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**Fueled Viking Generator S/N 106
Acceptance Vibration Test Report**

*Charles G. Anderson, Charles O. Brewer,
and Stanley G. Abrahamson*

June 8, 1976

Monsanto

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Miamisburg, Ohio
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U. S. Government Contract No. E-33-1-GEN-53

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Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
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Price: Printed Copy ~~\$4.00~~ 3.50; Microfiche \$2.25

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Foreword

The organizational responsibility for the Acceptance Vibration Test was as listed below.

Test Supervisor	- C. O. Brewer	- MRC
PMP Operation	- D. L. Fleming	- MRC
	- C. P. Johnston	- MRC
Vibration Equipment	- C. G. Anderson	- MRC
Observer	- S. Macarevich	- Teledyne Isotopes

Abstract

The Viking Generator S/N 106 was vibrated to the Teledyne Isotope Flight Acceptance Schedule (Random Only) with no deviation from normal generator functional output.

Radiographic analysis and power tests before and after the vibration test indicated no change in the condition of the generator.

This work was conducted in the Alpha Fuels Environmental Test Facility at Mound Laboratory.

Purpose

The purpose of this test was to subject Viking Generator S/N 106 to the required flight acceptance test, random schedule.

This schedule simulates the expected Martian reentry.

Methods and Procedures

PRETEST CONSIDERATIONS

Because the Alpha Fuels Environmental Test Facility vibration system had been used for similar tests,¹ only minor modifications were necessary for this test. A new adapter plate was needed to mount the generator to the shaker. The PMP cable and six thermocouple wires were pulled through the conduit from the operating hall to the test cell.

TEST PROCEDURES

The level of testing and other acceptance test criteria were taken from Teledyne Isotope procedure 452A6000414 and incorporated into the Mound Laboratory test procedure. This procedure and the Mound health physics procedure are attached as Appendix A.

Test Results

The results of the test indicated normal functional operation of the generator before, during, and after the test. Radiographic analysis of the generator prior to and after the vibration showed that no detrimental effects were experienced by the generator components. This test

suggests that the Viking flight generators can withstand the vibration which they will experience on a Martian reentry. The data for this experiment are given in Figures 1-5.

Reference

1. C. G. Anderson and C. O. Brewer, LES 8/9 Vibration Test on a Multihundred Watt FSA, MLM-2106 (May 2, 1974), 95 pp.

FIGURE 1 - Random vibration reference spectrum.

```

1 BANDWIDTH, HZ.: 2048
2 FREQUENCY RESOLUTION 64/128/256: 64
FREQUENCY INCREMENT, HZ.: 32
REFERENCE SPECTRUM:
3 INITIAL SLOPE DB/OCT: 3
4 FREQUENCY HZ.: 32
  LEVEL GSQR/HZ.: 0.0032
5 FREQUENCY HZ.: 64
  LEVEL GSQR/HZ.: 0.007
6 FREQUENCY HZ.: 256
  LEVEL GSQR/HZ.: 0.027
7 FREQUENCY HZ.: 992
  LEVEL GSQR/HZ.: 0.027
8 FREQUENCY HZ.: 1984
  LEVEL GSQR/HZ.: 0.0065
9 FINAL SLOPE DB/OCT: 6
ACCEL. LEVEL, GRMS = 5.9776
10 START UP TIME SEC : 1
11 SHUT DOWN TIME SEC : 1
12 TEST TIME HRS,MIN,SEC: 0 1 0
13 3 SIGMA CLIPPING 1=YES 0=NO: 1
CORRECTIONS 1=YES 0=NO: 0
LIST 1=YES 0=NO: 0
PUNCH 1=YES 0=NO: 0
FINISHED 1=YES 0=NO: 1
ACCEL. LEVEL, GHMS = 5.9776
ENTER PARAMETERS 1=YES 0=NO: 0
CORRECTIONS 1=YES 0=NO: 0
LIST 1=YES 0=NO:

```

FIGURE 2 - Computer parameters for vibration test.

FIGURE 3 - X-axis random vibration curve in relationship to reference curve.

FIGURE 4 - Y-axis random vibration curve in relationship to reference curve.

FIGURE 5 - Z-axis random vibration curve in relationship to reference curve.

Appendix A

Fueled Generator Vibration Test Procedure

1.0 OBJECTIVE AND SCOPE

- 1.1 Objective: The fueled generator shall be subjected to a vibration environment to determine its ability to withstand the specified vibration levels and duration.
- 1.2 Scope: The fueled generator will be subjected to sinusoidal and random vibration in three orthogonal axes while in an operational condition. Specific vibration levels and sweep frequencies are contained in Table 1.

2.0 APPLICABLE DOCUMENTS

2.1 Required Documents

Health Physics Procedure
Radioactive Safety Manual
Physical Safety Manual
AFETF Operating Manuals - Set
Generator Assembly

2.2 Information Documents

RTD Calibration Curve
Thermistor Calibration Curve
Generator Performance/Acceptance Criteria

3.0 FACILITIES AND EQUIPMENT

3.1 Alpha Fuels Environmental Test Facility

- 3.1.1 Random Frequency Generator, Time Data
- 3.1.2 XY Recorder
- 3.1.3 M. B. Electronics
  - 3.1.3.1 Shaker, Model C21
  - 3.1.3.2 Exciter, Model 1025
  - 3.1.3.3 Accelerometer, MB304
  - 3.1.3.4 Line Driver
  - 3.1.3.5 Zero Drive Amplifier, N400
- 3.1.4 Vibration Readout Equipment
  - 3.1.4.1 XY Recorder Input Selector, MB N-74
  - 3.1.4.2 Log Converter, Hewlett Packard 7560 AM
  - 3.1.4.3 XY Recorder, Hewlett Packard, 135
  - 3.1.4.4 Oscilloscope, Tektronics
  - 3.1.4.5 True RMS Voltmeter, Ballantine Lab M320

Thrust and Lateral # 1 Axes

Lateral # 2 Axes

FIGURE 1 - Generator and pickup mounting.

3.1.4.6 DC-AC Calibrator, Ballantine Lab M421A

3.1.5 Functional Readout Equipment

3.1.5.1 PMP Meter

3.1.5.2 Digital Voltmeter, Hewlett Packard, 3440A

3.1.5.3 Recorder, Bausch & Lomb, VOM5

3.1.6 Miscellaneous Electrical Equipment

3.1.7 Hand Tools

3.1.7.1 Generator Handling Gloves

3.1.7.2 Torque Wrench

3.1.7.3 Allen Wrench Set

3.1.7.4 Slip Table Wrench Set

3.1.7.5 Open End Wrench Set

4.0 WARNINGS AND CAUTIONS

4.1 Warnings

4.1.1 Exterior surfaces of the generator are hot; therefore, gloves should be worn when handling the generator.

4.1.2 Film badges are to be worn during all testing, monitoring, and handling of fueled generators and during entry into Health Physics-designated exclusion areas.

4.1.3 Any alarms of monitoring equipment will be reported to Health Physics immediately.

4.1.4 Once exclusion areas are marked by Health Physics, the generator will not be moved unless Health Physics or Health Physics-designated personnel are present.

4.1.5 Health Physics will be notified of all damage to the generator.

4.2 Cautions

4.2.1 When handling the generator, use gloves to protect the generator coatings.

4.2.2 Never leave the generator unattended in a closed container other than the shipping container.

4.2.3 The rate of change in the hot junction temperature shall not be permitted to exceed 33°F per 10 min.

4.2.4 The following temperature limits (indicated sensor readings) shall not be exceeded:

Hot junction temperature	1080°F (RTD measurement)
Fin root temperature	350°F (Thermistor measurement)

5.0 PRETEST PROCEDURES

5.1 Basic Requirements

5.1.1 Prior to any generator test, the availability of test equipment and the suitability of the facility for this and other conceivable tests should be carefully ascertained.

- 5.1.2 Assume and delegate responsibilities for generator monitoring and devise protective and/or alarm circuitry for an unattended generator. Also, be familiar with pertinent drawings describing configuration and performance characteristics of the product in normal use and during emergencies.
- 5.1.3 RTG's shall be transferred or located using handling fixture, overhead hoist, hydraulic boom, or approved transfer carts only.
- CAUTION: Lift RTG's using the handling adaptor properly attached to the top lifting lugs. Do not hand carry fueled generators by fins or body.
- 5.1.4 Adequate shielding shall be placed around designated RTG test areas where required prior to generator setup at the location and in accordance with guiding instructions by Health Physics or designated personnel.
- 5.2 Generator Setup
- 5.2.1 Inspect the generator for any anomalies not noted in the log.
- 5.2.2 Perform an initial power check in accordance with procedure. The generator is to remain on load throughout testing at a load voltage of 4.4 V.
- 5.2.3 Generator monitoring shall be performed every 10 min during periods of instability and/or as directed by the cognizant test engineer. The data to be recorded are a hot junction, fin root, output voltage, and current.
- 5.2.4 Connect the monitoring equipment to the generator (Figure 2) to record data in accordance with the data requirements of Paragraph 8.1 and remove any fiberglass insulation from the generator.
- 5.2.5 Rigidly attach the generator to the head of the vibratory by means of the test fixture, oriented for vibration along the axis as defined by the cognizant test engineer (Figure 3).
- 5.2.6 Take a chart record of all functions for zero point and calibration of traces.
- 6.0 TEST PROCEDURES
- 6.1 Perform the first axis sinusoidal vibration test designated in Table 1; continuously record functional data required by Step 8.0.
- 6.2 In sweeping the sinusoidal frequency range, the acceleration applied to the specimen shall be controlled according to the output of a reference accelerometer located at the generator mounting interface and passed through a tracking filter correlated to the shaker driving frequency.
- The applied vibration shall be recorded on an x-y plot of the filtered reference signal as a function of driving frequency, and the deviation from that specified shall not exceed $\pm 10\%$ over the frequency range.
- 6.3 Warning: (Applicable during sinusoidal and random vibration)
- During vibration, the generator hot junction temperature may rise. If a hot junction temperature in excess of 1080°F is observed, testing may be continued only at the discretion of the design engineer, if present, or of the test engineer. In any case of a hot junction temperature greater than 950°F , testing shall be discontinued at the conclusion of the vibration run if temperature does not return to the normal operating value.
- Should an open or short circuit occur as a result of vibration, as indicated by a sudden decrease in the monitored output power, discontinue testing immediately and take corrective action as designated by the cognizant test engineer.

FIGURE 2 - Connection diagram.

FIGURE 3 - Viking generator axes designation.

- 6.4 Continuously record operating functional data by manual and chart recordings during the above test.
- 6.5 Verify, by the x-y plot, that the specified vibration input has been maintained over the test frequency range.
- 6.6 Visually inspect the generator and record any adverse physical condition in the test log. Verify and record acceptable condition on the Operation Sheet.
- 6.7 Equalize for a random vibration input designated in Table 1. The acceleration spectral density applied to the generator, as determined by an analyzing filter with a maximum bandwidth of 50 Hz, shall be within ± 3 dB over the frequency range.
- 6.8 In setting the vibration equipment for proper filtering and control, it may be necessary to apply some vibrational energy to the generator prior to the actual test. In this case, the RMS vibration level being programmed will be kept to a minimum. If it is necessary (outside the actual test) to exceed 20% of the test value, it will be necessary to record the duration of the application of such additional environment, as well as the amplitude of such pretesting, in the test log.
- 6.9 Subject the generator to the designated random vibration spectrum, continuously recording functional data.
- 6.10 Verify by means of the RMS Acceleration Meter, that the applied overall vibration spectrum level is in compliance with the requirements of Steps 6.7 and 6.9 and record in log.
- 6.11 Perform a power check in accordance with procedure if designated by the cognizant test engineer.
- 6.12 Visually inspect the generator and record adverse physical condition in the test log. Verify and record acceptable condition on the Operation Sheet.
- 6.13 Reposition the generator for vibration along a second axis designated by the cognizant test engineer.
- 6.14 Subject the generator to the designated sinusoidal vibration per Steps 6.1 and 6.2 while continuously recording functional data of Step 8.0.
- 6.15 Repeat Steps 6.7 through 6.12 for application of random vibration.
- 6.16 Reposition the generator for vibration along a third axis designated by the cognizant test engineer.
- 6.17 Subject the generator to the designated sinusoidal vibration, continuously recording functional data of step 8.0.
- 6.18 Repeat Steps 6.7 through 6.12 for application of random vibration.
- 7.0 POST-TEST PROCEDURES
- 7.1 Remove the generator from the vibration equipment and conduct a complete visual inspection. Record physical condition in the test log.
- 7.2 Proceed with the next scheduled operation as directed by the cognizant test engineer.
- 8.0 DATA REQUIREMENTS
- 8.1 Measurements
- 8.1.1 Prior to and after the vibration test and where designated, a power check in accordance with procedure will be performed. A power check or data set

after one axis of vibration may be considered as the precheck prior to the following axis of vibration at the discretion of the test engineer when performed.

- 8.1.2 A visual inspection will be made after each axis of vibration, and the generator physical condition will be recorded in the test log when anomalies are detected.
- 8.1.3 During vibration of the generator, output voltage and current shall be continuously recorded in the test log and on a chart recorder or oscillograph. Hot junction and fin root temperature shall be continuously recorded in the test log (Operational Functional Data).
- 8.1.4 Also recorded during sinusoidal vibration will be the input responses of a reference accelerometer located in such a position as to sense the representative G-loading at the generator mounting points.
- 8.1.5 During random vibration a spectral density plot of the equalization spectrum shall be recorded by means of an x-y plotter, using the response of the reference accelerometer.

8.2 Tolerances

The maximum allowable tolerances on test conditions shall be as follows:

Sinusoidal Vibration Level	±10%
Vibration Frequency	± 2%
Random Power Spectral Density	± 3 dB
Time	+5%, -0%

8.3 Compliance Criteria

- 8.3.1 The normal progress of events prescribed by this procedure shall be documented in test logs which are identified as to test, test article, test procedure, and operator. Deviations from the terms of this procedure shall be signed off by cognizant engineering personnel and a quality representative when present. Such deviations from this procedure which might result in damage to the test article or failure to comply with the acceptance criteria of Ref. Par. 2.0 shall be documented.
- 8.3.2 All incidents of noncompliance with the terms of this procedure and failures to meet criteria of acceptance shall require engineering disposition prior to continuation of normal testing.

8.4 Complete Data Sets

- 8.4.1 A complete set of data shall be recorded before and after each axis of testing to determine the instrumentation status. Generator stability need not be demonstrated to validate this record.
- 8.4.2 Complete sets of data shall include:

- Date and time of measurement
- Hot junction temperatures
- Fin root temperatures
- Load voltage
- Load current
- Open circuit voltage

- 8.4.3 Computed parameters to be shown on the data sheets shall include:

$$\text{Power Output } (P_o) = E_L \times I_L = \text{watts}$$

where E_L is Load Voltage and I_L is Load Current

$$\text{Internal Resistance } (R_i) = \frac{E_{oc} - E_L}{I_L}$$

where E_{oc} = Open Circuit Voltage

- 8.4.4 When making load or insulation changes which may affect generator hot junction temperatures by 10°F or more, "short sets of data" (Figure 4) consisting of:

Fin root temperature
Hot junction temperature
Output voltage
Output current

shall be obtained and recorded in intervals of 10 min or less.

8.5 Generator Monitoring

- 8.5.1 If the hot junction change rate approaches and exceeds 30°F/10 min or if the rate is in danger of exceeding maximum limits, intensive hot junction temperature monitoring shall be instituted whereby hot junction temperature will be recorded in intervals not greater than 2 min. Short set requirements are waived during periods of intensive hot junction temperature monitoring.
- 8.5.2 After completion of power input, load voltage, or insulation adjustments, and when the hot junction temperature change rate is diminishing and less than 10°F/10 min, the frequency of recording short sets may gradually be diminished to one set per 30 min; however, close performance monitoring shall continue until the hot junction temperature change rate is down to 2°F/30 min or less and until a set of data has been attained. Automatic alarm systems shall be engaged throughout all periods of nonintensive monitoring. Automatic alarm systems shall, as a minimum, monitor hot junction temperature or load voltage.

9.0 HEALTH PHYSICS PROCEDURE

- 9.1 The building will be checked out by a Health Physics surveyor before the generator is removed from the shipping cask.
- 9.1.1 The air sample pump will be started and new air sample filters will be installed.
- 9.1.1.1 The time the air sample filters are changed will be recorded.
- 9.1.1.2 The changed air sample filters will be counted by the SM counting room for background reference.
- 9.1.2 The stack monitors will be checked out to ensure they are in operating condition.
- 9.1.2.1 New filter media will be installed.
- 9.1.2.2 The instruments will be set on the X1 scale, alarm at 50 counts/min, and the air flow at 40 liters/min.
- 9.1.3 The air monitors in the building will be checked with a source and set to operating levels.
- 9.2 Cell 107 shall be prepared by the following:

- 9.2.1 Five to ten general wipes shall be taken throughout the cell to check for levels of contamination.
- 9.2.2 A plastic sheet shall be installed over the entrance to the cell to act as a contamination control barrier between the cell and the cell main door and operating corridor 114.
- 9.2.3 Film badges shall be worn at all times by the operating personnel.
- 9.2.3.1 Personnel working with the generator will be issued wrist badges.
- 9.2.4 Work shall be done in two-piece whites, safety shoes, and respirators (worn either in use or around the neck).
- 9.2.5 The operating corridors will be treated as a yellow control zone.
- 9.3 The generator will be monitored for unloading inside the cell.
- 9.3.1 Gamma-neutron readings shall be taken on the shipping container and on the generator.
- 9.3.2 Wipes shall be taken on the generator to check for alpha contamination which may be present from a possibly ruptured generator.
- 9.3.3 During the unloading of the generator, respiratory equipment shall be worn until levels of contamination are determined.
- 9.3.4 If no high levels of contamination are present, the generator may be prepared for the test. When the preparation of the generator is completed, the personnel in the cell shall be checked for contamination upon their clothes and person before leaving the cell. After checkout, personnel shall leave the cell by the hole in the plastic barrier, and the plastic barrier shall be sealed and the cell main door shut.
- 9.4 Before and during the test, Health Physics shall monitor the outside operating corridors by:
  - 9.4.1 Performing gamma-neutron surveys at the cell window and walls.
  - 9.4.2 Checking air samples in the corridors.
  - 9.4.3 The air monitor inside the cell shall be observed to notice any increase in the meter or the alarming of the monitor by the flashing of the red visual alarm if a release has occurred.
  - 9.4.4 The air monitors in the corridors shall be checked for increases on the meters and possible alarming.
  - 9.4.5 Spot wipes shall be taken in the corridors to check contamination levels.
- 9.5 Upon reentry into the cell, the cell main door shall be opened and the plastic barrier shall be wiped on the outside to check for alpha contamination. The plastic barrier shall then be cut and wipes shall be taken on the inside of the plastic to check for contamination. If no or low-level contamination is present, operating personnel shall be allowed to enter the cell for preparation of the generator. General wipes shall be taken on the inside of the cell for contamination checks.

Exiting from the cell shall be in the same manner as prescribed in 9.2.
- 9.6 If, during the preparation or testing of the generator, the generator and source should accidentally rupture, appropriate Health Physics actions shall be taken to protect all operating personnel from high levels of contamination and the spread of contamination from the cell.

- 9.7 After the tests are completed on the generator:
- 9.7.1 All air samples shall be collected and counted.
- 9.7.2 Wipe surveys shall be taken of cell 107, the operating corridors, and all areas in the yellow control zone.
- 9.7.3 A water sample from cell 107 will be drawn if desired.
- 9.7.4 Records will be gathered and a report will be issued on the Health Physics aspects of the test.
- 9.8 The generator will be loaded into the shipping cask at the completion of the test.
- 9.8.1 The Health Physics surveyor will take the necessary surveys to return the generator into the shipping cask.

Table 1

ACCEPTANCE VIBRATION

Sinusoidal:

Frequency Range:	5 to 250 to 5 Hz
Acceleration Amplitudes:	5-19 Hz @ 0.25 in. D.A. 19-250 Hz @ 5.0 G peak
Logarithmic Sweep Rate:	6 octaves/min
Number of Sweeps:	1

Random:

20 to 250 Hz:	+3 dB/octave
250 to 1000 Hz	0.027 G^2 /Hz
1000 to 2000 Hz	-6 dB/octave

Overall Level: 6.0 G(RMS)
Duration: 60 sec

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