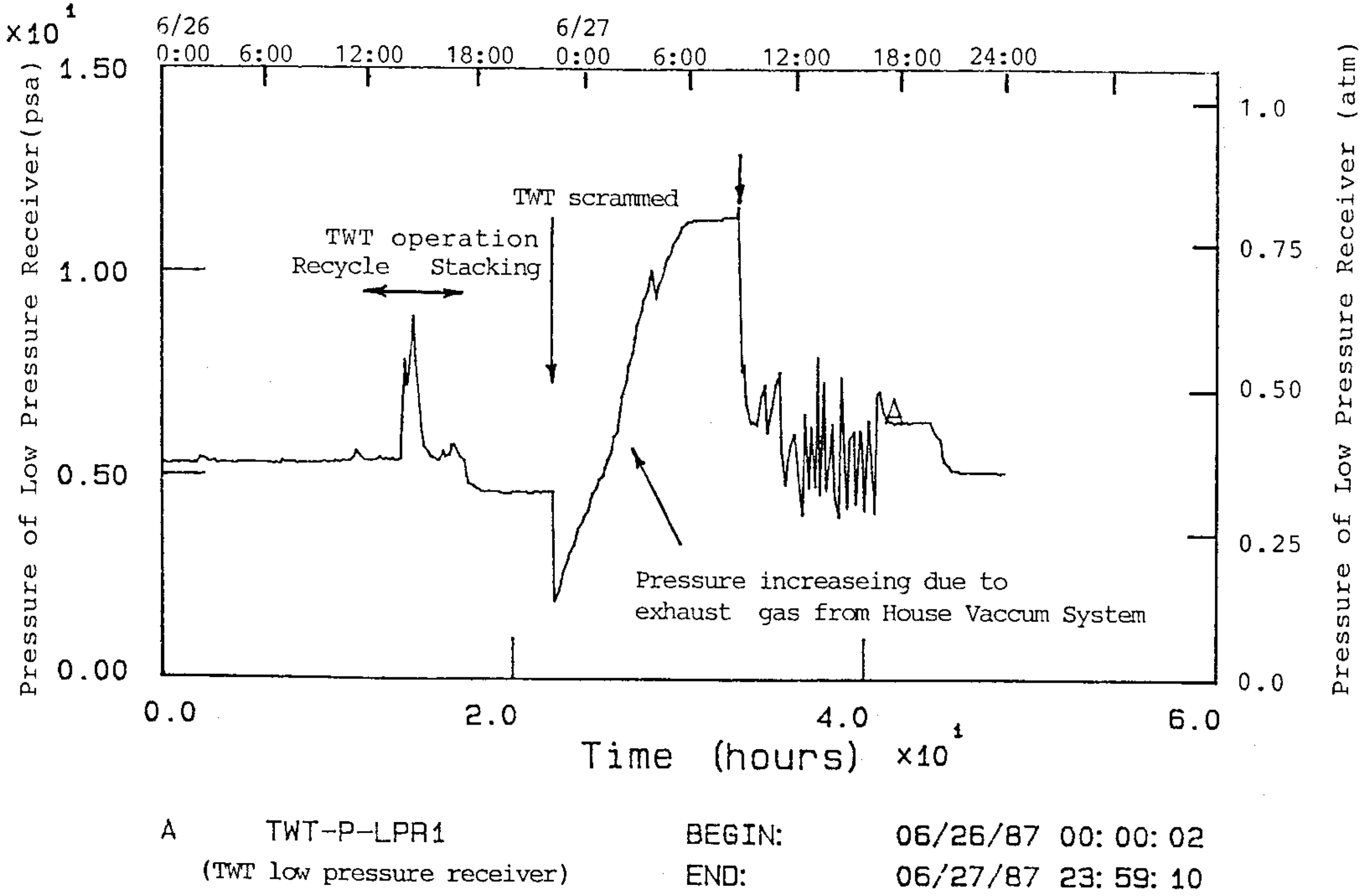


Fig. 4.17 Pressure variations in the LPR during the TWT scrammed

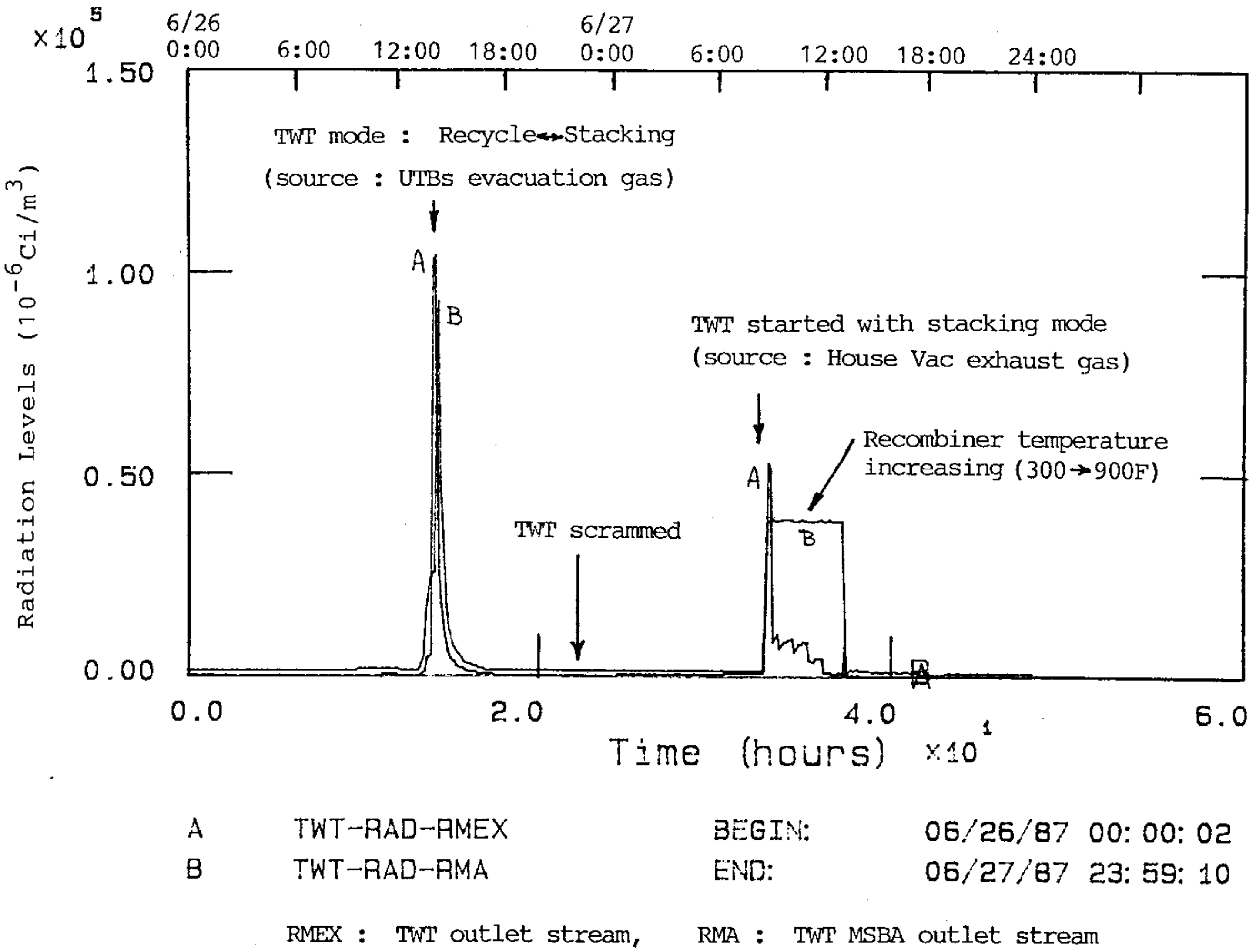


Fig. 4.18 Radiation levels in the outlet streams of the TWT(RMEX: stream to stack, RMA: stream of MSB dryer outlet) during the TWT scram

5. FINISHING WORK

After the ISS shutdown and the impurity injection experiment on the FCU, the following operations were performed to terminate this milestone run:

(i) Recovery of tritium as much as possible from the ISS. Pressures of the ISS continued to increase during warm up to the ambient temperature.

(ii) Recovery of tritium adsorbed on the cryogenic molecular sieve beds(MSB-1 and 3) by warming them up.

(iii)Treatment of methane adsorbed on the FCU-MSB1. In the present milestone run, the back-end processing to treat tritiated hydrocarbons was not done with the FCU. The methane injected to the FCU was routed to the TWT to receive detritiation.

Figure 4.15 shows pressures at the FCU(CR1, MSB1), NBI(MSB3) and ISS column I. Pressure reduction of the column I and the MSB3 were enhanced by stepwise evacuation of UTB residual gas(12:45-13:30), but did not proceed while under static condition without gas circulation(13:30-15:46). The FCU line was isolated until the pressure equalization was done at 15:46. Circulation of the ISS-UTB-TP3-TP1-FCU loop provided a rapid recovery of hydrogen isotope gases to UTB, and in that time period warmup of MSBs with electrical heaters were performed to desorb H-D-T mixture and impurities(N_2 and CH_4).

The radiation levels of gloveboxes(FCU-GB1 and ISS-GB1) during these operations can be seen in the stages(4)-(5) shown in Figure 4.12. The peak radiation(at around 14:00) found on the TWT outlet corresponded to these offnormal release.

Figures 4.16, 4.17 and 4.18 represent the TWT characteristics related to the above finishing work. As can be seen in Figure 4.16 , TWT was scrammed(at around 22:00) by the MDAC control program, which was actuated by a high temperature on the recombiner pre-heater(GGXA : gas-gas heat exchanger with electric heaters). The TWT was re-started at around 10:00 of June 27.

Figure 4.17 shows the pressure change during the scram. The pressure of the low pressure receiver(LPR) reached the limit value(11 psia ; Los Alamos atmospheric pressure) by receiving exhaust gas from the House Vac. The overflow from the LPR is routed to extra storage tanks through the LPR relief valve, which is designed to open at 0.01 atm above the barometric pressure(TWT operational limit). Figure 4.18 shows the radiation levels of TWT outlets(RMEX : exhaust radiation level to stack line, RMA : outlet radiation level of molecular sieve dryer A/B train). The peak release of the RMEX occurred at the startup of the TWT from its scram situation, and the plateau level of the RMA is considered to be related to both the recombiner temperature change(150 C to 480 C) and the reduction of radiation level in the LPR. The glovebox radiation levels during the above time period can be seen in Figure 4.12. Both levels in the ISS-GB1 and FCU-GB1 steadily increased while TWT was scrammed, because glovebox purge gas was stopped during that time period. It should be noticed that the radiation levels of all gloveboxes, some of them such as TPU-GB1 and GB2 had never show offnormal tritium release during this run, increased at the time of TWT re-startup.

These radiation levels might be caused by backstreaming through the glove box purge gas vent line from the LPR to all gloveboxes, because LPR pressure was slightly higher than that of gloveboxes, and the vent valves for purge gas on each gloveboxe are opened when the TWT operation begins the stacking mode. No other source of the glovebox radiation observed at this time can be found.

6. CONCLUSION

This milestone run conducted with three shifts/day was started on June 22(Sun) and halted on June 26(Fri) due to a mechanical failure of the helium refrigerator for the cryogenic distillation system(ISS) operated at 18-25K. The major tasks planned were started on schedule, but the achievement of a week operation of the ISS under steady state and demonstration of the impurity removal from D-T stream on the FCU was not sufficient.

On the contrary, demonstration of the other process systems such as LIO, TP1 and TP3, UTB, and the safety related systems such as SEC, TM, TWT, MDAC were fully achieved with 40-90 grams of tritium.

The successful results on the process systems obtained through this milestone run are:

- ISS was proved to be effective for continuous stripping of ^3He as well as H_2. The radiation level in the withdrawal stream from the top of column H was acceptably low. ^3He stripping using the UTB was also effective, but needs process gas circulation followed by evacuation treatment of the UTB to remove a blanketing effect with helium over the uranium beds.
- Although several offnormal tritium releases happened in the gloveboxes, no release into the room or no personnel exposure occurred during this run and at the ISS emergency situation. Releases to the environment were well below allowable levels.
- The non-planned emergency situation of the ISS, which was generated by a mechanical failure of cryogenic helium refrigerator, successfully terminated with the TSTA operation manual.

Problems found through this run are:

- The operating temperature of the TWT recombiner did not reach the design temerature(550-600 C) by unknown reason. Approximately 1.7Ci of tritium, assumed to be methane, was released to the environment through the TWT during regeneration of the FCU cryogenic molecular sieve bed(MSBs) adsorbed methane.
- The stack release of approximately 1.7Ci was not properly read by the TWT outlet tritium monitors(the monitor indicated low radiation levels for stacking operation mode). The reason should be identified to prevent further release from the TWT.

tritium release during this run, increased at the time of TWT re-startup.

These radiation levels might be caused by backstreaming through the glove box purge gas vent line from the LPR to all gloveboxes, because LPR pressure was slightly higher than that of gloveboxes, and the vent valves for purge gas on each gloveboxe are opened when the TWT operation begins the stacking mode. No other source of the glovebox radiation observed at this time can be found.

6. CONCLUSION

This milestone run conducted with three shifts/day was started on June 22(Sun) and halted on June 26(Fri) due to a mechanical failure of the helium refrigerator for the cryogenic distillation system(ISS) operated at 18-25K. The major tasks planned were started on schedule, but the achievement of a week operation of the ISS under steady state and demonstration of the impurity removal from D-T stream on the FCU was not sufficient.

On the contrary, demonstration of the other process systems such as LIO, TP1 and TP3, UTB, and the safety related systems such as SEC, TM, TWT, MDAC were fully achieved with 40-90 grams of tritium.

The successful results on the process systems obtained through this milestone run are:

- ISS was proved to be effective for continuous stripping of ^3He as well as H_2. The radiation level in the withdrawal stream from the top of column H was acceptably low. ^3He stripping using the UTB was also effective, but needs process gas circulation followed by evacuation treatment of the UTB to remove a blanketing effect with helium over the uranium beds.
- Although several offnormal tritium releases happened in the gloveboxes, no release into the room or no personnel exposure occurred during this run and at the ISS emergency situation. Releases to the environment were well below allowable levels.
- The non-planned emergency situation of the ISS, which was generated by a mechanical failure of cryogenic helium refrigerator, successfully terminated with the TSTA operation manual.

Problems found through this run are:

- The operating temperature of the TWT recombiner did not reach the design temerature(550-600 C) by unknown reason. Approximately 1.7Ci of tritium, assumed to be methane, was released to the environment through the TWT during regeneration of the FCU cryogenic molecular sieve bed(MSBs) adsorbed methane.
- The stack release of approximately 1.7Ci was not properly read by the TWT outlet tritium monitors(the monitor indicated low radiation levels for stacking operation mode). The reason should be identified to prevent further release from the TWT.

REFERENCES

1. TSTA design team,"TRITIUM SYSTEMS TEST ASSEMBLY; FINAL SAFETY ANALYSIS REPORT," SAR-82-1F, Los Alamos National Laboratory (1982).

Attachment I TSTA Safety Systems

A . Secondary Containment System(SEC)

A.1 System Functions

This system is designed to confine routine leakage and releases of tritium to small gas-tight volumes until the affected enclosure can be treated by either the Tritium Waste Treatment System (TWT) or the Emergency Tritium Cleanup System(ETC). By providing the enclosures for isolating tritium from the main experimental area, SEC enables the room atmosphere to be maintained below the maximum permissible concentration (MPC) for workers for any accident that does not breach the secondary containment. By providing interim containment for accidental releases, SEC also helps limit environmental releases to less than 200 Ci/yr.

A.2 System Description

The principal component of SEC is a series of gloveboxes enclosing the main process loop subsystems (FCU, ISS, TPU, etc.) and the piping that interconnects the processes. The gloveboxes are maintained with a static, ambient-pressure atmosphere of dry nitrogen with bleed and backfill components that operate automatically whenever tritium concentrations are detected.

Table A.1 lists these gloveboxes and some of their properties. All discharges from the glovebox pressure control system go to TWT. This is the largest single input stream to TWT. Each glovebox contains an ion chamber for tritium monitoring. The glovebox pressure relief bubblers exhaust into the XCS fume hood, thus allowing ETC to process the bubbler exhaust if necessary.

A.3 Performance and Characteristics

All SEC glovebox are locally instrumented to monitor tritium concentrations between 0.01 and 1000 mCi/M^3, and differential pressures between -500 and 500Pa.

B . Tritium Waste Treatment system(TWT)

B.1 System Functions

This system treats all gaseous effluents which are generated in various subsystems of TSTA to remove tritium from these effluents before they are released to the environment.

B.2 System Description

The TWT(shown in Figure B.1) is a computer actuated and controlled tritium removal system that operates by the catalytic conversion of all hydrogen isotopes in the input stream to water and of all hydrocarbon materials to water and carbon dioxide. Water generated by these processes is adsorbed on molecular sieve. The remaining gaseous effluent is then discharged to the atmosphere after it has been determined that the measured tritium level is below TSTA guidelines. Tritium-bearing gaseous effluents from various sources flow into a low pressure receiver (LPR). Pressure in this vessel is maintained between the limit of 0.27 atm (4 psi) and 0.54 atm (8 psi) which permits gases to flow freely from sources. Hydrogen and oxygen concentrations in the LPR are monitored by one of the two gas chromatographs. The gas radiation level in the LPR is monitored by an ionization chamber.

When the pressure in the LPR reaches the upper limit(0.54 atm), one of two oil-free piston type pumps is actuated, causing gas to flow from the tank through the catalytic recombiner. The recombiner is designed to be operated at 810 K to convert hydrogen isotopes and hydrocarbons. Vapors and gases from the recombiner are compressed to about three atmospheres.

The remaining components of the secondary part of this system consist of the high pressure storage tank, molecular sieve dryers, and radiation monitors. The pressure (3.04 atm) throughout the secondary part of the system is maintained by a back-pressure regulating valve located at the output of the radiation ion chamber. Gas and vapors from one of two high pressure tanks are passed through one of four molecular sieve beds where tritiated water vapor is adsorbed. The remaining gases are exhausted to the atmosphere through an ion chamber and back-pressure regulating valve. A second ion chamber monitors the tritium concentration before the gas is passed to the TSTA stack. However, depending on conditions measured at the output of the dryers, the flow may be directed back to the LPR to be recycled.

B.3 Major Components

(1) Low Pressure Receiver (LPR)

The LPR is a stainless steel tank of approximately 7.36 m^3. In the normal operation mode, the pressure varies between 0.27 atm and 0.54 atm in the LPR.

(2) Recombiner(RECA)

The recombiner consists of three stainless steel units; a gas-to-gas heat exchanger, catalytic reactor, and a water cooled gas aftercooler. The reactor vessel is capable of operating in a continuous duty cycle at 810 K in order to break down tritiated hydrocarbons. The temperature range in the reactor is 644K to

810K. The flow rate of gas through the system is a maximum rate of 0.025 m^3/s, at the operating pressure of 0.27 atm to 0.54 atm.

(3) Compressors(CA and CB)

The compressors are of the upright, reciprocating, dry cylinder, two-stage type with an inert-gas-pressurized sealed chamber between the compression cylinder and the crankcase. The nonlubricated dry cylinders utilize glass filled Teflon piston rings. The compressors operate at 0.27 atm to 0.54 atm on the suction side, compressing the effluent gas to 3.04 atm at discharge. The volumetric displacemant of the large compressor is 0.025 m^3/s (CA), and it is 0.007 m^3/s (CB) for the small one.

(4) Dryers(MSBA, MSBB, MSBC and MSBD)

There are four dryers, two of these(MSBA and MSBC) are filled with LINDE Type 13X molecular sieve, and the other two are filled with LINDE Type 4A molecular sieve. One of these dryers is on-line. A dryer in use is capable of drying effluent flowing at 3.04 atm at 295 K and 30% relative humidity, down to a 183 K dew point.

(5) Radiation Monitors

An inlet radiation monitor is on the LPR. It operates at a pressure between 0.27 atm to 0.54 atm. Three radiation monitors are at the outlet of dryers; these are called RMA, RMC and RMBY. RMA is placed at the outlet of 13X molecular sieve dryers. RMB is placed at the outlet of 4A molecular sieve dryers. And RMBY is a backup monitor for RMA or RMC. They operate at 3.04 atm. An exhaust radiation monitor (RMEX) is located at the outlet of the TWT in line to the stack. It operates at atmospheric pressure.

(6) Moisture Collectors(MCA and MCB)

The moisture collectors are 0.056m^3 stainless steel drums filled with molecular sieve. They collect water vapor from the generation of the molecular sieve dryers. Approximately 10kg of water can be collected in each collector.

B.4 Operations

The TWT is operated and controlled by computer. Gas is released to the stack in normal operation. Any radiation discharge to the stack from the TWT is monitored by radiation monitors. If the TWT is not adequately decontaminating the effluent stream, the computer will close the stacking path and open the recycle path. The TWT will remain in the closed loop recycle mode untill the radiation level of the gas is below the setpoint.

C . Tritium Monitoring System(TM)

C.1 System Functions

Tritium monitoring instrumentation performs the following functions:

- determining quantitatively stack releases to the environment

- monitoring tritium concentrations in room and room-exhaust air, secondary enclosure atmospheres, and process system lines,
- initiating local alarms and computer-control signals when preset tritium concentrations are reached in room or room-exhaust ducts,
- initiating room air isolation and an evacuation alarm when a preset room concentration is reached,
- initiating local alarms and computer-control signals following tritium releases into secondary enclosures, and
- monitoring non-loop experiments of the XCS programs.

C.2 System Description

The TM system consists principally of a number of tritium monitors which can be categorized according to their function. Table C.1 lists these monitors and some of their properties. With the exception of the ETC water monitor and stack bubbler, the instruments are ion-chamber instruments so chosen because of their proven reliability, simplicity, versatility and sensitivity.

C.3 Components

(1) Stack Bubbler

The stack bubbler consists of bubblers(two glycol and water),which remove the moisture in the air that is bubbled slowly through them, a precious metal catalyst and additional bubblers (for removing the gas converted to vapor by the catalyst). The concentration of tritium in the glycol, measured with a liquid scintillation spectrometer, gives a direct measurement of the total amount of tritium as either gas or vapor released to the environment through the stack. Air is directed through a flow sensor, three 30-cm^3 bubblers in series, a palladium sponge catalyst heated to 350^{0}C, three additional 30-cm^3 bubblers in series, a rotameter, a flow controller, and a pump. Once a week (or following a suspected or known release), the integrated stack release is measured and recorded.

(2) Ion Chamber Instruments

Power supplies of key instruments are monitored and the radiation response of the low-range ion chamber monitors are checked daily and automatically by computer.

The regular stack monitor provides two readings; concentration and integrated daily concentration. The duct monitors are identical to the stack monitor except for their ion chambers, which are smaller and open-walled.

Room monitors are strategically placed where tritium is located. Each monitor simultaneously samples 2 or 3 points through hoses or tubes connected in parallel.

D . Emergency Tritium Cleanup System(ETC)

D.1 System Functions

The TSTA cell contains approximately 3000 m^3 of building atmosphere which would be contaminated with an accidental spill of tritium from primary or secondary containments. This system is an operator controlled room-air detritiation system based on a precious metal catalytic recombiner and molecular sieve drying beds.

The primary functions are:

- Cleanup main experimental room after an accident,
- Cleanup XCS laboratory,
- Cleanup VAC facility enclosure,
- Cleanup releases into duct work from exhaust lines.

D.2 System Description

The ETC (shown in Figure D.1) is activated by operator. The sequence is as follows:

(i) When one room, duct or stack tritium monitor reaches a preset tritium level, the ventilation system is sealed off by hardwired signals from the tritium monitors.
(ii) When a second monitor reaches that level, the ETC is started.
(iii) When the ETC is actuated, the first steps will be to confirm that the hardwire isolation sequence has occurred.

Then the contaminated air is routed to compressors(A or B). The compressed air passes through the catalyst bed, which converts the hydrogen isotopes to water vapor. The water and air is run through the cooler and refrigerated dryer, which can condense most of the water vapor from the process stream. Steam can be added to the process stream between the two dryers to raise the moisture concentration to increase the tritium removal in the second stage molecular sieve dryer. The tritiated water regenerated from a saturated dryers is collected in one of three tanks.

The air from the dryer is then passed through two molecular sieve dryers in series to dry the air further.

The dry air is then divided and part recirculated to the room and the remaining routed to the stack. The fraction to be recirculated is determined by the requirement to keep the room at negative pressure.

D.3 Major Components

(1) Compressors

Compressor A is are reciprocating type with one stage and two cylinders with double acting piston. It uses Teflon coated cylinder liners and Teflon piston and rider rings. The free air capacity is 0.687 m^3/s with inlet conditions of 0.77 atm and 293K and outlet conditions of 3.5 atm and 450K.

Compressor B is standby equipment of a rotary-screw oil-free type. Free air delivery is 19 m^3/min with inlet conditions of 0.77 atm at 298K and outlet conditions of 2.7 atm at 460K.

(2) Catalytic Reactor

The reactor(0.91 m diameter) contains a precious metal catalyst of 0.225 m^3. To assure high conversion rate of elemental tritium, hydrogen can be added to the air stream at a rate to maintain a minimum hydrogen isotope concentration of 1000 vppm. The reactor can reduce this level to 1 ppb at nominal inlet conditions of 0.5 m^3/s, 450K and 3.5 atm.

(3) Air Cooler

The cooler is used to cool the hot exit gases from the catalytic reactor to near their dew point. It was designed to cool 0.5 m^3/s of air at a pressure of 3.1 atm from 460K to 274K.

(4) Refrigerated Dryer(Condenser)

The function of this component is to remove as much water as possible from the air before the molecular sieve dryers to minimize the water loading of these units. It is capable of cooling 0.5 m^3 from 310K to 275K at a pressure of 3.1 atm.

(5) Tritiated Water Storage Tanks

There are three tanks(11 gal x 2, 200 gal x 1). At nominal flow rates, the tritium concentration in the TSTA main cell is reduced by a factor of 10 every 3 hrs of ETC operation. At this rate 99% of the tritium is removed from the cell in the first 6 hrs. Condensate formed during this time period is collected in the two smaller tanks. They will overflow to the larger tank. The storage capacity is sufficiently for 50 hrs operation at 50% relative humidity in the main cell.

(6) Molecular sieve dryers

There are two complete dryer systems composed of two stages of molecular sieve dryers, one to be used for room cleanup experiments and the other to be in standby for emergency cleanup situations. One dryer is equipped to demonstrate in-situ regeneration of a dryer. The capacity(0.106m diameter, 1.4m packed hight) is sufficient to allow completion of an emergency operation without replacement of molecular sieve.

(7) Design operation after 100g-T_2 spill

After 100g-T_2 release in the cell, the initial average concentration would be 320 Ci/m3. Assuming complete mixing with the air in the cell, the ETC is designed to reduce this to 40×10^{-6}/Ci/m^3, at which time normal cell ventilation would be restored and the tritium concentration in the stack, averaged over the next 24 hrs period, would be 0.58×10^{-6}Ci/m^3 for a total release of 0.12 Ci. The tritium release as T_2O during the cleanup phase would average 2.0x10-6Ci/m3 from stack over the 20.1 hrs for a total release of 0.38 Ci-T_2O. The release of T_2 during this phase would be 0.38Ci.

During this time(230.1 hrs), 130 liters of condensate would be collected in the water storage tanks, and 100 liters of water would be collected in the molecular sieve dryers(water swamping is added to get 1200ppm of water vapor at the inlet of the second stage of the dryer).

Table A.1 Locations of tritium monitors

Glove Box	Enclosed System	Room	Volume (m^3)
INV-GB1	INV	Main Exp Room (5501)	0.8
INV-GB2	INV	Main Exp Room (5501)	2.3
TPU-GB1	TP1/TP2	Main Exp Room (5501)	2.5
TPU-GB2	TP3	Main Exp Room (5501)	1.7
FCU-GB1	FCU	Main Exp Room (5501)	4.6
ISS-GB1	ISS	Main Exp Room (5501)	1.2
ISS-GB2	ISS/GC	Main Exp Room (5501)	1.3
ISS-GB3	UTB	Main Exp Room (5501)	2.9
SWD-GB1	SWD	Main Exp Room (5501)	2.5
XCS-GB1		XCS Room (5507)	
XCS-GB2		XCS Room (5507)	
GAN-GB1		GAN Room (5508)	

Table C.1 Physical Description of Tritium Monitors

Type	Number	Sensor	Air Pump	Electrometer Amplifier	Interface (1)
Stack	1	10-ℓ ion chamber	GAST 440 V 109 A	LA Model 39	LA Model 39C
Stack (Hi-range)	1	0.1-ℓ ion chamber	Thomas Model 107CA18	Keithly Model No. 26320	
Duct	2	0.9-ℓ ion chamber	None (2)	LA Model 39	LA Model 39C
Room	8	1.5-ℓ ion chamber	Thomas Model 107CA18	Overhoff Betatec Model 210	
Room (Hi-range)	2	0.1-ℓ ion chamber	None (2)	Keithly Model 480	LA-Built
Glove Box (+VAC enclosure)	14	0.9-ℓ ion chamber	None (2)	Keithly Model 616	LA Model 1979A
Process Monitor (XCS/TWT/DCS)	11	1.7-ℓ ion chamber	(ETC) non-mechanical aspirator type. (XCS/TWT) none.	Keithly Model 616	LA Model 979
Process (FCU/ISS/ GAN)	6	0.01- 0.3-ℓ ion chamber	None	Keithly Model 480 (GAN lab: Model 616)	LA-Built

(1) The interface units provide high voltage for the ion chambers, local alarms and signals, connections for MDAC, and, where applicable, for the hard-wired readouts and building evacuation alarm.

(2) Perforated (double-walled) chambers are used.

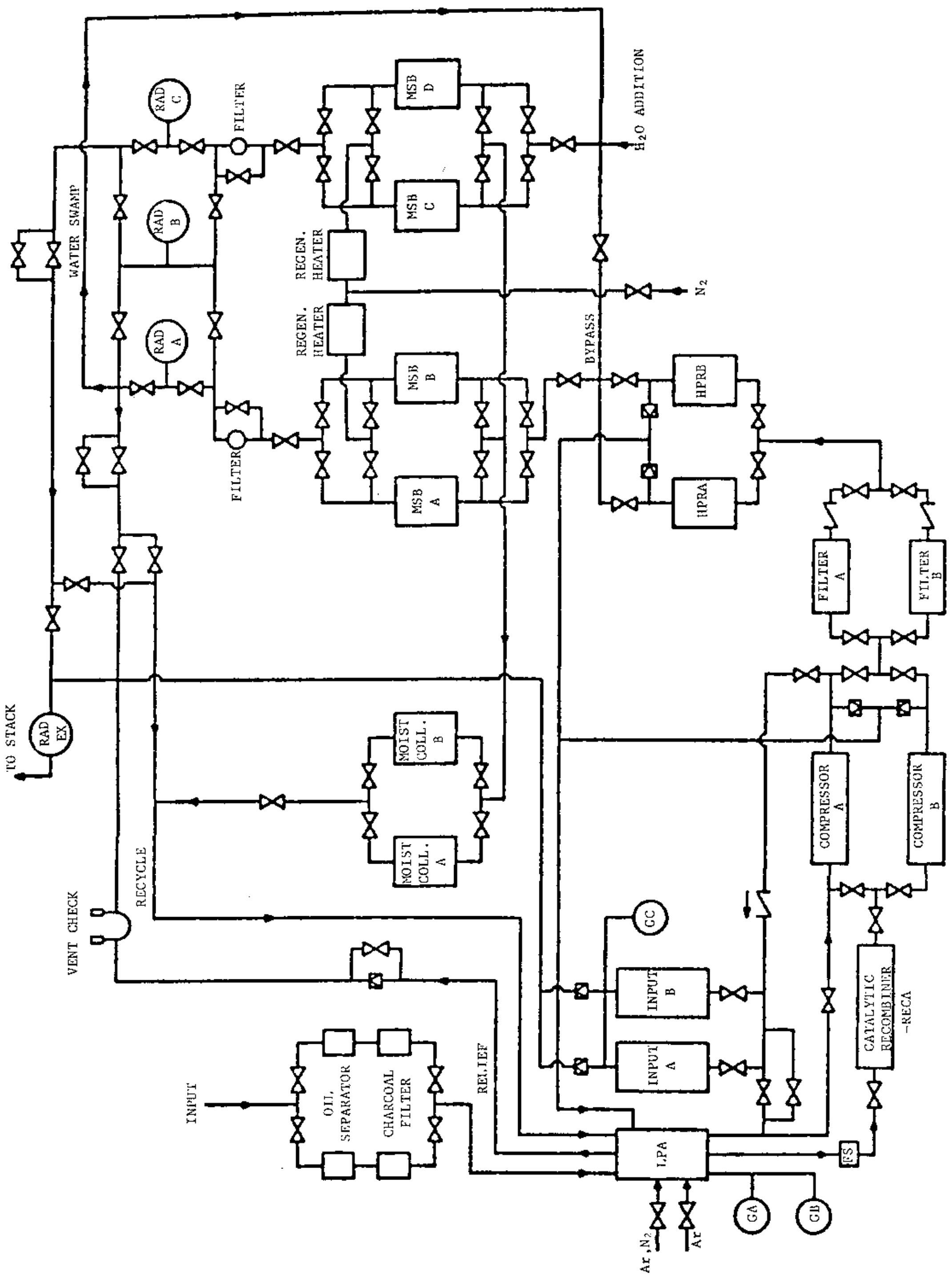


Fig. B.1 TWT primary components and flow paths

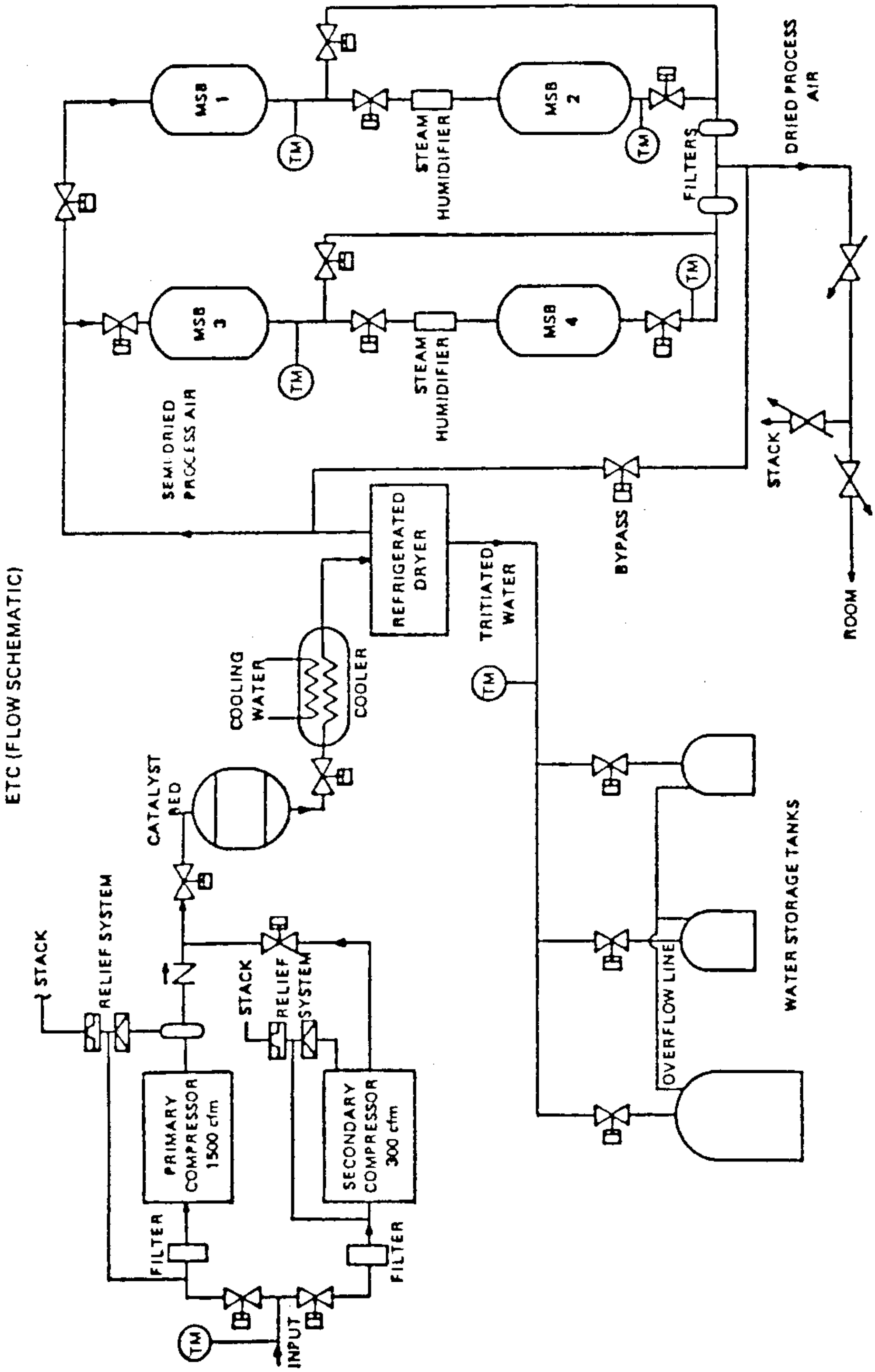


Fig. D.1 ETC primary components and flow paths

Attachment II Considerations of Annual Dose Based on TSTA Routine Tritium Release

The expected routine tritium releases to the environment from TSRA are summarized in Table AII-1.

For chronic releases, annual average normarized-concentration isopleths were estimated for the TSTA site based on wind and other atmospheric data compiled for that site. These data are plotted in Figure AII-1 for the 30-m stack height. For the 50-m effective stack height of the TSTA stack the values close to the stack would be decreased by a factor of about 2. No allowance was made for terrain features which would interrupt the normal flow.

From the isopleths, the annual doses to persons persistently exposed to tritium being chronically related at the rate of 200Ci/yr were calculated and transferred to the same isopleth curves(Figure AII-2). The tritium was assumed to be completely oxidized and absorption through the skin was included. On the basis of these calculations, no member of the public would receive over 1 mrem/yr. The projected population dose is approximately 0.2 man-rem/yr.

Using 1979 demographic data and the results in Figure AII-2, the average annual individual dose in Los Alamos Country resulting from the same routine release rate was estimated to be less than 0.2 mrem compared to about 140 mrem from natural background. Other Laboratory operations currently contribute up to about 2 mrem/yr to the individual dose at Los Alamos.

Based on Los Alamos experience, no significant increase of tritium concentrations in vegetation, soil, etc is expected in the vicinity of TSTA as result of the routine release from the facility.

Table AII-1 Estimated Routine Tritium Release to the Environment Per Year*

Subsystem	Release
Vacuum System	- Maintenance on VAC components, although having secondary containment will release some tritium to room. - Release less than 100Ci/yr to the environment.
TWT	- TWT will process tritium released in gloveboxes, a waste tritium from XCS experiments and effluents from process streams. - The decontamination factor of the TWT is estimated to be 10^5 - 10^6. - Release less than 20Ci/yr to the environment.

* 200 Ci/yr for all sources

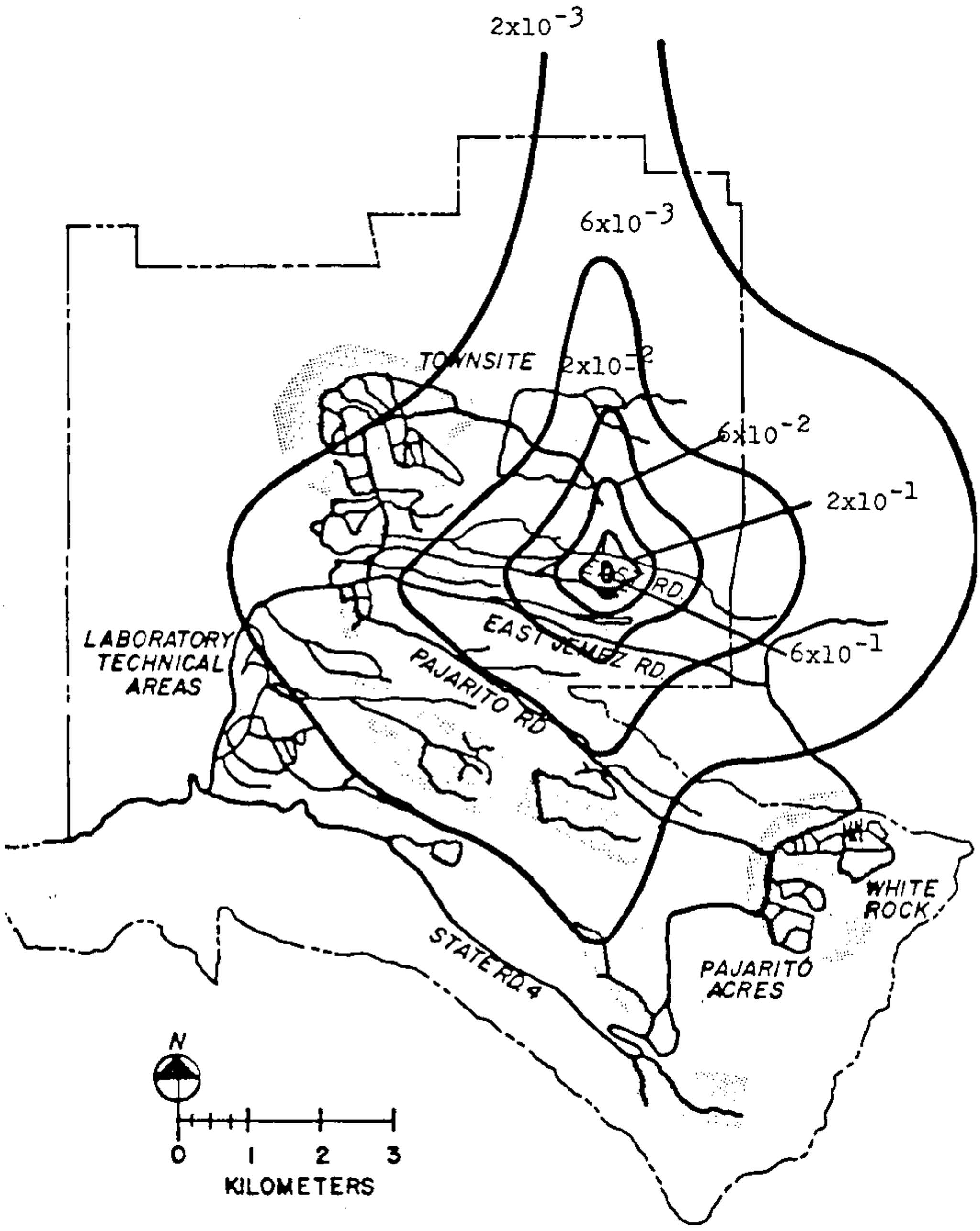


Fig. AII-1 Tritium whole-body isodose curves (mrem/yr) for a chronic release rate of 200 Ci/yr. For a 50-m release height, the values close to the stack would be decreased by a factor of about 2.

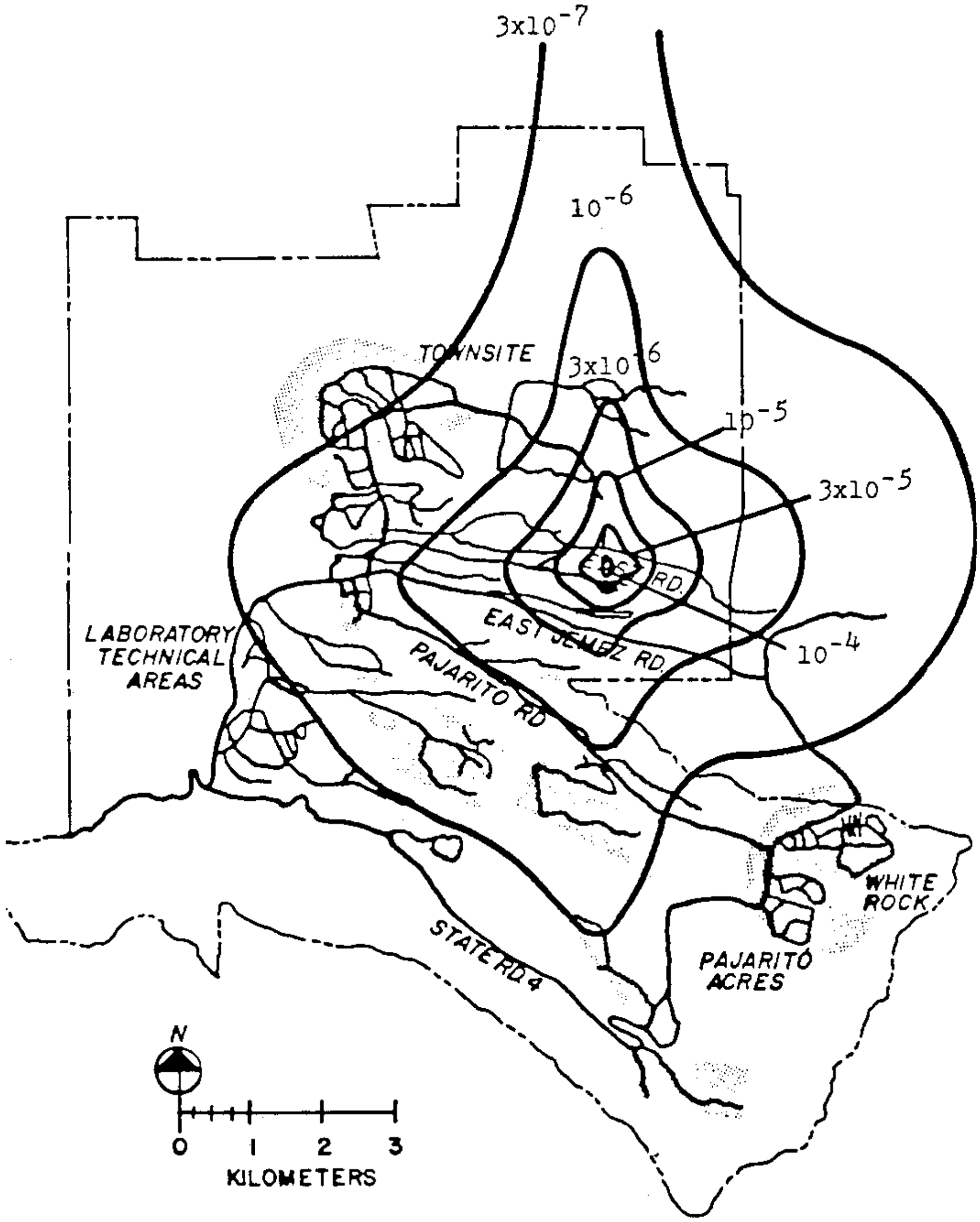


Fig. AII-2 Annual average normalized-concentration isopleths X/Q ($s{\cdot}m^{-3}$) for TSTA source at 30-m stack height.

Attachment III Log of Milestone Run in June, 1987

June 22(Mon)

(1) Loading T_2 from PCs to UB-1 and 3, and recovery of ^3He

(i) Set temperature controllers of UB-2 and 5 to 573K at 8:00, and increased to 673K at 21:00.

(ii) Set up process system for stripping of ^3He using UTB.

(iii) Loading tritium from the PC-TSC1-572(initial pressure 880 Torr) to process loop was performed batchwise (9:00-9:21). The flow path was LIO-TP1-FCU-ISS.

(iv) Gas circulation using TP1-FCU-ISS-UTB(1 and 3)-TP3 loop was started at 10:28 to separate T_2 from ^3He.
The residual gas pressure in the PC was approximately 4 Torr.
Circulation was continued for 64 min by watching residual gas pressure in ISS and temperatures of UTB.

(v) ^3He in the process loop was stripped(11:32-16:07) to PC-TSC1-572 using TP1(scroll pump). During this operation, TP3 was used to circulate through ISS recycle to enhance recovery of ^3He from the loop. Pressure of the recovered ^3He in the PC was 245 Torr.

(vi) Loading T_2 and stripping ^3He with PC-TSC2-1100 were performed with the same procedures followed as during the first PC stripping(17:09-20:33). The ^3He from this PC was transferred to the PC-TSC-572(20:38-23:20). The initial pressure of the PC-1100 was 1010 Torr on INV-pressure gauge. The final pressure in the PC-TSC1-572 (630 Torr) agreed with the estimated value(644 Torr).

(2) Cooling down of ISS with He refrigerator
Cooling down of four columns of ISS was parallelly performed in parallel with the procedures (1).

(3) Setup of FCU
Cooling of FCU MSB-1 and 2 (to 75K) was performed during procedures (1).

(4) Loading tritium from UTB to process loop

(i) Temperature controllers of UB-2 and 5 were changed from 498K to 573K at 8:00, and raised to 673K at 21:00.

(ii) Isolated Columns I and T from UB-1 and 3, respectively at 23:31.

(iii) Loading from UB-2 and 5 started at 23:46 to the ISS columns H and D with their respective flow paths. The required time periods were 1.5hrs for UB-2 and 6 hrs for UB-5, respectively. Maximum pressure in ISS reached 800 Torr.

(iv) Heating of UB1 and 3 started after completion of ^3He stripping procedures.

- Set temperature controllers to 473K at 01:00, June 23. Both UBs reached the temperature within 1 hr.
  - Increase the temperatures to 673K. About 2 hrs required to reach the temperature.

(5) Problems

(i) Plugging occurred at feed position(A2) of the ISS column I during the first stage of T_2 loading(with PC-TSC1-572) and 3He stripping. The feed point was changed from A2 to A1 in the column I to continue ^{3}He stripping. To open the plug, column I was warmed up to 50K and D_2 gas from UB-5 was put into the column through the plugging position(A1).
Cooling down of FCU-MSB1 and 2 were started to remove impurities in the process loop.

(ii) A tritium leak was found in the FCU(valve connection around MSB).

(iii)Large Liq.N_2 leak occurred at the outlet nozzle at the top of the MSB1. Temporary work to stop the leak was done by removing FCU glovebox window.

June 23(Tue)

(1) Loading tritium from UB-1 and 3
Loading of tritium from UB-1 to ISS column-I, and from UB-3 to column-T started at 06:35. The required time periods of each loading were 11 hrs and 7 hrs, respectively.

(2) Two additional PCs(TSC-648 ; 9.367g-T_2, TSC-664 ; 9.188g-T_2) were attached to LIO (TSC-572 and 1100 were removed).

(3) A preliminary regeneration test of FCU-MSB2 was performed:
- Warmed up to 100K, and evacuated with TP1(scroll pump) to FCU-MSB2.
- At above 120K, FCU-MSB1 was evacuated to TWT through house vacuum, and was purged with He. Approximately 100Ci of tritium was routed to the TWT.
- At above 300K, the purge was again done resulting in a tritium release of 150Ci to the TWT.

(4) Full loop operation was started at 21:30. The flow path in the MSB3(ambient temperature) was started at 21:50.

(5) Problems

(i) The maximum temperature of the TWT catalytic reactor was in the range of 450 C to 510 C and could not be increased to 550 C required to obtain high conversion of tritiated hydrocarbons(mainly methane). No solution was found during this milestone run.

(ii) The radiation level(RMEX) of the exhaust gas from TWT reached 8mCi/m^3.

June 24(Wed)

(1) Set up FCU
   (i) Regeneration of the FCU-MSB2 was completed.
   (ii) Adjustment of FCU-CR1 temperature control was continued because of the temperature fluctuation between 473K and 573K.
   (iii) Cooling down of MSB1 freezer was started and the temperature controller was set at 423K.
   (iv) MSB3 was cooled with liq.N_2.

(2) ^3He stripping from the top of column H in the ISS was carried out for 90 min(started at 11:00, flow rate was approximately 250 STP-cm^3/min). The helium was routed to the TWT through the effluent manifold.

(3) Addition of T_2 to the process loop
Tritium gas was added to the process loop from PC-1101 (started at 13:40) and 664(started at 18:50) with the same procedures done previously.
The total tritium inventory in the loop reached 82g.

(4) Stripping ^3He from process loop
   (i) The ^3He in the process loop was withdrawn from the top of the column H(CLHA line) and sent to the TWT. The tritium level in the CLHA stream was less than 1Ci/liter.
   (ii) Approximately 70 STP-liters through CLHA line were removed from the process loop.

(5) Process loop operation was continued, and efforts to stabilize the ISS(pressures, liquid levels, flow balance, etc) were major tasks.

(6) Others
   (i) Gas analysis of ISS with GC(on-line gas chromatograph) was carried out to determine the current characteristics of ISS separation performance.
   (ii) TWT dryer MSBD was taken offline and MSBA placed online at 20:00. By this change the radiation level of TWT output(RMEX) decreased from 8mCi/m^3 to 0.8mCi/m^3. This fact indicated the initial level 8mCi/m^3 was due to low levels of tritiated water vapor bleeding from the TWT MSBD.

(7) Problems
   (i) Problems with the temperature controller on FCU-CR1 were solved.

June 25(Thu)

(1) Loop operation was continued.
   (i) Many adjustments were performed to get a steady state of the ISS. GC measurements on the ISS indicated that the

compositions in columns are not as expected because of great fluctuation of the liquid levels and flow balance in each column.

(ii) Approximately 35-liters of H_2 was added to the process loop through PC-TSC3-1101(at 9:00). It took about 20min. The purpose is to make ^3He separation better in the column H. The withdrawal(300STP-cm^3/min) of ^3He and H_2 from the top of column H to the TWT was carried out from the initiation of H_2 addition, and continued for approximately 3hrs. Maximum tritium level in the stream was 12Ci/liter.

(iii) Gas analysis at the outlet of the FCU-MSB1 indicated that D_2/T_2 ratio was 3 (the ratio 1 is the desirable condition).

(2) Addition of tritium to process loop

Additional tritium was loaded from another T_2 gas cylinder(PC-648). The system tritium inventory reached 91.1g.

(3) Problems

(i) Tritium leak developed in one of the ISS rupture disks connections. A "hat", so that the glovebox purge exhaust was routed through the "hut" to the TWT, was placed over the leaking connection to reduce tritium level in the glovebox(ISS-GB1).

June 26(Fri)

(1) Loop operation

(i) Stabilization efforts and gas analysis on the ISS were continued in the morning.

(ii) injection of impurity(90%N_2-10%CH_4-H_2, 60 STP-cm^3/min) to FCU(MSB1) through TP3 and TP1 was initiated at 10:18(about 20 min).

(2) Emergency shutdown

Increase of He refrigerant temperature followed by rapid increase of ISS operating pressures were observed at about 10:30. The reason for the abnormal situation was determined to be a problem with the He refrigerator resulting in loss of refrigeration power. The ISS emergency shutdown procedures were immediately performed(at 10:41) after finding the reason of the pressure increase in ISS. Operation of the FCU was halted during the emergency procedures. Hydrogen isotope gases in the ISS were smoothly recovered by the UTB.

Maximum system pressure reached about 2.8 atm before the initiation of the emergency shutdown.

(3) FCU operation

When the system pressure dropped to approximately 1 atm, FCU was isolated from the process loop and operated with the FCU circulation mode for a short time period. Gas analysis on the

FCU with Raman Laser spectroscopy(off line analysis) was performed(at 16:00) to determine the impurity removal characteristics of the cryogenic adsorption bed(MSB1). The circulation was scrammed at 17:23.

(4) Shutdown of FCU

Opened a path through UTB-ISS-FCU-TP3-TP1, and circulated gas through the path to recover as much as hydrogen isotopes from He/impurity stream. The circulation was continued until the system pressure reached 200 Torr, then TP1 and TP3 were isolated. During that operation, warming up of all MSBs(1, 2 and 3) was performed to desorb hydrogen isotope gases and impurities from the molecular sieve beds.

Attachment IV ABBREVIVATIONS

INV	:	Inventory Control System
INV-P-LOAD	:	Tritium loading pressure at the INV
UTB	:	Uranium Tritide Bed system
UTB-T-UB1 - UB5	:	Temperature of uranium beds in the UTB
ISS	:	Isotope Separation System
ISS-GAN	:	Gas Analysis System
ISS-P-CLIA, A2	:	Pressure of the ISS cloumn I
ISS-P-CLHA, A2	:	Pressure of the ISS column H
ISS-P-CLDA, A2	:	Pressure of the ISS column D
ISS-P-CLTA, A2	:	Pressure of the ISS column T
ISS-T-CLIA	:	Condenser temperature of the column I
ISS-T-CLHA	:	Condenser temperature of the column H
ISS-T-CLDA	:	Condenser temperature of the column D
ISS-T-CLTA	:	Condenser temperature of the column T
ISS-T-CLI	:	Packed section temperature of the column I
ISS-T-CLH	:	Packed section temperature of the column H
ISS-T-CLT	:	Packed section temperature of the column D
ISS-T-CLD	:	Packed section temperature of the column T
ISS-T-CLIB	:	Reboiler temperature of the column I
ISS-T-CLHB	:	Reboiler temperature of the column H
ISS-T-CLDB	:	Reboiler temperature of the column D
ISS-T-CLTB	:	Reboiler temperature of the column T
ISS-Q-CLI	:	Liquid level in the column I
ISS-Q-CLH	:	Liquid level in the column H
ISS-Q-CLD	:	Liquid level in the column D
ISS-Q-CLT	:	Liquid level in the column T
ISS-W-HTI	:	Heater output of the column I reboiler
ISS-W-HTH	:	Heater output of the column H reboiler
ISS-W-HTD	:	Heater output of the column D reboiler
ISS-W-HTT	:	Heater output of the column T reboiler
ISS-T-HESUP	:	ISS inlet temperature of He refrigerant
ISS-T-HEDIS	:	ISS outlet temperature of He refrigerant
TP3-P-D_2	:	Pressure of D_2 stream at the TP3 inlet
TP3-P-DT	:	Pressure of DT stream at the TP3 inlet
TP3-P-T_2	:	Pressure of T_2 stream at the TP3 inlet
TP3-F-D_2	:	Flow rate of D_2 stream at the TP3 inlet
TP3-F-DT	:	Flow rate of DT stream at the TP3 inlet
TP3-F-T_2	:	Flow rate of T_2 stream at the TP3 inlet
TP3-F-DIS	:	Flow rate of TP3 discharge
FCU	:	Fuel Cleanup System
FCU-GAN	:	Gas Analysis System
FCU-P-CR1	:	Pressure of the catalytic reactor
FCU-P-MSB1	:	Pressure of the molecular sieve bed-1
FCU-P-MSB2	:	Pressure of the molecular sieve bed-2
FCU-P-MSB3	:	Pressure of the molecular sieve bed-3

TWT	:	Tritium Waste Treatment System
TWT-P-LPR1	:	Pressure of the low pressure receiver
TWT-T-RECA1	:	Temperature of the TWT recombiner
TWT-T-GGXA	:	Temperature of the heat exchanger
TWT-STATUS	:	Status of TWT operation mode
TWT-RECYCLE-LIMIT	:	Radiation limit to start circulation mode
TWT-RECYCLE-RESET	:	Radiation limit to start stacking mode
INV-RAD-GB1	:	Radiation level in the INV glovebox
TPU-RAD-GB1	:	Radiation level in the TP1, 2 glovebox
TPU-RAD-GB2	:	Radiation level in the TP3 glovebox
ISS-RAD-GB1	:	Radiation level in the ISS glovebox
ISS-RAD-GB2	:	Radiation level in the ISS-GAN glovebox
ISS-RAD-GB3	:	Radiation level in the UTB
ISS-CD-GB	:	Command signal for glovebox purging
FCU-RAD-GB1	:	Radiation level in the FCU glovebox
FCU-CD-GB	:	Command signal for glovebox purging
TWT-RAD-LPR	:	Radiation level in the TWT-LPR
TWT-RAD-RECYCLE	:	Radiation level at the TWT-MSBs outlet
TWT-RAD-RMEX	:	Radiation level at the TWT outlet
TWT-DF	:	Decontamination factor of the TWT
TM-R-RM1	:	Room radiation level at the FCU-MEZ
TM-R-RM2	:	Room radiation level at the FCU-PIT
TM-R-RM3	:	Room radiation level at the ISS-MEZ
TM-R-RM4	:	Room radiation level at the VAC-North
TM-R-RM5	:	Room radiation level at the VAC-South
TM-R-RM6	:	Room radiation level at the SWD glovebox
FCU-MEZ	:	Mezzanine located over the FCU glovebox
FCU-PIT	:	Pit area for the FCU glovebox
ISS-MEZ	:	Mezzanine for the ISS and ISS-GB1 and 2
SWD glovebox	:	Glovebox used for solid waste disposal
VEN-R-STK	:	Radiation level of the stack exhaust gas
VEN-R-STKI	:	Integrated radiation level of stack exhaust gas