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SEPAC System Test in NASDA Space Chamber

By

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1.0 INTRODUCTION

1.1 PURPOSE

This is a report on the test results of SEPAC EMI (Electromagnetic Interference), Charge-up and FO (Functional Objective) operation testing performed in the NASDA (National Space Development Agency) Space Chamber located at Tsukuba, Japan.

1.2 SCOPE

At the 3rd SEPAC NASDA space chamber test, the following test items were conducted.

1) EMI test: Evaluation of the effects of EMI when both the electron beam and the MPD arcjet are fired. Obtained data are regarded as reference ones, because effect of chamber wall cannot be accurately estimated.
2) Charge-up test: Evaluation of the electrical charge-up which occurs when the electron beam is emitted by analyzing data from probes, the pallet potential and return current monitor. Charge neutralization is augmented by MPD or NGP operation.
3) FO operation test: Studying the influence of beam/plasma emission on all FO's operating in the vacuum environment.

This report includes the data of the testing described above as well as SEPAC FM equipment operation data which shows whether SEPAC FM equipments were operated correctly during EMI and charge-up testing.

1.2.1 Science Data and PC Training Result

This report does not include the science data and PC (Payload Crew) training result which will be submitted as other documents.

1.2.2 Open Item Disposition

Items which requires remedy or further action for improvement are identified in this report.

2.0 Applicable Documents

2.1 NASA DOCUMENT

- ° SLP/2104, Spacelab Payload Accommodation Handbook
- ° MSFC-SPEC-521, Electromagnetic Compatibility Requirements on Spacelab Payload Equipment
- ° MIL-STD-462
- ° MORD

2.3 SEPAC DOCUMENT

- ° SEPAC-TR-101-ET
- ° SE-11, SEPAC Instrument System Performance Definition
- ° SE-41, SEPAC Manual
- ° SEPAC Flight Applications Software Design Specification (SDS Rev. 4)
- ° DEP Specification (74W00168)
- ° SEPAC Interface Unit Requirements and Capabilities Document (Feb. 1979)
- ° VT/FT Test Report (SE-1052E)

2.4 NASDA CHAMBER TEST DOCUMENT

- ° The 3rd SEPAC NASDA Space Chamber Test Plan (SE-1047)
- ° The 3rd SEPAC NASDA Space Chamber Test Spec. (SE-1048)

3.0 Test Conduct

3.1 LOCATION AND DATES

The tests have been performed at Large Space Chamber Building of NASDA Located at Tsukuba, Japan. The result of test conduct is shown in Table 3.1-1. The tests have been carried out almost on schedule.
Minor change against test schedule are:

1) PC training had extra half day by request from Payload Crew.
2) EMI test had extra half day for trouble shooting.
3) Charge-up test period was shortened by having obtained charge-up data successfully without consuming spare time.

3.2 TEST CONFIGURATION

Two configurations were used during the NASDA Chamber Testing the first being the EMI and second the charge-up. FO operation testing was conducted using the same configuration as the charge-up.

Block diagram and Power line connections are shown in Fig. 3.2-1～2.

TABLE 3.1-1 (1/2) NASDA CHAMBER TEST PROGRESS

		NOV. 1	2	3	4	5	6	7	8	9	10	11	12	13	14
					Dustproof Cover for 5M Chamber-door Assembling & Installation						Shroud Cover Installation				
											Power Line Cabling		Isolation Rooms Installation		
NOV. 15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Carry Equipments into Chamber Bld.								Electrical Check	EMI Test under Atomospheric Condition					
			Cables Connection & Antennas Setting												
		Insert Pallet to Chamber													
	Pallet Transfer														
			Antenna Poles Setting												
		FM Equip. Mounting													

TABLE 3.1-1 (2/2) NASDA CHAMBER TEST PROGRESS

DEC. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		14:00					13:00	9:00			14:00		9:00	19:00	
Final Check	Leak Check	Evacuation		EMI Test			Repress		Configuration Change		Evacuation		PC Training		
Cold Plate Setting												FO Operation & Charge-up			
DEC. 17	18	19	20	21	22	23	24	25							
	10:00	9:00													
FO Ope. & Charge-up		Repress		Remove Pallet from Chamber											
		Pack for CD		Dismount FM Equip. from Pallet											
		Review													
	Disassembling & Transportation Cleaning														

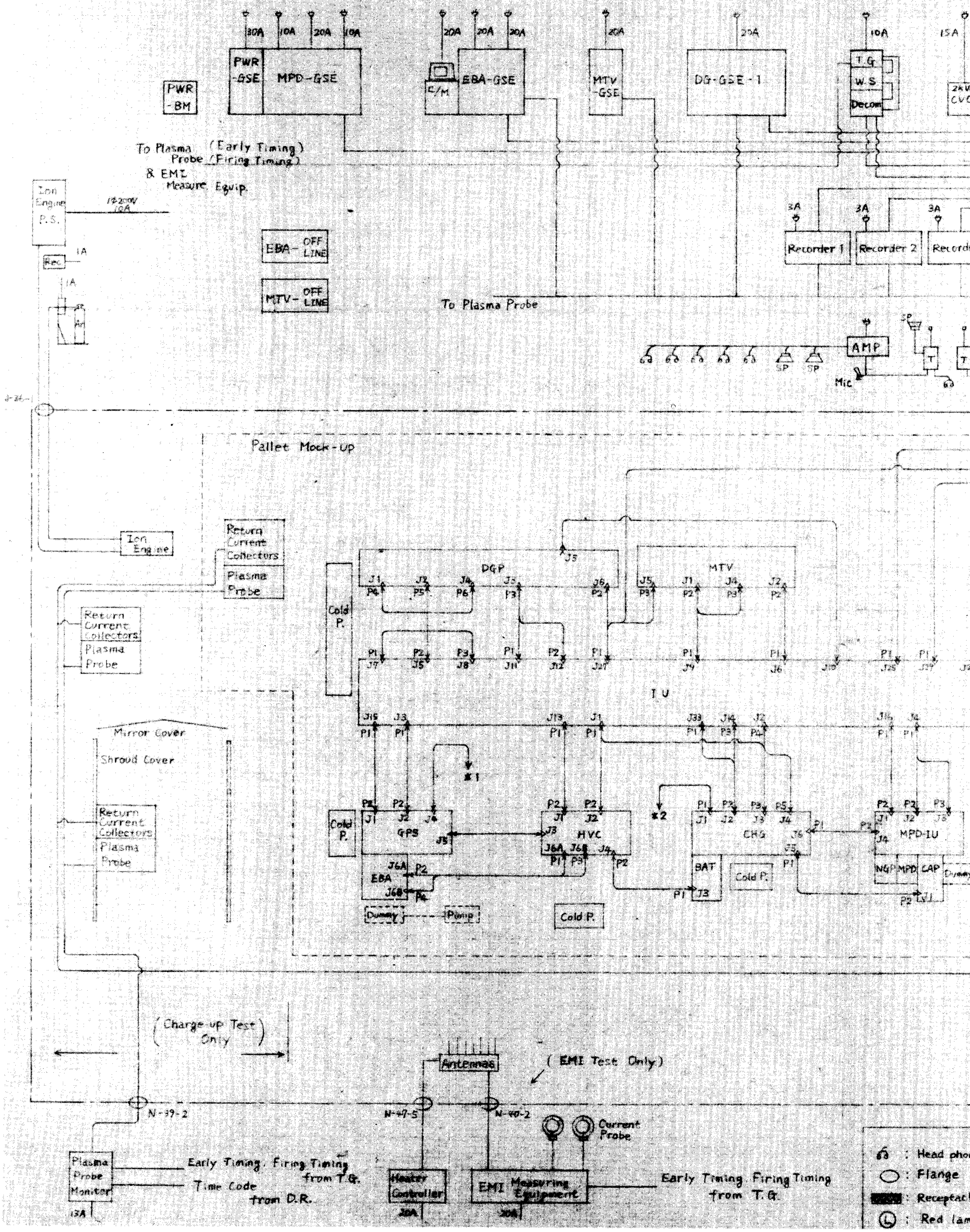
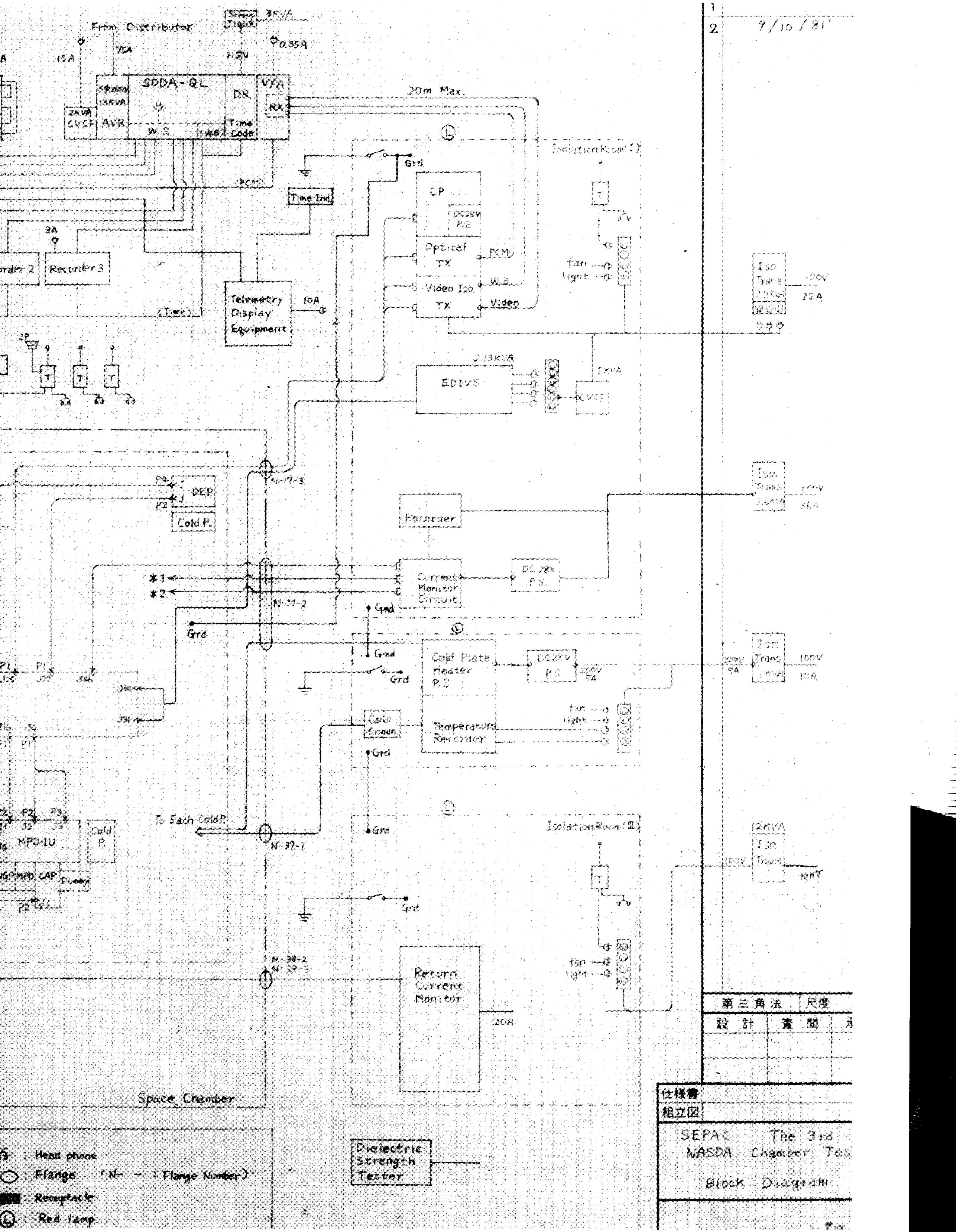


FIG. 3.2.1 SEPAC THE 3D NASDA CHA



NASDA CHAMBER TEST.

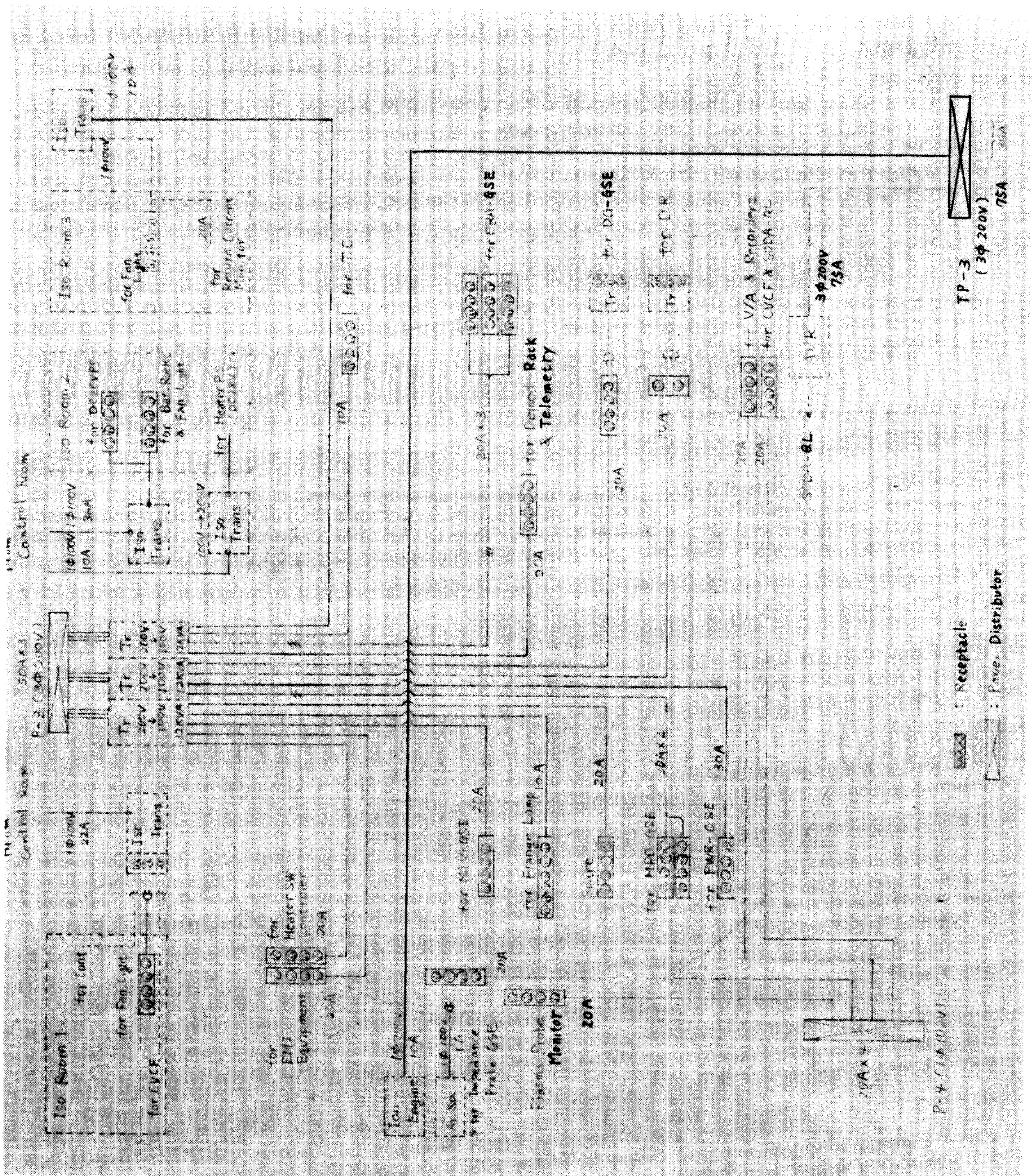


FIG. 3.2.2 SEPAC NASDA CHAMBER TEST Power Line Connections.

3.2.1 EMI Test

Figures 3.2.1-1 and 2 show instrument layout inside and outside the Chamber for EMI test Figure 3.2.1-3 is the block diagram of EMI test system and antenna. Figure 3.2.1-4 show the mechanical set up of antennas and Figure 3.2.1-4 indicates the distances between antennas and MPD/EBA.

Antennas that cover 30 MHz to 10 GHz were installed near MPD and EBA respectively but rod antennas that cover 14 KHz to 30 MHz were setted at one place. GSE's were arranged around the chamber as shown in Figure 3.2.1-5.

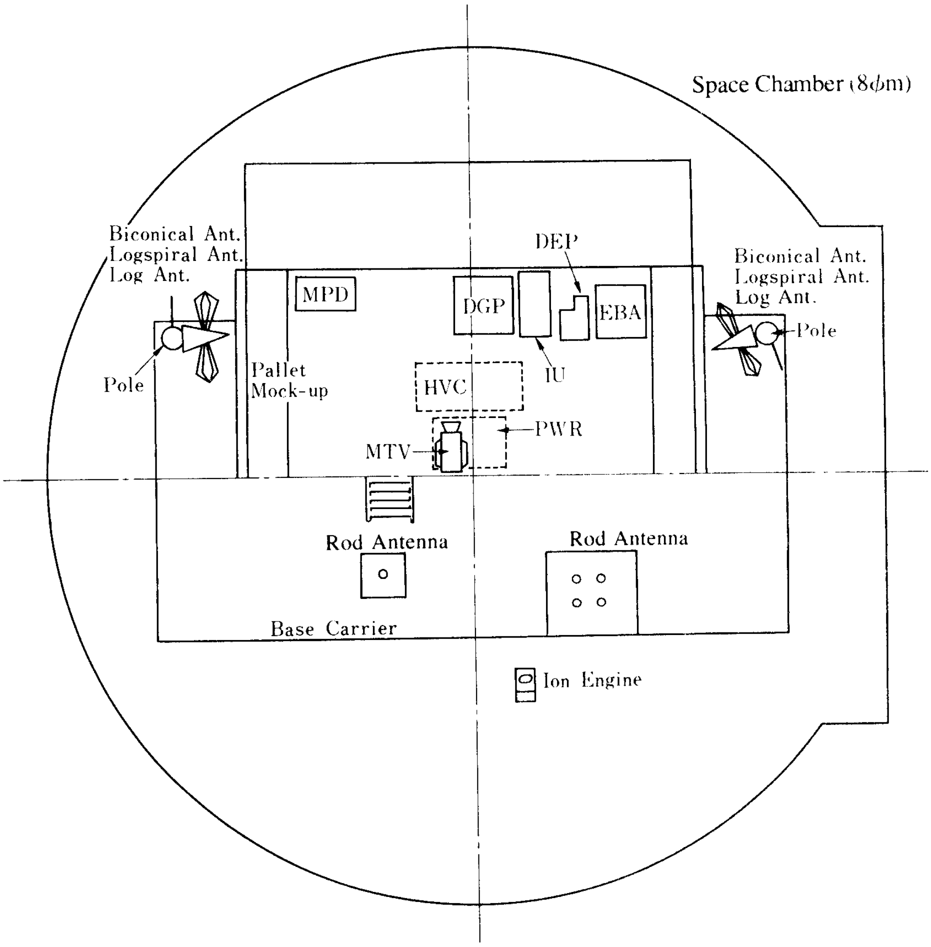


FIG. 3.2.1-1 Layout inside Space Chamber for EMI Test.

3.2.2 Charge-up Test

The experimental configuration is shown in Figure 3.2.2-1. The SEPAC FM instruments in the space chamber together with a simulated pallet could be isolated electrically from the chamber. All ground support equipments directly connected to FM instruments were also isolated from the ground in three isolated rooms. The chamber was evacuated to around 10^{-7} Torr. The isolation resistance was larger than 10G ohm.

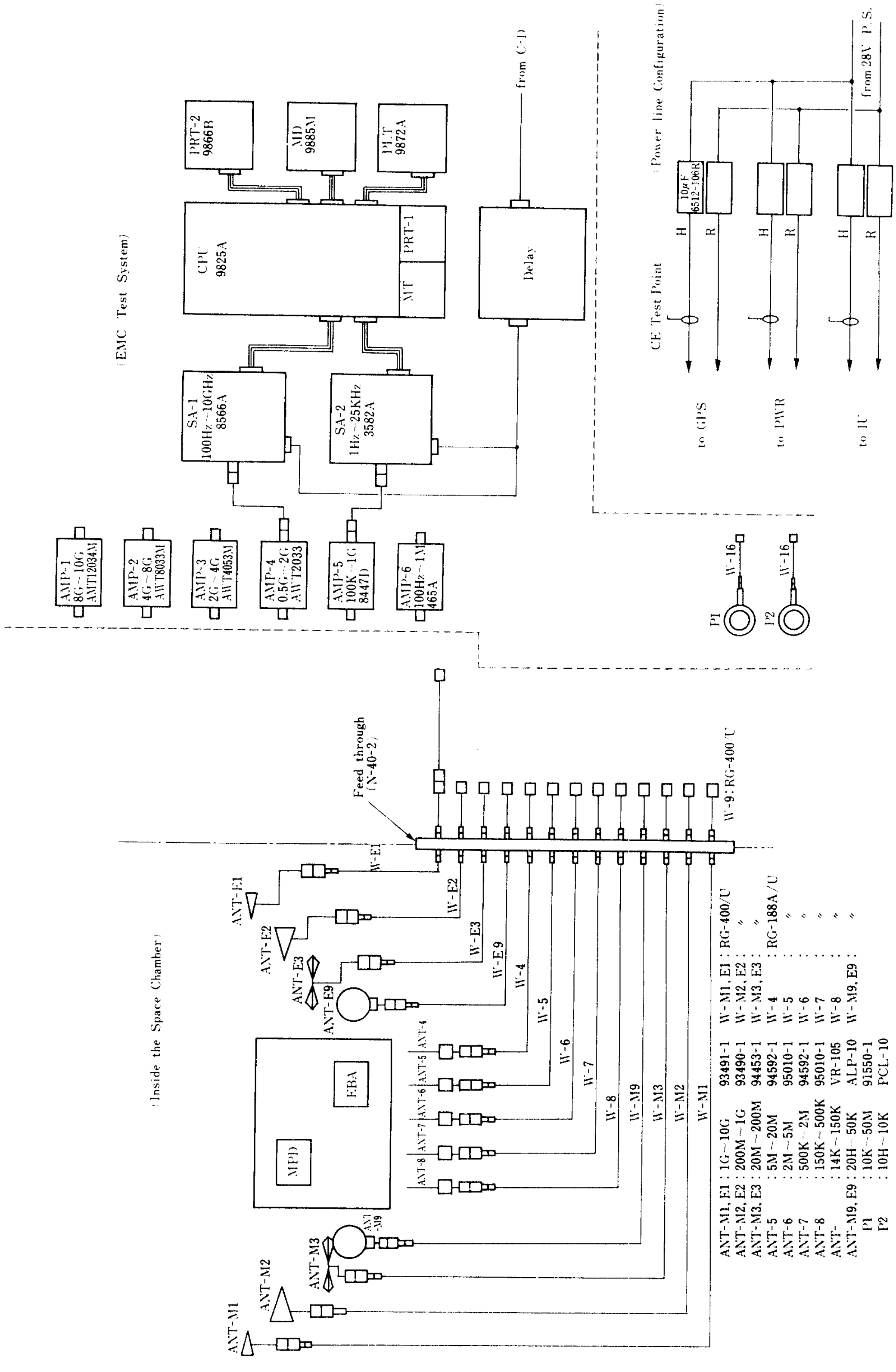


FIG. 3.2.1-2 EMI Test system Block Diagram.

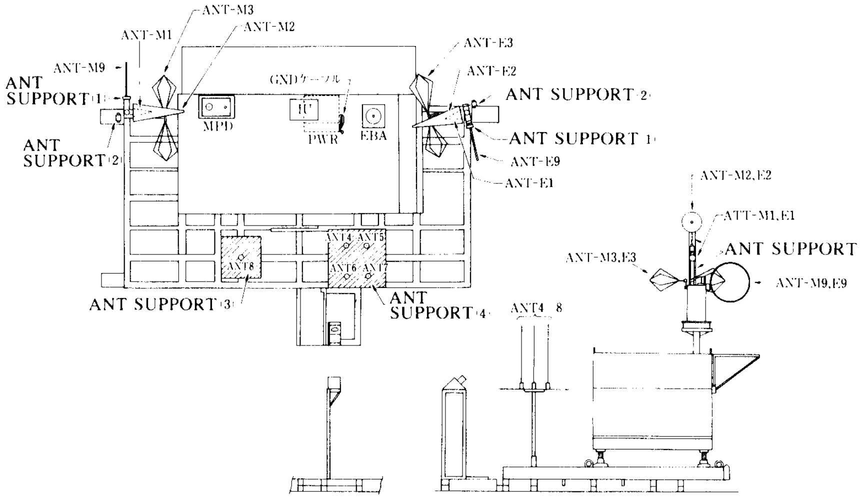


FIG. 3.2.1-3 EMI Test antennas Mechanical setup.

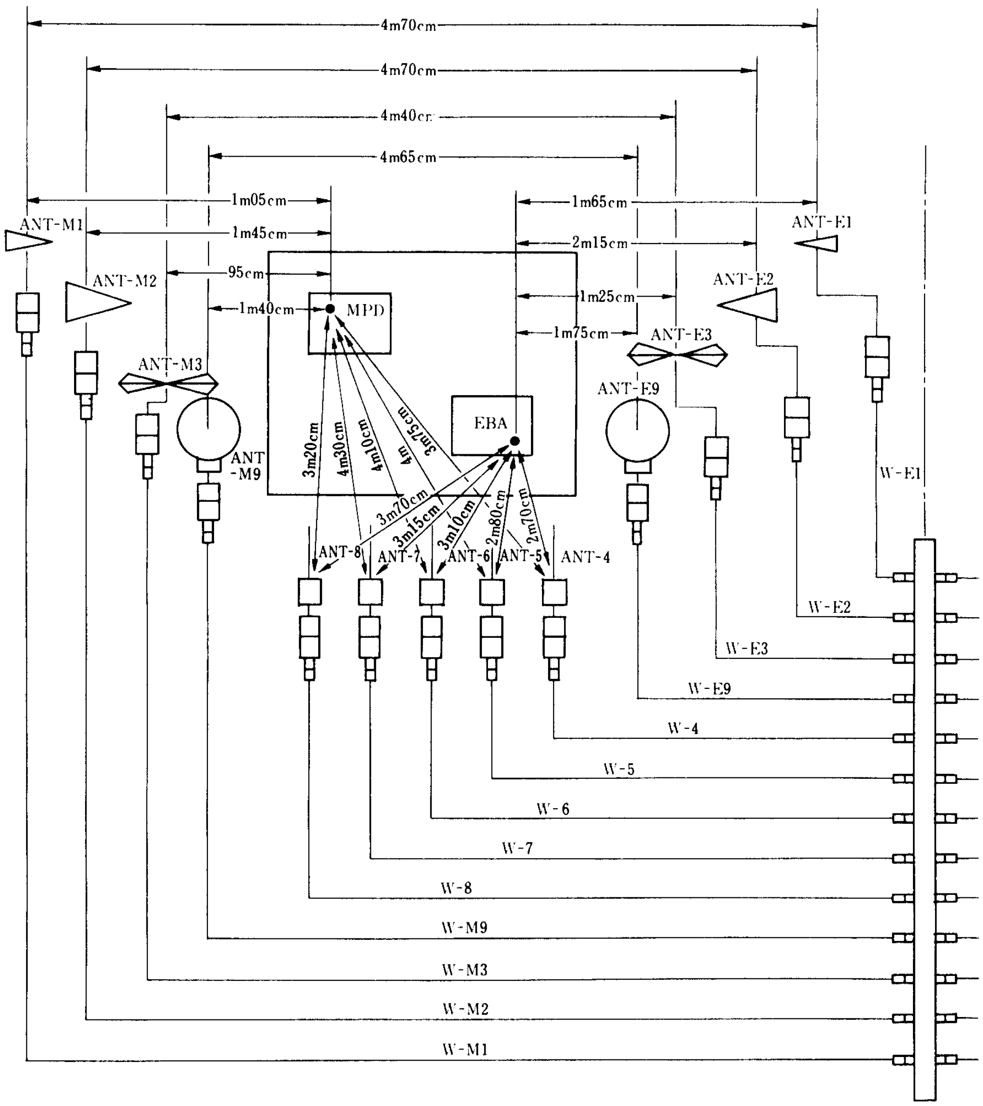


FIG. 3.2.1-4 Location of EMI Test antennas.

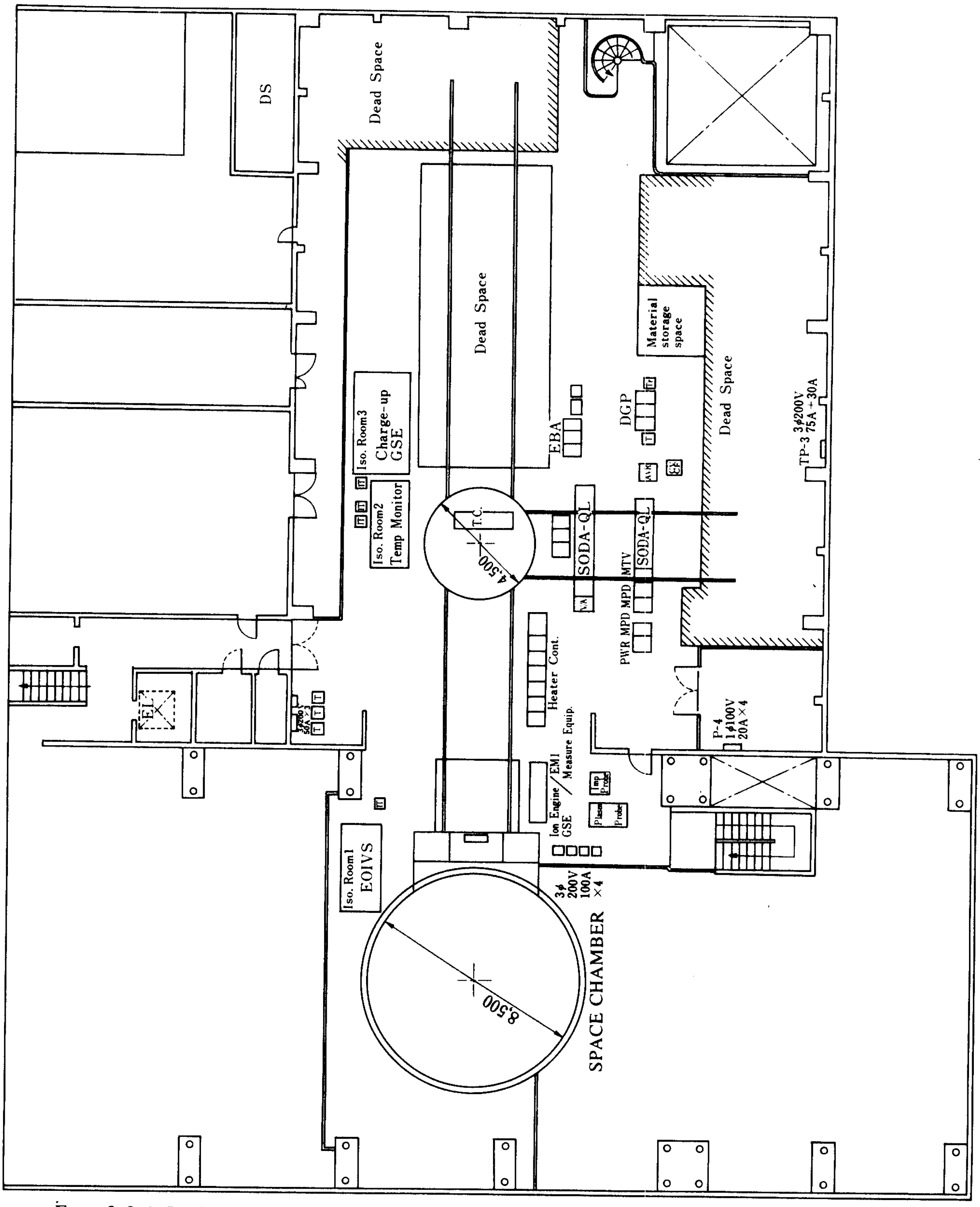


FIG. 3.2.1-5 SEPAC NASDA CHAMBER TEST Floor Layout for Charge-up/FO Ope Test.

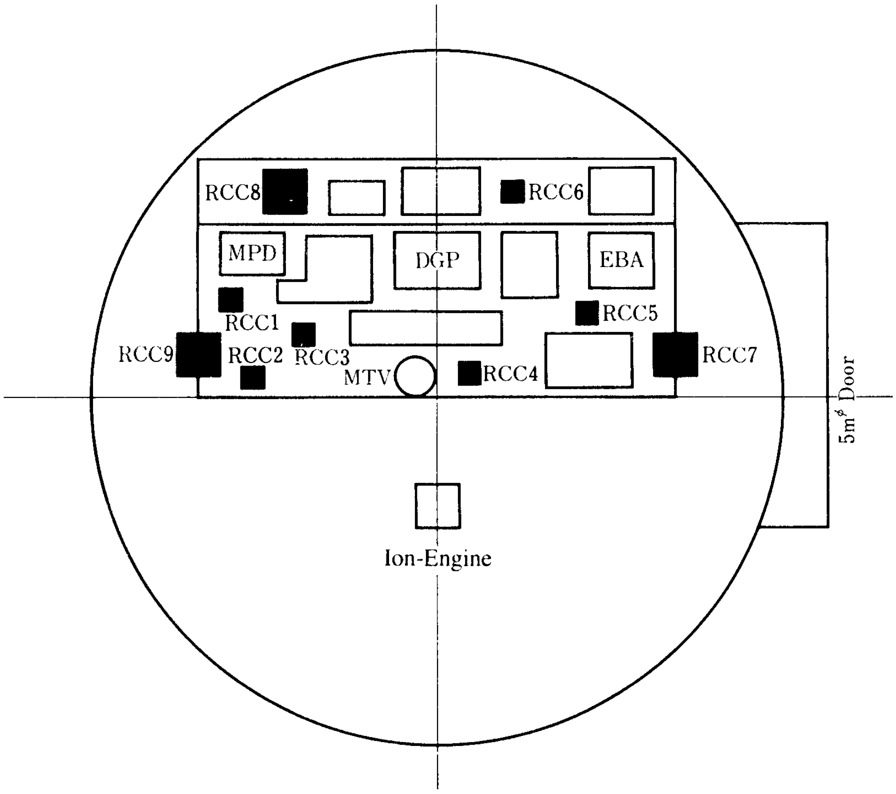


FIG. 3.2.2-1 Layout inside Space Chamber for Charge-up Test.

Diagnostics were as follows:

i) Pallet—Chamber wall potential difference

ii) Return current collectors (distributed on the pallet)

iii) Langmuir probes (distributed on the chamber wall)

iv) Flight Diagnostic Package (DGP)

Floating probes

Electron energy analyser

Wave detectors

3.3 METHOD OF TESTING

Each test was carried out according to the following order.

1) EMI test at atmospheric environment,
2) EMI test at vacuum environment,
3) FO Operation test at vacuum environment,
4) Charge-up test at vacuum environment.

3.3.1 EMI Test

Noise levels were measured by automated EMC test system of Mitsubishi Electric Corp. using digital spectrum analyzers and a micro-computor. Measuring parameters such as frequency and band width were controlled by S/W which was prepared by Mitsubishi Electric Corp. for this test.

Entire frequency region was divided into measuring units as shown in Table 3.3.1-1 by antenna and preamplifier limitation. In each measuring unit, noise level data was taken with one or two entire sweep in principle. Narrow band noises of radiated electrical fields (RE02) were distinguished by comparing the levels of the data taken by different band width. Broadband noises of radiated electrical fields (RE02) were normalized to 1 MHz band width.

All measured noise levels were corrected with antenna factors, calbe losses, preamplifier gain and distance and plotted.

From 5 MHz to 200 MHz, antenna factors were measured after antennas were fixed because space chamber wall causes some resonace effects and changes antenna factors from that measured in ideal condition. Distance correction was done to indicate the noise level at 1 meter from EBA and MPD.

The timing relation between start time of sweep and EBA fire is shown in Figure 3.3.1-1. Delay and sweep times were fixed to 0.15 sec. and 0.8 sec. and measured only steady firing period. EBA firing parameters were fixed at 7.5 KV, 1.6 A and MPD firing parameters were fixed to 480 V charge and 3 ATM propellant reservoir

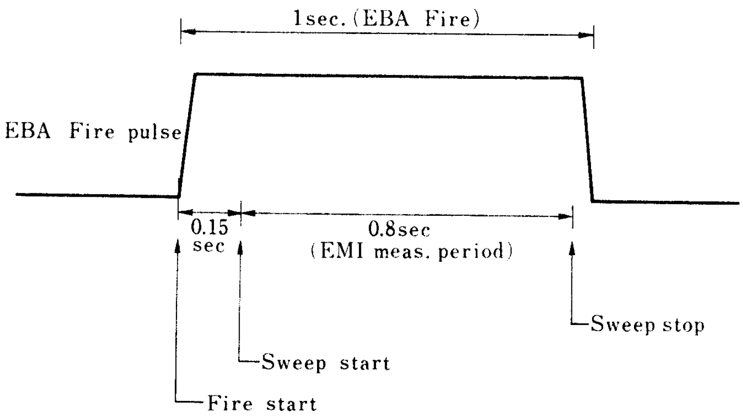


FIG. 3.3.1-1 EBA Fire and EMI measurement period.

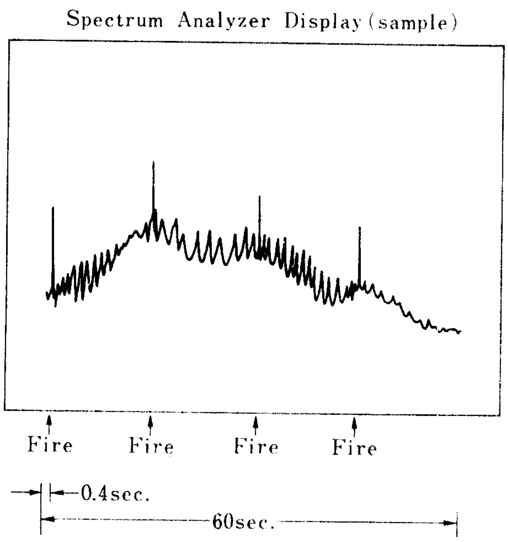


FIG. 3.3.1-2 MPD Fire and Spectrum Amalyzer Display.

pressure. EBA firing duration was 1 sec. or 0.1 sec. according to the test mode. MPD firing duration was fixed to 1 msec.

The feature of measuring the noise level of MPD firing is shown in Figure 3.3.1-2. Sweep rate is low and only the levels at MPD/EBA firing are effective. Delay time between the beginning of sweep and the first fire is fixed to 0.4 sec.

The frequency region from 20 Hz to 20 KHz especially for CE01 measurement, Fast Fóurier Transformation type digital spectrum analyzer was used. The pulsive noise from EBA/MPD fire was converted into frequency domain data so that the effective noise level data became continuous.

EMI noise level measurement of EBA/MPD fire was performed twice, once for dummy load operation in atmospheric condition and the other time for plasma ejection in vacuum condition to distinguish the effect of plasma.

The space chamber wall were cooled down by liquid nitrogen to keep vacuum condition during plasma ejection, so that most of critical points of antennas and coaxial cables were covered with thermal shields and warmed by heaters to maintain moderate temperature.

TABLE 3.3.1-1 Measuring frequency division

RE02	Unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Narrow Band Noise	Start freq.	14 KHz	150 KHz	500 KHz	2.0 MHz	5.0 MHz	30 MHz	200 MHz	500 MHz	1.0 GHz	1.77 GHz	2.0 GHz	2.3 GHz	4.0 GHz	8.0 GHz
	Stop freq.	150 KHz	500 KHz	2.0 MHz	5.0 MHz	30 MHz	200 MHz	500 MHz	1.0 GHz	1.77 GHz	2.0 GHz	2.3 GHz	4.0 GHz	8.0 GHz	10.0 GHz

RE02	Unit	1	2	3	4	5	6	7	8	9	10	11	12
Broad Band Noise	Start freq.	14 KHz	150 KHz	500 KHz	2.0 MHz	5.0 MHz	30 MHz	200 MHz	500 MHz	1.0 GHz	2.0 GHz	4.0 GHz	8.0 GHz
	Stop freq.	150 KHz	500 KHz	2.0 MHz	5.0 MHz	30 MHz	200 MHz	500 MHz	1.0 GHz	2.0 GHz	4.0 GHz	8.0 GHz	10.0 GHz

CE01/03	Unit	1	2	3	4	5	6
Narrow Band Noise	Start freq.	0 Hz	0 Hz	0 Hz	10.0 KHz	20 KHz	1.0 MHz
	Stop freq.	100 Hz	1.0 KHz	10.0 KHz	20.0 KHz	1.0 MHz	50 MHz

3.3.2 Charge up Test

The experiment modes were as follows:

i) Ground mode

ii) Floating mode in vacuum

iii) Floating mode with MPD arcjet neutralization

iv) Floating mode with NGP neutralization
v) Floating mode in ambient plasma produced by an ion thruster (provided by National Aerospace Laboratory)

3.3.3 FO Operation Test

Normal operation of FM equipment under vacuum condition was verified by monitoring PCM data, Wide band data and Video data. All FO's with PCF, SMO, Hold/Restart, shutdown and MFO operation were used to check FM equipment condition.

3.4 LIST OF ATTENDEES

Following organizations attended at the present test.

General Test Conductor/PI: Institute of Space and Astronautical Science (ISAS) and National Space Development Agency (NASDA),
Test Chief: ISAS and NASDA,
System: ISAS and Nippon Electric Co., Ltd. (NEC),
EMI: NASDA, Electrotechnical Laboratory (ETL) and Mitsubishi Electric Corporation (MELCO),
Charge-up: ISAS, National Aerospace Laboratory (NAL),
CD Subsystem: NASA Marshall Space Flight Center (MSFC), Southwest Research Institute (SwRI), Intermetrics Incorporated (Intermetrics) and NEC,
EBA/HVC Subsystem: Toshiba Corporation Ltd. (Toshiba),
MPD Subsystem: MELCO, Mitsubishi Heavy Industries Ltd. (MHI) and Meisei Electric Co., Ltd. (MEC),
PWR Subsystem: MELCO and Furukawa Battery Co., Ltd. (Furukawa),
DGP Subsystem: NEC and MEC,
MTV Subsystem: Toshiba,
SODA QL System: SwRI and Nippon Electronics Development Co., Ltd. (NED),
General Setup: Ushio Inc. (Ushio), Yushiya Manufacturing Co., Ltd. (Yushiya) and Unizon Electronics Co., Ltd. (Unizon).

4.0 PERFORMANCE ANOMALY

4.1 SOFTWARE

Prior to NASDA Chamber Test, the software prepared by NASA MSFC has been verified by CD individual running test/debug conducted at MSFC and system level check at Tsukuba, Japan to validate open action items which occurred at VT/FT. The verified software described above was used at SEPAC NASDA Chamber Test.

Some troubles of software and new requirements for software have been found out and decided by SEPAC team. Other software change requirements were requested by Payload Crew after PC training. Most of them were corrected and incorporated into software. Remaining open action items including new requirements will be closed by the starting of LEVEL IV Test.

4.2 HARDWARE

Prior to Chamber Test, troubles found out at VT/FT were fixed at Re-verification Test conducted at Tsukuba, but some other problems were found out during Chamber Test. The detailed explanations is given below.

4.2.1 Equipment Arrangement

The test equipment arrangement has been slightly changed from original plan. At charge-up test, ion engine GSE was set at the location of EMI measuring equipment at EMI test in order to shorten the cable length between ion engine and GSE.

4.2.2 Test Configuration

Power Supply for FM equipments was located in Isolation Room (I) instead of Iso. Room (II) in order to reduce the voltage drop by cable resistance as much as possible.

4.2.3 Individual Equipment

The following are items to be recorded here as special remark for individual equipment conditions.

4.2.3.1 DGP

The following major problems were found before the NASDA chamber test and all of them were confirmed to be fixed at that test.

PHO filter did not work.
PHO angle wobbled sometimes.
EPARCL input impedance was wrong.

On the other hand, the following problem was found during the test. The cause of the problem seems to be the slight abnormal voltage in the PLP amplifier. However, the abnormal voltage affects only the temperature monitor signals, LPT and FPTEMN. Because it will need much time to fix it, we will not fix it.

Temperature monitor signals LPT and FPTEMN for PLP sometimes represented abnormal values.

4.2.3.2 MTV

MTV worked as intended during the test except IRIS trouble. IRIS got out of control either by manual or DEP software on the second day of charging test. After the trouble occurred, the light control was performed only by sensitivity control. It was found after the test that it was caused by bad contact at the brush of IRIS motor. The repair and associated test have completed in January 1982.

4.2.3.3 EBA and HVC

EBA and HVC were operated without trouble. The performance deviation concerning electron emission condition was incorporated to modify EBA operation. The modified operation procedure was verified by this test.

4.2.3.4 PWR

Initially PWR Flight Model was planned to be used for this test. Because of overall schedule slip, Backup Model of PWR Assembly which had been completed and successfully tested in parallel with the VT/FT activities was available and used for this test.

This unit was designed, fabricated and tested according to exactly same specification, for the purpose to be the flight backup for PWR Flight Model of Spacelab One mission. This test provided the Backup Model with proper opportunity to verify the performance in combined operation with HVC and MPD as well as to accumulate operating time of new battery cells.

4.2.3.5 MPD

The major anomalies related to MPD were as follows.

1) TR-245: MPD gas leak in chamber,
2) TR-248: Fuse in CAP was broken.

The MPD gas leakage was caused by the inaccurate seating of metal plug in the gas-charging port. The plug seat was remachined and no leakage was proved. After a month long test of CAP fuse, the replacement of some of the fuses was concluded to be done at KSC prior to the Level IV integration.

4.2.3.6 CD

CD Subsystem (IU, DEP, FM cables), except for the software, showed following problems during the chamber test period.

1) FM cable name tag problem,
2) EMI level over spec.,
3) BML data noise,
4) System stop and command delay,
5) Hot isolation problem,
6) Power line for MTV in IU problem,

Most of these problems were solved during the chamber test period.

There remains yet the following action items which should be fixed by NASA MSFC prior to Level IV integration at KSC.

1) Conformal Coat DEP/IU Interface Board,
2) Remove the Test/Operate switches and plug the holes,
3) Replace MTV Fuses,
4) Touch up paint,
5) Blow flight software PROMs,
6) Investigate the hot isolation value,
7) SEPAC flight cable shielding,
8) IU function (internal software) changes depending on the results of PC change request analysis.

4.2.4 Test Condition

4.2.4.1 Vacuum

The space chamber has been operated by NASDA. The vacuum condition in the chamber was kept in the range of 10^{-6} and 10^{-7} throughout the test, when gas in not ejected. Vacuum data will be included in a separate data book.

4.2.4.2 Thermal

To keep equipments at operating temperatures against low temperature environment in the cryopumped space chamber, simulated Cold Plates warmed by electrical heater and thermostat. Anomaly occurred to two thermostats. But the temperatures of them were kept at specified value by manual control. The temperature data is contained in a separate data book.

4.3 MINOR CHANGE OF PROCEDURES

A minor change of test procedure was made by redline by the operator and reported daily to the Test Conductor before each test. But most of these changes were PCF parameters when EMI Level and charge-up were measured, and Hold/Restart timing and number so as to make the time of the measurement shorter.

5.0 Test Results

5.1 SUMMARY

The test results of SEPAC NASDA Space Chamber Test are summarized on Table 5.1-1. The detailed explanation about each test result is described item by item as follows:

Table 5.1-1 SEPAC NASDA space chamber result

No.	Item	Description	Result
1.	EMI Test	Evaluation of the effects of EMI when both the electron beam and the MPD arcjet are fired. Obtained data are dealt with reference ones, because effect of chamber wall cannot be correctly estimated.	
2.	Charge-up Test	Evaluation of the electrical charge up which occurs when the electron beam is emitted by analyzing data from probes, the pallet potential and return current monitor.	Good
3.	FO Operation Test	Studying the influence of beam/plasma emission on all FO's operating in the space environment.	Good

5.1.1 EMI Test Result

Test results of RE02, CE01/03 are summarized in Figure 5.1.1-1~Figure 5.1.1-23 according to the classification listed in table 5.1.1-1.

Measurement was exempted over 20 MHz region at RE02 standby mode because test results in the shield room showed no problems.

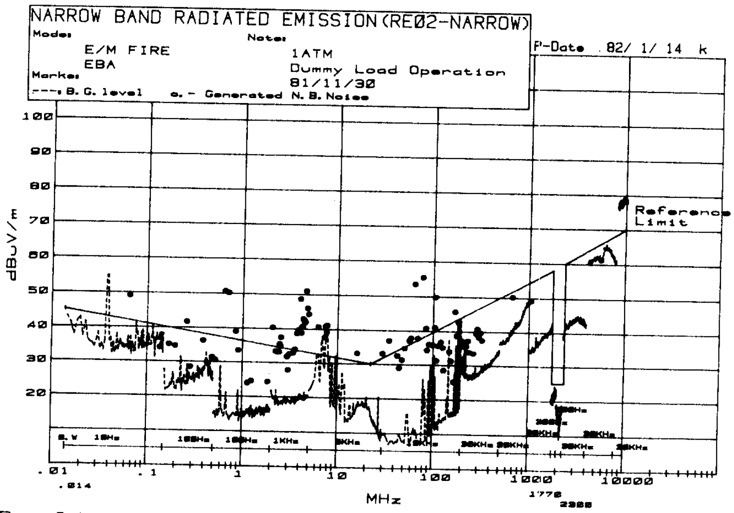


FIG. 5.1.1-1 EMI Result for EBA/MPD Fire, EBA Side, and RE02 Narrow Band Noise. Dummy Load Operation.

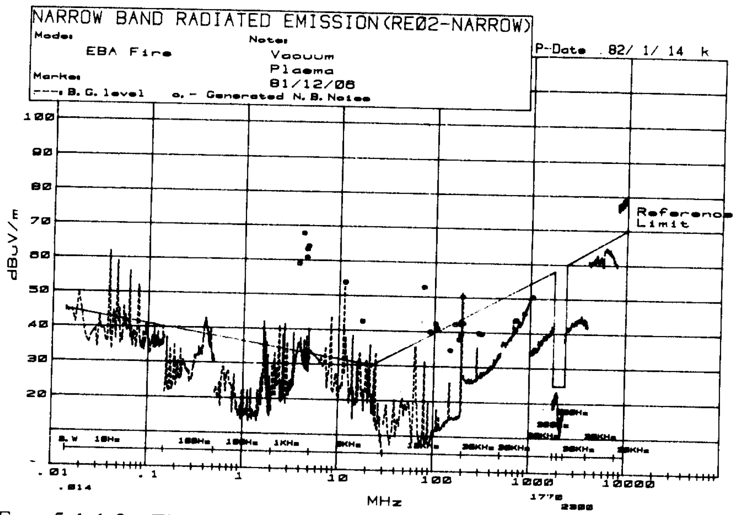


FIG. 5.1.1-2 EMI Result for EBA Fire, EBA Side, and RE02 Narrow Band Noise. Beam Ejection in Vacuum.

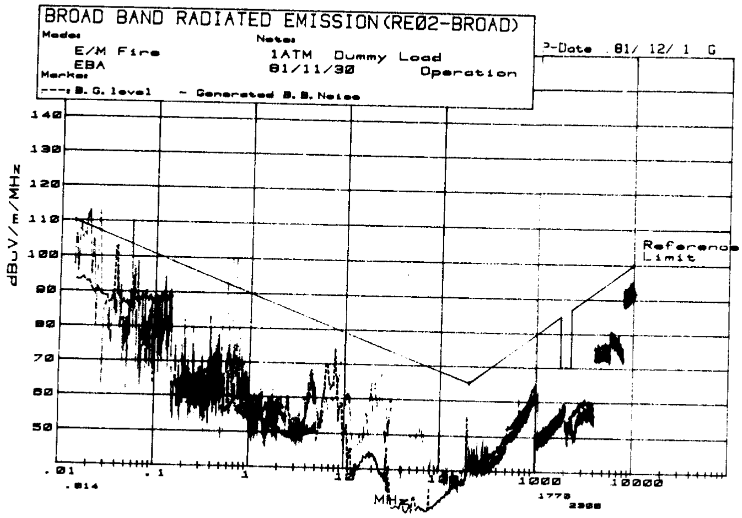


FIG. 5.1.1-3 EMI Result for EBA/MPD Fire, EBA Side, and RE02 Broad Band Noise. Dummy Load Operation.

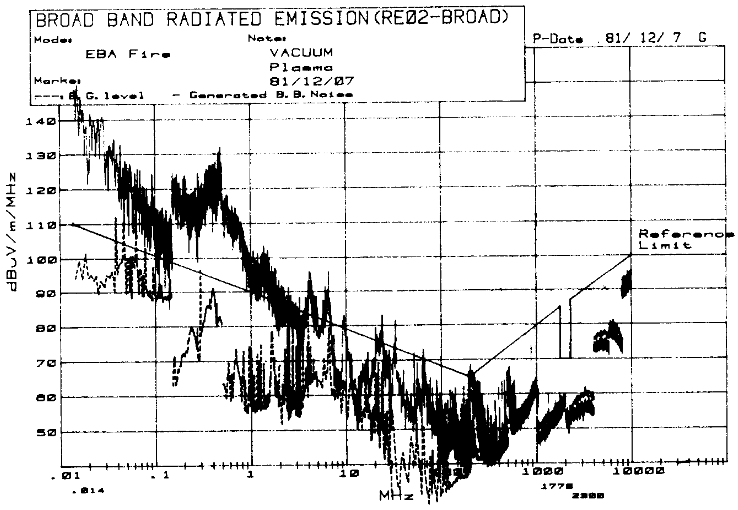


FIG. 5.1.1-4 EMI Result for EBA Fire, EBA Side, and RE02 Broad Band Noise. Beam Ejection in Vacuum.

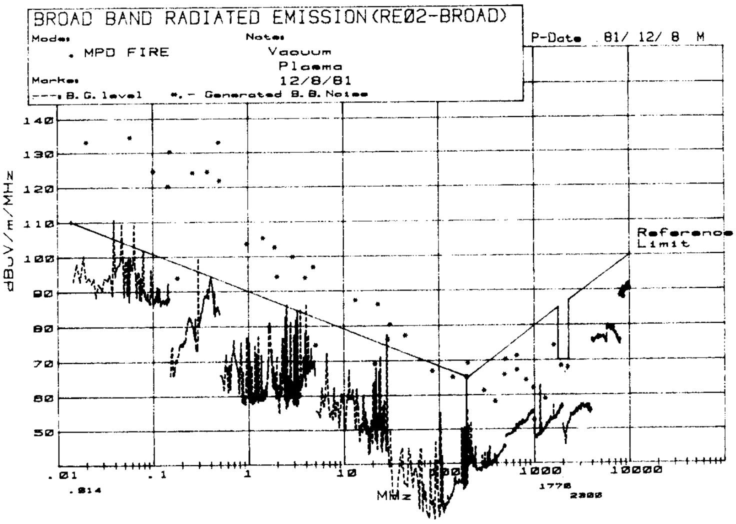


FIG. 5.1.1-5 EMI Result for MPD Fire, MPD Side, and RE02 Broad Band Noise. Dummy Load Operation.

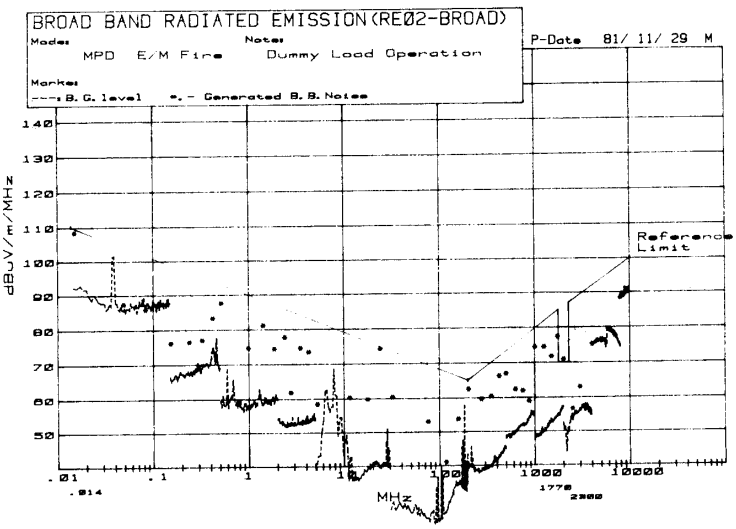


FIG. 5.1.1-6 EMI Result for EBA/MPD Fire, MPD Side, and RE02 Broad Band Noise. Beam and Plasma Ejection in Vacuum.

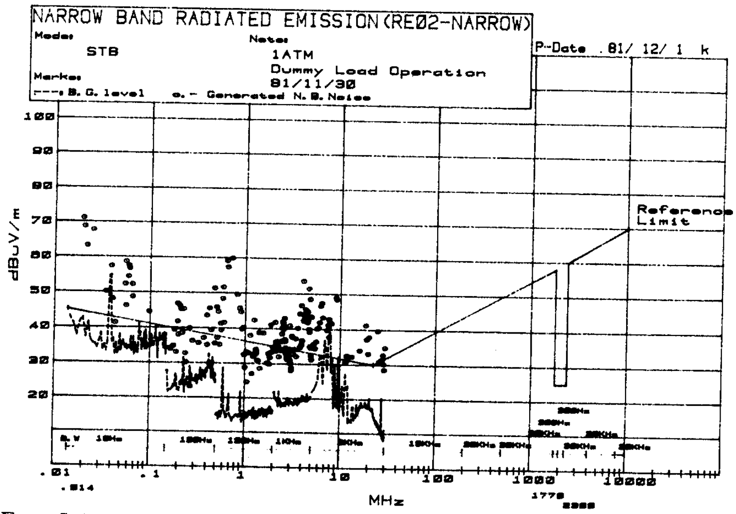


FIG. 5.1.1-7 EMI Result for Stand-by Mode. EBA Side, and RE02 Narrow Band Noise. Dummy Load Operation.

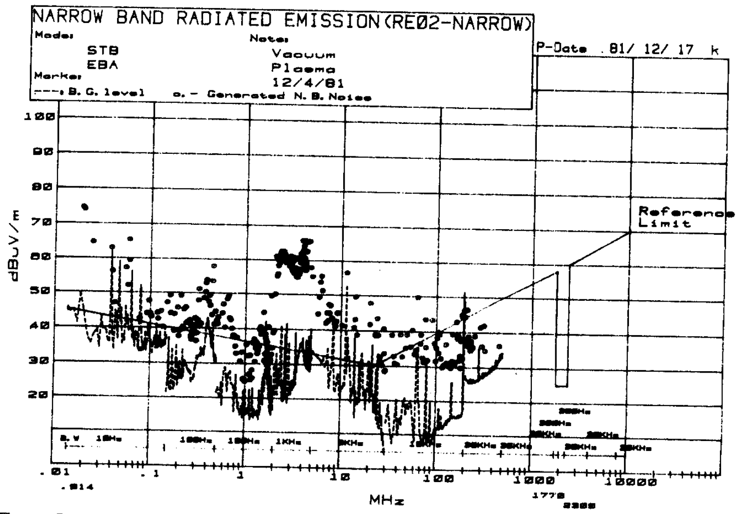


FIG. 5.1.1-8 EMI Result for Stand-by Mode. EBA Side, and RE02 Narrow Band Noise. In Vacuum.

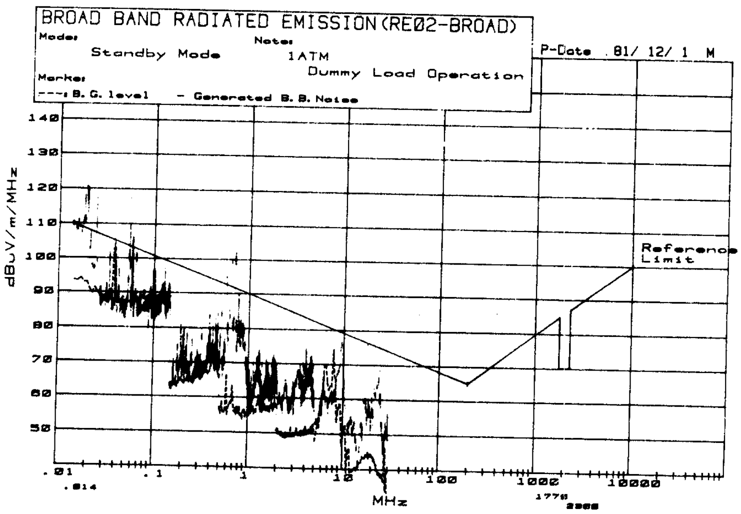


FIG. 5.1.1-9 EMI Result for Stand-by Mode. EBA Side, and RE02 Broad Band Noise. Dummy Load Operation.

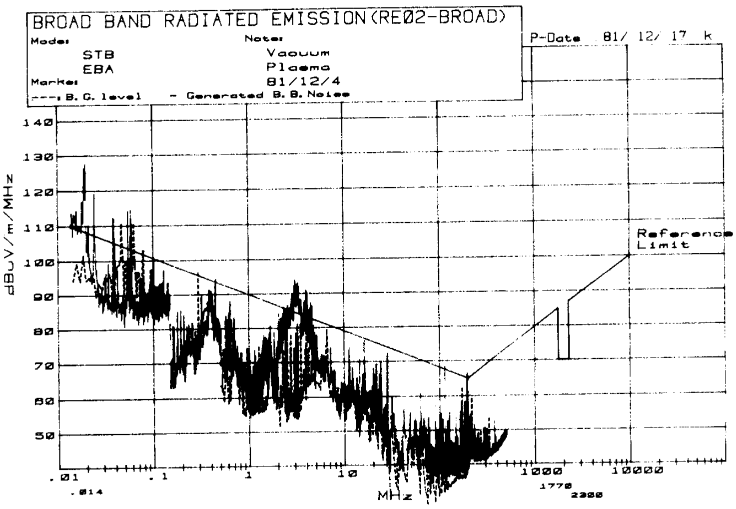


FIG. 5.1.1-10 EMI Result for Stand-by More. EBA Side, and RE02 Broad Band Noise. In Vacuum.

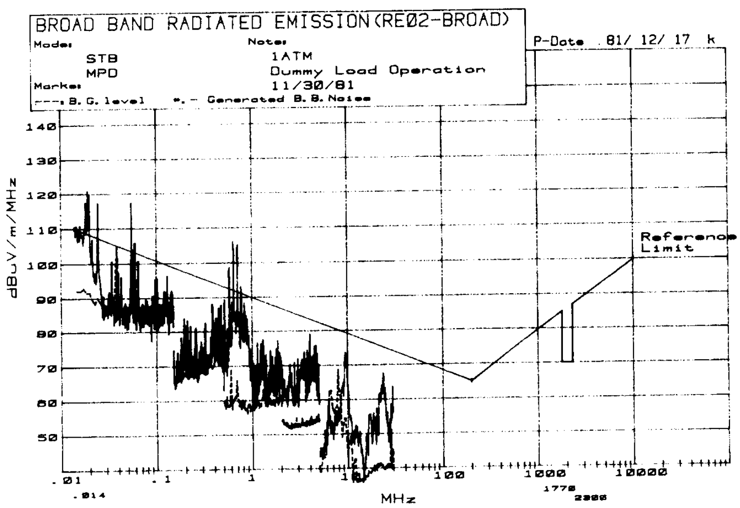


FIG. 5.1.1-11 EMI Result for Stand-by Mode. MPD Side, and RE02 Broad Band Noise. Dummy Load Operation.

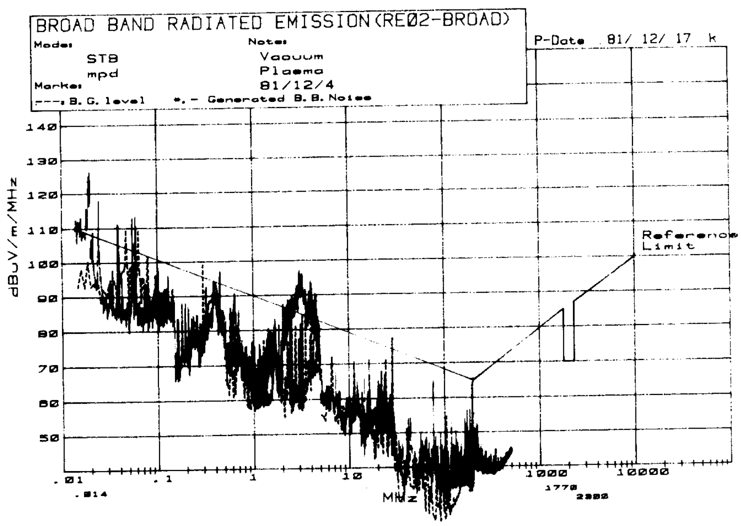


FIG. 5.1.1-12 EMI Result for Stand-by Mode. MPD Side, and RE02 Broad Band Noise. In Vacuum.

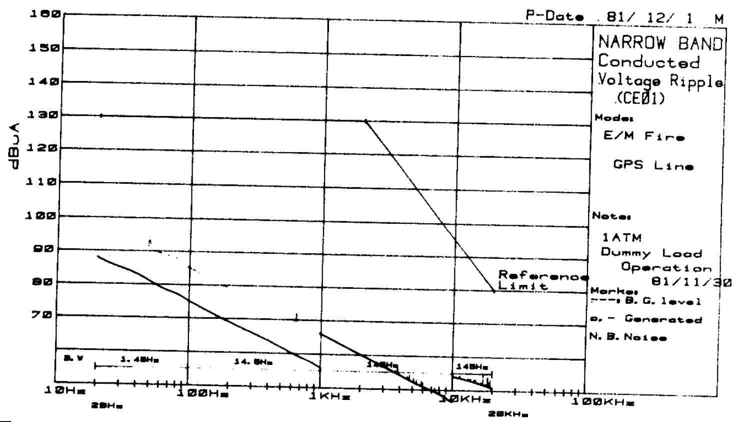


FIG. 5.1.1-13 EMI Result for EBA/MPD Fire, GPS Line, and CE01 Narrow Band Noise. Dummy Load Operation.

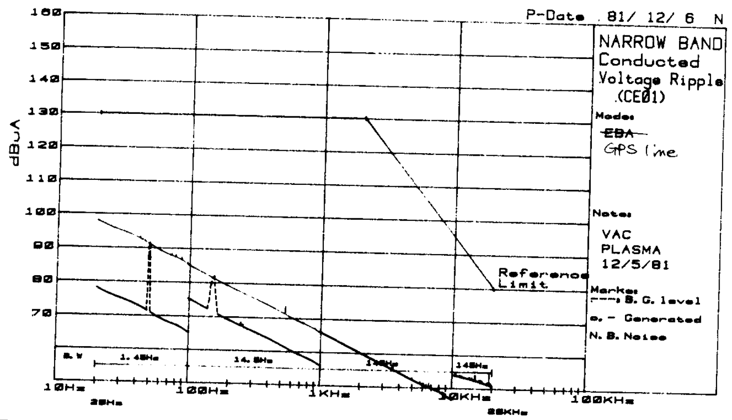


FIG. 5.1.1-14 EMI Result for EBA/MPD Fire, GPS Line, and CE01 Narrow Band Noise. Beam and Plasma Ejection in Vacuum.

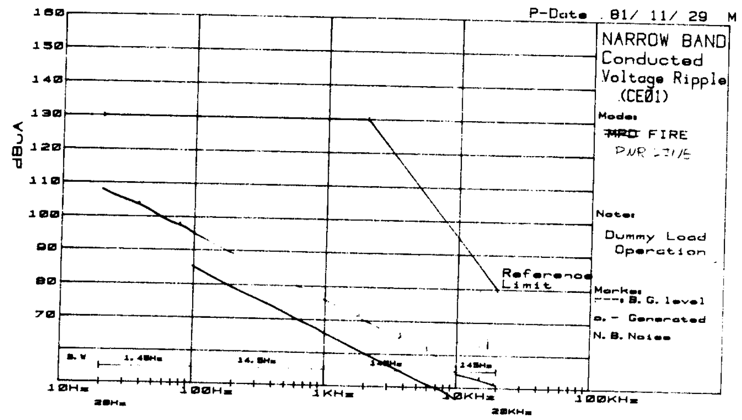


FIG. 5.1.1-15 EMI Result for EBA/MPD Fire, PWR Line, and CE01 Narrow Band Noise. Dummy Load Operation.

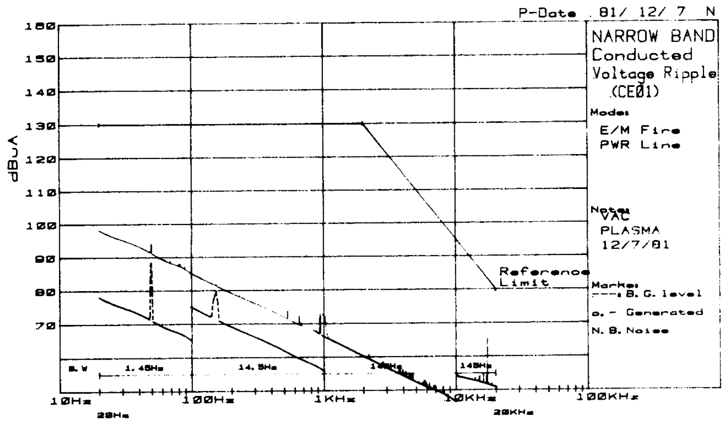


FIG. 5.1.1-16 EMI Result for EBA/MPD Fire, PWR Line, and CE01 Narrow Band Noise. Beam Ejection in Vacuum.

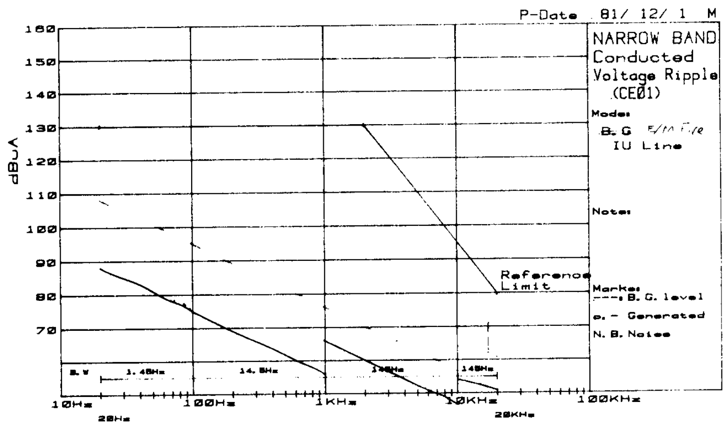


FIG. 5.1.1-17 EMI Result for EBA/MPD Fire, IU Line, and CE01 Narrow Band Noise. Dummy Load Operation.

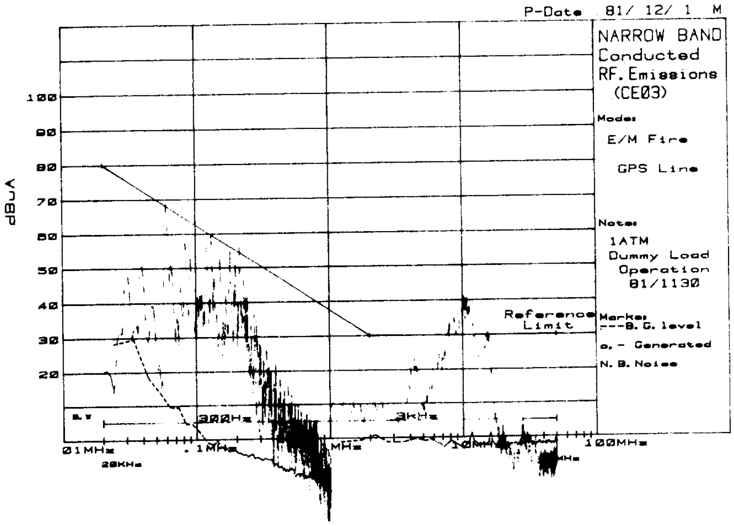


FIG. 5.1.1-18 EMI Result for EBA/MPD Fire, GPS Line, and CE03 Narrow Band Noise. Dummy Load Operation.

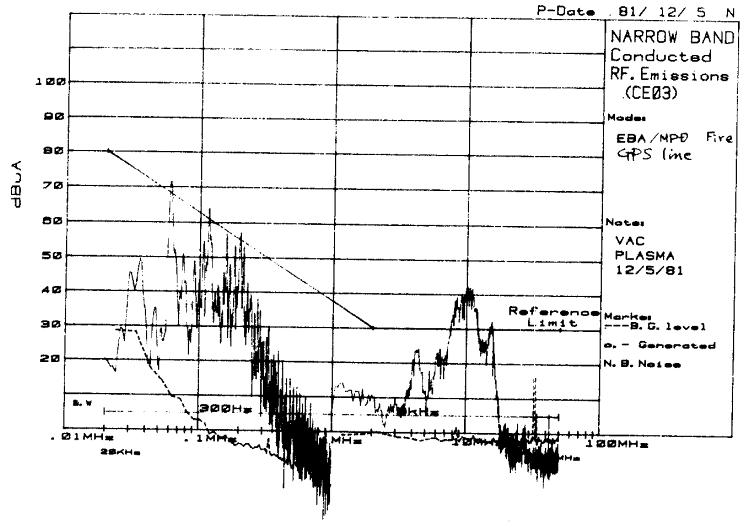


FIG. 5.1.1-19 EMI Result for EBA/MPD Fire, GPS Line, and CE03 Narrow Band Noise. Beam Ejection in Vacuum.

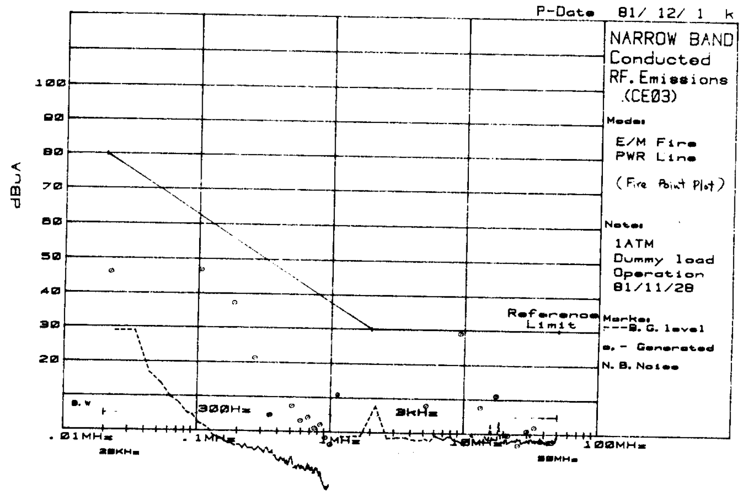


FIG. 5.1.1-20 EMI Result for EBA/MPD Fire, PWR Line, and CE03 Narrow Band Noise. Dummy Load Operation.

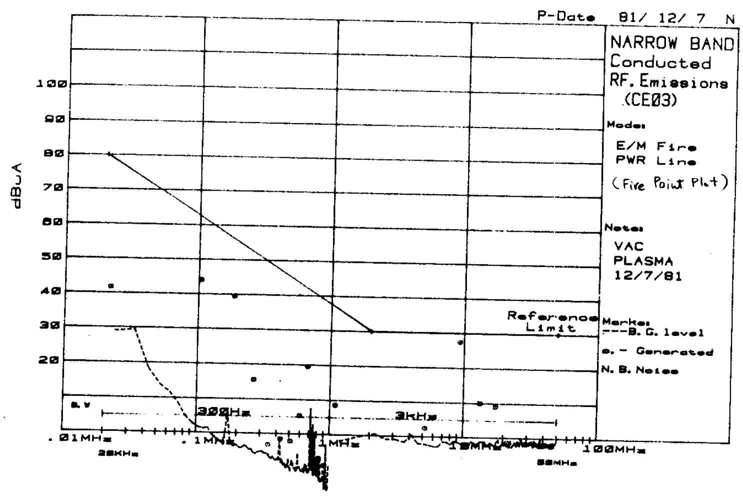


FIG. 5.1.1-21 EMI Result for EBA/MPD Fire, PWR Line, and CE03 Narrow Band Noise. Beam Ejection in Vacuum.

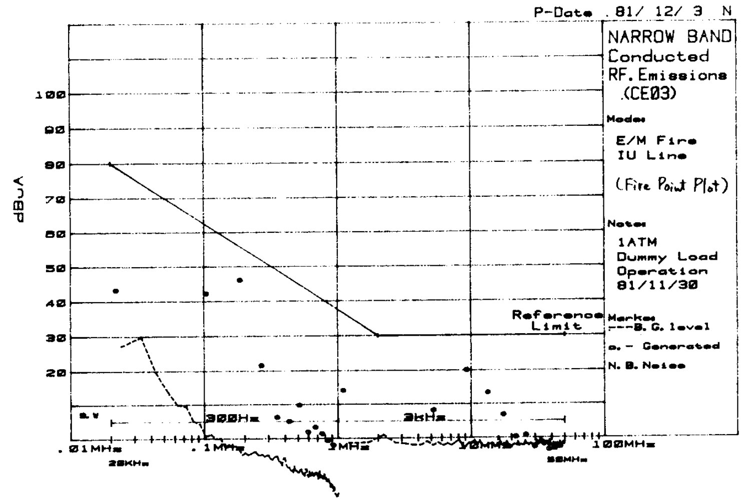


FIG. 5.1.1-22 EMI Result for EBA/MPD Fire, IU Line, and CE03 Narrow Band Noise. Dummy Load Operation.

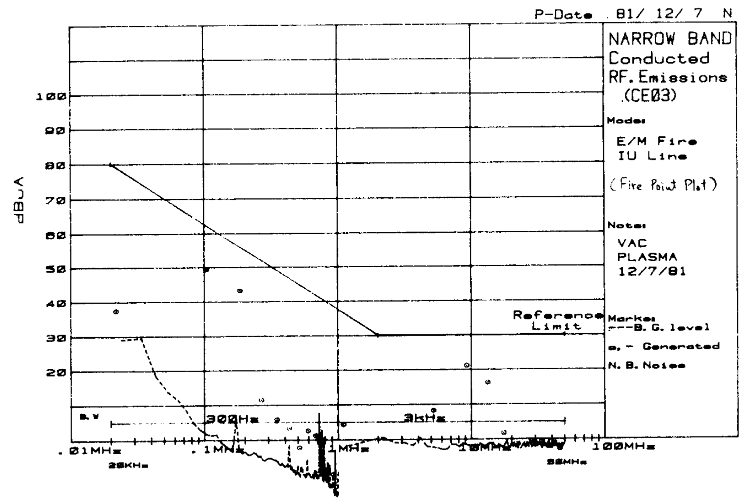


FIG. 5.1.1-23 EMI Result for EBA/MPD Fire, IU Line, and CE03 Narrow Band Noise. Beam Ejection in Vacuum.

5.1.2 Charge up Test Result

The floating potential of the pallet with respect to the chamber wall is shown in Figs. 5.1.2-1~4 as a function of the beam energy and beam current. In vacuum, the floating potential rises to the beam voltage irrespective of the beam current in the beam range SEPAC employs (Fig. 5.1.2-1). When MPD arcjet is fired, the floating potential drops for tens of milliseconds due to the neutralization of charging by MPD plasma. The floating potential recovers once due to the decay of MPD plasma in the space chamber of a finite size. After the plasma decay, Ar neutral gas from the MPD arcjet nozzle expands much slower than plasma filling the chamber to the pressure of 10^{-5} Torr. The floating potential drops again due to the ionization of this neutral gas and this lasts for about a second (Fig. 5.1.2-2).

The effect of NGP is shown in Fig. 5.1.2-3. When N_2 neutral gas is ejected from

TABLE 5.1.1-1 Classification of test results

	Classification	ANT/Probe Location	1 ATM Dummy load OP	Beam Ejection in Vacuum	Fire Cond
1	EBA/MPD Fire EBA side RE02 Narrow Band Noise	EBA	Fig. 5.1.1-1	Fig. 5.1.1-2	A
2	EBA/MPD Fire EBA side RE02 Broad Band Noise	EBA	Fig. 5.1.1-3	Fig. 5.1.1-4	A
3	EBA/MPD Fire MPD side RE02 Broad Band Noise	MPD	Fig. 5.1.1-5	Fig. 5.1.1-6	B
4	Stand by Mode EBA side RE02 Narrow Band Noise	EBA	Fig. 5.1.1-7	Fig. 5.1.1-8	C
5	Stand by Mode EBA side RE02 Broad Band Noise	EBA	Fig. 5.1.1-9	Fig. 5.1.1-10	C
6	Stand by Mode MPD side RE02 Broad Band Noise	MPD	Fig. 5.1.1-11	Fig. 5.1.1-12	C
7	EBA/MPD Fire MPD line CE01 Narrow Band Noise	GPS line	Fig. 5.1.1-13	Fig. 5.1.1-14	A
8	EBA/MPD Fire PWR line CE01 Narrow Band Noise	PWR line	Fig. 5.1.1-15	Fig. 5.1.1-16	B
9	EBA/MPD Fire IU line CE01 Narrow Band Noise	IU line	Fig. 5.1.1-17		B
10	EBA/MPD Fire GPS line CE03 Narrow Band Noise	GPS line	Fig. 5.1.1-18	Fig. 5.1.1-19	A
11	EBA/MPD Fire PWR line CE03 Narrow Band Noise	PWR line	Fig. 5.1.1-20	Fig. 5.1.1-21	B
12	EBA/MPD Fire IU line CE03 Narrow Band Noise	IU line	Fig. 5.1.1-22	Fig. 5.1.1-23	B

Remarks: Firing Conditions
- A: EBA 7.5 KV, 1.6 A, 1.0 sec. MPD 480 V, 3 ATM
- B: EBA 7.5 KV, 1.6 A, 0.1 sec. MPD 480 V, 3 ATM
- C: Not Firing Sweep time 60 sec. (RE02) or 180 sec. (CE03)

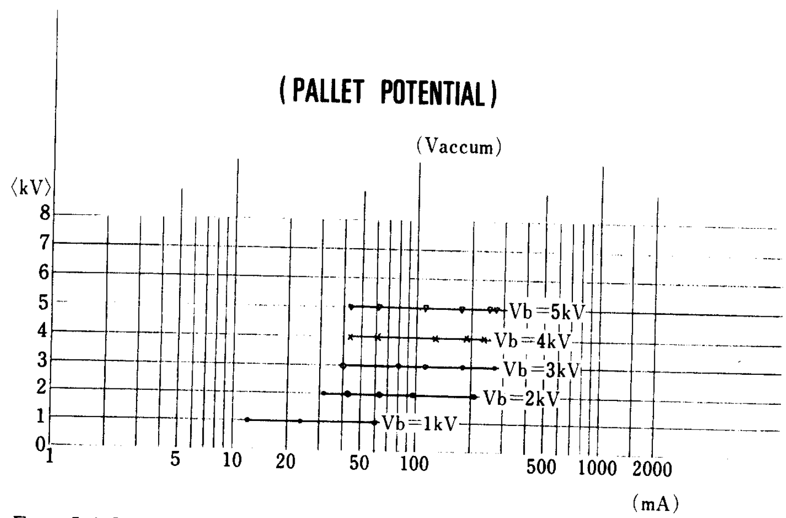


FIG. 5.1.2-1 Pallet potential as a function of beam current and voltage V_b. Operation in vacuum.

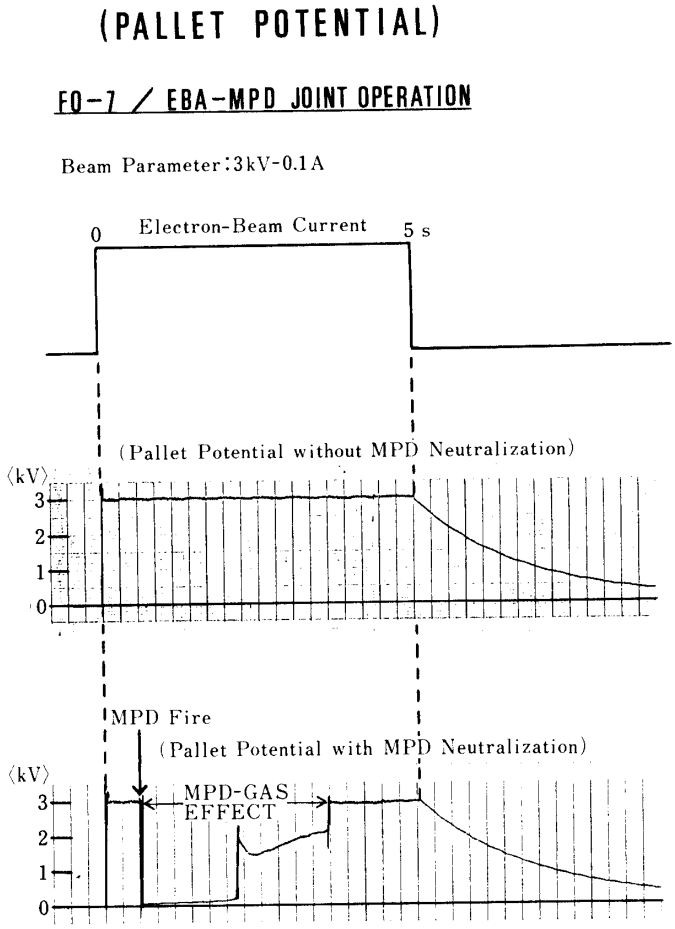


FIG. 5.1.2-2 Pallet potential variation for EBA-MPD joint operation.

NGP, the vacuum pressure in the space chamber goes up to 10^{-4} Torr. The floating potential goes down almost completely to the ground potential in the same way as the neutral gas from MPD arcjet and this lasts much longer than in the case of MPD arcjet because the amount of gas ejected is much larger.

The floating potential in the environment of ambient plasma produced by an ion thruster is shown in Fig. 5.1.2-4. The plasma density is around $10^6/cm^3$ and the background pressure is kept below 10^{-6} Torr. In contrast to Fig. 5.1.2-1 the potential rise is much lower than in the complete vacuum case and it does not depend on the beam energy. When the floating potential is much below the beam voltage, it should be determined by the beam current as

$$\phi \propto I^{7/6}$$

where ϕ is the floating potential and I the beam current, and Fig. 5.1.2-4 shows a good agreement with this equation.

On the space shuttle, however, the floating potential with respect to the ambient plasma cannot be determined as in this laboratory experiment because there is no reference electrode as the chamber wall. The diagnostic means are very important.

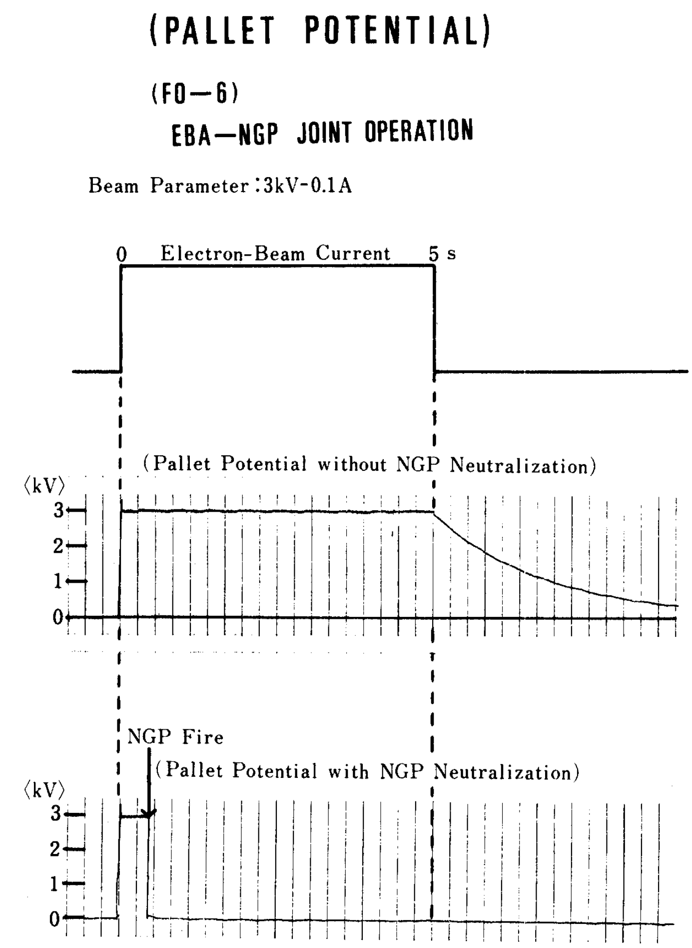


FIG. 5.1.2-3 Pallet potential variation for EBA-NGP joint operation.

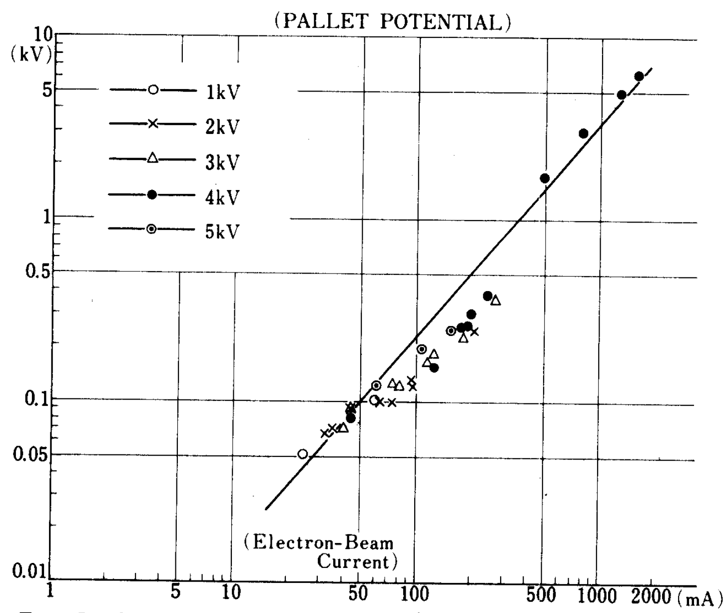


FIG. 5.1.2-4 Pallet potential as function of beam current and voltage. Operation with background plasma.

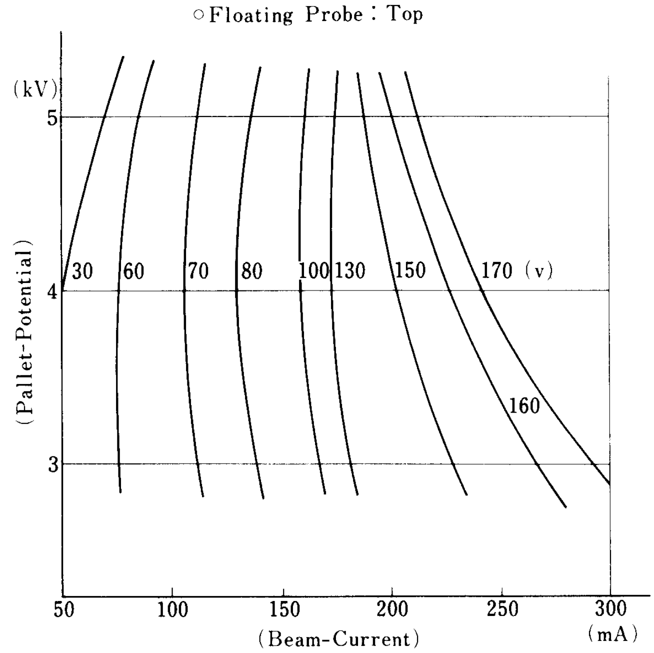


FIG. 5.1.2-5 Floating probe and pallet potential as a function of beam current. Operation in vacuum.

Two measurements will be employed in SL-1 and the following data shows how much we can rely on them in determining the floating potential.

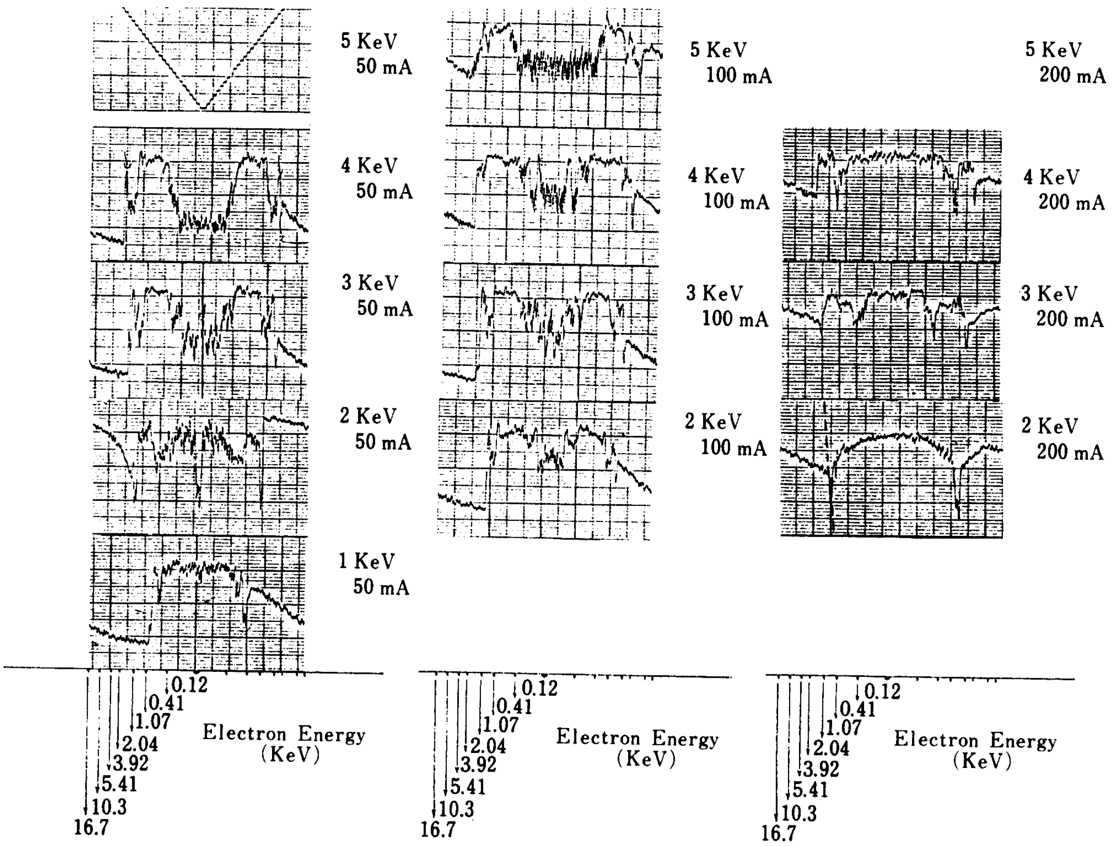
One is floating probes and the other is an electron energy analyser in SEPAC diagnostic package (DG). The former consists of 3 floating probes (Top: Middle: Bottom). Fig. 5.1.2-5 shows the correspondence between the floating probe (Top) measurements and the pallet potential measurement as a function of the beam energy, beam current. In general, the floating probe measurement does not directly reflect the floating potential because it strongly depends on the beam current. The corresponding floating potential measured between the pallet and the chamber wall should be independent of the beam current as shown in Fig. 5.1.2-1.

The result of the energy analyser is shown in Fig. 5.1.2-6. Fig. 5.1.2-6(a) corresponds to Fig. 5.1.2-1 (beam emitted in vacuum) and Fig. 5.1.2-6(b) to Fig. 5.1.2-4 (beam emitted in ambient plasma). From these Figures, we can see clearly that the return current profile has a sharp cut-off at the energy corresponding to the floating potential, though the former shows a slightly higher value than the latter.

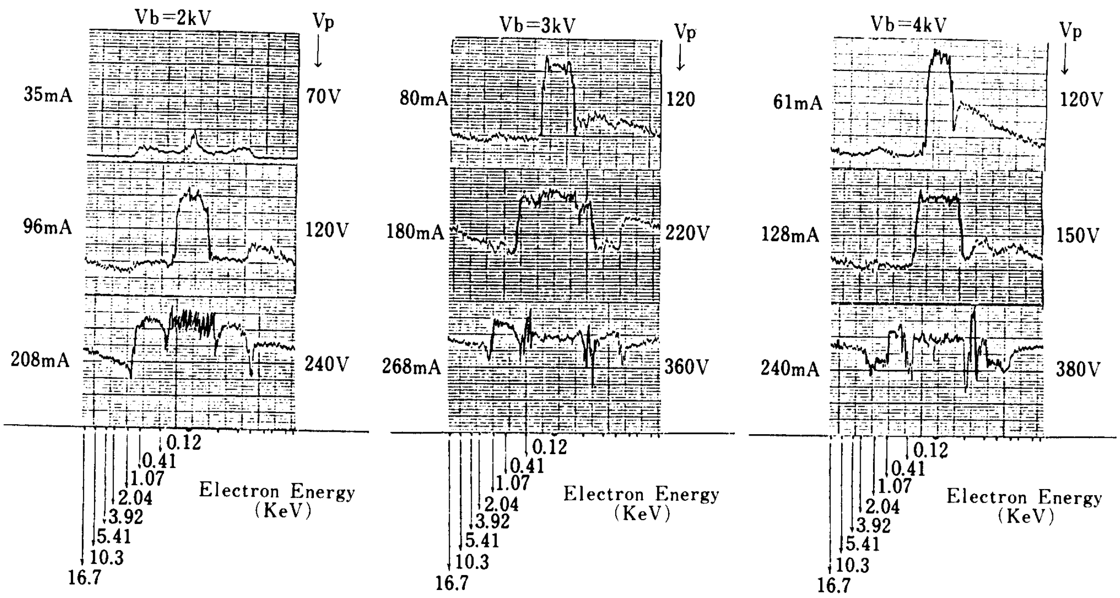
5.1.3 FO Operation Test Result

All FO functions have been verified through FO operation test as described in Appendix C. The FO operation test result is summarized and shown in Table 5.1.3-1. During the test, some minor hardware and software problems were found out. The list of problems is shown in Table 5.1.3-2.

Additionally the test called as system check was carried out to determine whether SEPAC system is ready to start the scientific experiment or not. System check consists of CFO, GCFO, T-1, T-2, A-7, CFR, BAT cell connection and BAT



(A)



(B)

FIG. 5.1.2-6 (A) Energy analyser measurement. Operation in vacuum.
(B) Energy analyser measurement. Operation with background plasma.

charging. System check result is described in Appendix D.

And also the trouble shooting to investigate and fix the trouble occurred during chamber test period was carried out. The result of trouble shooting is shown in Appendix F.

TABLE 5.1.3-1 FO Operation Test Result

Test Case No.	FO No.	Code	Type	Result	Date	Remarks
1	FO-1	CFO	Normal	Good	Dec. 13	HVC:INH
1-2	FO-1	CFO	〃	〃	〃	HVC:ENA
2	FO-13	P-1	〃	〃	〃	
3	FO-14	P-2	〃	〃	〃	
4	FO-3	T-2	〃	〃	〃	
5	FO-8	A-4	〃	〃	〃	
6	FO-2	T-1	〃	Good*	〃	MTV:manual mode
7	FO-5	A-1a	〃	Good	Dec. 14	MTV:manual mode
8	FO-5	A-1b	〃	〃	〃	MTV:manual mode
9	FO-6	A-2	〃	〃	Dec. 15	done as TC-2008 (PC Training)
10	FO-7	A-3	〃	〃	Dec. 14	MTV:manual mode
11	FO-4	T-3	〃	〃	〃	MTV:manual mode
12	FO-9	A-5a	SMO HLD/RST	〃	Dec. 15	same as TC-2006, 2007
13	FO-9	A-5b	〃	〃	〃	MTV:manual mode EBA-abnormal flag
13-1	FO-9	A-5b	〃	〃	〃	MTV:manual mode check for EBA
14	FO-10	A-6	Normal	〃	〃	MTV:manual mode
16	FO-12	A-8a	PCF change HLD/RST	Good*	Dec. 16	EBA check EBA:abnormal flag
18	FO-9	A-5c	PCF change	Good	〃	EBA check
16-2	FO-12	A-8a	〃	〃	〃	〃

*: This table shows that SEPAC whole system is basically good to operate. Only few subsystem has minor problems which were easy to correct.

TABLE 5.1.3-2 SEPAC NASDA Chamber Test Problem List

TR#	CLOSE	DESCRIPTION	PREP	EXP	OFF	PCF	SMO	STD	HOLD/RST	OTHERS	DGP	MTV	EBA	MPD	A.I. MSFC	A.I. ISAS	Remarks & Test Case
233		Interface in Data Recorder									SYSTEM					X	
234	X	Noise on the firing timing signal for EMI equipment									SYSTEM						
235	X	Cold plate for EBA is shorted											X				
236	X	FO elapsed time elongation about 40 sec.		X													TC-004
237	X	S/W system stop		X				X									FO-11
238	X	S/W system stop	X			X											FO-11
239	X	TLM Display equipment									SYSTEM						
240		DSI W/S does not work well (from MSFC)									SYSTEM				X		
242	X	DEP cold plate thermostat does not work									SYSTEM					X	
243		NGMVSW is 1 during HOLD		X					X					X		X	ISAS did not require
244	X	Prep time is 5 instead of 10 min.	X												X	X	
245		MPD GAS leak in chamber												X		X	
246		FAV PRESSURE is 3ATM when 2ATM regulator valve opened												X		X	
247		NGP ejection valve did not work well												X		X	TC-1010
248		Fuse in CAP was broken												X		X	
249	X	Some of MPD (PFN) charge is abnormal		X										X		X	Require S/W change
250	X	Word assignment for RESIST & MPD1 in PCM format is changed									PCM FORMAT				X	X	Document change
251	X	HVCOLD occured during CFO		X									X			X	TC-008
252		28V DC power of EBA was off for 1 sec.		X									X			X	TC-212
253	X	MODOLD occurred in FO-9a		X									X			X	TC-2006
254	X	HVCOLD in FO-4/charge up		X									X			X	TC-10 (CU)
255	X	HVCOLD in FO-12a		X									X			X	TC-16 (FOOT)
256		Beam current was not controll-ed at FIB=0.1 in FO-5a		X		X							X		X		TC-2, 4 (CU)
257	X	PCF change of EHVC=0 does not work during HOLD		X		X			X		X					X	Misunderstand TC-2, 4 (CU)
258		EPA-E high voltage was not shut off at EPAOUT (B5=1)										X or W/S				X	TC-12 (CU)
259		Temp monitors (LPT, FPTEMN) did not work correctly										X or IU			X	X	TC-6 (FOOT)
260		MTV IRIS not controlled										X				X	

5.2 CONCLUSION

5.2.1 EMI Test

1. Facility noises are low enough to investigate the effect of beam and plasma.
2. Noise from beam and plasma when EBA was fired mostly broadband noise. Figures 5.1.1-3 and 5.1.1-4 show about 30 dB above limit. Beam and plasma noise is considered to be 50 dB higher than noise from SEPAC hardware.
3. Although narrowband noise appeared at standby mode shown in Fig. 5.1.1-8 should be in Fig. 5.1.1-2, they were not plotted because buried under broadband noise and no plasma peculiar noise was observed.
4. Figures 5.2.1-1 and 5.2.1-2 show the difference between dummy load operation

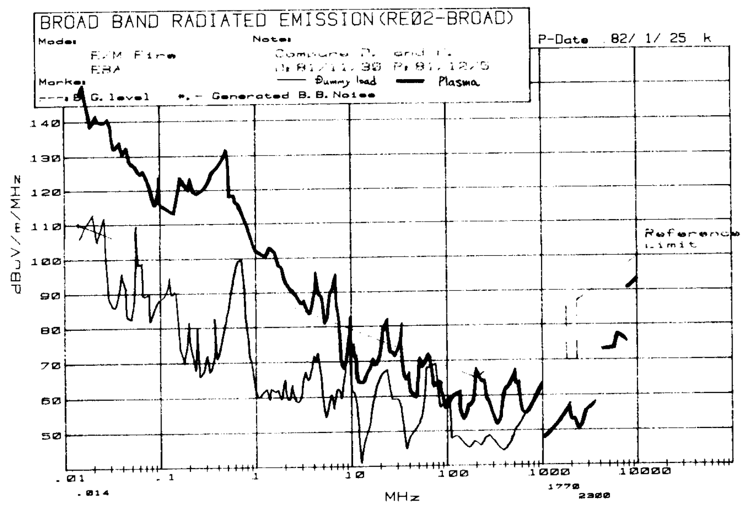


FIG. 5.2.1-1 Difference in RE02 broadband noise between cases with dummy load and plasma ejection. EBA oriented case.

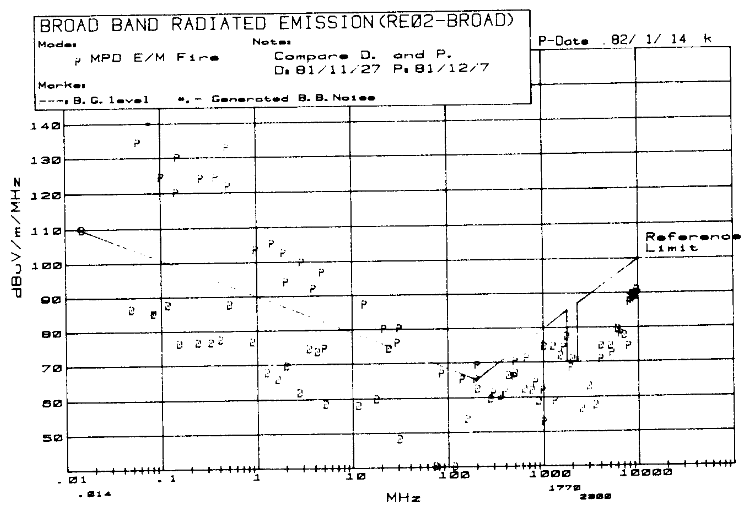


FIG. 5.2.1-2 Difference in RE02 broadband noise between cases with dummy load and beam and plasma ejection. MPD oriented case.

and beam and plasma ejection in RE02 broadband noise. The differences are noises peculiar to the beam and plasma.

5. No malfunction was occured by noise generated by beam and plasma and EMC was confirmed.
6. Noise at STS critical frequency are almost under the reference limit except S band noise which exceed 1 dB at MPD operation with dummy load as shown in Fig. 5.1.1-5.
7. Level fluctuation at STS critical frequencies were 10 dB maximum. Details of level fluctuation are shown in a separate data book.
8. As for conducted emission, noise is filtered out completely and no effect of beam and plasma can be see from the test results.

5.2.2 Charge up Test

1. Floating potential rose to the beam energy in the beam energy and beam current ranges in the present SEPAC FO's when the beam was emitted in vacuum ($<10^{-6}$ Torr).
2. Charging neutralization by MPD arcjet plasma and NGP neutral gas plume was verified though due to the finite size of the space chamber, as for MPD plasma, the plasma decayed faster than in space. While for NGP the neutral gas stayed longer in the chamber and the neutralization effect was much enhanced.
3. The floating potential versus the beam current in an ambient plasma produced by an ion thruster showed a good agreement of Beard Johnson's formula. This is the first measurement in the laboratory to be verified an effectiveness of neutralization by an externally generated plasma. Hetherto, the background neutral gas pressure was not low enough and it was very difficult to discriminate the externally produced plasma effect and the beam-produced plasma effect.
4. The correspondence between the direct pallet potential measurement and the floating probe measurement is rather complicated and it is difficult to deduce the pallet floating potential uniquely from the floating probe measurement.
5. A clear correspondence between the cutoff energy of the spectral profile in the energy analyser measurement of the return electrons and the pallet potential has been obtained. It will be useful in determination of the space shuttle potential in SL-1 experiment.
6. During nearly two weeks operation of SEPAC electron accelerator in vacuum and plasma in ground and floating modes, no disastrous bombind effects or damage by discharges were observed at all during the experiment nor in a detailed inspection after the experiments.

5.2.3 FO Operation Test

FO operation test has been completed under vacuum condition and ISAS/MSFC confirmed that SEPAC total system was ready to ship to KSC, U.S.A. for LEVEL IV Integration.

There remains still some action items listed in Table 5.2.3-1 to be closed by LEVEL IV Integration. Table 5.2.3-1 includes further required actions.

TABLE 5.2.3-1 Open Action Item List

TR#	Description	Required Action
240	DSI's W/S does not work well (from MSFC)	MSFC will check/fix Word Selector, which is not flight item.
243	NGMVSW is 1 during HOLD	It is necessary for MSFC to modify SEPAC Flight Software. ISAS will provide the procedure for it.
245	MPD GAS leak in chamber	ISAS will investigate/fix the problem by the starting of the Level IV Integration.
246	FAV pressure is 3 ATM when 2 ATM regulator valve opened	Ditto
247	NGP ejection valve did not work well	Ditto
248	Fuse in CAP is broken	Ditto
252	28 V DC power of EBA was off for 1 sec	ISAS/MSFC will investigate/fix the problem.
256	Beam current was not controlled when FIB=0.1 in FO-5a	MSFC will investigate Software and fix it.
258	EPA-E high voltage was not shut off at EPAOUT (B5=1)	ISAS will investigate/fix it.
259	Temp. monitors (LPT, EPTEMN) did not work correctly	ISAS/MSFC will investigate whether this problem is due to DGP or IU and fix it.
260	MTV IRIS not controlled	ISAS will investigate and fix it.

6.0 Detailed Test Results

All the test data of SEPAC NASDA Space Chamber Test referred in this report as Appendix A, B, C, D, E and F are filed under separate covers which will appear later.

Acknowledgement

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