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S-IVB/V AUXILIARY PROPULSION SYSTEM 90-DAY RECYCLE CAPABILITY TEST REPORT, MODULE II

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MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

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MCDONNELL DOUGLAS

CORPORATION

S-IVB/V AUXILIARY PROPULSION SYSTEM 90-DAY RECYCLE CAPABILITY TEST REPORT, MODULE II

DAC- 56729

APRIL 1969

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HUNTINGTON BEACH DEVELOPMENT ENGINEERING
SATURN/APOLLO & APOLLO APPLICATIONS PROGRAMS

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PREPARED FOR
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
UNDER NASA CONTRACT NAS7-101
MODEL DSV-4B

[redacted]

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ABSTRACT

This report presents an evaluation of the Auxiliary Propulsion System 90-Day Recycle Capability Test, Module II that was conducted at the Sacramento Test Center from 8 October to 19 November 1968. The test was conducted to verify the capability of the Auxiliary Propulsion System to withstand simulated flight vibrations and shock loads while loaded with propellants.

This test program was conducted under National Aeronautics and Space Administration Contract NAS7-101, Change Orders 1671 and 1987.

DESCRIPTORS

Saturn S-IVB/V Stage

Auxiliary Propulsion System Module

Complex Gamma Test Facility

Sacramento Test Center

Complex Alpha Test Facility

PREFACE

This report documents the evaluation of the Auxiliary Propulsion System 90-Day Recycle Capability Test on Module II as performed by MDAC-WD personnel at the Sacramento Test Center. The test was initiated on 8 October 1968 and completed 19 November 1968.

The purpose of the test was to demonstrate the capabilities of the S-IVB/V Auxiliary Propulsion System to withstand simulated flight vibration and shock loads while loaded with propellants.

This report, prepared under National Aeronautics and Space Administration Contract NAS7-101 (Change Orders 1671 and 1987), is issued in accordance with line item FQ-L-70 of report No. SM-41412, General Test Plan.

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1. INTRODUCTION

This report presents the results and evaluation of the S-IVB/V Auxiliary Propulsion System vibration tests, module II, that were conducted at the Sacramento Test Center, Complex Gamma and Alpha test facilities.

The test program consisted of a series of vibration tests and a partial disassembly and inspection.

The information contained in the following sections documents and evaluates the test program that was initiated on 8 October 1968 and completed 19 November 1968. A test schedule is presented in figure 1-1.

1 1 Objective

The purpose of the test was to verify the capability of the APS module to withstand simulated flight vibration and shock loads while loaded with propellants.

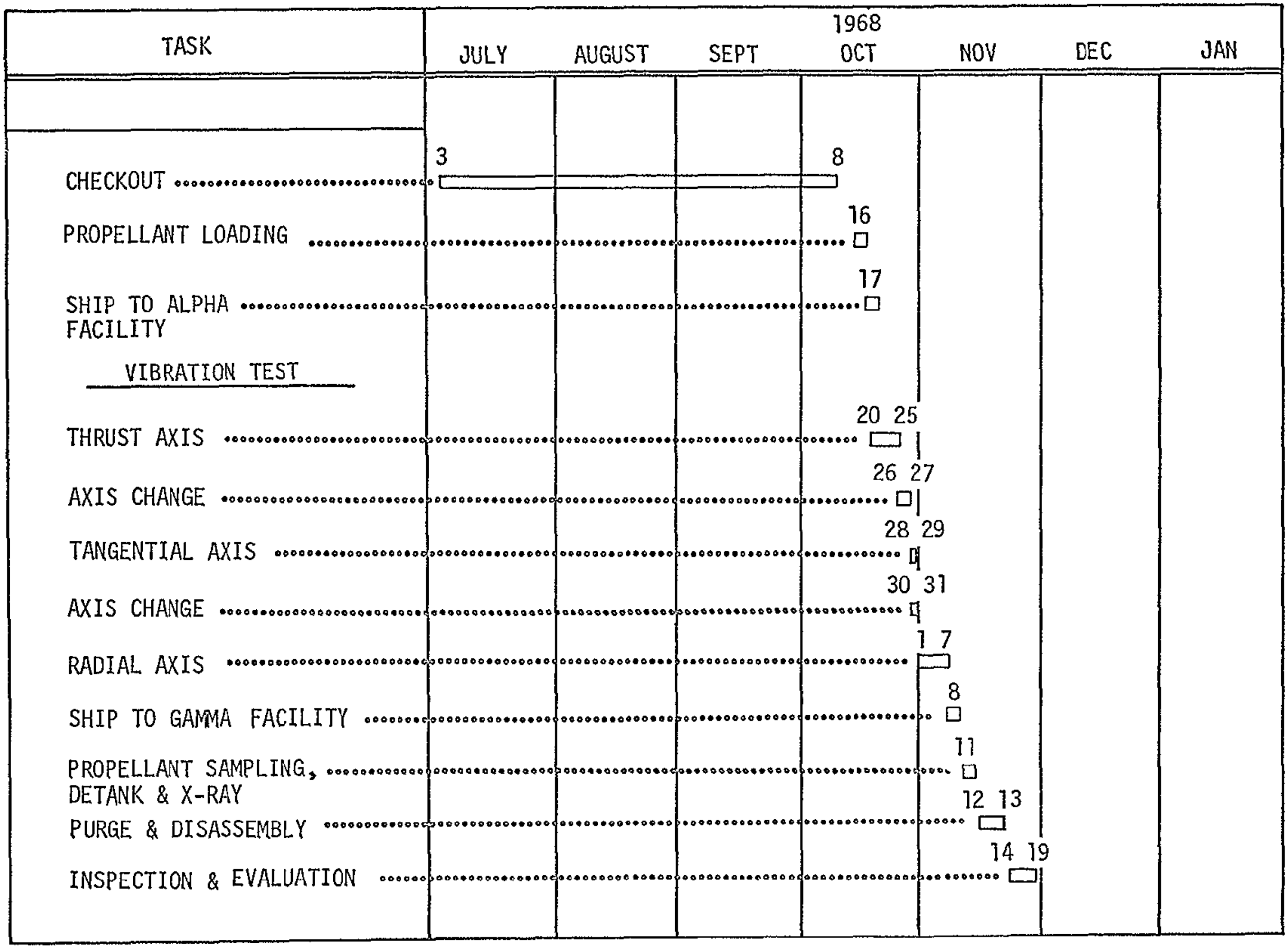


Figure 1-1. APS Module II Test Schedule

2. SUMMARY

The APS module II was subjected to vibration tests as presented in the S-IVB/V Auxiliary Propulsion System 90-day Recycle Capability Test Plan, DAC-56590E. The tests, conducted at the Sacramento Test Center, verified the capability of the APS module to withstand simulated flight vibration and shock loads while loaded with propellants.

The following paragraphs describe the failures and anomalies that were noted during the tests.

A failure is defined as any discrepancy which could possibly cause loss of mission or delay of launch.

An anomaly is defined as a discrepancy which is undesirable and not normal but which would not cause loss of mission or delay of launch.

2.1 Vibration Tests

The loaded APS module was installed in a vertical position and subjected to vibration and shock tests (as outlined in the Formal Qualification Test Procedure 1T31583) to simulate launch vibration.

The failures which occurred during the tests were as follows:

a. The fuel low pressure helium module developed a leak and caused a helium pressure decay. The failure was attributed to contamination and not to design deficiencies.

   This type of failure would normally be found during checkout prior to launch and the module would be replaced. However, it was classified as a failure because if it occurred during countdown, then launch could be delayed by having to replace the module.

b. The high pressure helium system developed leaks that were attributed to improper torque values and teflon seals. ECP 3160 authorizes replacement on all flight models of the teflon seals in the high pressure system with rubber (MS28778) "O" rings seals. The ECP also authorizes an additional high pressure (3,000 psia pressure decay and 1,500 psia bubble soap check) leak test. This test will be accomplished after the "O" ring replacement. The erroneous torque requirement has been corrected. The above should preclude any future leaks of this nature.

2.2 Disassembly and Inspection

After completion of the vibration tests, the APS module was partially disassembled and inspected. The following significant anomaly was noted:

a. The fuel bladder developed a pin hole in the ullage area.

3. AUXILIARY PROPULSION SYSTEM

The auxiliary propulsion system (APS) provides attitude control of the stage during all operational phases of S-IVB flight. The system also incorporates a propellant settling capability for damping mainstage propellant transients at the end of the first J-2 engine burn, and for J-2 engine restart after coast. Figure 3-1 is a schematic of the APS and instrumentation.

Subsystem components are contained in two separate modules placed 180 deg apart on the aft skirt. Each module (figure 3-2) contains hypergolic liquid bi-propellant engines, a positive expulsive propellant feed subsystem, and a helium pressurization subsystem. The fuel used by the APS is monomethylhydrazine (MMH) and the oxidizer is inhibited nitrogen tetroxide (N_2O_4). Propellants are stored in two separate tanks equipped with positive expulsive teflon bladders for propellant feed during zero g conditions.

Prior to launch countdown operations, each module is loaded with propellants through connections in the aft end of the module. During loading, the expulsion bladders must initially be in a fully expanded position against the tank wall. A differential pressure is maintained during the preparatory operations to assure that this condition is satisfied.

Propellant loading and recirculation are accomplished simultaneously. Propellant flow is established through the propellant control module transfer valve. The flow then divides, with a portion going to the propellant tank, and a portion circulating through the engine manifolding to eliminate gas from the system. After a full tank is achieved, propellant flow is continued for a short time to assure complete gas elimination. The propellant tank ullage is then established by off-loading the required amount of propellant through the transfer valve.

Helium used for propellant expulsion is loaded into the module through a pneumatic service line connected to the stage through the fly-away stage umbilicals.

The APS modules are enabled in flight after the second stage retrorockets have been ignited. The APS provides stage roll control during S-IVB J-2 engine burn. Commands for operation of the APS engines are provided by the instrument unit. Output from a guidance platform indicating measured vehicle attitude is received in the instrument unit (IU), and a comparison is made with the desired or programmed attitude. If a deviation exists, the IU gives the required commands (via a control relay package) to the APS engine injector valves for thrust duration proportional to the magnitude of the deviation.

At J-2 engine cutoff, the APS pitch and yaw controls are activated, and all controls (pitch yaw, and roll) remain active throughout the coast phase. At J-2 engine restart, the pitch and yaw modes are deactivated. The pitch and yaw modes are reactivated after J-2 engine second-burn cutoff to maintain 3 axes attitude control.

The APS ullage (propellant settling) engines (one in each module) are enabled during the J-2 engine first-burn cutoff transient to prevent undesirable stage propellant movement. Firing continues through the engine cutoff transient decay and the activation of the LH2 tank continuous propulsive vent system. The APS ullage engines are again fired at the end of orbital coast to provide propellant settling during J-2 engine restart.

3.1 Engine Systems

Three 150-lbf thrust attitude control engines and one 70-lbf thrust ullage engine are employed in each APS module. The 150-lbf thrust engines are manufactured by TRW Systems Group. The 70-lbf thrust engine was designed, developed, and manufactured under NASA contract by Rocketdyne Division of North American-Rockwell for the Gemini Program. The 150-lbf thrust engines employ quadruple injector valves for redundant valve action. The 70-lbf Gemini (ullage) engine employs single valves on both the fuel and oxidizer lines.

3.1.1 150-lbf Thrust Attitude Control Engines

Three 150-lbf thrust engines (figure 3-3) are employed in each APS module, and have quadruple propellant injector valves for redundancy. The thrust chamber is an integral part of the engine, and is composed of a combustion chamber, a nozzle throat section, and a nozzle expansion cone.

The injector consists of 12 pairs of unlike-on-unlike doublets arranged to minimize hot spots in the combustion chamber. The valve side of the injector is filled with a silver braze heat sink to reduce injector operating temperature.

The engine was qualified for a total pulse operation of 300 sec. During the 300-sec life requirement, the external wall temperature does not exceed 1,060 deg R, and the maximum valve body external temperature does not exceed 625 deg R. The maximum expected duty cycle requirements on the S-IVB/V is approximately 90 sec.

Engine propellant flow is controlled by a valve assembly which consists of eight solenoid valves arranged in two quad-redundant series-parallel valve arrangement to preclude any operational failure due to a single valve malfunction. A dual failure, such as two valves "failed open" in series or two valves "failed closed" in parallel, must occur to cause a failure.

The injector valves provide positive on/off control of propellant flow upon command from an external power source. Four valves, integral in an assembly, are capable of simultaneous operation and are synchronized to open or close within 3 ms of each other. The opening time for each valve assembly, defined as the time from initiation of open signal to fully open valve package, does not exceed 23 ms.

3.1.2 70-lbf Thrust Ullage Engine

Propellant settling is accomplished by a 70-lbf thrust film-cooled ullage engine (figure 3-4). Propellant flow to the engine is controlled by single solenoid valves: one for fuel and one for oxidizer. Engine operation has been qualified for continuous burn time of approximately 640 sec.

3.2 Propellant Feed System

The propellant feed system (figure 3-5) consists of separate fuel and oxidizer propellant tank assemblies, propellant control modules, and propellant manifolds for distribution of propellants to the engines. Filling of each tank assembly is accomplished through the outer (perforated) tube, the inner (solid wall) tube allows entrained gases in the bladder to be exhausted from the tank as the bladder is filled. Positive expulsion of propellants is accomplished by pressurizing the ullage space between the tank and the bladder.

3.2.1 Propellant Tanks

Each propellant tank (fuel and oxidizer) consists of an outer titanium pressure vessel (cylindrical shell with hemispherical ends of approximately 4,100 cu. in. capacity), an internal teflon bladder, and standpipe assembly (figure 3-5).

The bladder is fabricated of fluorinated ethylene propylene teflon laminated to polytetrafluoroethylene using a spray process resulting in a one-piece seamless unit with a nominal wall thickness of 6 mils. The bladder provides a separation membrane between the pressurization gas (ullage) and the propellant, and also provides a method of transferring propellant under zero g environment. The ullage space between the tank and the bladder is pressurized with helium gas to provide the expulsion pressure necessary for propellant flow.

A concentric tube standpipe assembly is located axially in the center of the tank assembly within the bladder. Propellant passes through perforations in the standpipe during expulsion as well as during filling operations. A vent tube is located within the standpipe assembly to allow removal of gas from inside the bladder.

3.2.2 Propellant Control Modules

The propellant control (figure 3-6) module provides for loading and recirculation of propellants and purging of the propellant systems.

The propellant transfer valve is a direct-operating, normally-closed solenoid valve. The transfer valve cannot be opened by application of power if the subsystem pressure exceeds external pressure by more than 10 psi, and the transfer valve will not close or remain closed if the external pressure exceeds subsystem pressure by more than 40 psi.

The propellant recirculation valve is a direct-acting, normally-closed solenoid valve with two independent poppets and seats. The two-poppet design isolates the engine recirculation line from the tank recirculation line, and all propellant flowing to the engine passes through a 10-micron nominal and 25-micron absolute rated filter.

3.2.3 Recirculation In-Line Filter

The filter assembly (figure 3-7) consists of a body with two in-line male tube fittings containing a filter element. The element is a welded assembly of a perforated support tube covered with corrugations of dutch twill weave wire cloth to provide an absolute filtering of particles greater than 25 microns.

Two filters are used in the fuel and oxidizer propellant recirculation lines to provide filtering of propellant or purge gas flowing through the propellant control module recirculation valve.

3.3 Helium Pressurization System

The helium pressurization system consists of two check valves in series, a helium storage tank, a helium pressure regulator assembly, two quadruple check valves, two filters, and two low pressure helium modules.

The helium storage tank stores helium at an initial pressure of 3,000 $\pm$200 psia. This pressure is reduced to 196 $\pm$3 psia for propellant tank ullage pressurization through a two-regulator module. These regulators are connected in series, and function by sensing the regulator downstream pressure.

Since a common pressurization subsystem is used, quadruple check valves are employed between the regulator and propellant tankage for added assurance that hypergolics will not mix as the result of leaks or normal permeation. The low pressure helium modules provide ground venting capabilities of propellant tank ullage pressure, and a means of establishing pneumatic control of the expulsion bladders during loading and checkout. Command venting capabilities during flight are not provided, although the propellant tanks are protected from overpressurization by relief valves in the low pressure helium modules. All helium entering the regulated pressure area of the subsystem is filtered upstream of the regulators.

3.3.1 High Pressure Helium Tank

The helium tank is a welded titanium assembly consisting of a cylindrical center section and two hemispherical end domes, each containing a female tube fitting boss. The helium tank is a gas reservoir for the propellant positive-expulsion system on the S-IVB/V attitude control system.

3.3.2 Helium Pressure Regulator Module

Helium stored at 3,000 $\pm$200 psia in the high pressure helium tank is fed to a helium regulator module. The helium gas entering the module passes through an internal filter and then through two regulators in series, both of which sense downstream pressure. The first (or primary) regulator regulates the gas pressure to 196 $\pm$3 psig while the redundant secondary regulator regulates the gas pressure to 200 $\pm$3 psig. During normal operation, regulated pressure is maintained by the primary regulator. Should the primary regulator fail, the secondary regulator then begins operation. Each regulator is of fail-open design. Ambient pressure sensing ports, provided on both regulators, furnish the necessary ambient pressure references. Regulator performance is evaluated by pressure transducers installed immediately before and after the regulators. Regulated helium is fed through quadruple check valves and filters to the ullage area of the fuel and oxidizer tanks.

3.3.3 Quadruple Check Valves

Two sets of quadruple check valves are employed in the helium pressurization subsystem; one set in the fuel tank pressurization line, and the other set in the oxidizer tank pressurization line. These check valves prevent contact of fuel and oxidizer vapors in the pressurization subsystem due to permeation through the bladders during normal operation or bladder leaks.

Each set of check valves consist of four check valves connected in a series-parallel arrangement and contained in one enclosure. Failure of a check valve set requires open-failure of two check valves in series or closed-failure of two check valves in parallel.

3.3.4 Low Pressure Helium Module

The low pressure helium module (figure 3-8) consists of a solenoid dump valve and a relief valve Two low pressure modules are employed in the pressurization subsystem, one module connected to each propellant tank ullage volume. The solenoid dump valve is a normally-closed, direct-acting valve with a dual (redundant) coil. The valve performs no flight function, and is employed only to vent or pressurize the propellant tank ullage during ground servicing and checkout operations.

The purpose of the relief valve is to provide overpressurization protection of the propellant tankage during ground or flight operations.

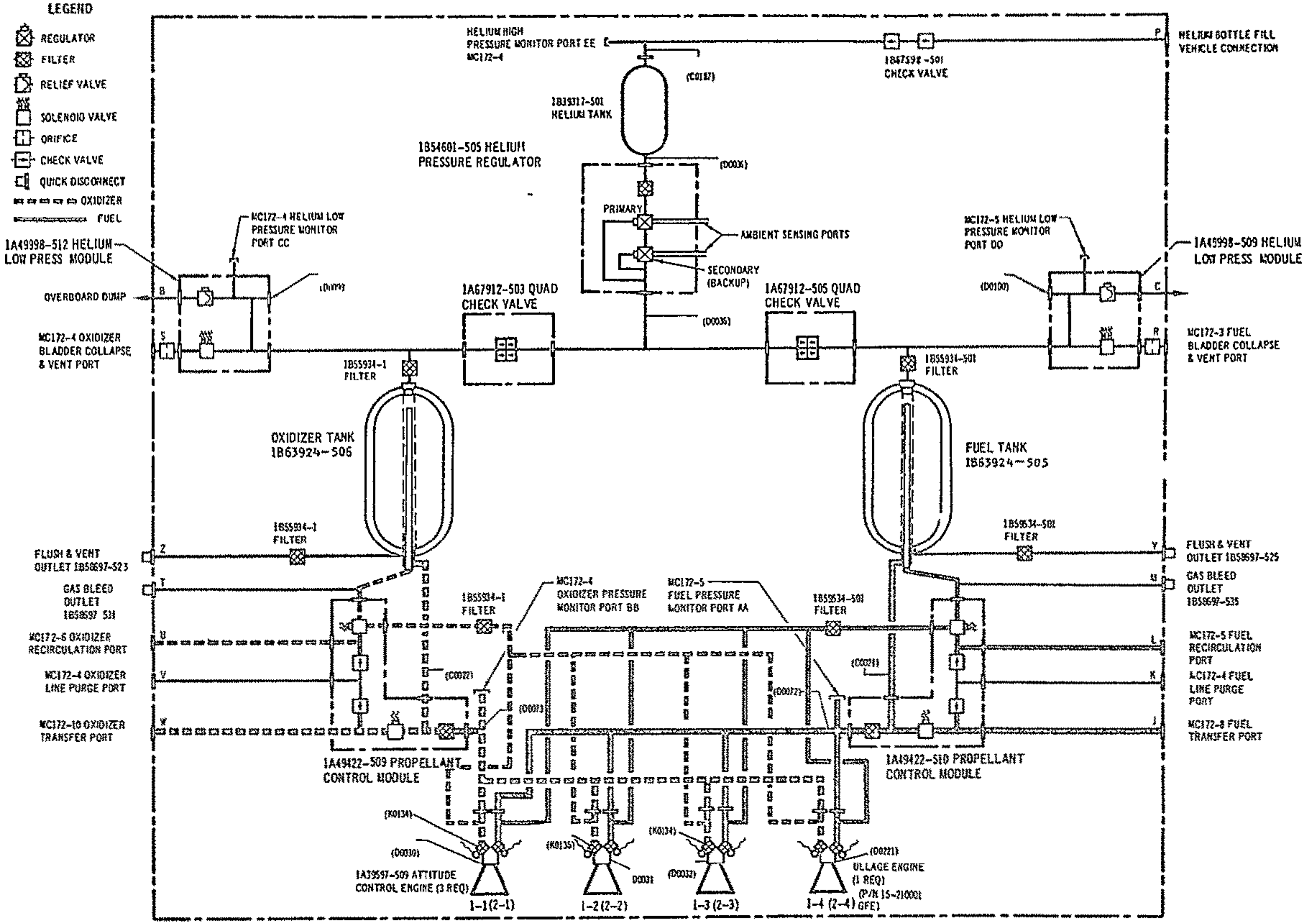


Figure 3-1. S-IVB/V Auxiliary Propulsion System and Instrumentation

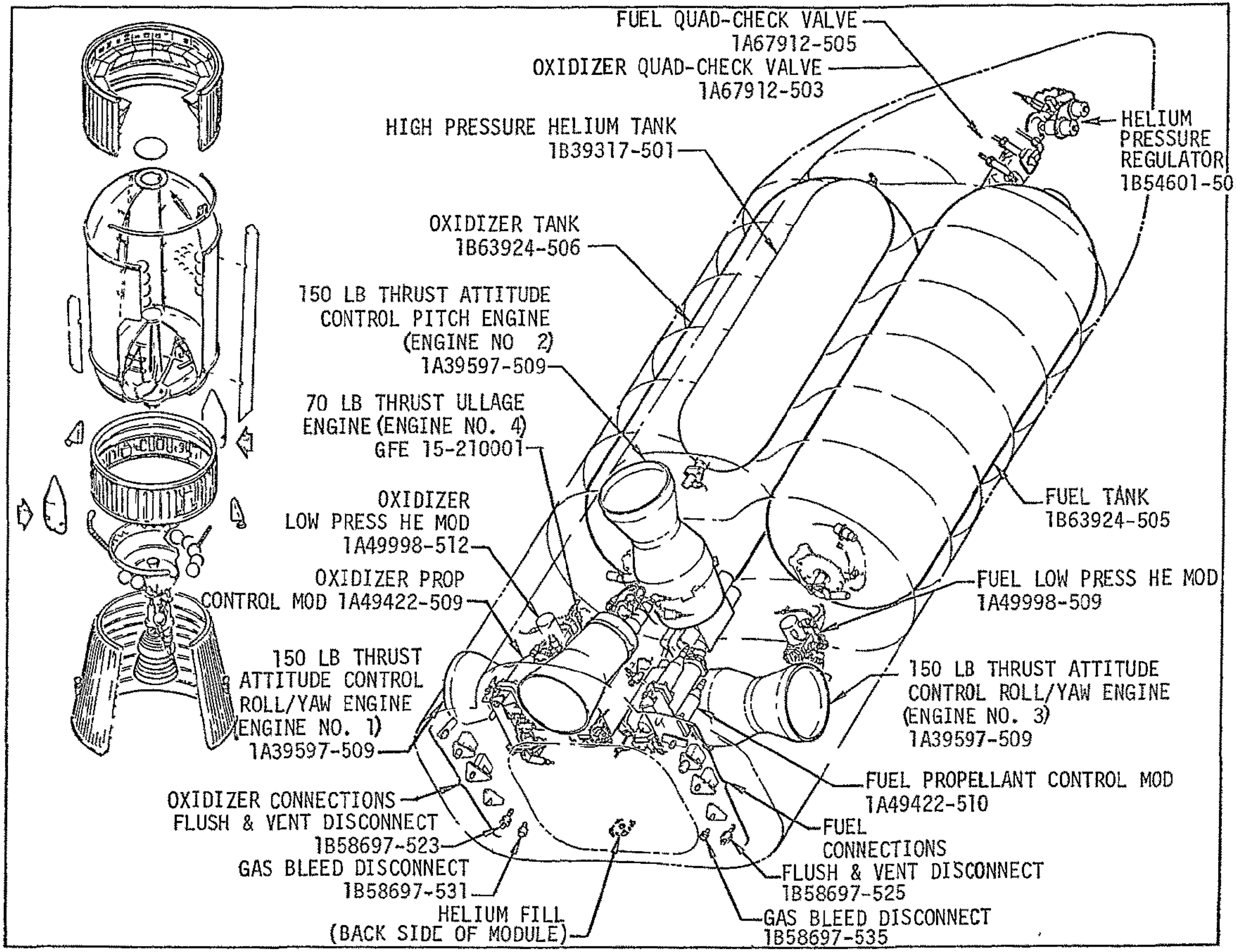


Figure 3-2. S-IVB/V Auxiliary Propulsion System Module

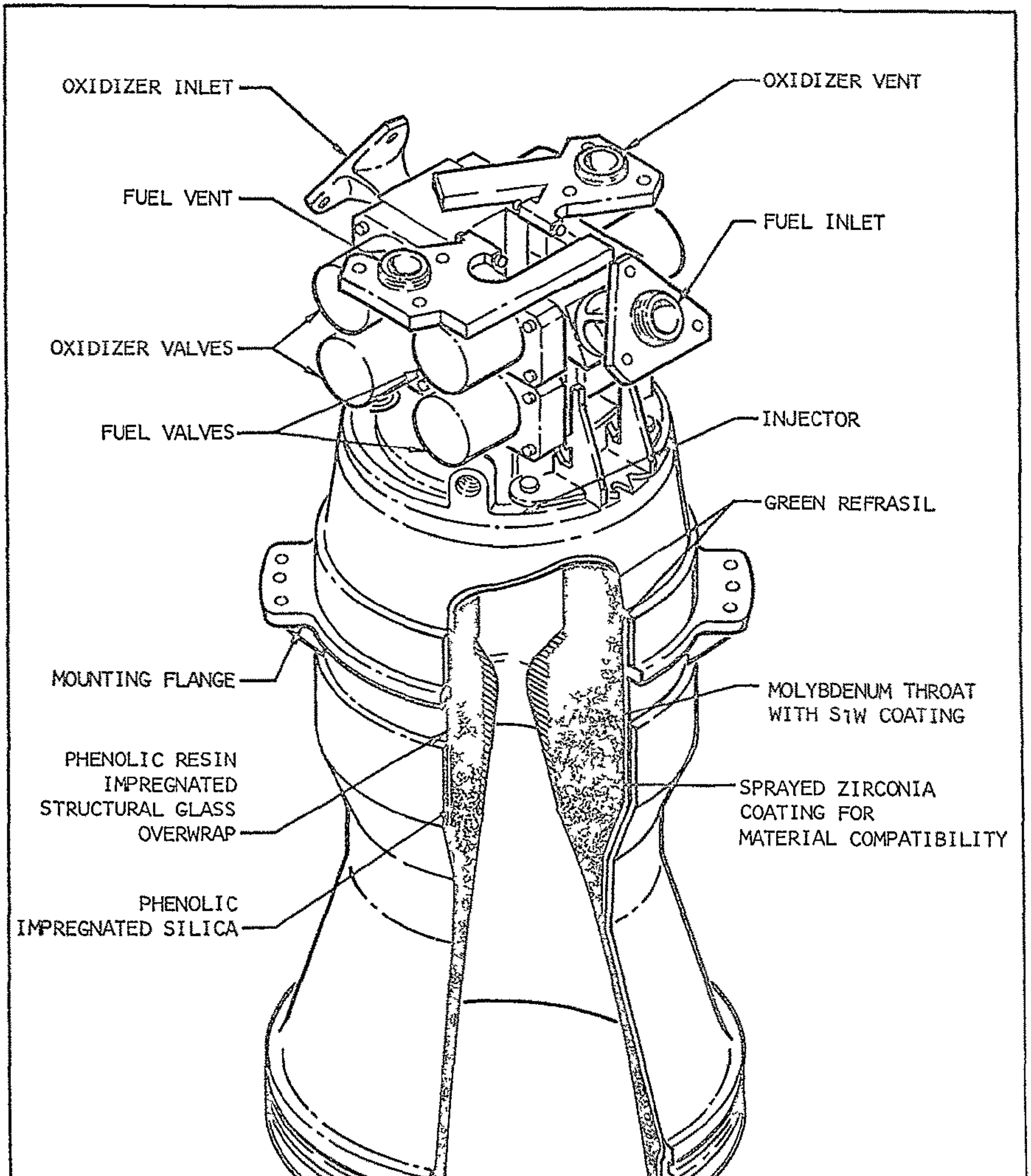


Figure 3-3. 150-lbf-Thrust Attitude Control Engine

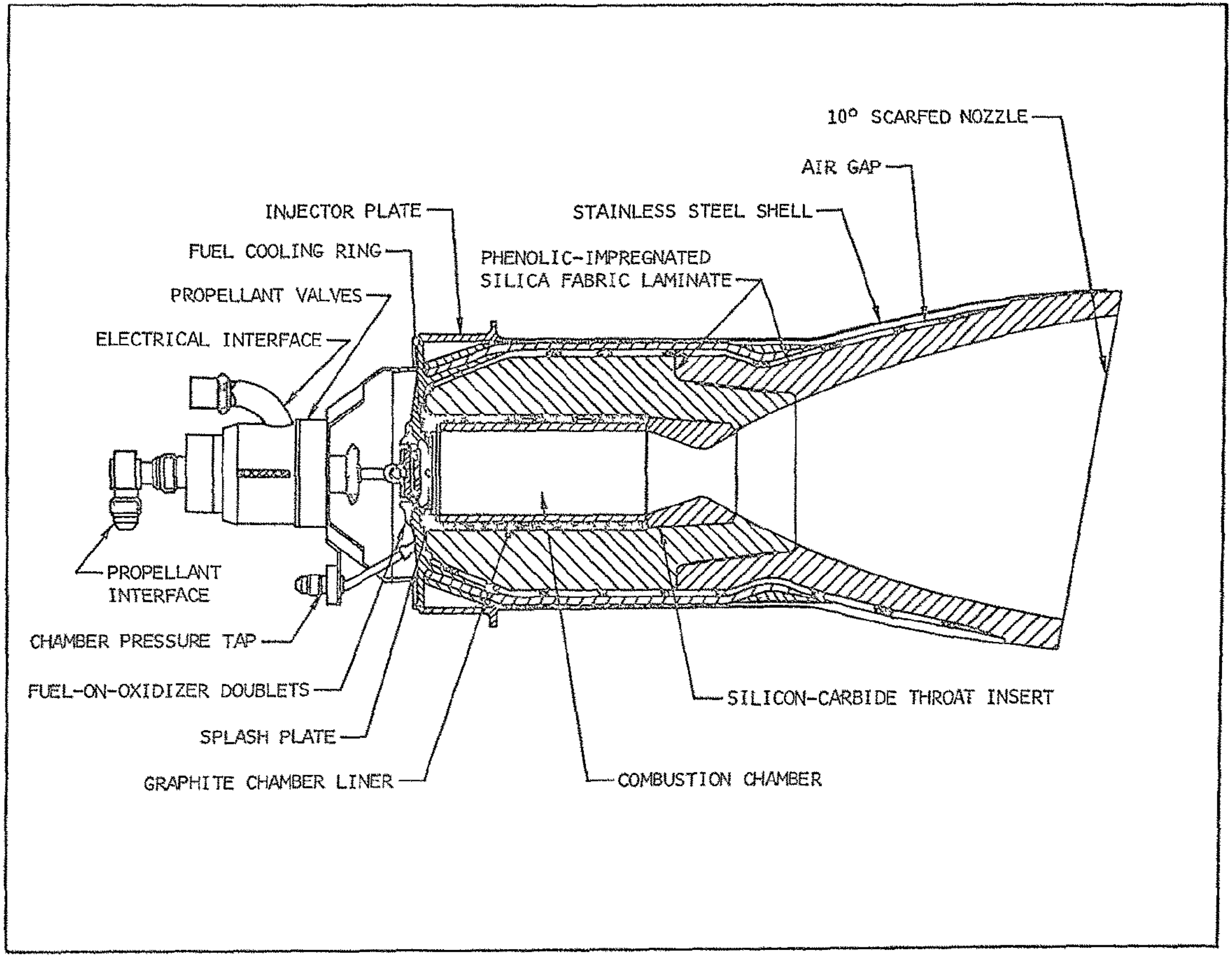


Figure 3-4. 70-lbf-Thrust Ullage Control Engine

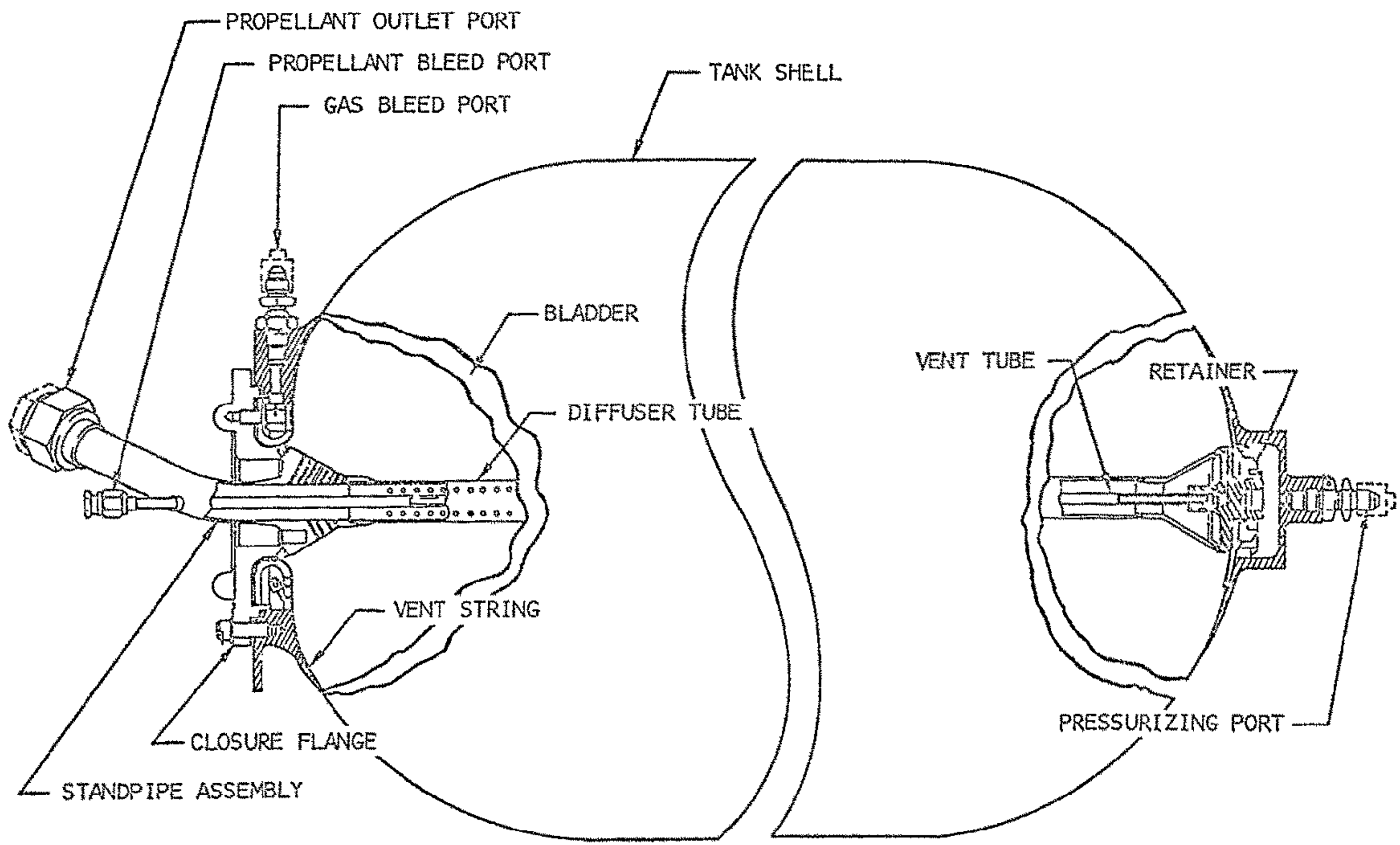


Figure 3-5. Positive Expulsion Propellant Tank

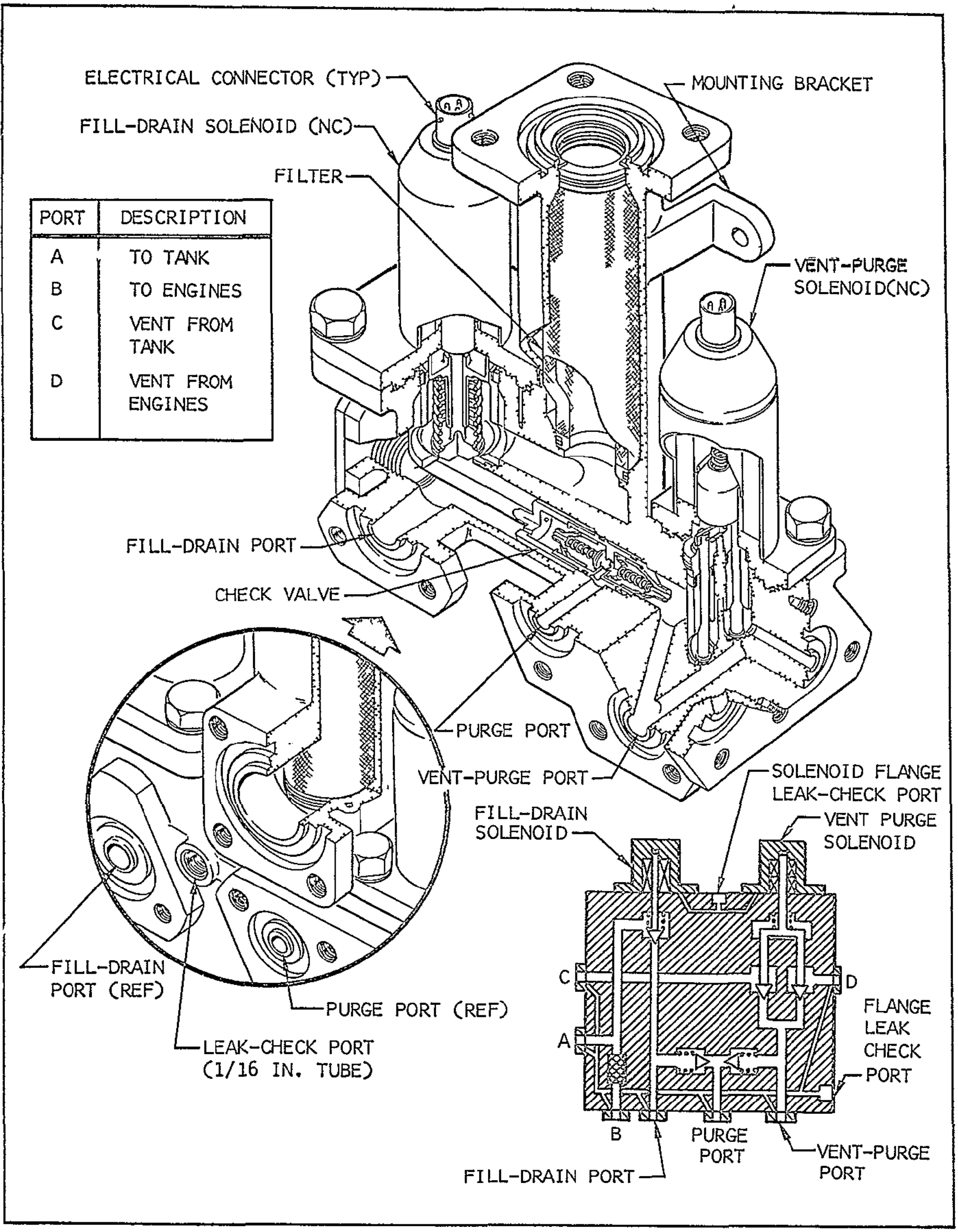


Figure 3-6. Propellant Control Module

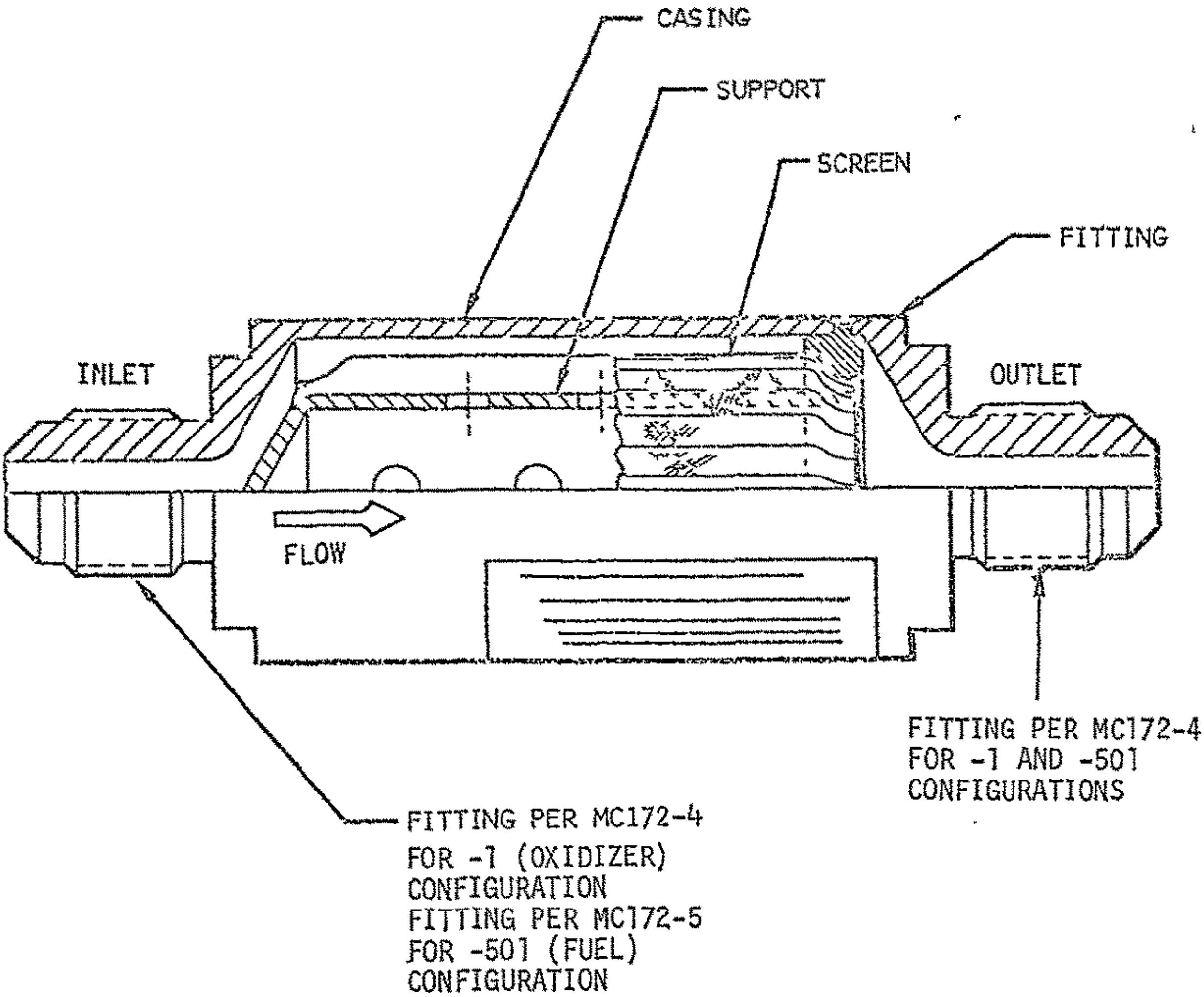


Figure 3-7. 25 Micron Recirculation In-Line Filter

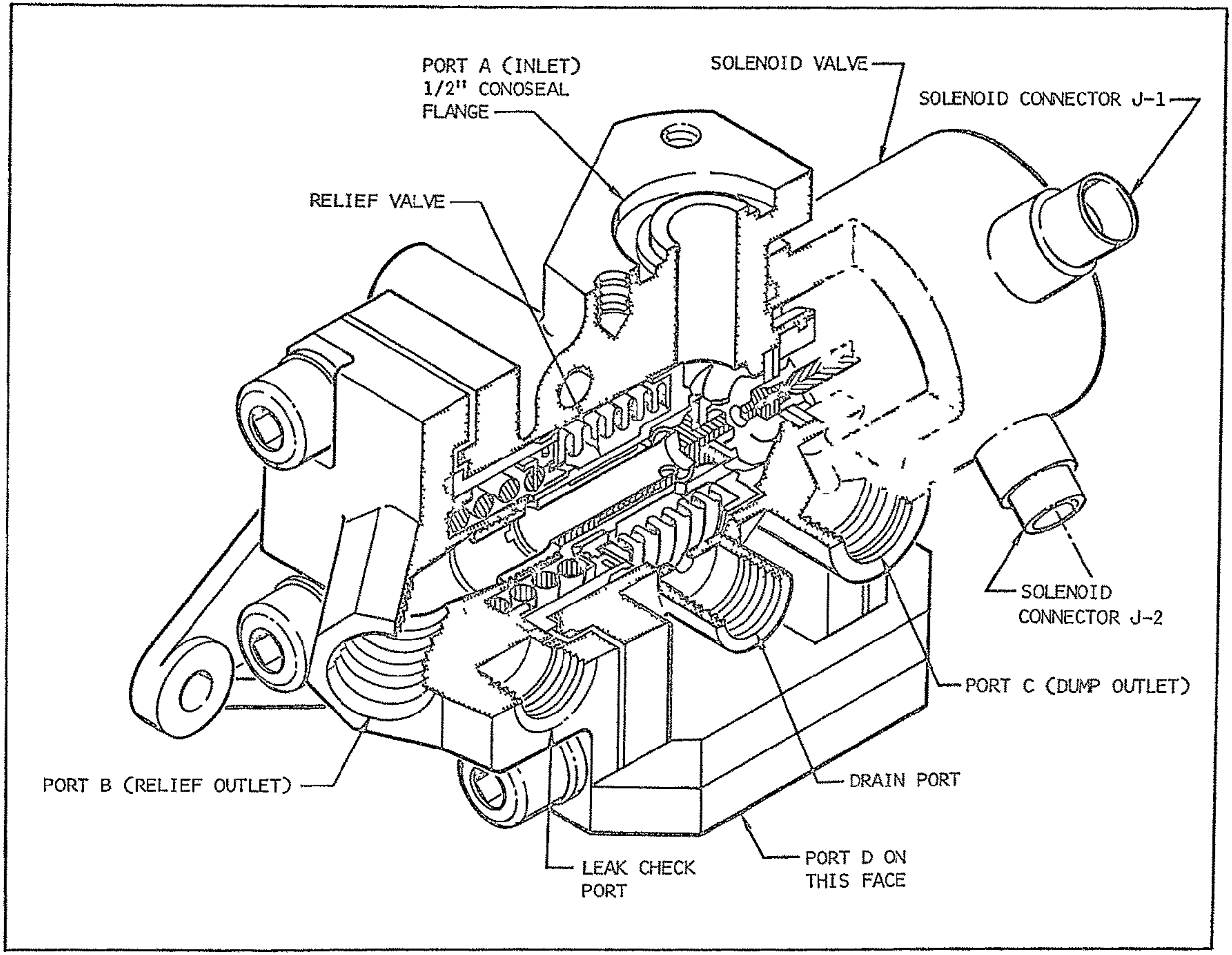


Figure 3-8. Low Pressure Helium Module

4. TEST CONFIGURATION

4.1 APS Module II

The APS module II (P/N 1A83918-535, S/N 507-2) was used in the vibration tests. APS module configuration at the completion of pretest checkout is shown in table 4-1. This table lists the major APS components, the manufacturers, the part numbers, and serial numbers.

4.2 Gamma Facility

The Gamma facility was utilized for pretest checkout, propellant loading, unloading, and disassembly.

4.3 Alpha Facility

The APS module I was transported to the Complex Alpha test facility for the vibration tests while loaded with propellants. The module was mated to a section of the aft skirt which was attached to a vibration fixture. The vibration fixture was attached to the shaker head of a C-210Y "MB" vibration exciter which was driven by two (2) "MB" model T999 power amplifiers. Because the test site is of open construction, an environmental control unit was required to maintain the module and propellant temperatures within the desired ranges. The environmental control unit was connected to the APS module by a flexible duct which supplied cool or warm air as required through the openings provided in the module fairing.

The electrical control panels located at Alpha Test Control Center provided for remote operation of the APS module and support equipment. Functions such as pressurizing, venting, and the ability to off load propellants in case of emergency were controlled manually. The test control center in addition to the meters on the operation console, also contained strip chart recorder channels for monitoring the critical redline parameters while the APS module was being vibrated.

A small portion of the Alpha Test Control Center instrumentation was used for the vibration test. The data recording equipment used included 10 strip chart channels, 3 dc amplifier channels, 3 signal condition channels, and 13 frequency modulation (FM) channels. The FM data was recorded on two 14-track tape recorders; one primary and one backup recorder. Two 14-track tape recorders were used by Engineering Laboratories and Services (EL&S) at the vibration site to record signals from twenty-two accelerometers and two strain gages. In addition, a time range generator, photo camera system, master calibration control console, closed circuit TV, and a video tape recorder were utilized.

TABLE 4-1 AUXILIARY PROPULSION SYSTEM CONFIGURATION RECORD AT COMPLETION OF PRE-TEST CHECKOUT

Module P/N 1A83918-535 S/N 507-2

Component	Vendor	DACo P/N	S/N
Helium Check Valves	J.C. Carter	1B68379-1*	Upstream 223 Downstream 231
Helium Tank	DACo	1B39317-501	020
Helium Pressure Regulator	Fairchild-Stratos	1B54601-505	3825C740071
Quad Check Valve (Oxidizer)	Vinson	1A67912-503	1107
Quad Check Valve (Fuel)	Vinson	1A67912-505	1096
Ullage Filter (Oxidizer)	Western Filter	1B55934-1	1036314
Ullage Filter (Fuel)	Western Filter	1B55934-501	1036305
Helium Low Pressure Module (Oxidizer)	Vinson	1A49998-512	135G
Helium Low Pressure Module (Fuel)	Vinson	1A49998-509	117G
Propellant Tank (Oxidizer)	Bell Aerosystems	1B63924-506	059
Propellant Tank (Fuel)	Bell Aerosystems	1B63924-505	075
Propellant Control Module (Oxidizer)	Leonard	1A49422-509	0000072
Propellant Control Module (Fuel)	Leonard	1A49422-510	0000216
Engine Manifold Assembly (Oxidizer)	DACo	1B65684-1 1B59670-1	- -
Engine Manifold Assembly (Fuel)	DACo	1B51482-1 1B59679-1	- -
Engine 1	Tapco	1A39597-509	805
Engine 2	Tapco	1A39597-509	806
Engine 3	Tapco	1A39597-509	801
Engine 4	Rocketdyne	15-210001 **	4071851

* Nonflight Configuration
** GFE

5. TEST PROGRAM

5.1 Pretest Checkout

Between 3 July 1968 and 8 October 1968, the APS module II was subjected to checkout operations at the Gamma test facility in accordance with standard checkout procedures. The following anomalies were discovered during this checkout:

a. Inability to obtain a high differential pressure current signature for the oxidizer valve No 2 (downstream on engine No. 3).

b. Excessive pressure decay for engine No. 4 during the thrust chamber leak check.

These problems are discussed in detail in paragraphs 6.2.1 and 6.2.2.

5 2 Propellant Loading

On 16 October 1968 the APS module was loaded with propellants in accordance with the standard loading procedure (DAC H&CO 1B73217). Table 5-1 summarizes the propellant loading.

Shortly after loading the module with propellants, the fuel ullage pressure was discovered to be decaying. Further investigation revealed that the fuel low pressure helium module (P/N 1A49998-509, S/N 117G), was leaking at the vent port. The helium module was removed and replaced with module (P/N 1A49998-509, S/N 108G). Paragraph 6.1.1 describes this problem.

After replacing the discrepant low pressure helium module, the APS module was repressurized to blanket pressure (65 ± 5 psia) and maintained in a hold condition at the Gamma test facility until it was transported to the Alpha test facility on 17 October 1968

5.3 Pressurization

The normal operating ranges for the specified parameters are as follows:

System	Parameter	Range (psia)
Low Pressure	Oxidizer Manifold and Ullage Pressure	203 - 222
Low Pressure	Fuel Manifold and Ullage Pressure	203 - 222
Low Pressure	Regulator Outlet Pressure	203 - 222
High Pressure	Helium Bottle Pressure	305 - 3,200

5.3.1 High Pressure System

The high pressure system was pressurized approximately 25 times between 20 October 1968 and 8 November 1968. Pressurization was always terminated below the helium bottle operating pressure limit of 3,200 psia.

During the pressurizations, the expected gas heating was observed. This heating usually peaked out at approximately 560 deg R. Most of the pressurizations were followed by a hold for temperature stabilization and a pressure decay check. Some pressure decay was noted indicating a possible helium leak (see paragraph 6.1.2).

During the venting of the system, after the required testing (or troubleshooting), the lowest temperature recorded was approximately 475 deg R.

5.3.2 Low Pressure System

The low pressure system was within the prescribed operating limits, however, two anomalies occurred during testing

The oxidizer manifold pressure exhibited pressure oscillations (ringing) during the random radial and tangential vibration modes. The maximum oscillations occurring were from zero to 400 psi Figure 5-1 is representative of the typical ringing phenomenon. It was concluded that these pressure spikes were due to the low damping efficiency of the dashpot fluid used in the oxidizer manifold transducer.

On 23 October 1968 it was discovered that the torque values on several helium system fittings were not as specified (see paragraph 6 1.2). The high pressure system was isolated from the low pressure system for leak tests. As a result the gas between the check valves and high pressure system vented. This accounted for the ambient pressure reading for the regulator outlet during this period.

5.4 Propellant Temperatures

The propellant temperature requirements during the vibration tests were as follows:

Parameter	Range (°R)
Oxidizer temperature	520 - 560
Fuel temperature	520 - 560

5.4.1 Oxidizer

The oxidizer temperature remained in the 520 - 560 deg R range for most of the test. The indicated temperature dropped to 519, 518, and 517 deg R on three different occasions (figure 5-2). The lower APS doors were removed during these periods which prevented the thermal conditioned air from flowing over the propellant control module where the temperature probe is located. However, the propellant within the tank was maintained well within the temperature limits during these periods

5.4.2 Fuel

The fuel temperature remained in the allowable range of 520 - 560 deg R for most of the test. The indicated temperature decreased to 518 deg R on two occasions (figure 5-3). The lower APS doors were removed during these periods which prevented the thermal conditioned air from flowing over the propellant control module where the temperature probe is located However, the propellant within the tank was maintained well within the temperature limits during these periods.

5.5 Vibration Tests

5.5.1 APS Module Transportation to Alpha Complex

The APS module, loaded with propellants, was transported to the Alpha test site on 17 October. Acceleration measurements were made during hoisting and transportation at the input to the module in the thrust, radial, and tangential directions. During transportation the allowable dynamic loading of 1.5 g's was not exceeded. Levels generally remained below 0.2 g at a predominant frequency of less than 4 Hz during road travel. During raising and lowering of the module, some isolated shocks reached 0.o g at 8 Hz.

5.5.2 General

The APS module was subjected to vibration and shock tests in the thrust, tangential, and radial axes per the levels and order presented in table 5-2. The vibration and shock requirements were as specified in

Test Control Drawing 1T10923F "Formal Qualification Test, Saturn IVB/V Phase V APS Vibration." The module was tested in liftoff orientation with the propellant tanks loaded and the helium system pressurized to 3,000 ±200 psi.

The test specimen consisted of an APS module installed on a portion of aft skirt vehicle structure, which in turn was mounted on a rigid fixture. Twenty-two accelerometers and two strain gages were used to monitor the input and response of the specimen (table 5-3). Accelerometer and strain gage locations are shown in figure 5-4. The random vibration input was controlled from the average of the input acceleration levels at the lower right and upper right APS attach brackets, accelerometer locations 1 and 2, respectively. Sinusoidal vibration and shock tests were controlled at accelerometer location 1. In shock testing the control accelerometer signal was filtered with a 200 Hz low pass filter Control signals in sinusoidal testing were filtered with a tracking filter.

Sinusoidal and random vibration testing was within specified test tolerances except for minor deviations considered acceptable by MSFC and MDAC dynamics personnel. Shock testing was per specification except in the radial axis where the shock level was reduced in amplitude to compensate for an uncontrollable increase in pulse duration. This change was considered acceptable by MSFC and MDAC dynamics personnel after reviewing the flight shock spectrum.

The vibration and shock tests are described in the following paragraphs. Table 5-4 presents a chronological history of vibration and shock testing. X-Rays and full leak checks were performed before any vibration testing.

5.5.3 Thrust Axis Test

Figure 5-5 presents the thrust axis test setup. Photographs of the control and response accelerometers are shown in figure 5-6.

5.5.3.1 Sinusoidal Sweep Test

On 21 October the APS module was subjected to a logarithmic sinusoidal sweep vibration test per the following specification:

(Upsweep only)

3 to 4 Hz at 0.24 inch double amplitude displacement 4 to 7 Hz at 0.2 g zero to peak	1 octave/min
7 to 20 Hz at 0.1 g zero to peak	3 octaves/min

The filtered control input is presented in figure 5-7. No resonance was noted at any of the response accelerometer locations. Leak checks and physical inspection did not reveal any malfunctions or failures.

5.5.3.2 Random Vibration Test

The APS module was subjected to random vibration excitation for 3 min on 25 October per the following specification

20 to 30 Hz at +6 db/octave
30 to 100 Hz at 0.01 g^2/Hz
100 to 200 Hz at +6 db/octave
200 to 1,000 Hz at 0 05 g^2/Hz
1,000 to 2,000 Hz at -3 db/octave

Leak checks and inspection did not reveal any malfunctions or failures except for the stripped nut plate described in paragraph 6.2.4. Accelerometer data are presented in figure 5-8.

5.5.3.3 Shock Test

The APS was subjected to shock testing on 25 October per the following specification·

Amplitude	15 g peak
Duration	5 ±1 millisecond
Shape	Half sine
Quantity	3 (in one direction)

The achieved input pulses are presented in figure 5-9. Representative shock spectrum analyses of the control and several response accelerometers are shown in figure 5-10. Thorough leak checks, X-rays, and physical inspection of the module did not reveal any malfunctions or failures.

5.5.4 Tangential Axis Tests

Figure 5-11 presents the tangential axis test setup. Photographs of the control and response accelerometers are shown in figure 5-12.

5.5.4.1 Sinusoidal Sweep Test

The APS module was subjected to a logarithmic sinusoidal sweep vibration test on 28 October per the following specification:

3 octaves/min. (upsweep only)

1.5 to 2.5 Hz at 0.04 g, zero to peak

2.5 to 3.5 Hz at 0.125 inch double amplitude displacement

3.5 to 20.0 Hz at 0.08 g, zero to peak

The filtered control input data are presented in figure 5-13. No resonance was noted at any of the response accelerometer locations. Leak checks and inspection did not reveal any malfunctions or failures except for the loose jam nut described in paragraph 6.2.5.

5.5.4.2 Random Vibration Test

The test described in paragraph 5.5.3.2 was repeated on 29 October, in the tangential axis. No malfunctions or failures were noted during or after the test. Accelerometer data for this test are presented in figure 5-14. Leak checks and inspection did not reveal any malfunctions or failures.

5.5.4.3 Shock Test

The test described in paragraph 5.5.3.3 was repeated on 29 October in the tangential axis. The achieved shock inputs for this test are presented in figure 5-15. Shock spectrum analyses of the control and several representative response accelerometers are shown in figure 5-16. Thorough leak checks, X-rays, and physical inspection of the module did not reveal any malfunctions or failures except for the stripped nut plate described in paragraph 6.2.6.

5.5.5 Radial Axis Tests

Photographs of the control and response accelerometers are shown in figure 5-17.

5.5.5.1 Sinusoidal Sweep Test

The test described in paragraph 5.5.4.1 was repeated on 1 November in the radial axis. No resonance conditions were noted at any of the response accelerometer locations.

The filtered control input data for this test are presented in figure 5-18. Leak checks and inspection did not reveal any malfunctions or failures.

5.5.5.2 Shock Test

The test described in paragraph 5 5.3.3 was repeated on 2 November in the radial axis. Leak checks and inspection revealed no malfunctions or failures after the test. The achieved shock inputs are shown in figure 5-19. Shock spectrum analyses of the control and several representative response accelerometers are shown in figure 5-20.

5.5.5.3 Random Vibration Test

The APS module was subjected to 2 minutes of low level random vibration excitation on 4 November per the following specification:

20 to 85 Hz at 0.025 g^2/Hz

85 to 280 Hz at +6.5 db/octave

280 to 1,000 Hz at 0.31 g^2/Hz

1,000 to 2,000 Hz at -12 db/octave

Accelerometer data are presented in figure 5-21. After this test, a post vibration leak test and inspection (bladder leak tests were not included) were performed on the APS module. This leak test did not reveal any malfunctions or failures.

On 5 November the APS module was subjected to high level random vibration excitation for 30 sec per the following specification:

20 to 170 Hz at 0.1 g^2/Hz

170 to 280 Hz at +6.5 db/octave

280 to 1,000 Hz at 0.31 g^2/Hz

1,000 to 2,000 Hz at -12 db/octave

Accelerometer data are presented in figure 5-22. After this test, a leak test which included bladder leak tests and X-rays was conducted on the APS module. A fuel bladder leak of 750 sccm gaseous nitrogen was discovered. After numerous tests as described in paragraph 6.2.9, the size of the hole was determined and the vibration test was continued.

The APS module was then subjected to an additional 55 seconds of random vibration excitation on 7 November per the above high level specification:

Accelerometer data for this test are presented in figure 5-23. After this test, a leak check which included bladder leak tests, inspection, and X-ray was conducted on the APS module. This leak check revealed that the fuel bladder still leaked approximately the same as after the 30 sec test, however, no other malfunctions or failures were present.

5.5.6 Transportation of the APS Module to Gamma

On the return trip from Alpha to Gamma on 8 November, load levels were similar to those measured on the trip to Alpha (paragraph 5.5.2). The shock loads were very similar to those in paragraph 5.5.2 with one exception. A shock load of 1.1 g was recorded when the crane cable slipped and dropped the module approximately 12 feet while suspended above the Gamma Test Cell. The module did not hit the ground when dropped, and was not damaged.

5.6 Propellant Unloading and System Purge

Propellant unloading was performed in accordance with standard operating procedures (MDAC H&CO 1B73218, Task Number 10) but just prior to unloading, 1,000 cc of oxidizer and fuel were removed from each system for sampling. (The fuel and oxidizer samples were within specifications except for inconsequential discrepancies.) The remaining propellant was unloaded from the APS module and transferred to the mobile servicer storage tanks. A summary of propellant unloading is presented in table 5-5.

5.7 Post Unloading Checkout

After propellant unloading, the APS module was subjected to a limited leak check and functional checkout in accordance with Task No. 11 of MDAC H&CO No. 1B73218. The only problem encountered during this checkout other than the fuel bladder leak, was a blowing leak on the upstream high pressure helium check valve. This problem is discussed in detail in paragraph 6.2.8.

5.8 Instrumentation System

The instrumentation system performed satisfactorily throughout pretest checkout, propellant loading, vibration testing, propellant unloading and post test checkout except as noted in the following paragraphs.

Two strain gages were attached to the oxidizer tank pressurization line at the outlet of the quad check valve. These were added to this APS module for failure analysis in the event this line failed in a manner similar to that experienced during the vibration testing of APS module I.

An instrumentation phenomenon which was experienced on APS modules during previous burp firings and vibration testing was again observed during the random shock tests in all three axes. A high frequency ringing occurred on measurement D0073, Oxidizer Supply Manifold Pressure, during the random vibration tests and during the shock tests. Table 5-6 shows the system pressure, average fluctuations and the min/max spike values that were recorded on the FM data.

It was noted that the oxidizer system transducer was damped with a Halocarbon 208 oil which has about the same viscosity as water. The fuel system transducer was damped with Dow Corning 510 lubricant which has a much higher viscosity. This may account for the ringing effect within the oxidizer supply manifold pressure transducer during the vibration tests.

Fluctuations were also noted on measurement D0036, Helium Tank Pressure, during random vibration in the tangential axis. Peak values of 3,500 psia were recorded on the FM data when the helium tank was pressurized to 3,200 psia.

All flight instrumentation was recorded. A list of the analog flight measurements is shown in table 5-7.

5.9 Electrical Control System

The electrical control system performed properly throughout the pretest checkout, propellant loading, and vibration testing. No problems or discrepancies were noted at any time.

5.10 Disassembly and Inspection

The results of the post test APS module inspection indicated one significant failure resulting from the vibration test program. A small hole was found in the fuel tank bladder (see paragraph 6.2.7). The hole was located near the upper end of the bladder and was approximately 0.01 inch wide and 0.04 inch long. Defects were found on the upper weld on the fuel tank diffuser stand pipe that are believed to have caused this damage to the bladder when it was in the collapsed position for vibration testing.

Two minor abnormalities, a rust-like deposit on the fuel tank outlet line and a chip missing from the oxidizer low pressure helium mount bracket, were found during the overall APS visual inspection.

TABLE 5-1
PROPELLANT LOADING SUMMARY

PARAMETER	OXIDIZER	FUEL
Mobile Servicer Storage Tank Pressure	45-50 psia	45-48 psia
APS Tank Outlet Pressure	36-42 psia	35-42 psia
APS Ullage Pressure	34 psia	32 psia
Mobile Servicer Collection Tank Pressure	35 psia	36 psia
Quantity Loaded	17.74 gal	17.74 gal
Loading Time	20 min	12 min
Loading Rate	0.89 gpm	1.48 gpm
Tank Temperature at Fully Loaded Condition	82 deg F	92 deg F
Quantity Recirculated	10 gal	6 gal
Recirculation Time	3 min	4 min
Quantity Off-Loaded	1.8 gal	0.3 gal

TABLE 5-2 (Sheet 1 of 2)
VIBRATION REQUIREMENTS

AXIS	MODE OF VIBRATION	FREQUENCY (Hz)	LEVEL	DURATION
Thrust	Sinusoidal (Upsweep Only)	3 to 4	0.24 in. double ampl	1 oct/min
		4 to 7	0.2 g zero to peak	1 oct/min
		7 to 20	0.1 g zero to peak	3 oct/min
	Random	20 to 30	+6 db/octave	
		30 to 100	0.01 g^2/Hz	
		100 to 200	+6 db/octave	3 min
		200 to 1,000	0.05 g^2/Hz	
		1,000 to 2,000	-3 db/octave	
	3 Shocks	half sine	15 g zero to peak	5 $\pm$1 ms
Tangential	Sinusoidal (Upsweep Only)	1.5 to 2.5	0.04 g zero to peak	
		2.5 to 3.5	0.125 in. double ampl	3 oct/min
		3.5 to 20	0.08 g zero to peak	
	Random	20 to 30	+6 db/octave	
		30 to 100	0.01 g^2/Hz	
		100 to 200	+6 db/octave	3 min
		200 to 1,000	0 05 g^2/Hz	
		1,000 to 2,000	-3 db/octave	
	3 Shocks	half sine	15 g zero to peak	5 $\pm$1 ms
Radial	Sinusoidal (Upsweep Only)	1 5 to 2.5	0.04 g zero to peak	
		2.5 to 3.5	0.125 in. double ampl	3 oct/min
		3.5 to 20	0.08 g zero to peak	
	3 Shocks	half sine	15 g zero to peak	5 $\pm$1 ms

TABLE 5-2 (Sheet 2 of 2)
VIBRATION REQUIREMENTS

AXIS	MODE OF VIBRATION	FREQUENCY (Hz)	LEVEL	DURATION
Radial	Random	20 to 85	0.025 g^2/Hz	2 min
		85 to 280	+6.5 db/octave	
		280 to 1,000	0.31 g^2/Hz	
		1,000 to 2,000	-12 db/octave	
		20 to 170	0.1 g^2/Hz	30 sec and 55 sec
		170 to 280	+6.5 db/octave	
		280 to 1,000	0.31 g^2/Hz	
		1,000 to 2,000	-12 db/octave	

TABLE 5-3 (Sheet 1 of 2)
ACCELEROMETER AND STRAIN GAGE LOCATIONS
AND ORIENTATIONS

LOC NO.	LOCATION	THRUST	TANGENTIAL	RADIAL
1	Control-Lower Right APS Attach Bracket	Thrust	Tangential	Radial
2	Alt Control-Upper Right APS Attach Bracket	Thrust	Tangential	Radial
3	Quad Check Valve and He Press Regulator-Input	Thrust	Tangential	Radial
4	Shaker Head	Thrust	Tangential	Radial
5	Quad Check Valve-Response	Thrust	Tangential	Radial
6	Fuel Tank-Aft-Response	Thrust	Tangential	Radial
7	Oxidizer Tank Aft Response	Thrust	Tangential	Radial
8	Oxid Prop Control Mod L-5 Input	Radial	Radial	Radial
9	Fuel Low Press He Mod (Ullage Vent Valve L04) Response	Thrust	Tangential	Radial
10	Engine No. 4 (Ullage) Input	Thrust	Tangential	Radial
11	Oxidizer Tank Press Line* Quad Check Valve End-Strain Gauge	--	--	--
12	Oxidizer Tank Press Line* Quad Check Valve End-Strain Gauge	--	--	--
13	Lower Left APS Attach Bracket	Thrust	Tangential	Radial
14	Upper Left APS Attach Bracket	Thrust	Tangential	Radial
15	APS Module-Center Response	Thrust	Tangential	Radial
16	Fuel Tank-Forward Response	Thrust	Thrust	Thrust
17	APS Module-Forward Response	Thrust	Tangential	Radial
18	Oxid Prop Control Mod L-5 Input	Tangential	Tangential	Tangential

Left and right are as viewed from outside vehicle

*Strain Gage

TABLE 5-3 (Sheet 2 of 2)
ACCELEROMETER AND STRAIN GAGE LOCATIONS
AND ORIENTATIONS

LOC NO.	LOCATION	THRUST	TANGENTIAL	RADIAL
19	Oxidizer Tank-Forward Response	Thrust	Thrust	Thrust
20	Oxidizer Tank-Forward Response	Radial	Radial	Radial
21	Oxidizer Tank-Forward Response	Tangential	Tangential	Tangential
22	Oxidizer Tank-Aft Input	Thrust	Tangential	Radial
23	Fuel Tank-Forward Response	Radial	Tangential	Radial
24	Amplifier-Engine Press Transducer-Response	Thrust	Tangential	Radial

Left and right are as viewed from outside vehicle

TABLE 5-4
CHRONOLOGICAL HISTORY

DATE COMPLETED	EVENT
	Thrust Axis
10-17-68	APS moved from Gamma to Alpha site.
10-18-68	Fixture and shaker alignment.
10-19-68	System checkout.
10-21-68	APS hookup. Sine sweep test.
10-22-68	Random vibration equalization. Shutdown due to leaks.
10-23-68	Helium tank leak checks performed.
10-24-68	Leaks fixed Random vibration equalization continued.
10-25-68	Random vibration test. Shock test.
	Tangential Axis
10-26-68	Rotated fixture to tangential axis.
10-27-68	System checkout.
10-28-68	APS hookup. Sine sweep test.
10-29-68	Random vibration test. Shock test.
	Radial Axis
10-30-68	Rotated fixture to radial axis.
10-31-68	System checkout.
11-1-68	APS hookup. Sine sweep.
11-2-68	Shock test.
11-4-68	Random vibration 2 minute test.
11-5-68	Random vibration 30 second test.
11-6-68	Leak checks
11-7-68	Random vibration 55 second test.
11-8-68	Leak checks. APS moved to Gamma.

TABLE 5-5
PROPELLANT UNLOADING SUMMARY

PARAMETER	OXIDIZER	FUEL
APS Ullage Pressure	36 psia	33.5 psia
APS System Pressure	44 psia	39.8 psia
Mobile Servicer Storage Tank Pressure	40 psia	37.5 psia
Quantity Unloaded	14 gal	15 gal
Unloading Time	18 min	45 min*

*The greater time required to unload the fuel tank was due to a problem encountered while readjusting a Mobile Servicer pressure regulator to meet flow conditions.

TABLE 5-6
OXIDIZER SUPPLY MANIFOLD PRESSURE (D0073)

AXIS	MODE OF VIBRATION	AVERAGE SYSTEM PRESS (psia)	AVERAGE FLUCTUATIONS (psia)	SPIKE VALUES (psia)	
				MIN	MAX
Thrust	Random	215	200-225	-	260
	Shock	215	200-225	-	-
Tangential	Random	215	200-240	190	400
	Shock	210	198-230	-	-
Radial	Shock	210	205-215	-	-
	Random				
	Phase I	210	200-220	-	-
	Phase II	210	200-260	120	400
	Phase III	210	200-260	0	400

TABLE 5-7
ANALOG FLIGHT INSTRUMENTATION

ITEM	TITLE	RANGE
C0187	Helium Tank Temperature	360-1,060 deg R
C0032	Oxidizer Tank Outlet Temperature	460-660 deg R
C0021	Fuel Tank Outlet Temperature	460-660 deg R
D0030	Engine 1 Chamber Pressure	0-200 psia
D0031	Engine 2 Chamber Pressure	0-200 psia
D0032	Engine 3 Chamber Pressure	0-200 psia
D0036	Helium Tank Pressure	0-3,500 psia
D0038	Helium Regulator Outlet Pressure	0-400 psia
D0072	Fuel Manifold Pressure	0-400 psia
D0100	Fuel Tank Ullage Pressure	0-400 psia
D0099	Oxidizer Tank Ullage Pressure	0-400 psia
D0221	Engine 4 Chamber Pressure	0-400 psia
D0073	Oxidizer Manifold Pressure	0-400 psia

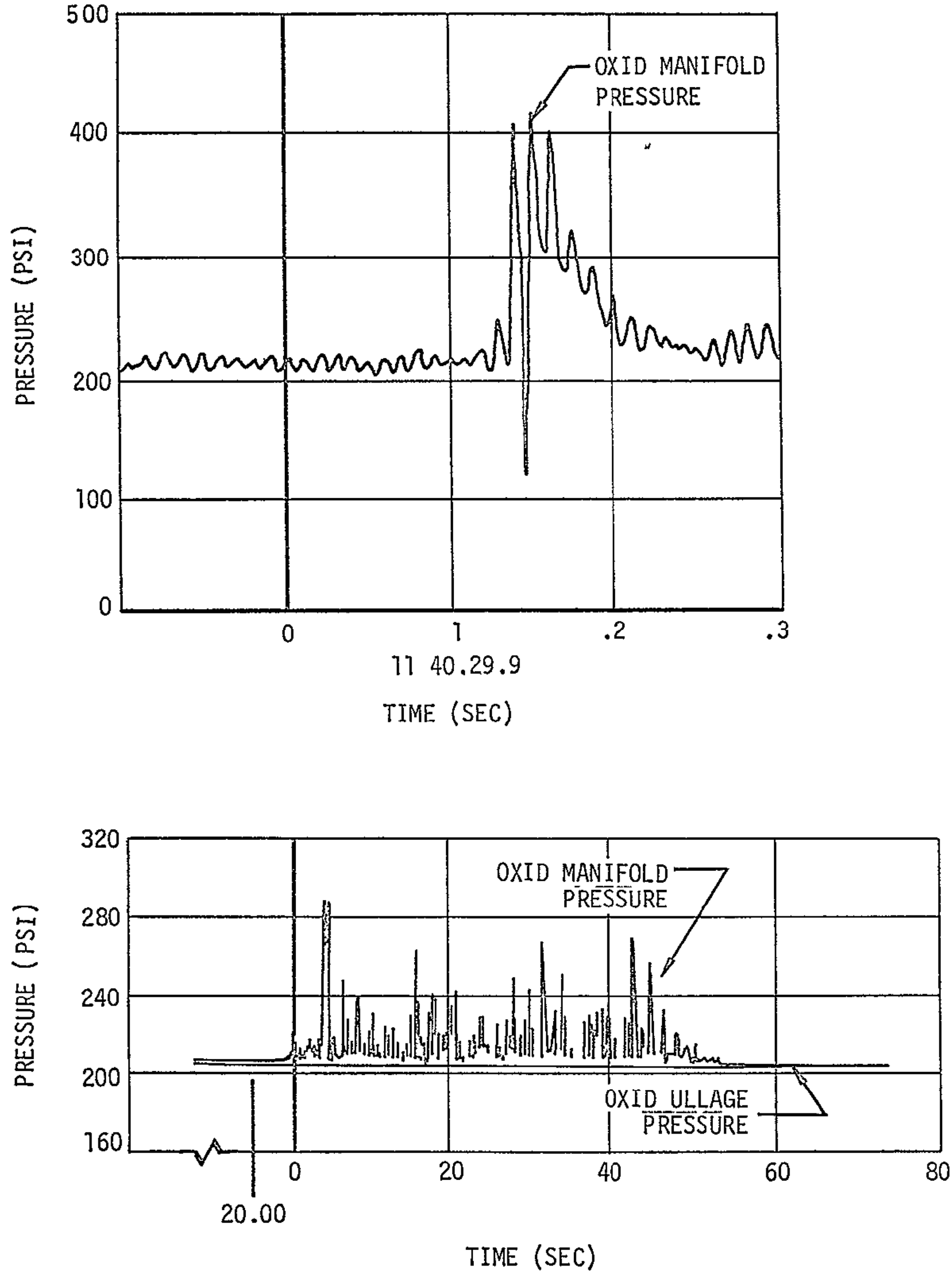


Figure 5-1. Typical Oxidizer Manifold Pressure

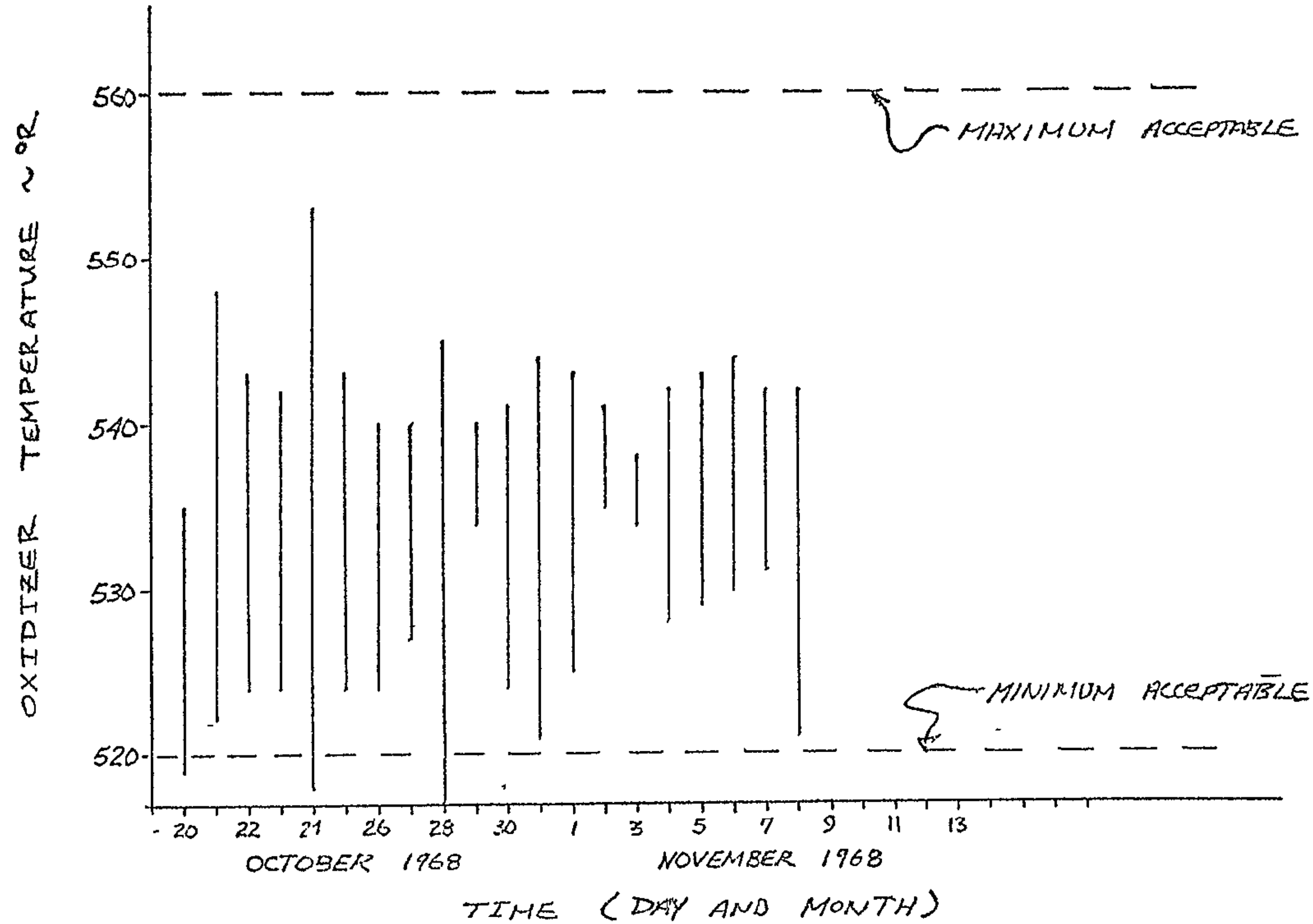


Figure 5-2 Oxidizer Temperature Range during Vibration Testing

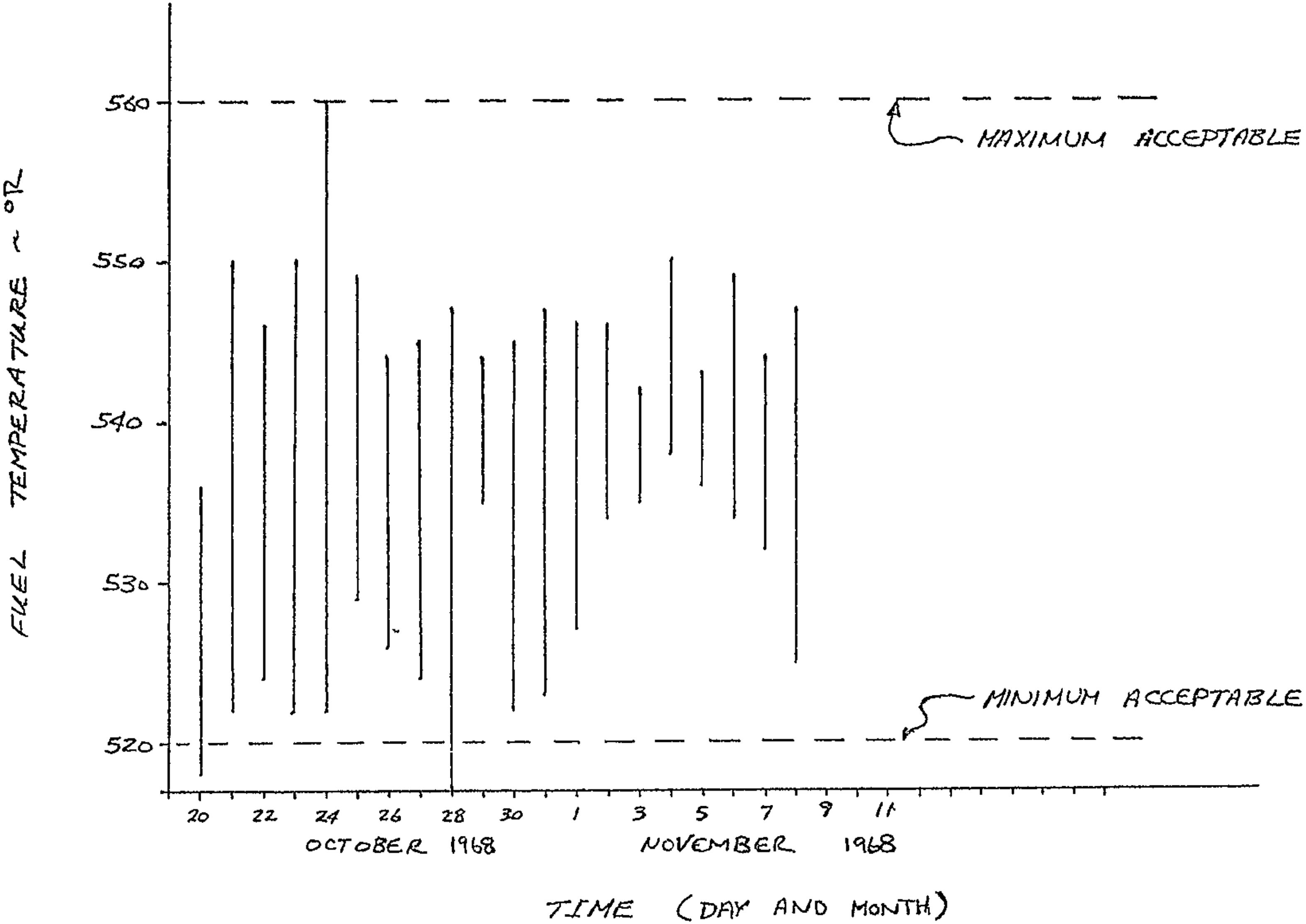


Figure 5-3 Fuel Temperature Range during Vibration Testing

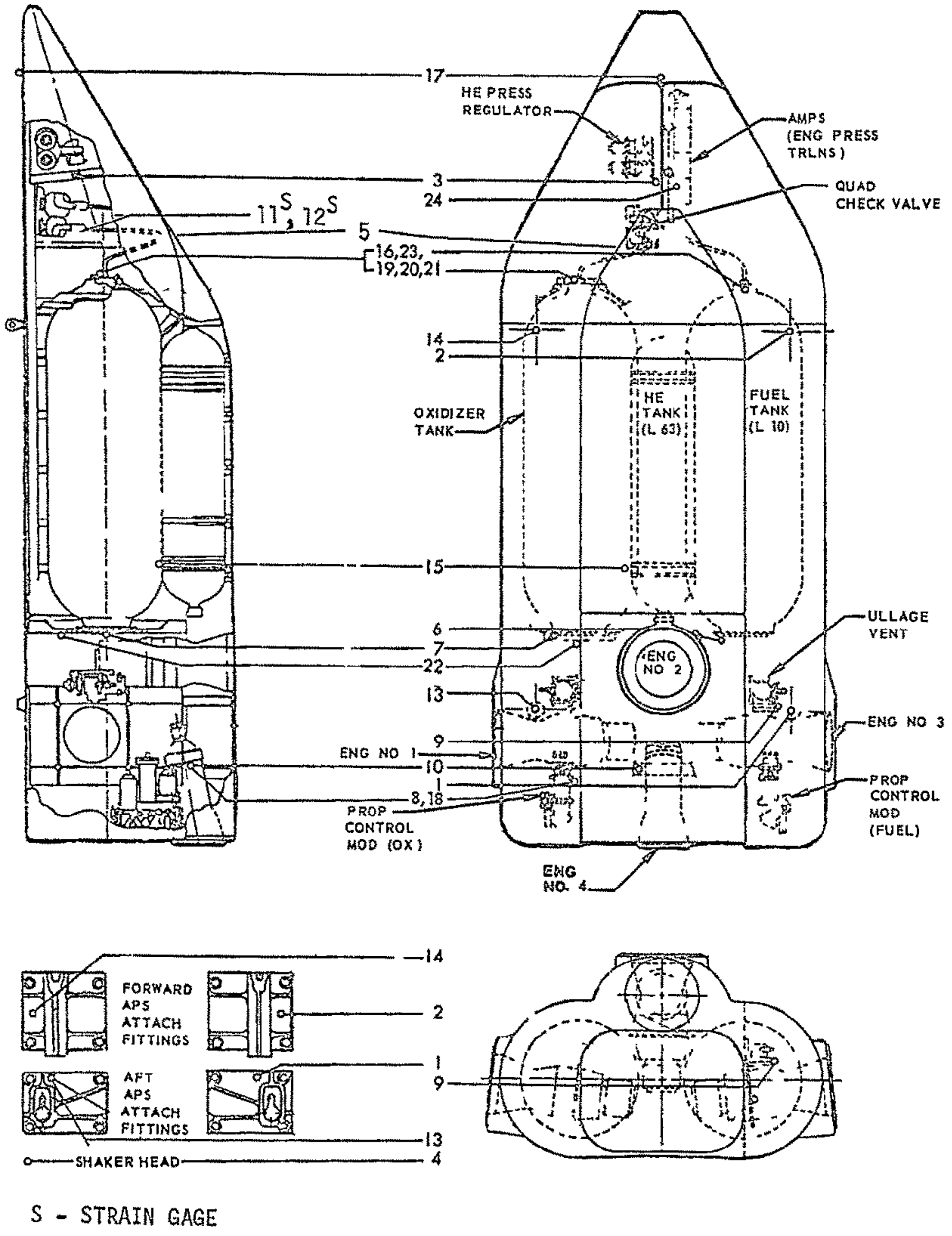


Figure 5-4. Accelerometer and Strain Gage Locations

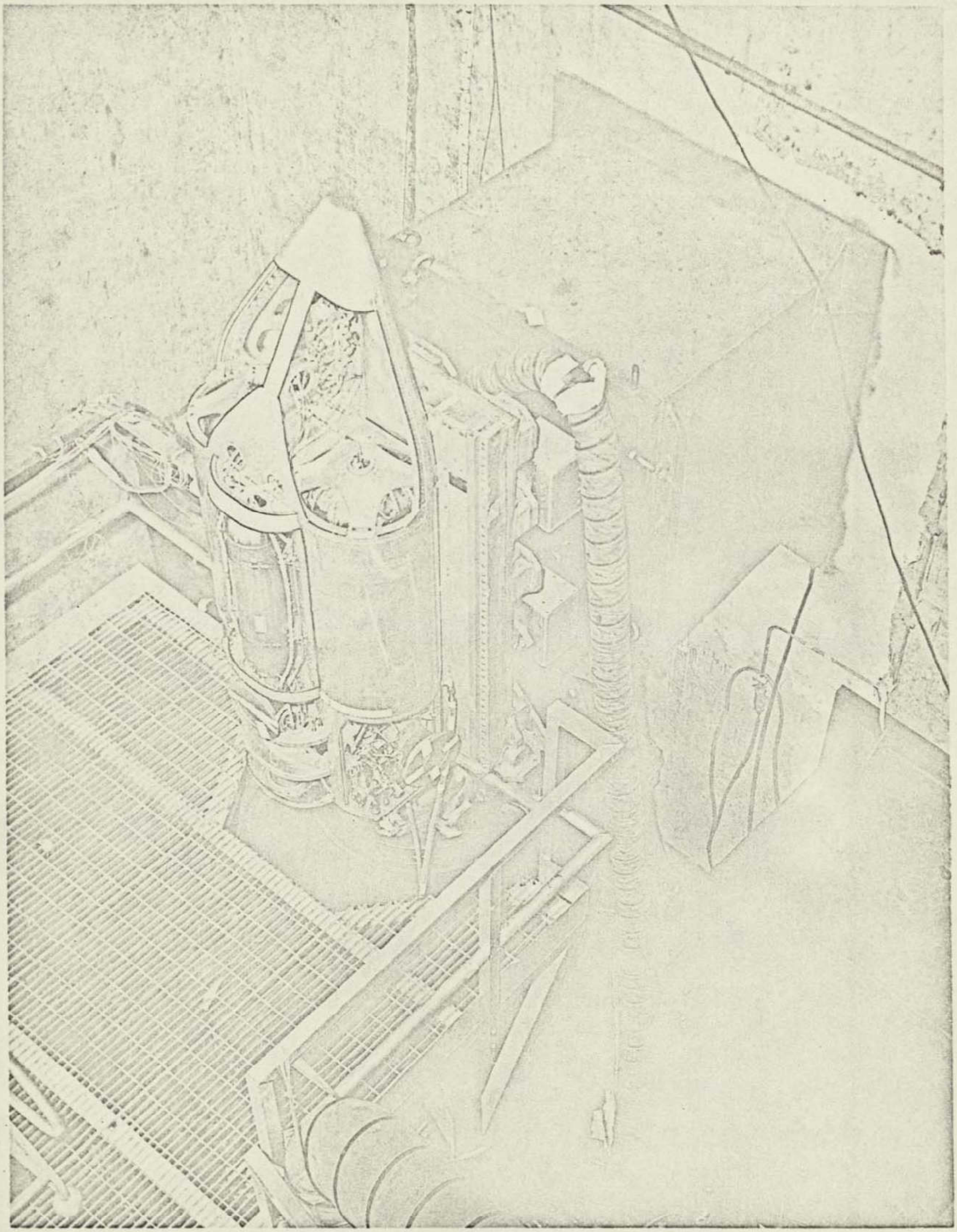
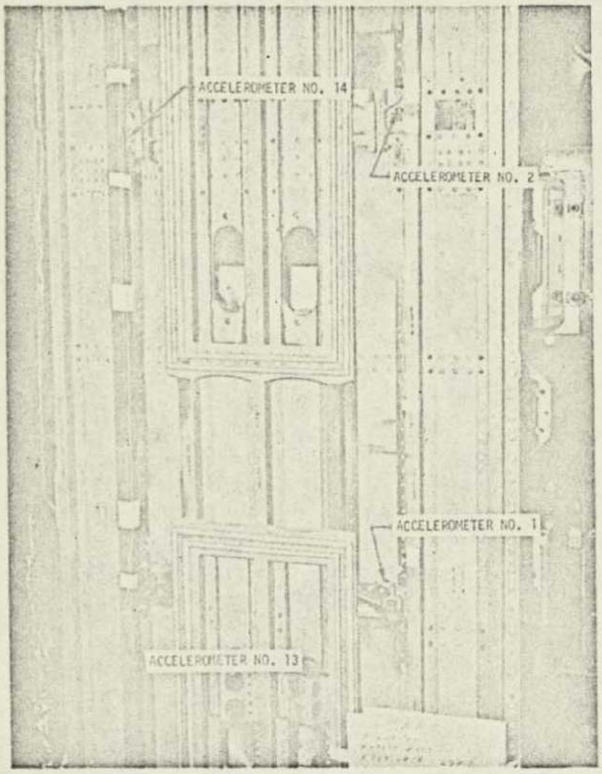
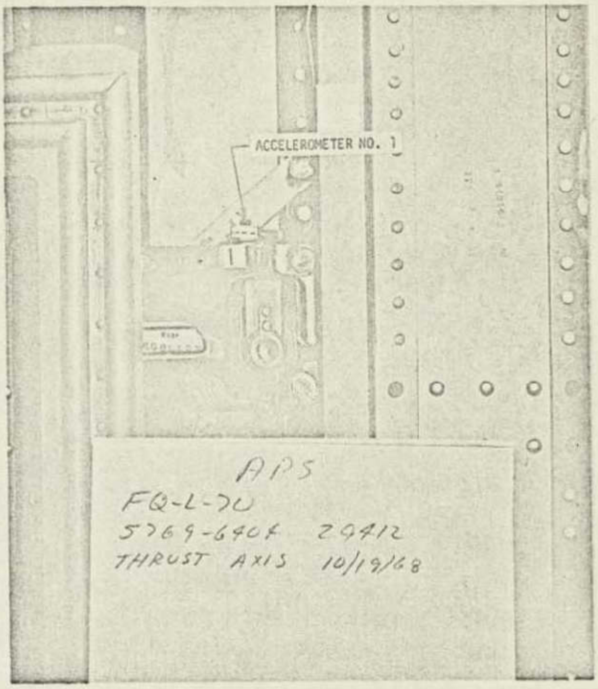
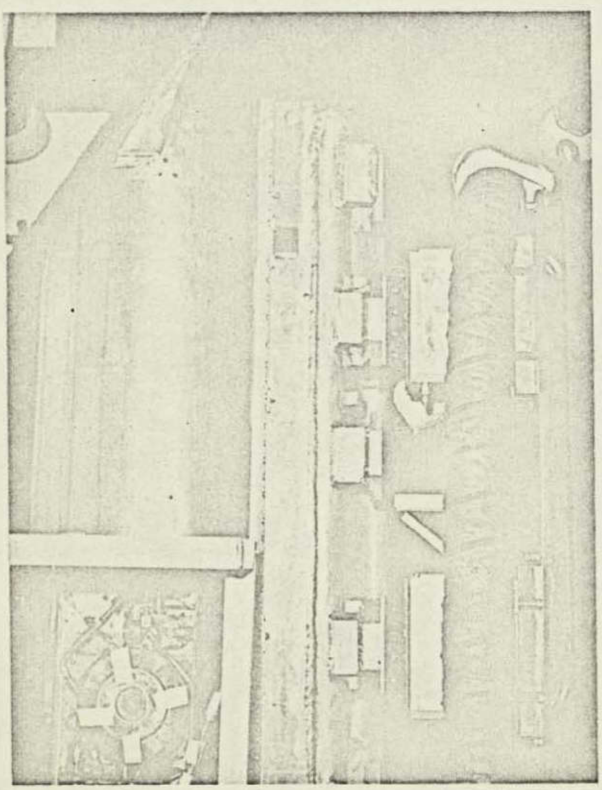


Figure 5-5. Thrust Axis Test Setup







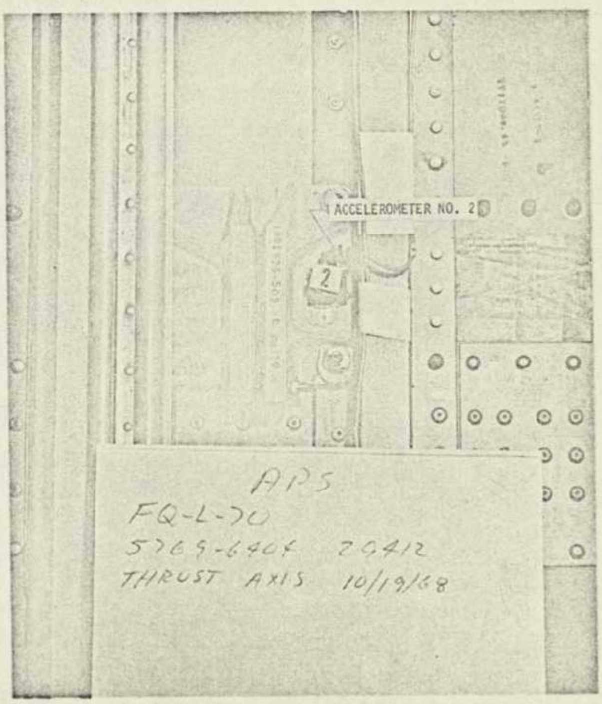
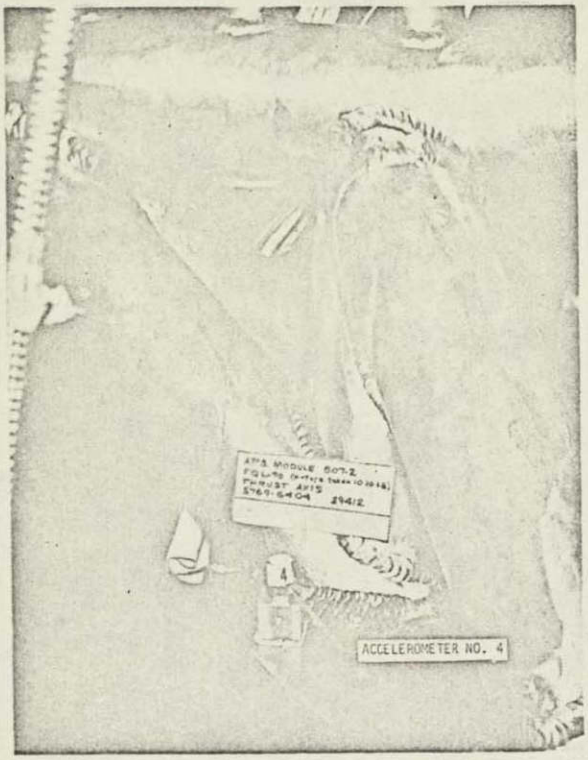
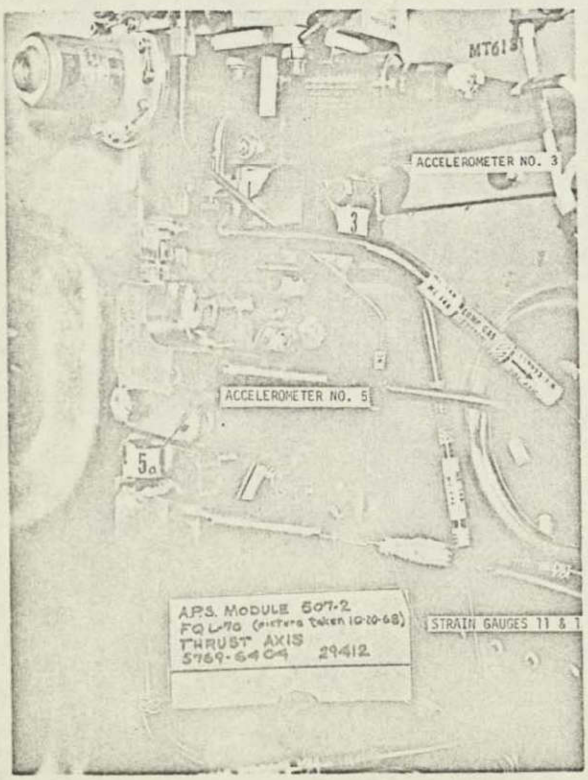


Figure 5-6. Thrust Axis Accelerometer Locations (Sheet 1 of 4)





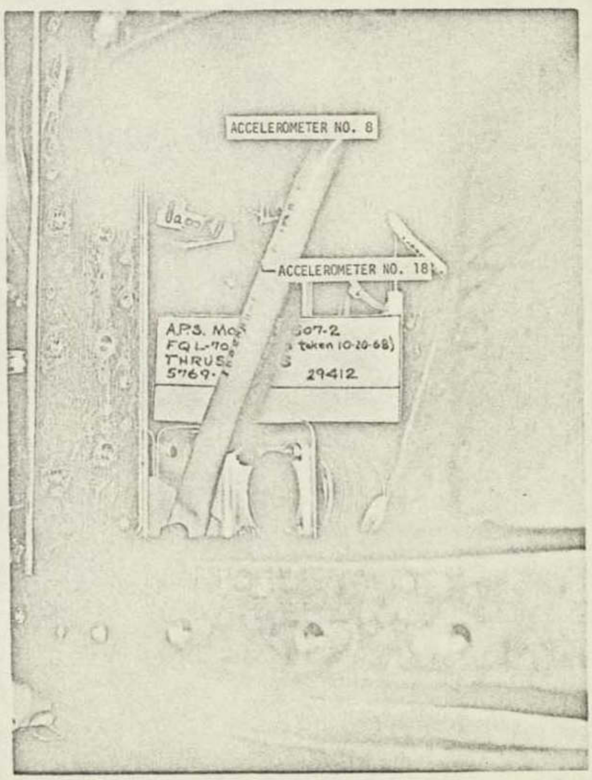
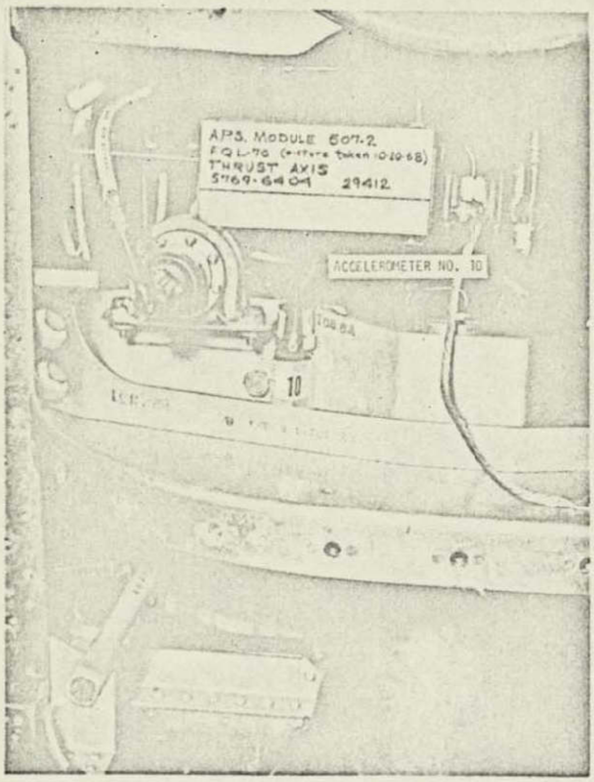
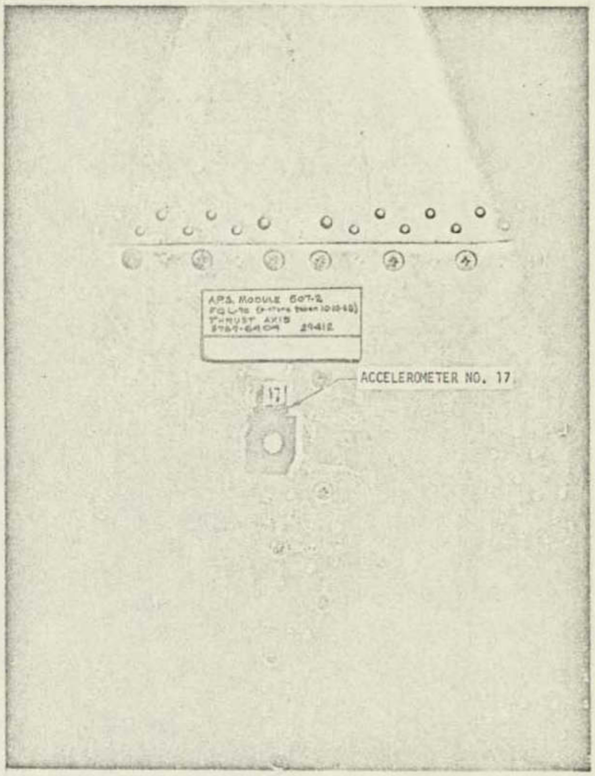
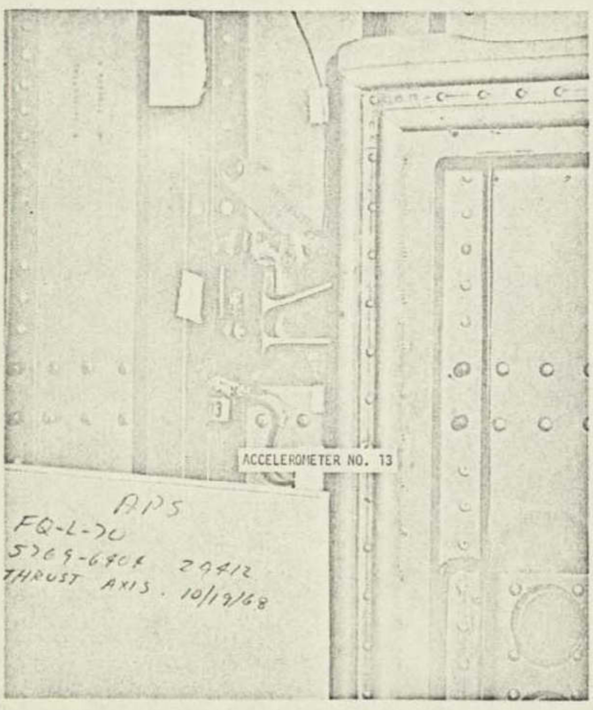


Figure 5-6. Thrust Axis Accelerometer Locations (Sheet 2 of 4)







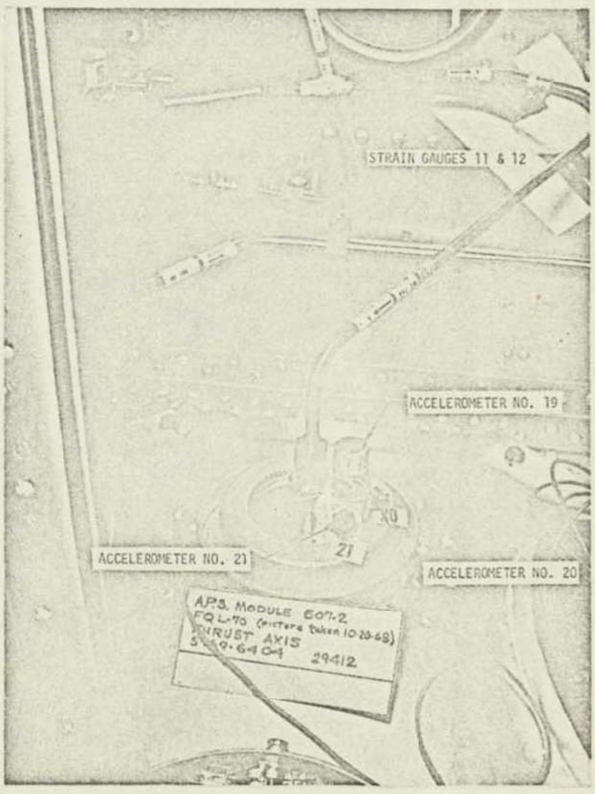


Figure 5-6. Thrust Axis Accelerometer Locations (Sheet 3 of 4)

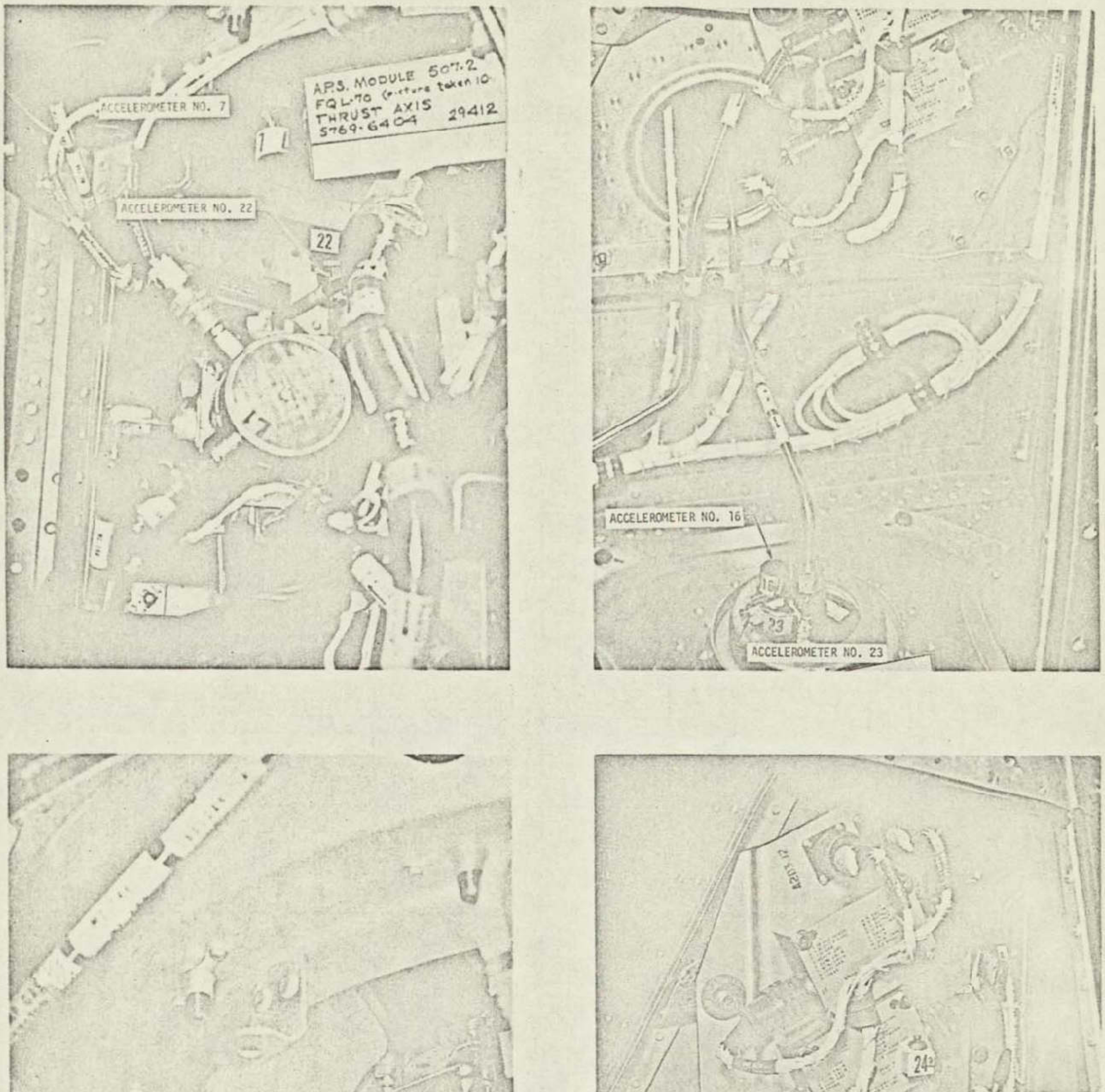


Figure 5-6. Thrust Axis Accelerometer Locations (Sheet 4 of 4)

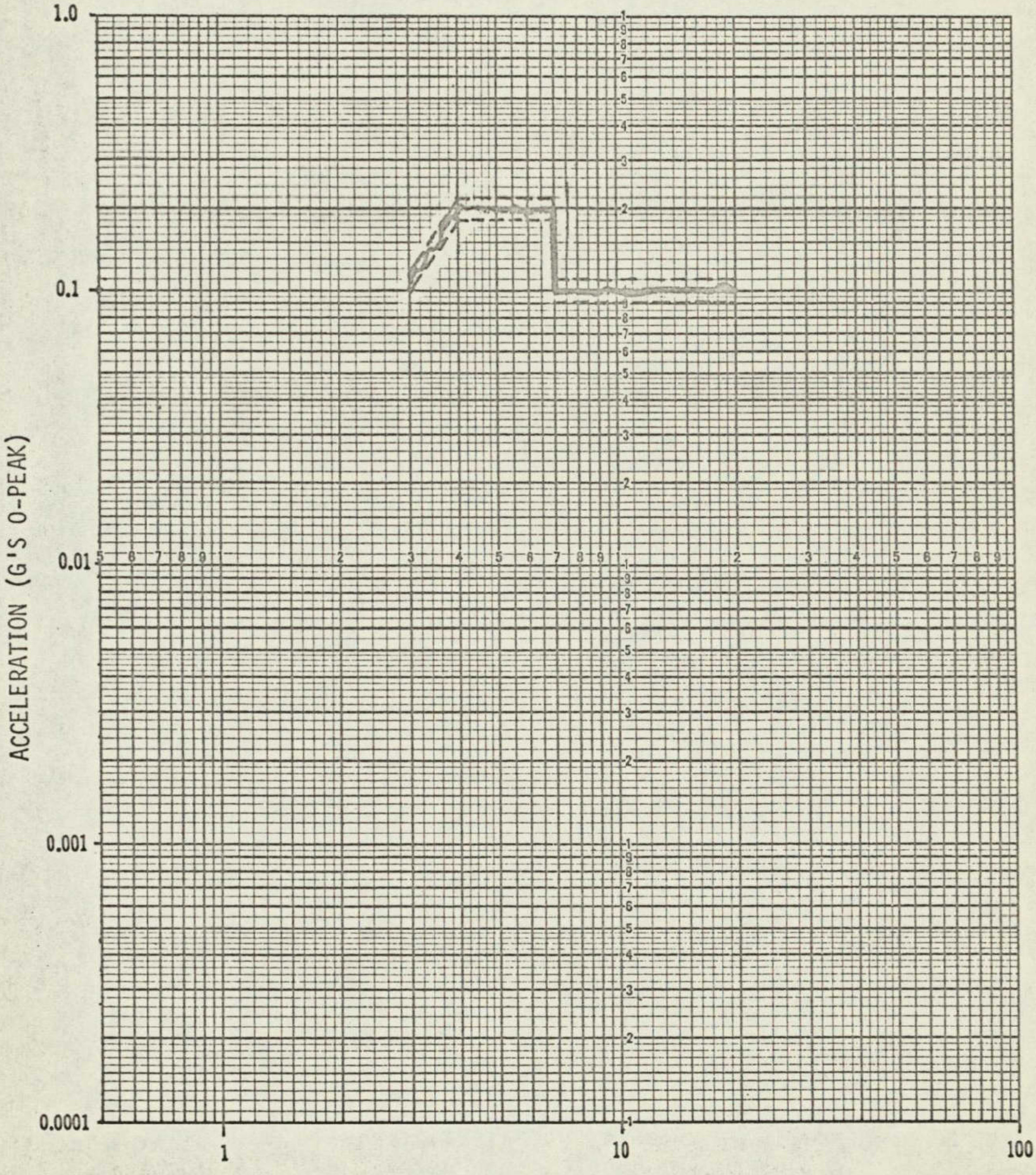


Figure 5-7. Thrust Axis Sinusoidal Vibration

(77 TO 82 SEC)

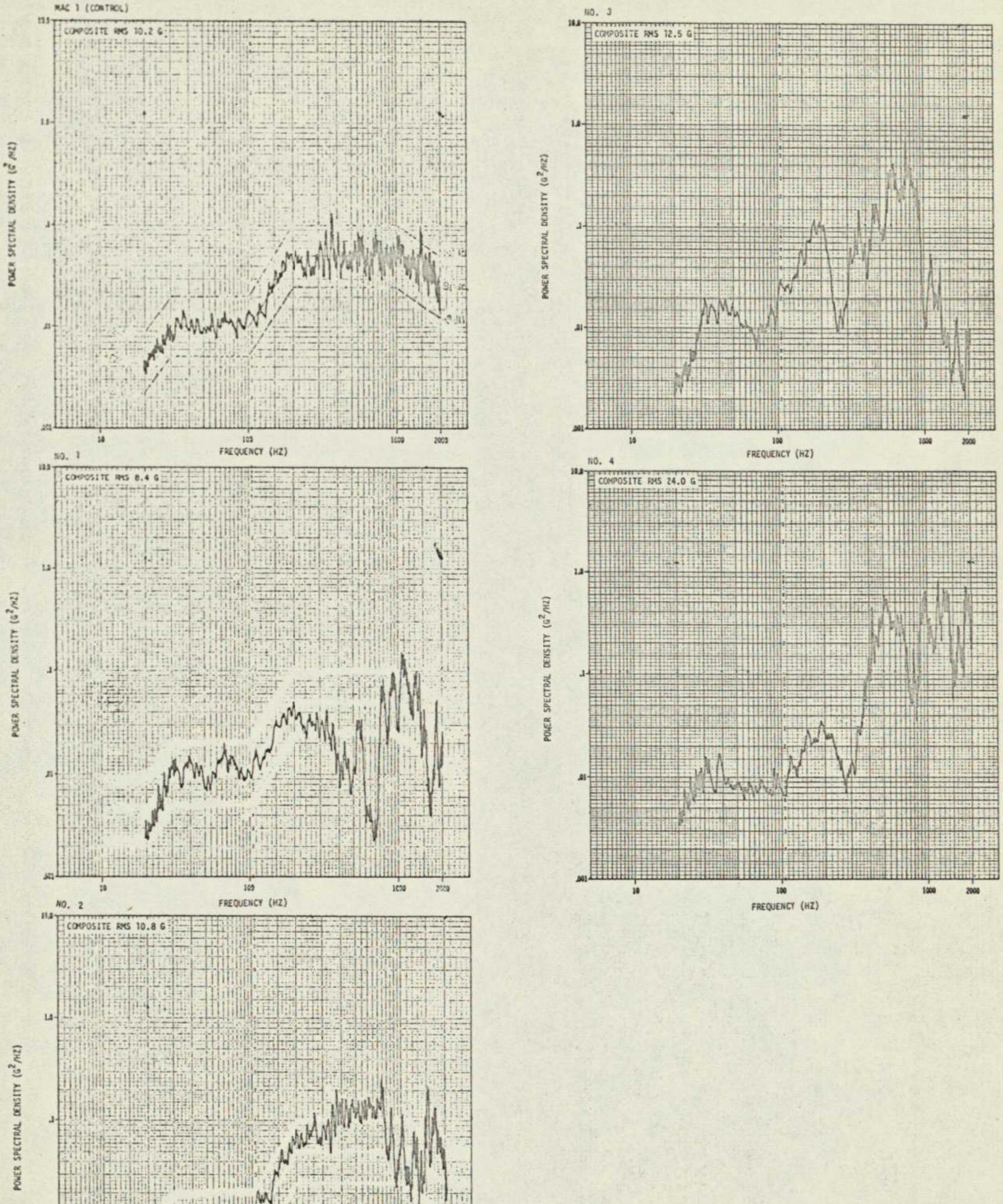


Figure 5-8. Thrust Axis Random Vibration (Sheet 1 of 5)

(77 TO 82 SEC)

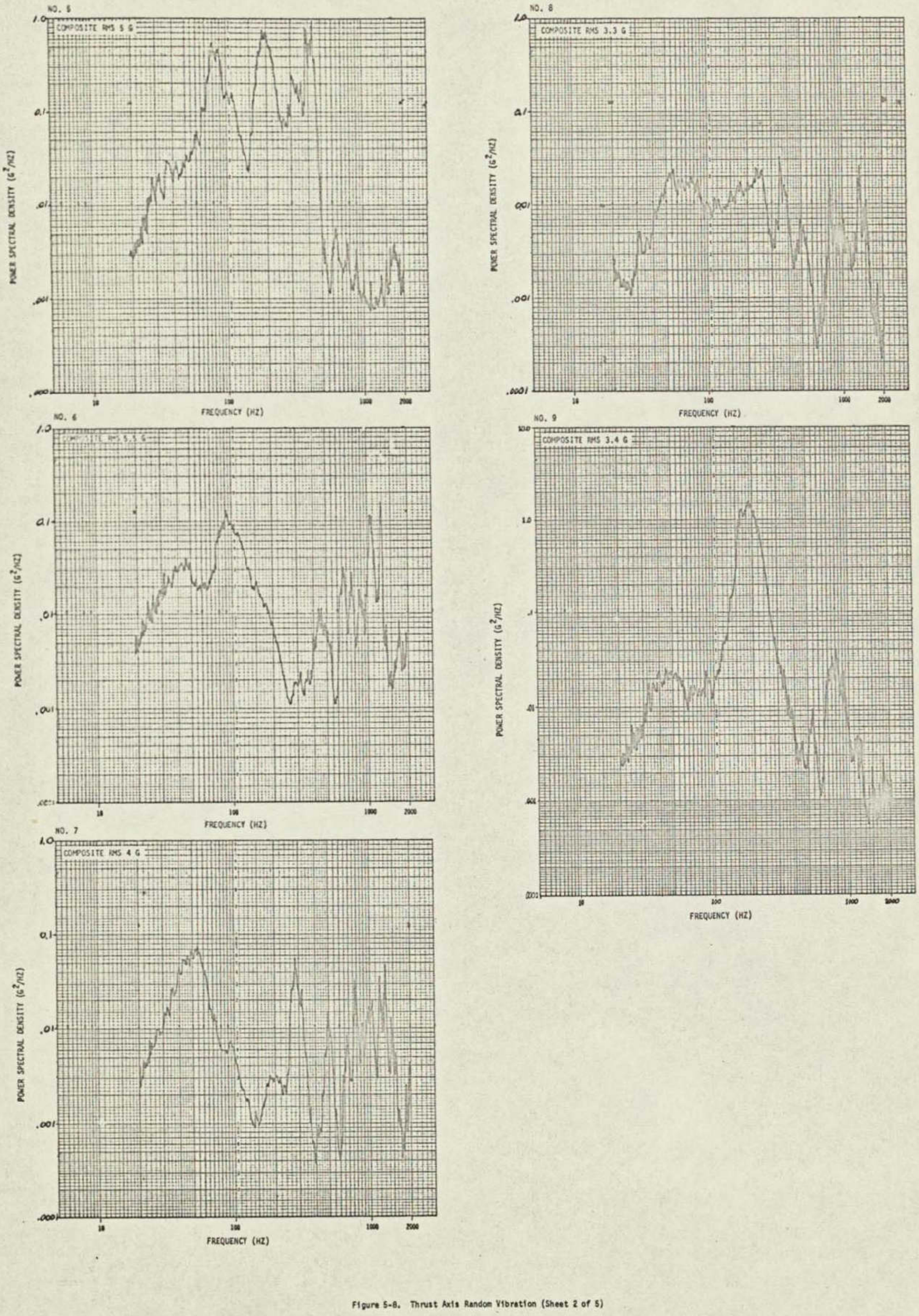


Figure 5-8. Thrust Axis Random Vibration (Sheet 2 of 5)

(77 TO 82 SEC)

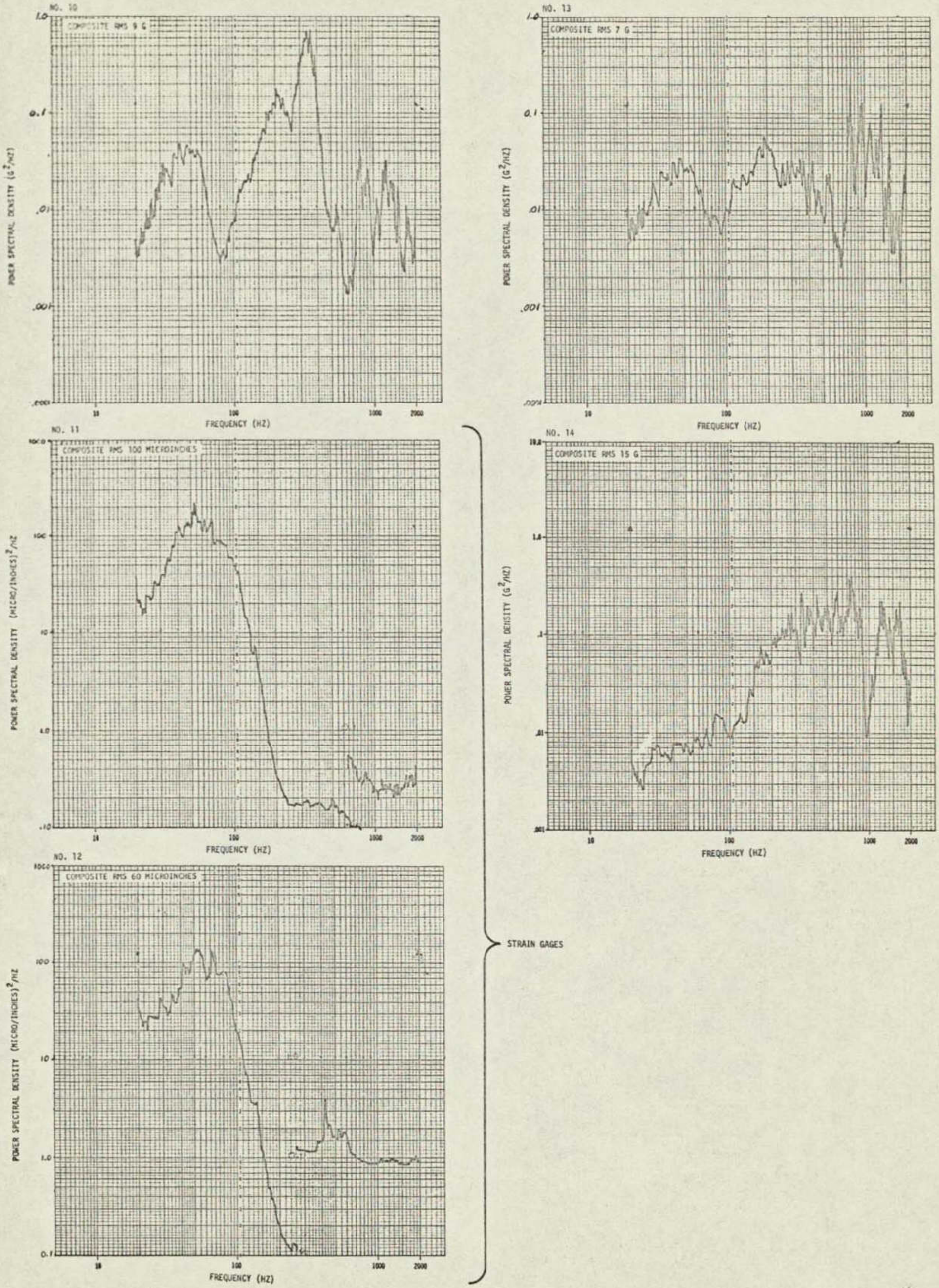


Figure 5-8. Thrust Axis Random Vibration (Sheet 3 of 5)

(77 TO 82 SEC)

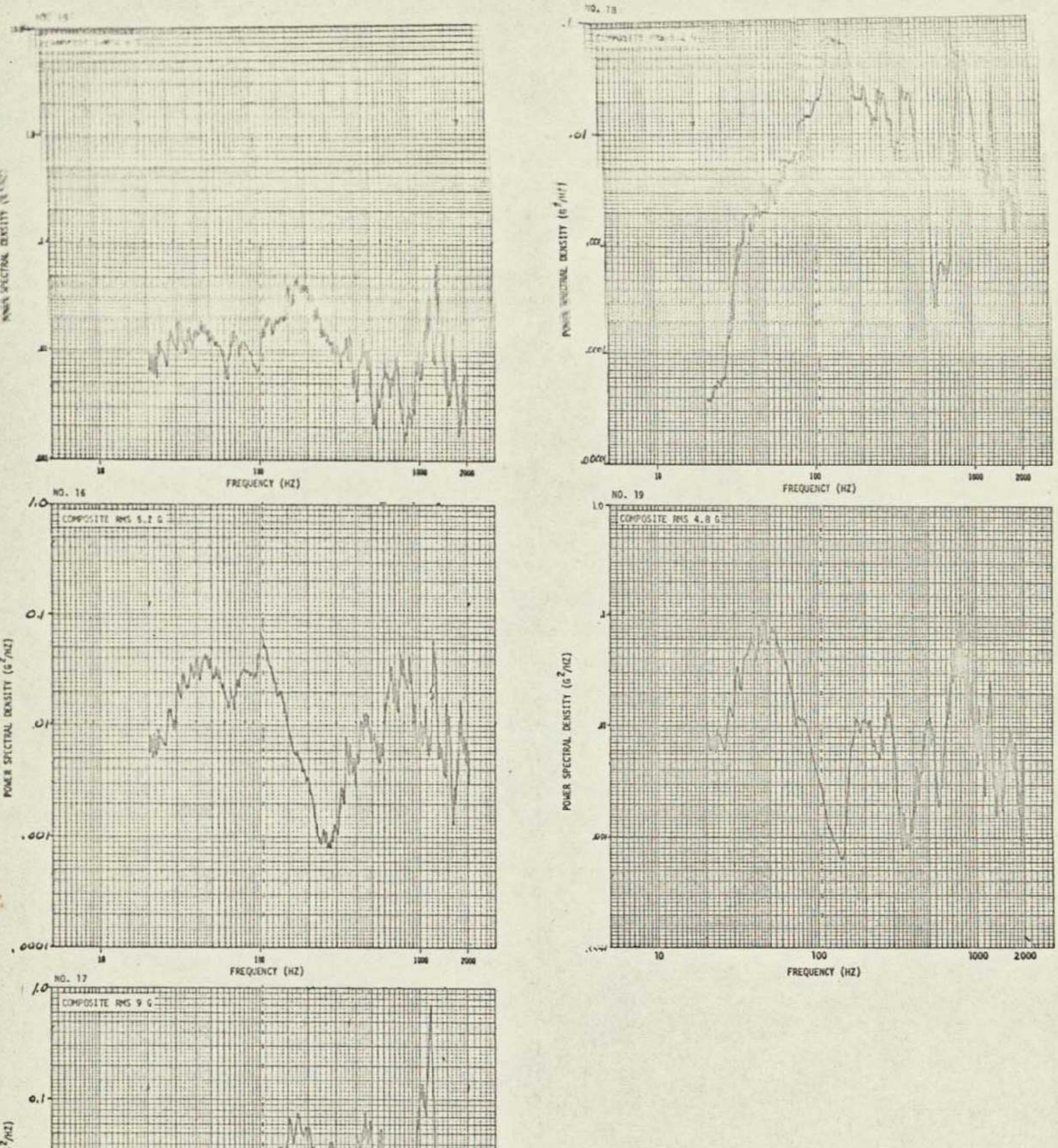


Figure 5-8. Thrust Axis Random Vibration (Sheet 4 of 5)

(77 TO 82 SEC)

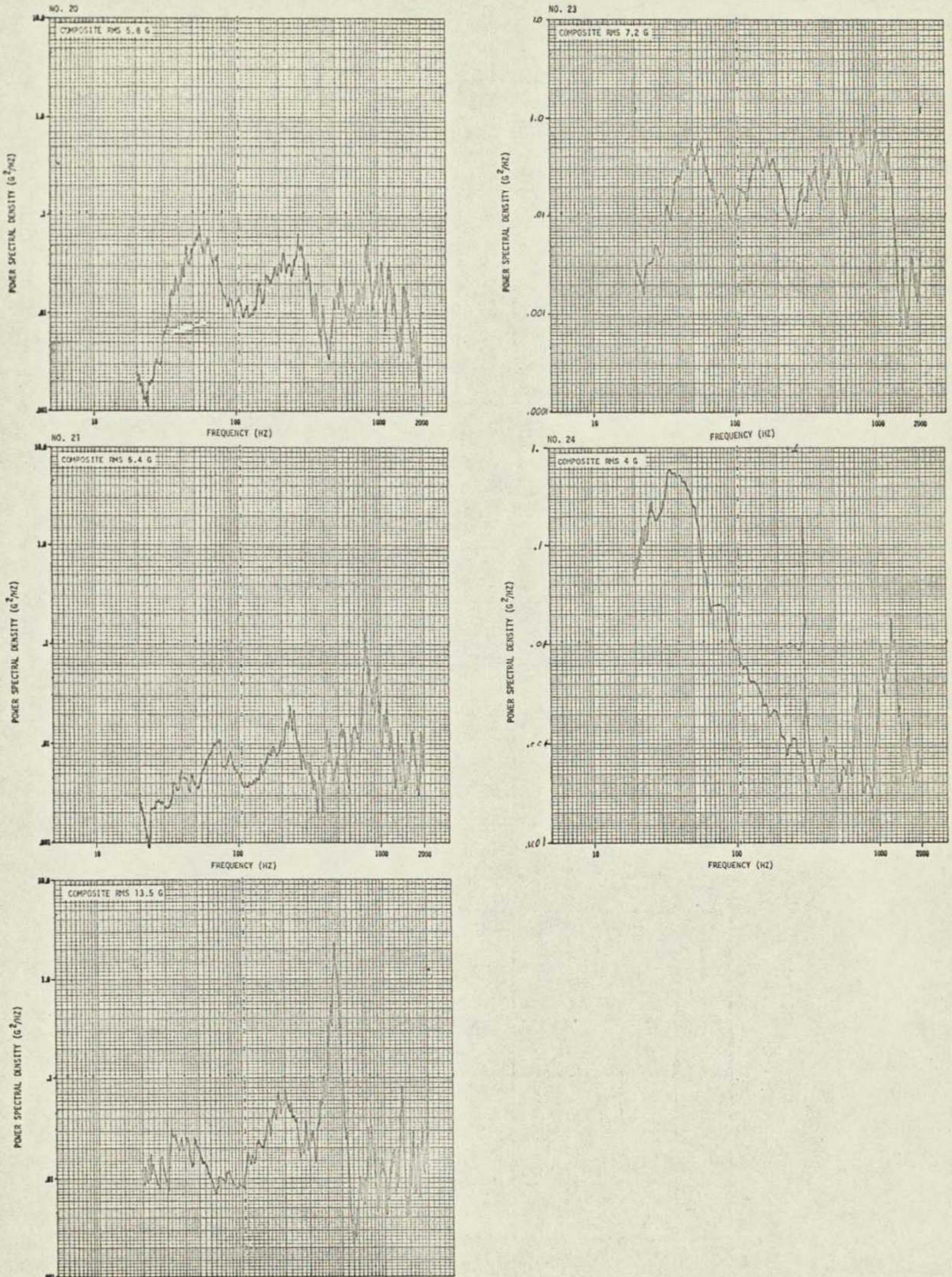


Figure 5-8. Thrust Axis Random Vibration (Sheet 5 of 5)

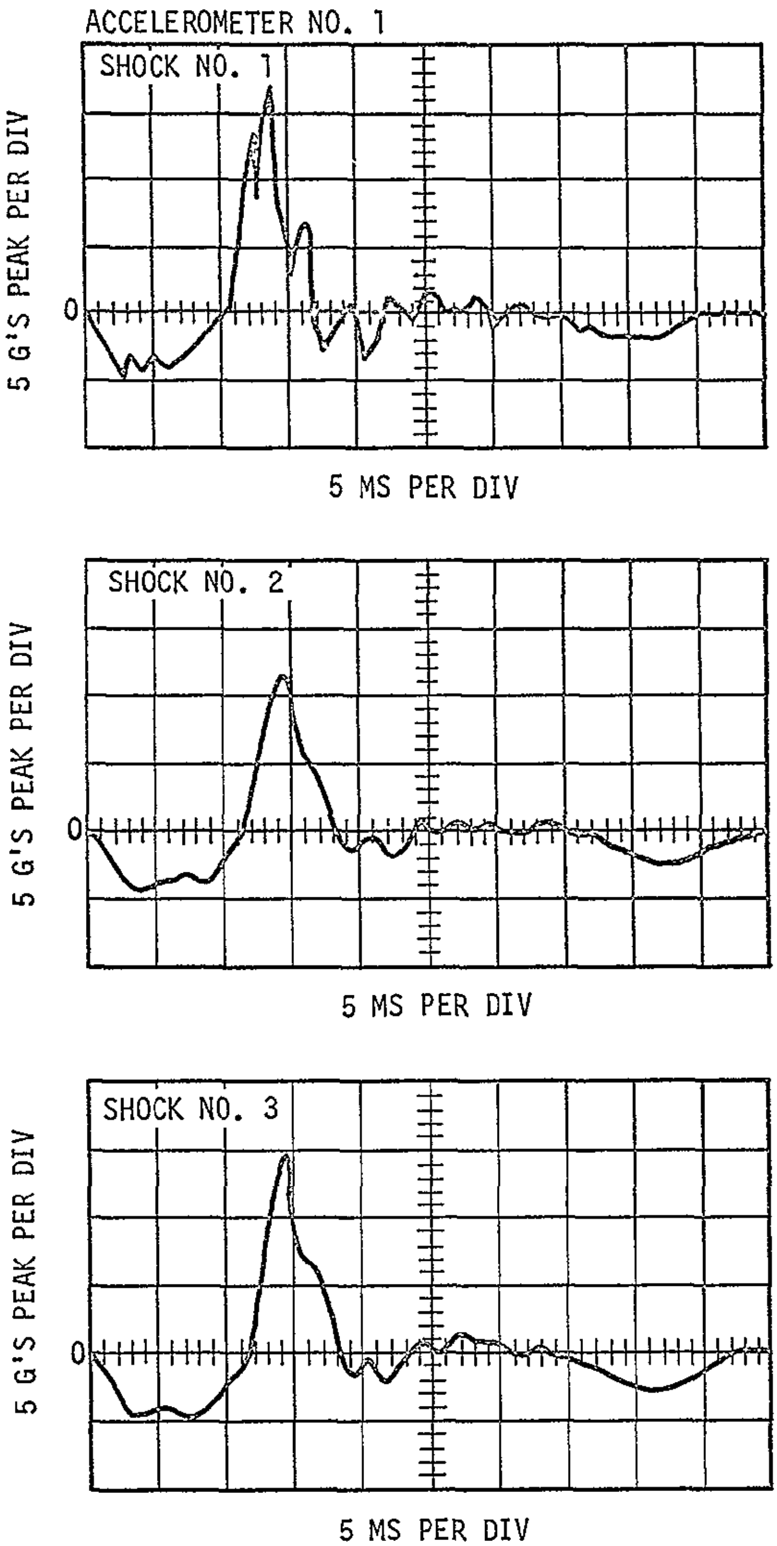


Figure 5-9. Thrust Axis Shock Input

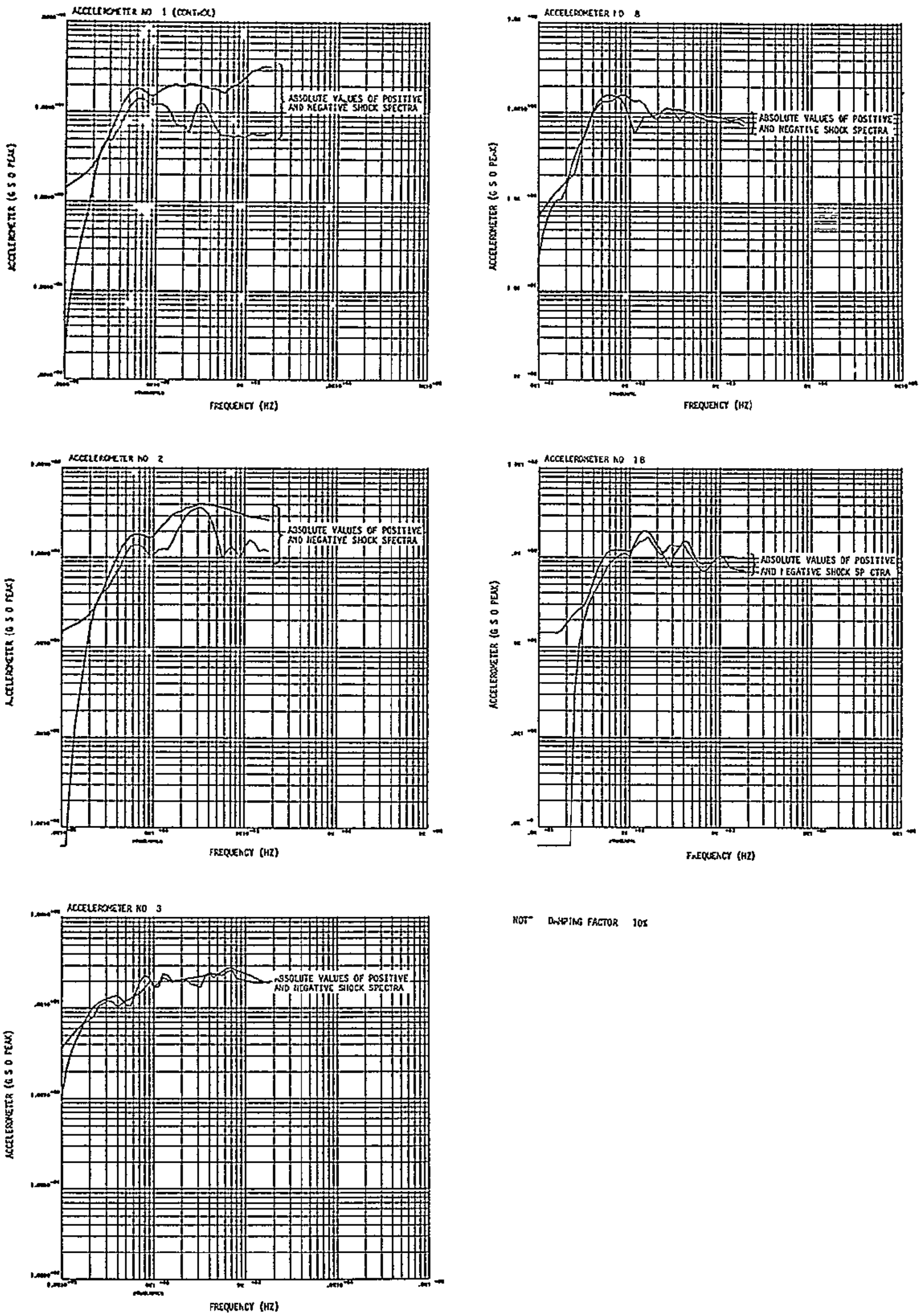


Figure 5 10 Thrust Axis Shock Spectrum

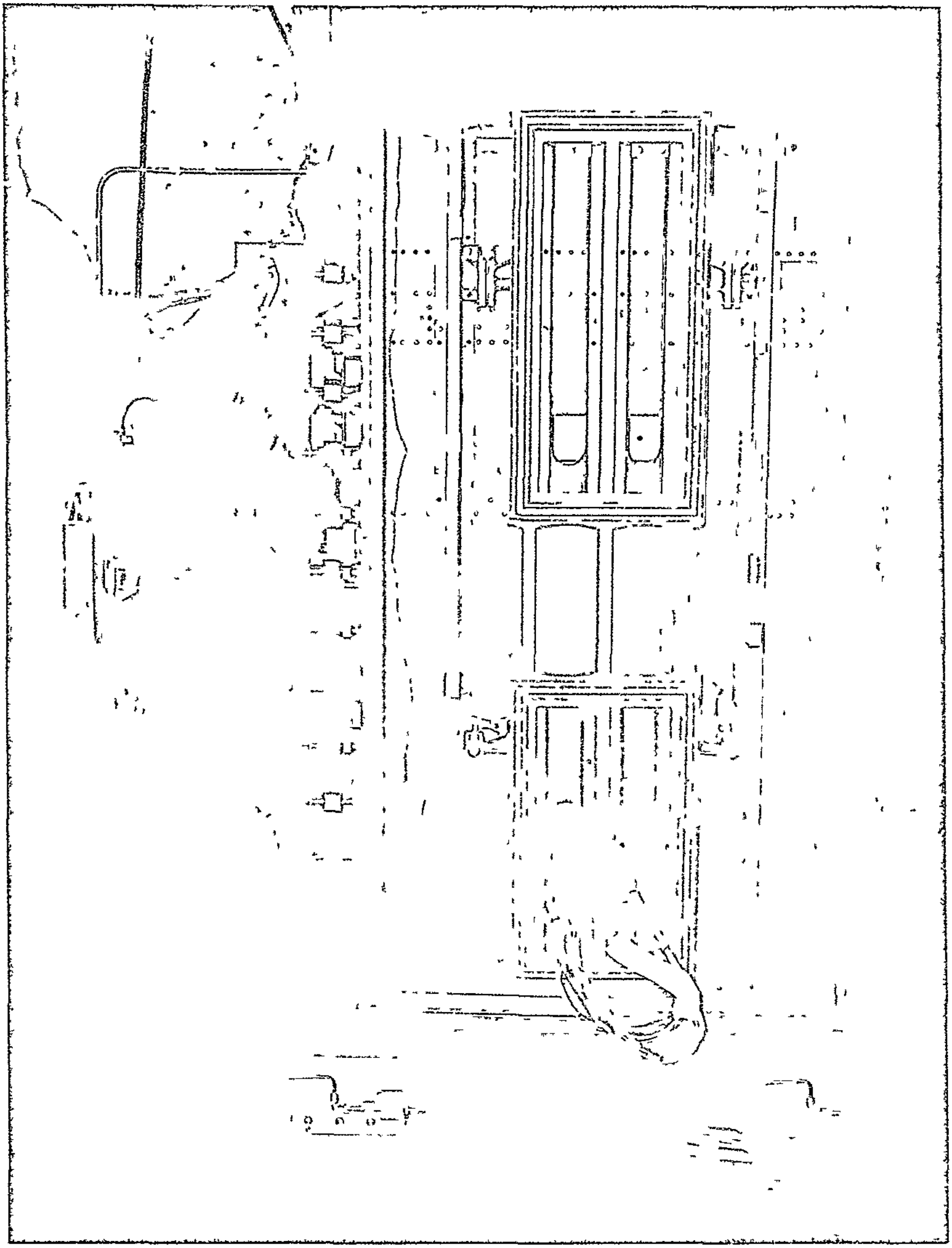


Figure 5-11. Tangential Axis Test Setup

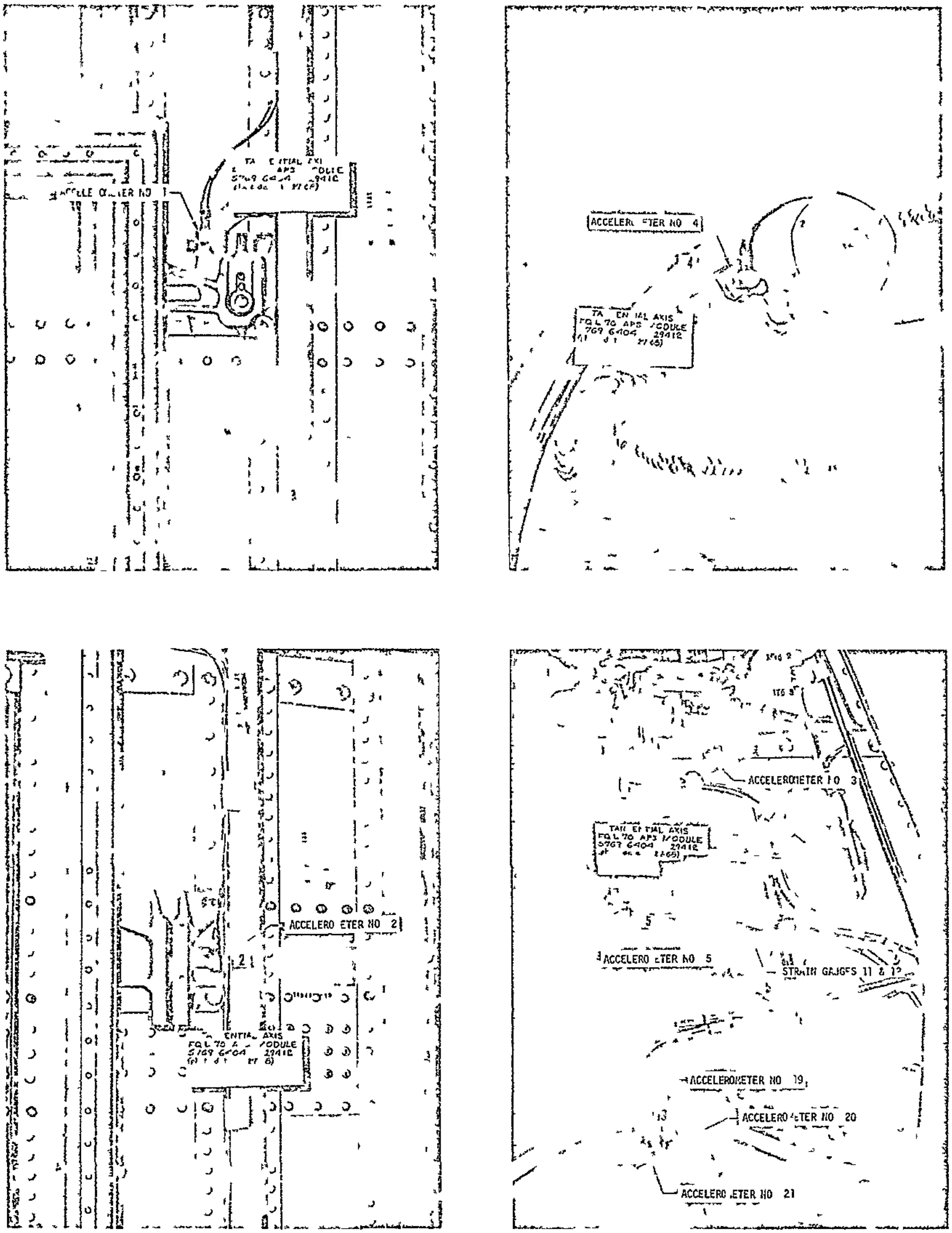


Figure 5 12 Tangential Axis Accelerometer Locations (Sheet 1 of 4)

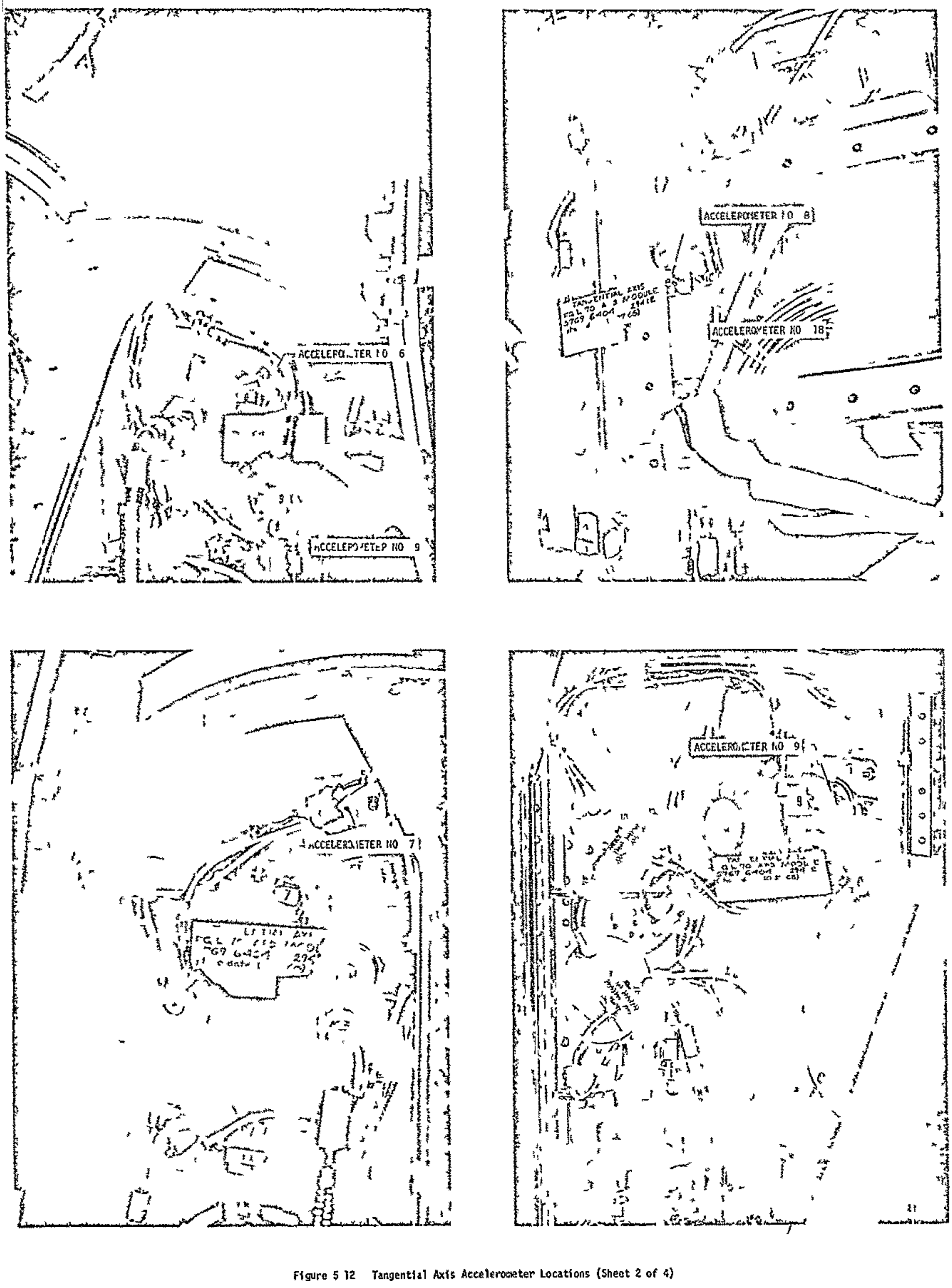


Figure 5 12 Tangential Axis Accelerometer Locations (Sheet 2 of 4)

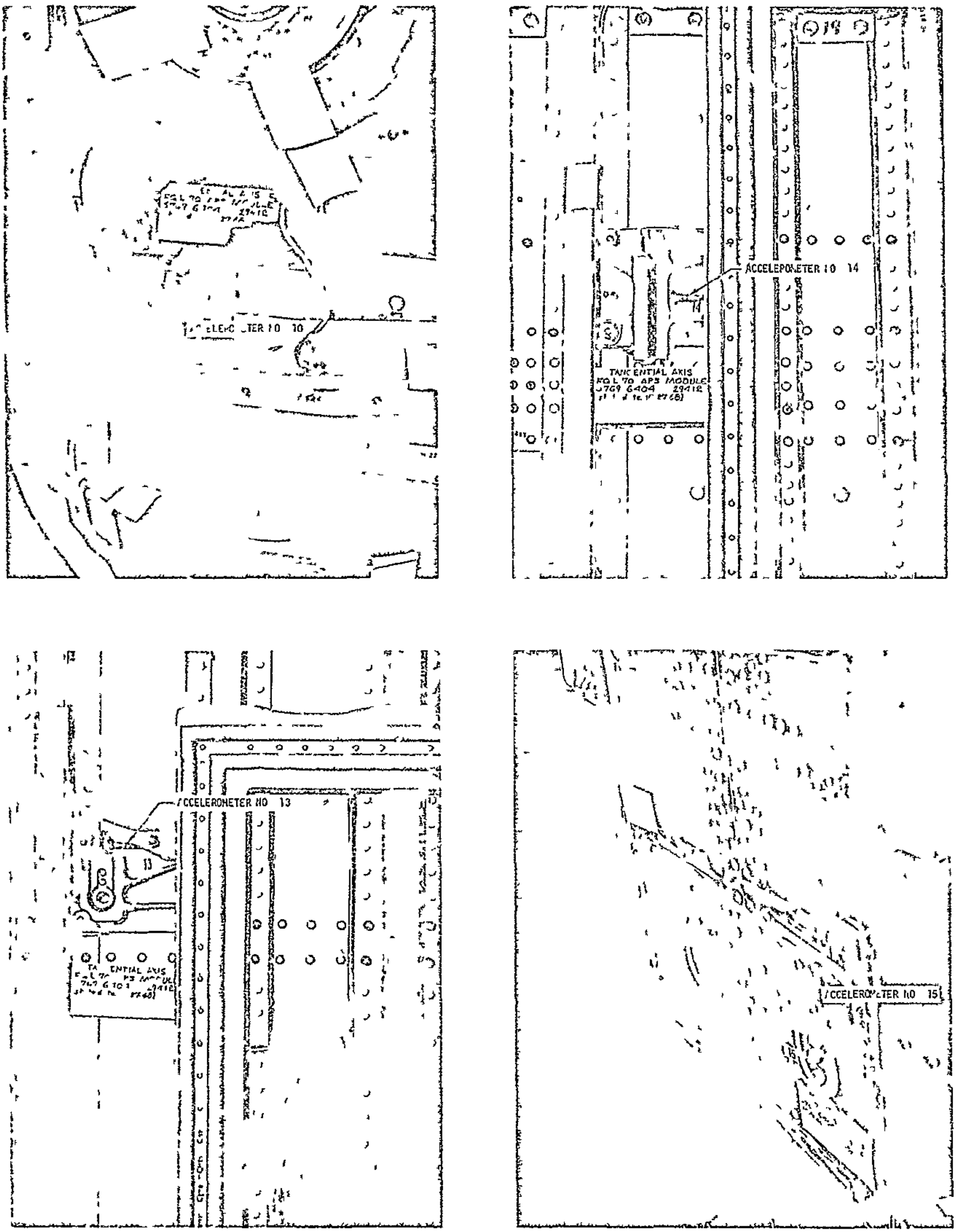


Figure 5 12 Tangential Axis Accelerometer Locations (Sheet 3 of 4)

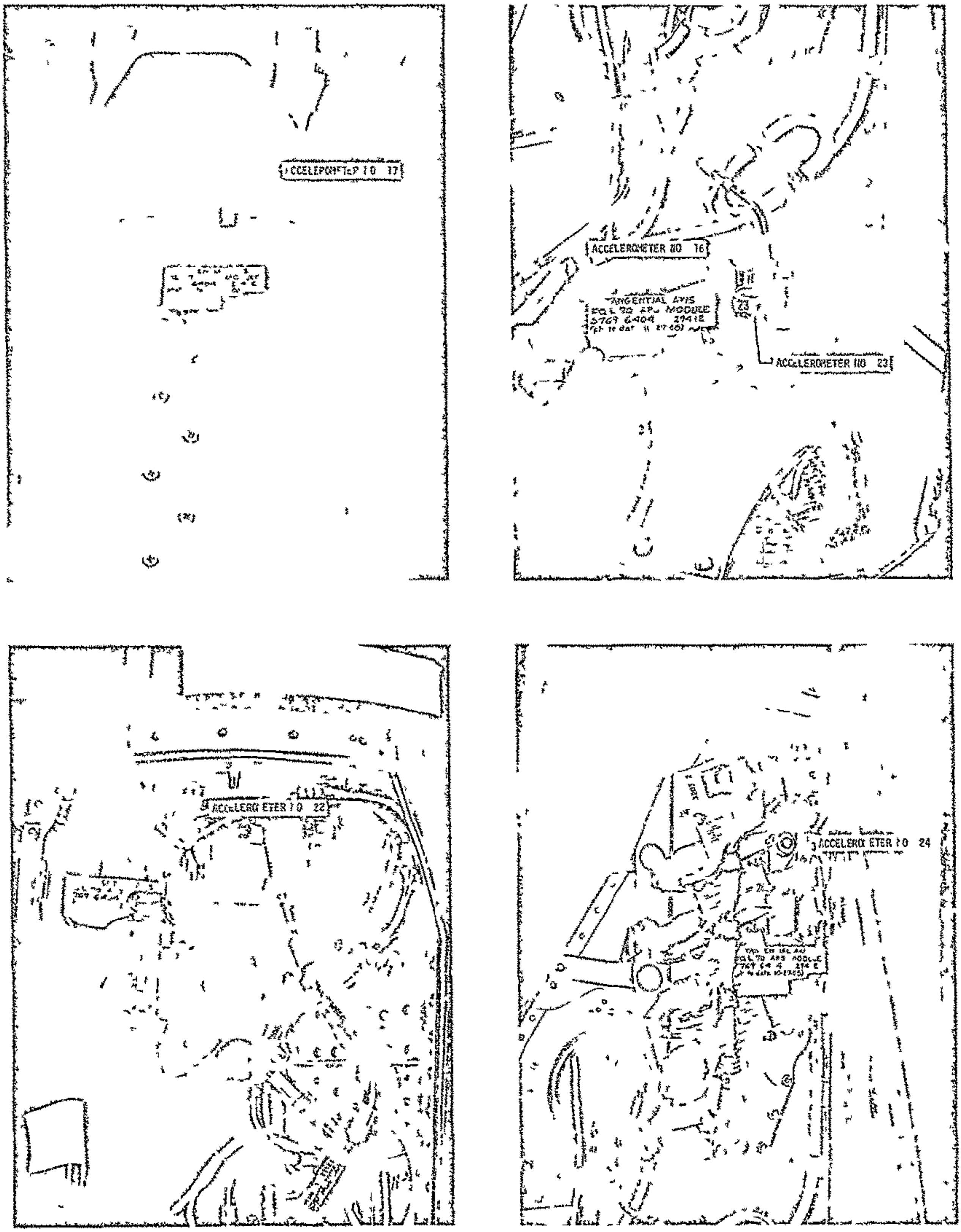


Figure 5-12 Tangential Axis Accelerometer Locations (Sheet 4 of 4)

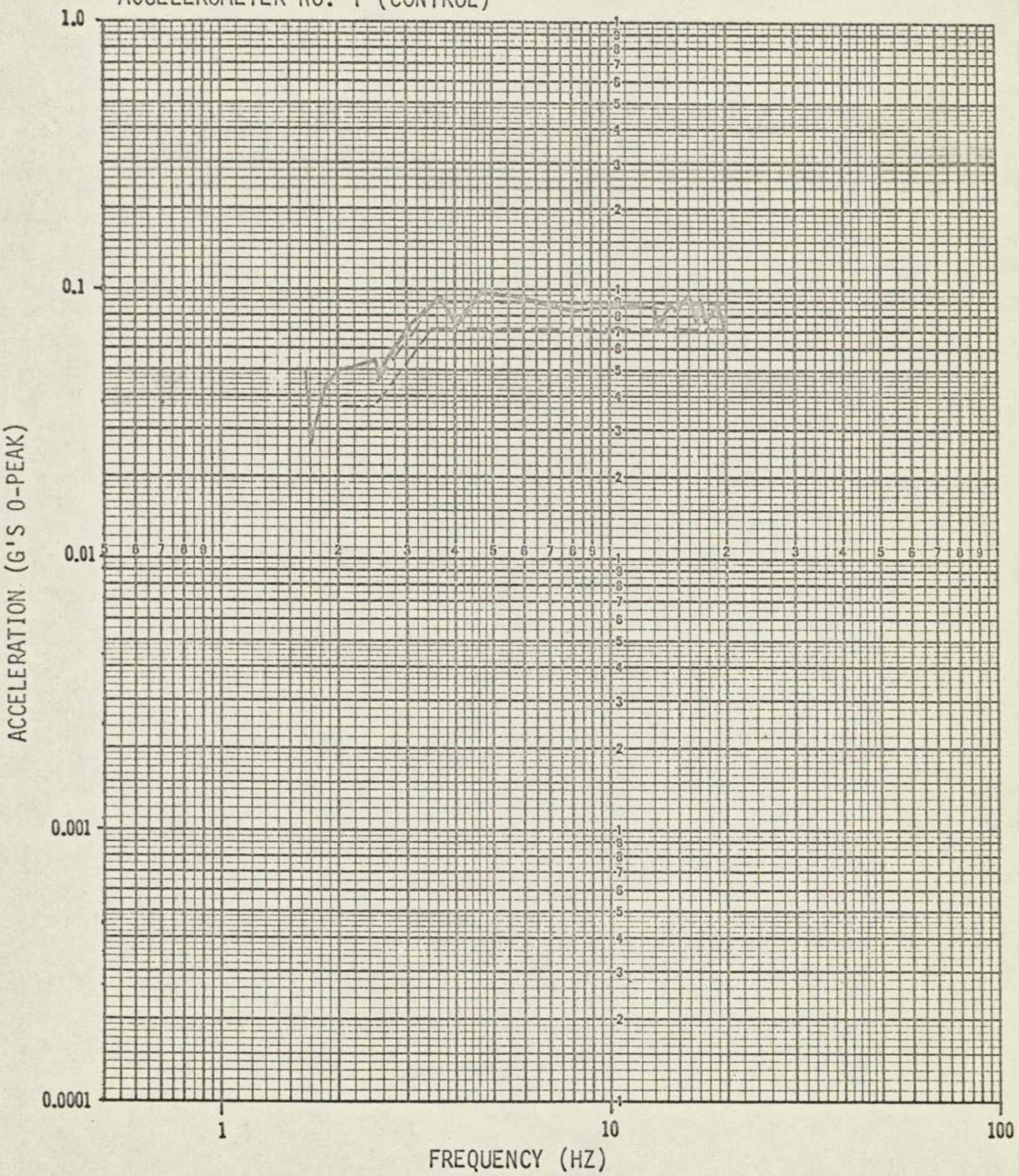


Figure 5-13. Tangential Axis Sinusoidal Vibration

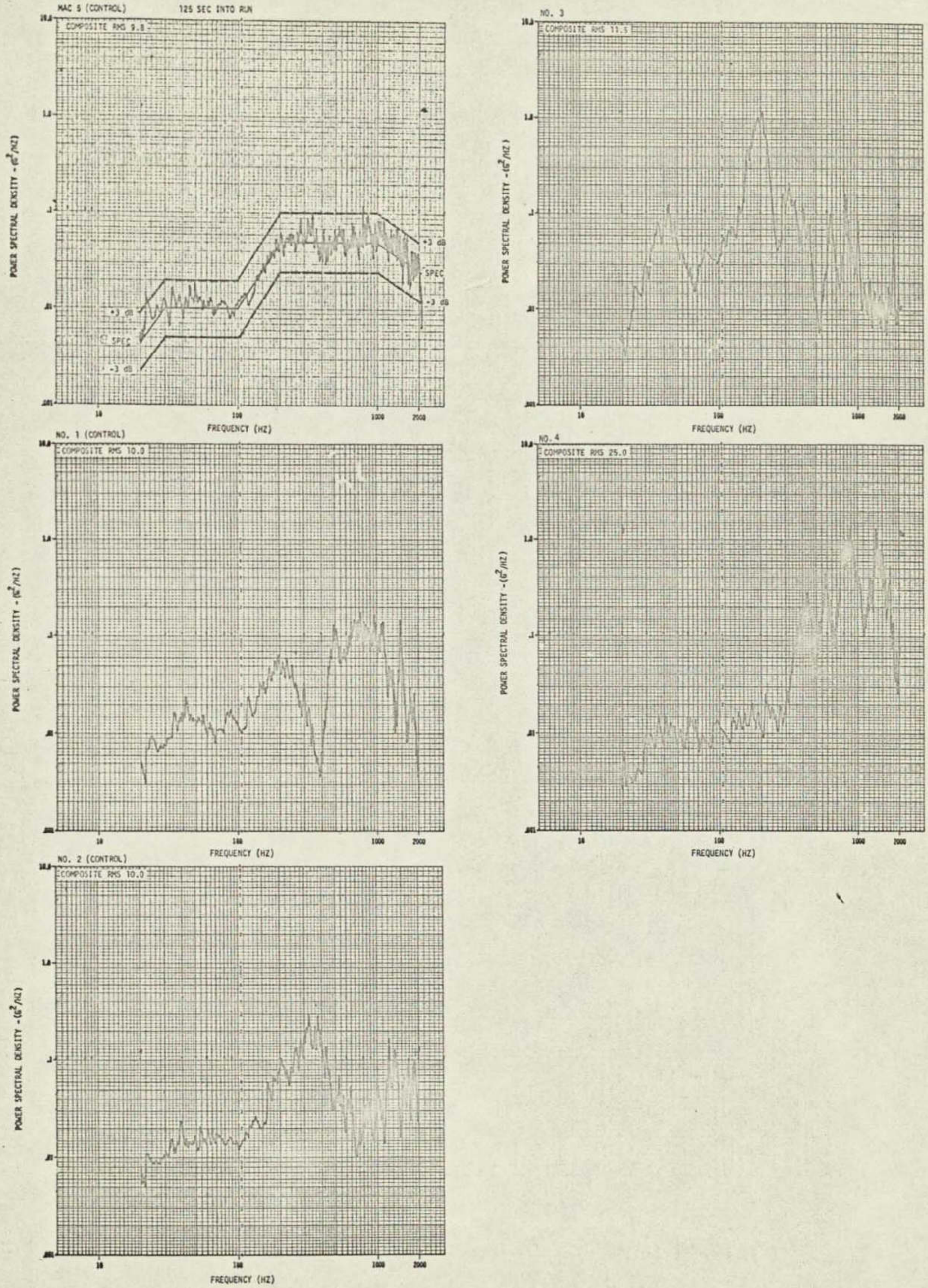


Figure 5-14. Tangential Axis Random Vibration (Sheet 1 of 5)

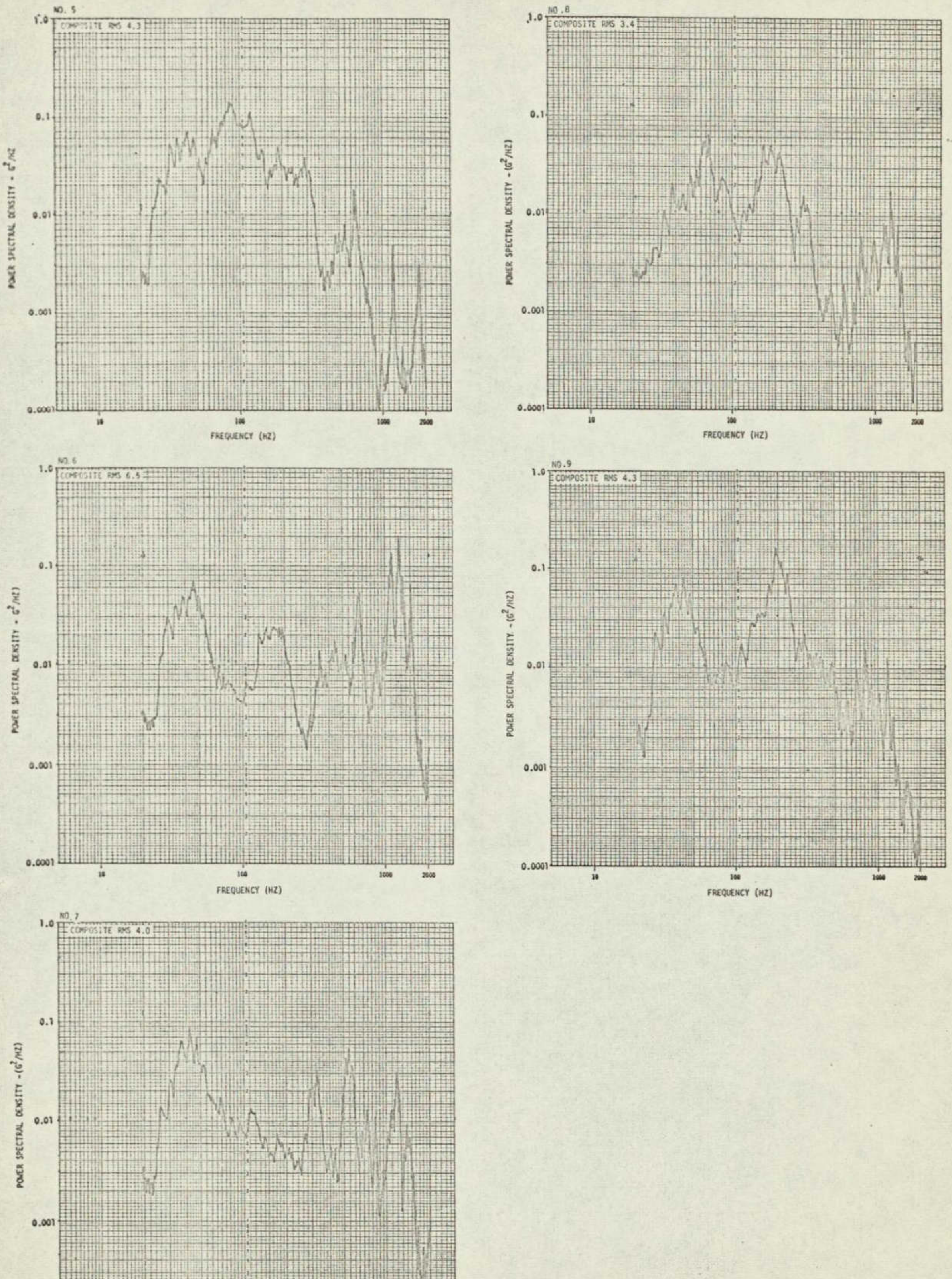


Figure 5-14. Tangential Axis Random Vibration (Sheet 2 of 5)

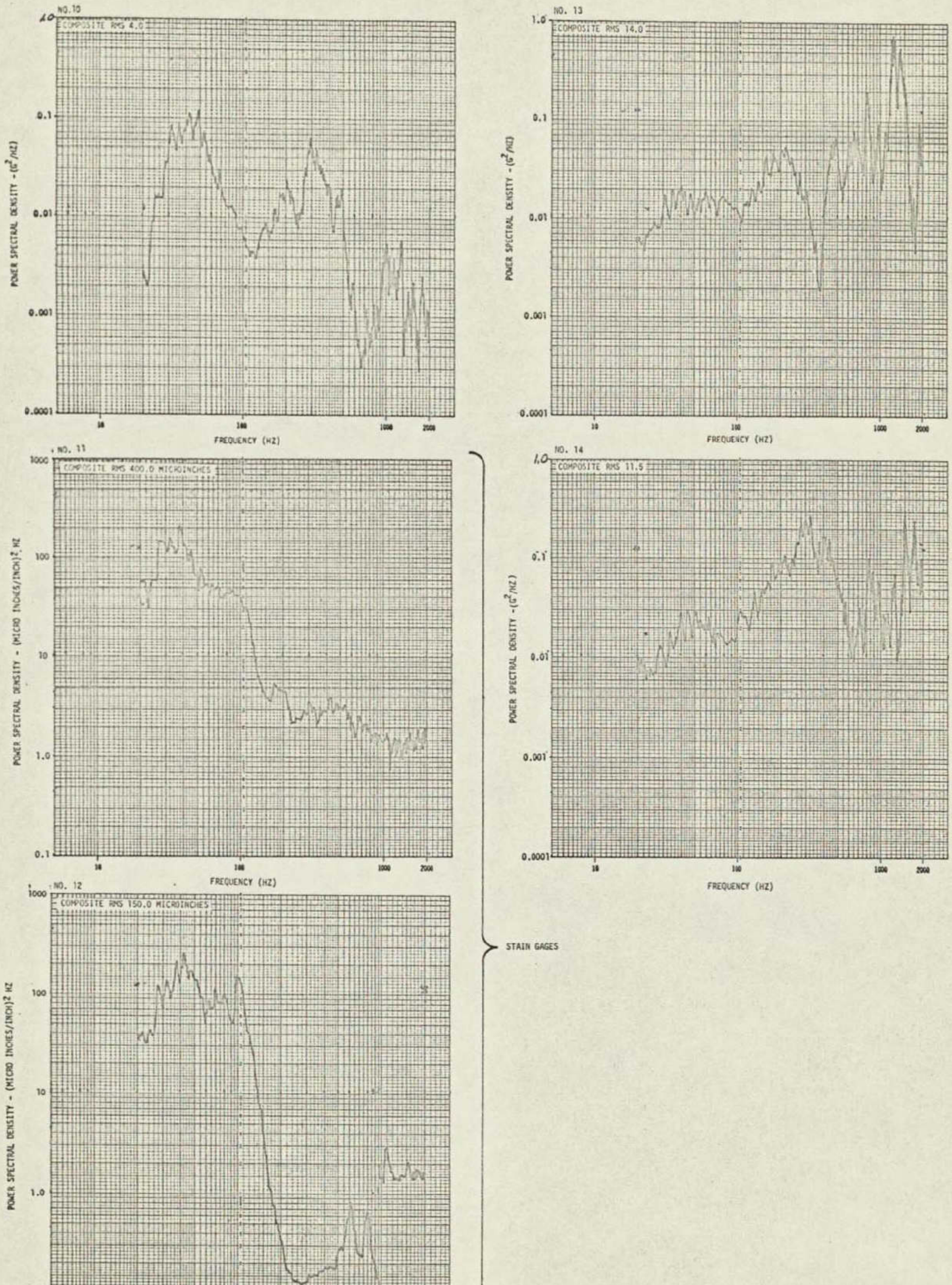
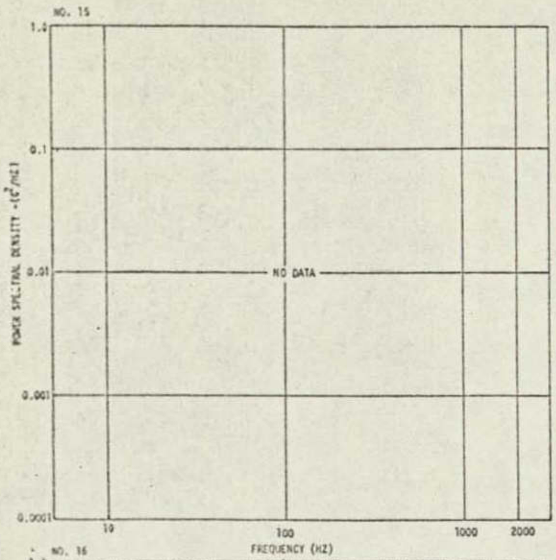
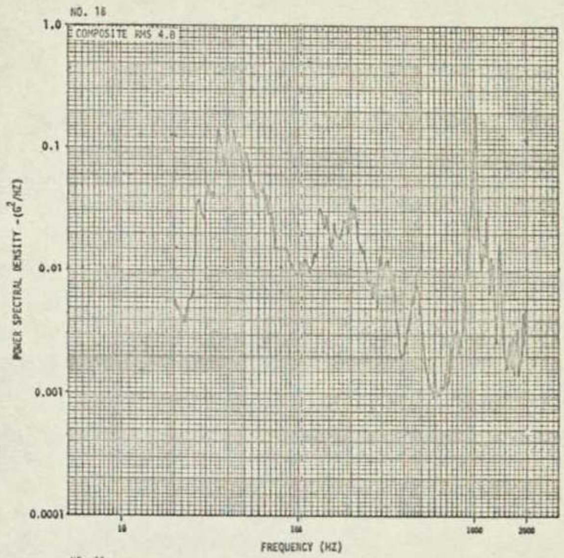
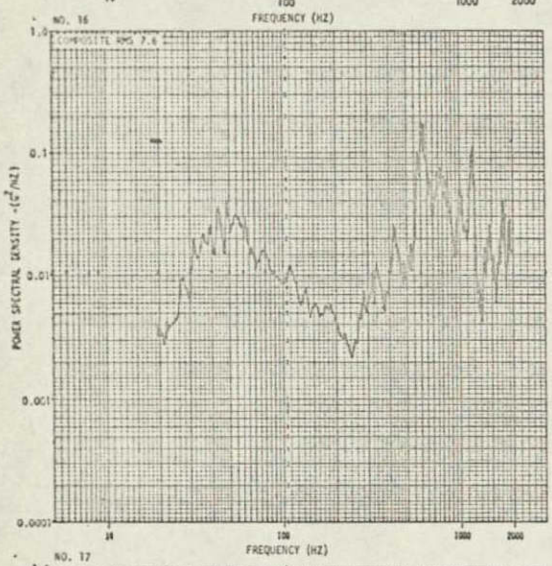
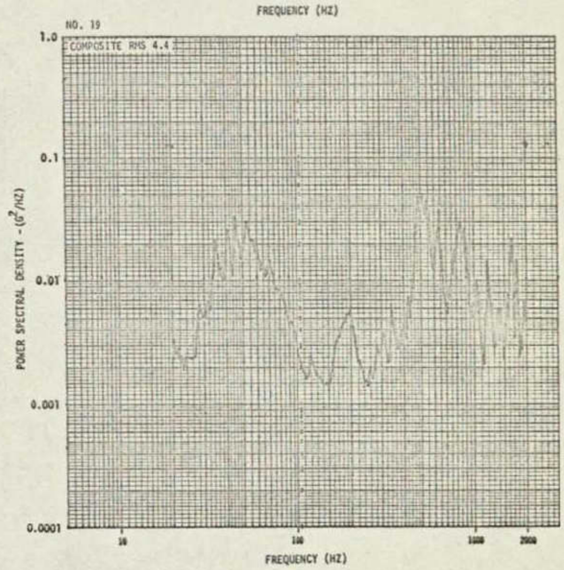


Figure 5-14. Tangential Axis Random Vibration (Sheet 3 of 5)









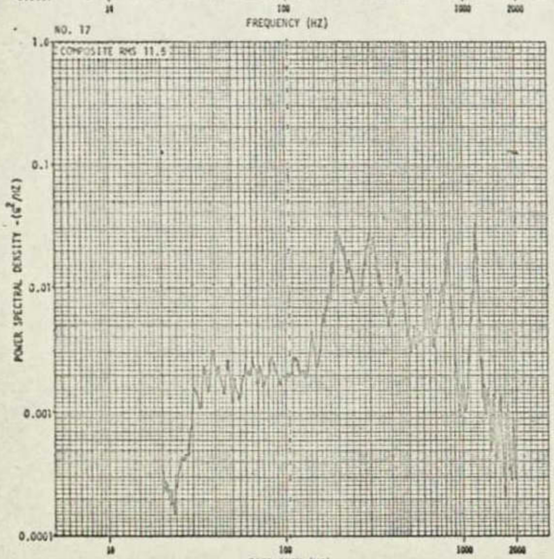


Figure 5-14. Tangential Axis Random Vibration (Sheet 4 of 5)

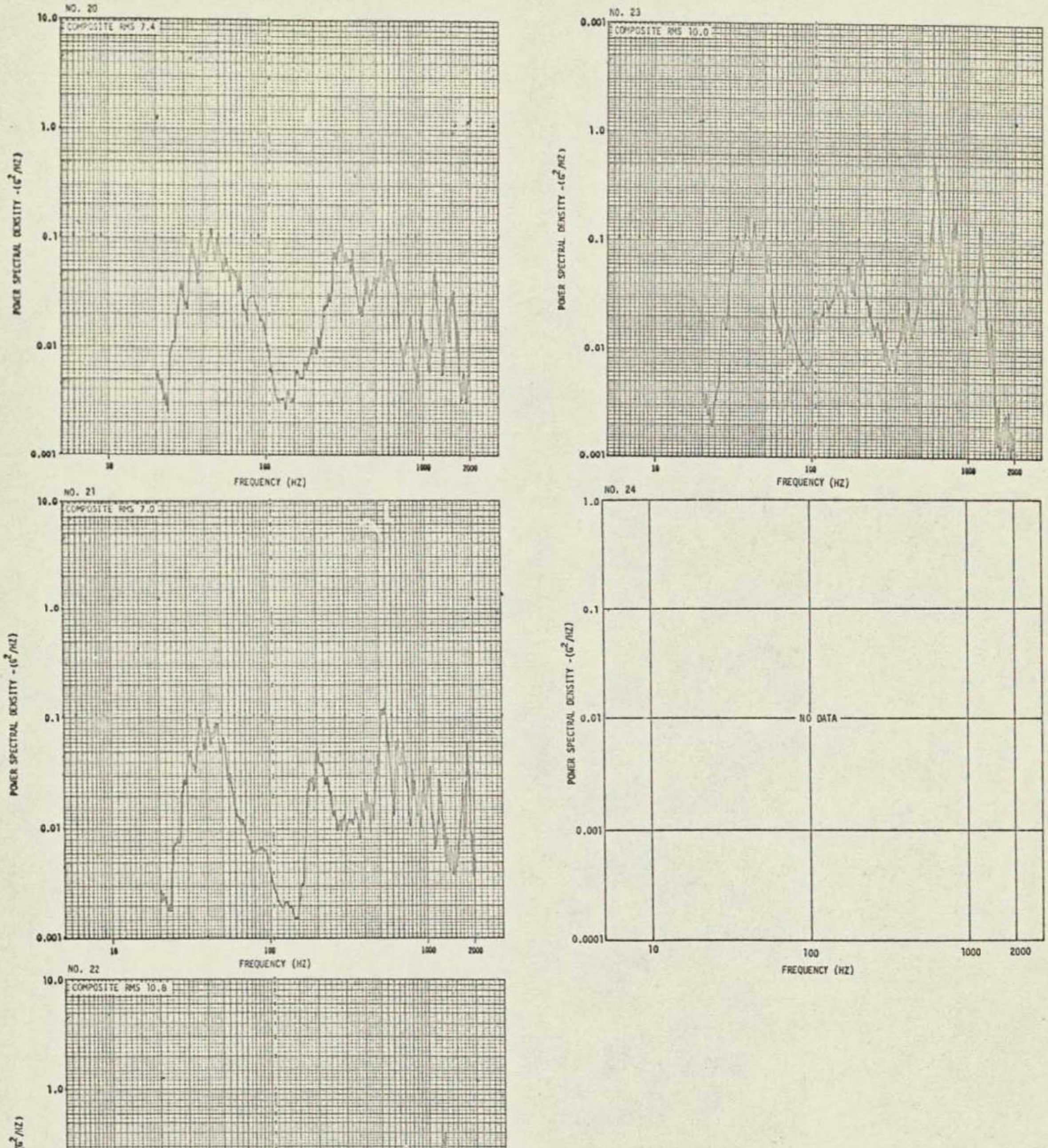


Figure 5-14. Tangential Axis Random Vibration (Sheet 5 of 5)

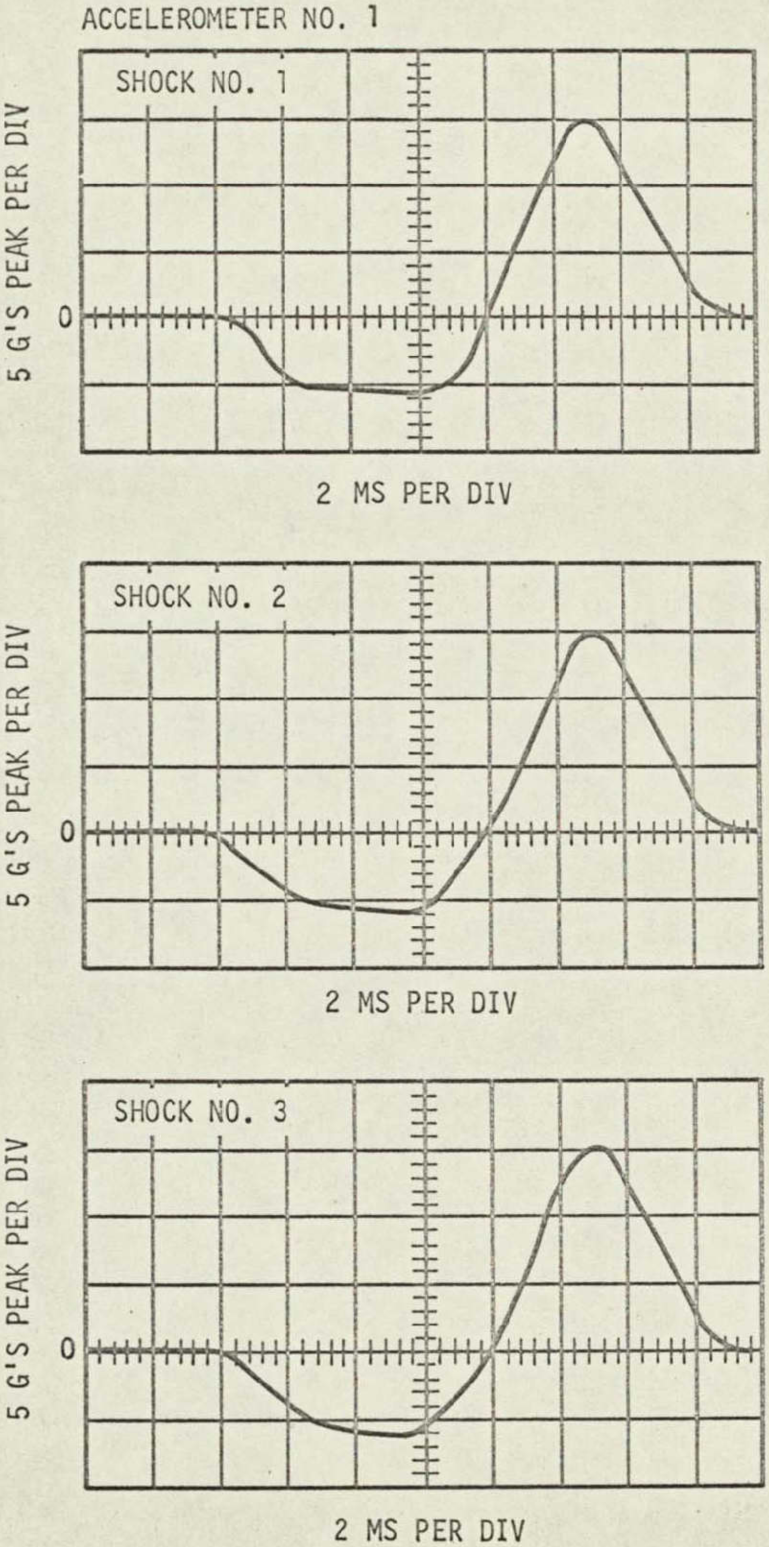
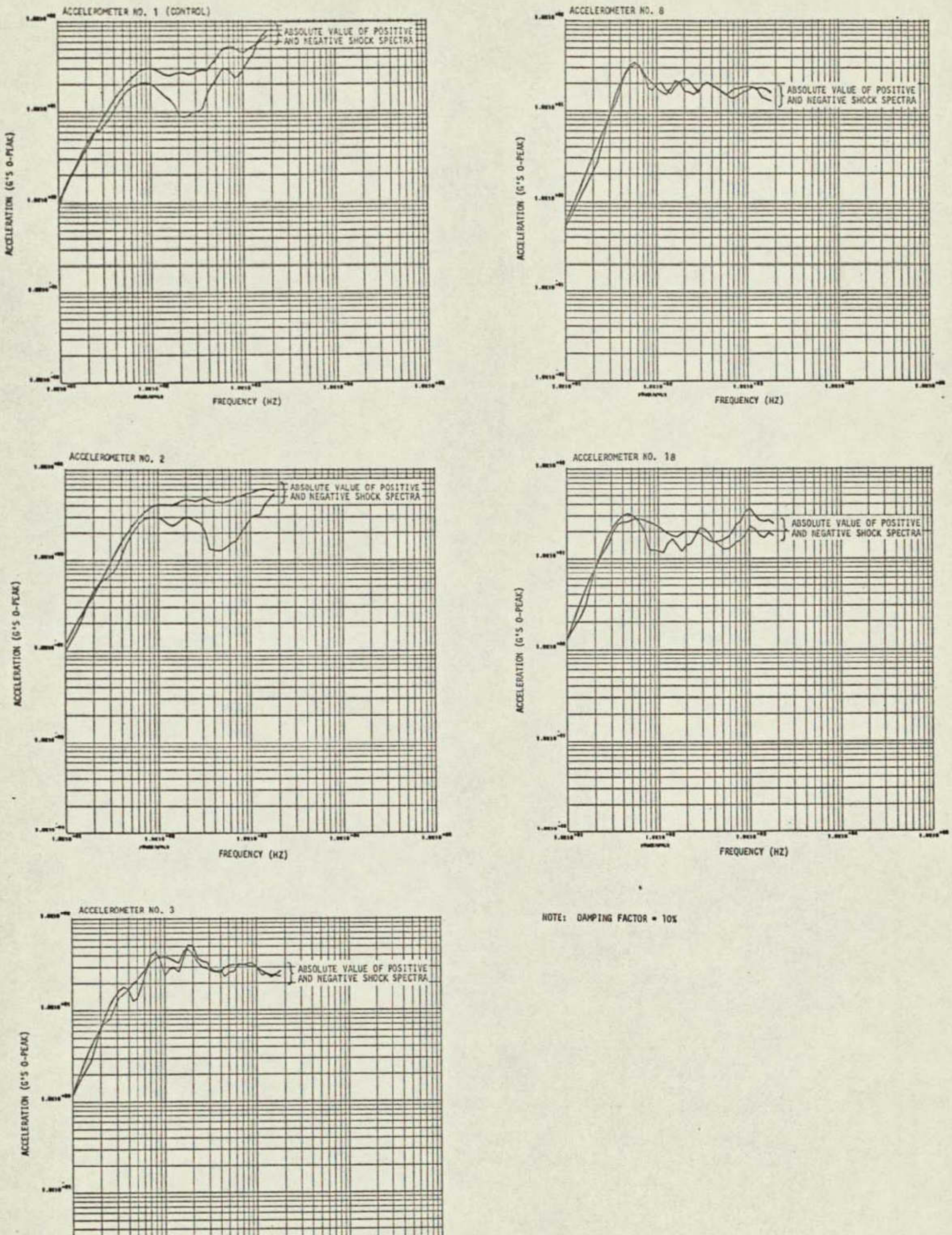


Figure 5-15. Tangential Axis Shock Input



NOTE: DAMPING FACTOR = 10%

Figure 5-16. Tangential Axis Shock Spectrum

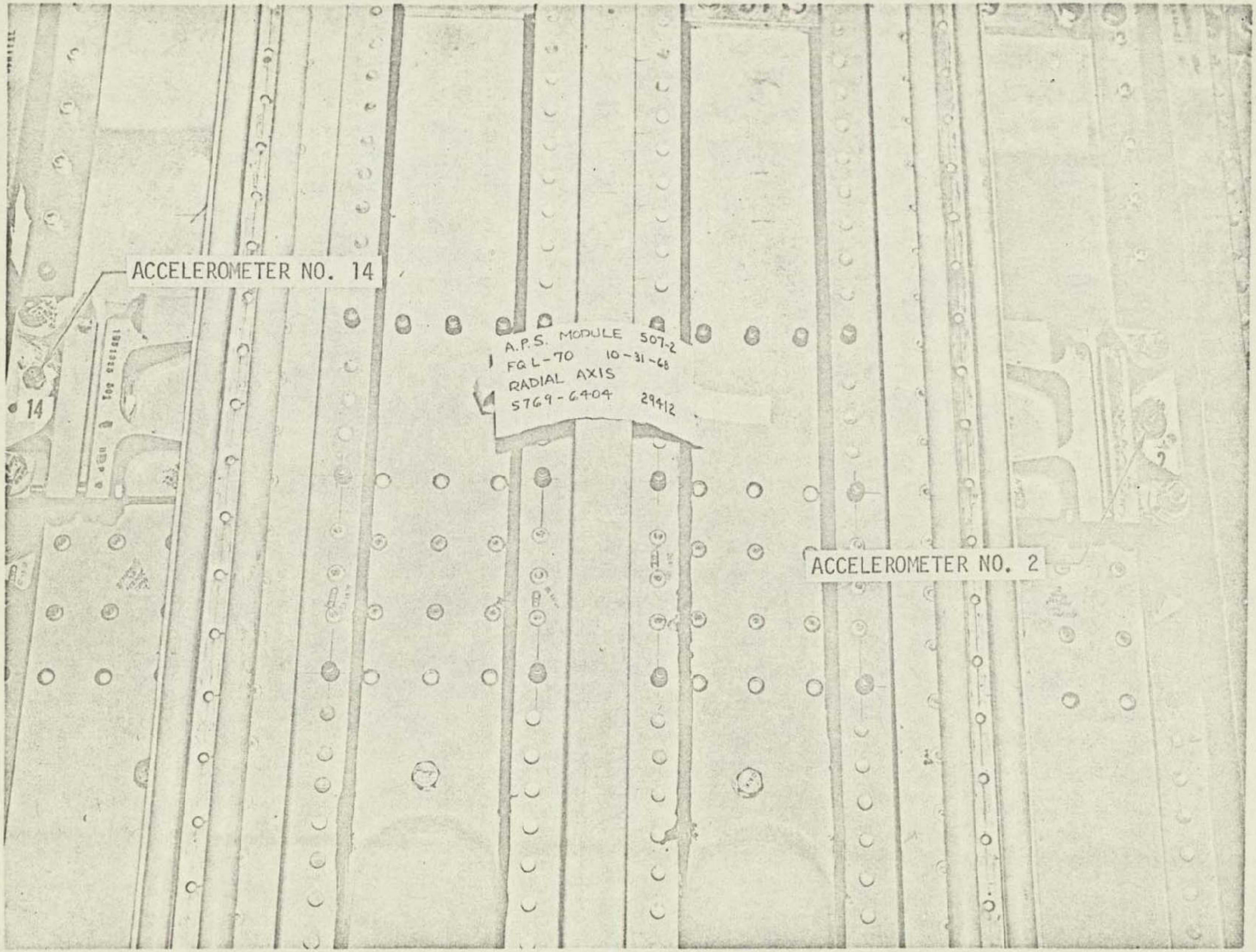


Figure 5-17. Radial Axis Accelerometer Locations (Sheet 1 of 4)

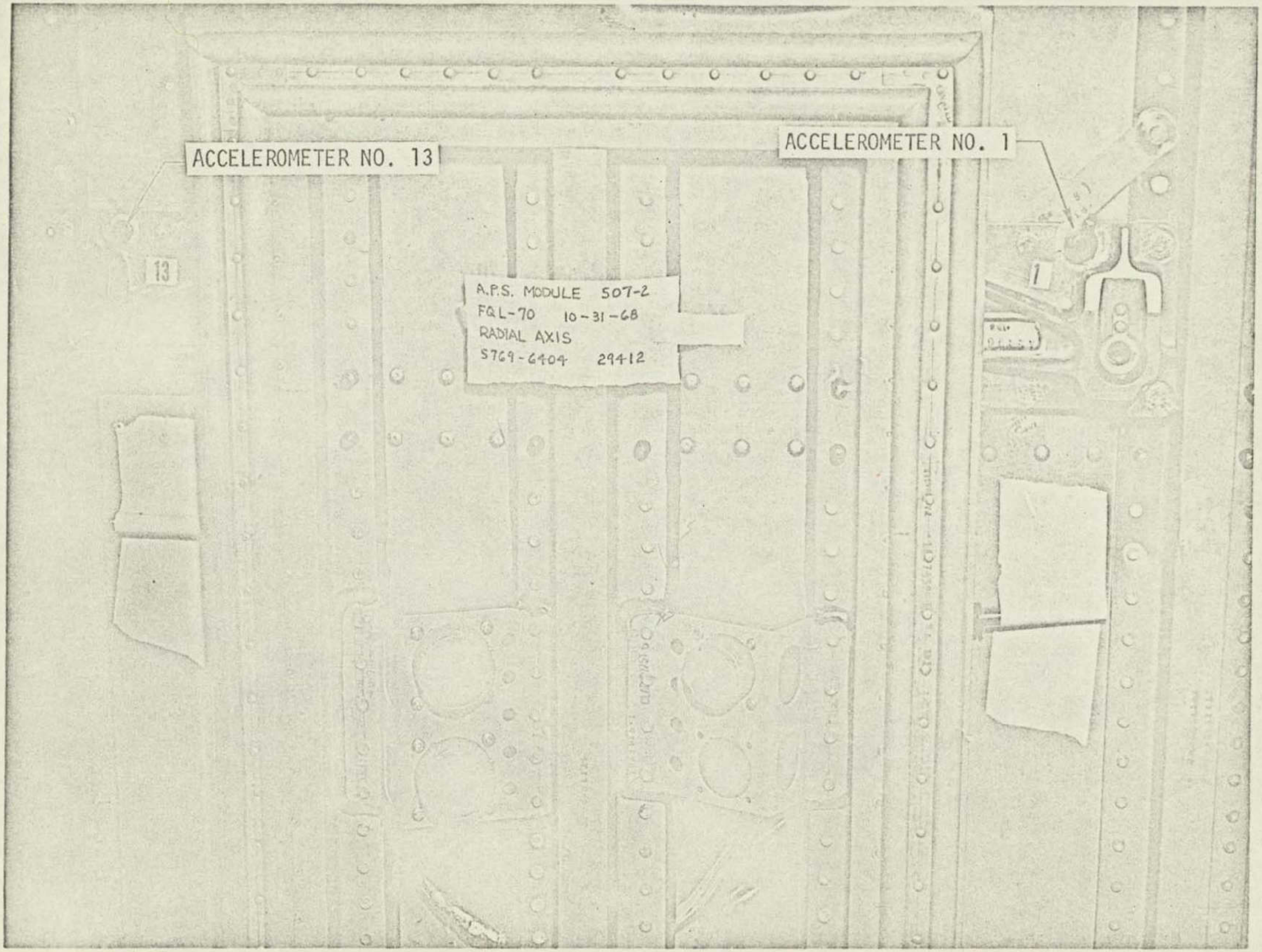


Figure 5-17. Radial Axis Accelerometer Locations (Sheet 2 of 4)

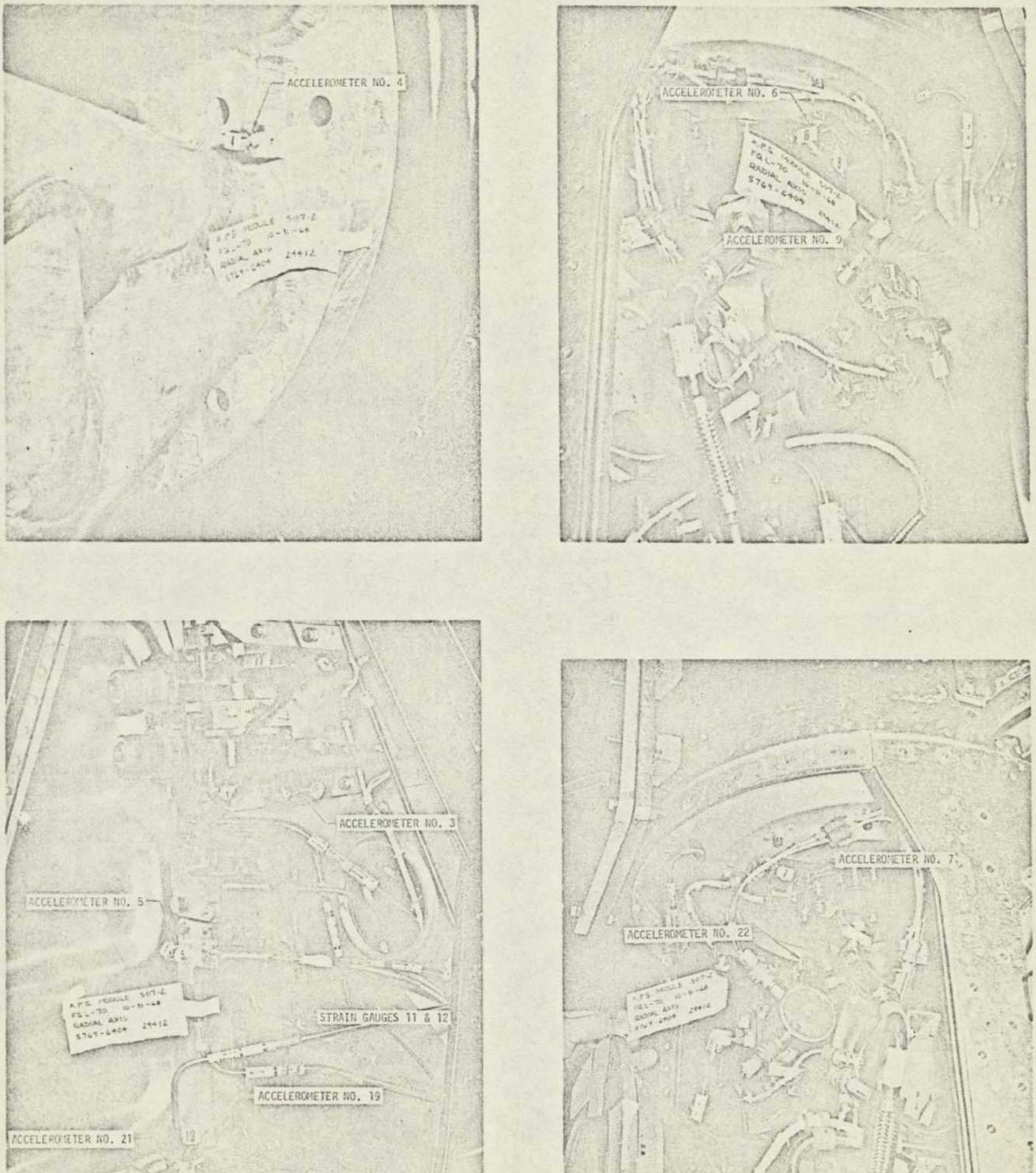
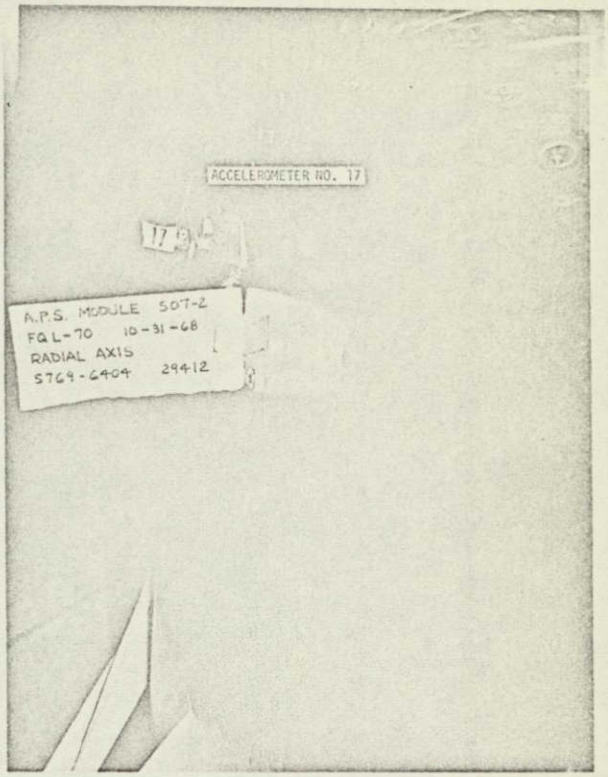
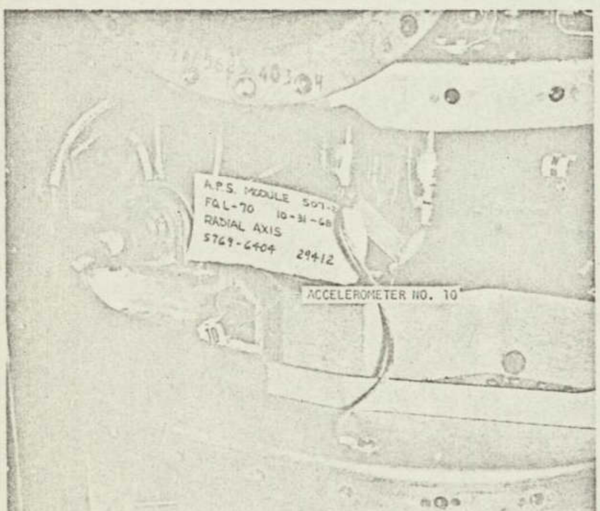


Figure 5-17. Radial Axis Accelerometer Locations (Sheet 3 of 4)





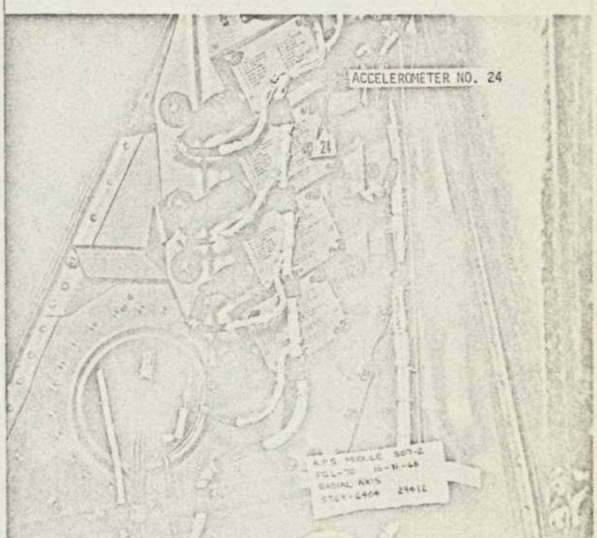


Figure 5-17. Radial Axis Accelerometer Locations (Sheet 4 of 4)

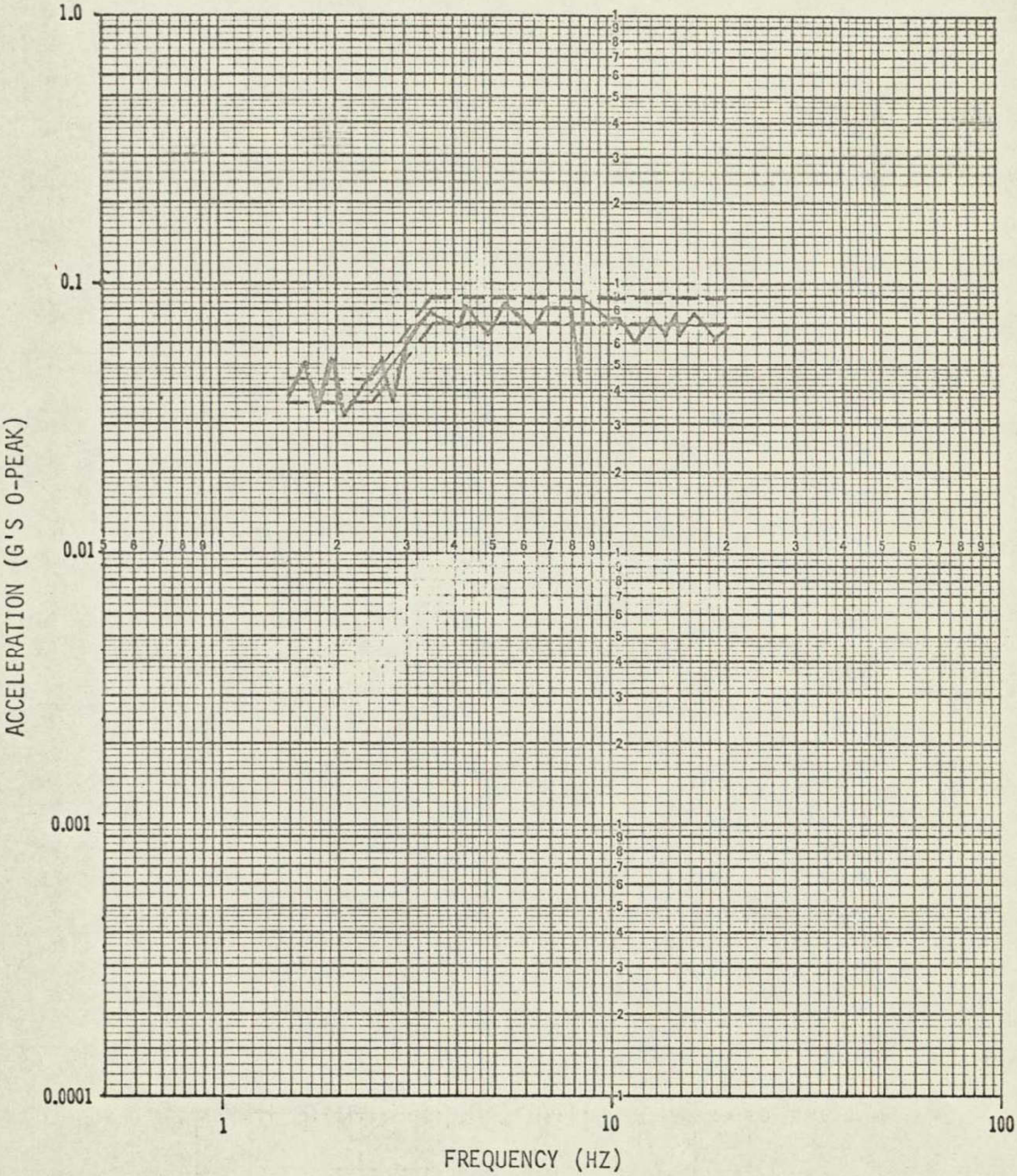


Figure 5-18. Radial Axis Sinusoidal Vibration

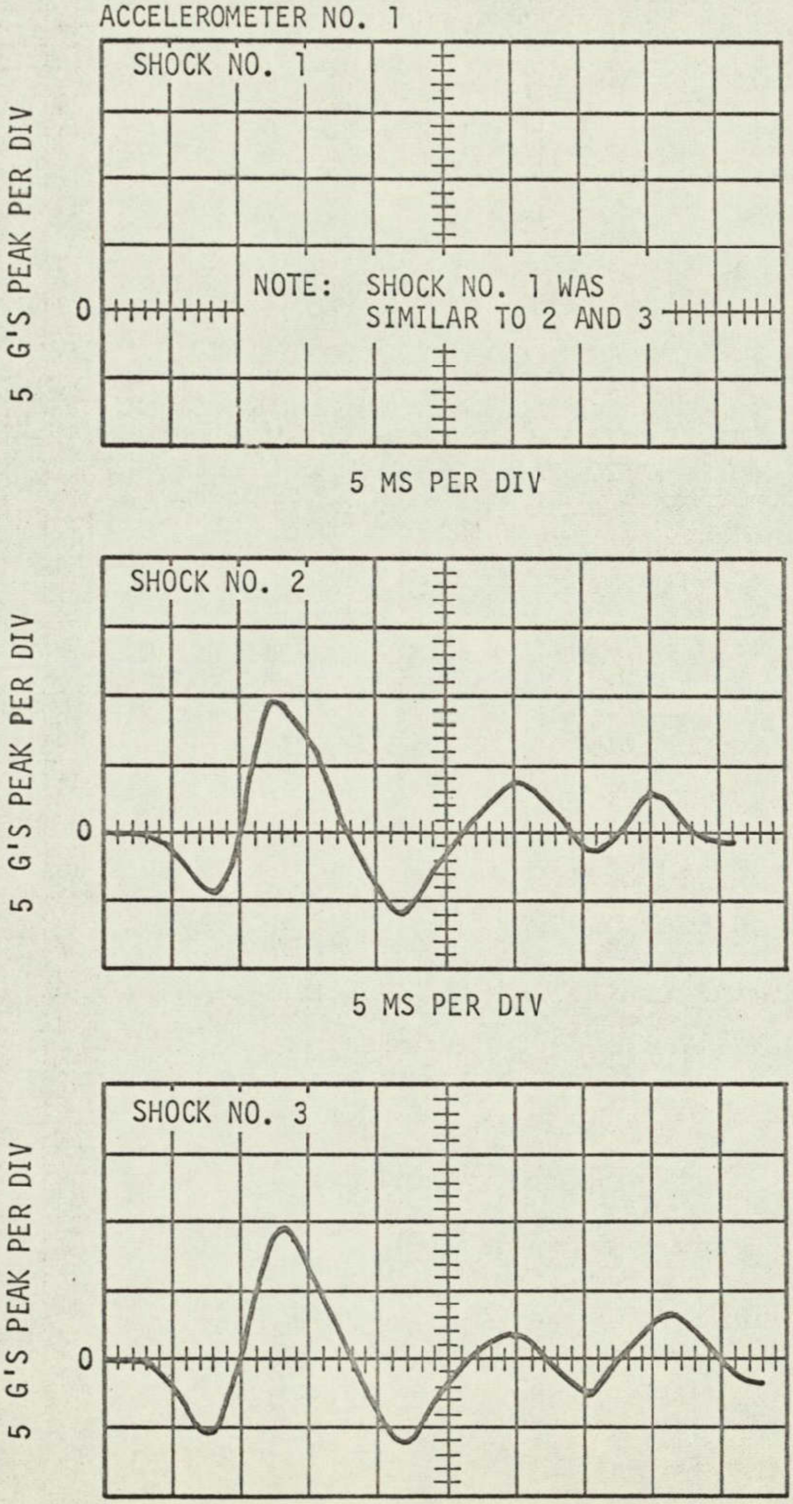


Figure 5-19. Radial Axis Shock Input

Figure 5-20. Radial Axis Shock Spectrum

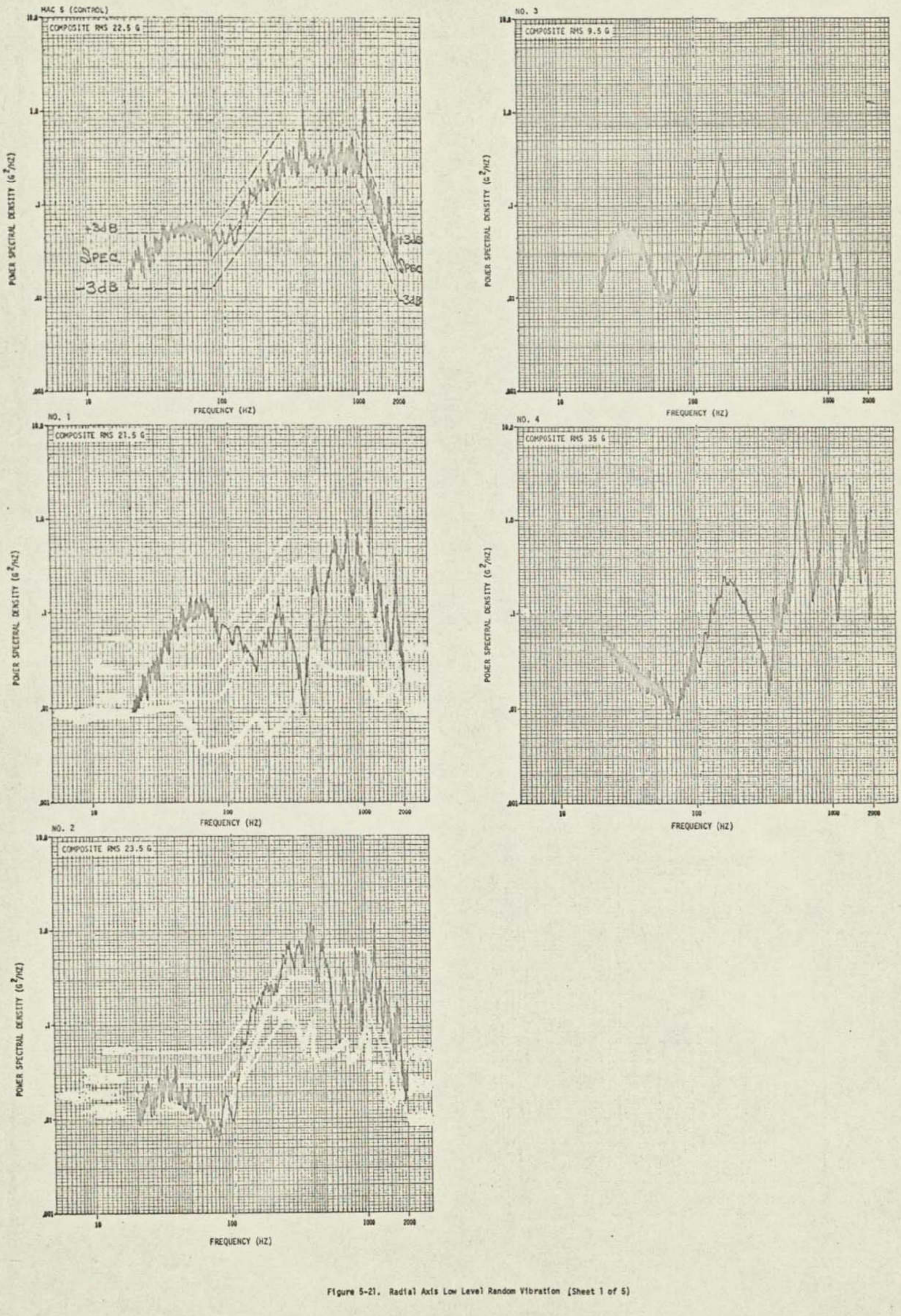


Figure 5-21. Radial Axis Low Level Random Vibration (Sheet 1 of 5)

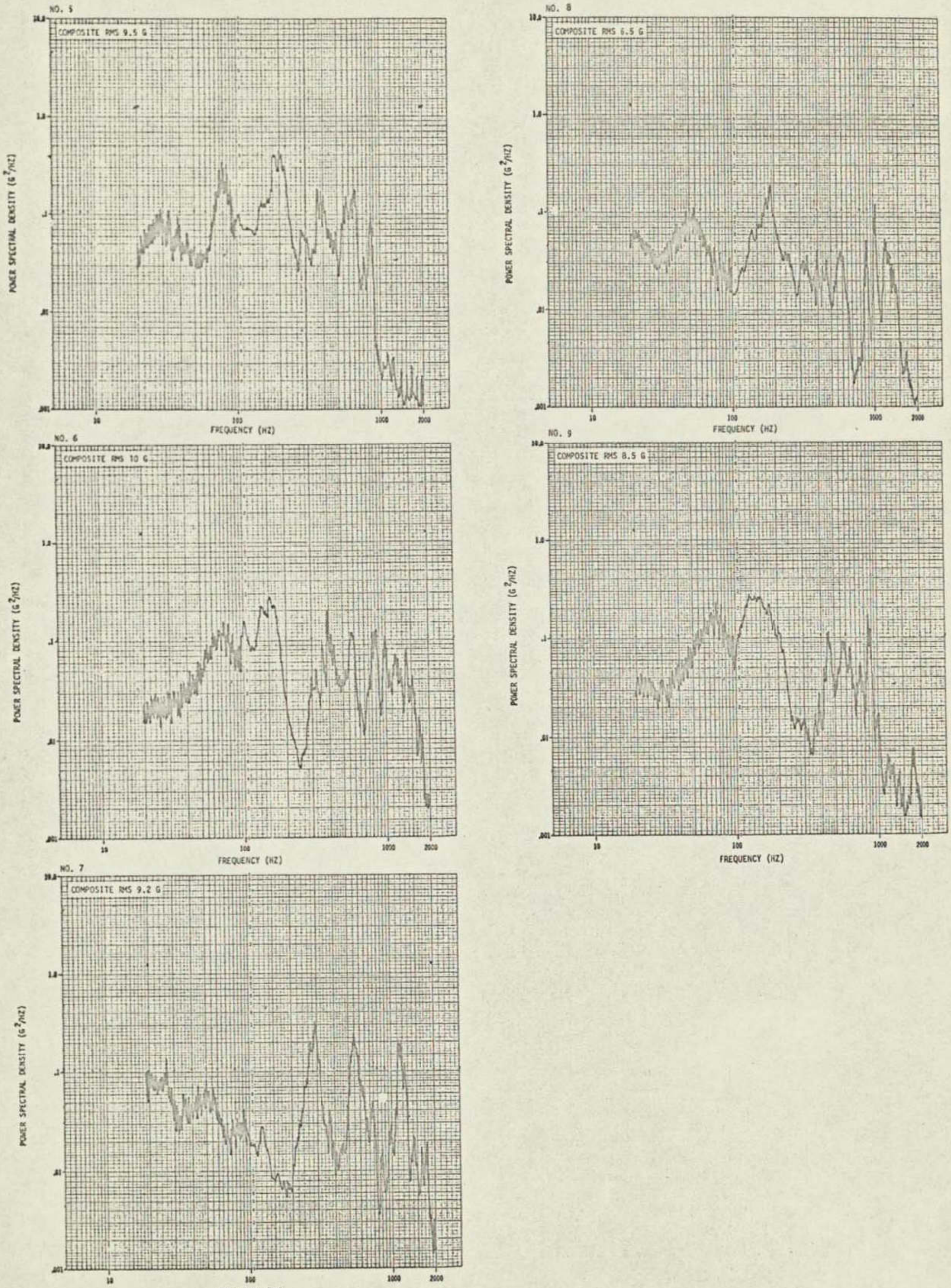


Figure 5-21 Radial Axis Low Level Random Vibration (Sheet 2 of 5)

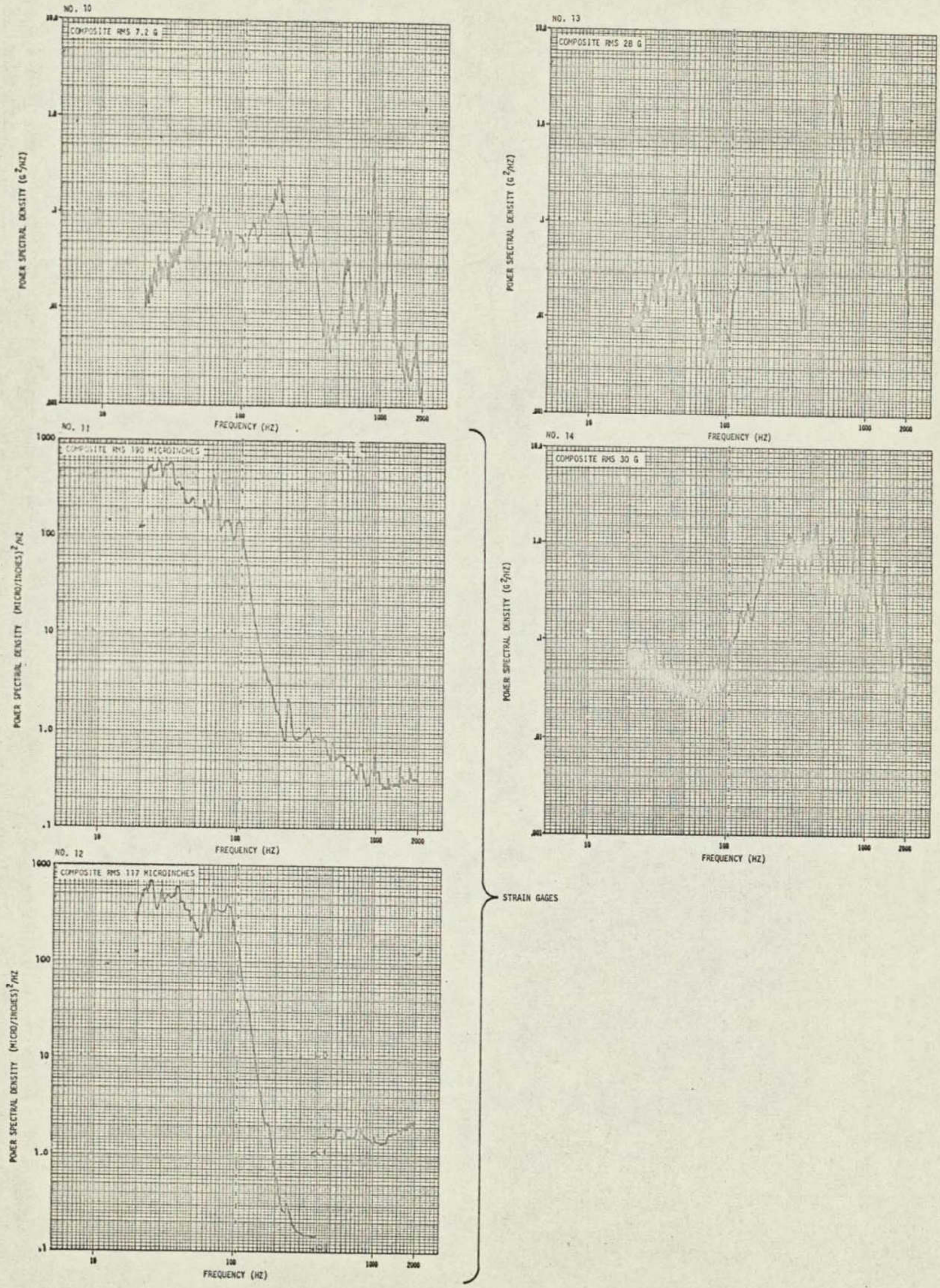


Figure 5-21. Radial Axis Low Level Random Vibration (Sheet 3 of 5)

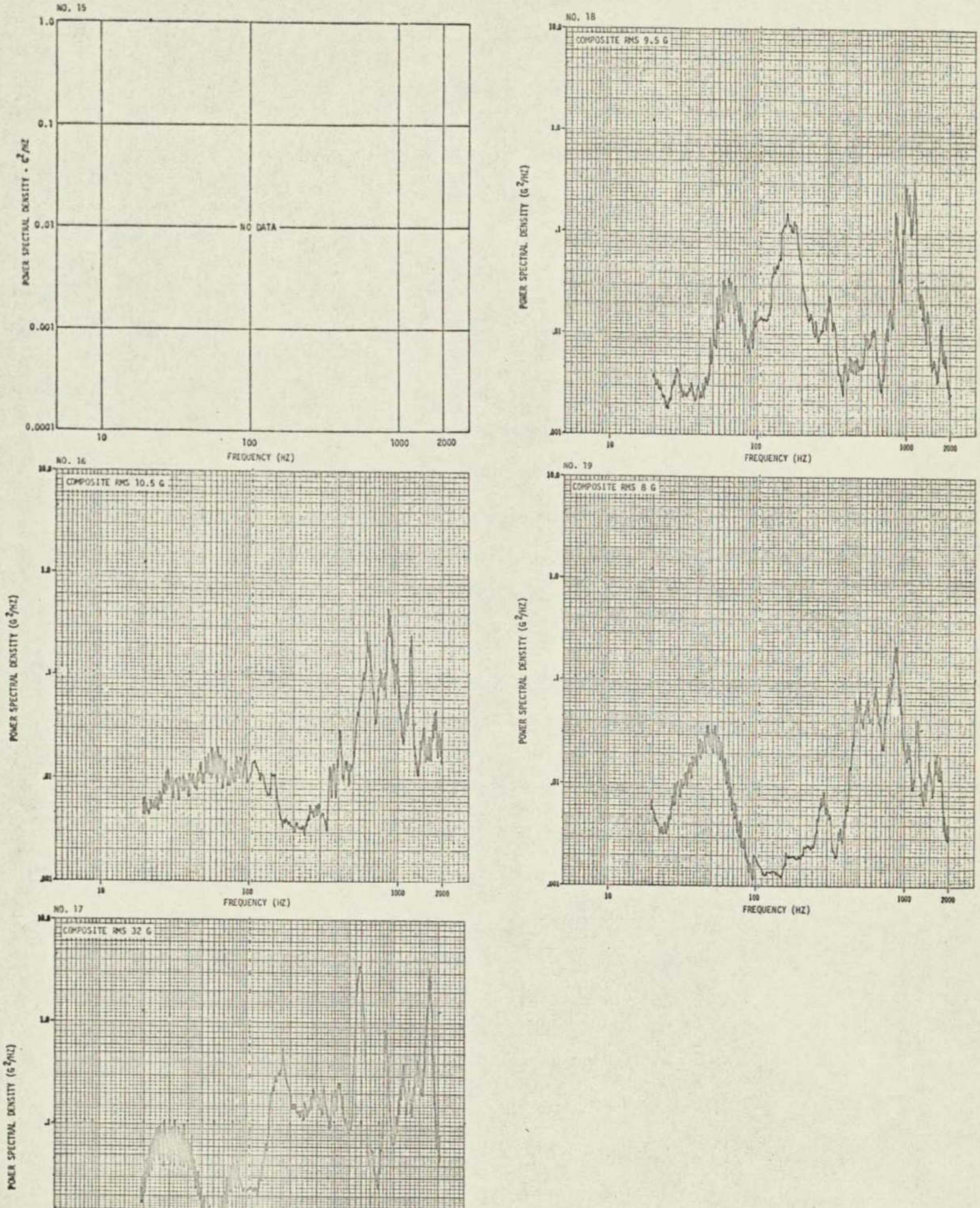


Figure 5-21. Radial Axis Low Level Random Vibration (Sheet 4 of 5)

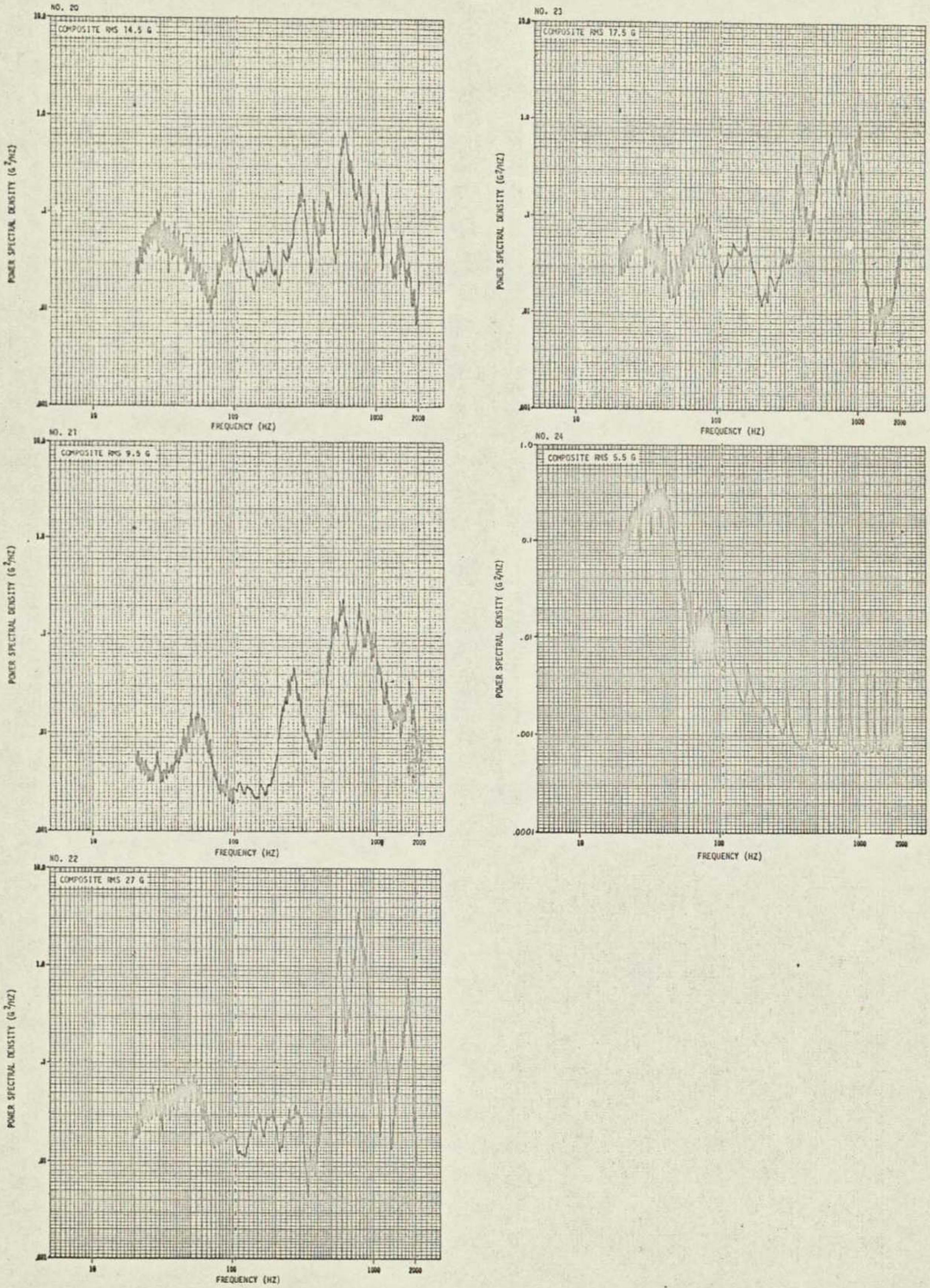


Figure 5-21. Radial Axis Low Level Random Vibration (Sheet 5 of 5)

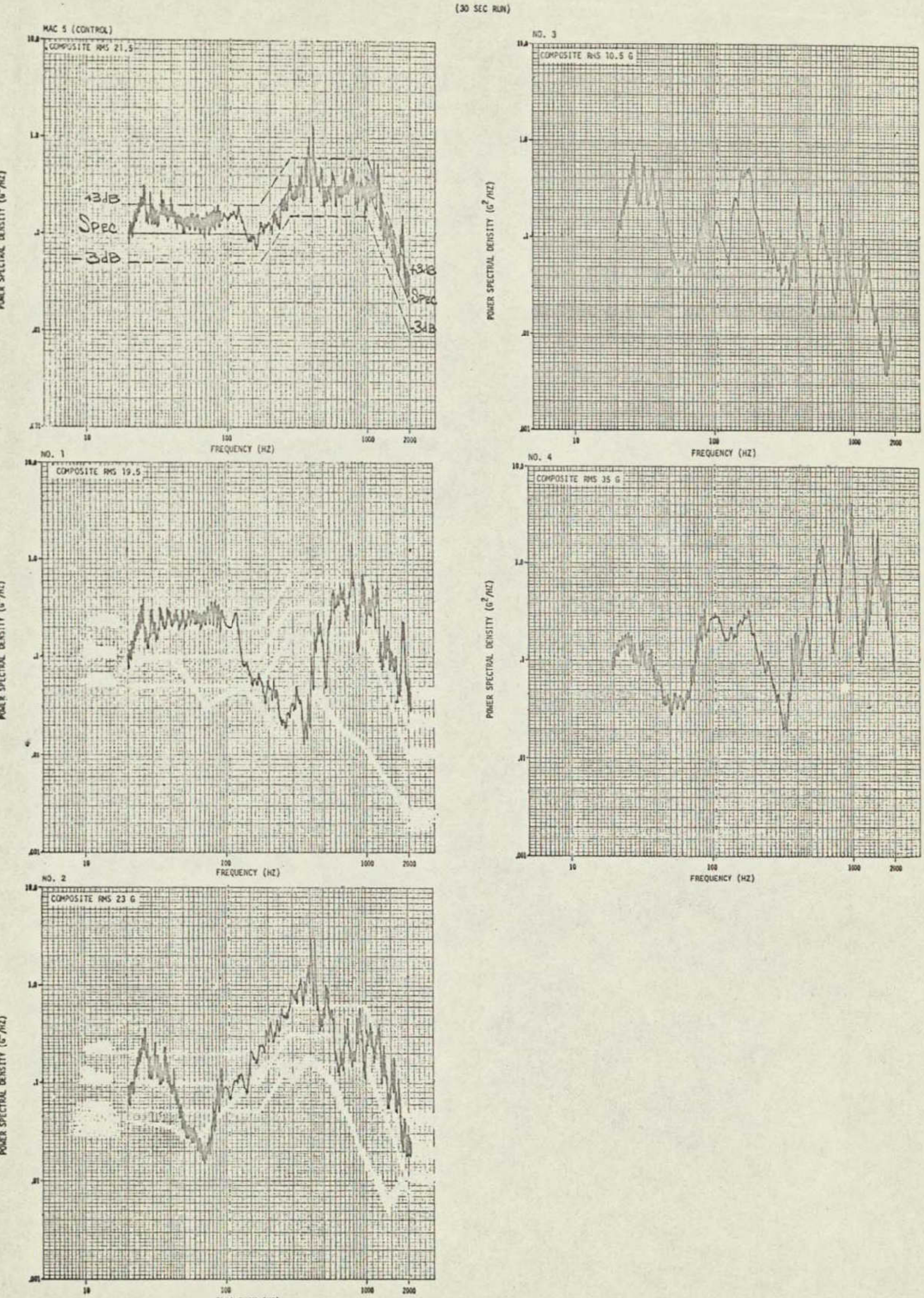
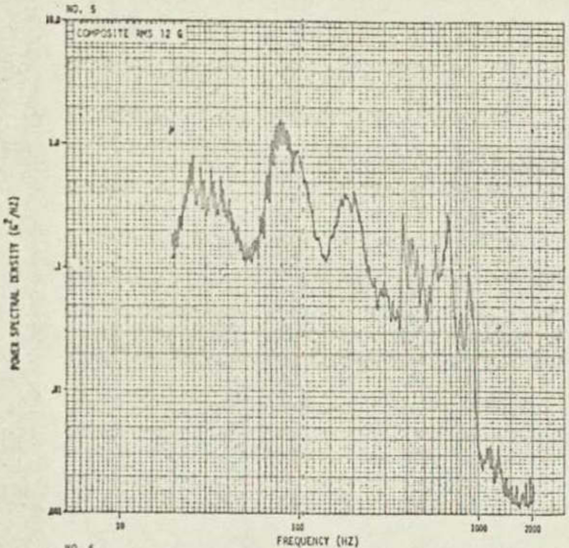
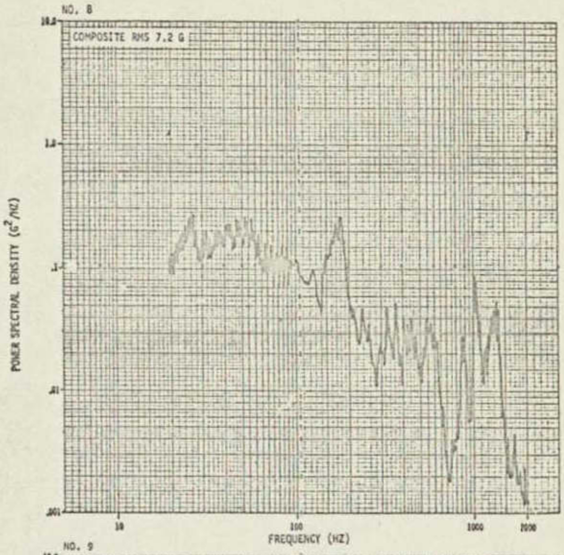
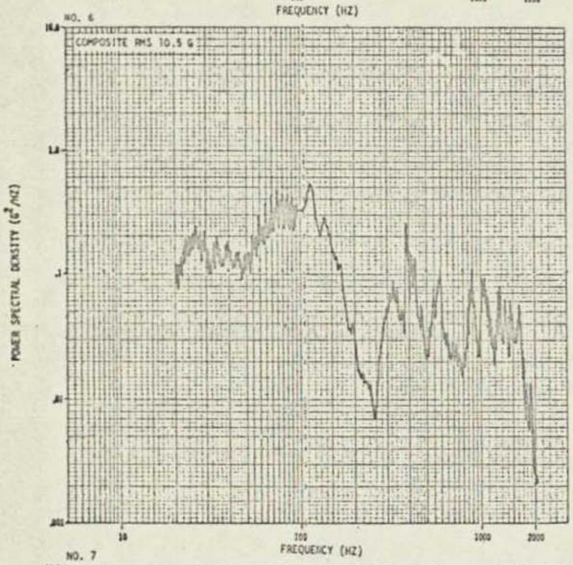
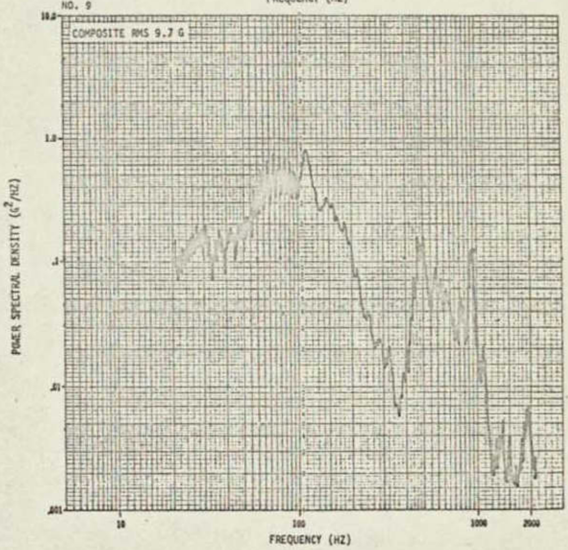


Figure 5-22. Radial Axis High Level Random Vibration (30-sec Run) (Sheet 1 of 5)









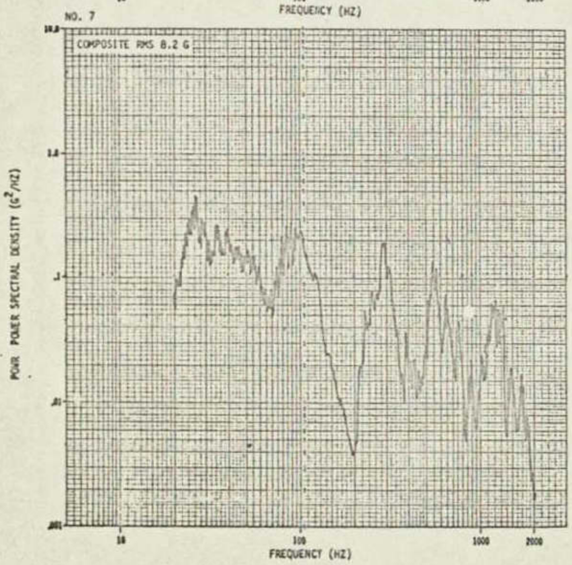


Figure 5-22. Radial Axis High Level Random Vibration (30-sec Run) (Sheet 2 of 5)

(30 SEC RUN)

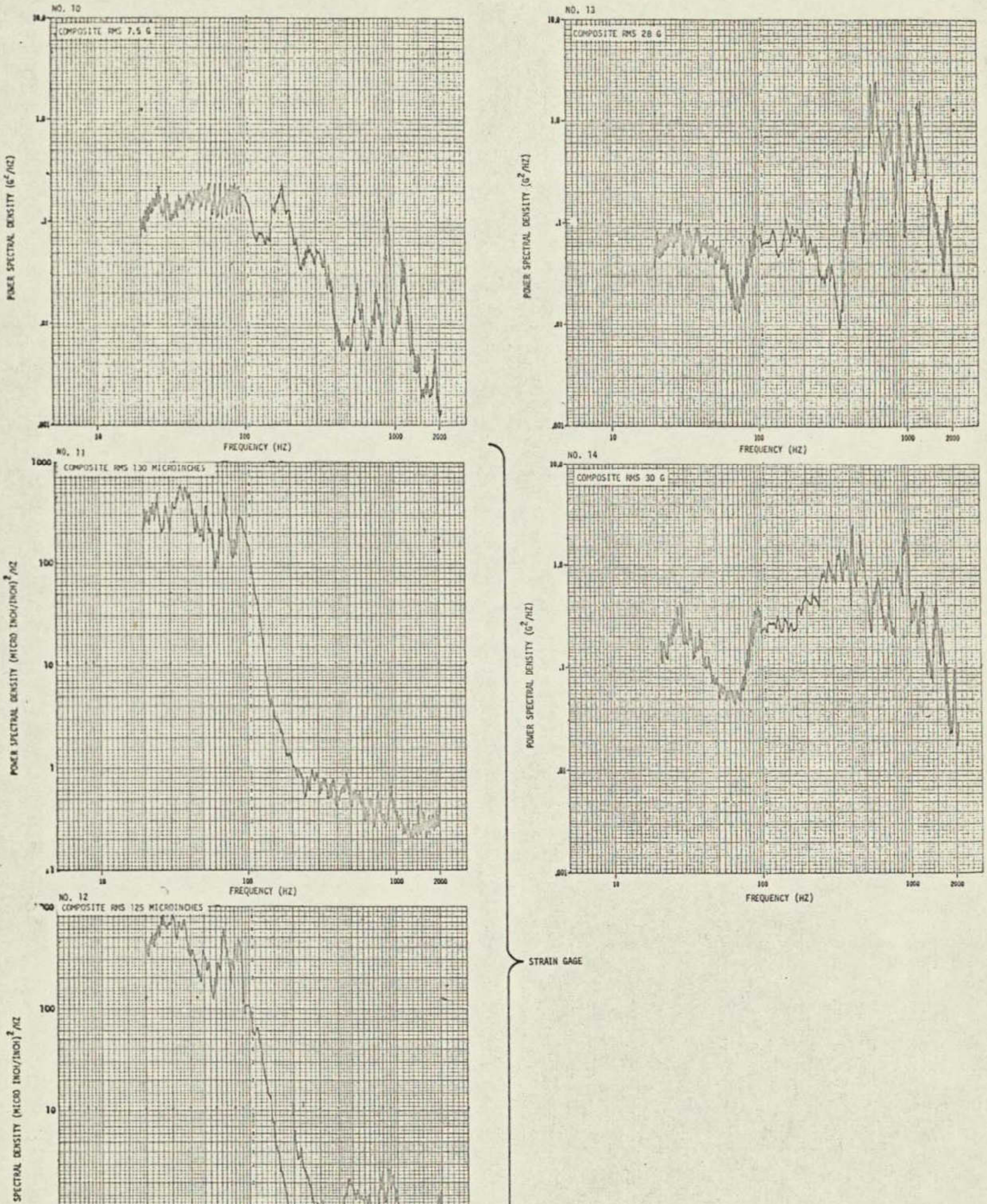


Figure 5-22. Radial Axis High Level Random Vibration (30-sec Run) (Sheet 3 of 5)

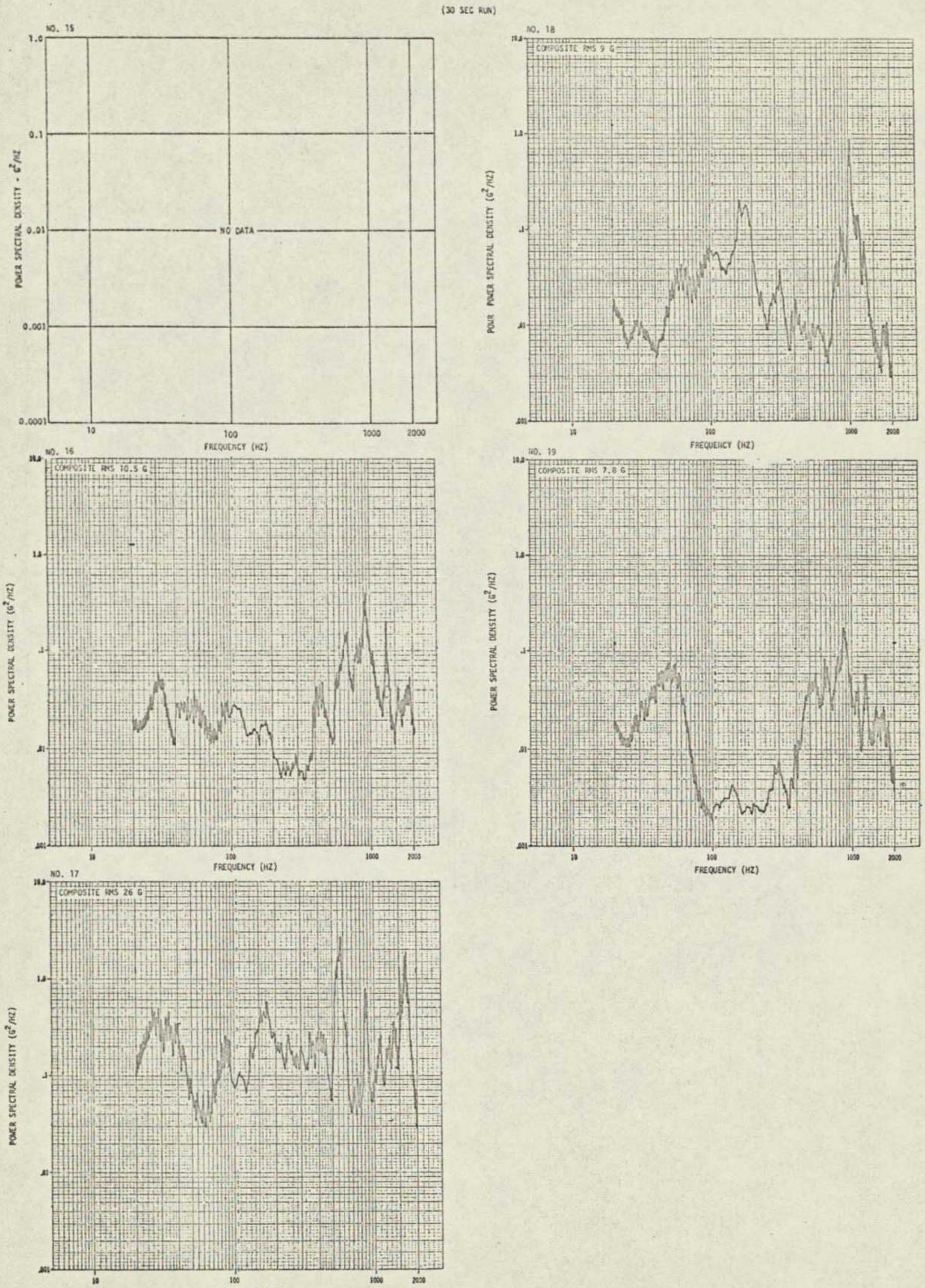
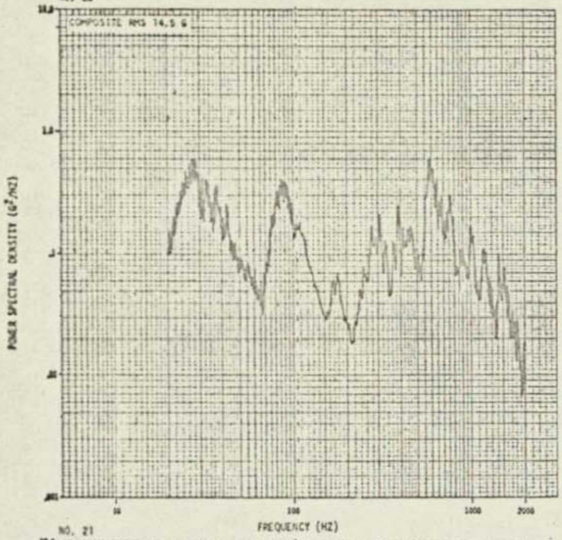


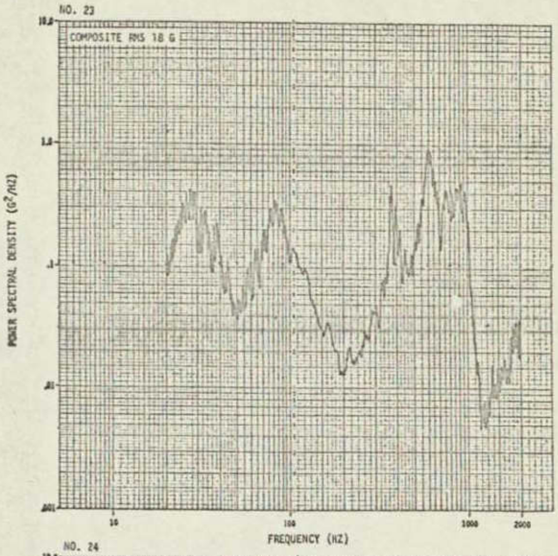
Figure 5-22. Radial Axis High Level Random Vibration (30-sec Run) (Sheet 4 of 5)

(30 SEC RUN)

NO. 20



NO. 23



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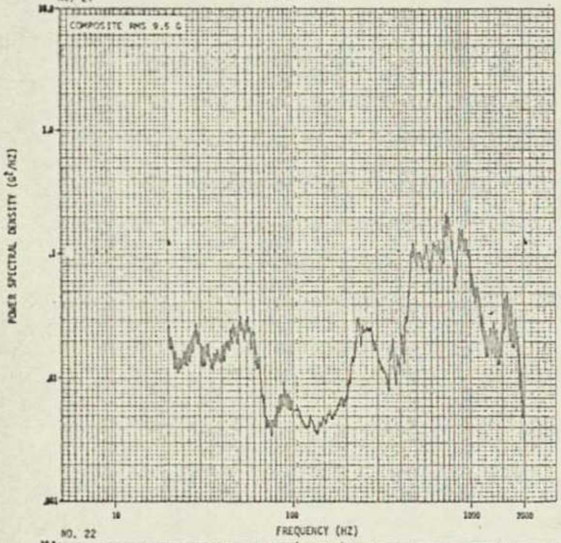

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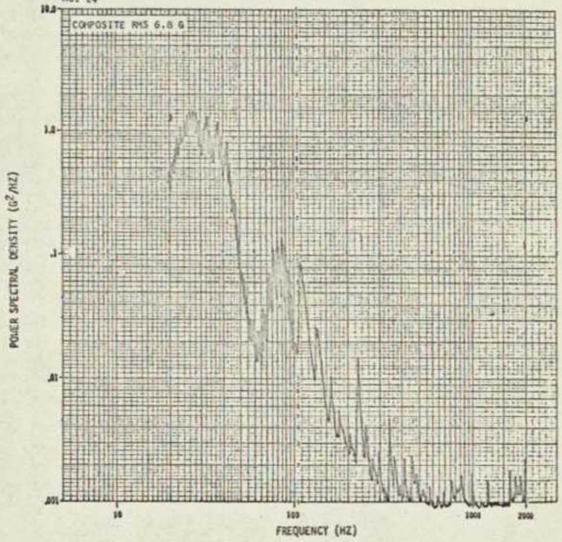


NO. 22

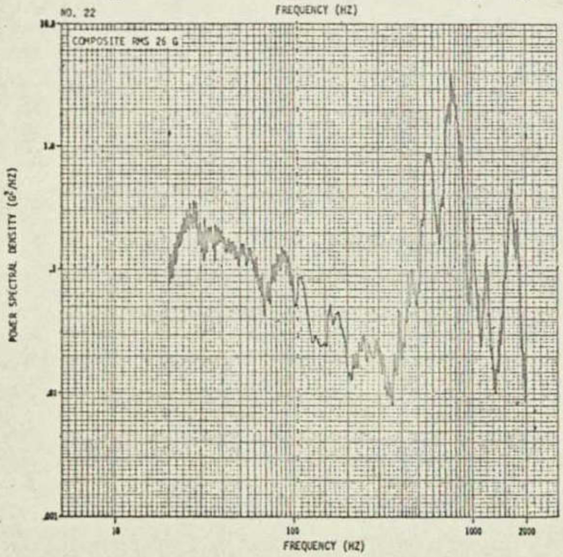


Figure 5-22. Radial Axis High Level Random Vibration (30-sec Run) (Sheet 5 of 5)

(30 SEC INTO 55 SEC RUN)

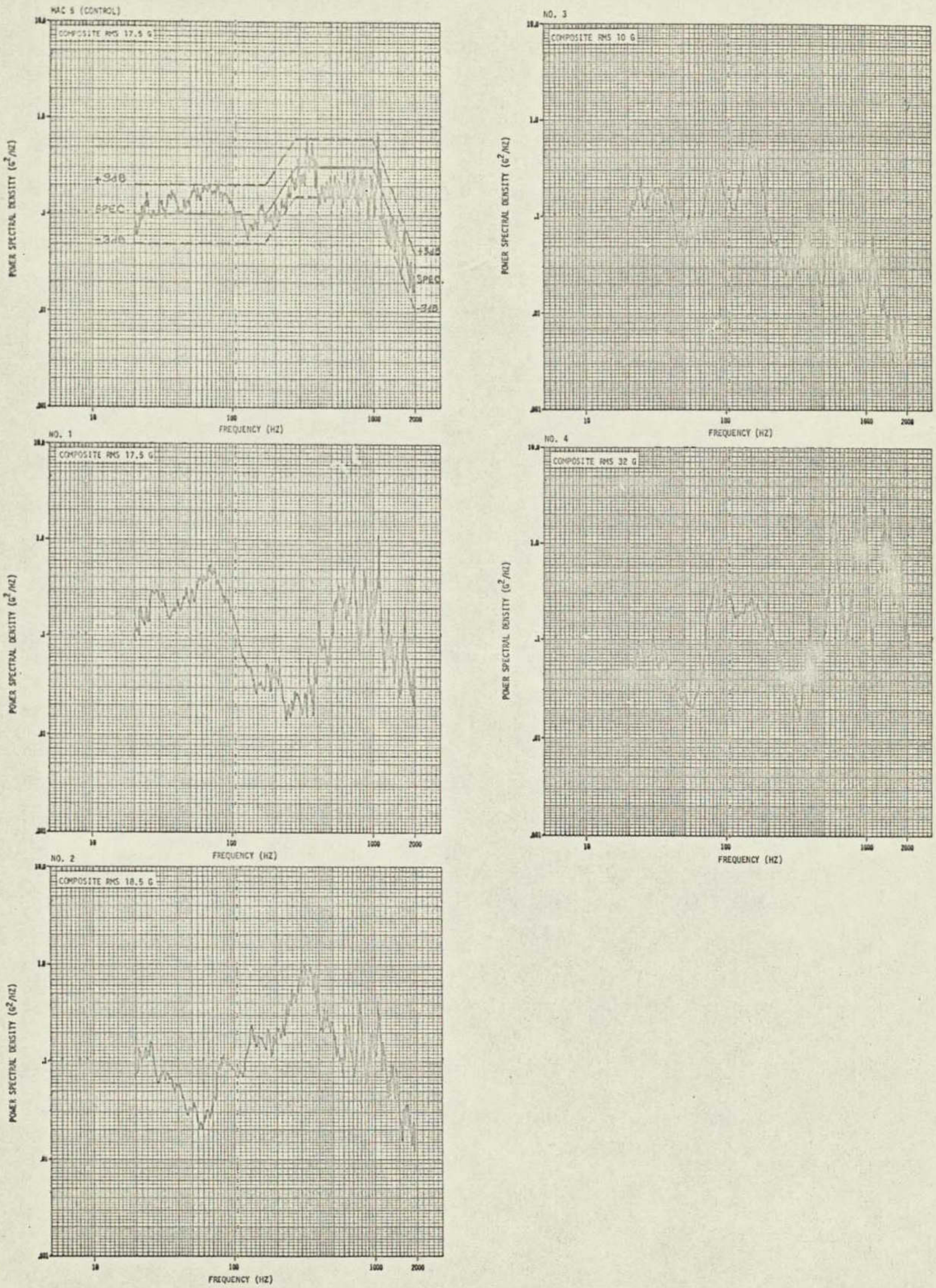


Figure 5-23. Radial Axis High Level Random Vibration (55-sec Run) (Sheet 1 of 5)

(30 SEC INTO 55 SEC RUN)

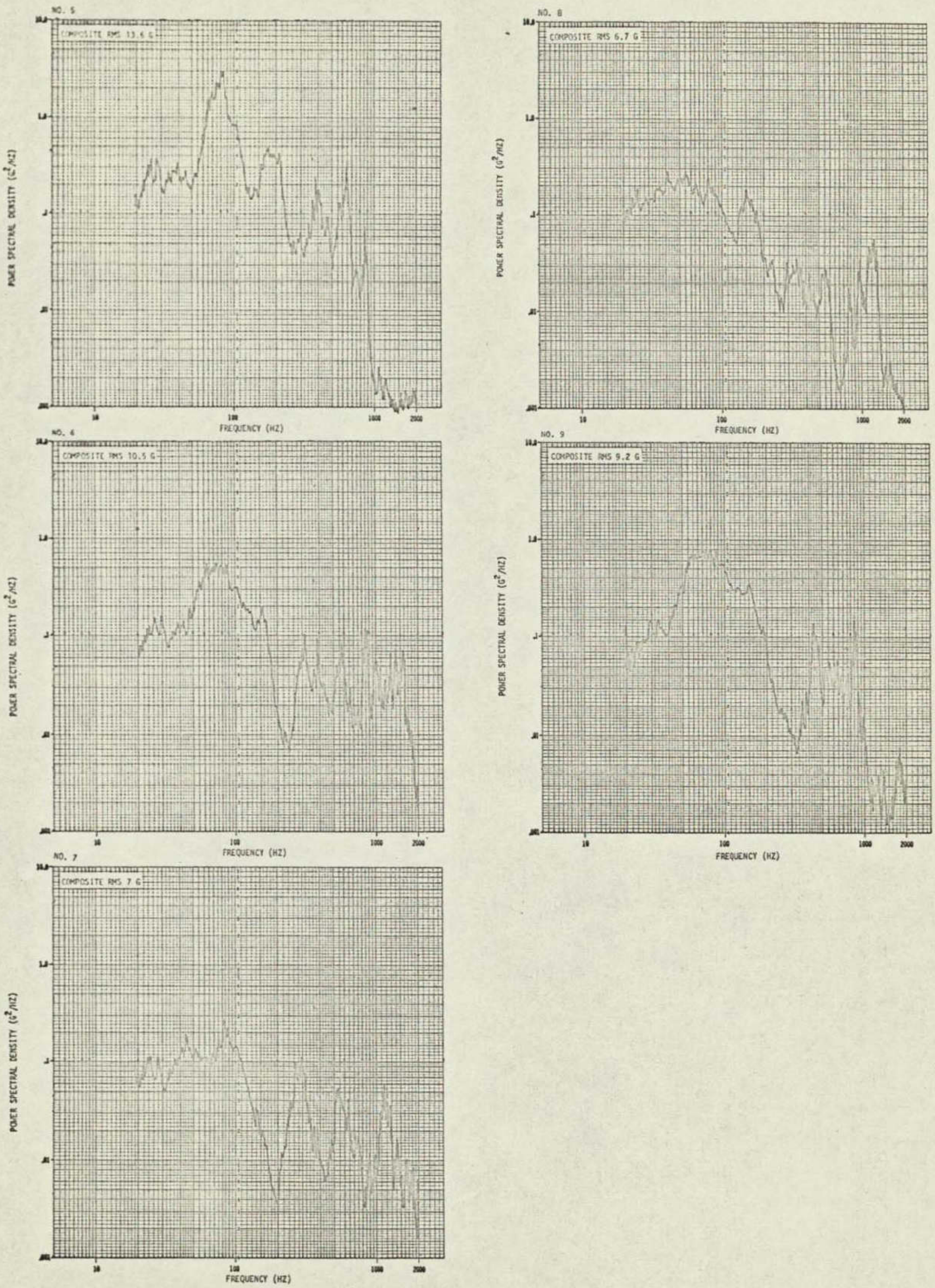


Figure 5-23. Radial Axis High Level Random Vibration (55-sec Run) (Sheet 2 of 5)

(30 SEC INTO 55 SEC RUN)

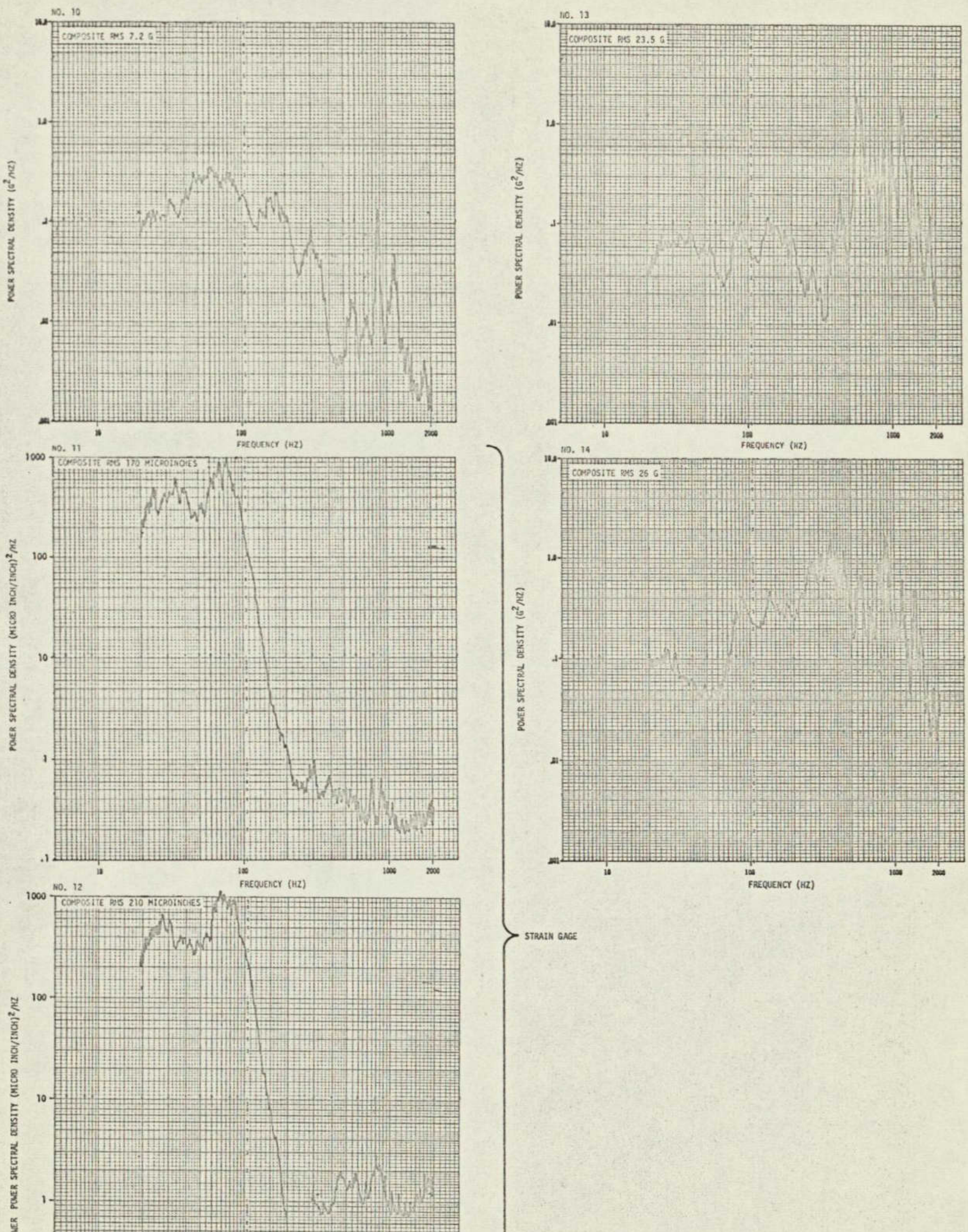


Figure 5-23. Radial Axis High Level Random Vibration (55-sec Run) (Sheet 3 of 5)

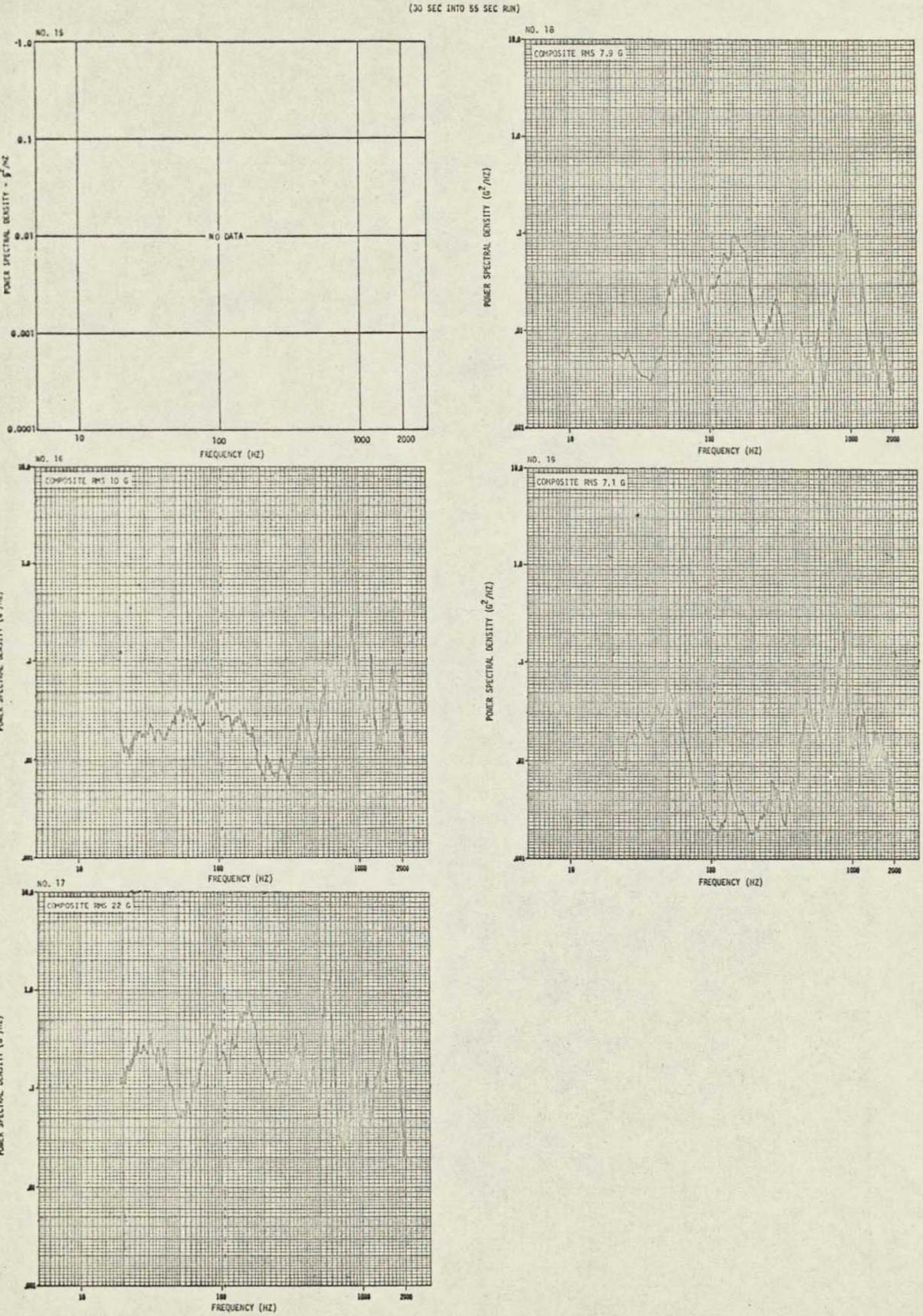


Figure 5-23. Radial Axis High Level Random Vibration (55-sec Run) (Sheet 4 of 5)

6. FAILURES AND ANOMALIES

This section describes the failures and anomalies which occurred on APS module II from the time of pretest checkout through the partial disassembly after all testing was complete. Also described are the results of investigations conducted and steps that were taken so that testing could be continued. Table 6-1 lists the failures and anomalies chronologically which occurred during these tests

6.1 Failures

A failure is defined as any discrepancy which could possibly cause loss of mission or delay of launch.

6.1.1 Fuel Low Pressure Helium Module

On 16 October 1968, after the APS module had been loaded with propellants, the fuel low pressure helium module (P/N 1A49998-509, S/N 117G) developed a leak causing the APS helium system pressure to decay. At the time the leakage occurred, the APS helium system was pressurized to blanket pressure (65 $\pm$5 psia). Further investigation revealed that the vent valve of the helium module was leaking 100 sccm (maximum leakage allowable is 5 sccm). Cycling the vent valve open and closed several times did not change the leak rate. The failed unit was removed from the APS module and replaced with P/N 1A49998-509, S/N 108G.

The helium module was sent to the M&A Building where a failure analysis was made on the failed part. Conclusions were that the leakage was caused by minute particles or contamination on the valve seat and that the module would have sealed within specifications at flight operating pressures (200 psia).

This type of failure would normally be found during checkout prior to launch and the module would be replaced. However, it was classified as a failure because if it occurred during countdown, then launch could be delayed by having to replace the module.

6.1.2 High Pressure Helium Leak

On 21 October 1968, the high pressure system was pressurized to 3,150 psia in preparation for the first vibration test (thrust sinusoidal). The temperature of the helium bottle at that time was 115 deg F. After a hold of approximately 30 min the helium pressure had decayed to 2,900 psia and the temperature had decreased to 95 deg F. This pressure decay was assumed to be caused by the temperature decrease and the helium bottle was repressurized to 3,150 psia. Sinusoidal vibration in the thrust axis was then completed and the post vibration leak checks (at 165 psia) were completed

On 22 October 1968 the high pressure system was pressurized to 3,150 in preparation for thrust random vibration. During a hold period, the helium system had to be repressurized several times because of pressure decay, which definitely indicated a leak. After numerous attempts to find the leak at low pressure, the tanks were disconnected from the system and the leak was then audible at 3,000 psia. (This was heard from a distance, since safety precautions prevent approaching the helium system when it is pressurized at 3,000 psia.) After reducing pressure to 1,500 psia, the leak was found at the bulkhead nut of a transducer elbow fitting on the aft end of the helium tank. The fitting was removed and found damaged. The damage consisted of two circumferential grooves around the portion of the fitting on which the teflon "O" ring seats and on which the backup washer must slide. It was observed that the washer could not move without excessive pressure. It was also noted that the jam nut torque seemed low when the fitting was removed The fitting and it's associated seal were replaced and the leak check repeated. This time two additional leaks were found; one at the temperature transducer adapter to APS helium tank interface and the other at a tee in the helium tank pressure sense line. The repair of these leaks necessitated the removing of the helium tank from the APS. After replacing the seals at these two points, the APS was repressurized and leak checked once again, no additional leaks were found. Figure 6-1 shows the location of two helium tank leaks. The helium tank was reinstalled in the APS module and the vibration tests were continued.

After the random vibration and shock tests were completed, it was determined that the torque specified in the MDAC process specification for bulkhead type elbows was in error (approximately 50 percent low). As a result, a DPS correction was initiated and all of the affected fittings on the module were retorqued to the proper values. All modules in the field were also retorqued.

6 2 Anomalies

An anomaly is defined as a discrepancy which is undesirable and not normal but which would not cause loss of mission or delay of launch.

6.2.1 Engine No. 3 Current Signature

During pretest checkout conducted between 3 July 1968 and 8 October 1968, the high differential pressure current signature for oxidizer valve No 2 (downstream) on engine No. 3 could not be obtained. Further investigation revealed that valve No. 2 was closing 2 to 3 ms slower than valve No. 1 (upstream), making it impossible to achieve the high differential pressure condition for valve No. 2. By making a minor change in the procedural technique (cycling the upstream valves open and closed before cycling all valves open) satisfactory valve signatures were obtained for valve No. 2.

6.2.2 Engine No. 4 Chamber Leakage

During pretest checkout conducted between 3 July 1968 and 8 October 1968, engine No. 4 chamber pressure indicated a pressure decay of 45 psid/min (1 psid/min is allowed). Further investigation revealed a leak at the throat insert to the ablative chamber interface and also that this particular engine had been test fired during the 1005-1 APS confidence firing. The engine was subsequently removed from the 1005-1 APS. This type of leakage for a fired engine is considered normal and this discrepancy was accepted.

6.2.3 Missing Transducer Lockwashers

On 23 September 1968, during pretest inspection, the engine chamber pressure transducers were found to have no lock washers under the heads of the retaining screws. Lock washers were added by loosening one screw at a time, installing a lock washer, and then retightening the screw.

6.2.4 Stripped Nutplate

On 27 October 1968, after random vibration in the thrust axis, the doors on the APS module had to be removed to check some of the accelerometers. During the door removal, a nut plate was stripped. Since this occurred as a result of removing the door and not as a result of vibration, the nut plate was replaced and the test continued.

6.2.5 Loose Jam Nut

On 29 October 1968, during post inspection after the tangential sinusoidal vibration test, the jam nut on the oxidizer relief port was found loose. This was thought to be caused by movement of the ground support flex lines which are connected to the port during this test only and not used at launch time. The nut was retorqued and the test continued.

6.2.6 Stripped Nut Plate

On 30 October 1968, after the tangential shock test was completed, the APS doors were removed to inspect the interior of the APS module. During the removal, one bolt galled in a nut plate and the bolt head had to be sawed off. This nut plate was located in such a position that it could not be replaced due to interference with other equipment in the APS module The remainder of the tests were conducted without the use of this nut plate.

6 2.7 Fuel Bladder Leak

On 5 November 1968, during the post axis leak check conducted after the 30-sec radial random vibration test, the fuel bladder was found leaking excessively. Further investigation revealed that the bladder was leaking 750 sccm of gaseous nitrogen. Calculations indicated that this leakage was approximately equal to the leakage through a .007 in. diameter sharp edge orifice. At this point, to further investigate the bladder leak, the gas was removed from the fuel bladder and X-ray photographs were taken of the ullage area. The first X-ray was taken 10 min after gas bleed. The X-ray showed that the liquid level in the standpipe had dropped to within 0.25 in. of the mean liquid level by the time the second X-ray was taken one hour later. This indicated that the hole in the fuel bladder was in the ullage area and allowed gas to enter the inside of the bladder very quickly.

The 55-sec radial random vibration test was then completed and leakage tests on the fuel bladder during post axis checkout indicated a leakage of 800 sccm of helium (which was approximately the same value it was before). This test indicated that the additional vibration did not increase the size of the hole

After all tests and operations were complete, the fuel tank was removed from the APS and the fuel bladder removed from the fuel tank. At this time it was noted that the fuel bladder had been exposed to propellant for 27 days and had accumulated a total of 4.5 cycles during the test. The fuel bladder was inflated and a small hole, in addition to several scratch-like defects, was found in the ullage end of the bladder. Figure 6-2 shows the expanded bladder and figure 6-3 shows the location of the defects. The hole is also shown in figures 6-4 and 6-5. The scratches are shown in figure 6-6 and again under approximately 50X magnification in figure 6-7.

The interior surface of the fuel tank was inspected for contamination, corrosion, or any defect that could have cut the bladder The tank interior was clean and free of any defects; however, there was some staining in the leak area and along the vent string paths. These stains, which are shown in figure 6-8, were apparently caused by fuel that leaked inside the ullage area.

The fuel bladder was then removed from it's standpipe assembly and the assembly inspected for any defect which could have cut the bladder. Three defects were found on the upper standpipe weld and one small defect was found on the lower standpipe weld. The largest of the upper weld defects is shown in the plan view in figure 6-9 and in profile in figure 6-10 This defect was approximately .015 in. high and had a sharp feel. The second defect was smaller in height (figure 6-11) and larger in diameter (figure 6-12) than the first defect while the third defect shown in figures 6-13 and 6-14, was a well rounded bump. A small, rather sharp mound was noticed on the lower weld and is shown in figure 6-15. Neither the upper nor the lower weld showed any cracks during a dye penetrant inspection.

The proximity of both the scratches and the hole in the bladder to the sharp defect on the upper weld indicates that these areas could have been in contact during the random folding of the bladder during the gas extraction exercise. If this did occur and these areas were in contact during vibration, then the cut in the bladder could result. The strong possibility exists that the large weld defect did, in fact, cut the bladder.

This problem was considered an anomaly rather than a failure because the bladder was still functional and the hole would not have affected flight or launch. As a result of this anomaly the tank vendor (Bell) is now inspecting all diffuser drawings for inadequate welding. Vendor drawings have been revised to require improved weld finish controls on the diffuser tube welds.

6.2.8 Check Valve Leakage

On 21 November 1968, during post unloading checkout, the upstream high pressure check valve (P/N 1B68379-1, S/N 223) was discovered to have a blowing leak. The check valve was removed for disassembly.

Since this check valve is redundant, the leak was not found until it was individually checked, however, it did not affect the vibration test. This check valve is no longer flight configuration since the check valves on S-IVB-503N and subs (except for the S-IVB-507 APS modules 1 and 2) are being changed.

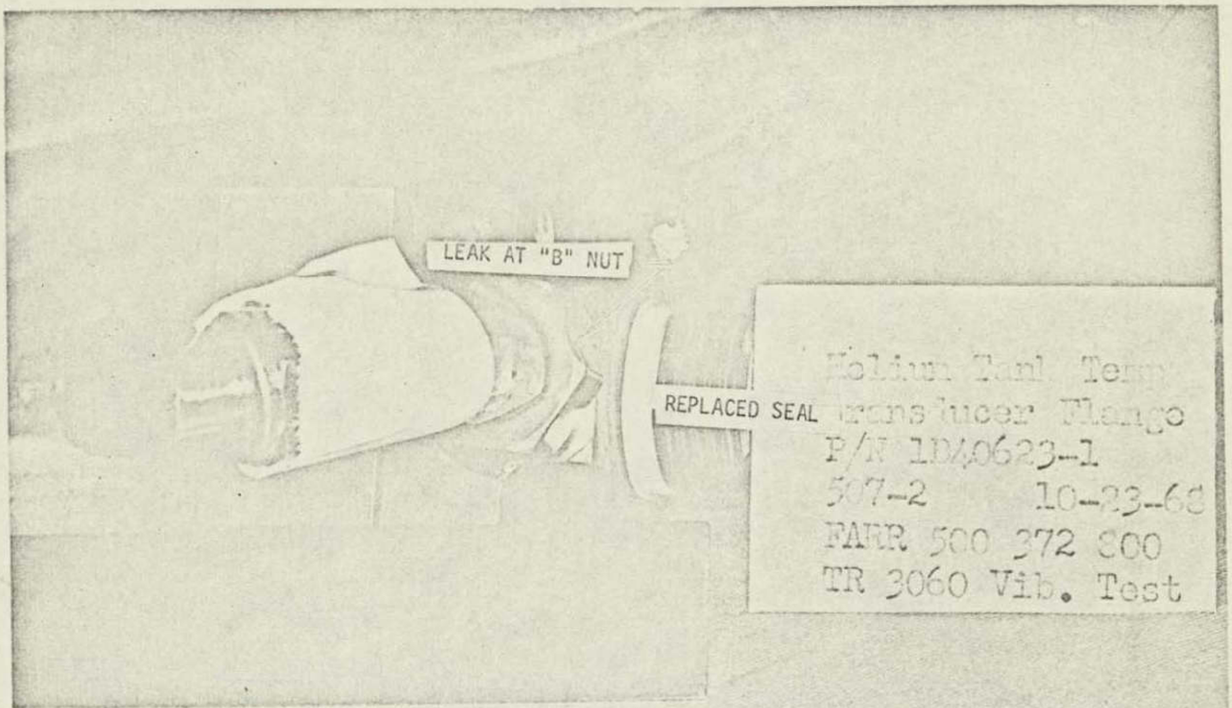
Disassembly of the check valve revealed that a piece of wire 0.012 in. in diameter and 0.75 in. long had lodged between the poppet and the seat and it's position indicated that it might have come from the pressurizing port. The piece of wire was removed and the valve reassembled. A 3-min leakage test on the reassembled valve, with 1,500 psia of helium, indicated no leakage.

6.3 Conclusion

The disassembly and inspection did not reveal any failures which reflected on the integrity of the APS unit. The failure in the low pressure helium module was attributed to contamination and not to design deficiencies The high pressure helium leaks resulted from improper torque specifications and defective seals at the temperature transducer adaptor to helium tank interface, and at a tee in the helium tank pressure sense line

TABLE 6-1
FAILURES AND ANOMALIES

SEQUENCE	DATE (1968)	PROBLEM	WHEN OBSERVED	CLASS	DISPOSITION
1		Engine No. 3, oxid valve No. 2 current signature	Pretest checkout	Anomaly	Procedure change corrected problem prior to vibration.
2		Engine No. 4 chamber leakage	Pretest checkout	Anomaly	Acceptable (engine No 4 fired before).
3	9-23	Missing washers on engine chamber transducers	Pretest inspection	Anomaly	FARR 500-607-050, washers installed per tag disposition.
4	10-16	Fuel low pressure module vent leakage	Propellant loading	Failure	FARR 500-607-068, replaced with S/N 108G.
5	10-22	High pressure helium leak	Thrust sinusoidal post mode test	Failure	Corrected - continued test.
6	10-27	Door nutplate stripped during door removal	Thrust random post mode inspection	Anomaly	Nutplate replaced - test continued.
7	10-29	Oxidizer relief bulkhead nut loose	Tangential sinusoidal post mode inspection	Anomaly	Retorqued nut - continued test.
8	10-30	Stripped nutplate and bolt	Tangential shock post mode inspection	Anomaly	Could not replace nutplate due to limited clearance - continued test without bolt and nutplate.
9	11-5	Fuel bladder leak	Radial post 30 sec random check	Anomaly	Calculated to be 007 in. dia hole - not considered failure - test continued
10	11-14	Upstream high pressure check valve leakage	Post unloading checkout	Anomaly	Redundant check valve - not failure - checkout continued.



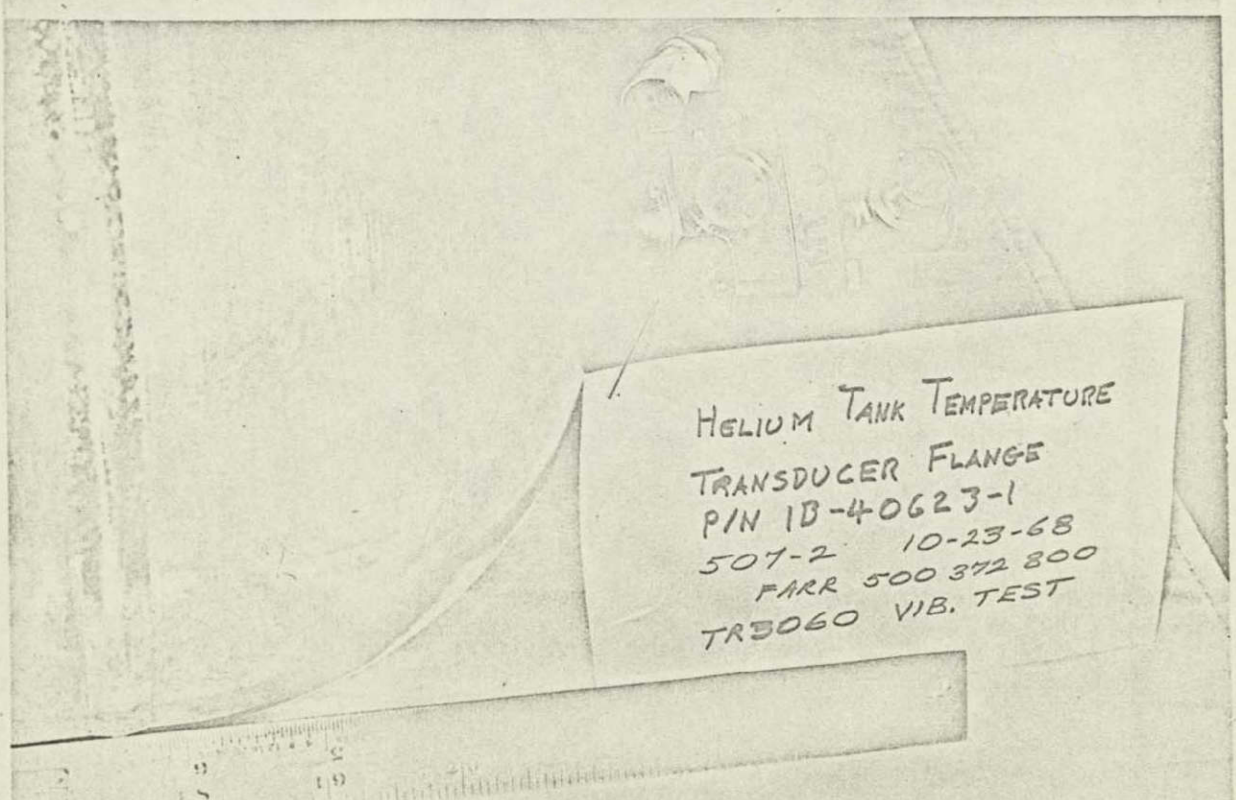


Figure 6-1. Helium Tank Leaks

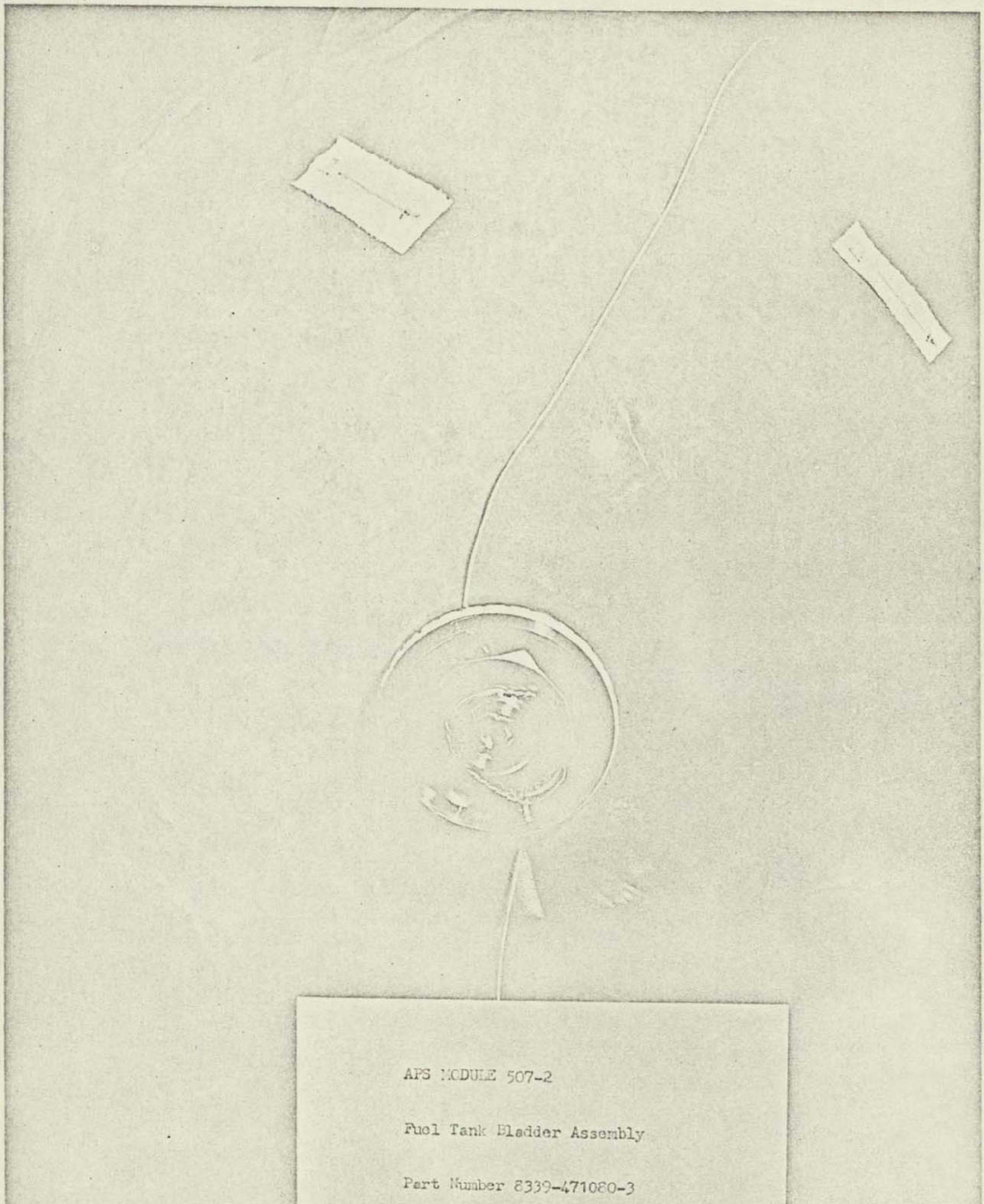


Figure 6-3. Fuel Bladder Defect Locations

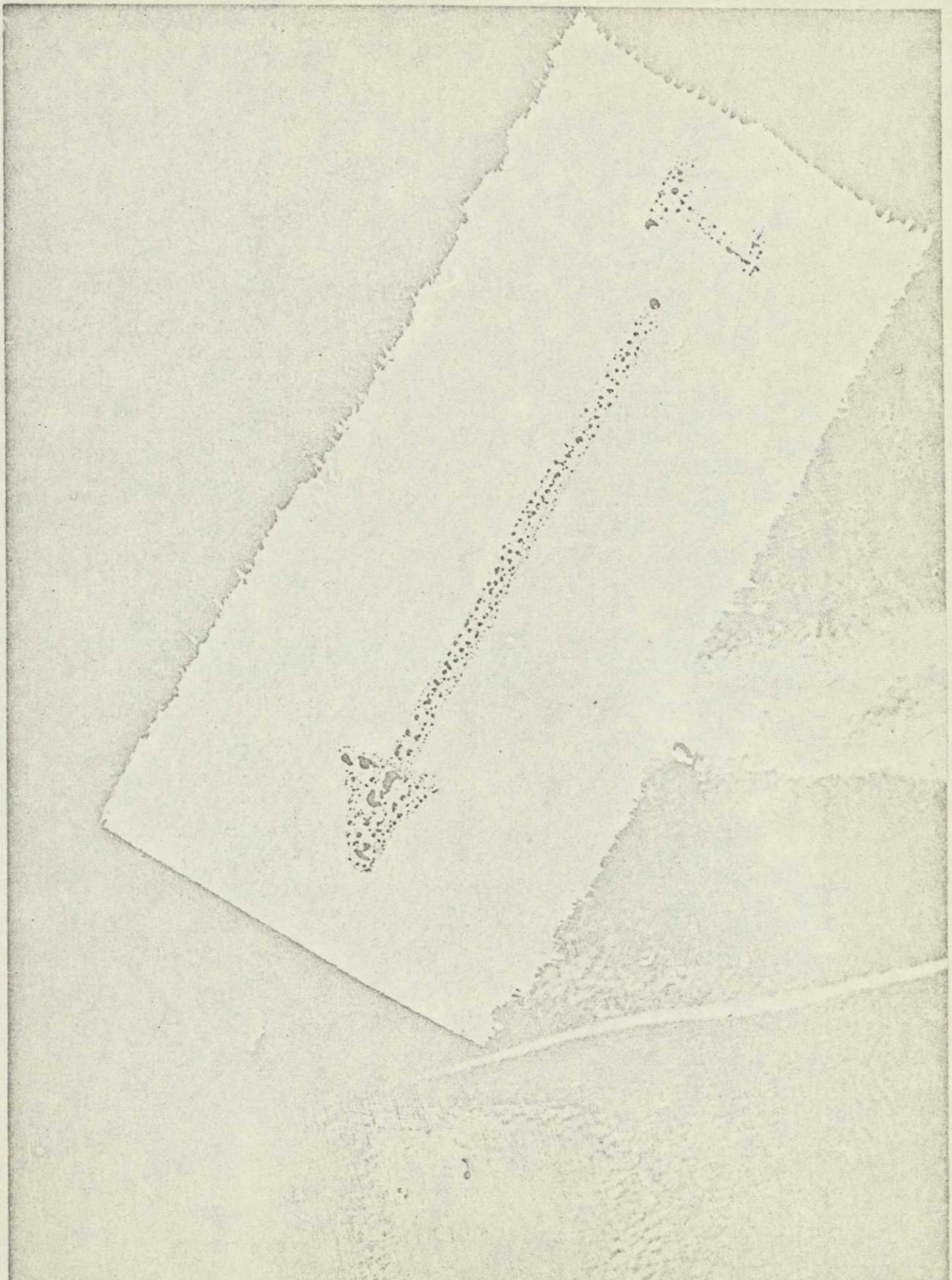


Figure 6-4. Hole in Fuel Bladder

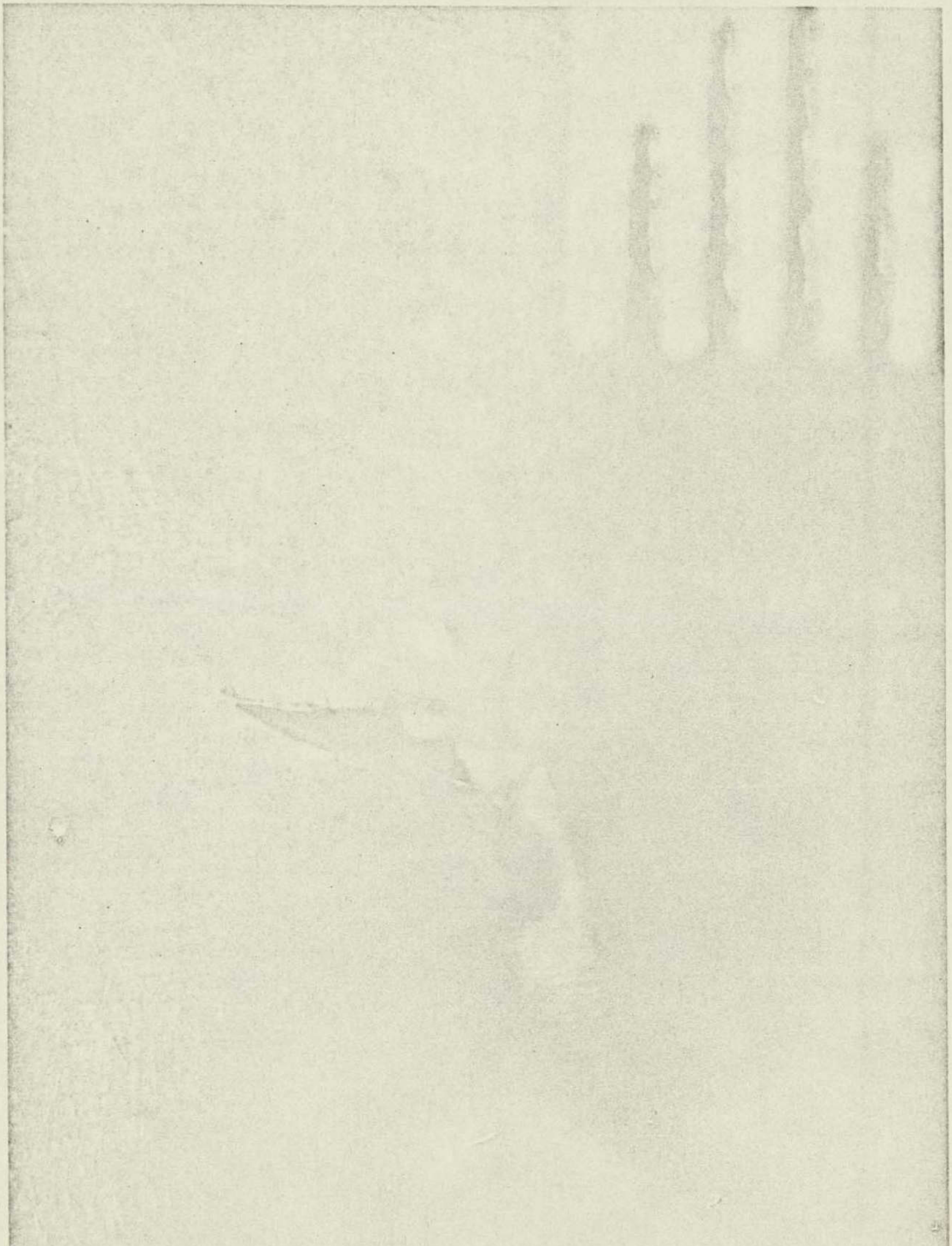


Figure 6-5. Hole in Fuel Bladder Magnified

NOT REPRODUCIBLE

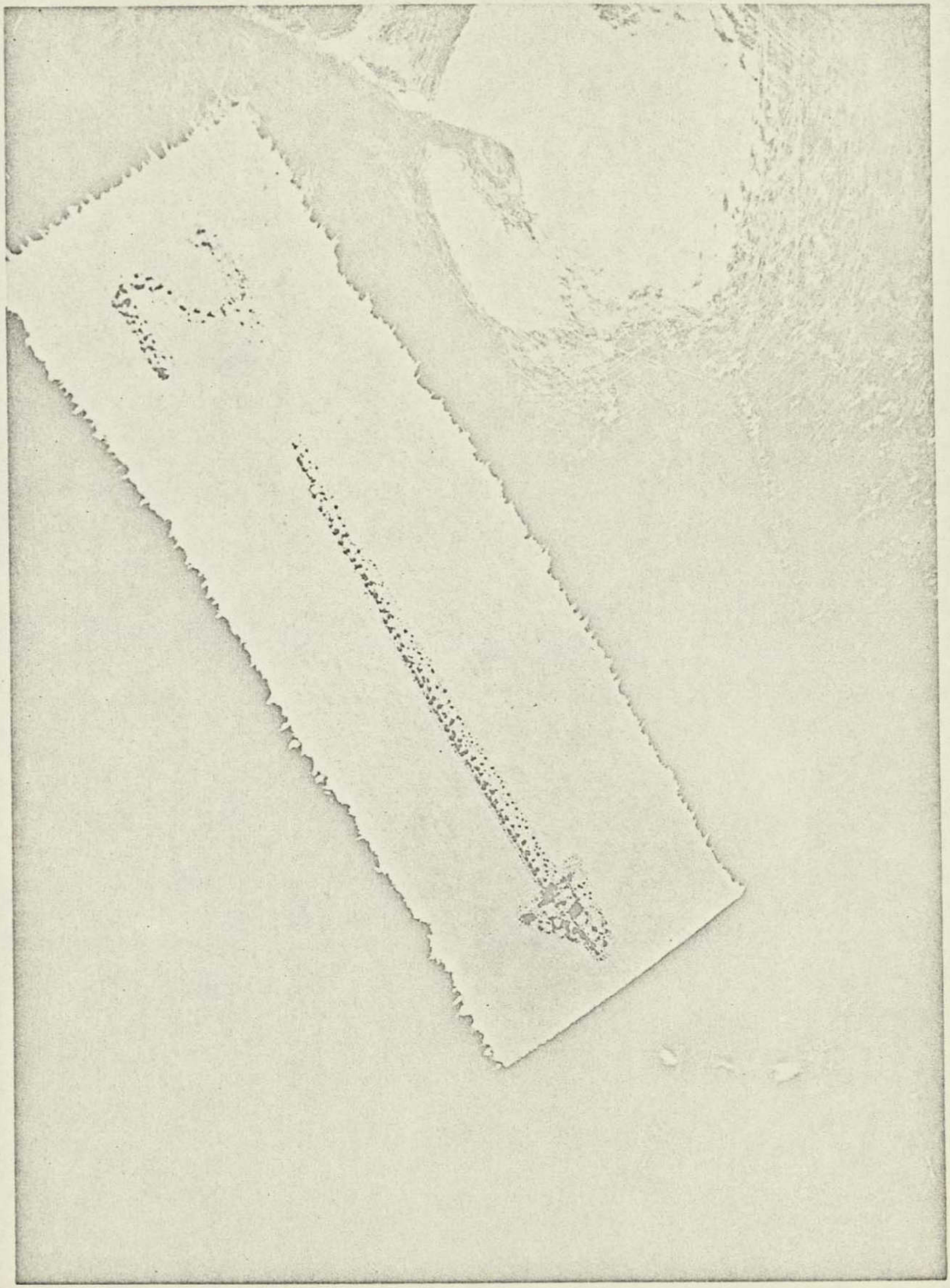


Figure 6-6. Scratches on Fuel Bladder

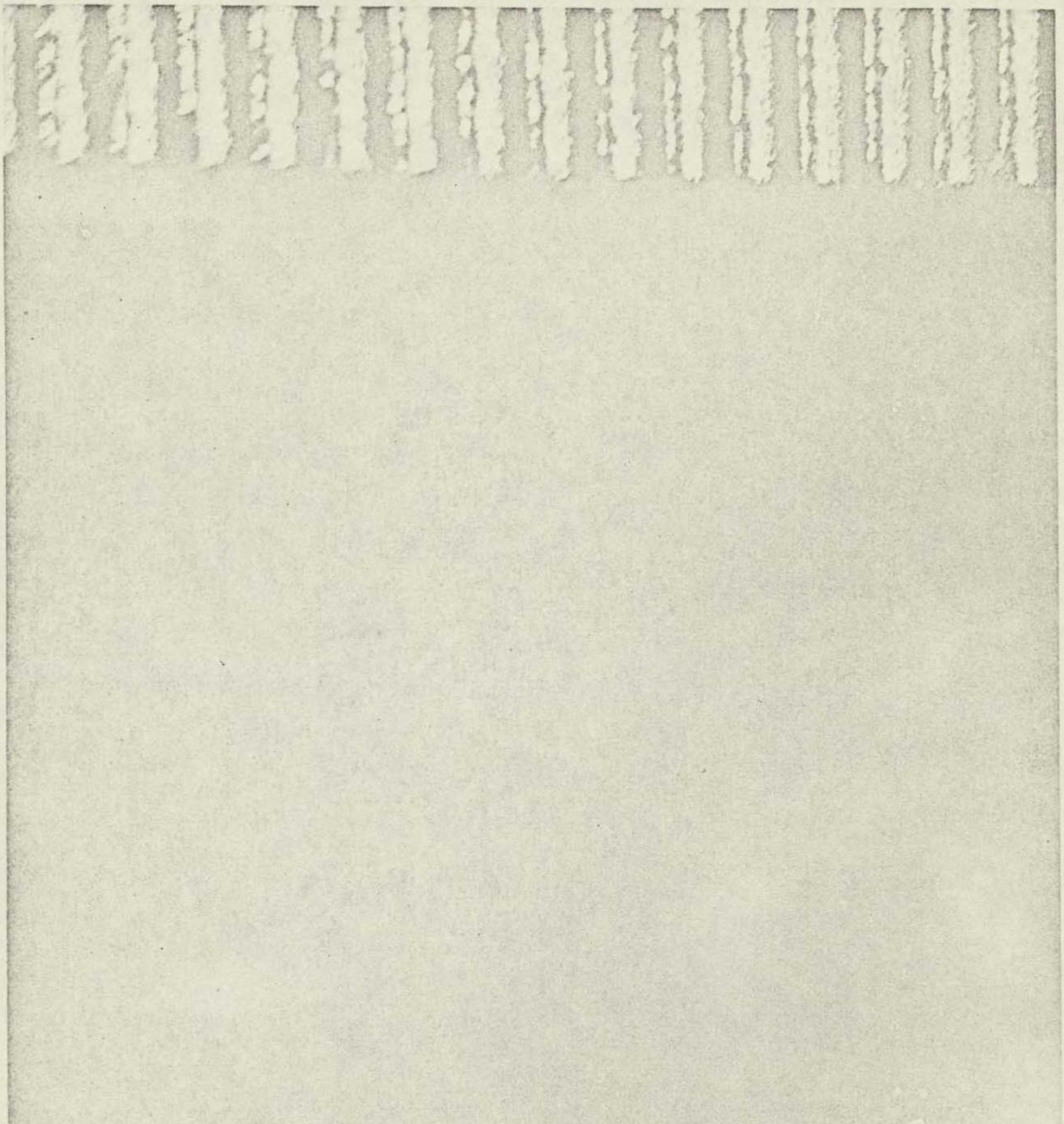


Figure 6-7. Scratches on Fuel Bladder Magnified

Figure 6-9. Large Weld Defect - Upper Standpipe

 0

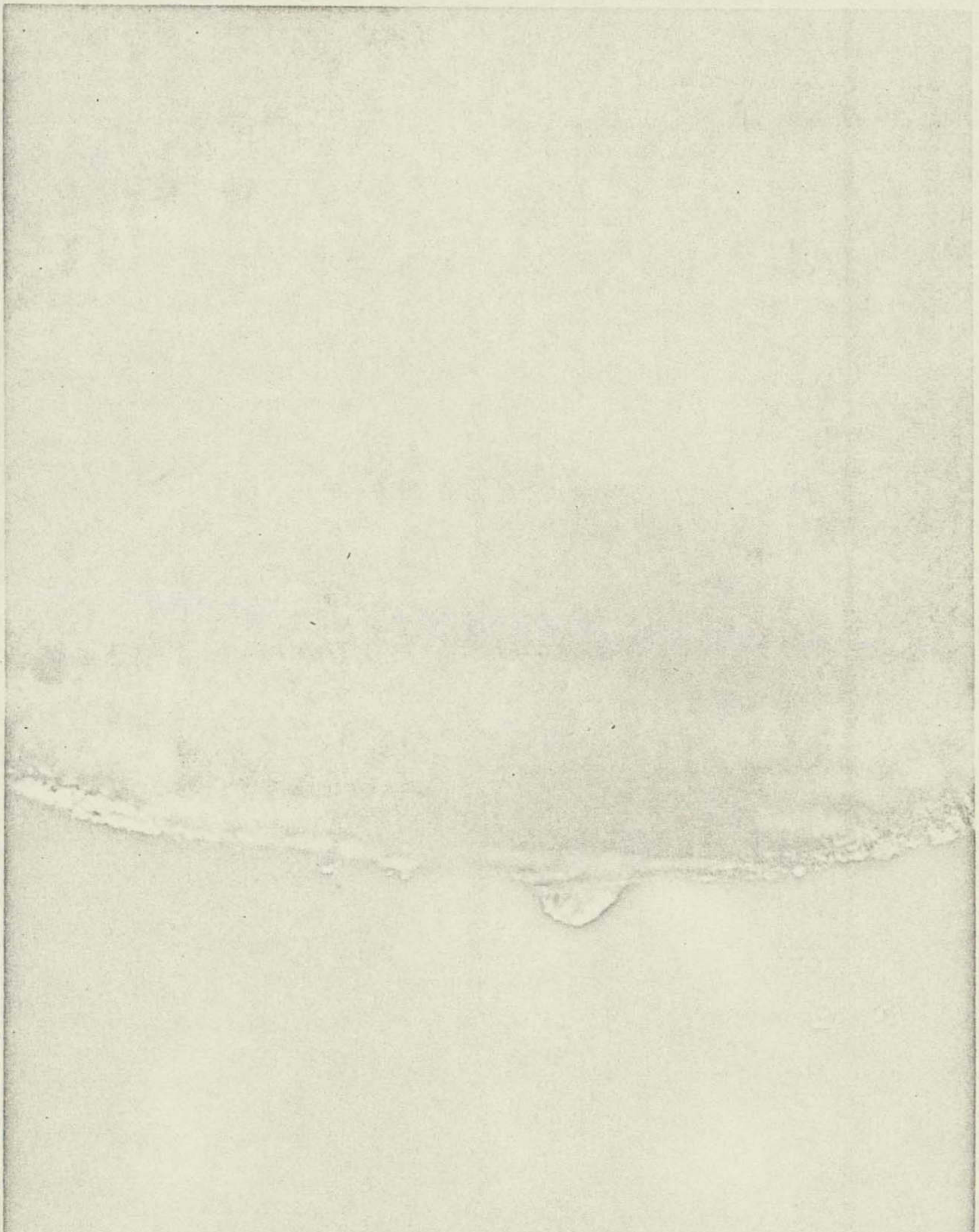


Figure 6-10. Large Weld Defect Profile - Upper Standpipe

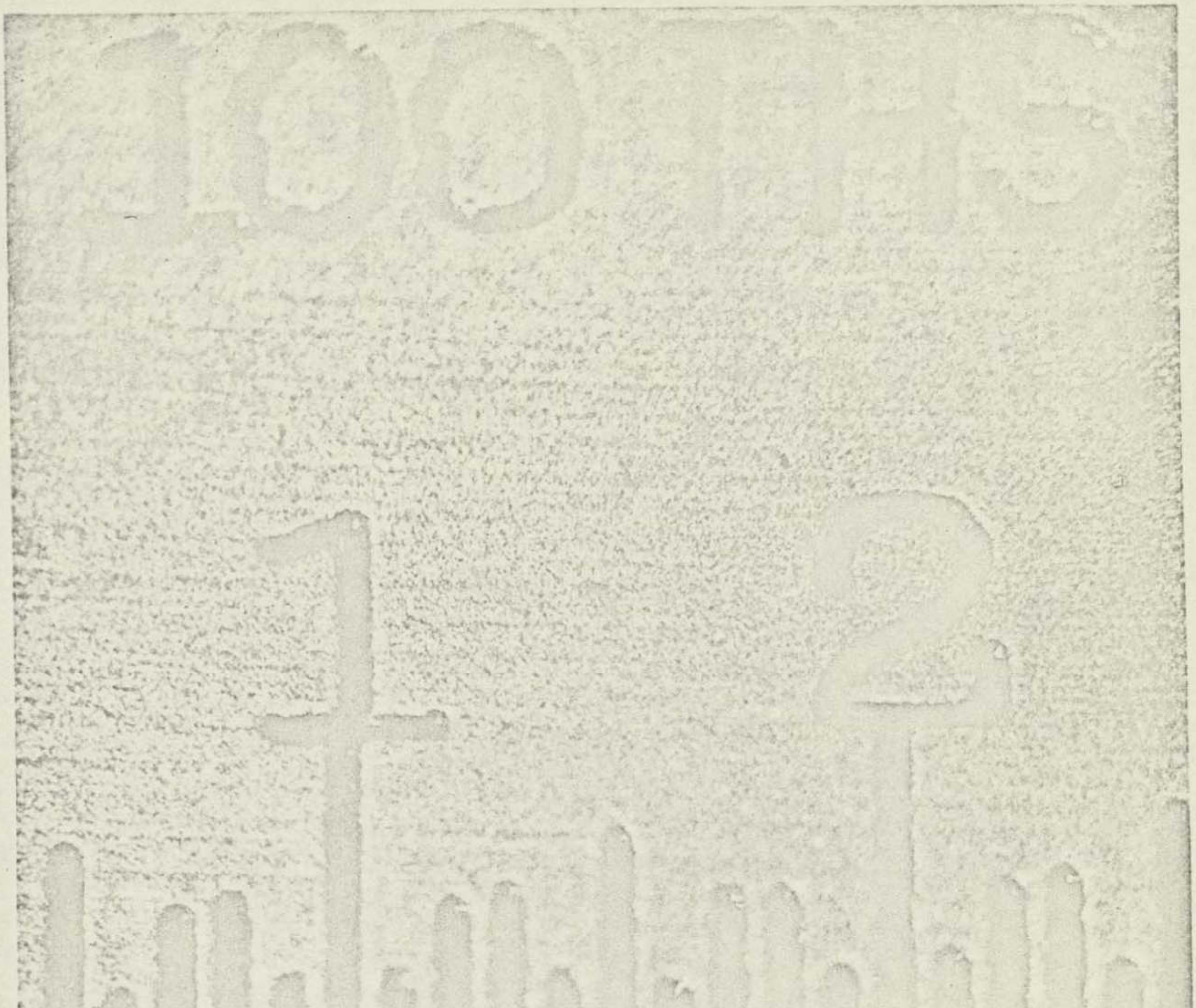


Figure 6-12. Small Weld Defect - Upper Standpipe

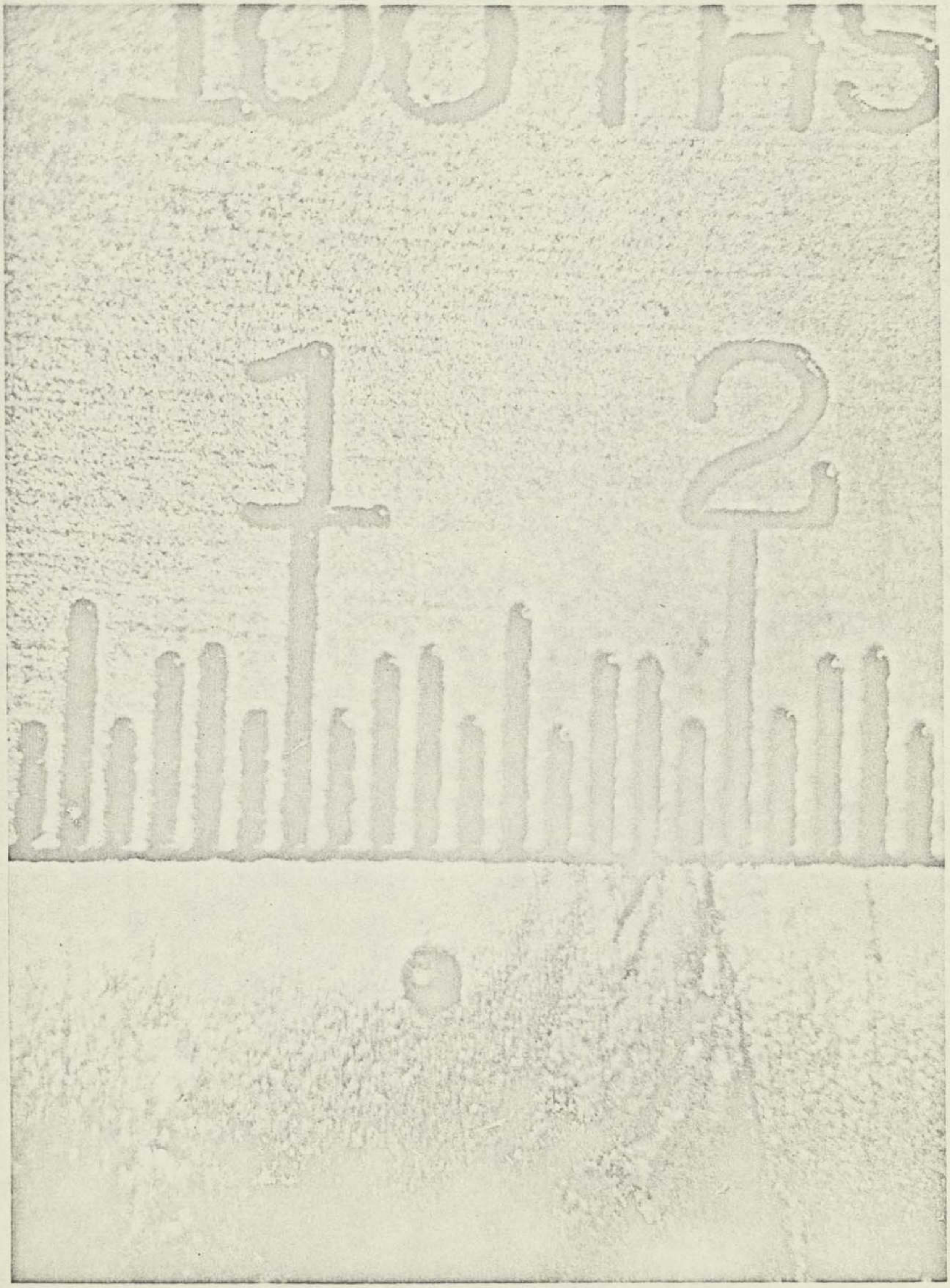


Figure 6-13. Small Weld Defect No. 2 - Upper Standpipe

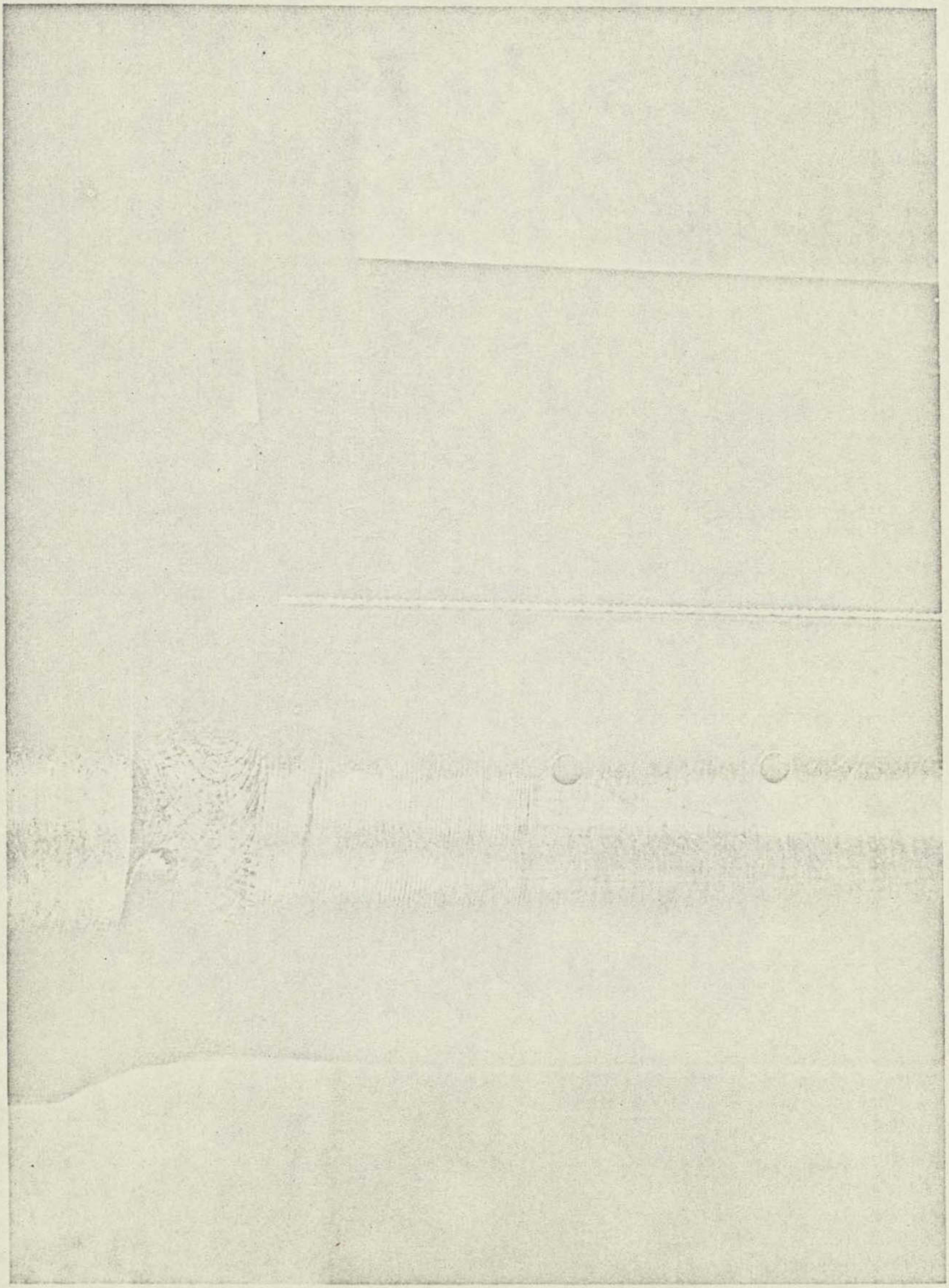


Figure 6-15. Small Weld Defect - Lower Standpipe

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