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TO
AEC-NASA SPACE NUCLEAR PROPULSION OFFICE

XE CRYOGENIC TEST PLAN

OCTOBER 1966

NERVA PROGRAM

CONTRACT SNP-1

MASTER

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RN-S-0344

CRYOGENIC TEST PLAN

OCTOBER 1966

ROCKET ENGINE OPERATIONS - NUCLEAR

NERVA PROGRAM

CONTRACT SNP-1

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ABSTRACT

This plan defines the XE Cryogenic Test Programs for the Upper Thrust Structure components, UTS Test Segment and the UTSM/Shield/TSA Assembly. It includes a description of the test items, the test objectives, tests to be performed, assembly and installation, and the post-test operations.

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I. SCOPE

A. PURPOSE OF THE TEST PLAN

This document defines the XE Cryogenic Test Program and serves as the engineering basis for the conduct of the XE Cryogenic Test Program. It performs the following functions:

1. It establishes the scope of the XE Cryogenic Test Program and includes a description of the test items, the test objectives, tests to be performed, assembly and installation, post-test operations, and other pertinent information.

2. It provides the information necessary to initiate the long range planning required for the conduct of the test.

3. It forms a basis for all other test documentation. It serves as a basis for establishing the requirements for the test requests. It is a document which will provide the pertinent engineering information and requirements for conducting all phases of the test program.

B. DESCRIPTION OF MAJOR SECTIONS

The major sections of the XE Cryogenic Test Plan are as follows:

1. Introduction

This section presents background information and states generally what will be accomplished by the program.

2. Test Objectives

The objectives are defined for determining environmental conditions in the Upper Thrust Structure Module (UTSM), effects of cryogenic pumping, insulation of LH₂ lines, effects of GN₂ purge, effects of LN₂ dripping on On-Mark and electrical connectors, and checkout of the UTS TV monitoring system.

3. Description of Test Articles

The configuration of the XE Cryogenic test articles are described in this section.

4. Assembly, Installation, Test and Post Test

The requirements for the preliminary assembly, shipment to the Cryogenic Test Facility, reassembly, and installation into the test stand are specified. The tests to be run and the requirements for conducting the various test phases in order to meet the test objectives are discussed. Also, requirements are specified for the removal of the test articles from the test stand, disassembly into components or subassemblies, and the disposition of hardware.

II. INTRODUCTION

Based on analysis and NRX/EST experience, it appears that formation of LN_2 in the upper thrust structure is eminent when the GN_2 purge gas contacts the surface of lines carrying LH_2 . These series of cryogenic tests are designed to investigate the effects of the liquid nitrogen on various components and to evaluate means to prevent the LN_2 formation or to provide a method of channeling the LN_2 harmlessly overboard.

In addition, the tests will provide a checkout of the UTS TV system, a gross leak check of joints under cryogenic condition, and operation of valves.

The tests will consist of three parts, the results of each determining to some extent what will be done on the succeeding tests. First, component tests will determine what, if any, deleterious effects the liquid nitrogen has on the electrical and On-Mark connectors. Second, UTS/shield segment tests will determine the extent of LN_2 formation and means of preventing this by insulation and/or channeling the liquid overboard. Third, UTSM/Shield Tests will confirm the results of the previous tests, give an indication of any gross leaks in the system and at the UTS/TSA interface, check out certain valves, and verify the operation of the UTS TV system.

This test plan indicates the probable sequence of events but will, of necessity, be modified if prior test results indicate a need for deletion or change for any subsequent tests.

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III. TEST OBJECTIVES

The Cryogenic Test Program will consist of three parts; the component cryogenic tests, the shield/UTS segment cryogenic tests, and the Upper Thrust Structure Module cryogenic tests.

The basic objectives of the component tests are to determine the effects of liquid nitrogen dripping on the On-Mark connectors and the electrical connectors.

The objectives of the UTS/shield segment cryogenic test will be to determine if LN_2 is formed in the UTS when GN_2 purge gas contacts the lines carrying LH_2 and, if so, the effects of insulating the LH_2 lines (Figure 1), the run-off characteristics of a drip pan, and effects of insulating the drip pan.

The UTS/shield cryogenic tests will: confirm the results obtained on the UTS/shield segment tests, provide a gross leak check of joints under LH_2 conditions, provide a checkout of the UTS TV system, and check the operation of certain valves under cryogenic conditions.

Figure 1
LH₂ Line Insulation

IV. DESCRIPTIONS OF THE TEST ARTICLES

A. COMPONENTS

1. The components test articles consist of two assemblies, the On-Mark connector and frame and the electrical connector and mount.

2. The On-Mark connector assembly consists of the two halves of the On-Mark connector mounted in a frame and capped at both ends with appropriate connections for pressurizing the unit during test. See Figure 2.

3. The electrical connector assembly consists of two halves that provide the electrical connections at the 18 inch interface in the Upper Thrust Structure. These connectors are suitably wired and installed in a mount that will allow electrical measurements during the test. See Figure 3.

B. UTS/SHIELD CRYOGENIC TEST SEGMENT

The UTS/shield segment consists of a 1/12 section of the external shield and a similar section of the Upper Thrust Structure. An LH_2 line passes through the Upper Thrust Structure and shield sections. Gaseous nitrogen purge is introduced through the top of the UTS and a drip pan is provided to carry off any LN_2 that is formed. The shield section will be filled with steel balls and borated water and will contain thermocouples for temperature measurements. A fill and drain system will be provided for filling, recirculating and draining the borated water. The UTS will be fully instrumented for temperature measurements and will have an access port for a TV camera. See Figure 4.

C. UTSM/SHIELD CRYOGENIC TEST ASSEMBLY

The test assembly consists of the Test Stand Adapter (TSA), Upper Thrust Structure Module (UTSM), and Engine External Shield mounted on GSE Item 4008 (Stand, External Shield). Testing will require a TV monitoring system; instrumentation;

Figure 2
On-Mark Test Assembly

Figure 3
Electrical Connector Test Assembly

Figure 4
UTS/Shield Cryogenic Test Segment

instrumentation data recording system; a hydrogen detection system; motion picture coverage system; and test facility LH_2 , GN_2 , LN_2 and GHe distribution and exhaust system. A cover of polyethylene or coated nylon will be mounted on a frame attached to the TSA (see Figure 5) and will extend to ground level to provide an enclosed area for the test article which will be purged with GN_2 . Hydrogen and oxygen detection systems will be located at the upper end of this cover as well as in the UTM. The apex of the cover will have a flapper valve to allow rapid escape of H_2 in the event of a system leak.

Figure 5
UTSM-Shield-TSA Cover

V. ASSEMBLY, INSTALLATION, TEST, AND POST TEST

A. COMPONENT TESTS

1. On-Mark Connector

a. The two halves of the On-Mark connector will be assembled in the special mount (see Figure 2). The closure at each end will be attached to tubing and pressure gages for pressurizing and pressure monitoring purposes.

b. The test assembly will be mounted on a shaker and vibrated from 0 to 2000 cps in each of three mutually perpendicular axes to determine resonant frequencies. The unit will then be vibrated from 0 to 15 g's at each resonant frequency in the appropriate axis. Each pass will be completed in steps of 5, 10 and 15 g's in approximately 10 minutes. During the pass, liquid nitrogen will be poured on the connector which has been pressurized to 500 psig with GHe. The pressure will be monitored during the test by observation of the gages. Internal and external temperature will also be monitored.

c. Before and after completion of the test, an ambient helium leak check will be made and the assembly visually checked for damage or loosening of parts.

2. Electrical Connectors

a. The two halves of the electrical connectors will be installed in a mount (see figure 3). One connector will be fully wired while the others will have only the corner pins wired to allow electrical checking during the cryogenic testing.

b. With the connectors in place, the mount will be fastened to a shaker. The connectors will be wired to record resistance, continuity, and pin-to-pin insulation resistance. These measurements will be taken and recorded

prior to determination of resonant frequencies. Liquid nitrogen will be poured on the unit while it is being vibrated as in the previous test. Under these conditions, resistance, continuity, and pin-to-pin resistance values will be recorded.

c. Before and after completion of the test, the above values will be recorded at ambient temperature. It will then be disassembled and visually checked for any physical damage.

B. UTS/SHIELD SEGMENT

1. The UTS/shield segment will be completely assembled in the shop and will include any instrumentation that may be available at the time prior to installation. Initially, the drip pan will not be installed nor will there be any insulation of the LH_2 line.

2. The assembly will be transported to the Cryogenic Test Facility where the shield segment will be loaded with the steel balls and filled to within 1 inch of the top with an aqueous solution of 1.8 lbs of ammonium pentaborate ($\text{NH}_4\text{B}_5\text{O}_8$) and 178 lbs of demineralized water. The instrumentation, TV monitoring system, LH_2 supply and return, and the GN_2 supply will be connected.

3. Testing will begin by flowing LH_2 through the line until LH_2 temperatures are stabilized while also purging the UTS segment with .025 lb/sec of GN_2 at approximately 40°F inlet temperature. While maintaining these conditions and monitoring all instrumentation, the following configurations will be tested:

a. UTS/shield segment, no drip pan, no insulation (except external UTS insulation). During this test the GN_2 flow will be varied to check whether the LN_2 formation varies proportionately.

NOTE: The effect of recirculating the water in the shield will also be checked during this test.

- b. UTS/shield segment, drip pan, no insulation.
 - c. UTS/shield segment, insulated drip pan, no LH₂ line insulation.
 - d. UTS/shield segment, insulated drip pan, insulated LH₂ line, manifolded GN₂ line (for greater GN₂ distribution).
4. After completion of the tests, the assembly will be removed from the test facility and returned to the NERVA Assembly Area. The results of the tests will be studied and recommendations made for the final configuration of the UTSM/shield test assembly, i.e., LH₂ lines insulated, drip pan installed, etc.

C. UTSM/SHIELD

1. The UTSM will be assembled in the NERVA Assembly Area, Building 2002, in accordance with recommendations based on studies of the UTS/shield segment tests. The UTSM, shield and TSA will be mated for a fit check while mounted on the shield stand, Item 4008.
2. The TSA will be unbolted from the UTSM and transported to the Cryogenic Test Facility. The UTSM, shield and shield stand (Item 4008) will be placed on a truck and delivered to the test facility. The speed will be limited to 5 mph for this trip.
3. On arrival at the test facility, the UTSM/Shield/TSA assembly will be built up on an external shield stand, Item 4008, as shown in Figure 6. The shield will be filled to within 1 in. of the top with the same borated water solution as in the segment test and will have the capability of being recirculated. GSE items required for this test are listed below.

<u>Item No.</u>	<u>Name</u>
4008	Stand, External Shield
4746	Sling, Test Stand Adapter
4009	Lifting Fixture, External Shield
4701	Adapter, Handling Thrust Structure (or substitute)
4027	Stand, UTS/TPA Storage (or substitute)

Figure 6
UTSM-Shield Cryogenic Test Assembly

4. Instrumentation and monitoring equipment will be required to provide the following data:

- a. Temperature in PIL, CSL and vent lines
- b. Pressure in lines
- c. Flow rates of LH_2 and GN_2
- d. Temperature vs time of UTS internal environment (approximately 30 thermocouples)
- e. Water temperature in shield
- f. Temperature of 3/8" pilot valves
- g. Movie coverage of interior of UTS by means of two television monitors
- h. Extent of H_2 leakage and area if detectable; this will be continuously monitored in the UTS.

5. Test Procedure

a. The Propellant Feed System (PFS) will be purged with GHe through the Propellant Inlet Line (PIL), Cooldown Supply Line (CSL), Turbopump (TPA) purge port, and Turbine Exhaust Line (TEL) purge ports. To purge, the system will be pressurized to 50 psig and vented six times. See Figure 7.

NOTE: Bearing Dehydration Purge

A bearing dehydration purge must be performed prior to turbopump operation, following removal of protective covers, installation of the turbopump, or disconnecting of ducting.

Figure 7
UTSM-Shield Cryogenic Test Flow

The purge will consist of introduction of low pressure (1-5 psig at inlet boss), filtered (10 micron particle size), dry gaseous nitrogen or helium at a temperature below 155°F at the P_{BH} (purge boss). The purge must be maintained until bearing temperatures (TB-1 and TB-4) remain above 80°F for 20 minutes.

A low pressure continuous purge must be maintained inside the turbopump at all times except when the system contains propellant or the turbopump is being shipped as part of the upper thrust structure module.

This purge will introduce dry gaseous nitrogen or helium at 1 - 20 psig, at P_{BH} boss or pump inlet. Purge gas must be filtered to 10 micron particle size. If gaseous nitrogen is used as a purge medium, gaseous helium or gaseous hydrogen purge must be introduced prior to propellant entering the system.

Purging of the turbine or turbine exhaust duct must be accomplished with turbine power control valve closed. Trickle purging through turbine exhaust collector pressure boss is permitted during inspection or torque check. Trickle purge cannot exceed that produced by 70 psi across a .25 in. diameter orifice.

b. Oxygen content within the PFS will be less than 1% by weight.

c. The GN_2 purge within the UTS will then be started at .3 lb/sec and 40°F for the first run.

NOTE: The next step will not be initiated until the oxygen content within the test article environment is at a safe level as measured by the oxygen detection system.

d. LH_2 will be flowed through the Cooldown Supply Line (CSL) and the PIL. The LH_2 will then vent through the Pump Discharge Vent Line (PDVL) and the Cooldown Vent Line (CVL), until LH_2 conditions are reached within the CSL and PIL.

NOTE: At any time during this test a shutdown will be initiated if the hydrogen content exceeds a safe level as measured by the hydrogen detection system.

e. LH_2 flow will be continued to maintain LH_2 in the lines for 20 minutes or until UTS environmental temperatures reach equilibrium, whichever occurs first.

f. The foregoing procedure will be repeated with a GN_2 purge of 1 lb/sec.

g. The LH_2 flow test will be repeated with a GN_2 purge rate to be determined during testing.

h. Additional testing will be run at different GN_2 purge temperatures, and for distribution systems which will be determined from results of prior tests.

i. The pump discharge valve will be tested by actuating from closed to open and back to closed while flowing LH_2 (after LH_2 temperatures are reached in the line). The response time from signal to pilot valve actuation to actuation of the PDV will be measured.

6. After completion of the tests, the entire assembly will be inspected and checked for damage and then disassembled for shipment to NTO.

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