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This report presents a programmatic review of the design, fabrication, and demonstration testing of a hydrazine Gas Generator/Plenum System, used to supply gas to very low thrust engines.

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TECHNICAL REPORT

DEVELOPMENT OF

N_2H_4 GAS GENERATOR/PLENUM SYSTEM

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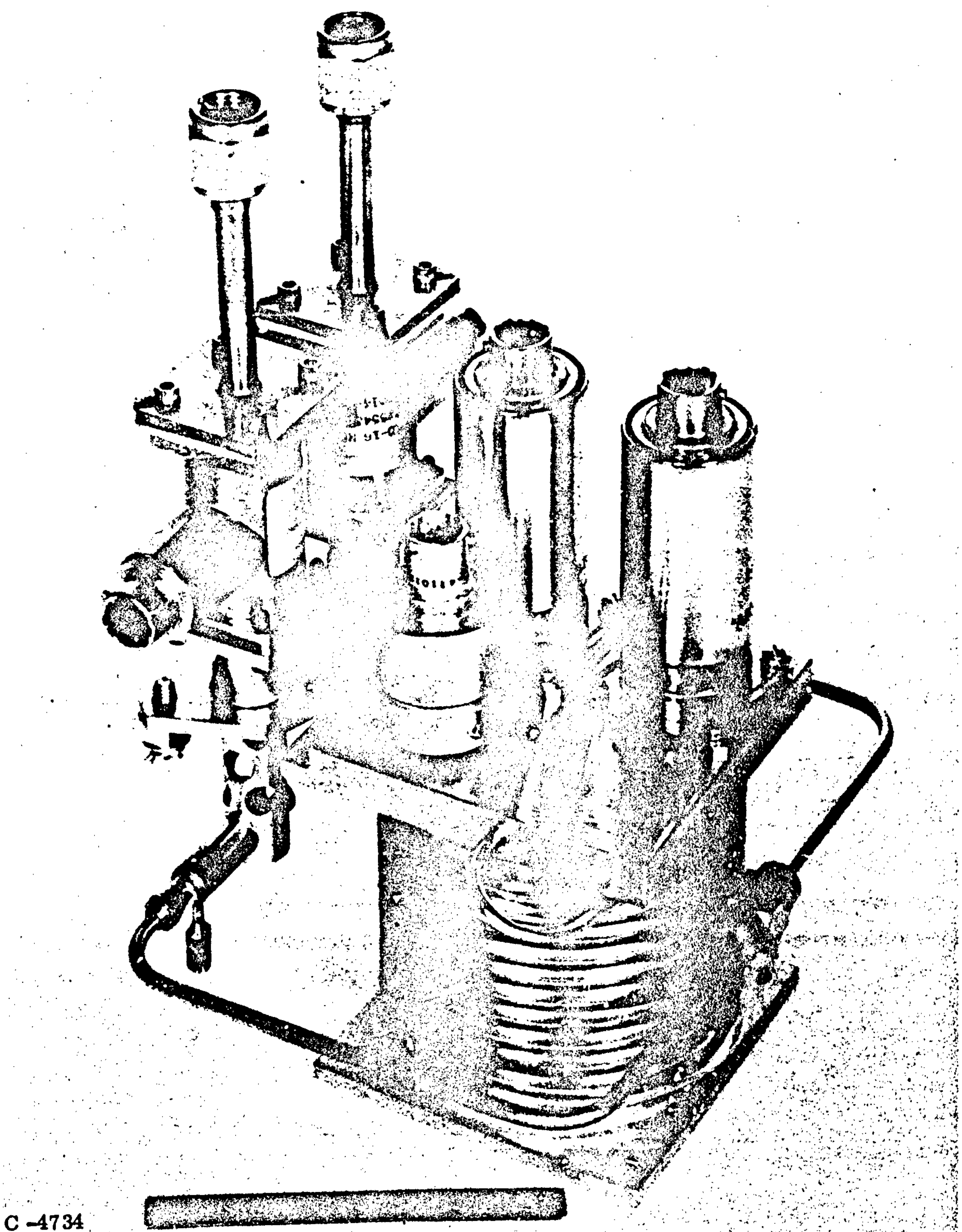

C-4734

FIGURE 1. N_2H_4 GAS GENERATOR/PLENUM SYSTEM

1.0 INTRODUCTION AND SUMMARY

Under ONR Contract Number N00014-75-C-1078, Hamilton Standard has designed, fabricated and completed a demonstration test program of a hydrazine Gas Generator/Plenum System (reference Hamilton Standard Drawing SV764130-1). This report presents a review of this effort.

The function of the N_2H_4 Gas Generator/Plenum System (GGPS) is to supply gas for the operation of milli (0.010 lb_f) thrusters and mic (30 to 1000μ lb_f) thrusters.

The GGPS is comprised, as illustrated in Figure 1, of two (2) Model 10-16 Rocket Engine Assemblies (REA), a coiled tube heat exchanger, a plenum chamber, two (2) GFE Linear Variable Differential Transformers (LVDT), and one (1) GFE potentiometric pressure sensor. The second LVDT and REA serve as redundant, backup components. Additional descriptive details of the GGPS are presented in Section 2.3.

The basic operation of the GGPS is as follows: With the milli-thru valve activated, gas exits from the PT Plenum Chamber - thereby decreasing the plenum chamber pressure. The LVDT continually senses this pressure, and when the pressure diminishes to a preset level (established by electronic controls) the REA valve is signalled ope Hydrazine enters the catalyst bed chamber and is catalytically decomposed, with the gases supplied to the plenum chamber. When the plenum chamber pressure attains a second predetermined level, the electronic controls automatically de-energize the REA valve to its closed position. Further details of the unit's operation are presented in Section 2.6.6.

The primary design and performance requirements along with the related results are outlined in Table I. Typical operating characteristics of the GGPS, when operating in conjunction with the GFE mill micro thruster system and associated electronic controls, are presented in Table II. These characteristics include the operating pressure band for each of Reactor Threshold (R/T) and ΔV Threshold (ΔV/T) select positions, the cyclic period for each of these, and the Gas Generator operating times. Further information regarding the operation and performance characteristics of the GGPS are provided in Test Sections 2.6.6 thru 2.6.9. Included in these section are typical analog data traces depicting the characteristics of PT plenum pressure, PC plenum (gas supply for micro thruster) pressure and REA chamber pressure during milli-thruster and micro-thruster activation periods.

TABLE I

Summary of
Principal Design and Performance Characteristics

	Item	Requirement	Results
1.	Envelope	Minimal and compact.	5.6" x 4.75" x 5.4"
2.	Maximum Weight (Note 1)	4.0 lbs.	3.1 lbs.
3.	Minimum Duration to 150°F Gas Out Temperature (Note 2)	90 secs.	737 secs (12.3 mins.) demonstrated
4.	PT Plenum Operating Pressure	0-60 psia	0-60 psia
5.	Proof	375 psia	375 psia
6.	Micro-Thruster Operation	Continuous	8 hrs. demonstrated

NOTE: (1) Excludes GFE items (2 LVDT's and 1 pressure sensor)

(2) The requirement here is that the GGPS be capable of sustaining continuous milli-thruster operation for a period not less than 90 seconds, during which time the gas outlet temperature shall not exceed 150°F.

TABLE II

Summary of Gas Generator/Plenum Operational Characteristics

Milli-Thruster Operational Characteristics

Select Position	Lo - Hi Pressure (psia) @ P_{in} = 250	Lo - Hi Pressure (psia) @ P_{in} = 130	PT Cycle Duration @ P_{in} = 250 psia (seconds)
R/T-1	8 - 20	6 - 18	7.1
R/T-2	16 - 28	12 - 25	4.5
R/T-3	31 - 44	28 - 40	2.4
R/T-4	40 - 53	36 - 50	1.9

Notes: (1) Gas Generator on-time: 0.25 seconds at P_{in} = 250; 0.4 seconds at P_{in} = 130 psia

(2) Cycle duration not significantly affected by GG supply pressure, slightly less at P_{in} = 130 psia.

Micro-Thruster Operational Characteristics

Select Position	Lo - Hi Pressure (psia) @ P_{in} = 250	Lo - Hi Pressure (psia) @ P_{in} = 130	PC Cycle Duration @ P_{in} = 250 psia (seconds)
ΔV/T-1	4.5 - 5	-	28
ΔV/T-2	9 - 11	8.5 - 11	60
ΔV/T-3	18 - 21	18 - 21	25
ΔV/T-4	37 - 44	36 - 43	45

Notes: (1) For R/T-4, ΔV/T-2, P_{in} = 250 psia test condition - time between PT plenum refills was 7 3/4 minutes.

(2) PC plenum cyclic duration essentially independent of GG supply pressure.

2.0 DISCUSSION

2.1 Introduction

The major steps in the program, leading to the demonstration testing of the Gas Generator/Plenum Assembly, included:

a) The preparation of a general design specification.
b) The design and analysis of the unit, including the preparation of drawings.
c) Test Plan preparation.
d) Fabrication of hardware.
e) Testing of the unit.

2.2 General Design Specification

A General Design Specification was prepared at the outset of the program. This specification establishes the essential design and performance criteria of the GG/Plenum Assembly. The specification also describes the unit, defines requirements for mechanical and electrical interface with NRL equipment, defines its physical and operating requirements, establishes its operational environmental conditions, and outlines a general test program for demonstrating the unit's conformance to its requirements.

The primary design and performance requirements are presented below:

Item	Requirement
Configuration	Singular compact module with minimal envelope
Weight	4.0 lbs., maximum
Plenum Operating Pressure	4 to 60 psia
Plenum Gas Out Temperature	200°F, maximum 150°F, design goal
Milli-Thruster Operation	90, seconds, maximum (at .01 lb_f)
Micro-Thruster Operation	Continuous at 30 x 10^{-6} lb_f

Further details may be found in SVHS 6969, Hydrazine Gas Generator/Plenum System, General Design Specification For, and is included herein as Appendix A. The contents of this specification are based upon inputs from NRL, and the completed specification was reviewed and approved by NRL.

2.3 Unit Design

Based on the General Design Specification, the design of the Gas Generator/Plenum System was implemented. The resultant design, as defined in drawing SV764130, consists of the following:

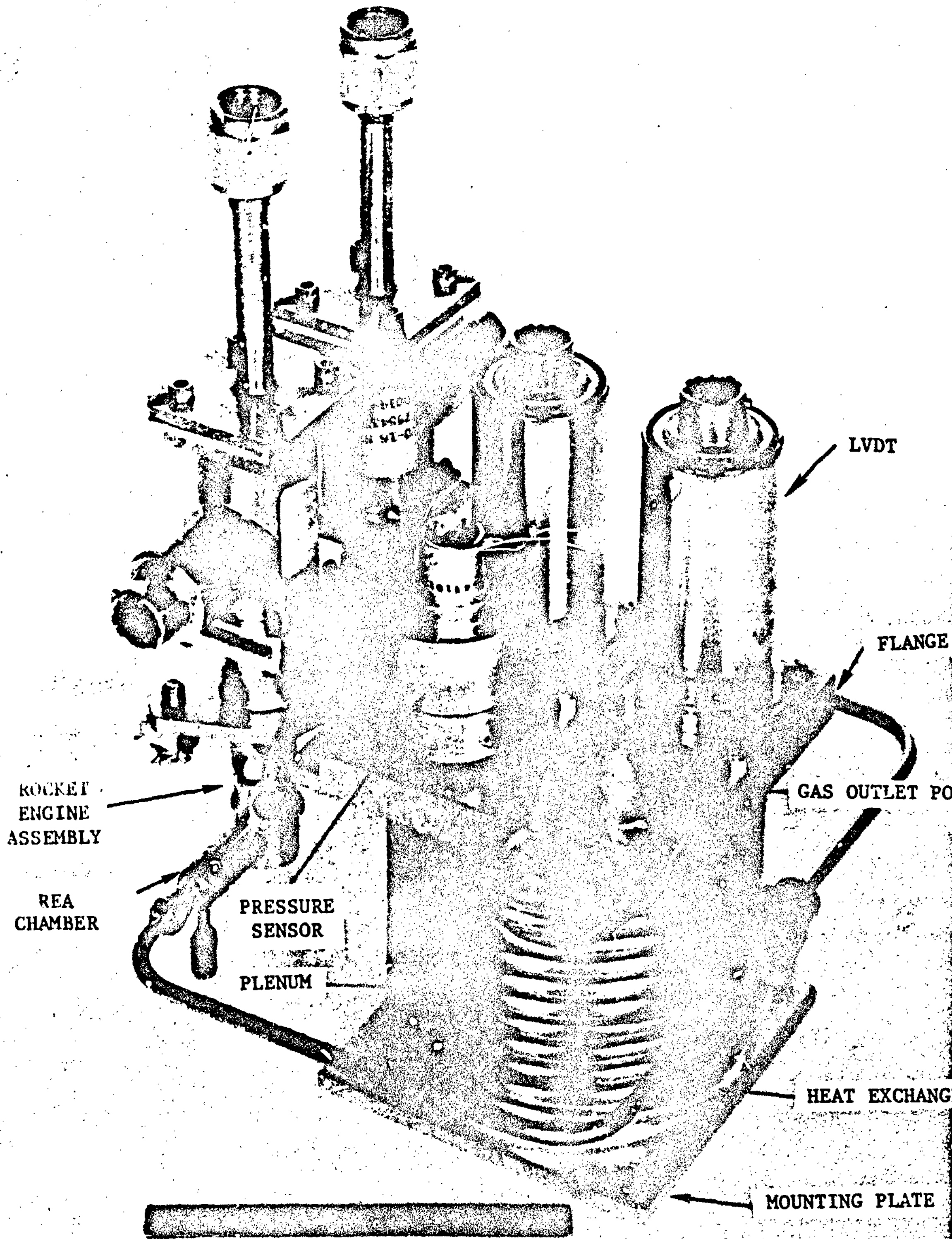

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FIGURE 2. PARTS IDENTIFICATION OF GAS GENERATOR/PLENUM SYSTEM

2.3 continued

Two Model 10-16 Rocket Engine Assemblies

A Plenum Chamber

A Heat Exchanger

Two GFE Linear Variable Differential Transducers

One GFE Potentiometric Pressure Transducer

Mounting and Sealing Hardware

As shown in Figure 2, the photograph of the unit, the plenum chamber is fabricated from a cup approximately 2 1/2 inches in diameter and 2 1/4 inches long. A flange is welded at the top of the open cup, and serves as the mounting base for the various components. The top of the flange has four ports: two are for the LVDT's, one for the pressure sensor, and the fourth is the gas outlet port. Attached to the bottom of the cup is a plate, having a hole so as to fit about the cup. The plate contains four bolt holes for attachment of the GG/Plenum System to the NRL mounting plate.

Two Rocket Engine Assemblies are mounted off the flange extension. At each of the REA nozzle exits, 1/8 inch tubing is welded, with tubing subsequently manifolded to the heat exchanger. The heat exchanger consists of coiled tubing about the plenum, and is brazed to the plenum exterior for optimum thermal conductivity. The tubing outlet of the heat exchanger is brazed to the flange, with internal porting allowing gas to enter the plenum chamber.

The plenum chamber cup, its mounting plate, and the top flange are all fabricated from 347 stainless steel, with tubing fabricated from Inconel 600. All the component interfaces, exclusive of the thrust chamber/heat exchanger but including the REA valve/thrust chamber and the inlet fitting/valve interfaces, are of mechanical configuration, with sealing effected by ethylene propylene rubber O-ring seals.

In support of the design, analyses were conducted for sizing the plenum and for sizing the heat exchanger. Supplementary analyses included predicted performance and thermal operating characteristics, with their submittal to NRL for review.

Culmination of the design/analysis took the form of fabrication drawings (Ref. SV764130), which were submitted to NRL for review and approval. A parts list for the Gas Generator/Plenum System is included in Appendix B.

2.4 Test Plan

In parallel with the design effort, a test program was formulated and outlined in Test Plan SVHS 7029 (included as Appendix C). Th test plan defines the test sequence, test objectives, data requir ments, and includes a general description of each test. The spec tests, in the sequence given, and a brief description of the test conducted are given below:

a) Examination of Product - visual examination of hardware for defects and review of build data package.

b) Proof - at 375 psig GN_2, for structural integrity.

c) External Leakage - verify compliance with maximum leakage requirements of 10^{-6} scc GH_e/sec at 50 psia.

d) Random Vibration - demonstrates unit's ability to withstand structural vibration loads.

e) External Leakage - repeat of (c) above, verifying no damage resulting from prior vibration exposure.

f) Functional Checkout - brief operational checkout to verify readiness of unit for demonstration testing.

g) Performance Demonstration - operation of the Gas Generator/ Plenum System, demonstrating unit's ability to perform per specified requirements.

h) External Leakage - repeat of (c) above.

i) Internal Leakage - verify unit has been properly cleaned prio to shipment.

j) Post-Test Inspection - visual examination of hardware for discrepancies and/or damage.

2.5 Fabrication

Fabrication of the Gas Generator/Plenum System was initiated in July 1975 and completed at the end of October 1975. The most for midable manufacturing task, as expected, proved to be the fabrica tion and assembly of the heat exchanger. Experimenting with samp pieces of coiled tubing and simulated plenum cylinders eventually resolved the techniques in tube forming (obtaining the best coil diameter and maintaining design coil-to-coil spacing) and brazeme of the coiled tube to outer diameter of the simulated plenum cup. This approach proved beneficial in enabling success with the firs endeavor of the actual hardware fabrication.

2.6 Test Results

Testing per SVHS 7029, and as briefly described in Section 2.4 of this report, was initiated in early November 1975 and completed two months later. The test results are presented below.

2.6.1 Examination of Product - was visually examined for defects, and data package reviewed for completeness. The unit weighed 3.1 lbs vs. 4.0 lb maximum requirement. (The weight does not include GFE items).

2.6.2 Proof - No deformation noted after unit, exclusive of LVDT's and pressure transducer, exposed to 380 psig GN_2 for 5 minutes - and with REA valves energized to open position.

2.6.3 External Leakage - The unit satisfactorily met the maximum leakage requirement of 1×10^{-6} scc GHe/sec at 50 psia with each test:

Pre-Vibration Leakage - 4.6×10^{-7} scc GHe/sec at 50 psia

Post-Vibration Leakage - 8×10^{-7} scc GHe/sec at 60 psia

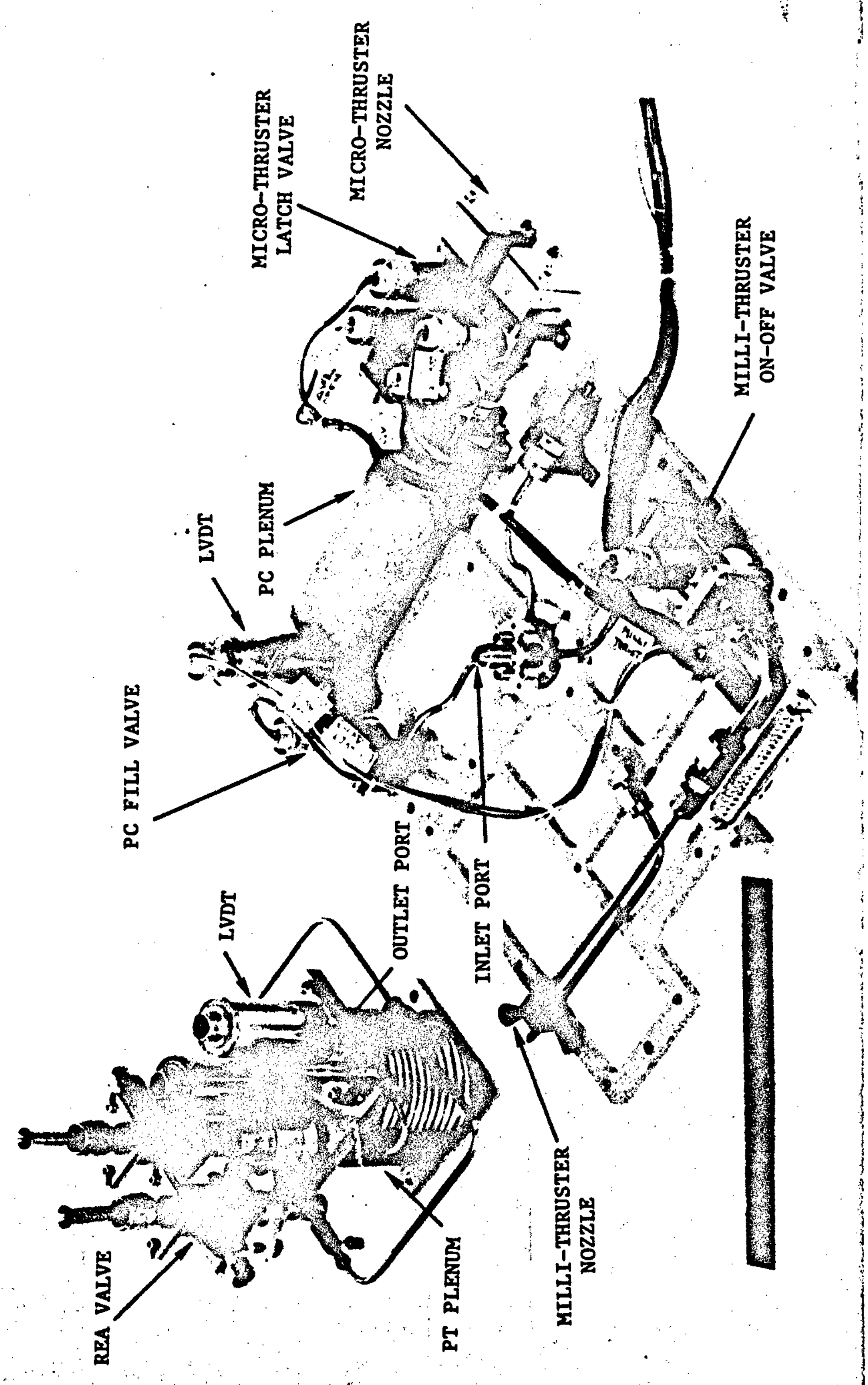
Pre-Shipment Leakage - 5×10^{-7} scc GHe/sec at 50 psia

2.6.4 Internal Leakage - The unit satisfactorily met the maximum internal (REA valve seat) leakage requirement of 1×10^{-6} scc GHe/sec at 250 psia.

Pre-System Testing (at the REA component level)
- each REA exhibited less than 1.5×10^{-7} scc GHe/sec leakage

Post-System Firing (pre-shipment)
- each REA exhibited less than 0.2×10^{-7} scc GHe/sec leakage

2.6.5 Vibration - The unit was hard mounted to a rigid fixture and subjected, for two minutes in each of three orthogonal axes, to the specified random levels. The resultant vibration data, in the form of g^2/Hz vs. Hz graphs, are presented in Appendix D. Subsequent to the test, a visual examination of the unit was made. No damage was noted. Also, subsequent leakage and performance testing were satisfactorily conducted.


MICRO-THRUSTER NOZZLE
MICRO-THRUSTER LATCH VALVE
LVDT
PC PLENUM
PC FILL VALVE
MILLI-THRUSTER ON-OFF VALVE
OUTLET PORT
INLET PORT
LVDT
REA VALVE
PT PLENUM
MILLI-THRUSTER NOZZLE

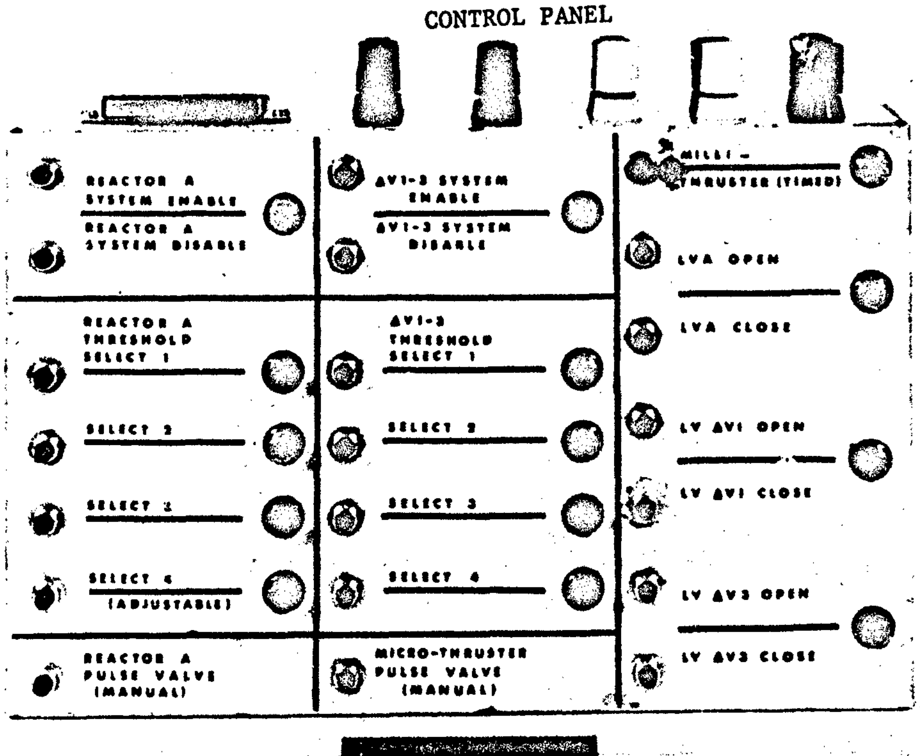
2.6.6 Test Operation - The basic mechanical test setup for the Functional Checkout and Performance Demonstration test setup, is shown in Figure 3, and consists of two major subassemblies: the Hamilton Standard Gas Generator/Plenum System and the GFE milli/micro-thruster system.

The GG/Plenum System is mounted to a test plate, capable of being thermally conditioned. The milli/micro-thruster system is mounted next to it, with a short section of tubing (not shown in figure) interconnecting the outlet of the GG/Plenum to the inlet of the milli/micro-thruster system. The integrated system is contained within a test altitude chamber so that operation of the unit can be conducted in a low ambient pressure environment.

Maintaining PT plenum pressure is achieved by the LVDT sensing pressure, and in conjunction with electronic controls effects opening and closing of the primary REA valve. When the plenum pressure decreases to a pre-set value, the REA valve is energized open, allowing hydrazine to enter the engine's catalytic chamber. The hydrazine is then catalytically decomposed, with the decomposition gases entering the plenum via the heat exchanger and thereby increasing the plenum pressure until the preset high limit is attained. At this time, the REA valve is automatically de-energized to its closed position.

The depletion of plenum chamber pressure is brought about by either operation of the milli-thruster or the micro-thruster. In the case of the latter, it has its own plenum, pressure sensing LVDT, and electronic controls. Thus, when the PC plenum (gas supply tank for micro-thruster) requires pressure replenishment, an upstream pulse valve is energized open to permit drawing of gas from the PT plenum chamber.

CONTROL PANEL



JUNCTION BOX

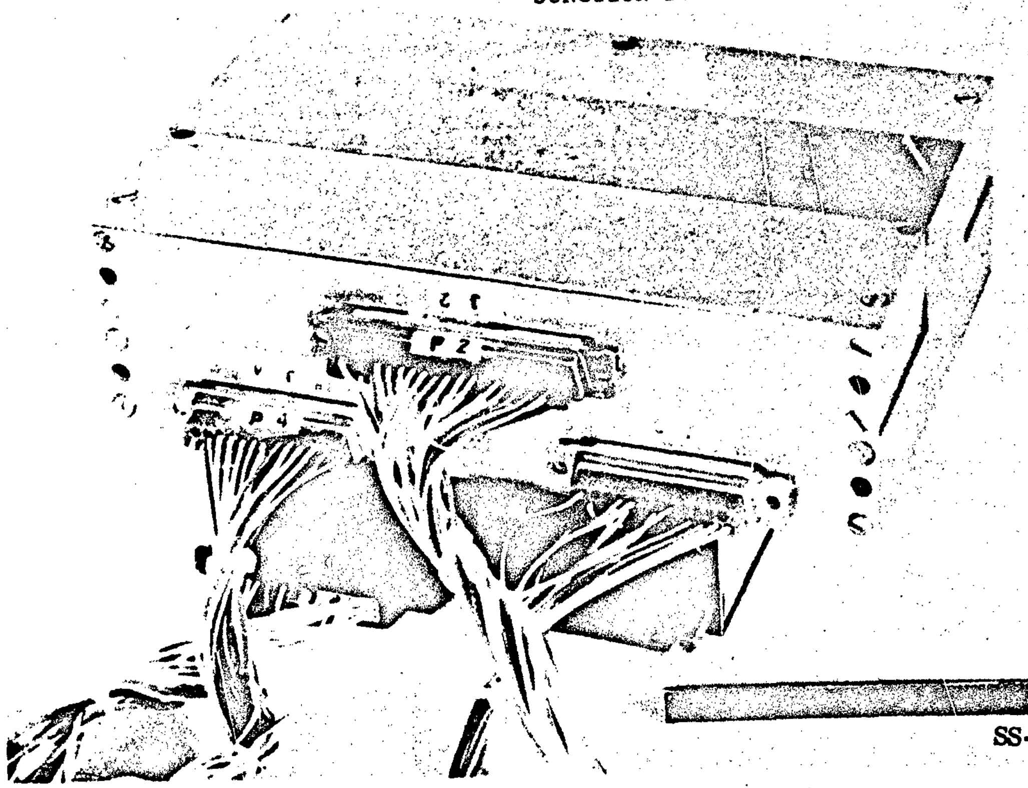


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FIGURE 4. CONTROL PANEL AND JUNCTION BOX

2.6.6 continued

The principal electronic controls used in establishing and controlling the hi-lo pressure settings, and for operation of the milli and micro thruster is shown in Figure 4. The Control Panel provides the test operator with switches for activating the hydrazine GG/Plenum System (Reactors A & B) and the PC Plenum System (ΔV1-3); for operating the milli and micro-thrusters (right hand side of panel); and for selecting the hi-lo pressure levels. As shown in the panel, each of the two plenum systems has four pre-set pressure ranges.

The Junction Box, also shown in Figure 4, contains all circuitry essential to pressure sensing and controls, and provides the interface with the control panel and the signal/data terminal board mounted on the milli/micro-thruster assembly breadboard. At the rear of the Junction Box are two adjustment screws for enabling altering the hi-lo pressure limits of "Select 4" (see photograph of Control Panel). Adjustment of the Select 4 levels was not made during the course of the program.

2.6.7 Functional Checkout - A functional checkout of the GGPS was conducted to ensure readiness of the unit for Performance Demonstration tests. More specifically, the checkout permitted the user to familiarize himself with the controls; permitted verification of data acquisition adequacy; and enabled basic operational functionality to be checked out. The tests were conducted with high and low hydrazine supply pressures, with room ambient temperature fuel and hardware, and in a simulated high altitude environment. The initial conditions and the operational mode (pressure control select positions, thruster activated, etc.) are presented in Table III.

The Gas Generator/Plenum System operated satisfactorily and demonstrated its readiness for the subsequent Performance Demonstration tests.

2.6.8 Performance Demonstration - The purpose of the Performance Demonstration is to verify compliance with the specified requirements. The testing included:

Milli-thruster activation at various Reactor Threshold (R/T) select positions and extreme supply pressure levels

Micro-thruster activation at various ΔV-3 Threshold (ΔV/T) select position

Long duration milli-thruster operation

TABLE III

Functional Checkout Test Descriptions

Run Number	Initial Conditions		Operation
2220	P_{in} = 250 psia T_f = 78°F T_{go} = 87°F	 T_{f1} = 87°F T_t = 150°F	With milli-thruster "on", Reactor A Threshold (R/T) Select positions were altered from 4 - 3 - 2 - 1.
2221	P_{in} = 250 psia T_f = 78°F T_{go} = 91°F	 T_{f1} = 88°F T_t = 95°F	Unit operated for 2 minutes with milli-thruster "on" and R/T in Select 4.
2222	P_{in} = 130 psia T_f = 78°F T_{go} = 97°F	 T_{f1} = 95°F T_t = 100°F	Similar to Run 2220, except at low inlet pressure.
2223	P_{in} = 130 psia T_f = 77°F T_{go} = 96°F	 T_{f1} = 94°F T_t = 149°F	With micro-thruster on, R/T-4, unit was operated by varying ΔV1-3 Threshold (ΔV/T) from 4 - 3 - 2.
2224	P_{in} = 130 psia T_f = 77°F T_{go} = 95°F	 T_{f1} = 93°F T_t = 139°F	Unit operated for 15 minutes with R/T-4 and ΔV/T-2.

P_{in} - Inlet Pressure (to REA)

T_f - Fuel Temperature

T_{go} - Gas Outlet Temperature

T_{f1} - Plenum Flange (base plate) Temperature

T_t - REA Throat Temperature

2.6.8 continued

Long duration micro-thruster operation

Low temperature operational checks

Operational test after long term PT plenum chamber lockup

The basic operational characteristics of the integrated GGPS - Milli-Micro-Thruster System exhibited during the subject testing are presented in Table II (Introduction and Summary Section). These characteristics include: the pressure range - as effected by the Threshold Select position and the operational characteristics of the related components, the cyclic duration (time between plenum refills) and the hydrazine gas generator on-time as a function of hydrazine supply pressure.

The characteristics of the unit's operation are shown in Figures 5 thru 12. These figures depict typical PT plenum pressure, PC plenum pressure, and REA chamber pressure cycles for the various test conditions of threshold select positions and supply pressure previously described. These figures are copies of sections of Sanborn data.

In order to better depict the pulse shape of the REA chamber pressure, higher response, faster paper speed oscillographic data are shown in Figures 13 thru 15. These figures show typical REA chamber pressure and PT plenum pressure cycles for both high and low hydrazine supply pressures. It should be noted that the R/T Select position did not significantly alter, exclusive of start and end, the REA chamber pressure pulse shape. That is, the nominal chamber pressure and REA firing duration are similar from one R/T Select position to the other. This is attributed to the fact that the delta pressures among the R/T select positions demand about the same gas quantity for plenum refills.

Two long duration milli-thruster firing tests were conducted with R/T Select in Position 4. The first test was conducted with the fuel and PT Plenum mounting plate conditioned to 97°F and 105°F respectively. The second test was conducted with ambient temperature conditions (initial and fuel and hardware temperature about 88°F). Both tests were conducted with a hydrazine supply pressure of 250 psia. The test duration for these tests was established as the time to take for the gas outlet temperature to attain the design goal of 150°F. The resultant durations were 12.3 minutes for the first and 12.8 minutes for the second test. From the limited temperature data obtained, and assuming a mount resistance of 1.0 hr-°F/BTU, a heat flux of 100 BTU/hr between plenum and mount is estimated.

2.6.8 continued

One of the tests conducted consisted of operating the micro-thruster for eight continuous hours. The basic test condition for this test was: 250 psia hydrazine supply pressure, 100°F conditioned fuel and hardware, R/T in Select #4, and ΔV/T in Select #2. The unit performed satisfactorily throughout the test, with critical PT plenum temperatures (e.g., gas outlet) exhibiting no temperature increases.

Low temperature, long REA off-time tests were also conducted at high and low GG supply pressures. Test conditions for these tests consisted of: conditioning fuel and hardware to 40-50°F, and operating micro-thruster with R/T Select #4 and ΔV/T Select #1 until a few REA firings were obtained. The unit performed satisfactorily during both tests, with the basic behavioral difference from ambient tests being that REA chamber pressure exhibited high or start overshoots. As discussed in the qualification report of the subject Rocket Engine Assembly, the start overshoot is a function of fuel and hardware temperature - with overshoots diminishing with increase in temperature.

A test was also conducted to show that the unit could be operated satisfactorily after a long term lockup of gases within the PT plenum chamber. Thus, subsequent to the termination of one of the conducted tests, the hydrazine decomposed gases were stored in the plenum for a period of eleven days. At the end of this period, the 12.8 minute milli-thruster firing (previously discussed) was conducted with completely satisfactory results.

The final test conducted in the series of Performance Demonstration test was the operation of the milli-thruster with the redundant gas generator, rather than the primary REA. The redundant REA thrust chamber had been exposed to decomposition gases effected by the primary REA operation of all prior tests. The test operation was satisfactory and the redundant REA performance showed no impact from its prior exposure to the PT plenum operation.

Further details of test descriptions and test results for the Performance Demonstration tests are provided in Appendix E.

Overall, the Gas Generator/Plenum System performed quite satisfactorily, with the PT plenum refill cycles exhibiting good repeatability characteristics.

2.7 Problems and Anomalies

a) Electrical Noise - Electrical noise, as shown in Figure 15, was frequently encountered. This noise/interference is attributed to a combination of the employed grounding concept and lack of

2.7 continued

shielding. The electronic controls utilized a common return concept as opposed to individual returns. The problem was further aggrevated by the extensive line lengths and splitting of signals employed in data acquisition.

The electrical noise, of the type shown in Figure 16, occurred only with the actuation of the REA during micro-thruster operation. The noise would then disappear with the next refill of the PC plenum chamber. Although the electrical noise was exhibited frequently under these conditions, it would not always occur as is shown by Figure 10. It should also be noted that the PC plenum refill cycle is considerably shorter with the presence of noise: approximately 28 to 42 seconds vs. the normal 54 to 60 seconds. See the two aforementioned figures for comparison.

b) Brown Residue - During early checkout tests, the milli-thruster valve failed to open. The unit was returned to NRL where it was disassembled and examined. The internal parts were observed to contain a brown residue. Similarly, at the conclusion of the test program and during the flushing operation, a brown residue was noted to be in solution while flushing out of the milli-thruster.

A sample of the residue was given to the Materials Department for an infrared spectrum analysis. The results of this inspection is that the brown residue shows the features of hydrazine decomposed gases with ambient air. The test unit was frequently vented to ambient atmospheric conditions, which thus accounts for the presence of air. Since air is not present during flight application, it is concluded that the brown residue represents a ground test problem only. Shutting off all downstream valves upon test termination, thereby locking up the decomposition gases, will minimize this problem. Considerable testing was accomplished in this fashion. However, to preclude this residue formation with future ground tests, it is recommended that between tests that the altitude test cell be returned to ambient via nitrogen, rather than air.

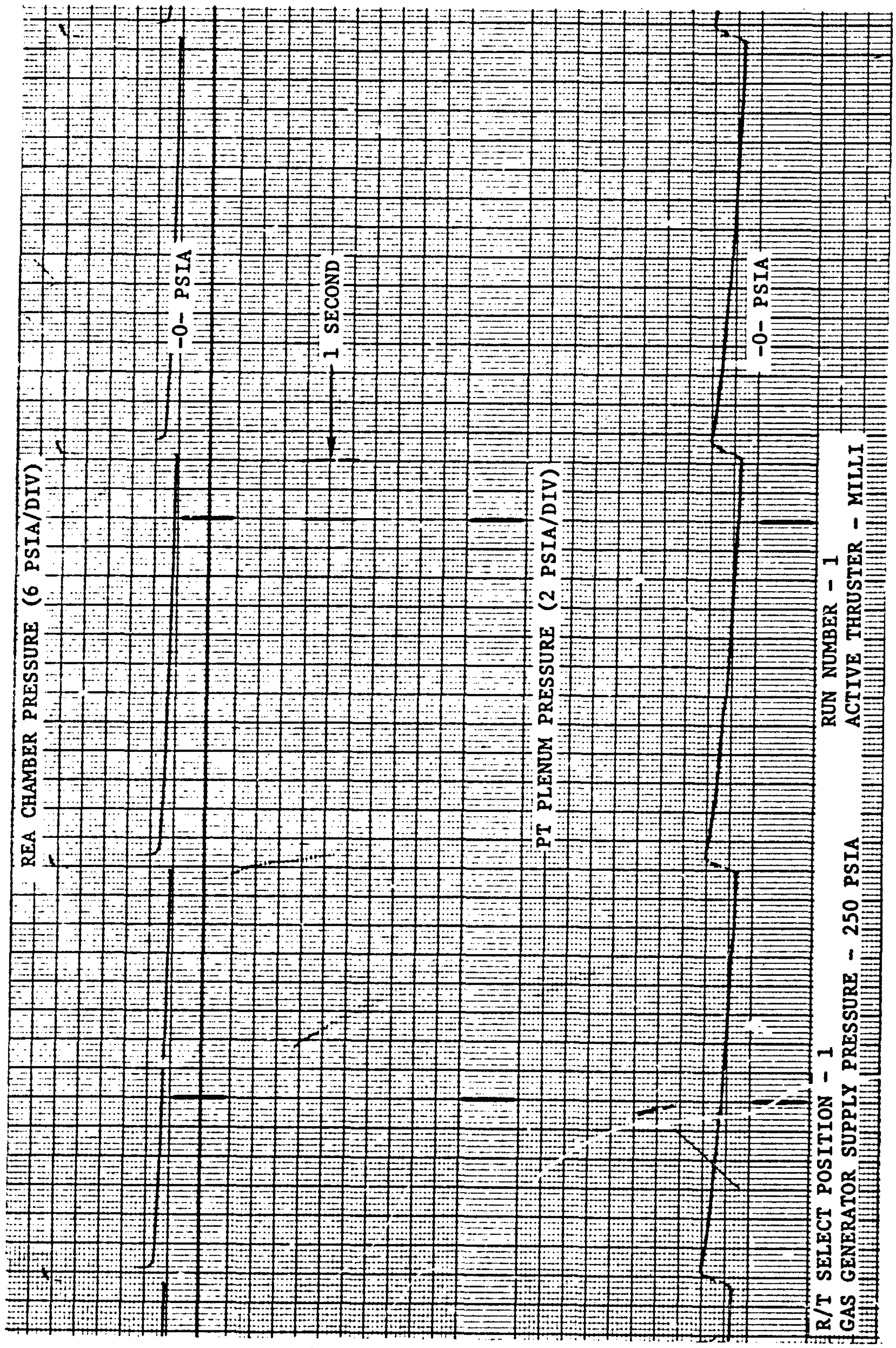
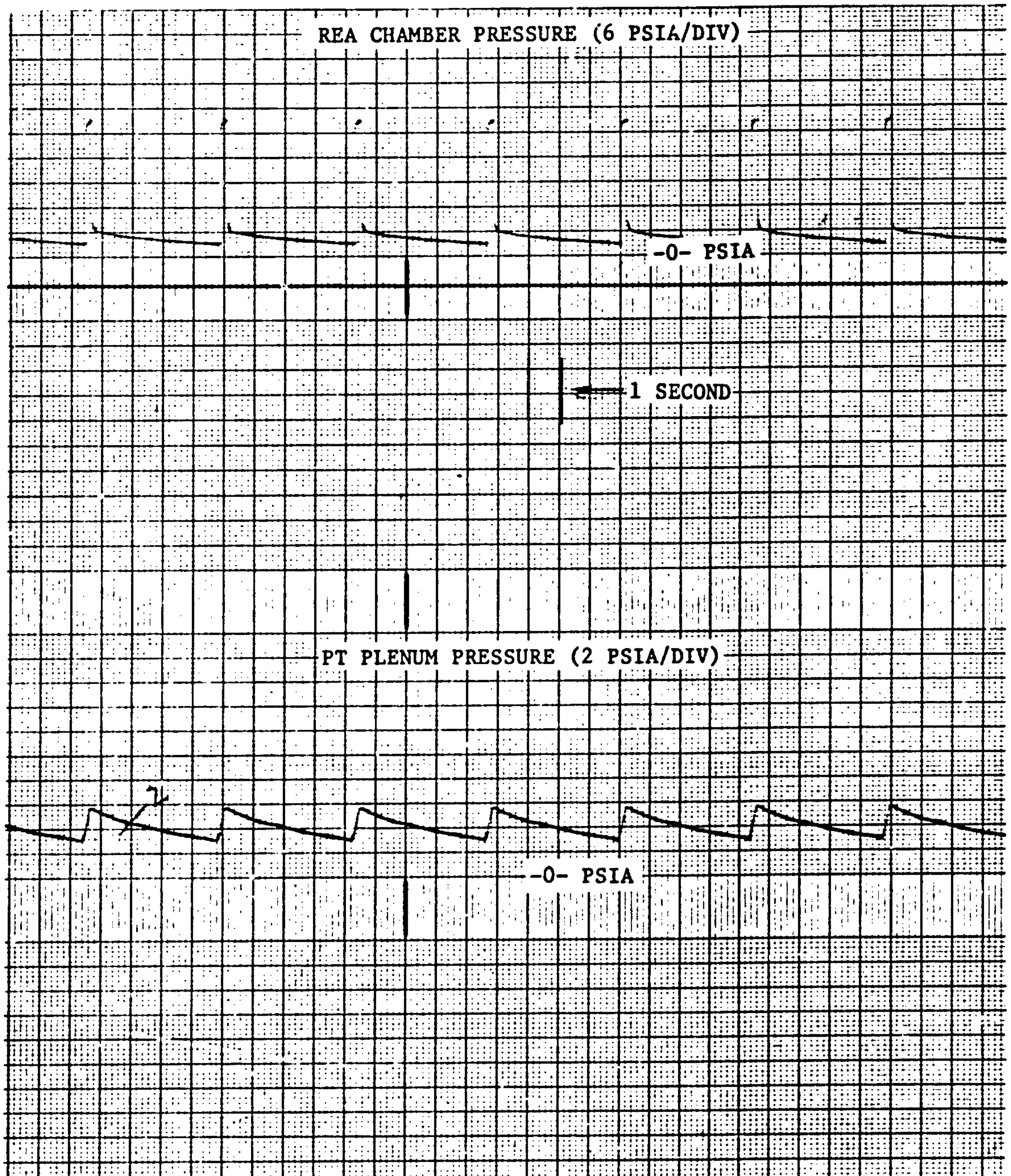


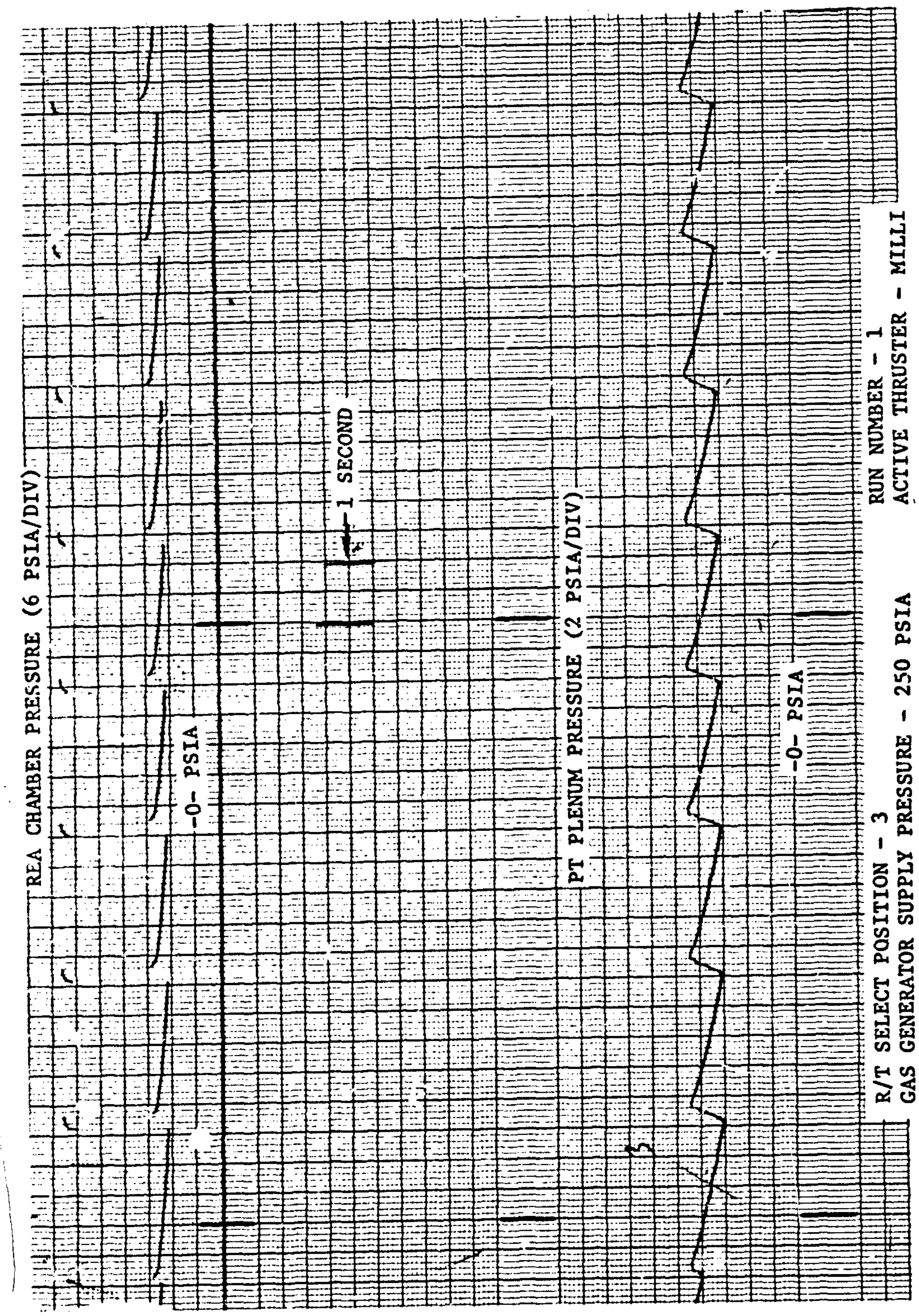
FIGURE 5. TYPICAL ANALOG DATA (R/T-1)



R/T SELECT POSITION - 2
GAS GENERATOR SUPPLY PRSSURE - 250 PSIA

RUN NUMBER - 1
ACTIVE THRUSTER - MILLI

FIGURE 6. TYPICAL ANALOG DATA (R/T-2)


REA CHAMBER PRESSURE (6 PSIA/DIV)
-0- PSIA
1 SECOND
PT PLENUM PRESSURE (2 PSIA/DIV)
-0- PSIA
RUN NUMBER - 1
ACTIVE THRUSTER - MILLI
R/T SELECT POSITION - 3
GAS GENERATOR SUPPLY PRESSURE - 250 PSIA

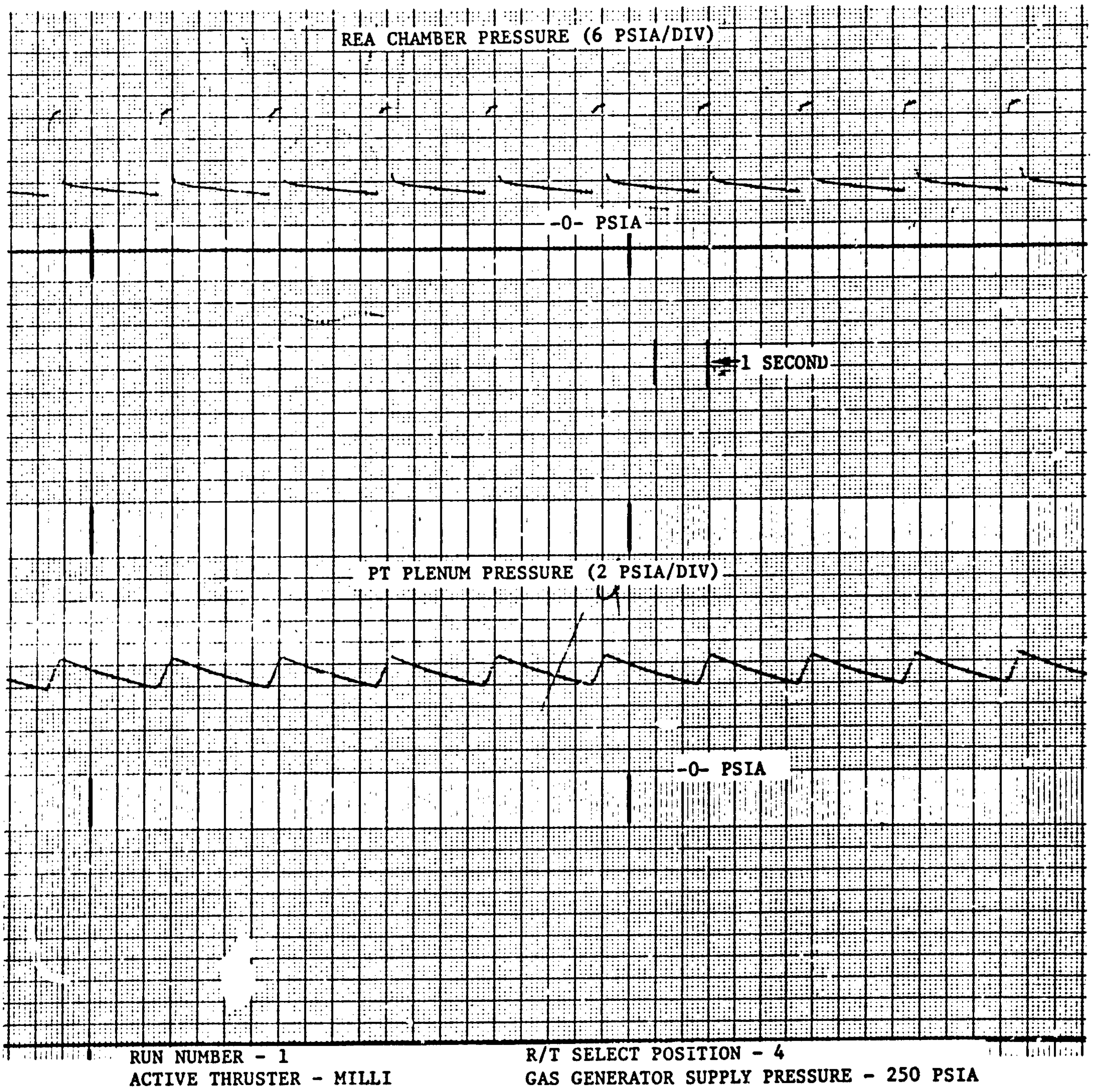


FIGURE 8. TYPICAL ANALOG DATA (R/T-4)

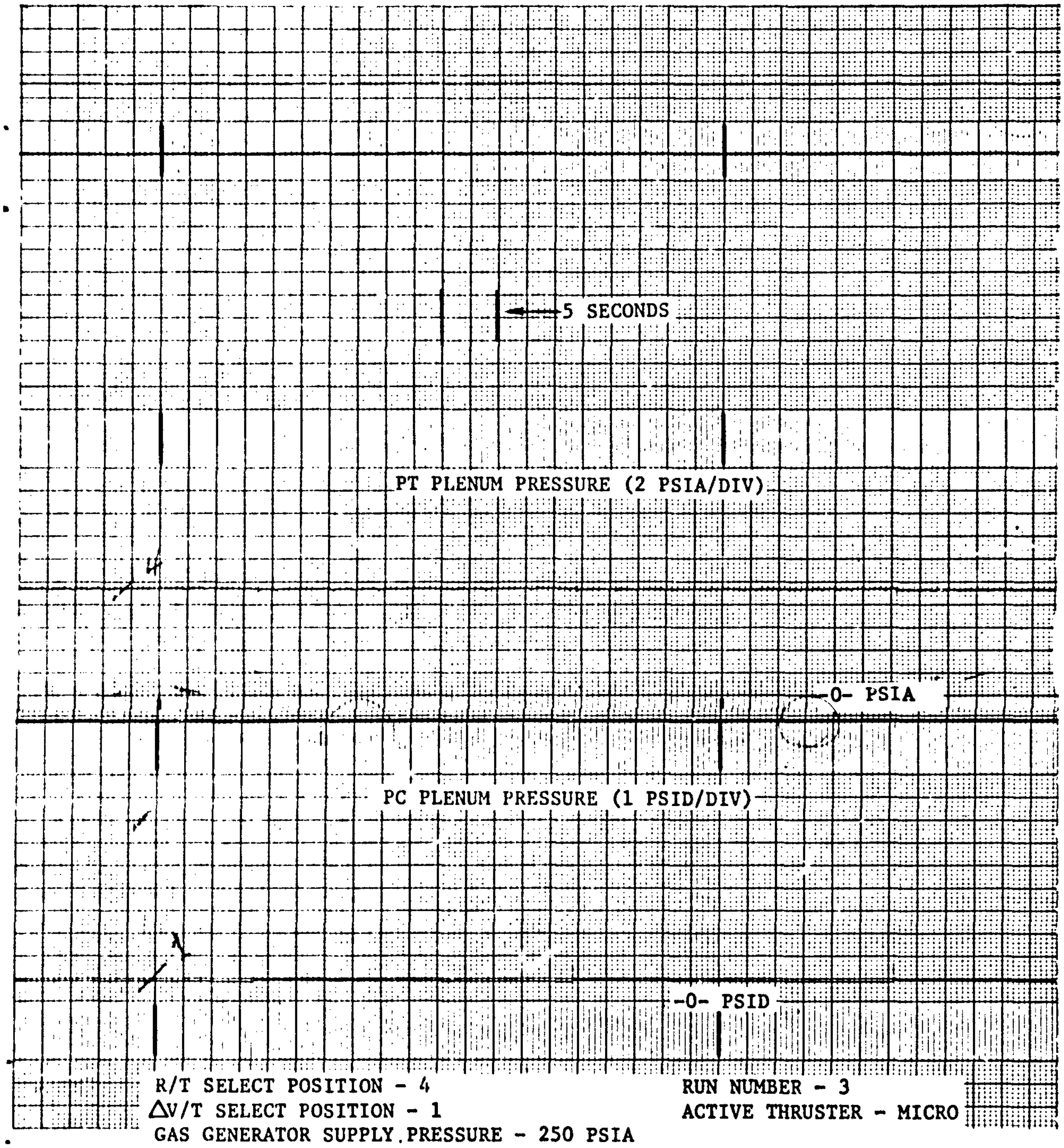


FIGURE 9. TYPICAL ANALOG DATA (R/T-4, ΔV/T-1)

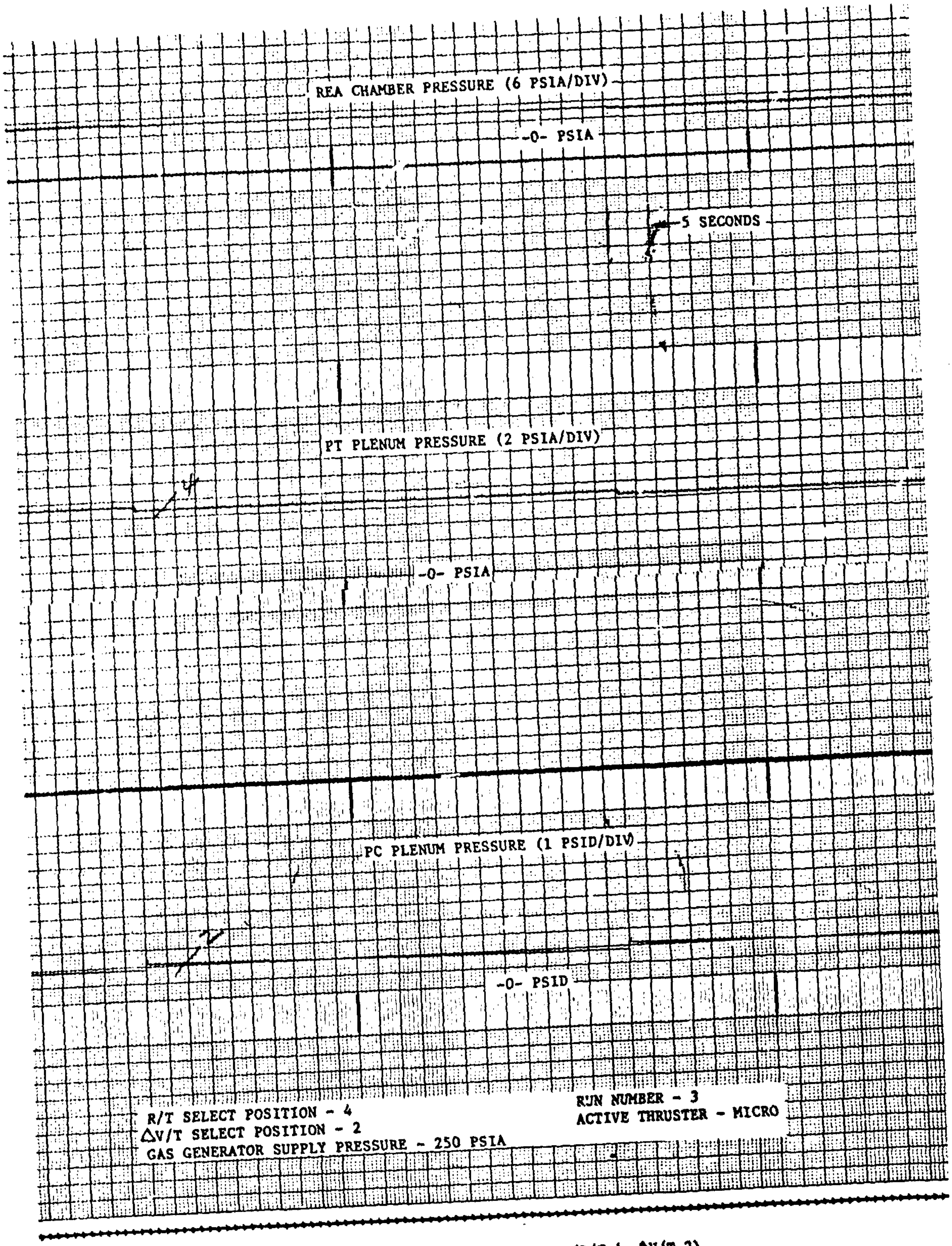


FIGURE 10. TYPICAL ANALOG DATA (R/T-4, ΔV/T-2)

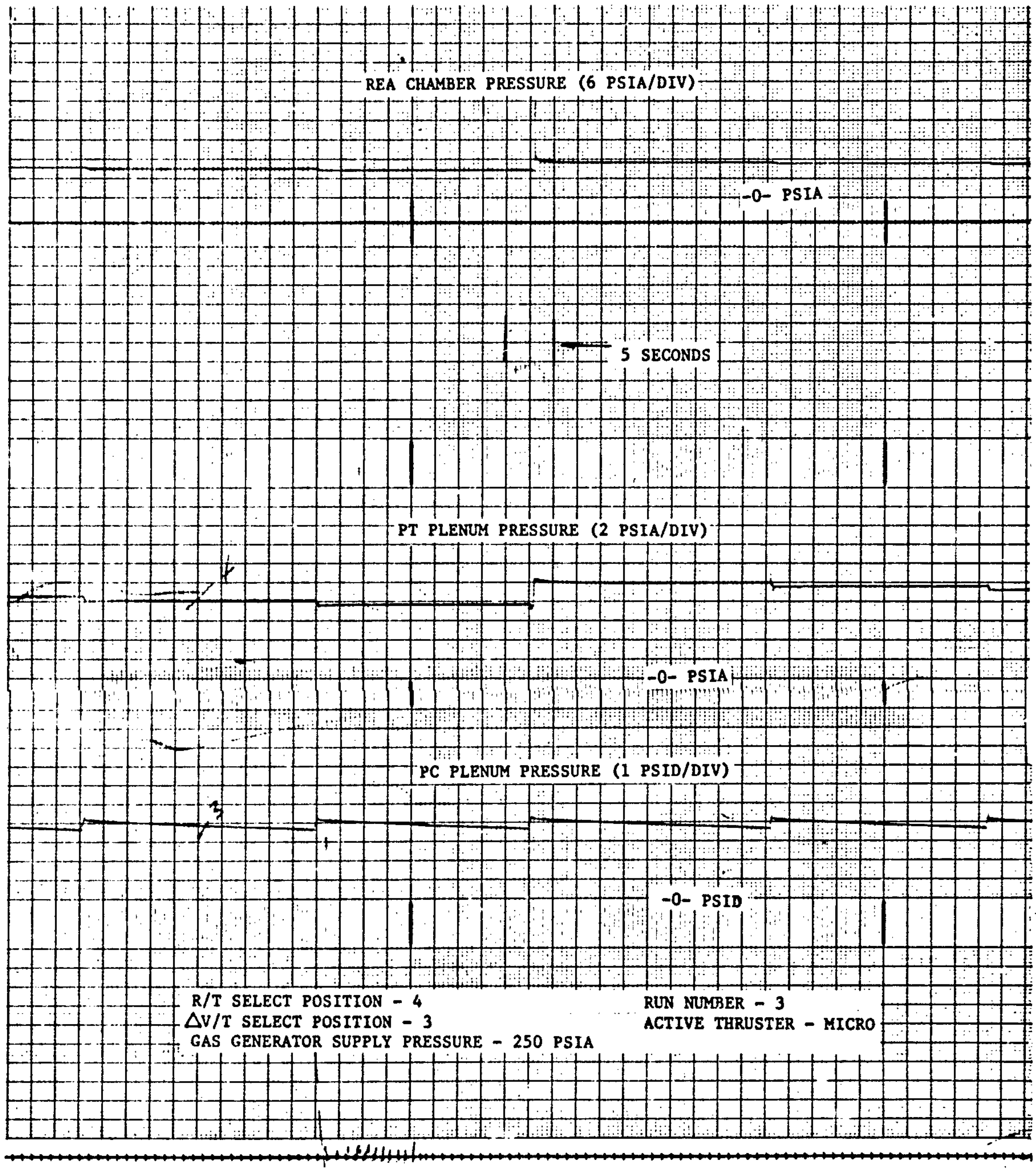


FIGURE 11. TYPICAL ANALOG DATA (R/T-4, ΔV/T-3)

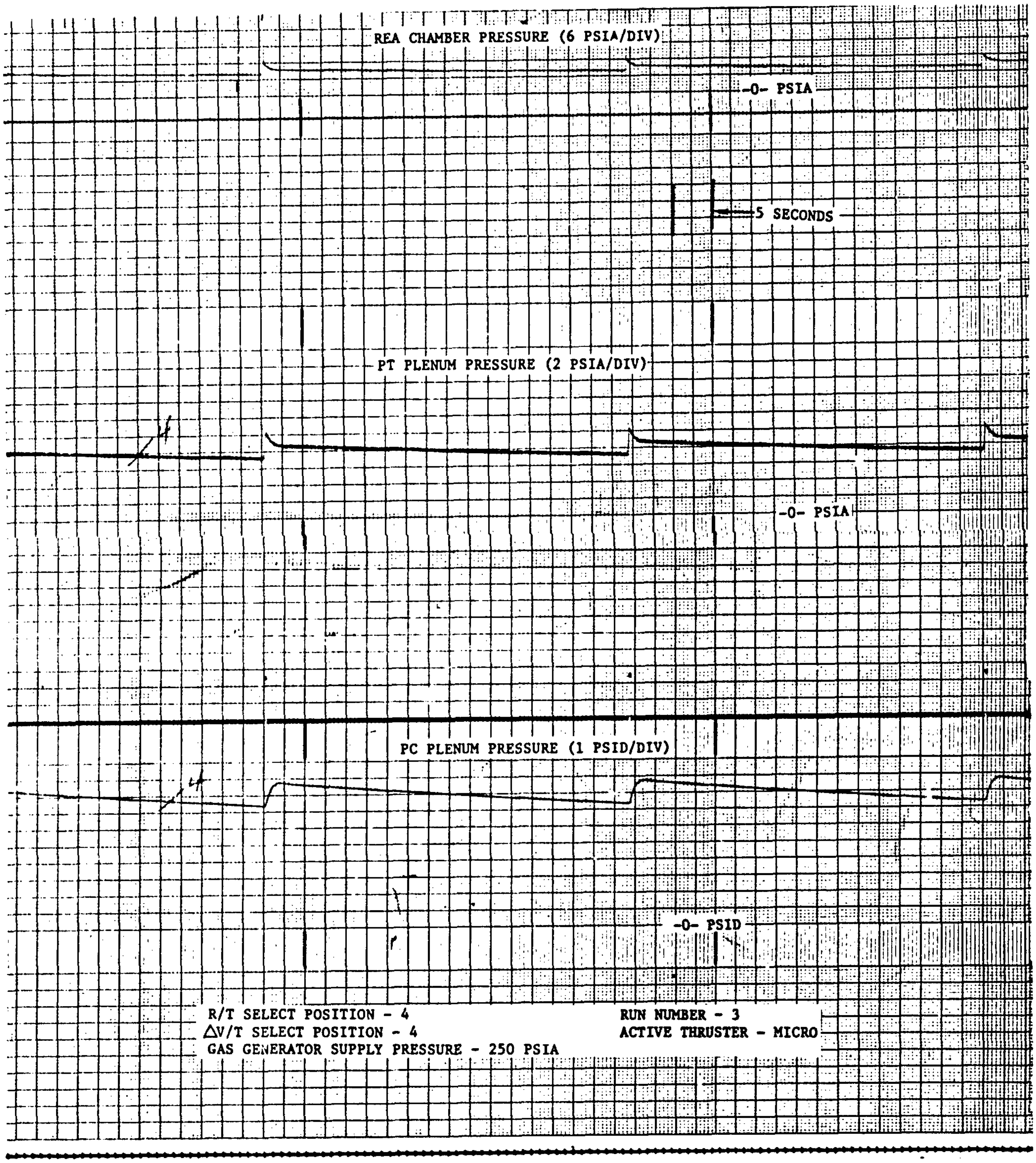


FIGURE 12. TYPICAL ANALOG DATA (R/T-4, ΔV/T-4)

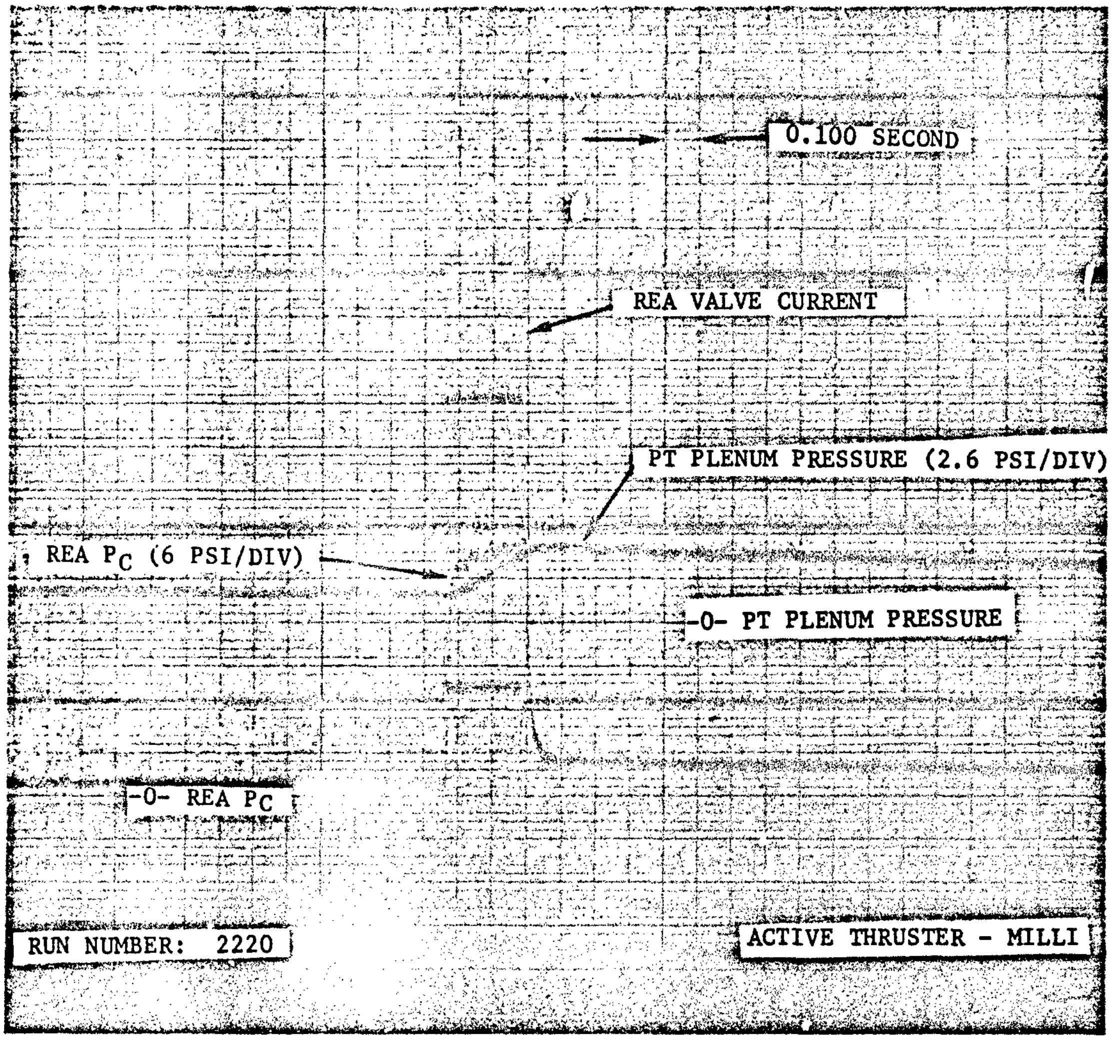


FIGURE 13

TYPICAL PULSE SHAPE
@ P_{IN} = 250 PSIA, R/T - 1

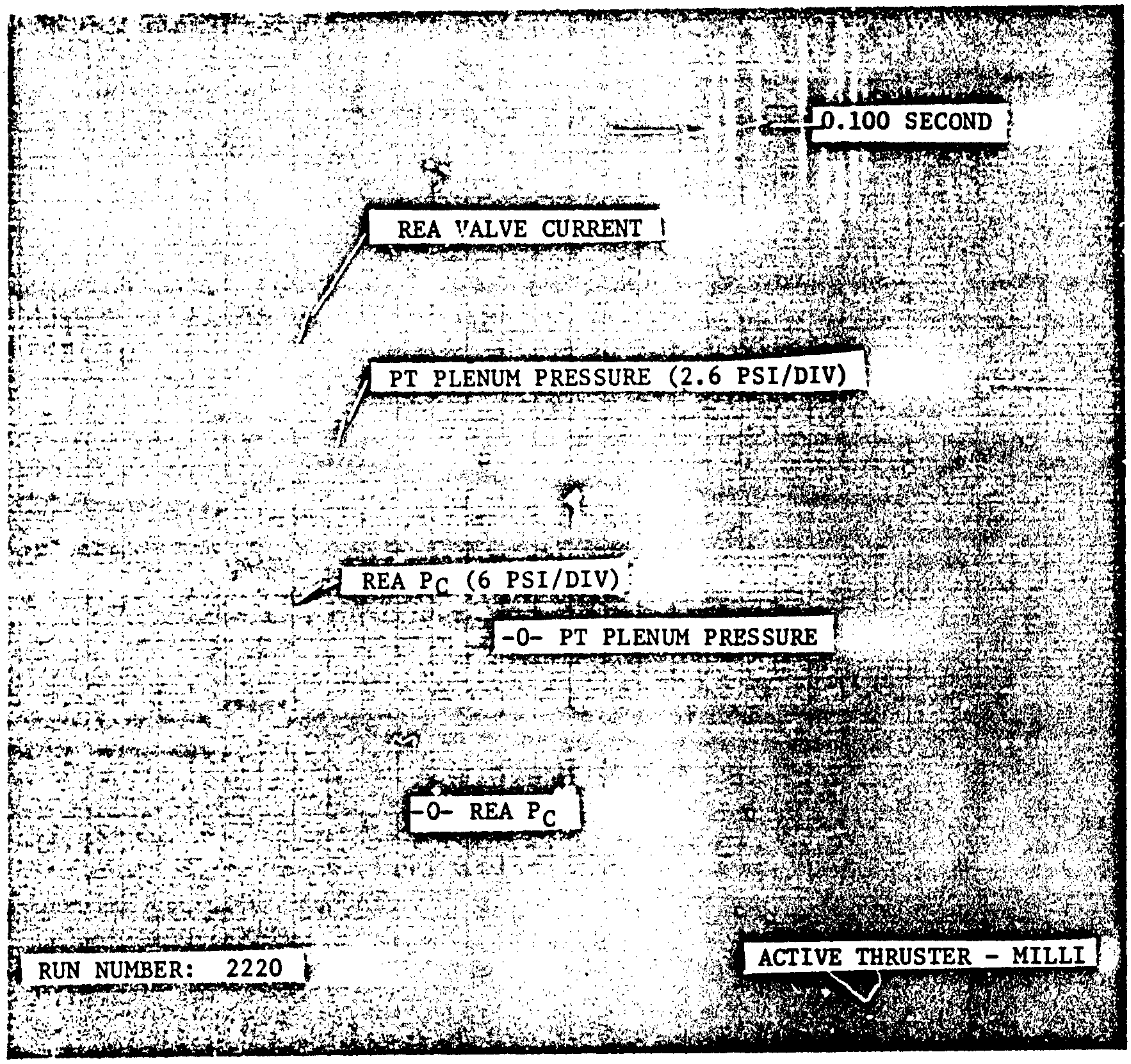


FIGURE 14

TYPICAL PUSLE SHAPE
@ P_{IN} =250 PSIA, R/T - 4

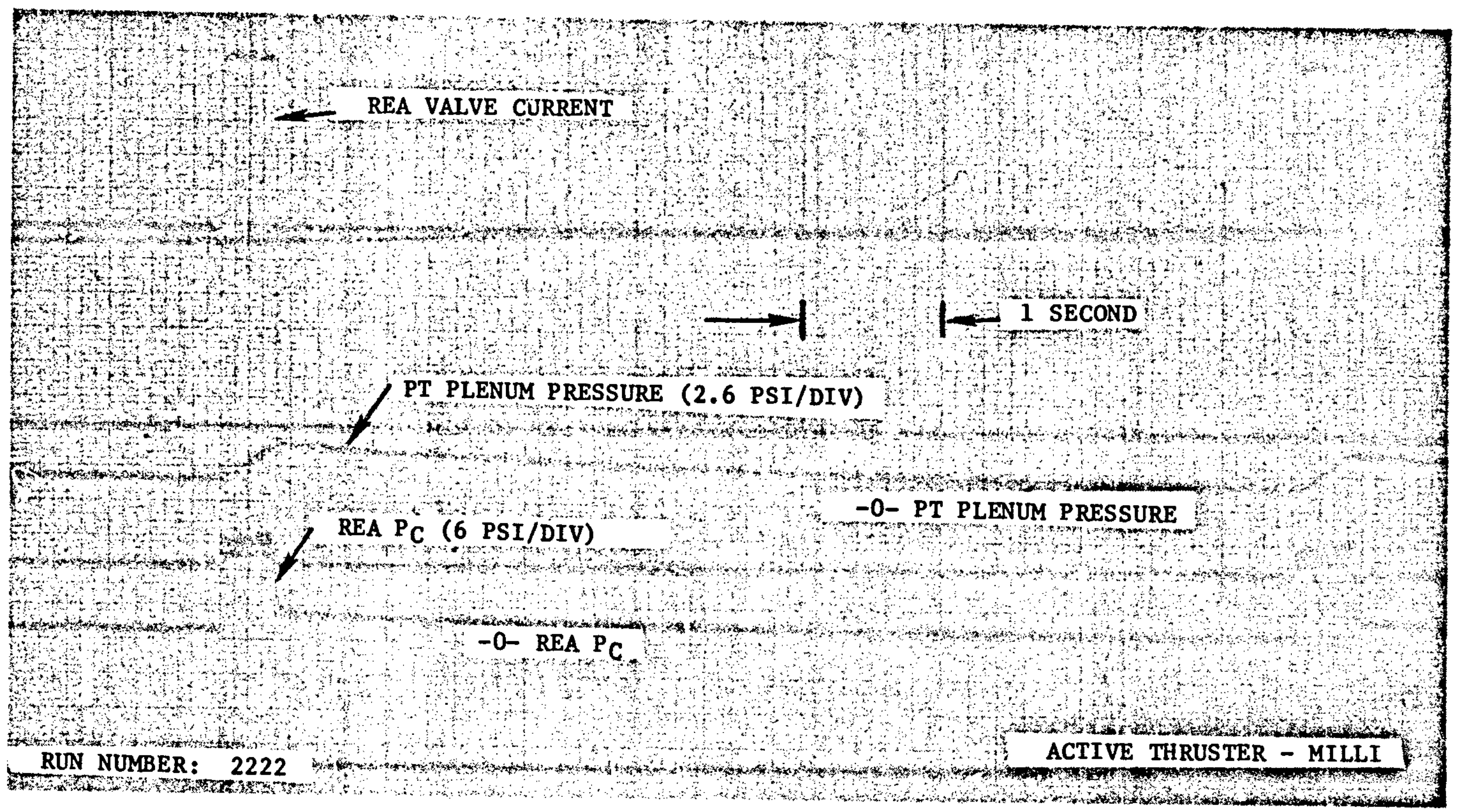
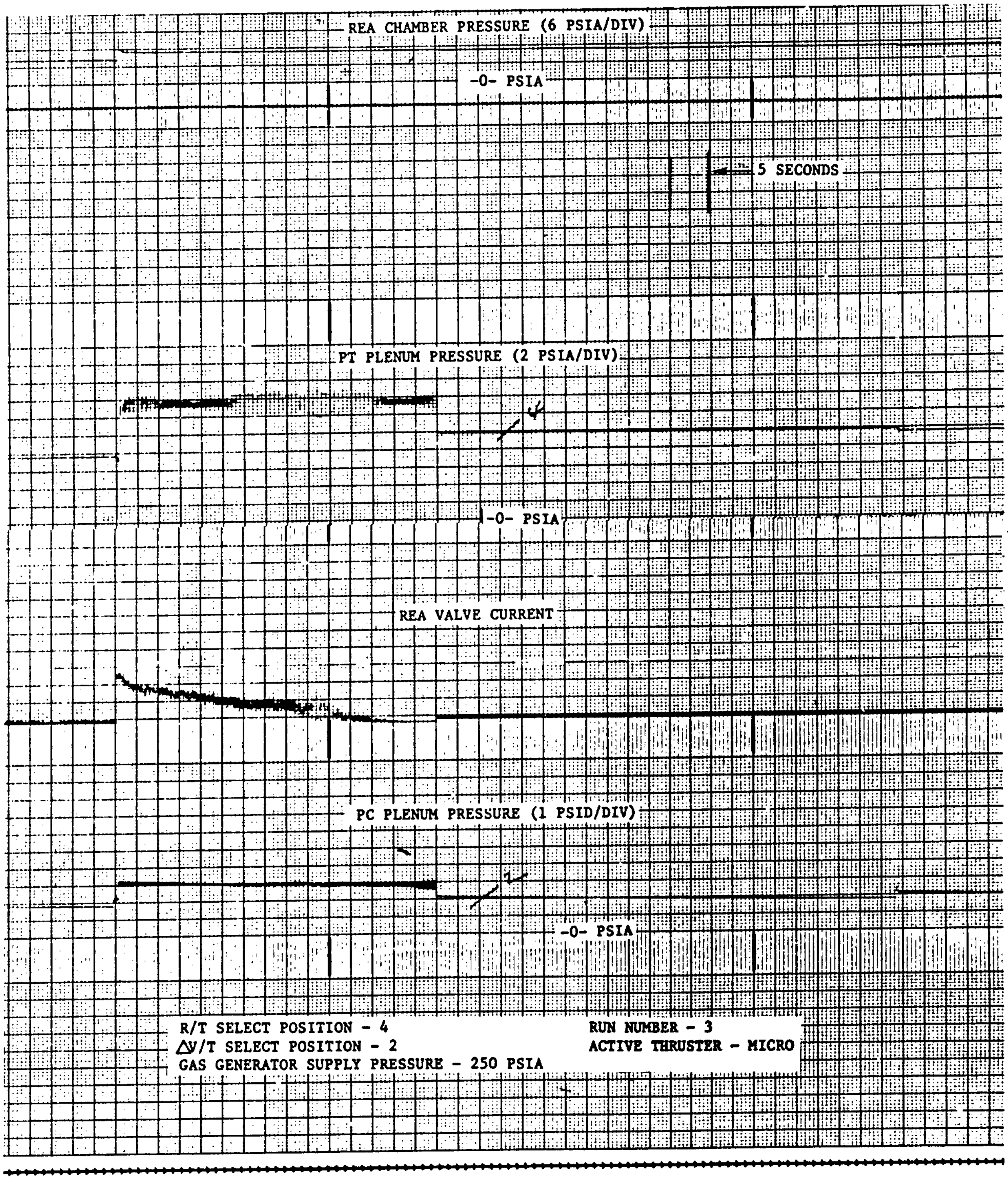


FIGURE 15

TYPICAL PULSE SHAPE
@ P_{IN} = 130 PSIA, R/T - 1



FIGURF 16. ANALOG DATA DEPICTING ELECTRICAL INTERFERENCE

APPENDIX A

GENERAL DESIGN SPECIFICATION

SVHS 6969

HSF-#239 9-70

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT • U.S.A.

CODE IDENT NO.	SPECIFICATION NO.	REV.
73030	SVHS 6969	

SPECIFICATION TITLE HYDRAZINE GAS GENERATOR/PLENUM SYSTEM, GENERAL DESIGN SPECIFICATION FOR

PREPARED BY		DATE	APPROVED BY QUALITY	AB Hooker	6/25/ DATE
APPROVED BY PROJECT	E Abbott	5-9-75 DATE	APPROVED BY PURCHASING		DATE
APPROVED BY TECH. STANDARDS		DATE	APPROVED BY MANUFACTURING	[illegible]	6-23- DATE
APPROVED BY MATERIALS		DATE	APPROVED BY DESIGN	C. Davidson	6-20- DATE
APPROVED BY SPEC. CONTROL	M. Harris	7/22/75 DATE	APPROVED BY RELIABILITY		DATE
APPROVED BY	Joseph Lipsnowcer	7-2-75 DATE	APPROVED BY		DATE
APPROVED BY		DATE	APPROVED BY		DATE

CUSTODIAN

~~EXP. RELEASE~~ ~~DATE~~ ~~PROD.~~ RELEASE D.J. Honyer 7/2 DATE

1.0 SCOPE

This specification defines the general performance, design and test requirements for a Hydrazine Gas Generator/Plenum System.

2.0 APPLICABLE DOCUMENTS

2.1 Government Documents

Federal

TT-I-735	Isopropyl, Alcohol

Military

MIL-P-26536	Propellant, Hydrazine
MIL-P-27401	Propellant Pressurizing Agent, Nitrogen
MIL-P-27407	Propellant Pressurizing Agent, Helium

2.2 Hamilton Standard Documents

Specifications

HS 3150	Cleanliness Levels, High - Processing, Testing, and Pressurization of Parts Subject to.
HS 4618	Packaging, Precision - Cleaned Articles.
SVHS 6007	Engine, Rocket - Monopropellant - NRL-0.2 lb_f Thrust, Acceptance Test Plan for

Drawings

SV 764130	Gas Generator/Plenum System, Hydrazine

3.0 REQUIREMENT

3.1 Item Definition

The Hydrazine Gas Generator/Plenum System shall consist of the following:

- two (2) Model 10-16 Rocket Engine Assemblies, used to generate low pressure gas
- a Plenum, for storage of the gas
- two (2) LVDT pressure transducers, used for on - off control

of REA's - in conjunction with a separate electronic control package.

- a heat exchanger, for lowering of gas temperature
- a (potentiometric type) pressure transducer for plenum pressure data acquisition.

3.1.1 Item Diagram - A flow schematic depicting the item components is presented in Figure 1.

3.1.2 Interface Definition

3.1.2.1 Mechanical Interface - Per SV 764130.

3.1.2.2 Electrical Interface - Per SV 764130.

3.2 Characteristics

3.2.1 Performance Characteristics

3.2.1.1 Milli-Thruster Supply Pressure - The gas supply pressure to the milli-thrusters during steady-state operation shall be 40 to 60 psia.

3.2.1.2 Milli-Thruster Gas Supply Temperature - The item's outlet gas temperature shall not exceed 200°F, with a design goal of 150°F.

3.2.1.3 Milli-Thruster Operation - The item shall be capable of furnishing gas (at required pressure - temperature conditions), when starting from base line thermal environment per paragraph 3.2.3.1.2, for a minimum of 90 seconds of 0.010 lbf thruster.

3.2.1.4 Micro-Thruster Operation - The item shall be capable of furnishing gas (at required pressure - temperature conditions), when starting from base line thermal environment per paragraph 3.2.2.1.2, in a continuous mode operation at 30 micro-pounds thrust.

3.2.2 Physical Characteristics

3.2.2.1 Configuration - The item shall be packaged in a single compact module with minimal envelope. Mechanical connections shall be limited to interface and instrumentation/item interface.

3.2.2.2 Weight - As a design goal, the dry weight of the item shall not exceed 4.0 lbs.

3.2.2.3 **Leakage** - The item's external leakage shall not exceed 10^{-6} scc GHe/sec at 50 psia.

3.2.3 **Environmental Conditions**

3.2.3.1 **Operating Conditions** - The item shall be capable of meeting performance requirements of this specification while operating in any natural combination of the environmental conditions below.

3.2.3.1.1 **Ambient Pressure** - Sea level to 10^{-11} torr.

3.2.3.1.2 **Ambient Temperature** - 40 - 95°F (both conductive and radiative).

3.2.3.2 **Non-Operating Conditions** - The item shall be capable of meeting performance requirements of this specification following exposure to the environmental conditions below.

3.2.3.2.1 **Vibration**

(a) Sinusoidal (all axes)	25-2000 Hz at 11 g, sweeprate not to exceed one (1) octave per minute;
(b) Random (all axes)	20-200 Hz at 0.1 g^2/Hz 200-2000 Hz at -6 db/octave roll off, two (2) minutes per axis.

3.3 **Design Construction**

3.3.1 **Materials** - The item shall be constructed from materials which are compatible with the operating and/or test fluids and mixtures thereof. The operating fluids are hydrazine (per MIL-P-26536L) and the products of catalytically decomposed hydrazine.

Test Fluids	Specification Reference
Gaseous Nitrogen	MIL-P-27401
Gaseous Helium	MIL-P-27407
Water, High Purity	HS3150, paragraph 3.2.2
Isopropyl Alcohol (Gr[illegible])	TT-I-735

3.3.2 **Pressure** - All components downstream of the REA's shall be capable of withstanding a proof pressure of 375 psia and a minimum burst pressure of 50[illegible] psia.

4.0 DEMONSTRATION TEST PROGRAM

The Demonstration Test Program shall be conducted in the sequence of test descriptions below. The test methods/descriptions may be altered at the discretion of the cognizant Project Engineer.

4.1 Examination of Product

The item shall be examined for physical defects and for compliance with the requirements of Hamilton Standard Drawing per SV 764130. The unit shall be weighed and the data recorded.

4.2 Proof

The item shall be pressurized to proof pressure (without plenum pressure transducer) per paragraph 3.3.2 for a minimum duration of five (5) minutes. Pressure applied, time at pressure, fluid medium, and evidence of leakage or permanent deformation - if any, shall be recorded. There shall be no damage or permanent deformation, and the item shall subsequently satisfactorily pass the external leakage test.

4.3 External Leakage

The item shall be pressurized with 50^{+15}_{-0} psia gaseous helium and external leakage shall be measured with a helium mass spectrometer. The external leakage shall not exceed the requirements of paragraph 3.2.2.3.

4.4 Random Vibration

The item shall be hard mounted to a test fixture and subjected to random vibration in each of three (3) orthogonal axes per the requirements of paragraph 3.2.3.2.1(b). There shall be no damage or permanent deformation as a result of this test.

4.5 Functional Tests

4.5.1 Test Conditions

The item shall be installed in a test chamber and mounted to a 95 to 105°F heat sink. When operating the item, the ambient pressure shall be reduced to the equivalent of 100K feet altitude, or greater.

Prior to normal operation of the milli-thrusters, the plenum shall be filled with gas by evacuating the plenum (via opening of the milli-thruster valves to low ambient pressure), then closing th valves, followed by energizing the item's control circuitry.

4.5.2 Test Operation

(a) With a hydrazine supply pressure of 250 ± 10 psia, the mill thruster shall be operated for duration of 10 seconds, 30 seconds, and 90 seconds. Each thruster operation shall be initiated with the item temperature not exceeding 40°C.

(b) Repeat above with the micro-thruster operating at 30 micro pound level until thermal equilibrium is attained.

(c) Repeat (a) above with a hydrazine supply pressure of 120 ±

(d) Repeat (a) above with the redundant system in operation.

4.5.3 Data Requirements

The following minimum data shall be recorded:

- Pressure, Inlet, REA Model 10-16
- Pressure, Chamber, REA Model 10-16
- Temperature, Inlet, REA Model 10-16
- Pressure, Plenum Outlet
- Temperature, Mount Flange, REA Model 10-16
- Temperature, Throat, REA Model 10-16
- Temperature, Inlet, Plenum
- Temperature, Heat Exchanger
- Temperature, Plenum
- Temperature, Inlet, Milli-Thruster
- Current, Valve, REA Model 10-16
- Current, Valve, Milli-Thruster

4.6 External Leakage Test

Repeat of test per paragraph 4.3.

4.7 Post-Test Inspection

The item shall be visually examined for discrepancies and/or damage.

5.0 SPECIAL INSTRUCTIONS

5.1 Packaging

5.1.1 Interim Packaging - All openings shall be sealed with nylon f and the item shall be bagged in polyethylene for interim stor and transportation between tests. Packaging integrity shall broken only prior to test setup.

5.1.2 Final Packaging - Packaging for delivery to stores or to the customer shall be per SVHS 4618 Type I. The double bagged unit shall be further packaged in a container for protection during handling, transit and storage.

5.2 Cleaning

External cleanliness (visual) per HS 3150 shall be verified after Examination of Product.

5.3 Pressurization and Venting

Pressure shall be introduced only at the REA inlet. All test fluids (liquid or gaseous) used to pressurize the REA shall be filtered to 10 microns abs, as a minimum. The REA shall be vented only in positive flow direction.

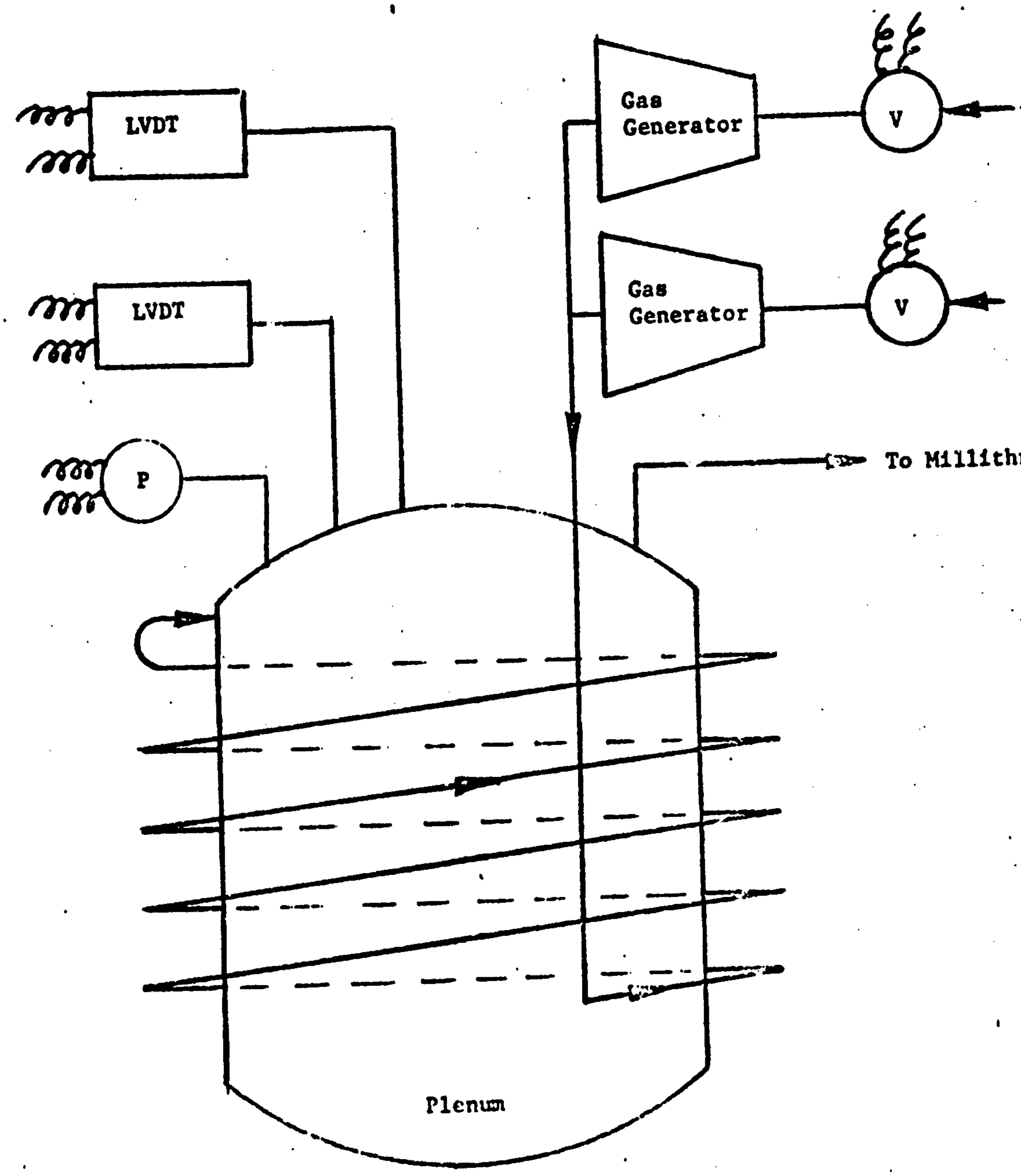
5.4 Data Package

The data package shall contain the following items:

a. Copy of all test data sheets

b. Copy of reduced digital performance data

c. Drawing SV 764130



Schematic
N_2H_4 GG/Plenum System

Figure 1

APPENDIX B

GAS GENERATOR/PLENUM SYSTEM

PARTS LIST

Parts List
for
Gas Generator/Plenum System
SV764130-1, Model GGA-9

No. Req'd.	Part Identification	
1	SV764130-1 Gas Generator/Plenum System	
6	AN960C8 Washer-Flat	
AR	MS20995C2 Wire, Safety or Lock	
6	MS24674-8 Screw, Cap, Socket Head	
8	MS 35275-214 Screw, Machine	
8	NAS620C4 Washer	
1	SV748537-103 Fitting, Brazed Tube	
1	SV764130-200 Base	
1	SV764130-202 Plate	
2	SV764130-203 Plug, Nozzle	
2	SV764130-204 Tube, Nozzle Exit	
2	SV764130-205 Tube, Connecting	
1	SV764130-206 Tube, Wound	
2	SV764130-207 LVDT (GFE)	(Note 1)
1	SV764130-208 Transducer, Pressure (GFE)	(Note 2)
2	SV764130-209 Packing, Preformed (GFE)	
1	SV764130-210 Packing, Preformed (GFE)	
1	SV764130-211 Engine	SV755437-7 S/N 38
1	SV764130-212 Engine	SV755437-7 S/N 45
1	SV764130-213 Flange	

Note (1) LVDT - Gulton P/N 3255-8801, S/N 1021 and 1023.

(2) Pressure Transducer - Bourns P/N 80294-2004831901

APPENDIX C

TEST PLAN, SVHS 7029

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT • U.S.A.

CODE IDENT NO.	SPECIFICATION NO.	REV.
73030	SVHS 7029	

SPECIFICATION TITLE TEST PLAN FOR
NRL HYDRAZINE GAS GENERATOR/PLENUM SYSTEM

PREPARED BY ______ DATE		APPROVED BY O.B. Hooker 1/14/76 QUALITY	DATE
APPROVED BY [signature] PROJECT	1/14/76 DATE	APPROVED BY ______ PURCHASING	DATE
APPROVED BY ______ TECH. STANDARDS	DATE	APPROVED BY ______ MANUFACTURING	DATE
APPROVED BY ______ MATERIALS	DATE	APPROVED BY ______ DESIGN	DATE
APPROVED BY M. Harris SPEC. CONTROL	1/14/76 DATE	APPROVED BY ______ RELIABILITY	DATE
APPROVED BY ______	DATE	APPROVED BY ______	DATE
APPROVED BY ______	DATE	APPROVED BY ______	DATE

CUSTODIAN ______

~~EXP.~~ RELEASE [signature] DATE ... RELEASE ______ DATE

1.0 SCOPE

This test plan defines the Demonstration Test Program of the SV764130 Hydrazine Gas Generator/Plenun System. The test plan defines the test sequence, test descriptions, and data requirements. The primary functions of the test plan are (1) to present an overview for Engineering/Management personnel and (2) to serve as a basis for the preparation of Test Procedures, which define the Specialized Test Equipment, the test setup (including schematics), and presents the step-by-step directions essential to accomplishing each specified test.

2.0 TEST ITEM DEFINITION

The test item, referred herein as the item, is the Gas Generator/Plenum Assembly per SV764130 (including customer furnished electronic controls).

3.0 TEST SEQUENCE

Testing shall be conducted in the following sequence:

1) Examination of Product
2) Proof
3) External Leakage
4) Random Vibration
5) External Leakage
6) Functional Checkout
7) Performance Demonstration
8) External Leakage
9) Internal Leakage
10) Post-Test Inspection

4.0 TEST DEFINITIONS

4.1 Examination of Product

4.1.1 Purpose - To verify that the unit is ready for testing.

4.1.2 Test Description - The item shall be examined for defects or imperfections. The items's record log shall be examined for compliance verification with applicable Hamilton Standard drawings.

The item, exclusive of customer furnished equipment (CFE), shall be weighed with the test equipment having an accuracy within ± 1%.

4.1.3 Data Requirements - Any physical anomalies, evidence of substandard workmanship, or nonconforming dimensions and dry weight shall be recorded.

4.2 Proof

4.2.1 Purpose - To verify unit is capable of withstanding proof pressure load.

4.2.2 Test Description - The item, exclusive of the three CFE pressure transducers, shall be slowly pressurized to $375 ^{+15}_{-0}$ psig for a minimum of five (5) minutes. Pressurization of the item shall be applied at the inlet, with both REA 10-16's energized in the open position, and depressurization shall be effected by slowly venting downstream of the catalyst bed.

Subsequent to this test, the item shall be examined for damage or deformation.

4.2.3 Data Requirements - Pressure applied, time at pressure, fluid medium, and visual findings shall be recorded.

4.3 External Leakage

4.3.1 Purpose - To verify external leakage of item does not exceed 10^{-6} scc GH_e/sec at 50 psia.

4.3.2 Test Description - The item shall be slowly pressurized to $50 ^{+10}_{-0}$ psia with gaseous helium at the inlet of the item, with both REA 10-16's energized in the open position. Using a mass spectrometer, external helium leakage shall be measured. Depressurization shall be effected by slowly venting downstream of the catalyst bed.

4.3.3 Data Requirements - Applied pressure, fluid medium, and leakage readings shall be recorded.

4.4 Random Vibration

4.4.1 Purpose - To demonstrate units ability to withstand structural vibratory loads.

4.4.2 Test Description - The test item shall be hard mounted to a rigid fixture and subjected for two (2) minutes in each of three orthogonal axes, to random vibration levels, as defined below.

4.4.2 continued

Frequency (Hz)	Power Spectral Density (g^2/Hz)
20 - 200	0.1
200 - 2000	-6 db/octave

4.4.3 Data Requirements - A curve of frequency or vibration level of the control accelerometer and response accelerometer (input to thruster) for each applicable axis shall be obtained. The unit shall be visually examined for damage following this test, with observations recorded.

4.5 Functional Checkout

4.5.1 Purpose - To ensure unit is ready for Performance Demonstration testing. More specifically:

- to familiarize user with controls and basic GG operation.
- to verify data acquisition adequacy.
- to demonstrate basic operational functionality.

4.5.2 Test Description - With the item installed in a test chamber and mounted to a base plate, the item shall be operated at various control select positions with high and low Gas Generator supply pressures. The specific tests shall be defined at time of testing by the cognizant Project Engineer.

4.5.3 Data Requirements - The following data shall be analog recorded with each test:

Parameter	Range
Pressure, Inlet, REA Model 10-16	0-500 psia
Pressure, Chamber, REA Model 10-16 (2)	0-100 psia
Pressure, Plenum Outlet	0-150 psia
Temperature, Base Plate	0-200 °F
Temperature, Throat, REA Model 10-16	0-2000°F
Temperature, Inlet, Milli/Micro Thruster	0-500 °F
Temperature, REA 10-16, Inlet	0-500 °F
Temperature, Heat Exchanger	0-500 °F
Temperature, Plenum	0-500 °F
Temperature, Mount Flange	0-500 °F
Current, Valve, REA Model 10-16	0-1 amp
Current, Valve, Milli/Micro Thruster	0-1 amp
Voltage, Valve, REA Model 10-16	0-36 VDC

4.5.3 continued

In addition to analog data above, ambient pressure and fuel temperature data at start and end of test shall be recorded in the test log.

The paper speed for analog data shall be per Engineering instructions at time of test.

4.6 Performance Demonstration

4.6.1 Purpose - To demonstrate the unit's capability under the conditions specified in Specification SVHS 6969, and to meet the plenum outlet temperature requirements specified in SVHS 6969.

4.6.2 Test Description - The item shall be installed in a test chamber and mounted to a plate capable of being conditioned to levels specified in Table I. A heat sink grease shall be applied to the surface between the item and mounting plate per Drawing SVHS 764130.

Initial pressurization shall be achieved by activation of the pressure regulation controls, with a hydrazine supply pressure of 250 ± 10 psia. Testing shall be conducted per Table I.

4.6.3 Data Requirements - The following data shall be analog recorded with each test:

Parameter	Range
Pressure, Inlet, REA Model 10-16	0-500 psia
Pressure, Chamber, REA Model 10-16 (2)	0-100 psia
Pressure, Plenum Outlet	0-150 psia
Temperature, Base Plate	0-200 °F
Temperature, Throat, REA Model 10-16	0-2000°F
Temperature, Inlet, Milli/Micro Thruster	0-500 °F
Temperature, REA 10-16, Inlet	0-500 °F
Temperature, Heat Exchanger	0-500 °F
Temperature, Plenum	0-500 °F
Temperature, Mount Flange	0-500 °F
Current, Valve, REA Model 10-16	0-1 amp
Current, Valve, Milli/Micro Thruster	0-1 amp
Voltage, Valve, REA Model 10-16	0-36 VDC

In addition to analog data above, ambient pressure and fuel temperature data at start and end of test shall be recorded in the test log.

The paper speed for analog data shall be per Engineering instructions at time of test.

4.6.4 General Remarks

(1) The test setup shall include provisions to protect the system in the event of a high pressure overshoot due to excessive ignition delay. A suggested protective method is to effect an automatic shutdown of REA 10-16 if the REA 10-16 chamber pressure does not attain 75 $^{+10}_{-0}$ psia within 0.100 secs of thrust chamber valve energization. In the event a malfunction occurs, the test shall be terminated and Project Engineering notified.

(2) Plenum pressure shall be monitored during each test. If the plenum pressure exceeds 70 psia, the test shall be terminated.

4.7 Internal Leakage

4.7.1 Purpose - To verify REA 10-16's valve seat leakage meets specified requirements following functional testing of the CC/Plenum assembly and prior to shipment.

4.7.2 Test Description - The inlet of each REA, with the valve de-energized, shall be pressurized one-at-a-time to 250 ± 10 psia with gaseous helium. Leakage shall be measured downstream of the valve seat with gaseous helium, using a mass spectrometer. Leakage shall not exceed 1 x 10^{-6} scc GHe/sec.

4.7.3 Data Requirements - Applied pressure, fluid used, and obtained leakage data.

4.8 Post-Test Flush

4.8.1 Purge test unit with 10 - 15 psig GN_2.

(a) Set REA inlet pressure to 10 - 15 psig GN_2.
(b) Set controls to R/T-1 and ΔV/T-1.
(c) Enable Reactor A and ΔV1-3 Systems. Then change control levels to R/T-4 and ΔV/T-4. (Monitor PT and PC pressures to ensure control valves have actuated).
(d) Actuate milli-thruster and micro-thruster for 15 minutes. (Adjust inlet pressure, if necessary, to ensure 10 - 15 psig supply. PT pressure will be 25 - 30 psia while PC pressure will be 10 - 15 psid).
(e) After 1 - 2 minutes, switch to Reactor B. Then alter between Reactor A and Reactor B every 3 - 5 [illegible] time.
(f) Disable Reactor A and ΔV1-3 systems. De-energize milli and micro thrusters.

4.8.2 Water flush test unit with 10 - 15 psig high purity water.

(a) Separate Gas Generator/Plenum assembly from milli-thruster and micro-thruster subassembly.
(b) Flush Gas Generator/Plenum assembly with 10 - 15 psig water, actuating each REA valve open/close at approximately 20 to 60 cycles per minute for minimum of two minutes.
(c) Flush milli and micro thruster subassembly with 10 - 15 psig water, by energizing small plenum control valve open and cycling thruster valves 20 to 60 cycles per minute for minimum of two minutes.

4.8.3 Isopropyl alcohol (IPA) flush test unit with 10 - 15 psig IPA.

(a) Repeat 4.8.2 above, except with IPA.

4.8.4 Purge unit with gaseous nitrogen.

(a) Repeat 4.8.1 above.

4.8.5 Vacuum dry unit as 1.5 mmHg or less for four (4) hours minimum at 80 - 120°F.

4.9 <u>Post-Test Inspection</u>

4.9.1 <u>Purpose</u> - To verify prior testing has not physically damaged the item.

4.9.2 <u>Test Description</u> - The item shall be visually examined for discrepancies and/or damage.

4.9.3 <u>Data Requirements</u> - The visual findings shall be recorded in the log book.

TABLE 1. CG/PLENUM ASSEMBLY FUNCTIONAL TESTS

Test No.	Test Objective	Test Conditions	Operation
1	Nominal Performance Evaluation of varied R/T Select positions - at hi P_{in}	P_{in} = 250 psia Room Temp. (hdw-fuel)	Vary R/T - 1 - 2 - 3 - 4; operate milli-thruster for 10 cycles minimum at each select position.
2	Same, except at low P_{in}	P_{in} = 130 psia Room Temp. (hdw-fuel)	Same.
3	Nominal Performance Evaluation of varied V/T Select positions	P_{in} = 250 psia Room Temp. (hdw-fuel)	With R/T - 4, vary Δ V/T 4 - 3 - 2 - 1; operate micro thruster for three PT cycles minimum at each position.
4	Max. Gas Temp. Determination	P_{in} = 250 psia Hdw-fuel Temp. = 95-105°F	With R/T - 4, operate milli thruster until 105°F gas outlet temperature is attained.
5	Long Duration Δ V Operation Evaluation	P_{in} = 250 psia Hdw-fuel temp. - 95-105°F	With R/T - 4, Δ V/T - 2, operate micro thruster for not less than 8 hrs.
6	Evaluate worst case REA operation (max. off time) at low inlet pressure	P_{in} = 130 psia Hdw-fuel temp. = 40-50°F	With R/T - 4, Δ V/T - 1, operate micro-thruster for a minimum of 3 PT cycles.
7	Same as #6, except at high inlet pressure	P_{in} = 250 psia Hdw-fuel Temp. = 40-50°F	Same as #6 above.
8	Long hold period effect evacuation	Pre-test Conditions: Plenum locked up with [illegible] for minimum of 7 days.	With R/T - 4, operate milli-thruster

TABLE I. GG/PLENUM ASSEMBLY FUNCTIONAL TESTS - continued

Test No.	Test Objective	Test Conditions	Operation
8	(continued)	Test Conditions: P_{in} = 250 psia Ambient Fuel-Hdw. Temp.	
9	Nominal Performance Evaluation of Redundant REA	P_{in} = 250 psia Room Temp. (Hdw-Fuel)	same as #1 above.

GENERAL NOTES

(1) Milli-thruster operation is preceded by "enabling" Reactor A; micro-thruster operation is preceded by "enabling" both Reactor A and then AV1-3 system.

(2) Paper speed of instrumentation shall be per Engineering instructions.

(3) Ambient or room temperature is defined as 70°F to 95°F.

(4) Immediately preceding and immediately following each test all temperature data and ambient pressure shall be entered in Test Log.

(5) The test sequence is optional.

APPENDIX D

VIBRATION TEST LOG DATA

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: DEMONSTRATION TEST
TEST ENGINEER: T. JOHNSTON
NAME OF RIG: I&M VIB.
PROJECT & ENG. ORDER NO.: A82-500-200A

SHEET 1 OF
DATE 11/6/75
TEST PLAN NO. SVHS 7029
MODEL NO. NRL PLENUM
PART NO. SV764130-1
SERIAL NO. B8801
OPERATORS W. MERRILL

RUN	AXIS	MODE	LEVEL	DUR.	PARA.		
3	Z	RAND	6.1 GRMS	2.	4.4	[illegible]	11-6-75
5	X	RAND	6.1	2.	4.4	[illegible]	11-6-75
7	Y	RAND	6.1	2.	4.4	[illegible]	11-6-75

REMARKS:

11477

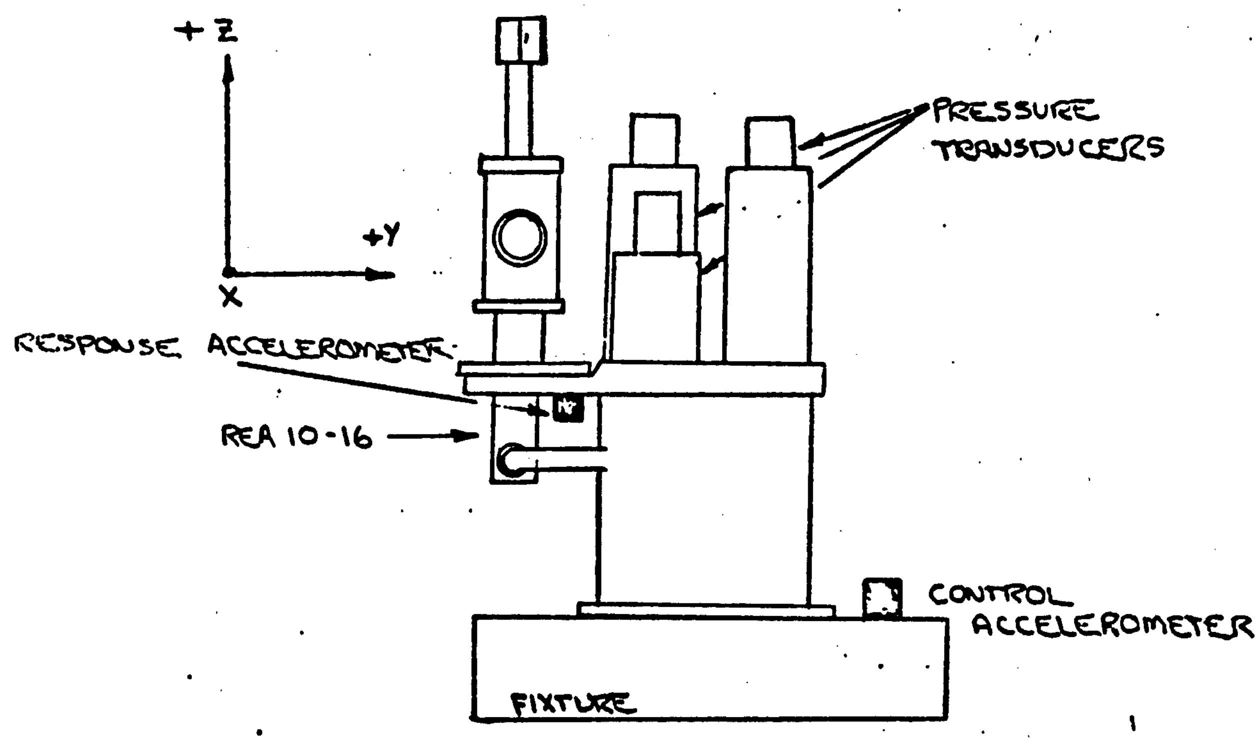
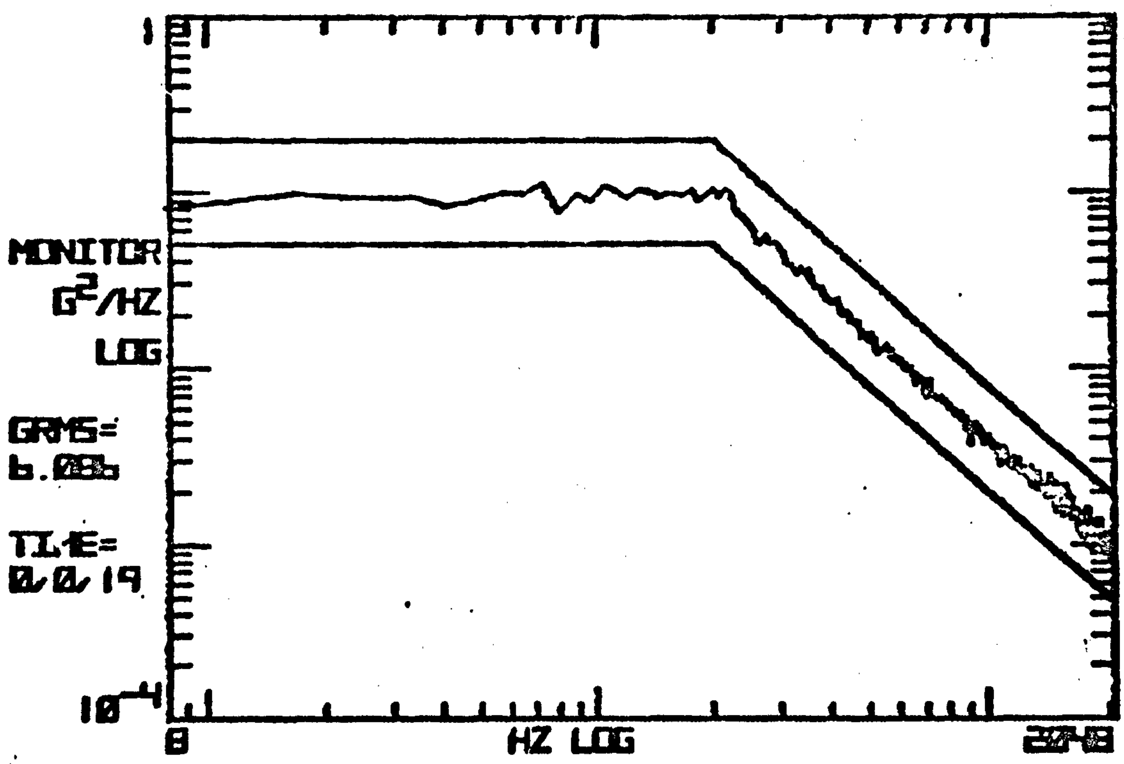


FIGURE 4-1 ~ VIBRATION TEST SET-UP

Hamilton Standard	SIZE A	CODE IDENT NO. 73030	
			SHEET

RUN 3 Z-AXIS LOC. AZ



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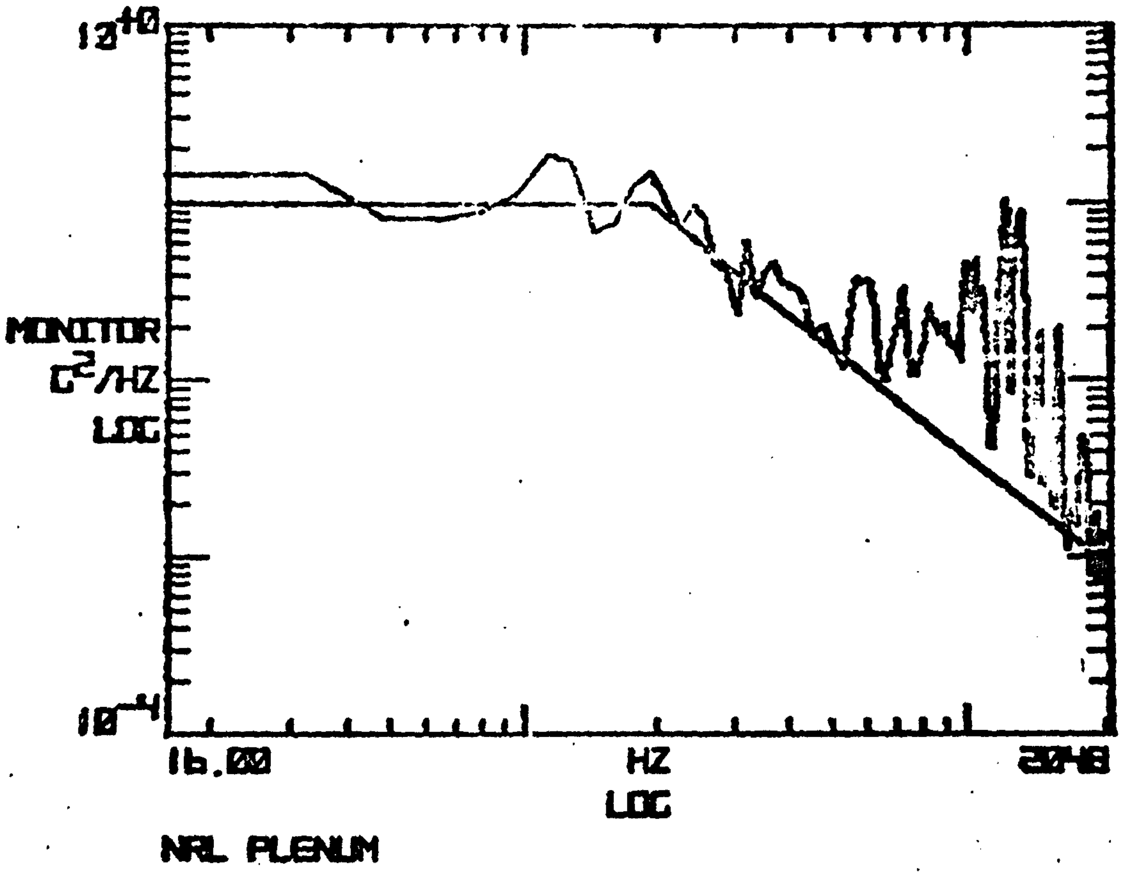
P/N SV764130 S/N 82201

11/6/75

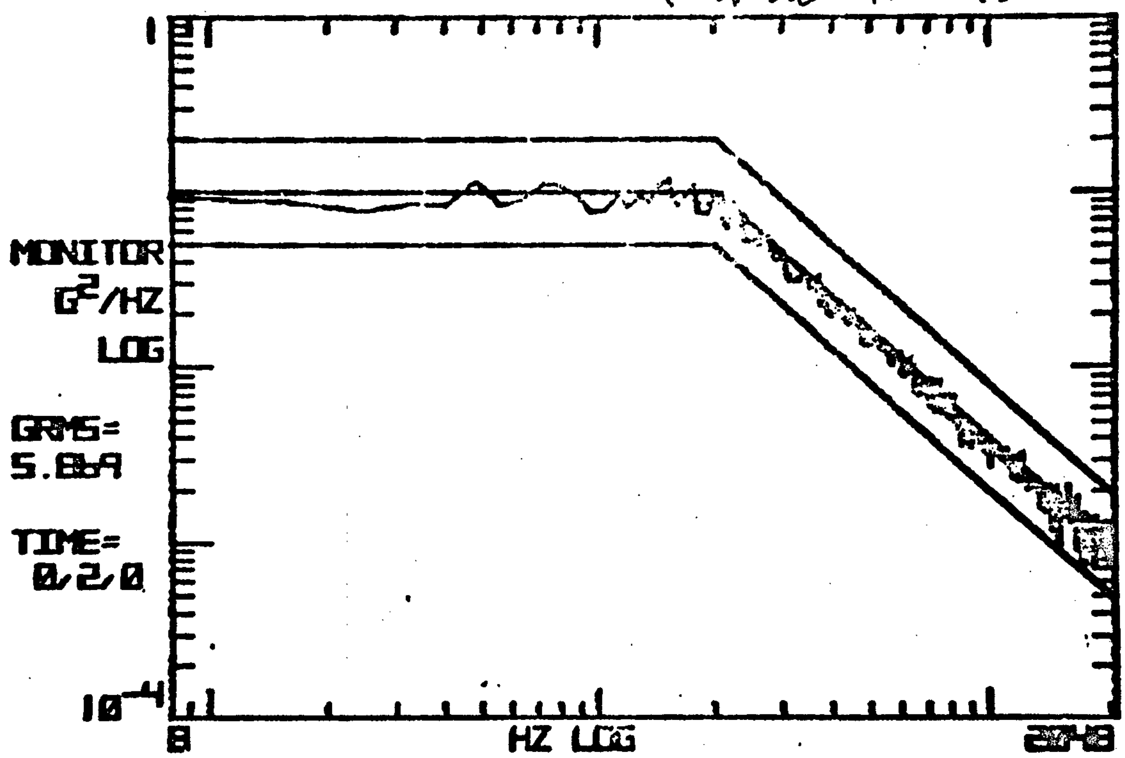
2

RUN 3 Z-AXIS LOC BZ



Run 3

RUN 5 X AXIS LOC AX



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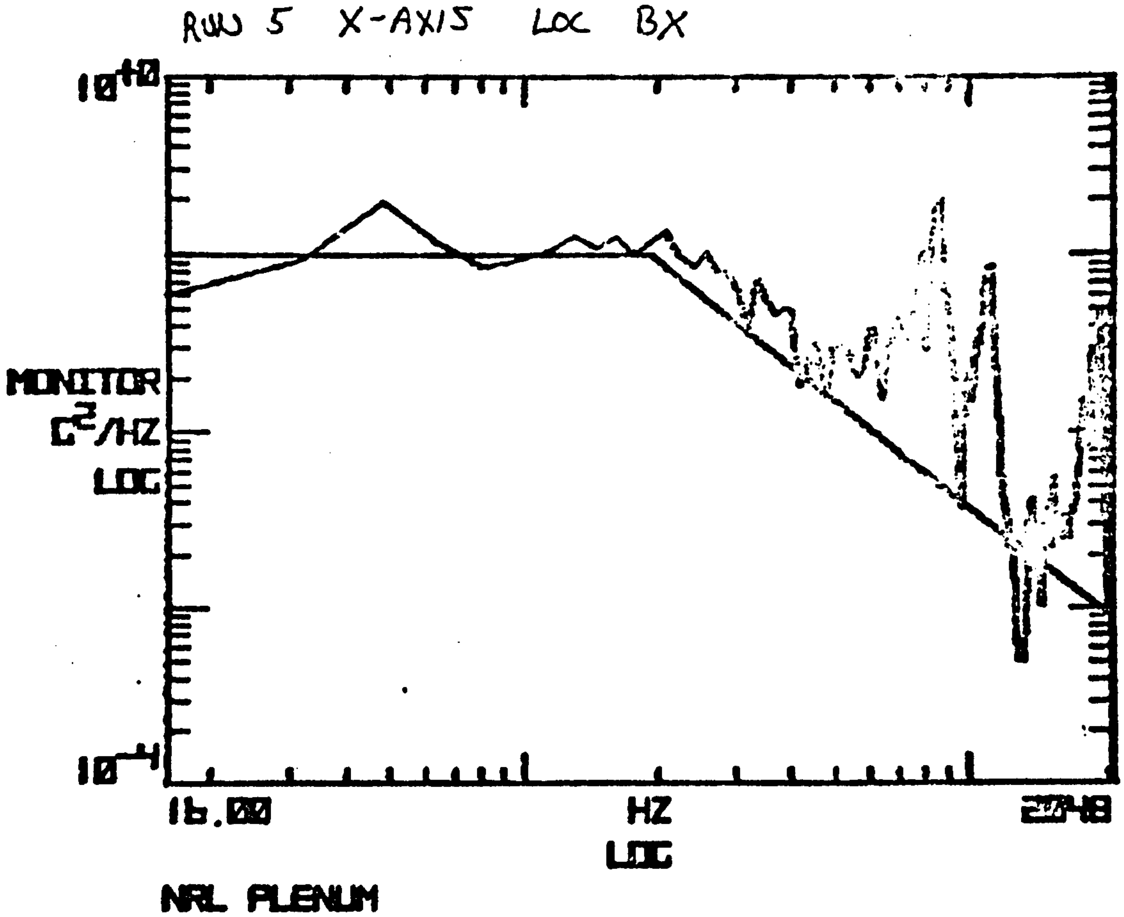
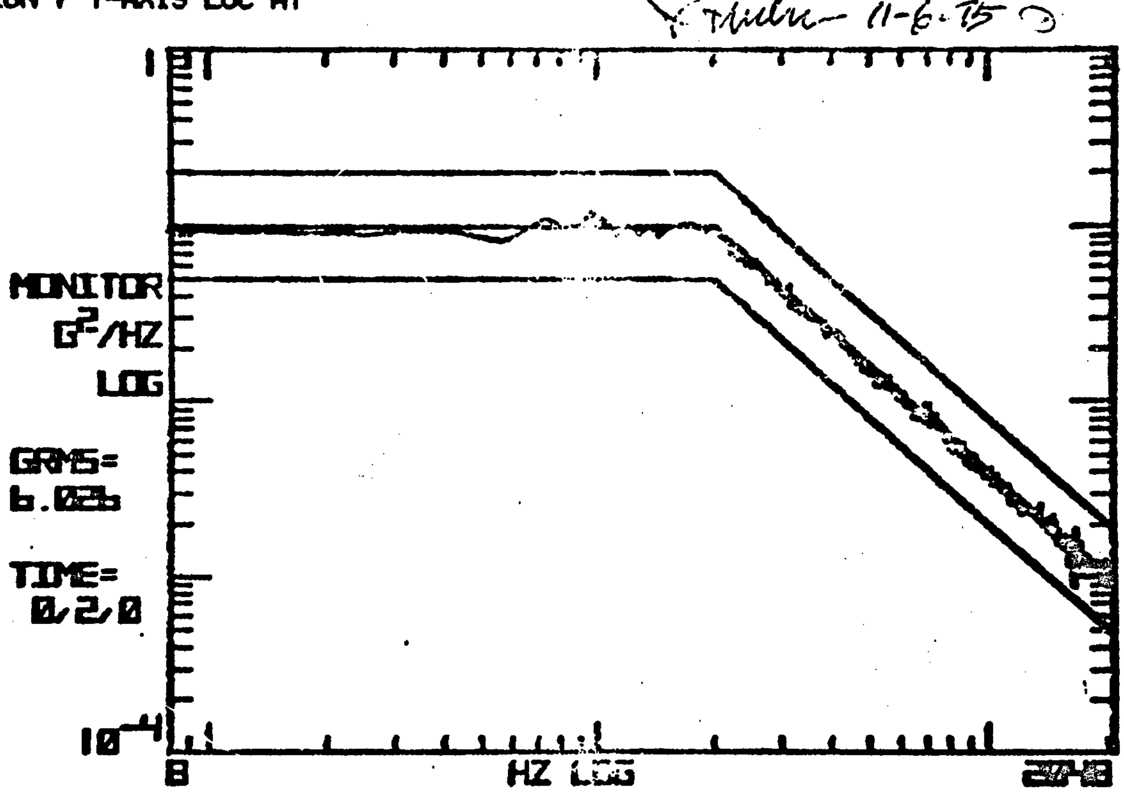
P/N SV764130 S/N 68801



RUN 5 X-AXIS LOC BX
10+10
MONITOR
G²/HZ
LOG
10-4
16.00
HZ
LOG
2048
NRL PLENUM

RUN 7 Y-AXIS LOC AY



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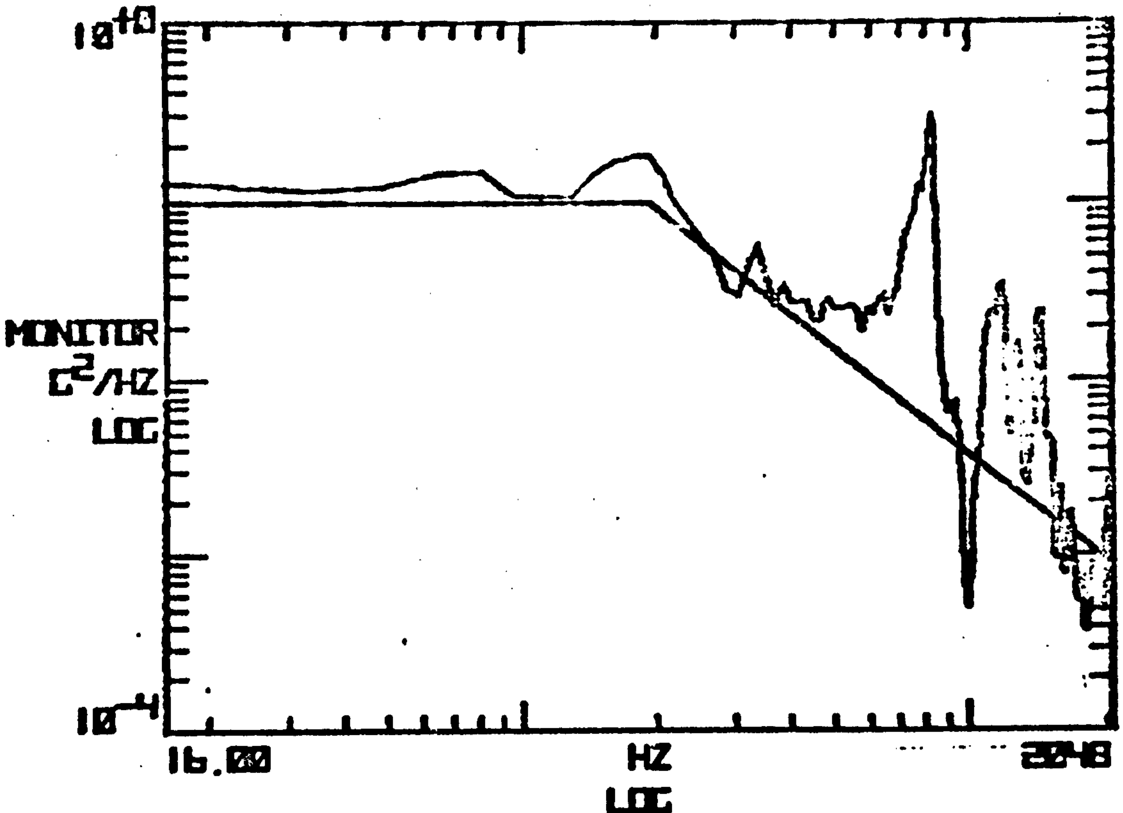
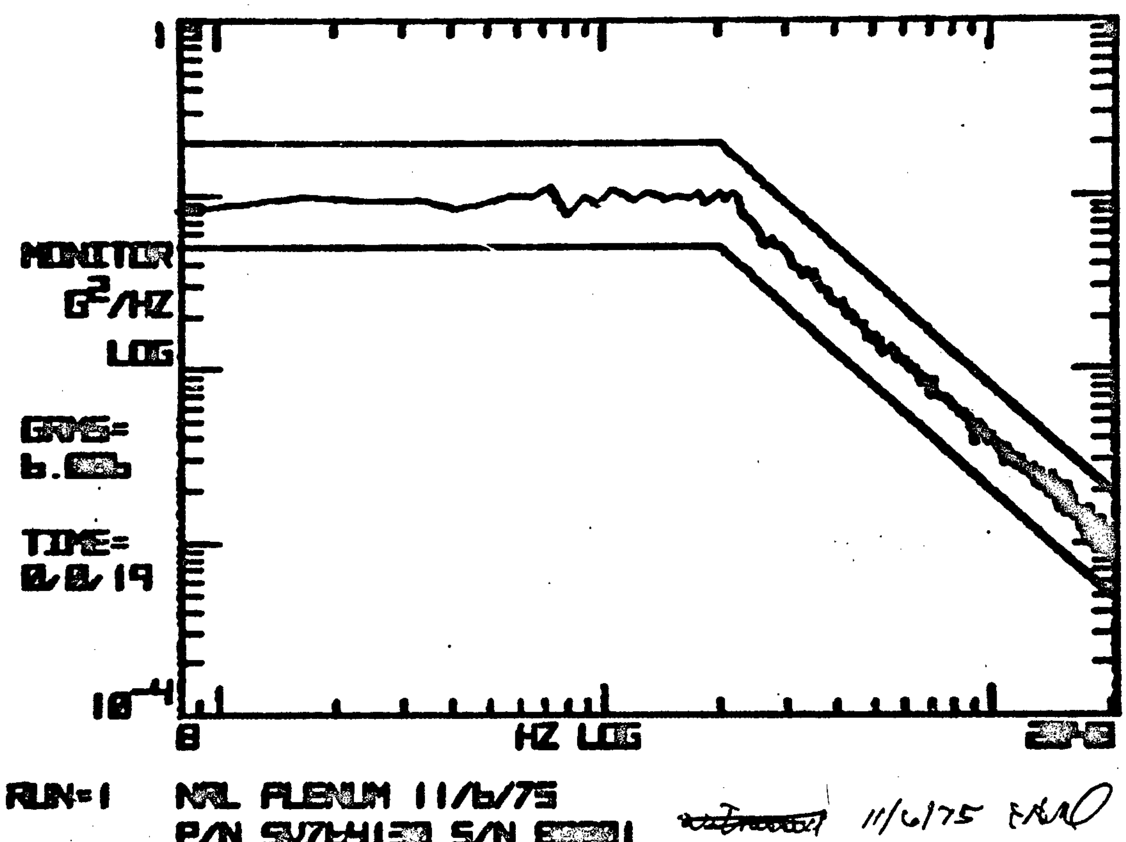
P/N SV764130 S/N 8[illegible]1

RUN 7 Y-AXIS LOC BY



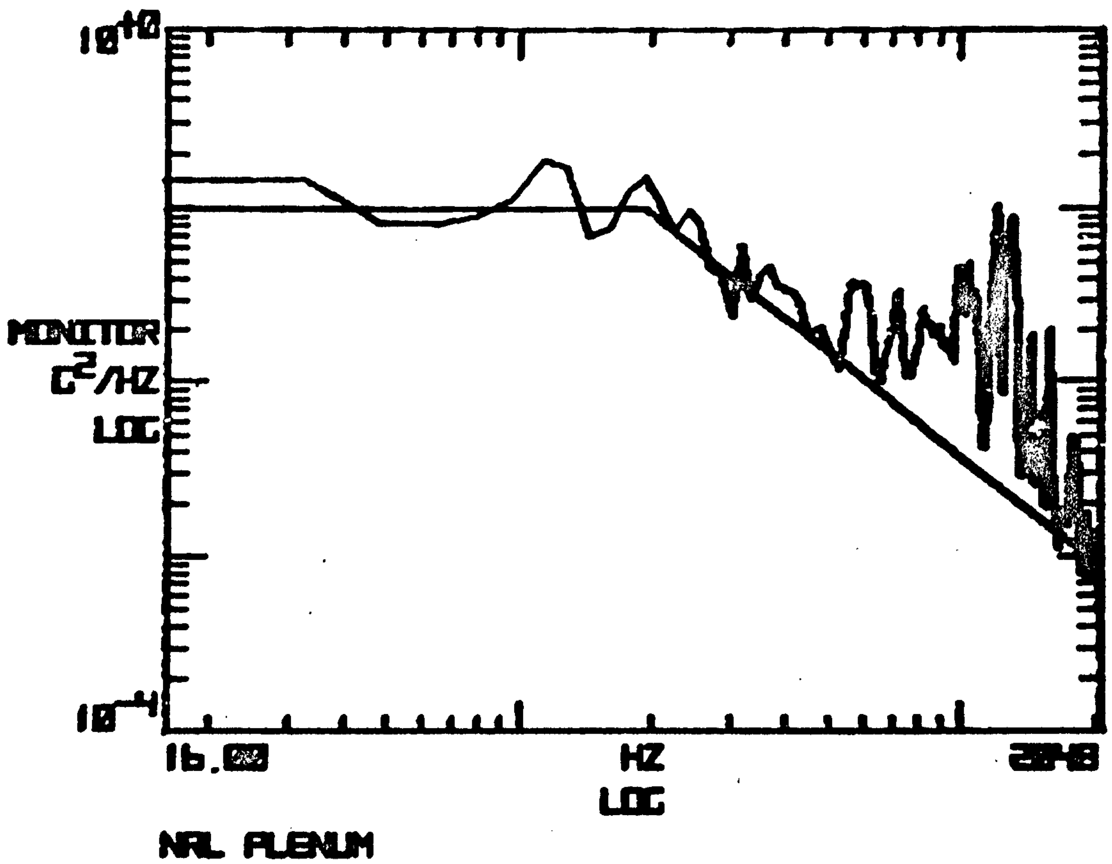
NRL PLENUM

RUN 3 Z-AXIS LOC. A2



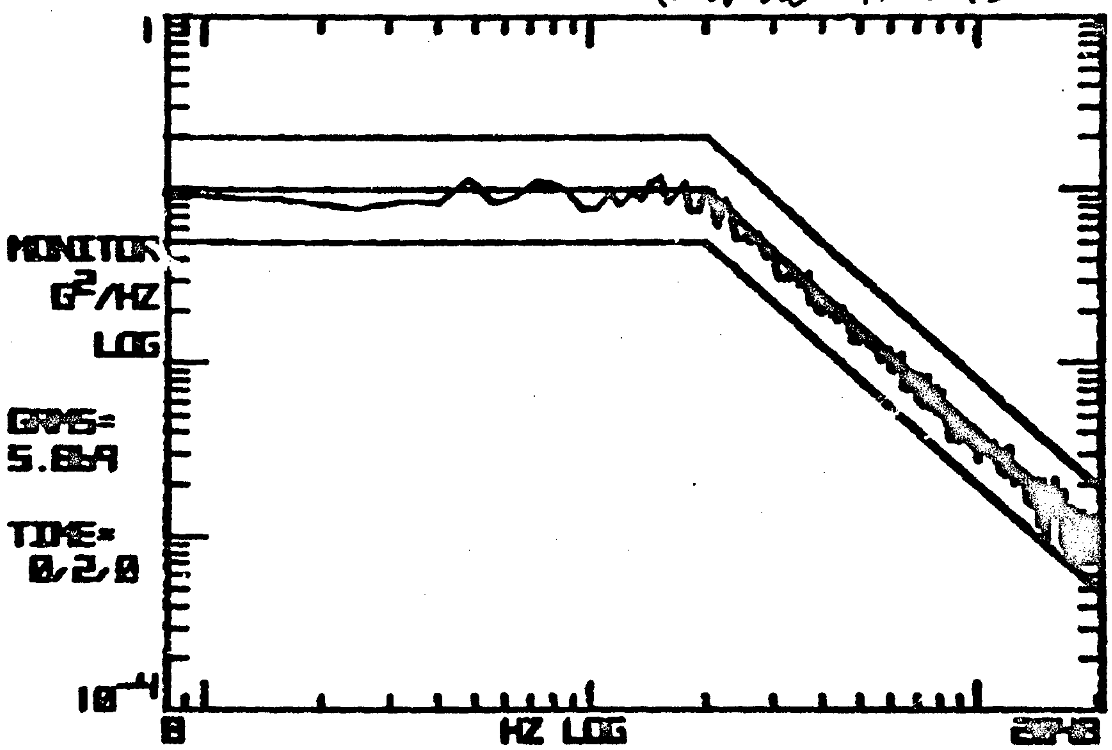
11/6/75

RUN 3 Z-AXIS LOC BZ



RUN 5 X AXIS LOC AX

11-6-75



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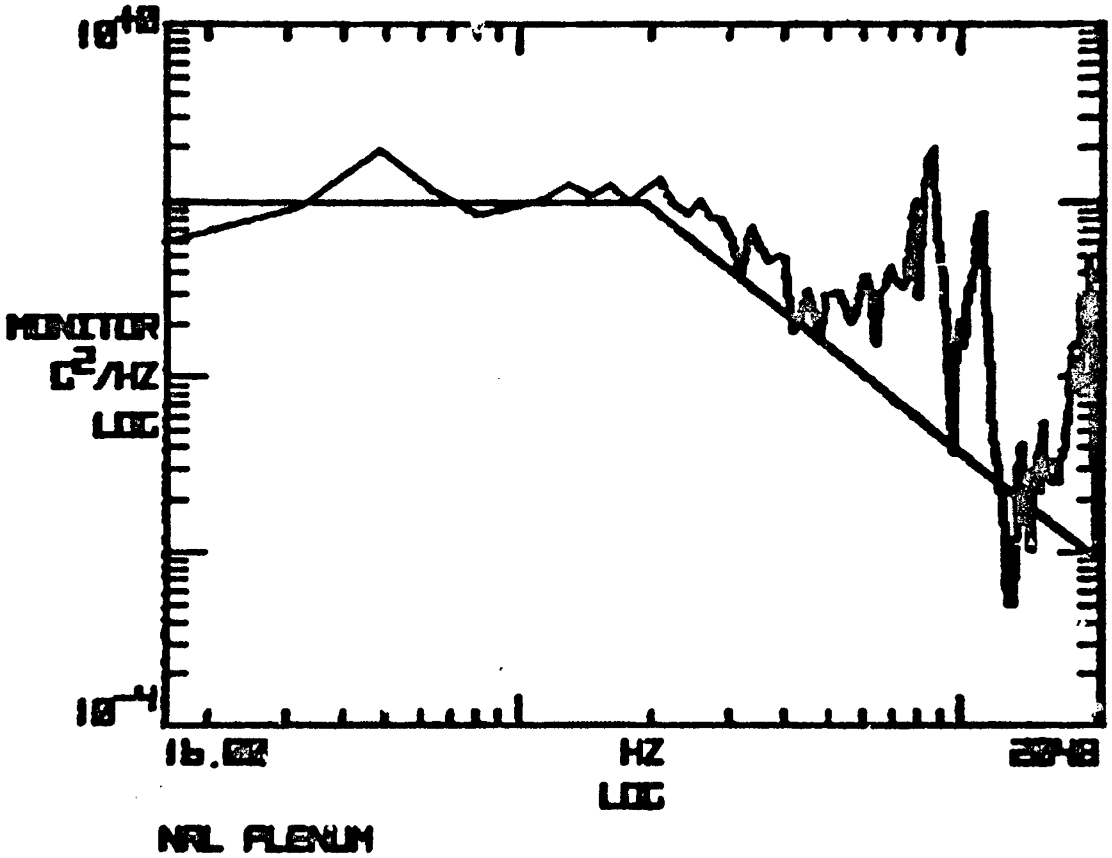
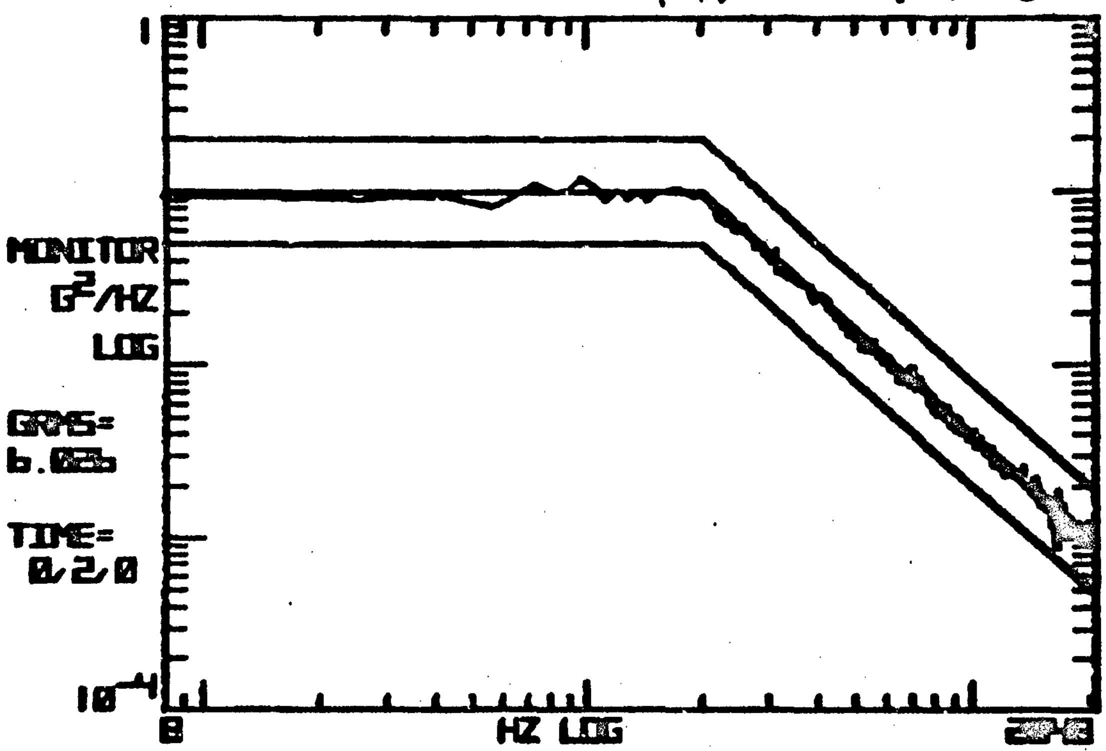
P/N SV764130 S/N [illegible]

RUN 5 X-AXIS LOC BX



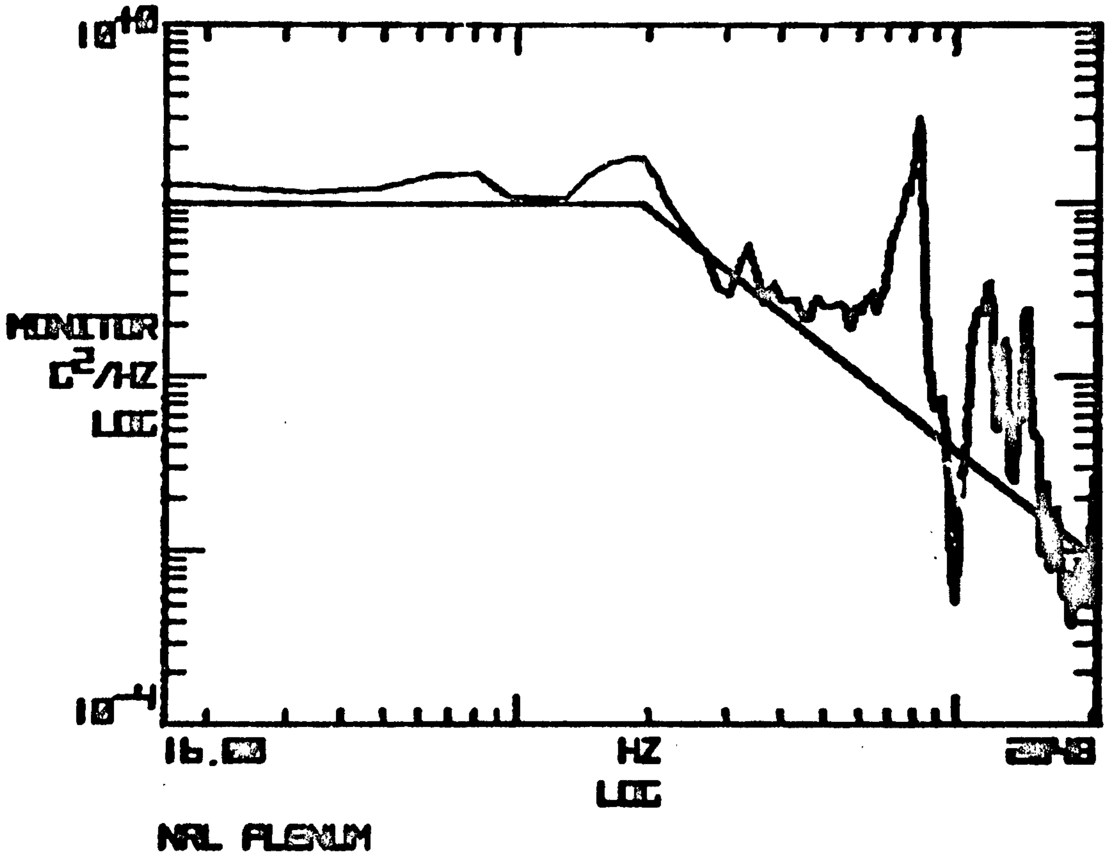
RUN 7 Y-AXIS LOC AY

11-6-75



RUN=1 NRL PLENUM 11/6/75
P/N SV764130 S/N [redacted]1

RUN 7 Y-AXIS LOC BY



APPENDIX E

PERFORMANCE DEMONSTRATION TEST SUMMARY

PERFORMANCE DEMONSTRATION TEST SUMMARY

Run No. 1

Test Objective - To evaluate nominal performance of PT plenum chamber at high inlet pressure while varying R/T select positions.

Test Conditions - P_{in} = 250 psia; fuel and hardware temperature at room ambient; ambient pressure at less than 8 mmHg (0.16 psia).

Base Operation - With milli-thruster energized to active mode, vary R/T select positions 1 thru 4 - obtaining a minimum of ten on-off cycles of the REA at each R/T select position.

Test Results - The unit performed satisfactorily, with plenum operating characteristics given below.

R/T Select Position	PT Pressure Cycle Hi-Lo	Cycle Duration
1	20 - 8 psia	7.1 seconds
2	28 - 16 psia	4.5 seconds
3	44 - 31 psia	2.4 seconds
4	53 - 40 psia	1.9 seconds

Run No. 2

Test Objective - To evaluate nominal performance of PT plenum chamber at low inlet pressure while varying R/T select positions.

Test Conditions - P_{in} = 130 psia; fuel and hardware temperature at room ambient; ambient pressure at less than 8 mmHg (0.16 psia).

Basic Operation - With milli-thruster energized to active mode, vary R/T select poisitions 1 thru 4 - obtaining a minimum of ten on-off cycles of the REA at each R/T select position.

Test Results - The unit performed satisfactorily, with plenum operating characteristics given below.

R/T Select Position	PT Pressure Cycle Hi-Lo	Cycle Duration
1	18 - 6 psia	6.8 seconds
2	25 - 12 psia	4.5 seconds
3	40 - 28 psia	2.1 seconds
4	50 - 36 psia	1.6 seconds

Run No. 3

Test Objective - To evaluate nominal performance of PC plenum chamber, while varying ΔV/T select positions.

Test Conditions - P_{in} = 250 psia; fuel and hardware temperature at room ambient; ambient pressure at less than 8 mmHg (0.16 psia).

Basic Operation - With R/T in Select 4 position and the micro-thruster energized to active mode, vary ΔV/T select positions 1 thru 4.

Test Results - The unit performed satisfactorily, with plenum operating characteristics given below.

ΔV/T Select Position	PC Pressure Cycle Hi-Lo	Typical Duration
1	5 - 4.5 psia	28 seconds
2	11 - 9 psia	60 seconds
3	21 - 18 psia	25 seconds
4	44 - 37 psia	45 seconds

Run No. 4

Test Objective - To determine milli-thruster duration to attain 150°F gas outlet temperature.

Test Co[illegible]itions - P_{in} = 250 psia; fuel and hardware conditioned to 95-105°F; ambient [illegible] at less than 8 mmHg (0.16 psia).

Basic Operation - [illegible]h R/T in Select 4 position, operate milli-thruster until gas outlet t[illegible]rature attains 150°F.

Test Results - The unit pe[illegible]ormed satisfactorily, attaining 150°F in 737 seconds (12.3 minutes). Other pertinent data are presented below.

(a) Temperature Data:

	Run Start	Run End
Gas Outlet	87°F	150°F
Throat	88°F	600°F
Milli-Thruster	87°F	88°F
Fuel	104°F	99°F
Heat Exchanger	93°F	211°F
Flange	99°F	114°F

(b) Pressure Cycle: 38 to 52 psia

(c) Cycle Duration: 2 seconds at beginning of run, 1.7 seconds at end of run.

Run No. 5

Test Objective - To evaluate Gas Generator/Plenum performance during long duration micro-thruster operation at maximum ambient temperature conditions.

Test Conditions - P_{in} = 250 psia; fuel and hardware conditioned to 95-105°F; ambient pressure at less than 8 mmHg (0.16 psia).

Basic Operation - With R/T in Select 4 position and ΔV/T in Select 2 position, operate micro-thruster for 8 hours, minimum.

Test Results - The unit performed satisfactorily over the 8 hour test with pertinent test data presented below.

(a) Temperature Data:

	Initial	Final
Fuel	97°F	94°F
Gas Outlet	103°F	94°F
Plate	100°F	94°F
Heat Exchanger	105°F	93°F

(b) PT Plenum Operation:

- pressure increased from 36 psia to 52 psia with each refill from Gas Generator.
- pressure decreased approximately 2 psi with each refill of PC plenum chamber.
- PC plenum cycles between PT plenum replenishings were 8, with 7 cycles occasionally occurring early in the test and 9 cycles occasionally occurring at end of test.
- duration between PT plenum refills varied between 423 to 490 seconds.

(c) PC Plenum Operation:

- pressure decreased from 11 psid to 9 psid during PC plenum cycle.
- time between PC plenum cycles varied from approximately 53 seconds to 70 seconds, exclusive of first cycle which was frequently influenced by electrical noise.

(d) Remarks: Frequently, the data exhibited electrical noise in PT plenum pressure, PC plenum pressure, and REA current data. Its occurrence would always coincide with the activation of the REA during refill of the PT plenum. The noise would remain present beyond the REA valve on-off phase and for the length of the first PC plenum cycle, with the data of subsequent cycles being "clean".

It is also noteworthy that the duration of the PC plenum cycle is apparently impacted by the electrical disturbance. With noise present in the data, the duration of the cycle would be 28 to 42 seconds, whereas with the absence of noise the duration would be 54 to 60 seconds. The latter is more typical of the second and subsequent cycles in the series of PC plenum cycling which occurs between refills of the PT plenum.

Run No. 6

Test Objective - To evaluate low temperature, long REA firing off-time impact on Gas Generator/Plenum performance - at low inlet pressure.

Test Conditions - P_{in} = 130 psia; fuel and hardware temperature conditioned to 40-50°F; ambient pressure at less than 8 mmHg (0.16 psia).

Basic Operation - With R/T in Select 4 position and $\Delta V/T$ in Select 1 position, operate micro-thruster for a few PT plenum refill cycles.

Test Results - The unit performed satisfactorily, with PT plenum refills (including REA firings) occurring 18 minutes apart.

Run No. 7

Test Objective - To evaluate low temperature, long REA off-time impact on Gas Generator/Plenum performance - at high inlet pressure.

Test Conditions - P_{in} = 250 psia; fuel and hardware temperature conditioned to 40-50°F; ambient pressure at less than 8 mmHg (0.16 psia).

Basic Operation - With R/T in Select 4 position and $\Delta V/T$ in Select 1 position, operate micro-thruster for a few PT plenum refill cycles.

Test Results - The unit performed satisfactorily.

Run No. 8

Test Objective - To evaluate impact of long hold period between unit operations.

Test Conditions - De-activate unit, locking up plenum in R/T Select 4 condition. Hold in this condition for minimum of one week, and then reactivate system (P_{in} = 250 psia); fuel and hardware temperature at room ambient; ambient pressure at less than 8 mmHg (0.16 psia).

Basic Operation - With R/T in Select 4 position, repeat Run #4 (operating milli-thruster until gas outlet temperature attains 150°F).

Test Results - The unit remained inactive (with decomposed hydrazine gases contained in PT plenum) for a period of eleven (11) days. The milli-thruster was then operated, with R/T controls in Select 4 position, for a period of 12.8 minutes. The unit performed satisfactorily during this duration, and the test was terminated since the 150°F gas outlet shutdown condition was attained at this time. Other pertinent test data are presented below.

(a) Temperature Data:

	Initial	Final
Gas Outlet	87°F	150°F
Fuel	88°F	88°F

(b) Pressure Cycle: 39 to 52 psia

(c) Cycle Duration: 2 seconds at beginning of run; 1.7 seconds at end of run.

Run No. 9

Test Objective - To verify operational adequacy of redundant Rocket Engine Assembly.

Test Conditions - P_{in} = 250 psia; fuel and hardware at room ambient.

Basic Operation - With R/T in Select 4 position and the control switch moved to Reactor B, operate milli-thruster for a minimum of 10 PT plenum cycles.

Test Results - The unit operated satisfactorily. The PT plenum cycled between 38 and 52 psia, at the rate of 2 seconds per cycle for 10 cycles.