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MASTER

SELENIDE ISOTOPE GENERATOR

for the

GALILEO MISSION

Galileo-1632

TELEDYNE ENERGY SYSTEMS

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Pictured on the cover is Galileo's drawing of the solar system, which includes the four satellites of Jupiter he discovered in the 1600's. A Renaissance professor, inventor and astronomer, Galileo perfected the telescope with which he made his Jupiter discoveries. The 1982 NASA mission to Jupiter is named in his honor. Like Galileo and his telescope, the NASA mission to the far reaches of outer space will be contributing to Mankind's never ending quest for knowledge.

SELENIDE ISOTOPE GENERATOR

for the
GALILEO MISSION

ETG ACCEPTANCE TEST PLAN

TES-2865-30

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I. INTRODUCTION

Electrically-Heated Thermoelectric Generators (ETGs) shall be subjected to a flight level acceptance test program to certify the design of the SIG/Galileo flight generator. Each test in the test program is designed to simulate critical conditions and environments associated with generator ground handling, spacecraft launch and in-space operations. Successful completion of the test program shall be evidenced by the satisfactory performance of the ETG during and after the application of the various test environments.

The ETG Acceptance Test Plan is designed to specify the testing sequence, the severity of the applied test environments and the acceptance criteria for assessing generator performance. Two (2) test facilities shall be required for the execution of the proposed test program. The Teledyne Energy Systems (TES) facility in Timonium, Maryland shall be the site for the ETG thermal performance evaluation testing; and the Naval Surface Weapons Center (NSWC) facility in White Oak, Maryland, shall be the site of the dynamic, mass-properties and magnetic properties testing.

II. TEST OBJECTIVE

The objective of this document is to outline the flight acceptance test program necessary to qualify the SIG generator design for the Galileo Mission. ETGs shall be subjected to the following tests: functional performance, random vibration, mass properties, magnetic properties and thermal vacuum testing.

The performance parameters of each ETG shall be monitored and recorded both during and after the application of the environmental conditions dictated by the test. Successful completion of the testing program shall be characterized by satisfactory performance of the ETG during and after the tests without sustaining physical damage or performance degradation.

In addition to outlining the test requirements, this document also specifies the requirements for generator handling, generator transportation and storage, generator security and Quality Control surveillance.

III. REFERENCE DOCUMENTS

The following documents* are applicable to the extent specified herein.

SIG110010	ETG Generator Assembly
SIG114001	Generator Test and Operations Sequence
SIG114002	Generator Vibration Test Procedure
SIG114003	Generator Mass Properties Test Procedure
SIG114004	Generator Thermal Vacuum Test Procedure
SIG114006	Generator Gas Exchange Procedure
SIG114008	Generator Electrical Isolation Test Procedure
SIG114010	ETG/RTG Handling and Operating Procedure
SIG114011	Generator Magnetic Properties Test Procedure
SIG114012	Load Voltage Parametric Test Procedure
SIG114013	Generator Hot Leak Test Procedure
SIG114014	Procedure for Installation of ETG in Shipping Container
MIL-STD-810C	Military Standard Environmental Test Methods, 10 March 1975

*These documents are for future reference and most have not been prepared at this time.

IV. TEST EQUIPMENT AND FACILITIES

A. TEST SPECIMEN

ETGs (SIG110010) will be tested; the generator will be heated electrically. It will have the same outside configuration as the flight generators including mounting points, heat pipes, radiator structure, and emissive coating.

B. TESTING FACILITIES

The Teledyne Energy Systems (TES) facility in Timonium, Maryland shall be the site of the initial generator performance test, and the thermal vacuum test. The Naval Surface Weapons Center (NSWC) facility, in White Oak, Maryland, shall be the site of the vibration test, the mass properties tests and the magnetic properties test.

C. EQUIPMENT

Table 1 specifies the major equipment and its location needed to perform each acceptance test. All handling equipment attaching to the ETG will be provided by TES. Lifting equipment needed to move the generator will be provided by the facility where the tests are being conducted.

For all tests, TES will provide the heater power supply, load bank, test cabling and measuring equipment needed to monitor the generator while it is hot. NSWC will provide the peripheral equipment needed to record or monitor the outputs associated with their environmental test equipment and the facility power required for operation of the TES equipment.

TABLE 1
LOCATION AND EQUIPMENT FOR ETG ACCEPTANCE TESTS

<u>Test</u>	
Thermal Vacuum Test	TES - CVC 8 ft. Horizontal Chamber
Random Vibration	NSWC - Bldg. 20, Room 167; Ling Model 335 shaker with Ling ASDE-40 synthesizer
Mass Properties	NSWC - Bldg. 20; C.G. and M.O.I. - Space Electronics, Inc., Model KGR2000-3
Magnetic Properties	NSWC - Bldg. 203 - Magnetic Structures Test Facility

D. TEST FIXTURES

TES will design and fabricate fixtures for the thermal vacuum test, mass properties test, and magnetics test. NSWC will design and fabricate the vibration fixture with inputs from TES for mounting provisions.

E. TEST PERSONNEL RESPONSIBILITIES

NSWC personnel are responsible for operation of the test equipment at their facility and the placement of any sensors or test instrumentation. TES personnel are responsible for the operation and handling of the ETG.

V. TEST PLAN

A. TESTING SEQUENCE AND SCHEDULE

The sequence of tests for the ETG is shown in Table 2 and in SIG114001, Generator Test and Operations Sequence, along with the facility where the test will be conducted. The acceptance tests listed in this table will be conducted during the period July through August 1979. Engineering performance tests and a life test (not part of the acceptance test) will be conducted on ETG, S/N-1, following the acceptance tests and will continue through March 1982.

Prior to beginning the acceptance test, initial performance tests will be conducted on the ETG at TES to obtain a baseline of the generator performance. A steady-state E-I curve per SIG114012 will be generated at the design heat input and fin root temperature. Data will be obtained at several output voltages including 30 ± 0.5 volts. Insulation "booties" may be used to keep the fin root temperature at the design point.

An electrical isolation test per SIG114008 will also be performed. A measurement will be made of the D.C. resistance between the electrical circuit and the ETG housing with 100 volts imposed between a power output lead and the housing. The test will be performed at the design heat input and fin root temperature at a load voltage of 30 ± 0.5 volts.

These tests will be conducted in a laboratory air environment. The tests will be performed twice; the first time with the ETG evacuated and the second time after the ETG is backfilled with gas per SIG114006. This second test is being performed to establish an acceptance criteria for the functional performance tests when the generator is operating with a gas fill.

TABLE 2
ACCEPTANCE TEST SEQUENCE FOR ETG

<u>Acceptance Test Description</u>	<u>Test Procedure Number</u>	<u>Test Facility</u>
Random Vibration*	SIG114002	NSWC
Mass Properties*	SIG114003	NSWC
Magnetic Properties*	SIG114011	NSWC
Thermal Vacuum Test*	SIG114004	TES

*Functional performance tests will be made before and after this test.

All data from these tests will be recorded on data sheets as read from wattmeters, digital voltmeters, and digital thermometers. Continuous recording equipment will be used to monitor key temperatures on the generator such as heater, hot junction, cold junction, and fin root.

The following sections describe in detail the tests listed in Table 2.

B. FUNCTIONAL PERFORMANCE TEST

Functional performance tests will be conducted to verify that the ETG meets specified requirements before and after each environmental test as indicated in Table 2. The ETG may be operated on the test fixture during these tests so long as the generator orientation is the same for both the "before" and "after" tests. The tests can be performed with the generator evacuated or filled with gas. The initial performance tests described previously will be used to determine the acceptance criteria for the gas filled tests since the hot junction will be colder in this test than for the evacuated condition.

All functional tests will be performed at the design heat input and fin root temperature and with the generator output voltage at 30 ± 0.5 volts.

Functional testing consists of measuring the output power at the above conditions per SIG114010 and performing an electrical isolation test per SIG114008. Data will be recorded on data sheets. Continuous recording equipment will be used to monitor key temperatures.

C. RANDOM VIBRATION TEST

The ETG will be subjected to a high frequency random vibration test while operating at the design heat input with the fins uninsulated in air, and at a load voltage of 30 ± 0.5 volts. The test duration shall be one (1) minute in each of the three ETG axes using the flight acceptance test levels given in Figure 1. The ETG shall be rigidly attached to the test fixture using the attachment points for the RTG/spacecraft mounting surface with the orientation such that the heat pipes are in a vertical refluxing position for all tests. The generator will be filled with gas for this test.

The output of the control accelerometers will be recorded continuously during the test and an analysis made to show that the test spectrum matches that given in Figure 1 within the specified tolerance. The output power and key generator temperatures will also be recorded continuously during the vibration test.

D. MASS PROPERTIES TEST

The weight, center of mass, and moments of inertia about the principal axes of the ETG will be measured while the generator is filled with gas, not operating, and at room temperature. All extraneous cabling will be removed during the tests. The ETG weight will be measured using a load cell. The center of mass and moments of inertia will be measured using the Space Electronics, Inc., Model KGR2000-3 Mass Properties System.

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The weight and the center of mass and moments of inertia about the principal axes of the ETG will be recorded on data sheets.

E. MAGNETIC PROPERTIES TEST

The magnetic properties of the ETG will be measured with the generator at room temperature. A current of 8.0 ± 0.1 amp will be forced through the thermoelectric circuit using an external D.C. power supply during the magnetics test.

The ETG will be placed on a test fixture and rotated about its Y and Z axes as the residual magnetic field is measured at a distance of one meter from the center of mass. If required, a distance greater than one meter can be used and the data reduced to that at one meter. The ETG will then be demagnetized along the Z axis in a peak magnetic field of 4×10^{-3} tesla (40 gauss) after which the residual magnetic field will again be mapped.

The measured magnetic field will be recorded continuously during the mapping process.

F. THERMAL VACUUM TEST

The ETG will be returned to TES from NSWC still charged with gas, a portion of which will be helium. The generator will be placed in the vacuum chamber, heated to the normal operating fin root temperature and helium leak checked per SIG114013, Generator Hot Leak Test Procedure.

The generator will then be evacuated and operated at steady state for seven (7) days at the design heat input conditions at a load of 30 ± 0.5 volts. The chamber pressure will be maintained at less than 10^{-5} torr and the sink temperature presented by the chamber walls will be representative of sink temperatures during the SIG/Galileo mission. The generator will be orientated with its Z axis horizontal such that the operation of the heat pipes is assured.

Measurements will be taken of power input and output and key temperatures such as heater, hot junction, cold junction, fin root, radiator (at several locations), and sink.

VI. TESTING COMPLIANCE CRITERIA

A. TESTING TOLERANCES

Table 3 lists the test tolerances to be held during the ETG acceptance testing.

B. STANDARD AMBIENT CONDITIONS

All measurements and tests shall be made at the following conditions:

Temperature	$23^{\circ} \pm 10^{\circ}\text{C}$
Relative humidity	$50\% \pm 30\%$
Atmospheric pressure	$725 \begin{smallmatrix} + 50 \\ - 115 \end{smallmatrix} \text{ mm Hg}$

C. TEST ACCEPTANCE CRITERIA

The criteria by which a test is determined to be successful is specified in Table 4. Successful completion of all tests in this document is required for final acceptance of the ETG.

D. COMPLIANCE CRITERIA

The normal progress of events prescribed by a procedure shall be documented in test logs which are identified as to test, test article, test procedure and operator. Deviations from the terms of a procedure where authorized by the procedure shall be signed off by cognizant Engineering personnel and a Quality representative when present. Such deviations from a procedure shall be documented by an RS tag and referred to the Failure Review Board.

TABLE 3
TOLERANCES FOR ETG ACCEPTANCE TESTS

<u>Condition</u>	<u>Tolerance</u>
Temperature	$\pm 2^{\circ}\text{C}$
Power	$\pm 1/2\%$ of full scale meter reading
Voltage	$\pm 1/2\%$ of reading
Current	$\pm 1/2\%$ of reading
Time	$\pm 5\%$
Pressure	
1 to 0.1 atmosphere	$+ 0$ $- 5 \%$
0.1 atmos. to 10^{-3} torr	$\pm 5\%$
10^{-3} torr to 10^{-4} torr	$\pm 10\%$
10^{-4} torr to 10^{-5} torr	$\pm 15\%$
10^{-5} torr to 10^{-6} torr	$\pm 30\%$
10^{-6} torr and below	$\pm 50\%$
Random Vibration	per MIL-STD-810C
	$+ 3, -1.5$ db 10 - 500 Hz
	± 3 db 500 - 2000 Hz
Frequency	$\pm 5\%$ or ± 1 Hz, whichever is greater
Magnetics Tests	
mapping distance	± 1 cm
location of C. G. from rotation axis	± 5 cm
turntable angular position	$\pm 3^{\circ}$
field strength	± 1 nanotesla
repeatability of measurements	$\pm 5\%$ or ± 2 nT, whichever is greater
demagnetizing field	$\pm 5\%$
Mass Properties	
Mass	$\pm 0.2\%$
C. G. location	± 0.05 cm in each axis
Moments of inertia	$\pm 1 \times 10^{-3}$ kg-m ² (3 lb-in ²)

TABLE 4
ACCEPTANCE CRITERIA FOR ETG TESTING

<u>Test</u>	<u>Acceptance Criteria</u>
Random Vibration	No physical damage to ETG. Output power steady within TBD watts.
Mass Properties	N/A
Magnetic Properties	Maximum dipolar field of 10×10^{-9} tesla and maximum quadrapole and higher order fields of 40×10^{-9} tesla after specified demagnetization.
Thermal Vacuum	Minimum output power - TBD watts at 30 volts.
Functional Performance	<u>Vacuum inside</u> Minimum output power - TBD watts at 30 volts. Minimum isolation resistance - TBD ohms. <u>Gas inside</u> Minimum output power - TBD watts at 30 volts. Minimum isolation resistance - TBD ohms.

Deterioration or change in performance of the ETG that in any way prevents the ETG from meeting acceptance criteria shall be reported as a failure subject to standard Quality Engineering disposition. All incidences of non-compliance with the terms of a procedure and failures to meet criteria of acceptance shall require Corrective Action Board disposition of the applicable RS tag prior to continuation of normal testing.

E. SURVEILLANCE REQUIREMENTS

During all testing, a Quality Control representative or a designated alternate will be present. JPL/Galileo personnel shall be notified one week prior to all acceptance tests and invited to witness tests.

F. CALIBRATION REQUIREMENTS

The proper calibration status of all instrumentation readout devices shall be verified prior to initiation of testing.

VII. GENERATOR HANDLING, STORAGE, AND TRANSPORTATION REQUIREMENTS

A. ETG MONITORING PROVISIONS

The ETG will be monitored only during those tests while the generator is hot. While the generator is cold such as transport between test facilities, unattended overnight storage, and extended storage in a security area, no monitoring is required.

B. ETG STORAGE PROVISIONS

No special storage provisions for the ETG are required. The generator may be left on a test fixture or stored in any convenient location away from the test facility. The only requirement is that the generator is protected during storage. If the ETG is removed from a test facility for storage, it will be placed in its shipping container. The Shipping Container Installation Procedure (SIG114014) defines this operation.

C. TRANSPORTATION REQUIREMENTS

Teledyne Energy Systems shall provide transportation for the ETG to and from the NSWC test facility. NSWC shall provide transportation for the ETG under TES supervision, as necessary, during the test interval at their facility. All transportation to and from a test facility or storage site will be performed with the ETG in its shipping container. Proper handling of the ETG is described in SIG114010, ETG/RTG Handling and Operating Procedure.

D. ETG SECURITY PROVISIONS

No special security provisions are required during transportation, test or storage of the ETG. The normal security provided by TES and NSWC is adequate to safeguard the generator.