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REON

ROCKET ENGINE OPERATIONS - NUCLEAR

PRELIMINARY EDITION REPORT RN-DR-0021
TO
AEC-NASA SPACE NUCLEAR PROPULSION OFFICE

NES DESIGN DEMONSTRATION TEST PROGRAM

NERVA PROGRAM
CONTRACT SNP-1

MASTER

APRIL 1964

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I. INTRODUCTION

The purpose of the NES is to direct the hot nuclear exhaust gases and fission products away from the test stand during a NERVA engine firing and to provide a steam safety purge. Because of these requirements, it is necessary that a high confidence level in NES duct installation, removal, and performance be attained prior to utilizing a prototype NES duct in a full scale NERVA engine firing. To meet these requirements, the prototype NES duct will be installed, cold flow tested for performance at both NERVA design and off-design conditions, and remotely removed; thus simulating operational conditions prior to testing under actual environments.

II. PROGRAM DESCRIPTION

Due to facility limitations (i.e., engine compartment is not available at the scheduled initiation of the program), the Design Demonstration test program will be conducted in two phases. Phase I testing will use a Temporary Engine Compartment (TEC) and GN_2 tests will be conducted while the permanent engine compartment is being completed. Upon completion of the permanent engine compartment checkout, the TEC will be removed and the testing described as Phase II, involving GH_2 , will be conducted.

All GN_2 -primary tests at off-design conditions will be conducted using the TEC. The GH_2 -primary test at off-design conditions will not be conducted until the permanent engine compartment is complete. This will preserve program continuity by avoiding unnecessary changeovers.

The tests at design conditions, where startup and shutdown transients are significant, will be conducted after completion of the permanent engine compartment where the actual test cell volume is duplicated. However, to demonstrate satisfactory NES operation as soon as possible, checkout tests at design conditions will be conducted using the TEC. Figure 1 presents a tabular summary of the total test program.

III. SCHEDULE

The Design Demonstration test program has been scheduled to be compatible with facility scheduling for activation of ETS-1. An estimated test time is included in the test summary shown in Figure 1.

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PRELIMINARY DRAFT

DESIGN DEMONSTRATION TEST PLAN

FOR

PROTOTYPE NERVA EXHAUST SYSTEM, FOR ETS-1 AT NRDS

1. SCOPE

This test plan establishes instructions for performing design demonstration tests on the NERVA Exhaust System (NES). The test program will be conducted at NRDS using the facility permanent I&C, process water, gas supply system, and ETS-1.

2. APPLICABLE DOCUMENTS

2.1 The following documents are applicable to, and form a part of, this test plan.

NES Duct Process Specification (to be supplied)

NERVA DESIGN CRITERIA (REON Report No. 2630)

NDC-66	Exhaust System, NERVA (SST-2) for Use at Test Stand ETS-1
NDC-67	Duct Assembly, Exhaust (SST-2) for NERVA Exhaust System at ETS-1
NDC-68	Instrumentation, Exhaust Duct Assembly, (SST-2) at ETS-1, Requirements for
NDC-69	Installation and Removal, NES Exhaust Duct (SST-2) at ETS-1, Procedure for
NDC-70	Trailer Assembly, for Transporting the NES Exhaust Duct (SST-2)
NDC-71	Fabrication and Assembly of the NERVA Exhaust Duct Assembly (SST-2) at ETS-1, Process for

3. DESCRIPTION OF TEST SPECIMEN

3.1 The NES duct prototype design conforms to the following preliminary design drawings:

PD-1100	ETS-1 NES (SST-2) Exhaust System - General Arrangement
PD-1101	Primary Duct Section
PD-1106	Duct Elbow Section
PD-1109	Secondary Ejector Duct Section

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PD-1113 Carrying Truss
PD-1114 Duct-to-Facility Seal Details
PD-1115 Instrumentation & Water Flow Diagram
PD-1116 ETS-1 NES (SST-2) Duct Installation and Connection

3.2 The TEC, simulated chamber, nozzle, turbine exhaust and TEC pre-fire purge header will be designed in CY 1965. The conceptual design is indicated by the following drawings:

(Fig. 2) SK-TD-1203 NES Duct Design Demonstration Test Hardware with TEC-Concept No. 4
(Fig. 3) SK-TD-1204 NES Duct Design Demonstration Test Hardware Without TEC-Concept No. 5

4. TEST PROGRAM

4.1 TEST SETUP

4.1.1 Install NES duct test device, TEC, and test device instrumentation. Exact method of supporting this hardware will be specified during the design phase.

4.1.2 Connect facility gas supply lines. These lines shall provide the following capability:

a. Primary Flow Requirements

Gaseous nitrogen and hydrogen in sufficient quantity and at sufficient pressure to accomplish the following:

	Pressure at Interface (Ref. SK-TD-1203) Figure 2 PSIA	Flow Rate lb/sec	Equivalent Duration at Noted Flow sec	Storage Temp.
		N ₂ H ₂		
Minimum allowable	255	390 104	35	amb.
Desired maximum	512	780 208	60	amb.

The primary gas flow control valve must control the primary gas flow to simulate, within $\pm 20\%$, and XE-engine startup and shutdown transient as shown in Figures 4 and 5. The transients may be anywhere within the limits

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shown in Figures 4 and 5; however, it must be continuous without step changes in either pressure or time. In addition, the valve should permit a rapid increase in pressure, to conserve the gas supply, for those tests where transients are not significant. Also, the valve must provide a rapid shut-down to simulate an XE-engine malfunction. A malfunction will consist of decreasing chamber pressure from maximum to zero in approximately 0.6 seconds.

b. Pre-fire Purge - Test Cell Requirements

Gaseous nitrogen at ambient temperature and 40 lb/sec for a duration of 100 sec plus an additional 20 sec for simulated seal leakage.

c. Simulated Seal Leakage Requirements

Pre-fire purge system will be used to provide simulated seal leakage.

d. Simulated Turbine Exhaust Requirements

Gaseous hydrogen at ambient temperature and 15 lb/sec at an interface pressure of 92 psia for a duration of 12 seconds.

4.1.3 Install duct exhaust flare system.

4.1.4 Calibrate all instrumentation.

4.1.5 Visually inspect all connections; electrical and mechanical.

4.2 TEST OPERATIONS

4.2.1 Phase I Testing With the TEC (14 Tests) Ref. Figure 1

4.2.1.1 Final System Check

Leak check all seals, functional check gas supply valves, continuity check the NES instrumentation and functional check the duct exhaust flare system.

4.2.1.1.1 Objective

- a. Verify all systems are ready for use.
- b. Perform simulated countdown.

4.2.1.1.2 Tests Conducted

- a. Number of tests 1
- b. Duration of run not applicable

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4.2.1.2 Steam Generator System Checkout

Test fire steam generator system (SGS) only at design conditions for approximately 100 seconds duration. During this test, after steady-state operation is achieved, introduce simulated GN_2 leakage into the TEC and record compartment pressure vs leakage. The leakage shall be increased from 0 to 40 lb/sec in approximately 10 seconds, decreases to 0 and again increased to 40 lb/sec in approximately 10 seconds, then hold this for 30 seconds. Flow 200 to 300 lb/sec of process water through the duct when the SGS is operating. Oxygen concentration in the TEC shall be recorded.

4.2.1.2.1 Objectives

- a. Demonstrate satisfactory operation of the SGS.
- b. Establish the effects of leakage on the cell pressure.
- c. Establish adequacy of the TEC pre-fire purge system.

4.2.1.2.2 Tests Conducted

- a. Number of tests 1
- b. Duration of run 100 seconds

4.2.1.3 NES Checkout Tests

The 10:1 nozzle, GN_2 -primary, and GH_2 turbine exhaust shall be used for all tests. SGS shall be operated 50 seconds preceding, during, and 50 seconds following primary duct or turbine exhaust flow. TEC pre-fire GN_2 purge shall be operated for 50 seconds preceding and 50 seconds following primary duct or turbine exhaust flow. The TEC shall be returned to ambient conditions between tests. Flow 200 to 300 lb/sec coolant water through the duct when the SGS is operating.

4.2.1.3.1 Checkout Test at 275 PSIA P_{pc}

Primary chamber pressure shall be increased to 275 psia per the startup shown in Figure 4. The SGS and TEC pre-fire purge shall be operated per paragraph 4.2.1.3. The primary flow shutdown shall be per Figure 5. Oxygen concentration in TEC shall be recorded.

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4.2.1.3.1.1 Objectives

- a. Establish NES duct pull-in
- b. Verify structural integrity
- c. Verify TEC pre-fire purge system

4.2.1.3.1.2 Tests Conducted

- a. Number of tests 1
- b. Duration of run 10 sec steady-state, primary flow

4.2.1.3.2 Checkout Test at Maximum Operating P_{pc}

A test shall be conducted using GN_2 primary flow, GH_2 turbine exhaust, GN_2 pre-fire purge, SGS, and duct design process water flow. Primary chamber pressure shall be increased to maximum operating value per the start-up shown in Figure 4. The turbine exhaust shall then be increased, in 10 seconds, to design value. During increase of the turbine exhaust, the cell pressure and nozzle exit pressure shall be closely observed for indication of flow separation and/or cell overpressurization. Turbine exhaust shall be shutdown prior to primary flow which shall be shutdown per Figure 5. Duct design process water flow shall be used during this test. The sequence of operation of the process water flow shall be per Figure 6 except that the SGS duration shall be per paragraph 4.2.1.3 and no simulated cooldown time is required. Oxygen concentration in the TEC shall be recorded to verify adequacy of the pre-fire purge system.

4.2.1.3.2.1 Objectives

- a. Confirm previous test results.
- b. Demonstrate satisfactory operation at full flow conditions (primary flow, turbine exhaust, and process water).
- c. Verify TEC pre-fire purge system.

4.2.1.3.2.2 Tests Conducted

- a. Number of tests 1
- b. Duration of run 10 sec. steady-state, primary flow

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4.2.1.4 NES Duct Off-Design Tests

A series of ten (10) tests shall be conducted to evaluate aerodynamic performance, structural integrity, and operational safety of the prototype duct at off-design conditions. The first eight tests will use a 10:1 conical nozzle and the last two (2) tests will use a 12:1 contoured nozzle. All tests will use GN_2 -primary and GH_2 turbine exhaust. The startup for the tests shall be accomplished as rapidly as possible consistent with safety to the facility and NES. The shutdown shall be accomplished in approximately 5 seconds except where noted. SGS and TEC pre-fire purge system shall be used for all tests as described in paragraph 4.2.1.3. Primary gas supply line must be purged with GN_2 prior to turning on the GH_2 turbine exhaust on all the tests where turbine exhaust is operated at design conditions.

4.2.1.4.1 Off-Design Tests at 275 psia P_{pc} (Design Turbine Exhaust)

Subsequent to GN_2 pre-fire purge, set GH_2 turbine exhaust at design flow rate (for P_{pc} at 275 psia) and P_{pc} at 275 psia, then increase simulated leakage, in 5 to 10 seconds, until flow separation occurs in the nozzle or the flow rate is * _____ lb/sec. See Figure 7 for sequence of operation.

4.2.1.4.1.1 Objectives

- a. Determine amount of leakage to cause nozzle flow separation.

4.2.1.4.1.2 Tests Conducted

- a. Number of tests 2
- b. Duration of run 10 sec. steady-state, primary flow

4.2.1.4.2 Off-Design Tests at Maximum Operating P_{pc} (Design Turbine Exhaust)

Perform test similar to 4.2.1.4.1, except set P_{pc} at maximum with turbine exhaust at design flow rate (for maximum P_{pc}). Then increase simulated leakage in 5 to 10 seconds until flow separation occurs in the nozzle, or the flow rate is * _____ lb/sec. Also, the shutdown for these tests shall simulate an XE-engine malfunction (i.e., shutdown in 0.6 sec).

* to be determined

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4.2.1.4.2.1 Objectives

- a. Determine amount of leakage to cause nozzle flow separation at maximum P_{pc} .
- b. Determine NES performance under XE-engine malfunction shut-down conditions.

4.2.1.4.2.2 Test Conducted

- a. Number of tests 2
- b. Duration of run 10 sec. steady-state, primary flow

4.2.1.4.3 Off-Design Tests at 275 psia P_{pc} (Excessive Turbine Exhaust)

Subsequent to pre-fire purge, set simulated leakage at maximum expected value, then increase the GH_2 turbine exhaust in 5 to 10 seconds until flow separation occurs in the primary nozzle or the GH_2 flow rate is 15 lb/sec. See Figure 7 for sequence of operation.

4.2.1.4.3.1 Objective

- a. Demonstrate that NES duct will maintain full flow with above design turbine exhaust and maximum expected seal leakage (with P_{pc} at 275 psia and 10:1 nozzle).

4.2.1.4.3.2 Test Conducted

- a. Number of tests 2
- b. Duration of run 10 sec. steady-state

4.2.1.4.4 Off-Design Tests at Maximum Operating P_{pc} (Excessive Turbine Exhaust) and Maximum Expected Seal Leakage

Perform test similar to 4.2.1.4.3, except set P_{pc} at maximum value with maximum expected seal leakage. Increase the GH_2 turbine exhaust in 5 to 10 seconds until flow separation occurs in the primary nozzle or the GH_2 flow rate is 15 lb/sec.

4.2.1.4.4.1 Objectives

- a. Demonstrate NES duct will maintain full flow with above design turbine exhaust and maximum expected seal leakage (with P_{pc} at maximum and 10:1 nozzle).

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4.2.1.4.4.2 Test Conducted

- a. Number of tests 2
- b. Duration or run 10 sec steady-state

Note: Remove 10:1 conical nozzle and install 12:1 contoured nozzle to be used for all the remaining tests.

4.2.1.4.5 Off-Design Tests at 275 psia P_{pc} (Excessive Turbine Exhaust) and Maximum Expected Seal Leakage

Perform tests with P_{pc} at 275 psia and maximum expected seal leakage. Increase the GH_2 turbine exhaust in 5 to 10 seconds until flow separation occurs in the primary nozzle or the GH_2 flow rate is 15 lb/sec. See Figure 7 for sequence of operation.

4.2.1.4.5.1 Objective

Demonstrate that NES duct will maintain full flow with above design turbine exhaust and maximum expected seal leakage (with P_{pc} at 275 psia and 12:1 nozzle).

4.2.1.4.5.2 Test Conducted

- a. Number of tests 1
- b. Duration of run 10 sec. steady-state, primary flow

4.2.1.4.6 Off-Design Tests at Maximum Operating P_{pc} (Excessive Turbine Exhaust) and Maximum Expected Seal Leakage

Perform test similar to 4.2.1.4.5, except set P_{pc} at maximum with maximum expected seal leakage. Increase the GH_2 turbine exhaust in 5 to 10 seconds until flow separation occurs in the primary nozzle or the GH_2 flow rate is 15 lb/sec. The shutdown shall simulate an XE-engine malfunction (i.e., shutdown in 0.6 sec.).

4.2.1.4.6.1 Objectives

- a. Demonstrate that NES duct will maintain full flow with above design turbine exhaust and maximum expected seal leakage (with P_{pc} at maximum and 12:1 nozzle).

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b. Determine NES performance under XE-engine malfunction shutdown conditions with 12:1 contoured nozzle.

4.2.1.4.6.2 Test Conducted

- a. Number of tests 1
- b. Duration of run 10 sec steady-state, primary flow

Note: Subsequent to the test in Para. 4.2.1.4.6, approximately four weeks are required for facility changeover to the permanent engine compartment, including leak checks. It is anticipated that the TEC will be used to assist in the leak checks of the permanent engine compartment prior to removal. This will be accomplished by closing the permanent engine compartment around the TEC, operating the SGS, and (after system stabilization) recording flow rate through the orifice provided in the TEC as shown in Figure 2. This flow rate will indicate leakage.

4.2.2 Phase II Testing with Permanent Engine Compartment (9 Tests), (Reference Figure 1)

4.2.2.1 Permanent Engine Compartment Purge Tests

Engine compartment purge tests shall be conducted (with steam generator operating) by flowing gaseous nitrogen into the simulated engine compartment (simulated thrust structure and water shield shall be in place) and recording oxygen concentration as a function of time. Three tests of 100, 70, and 50 seconds duration at flow rates of 20, 30, and 40 lb/sec, respectively, shall be conducted with the purge gas discharged from the pre-fire purge header system. The engine compartment shall be returned to ambient conditions between tests. If the results of these tests indicate oxygen is concentrated in local areas, the header configuration shall be changed and the test repeated. This procedure shall be continued, changing the purge flow rate if necessary, until the test results indicate the oxygen content in the engine compartment can be reduced to 4% or less (by volume) by flowing approximately 2000 lb of N₂ through the environmental cell.

4.2.2.1.1 Objectives

a. Establish satisfactory operation of the permanent pre-fire purge system.

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4.2.2.1.2 Tests Conducted

- a. Number of tests 3 minimum
- b. Duration of run 50 to 100 sec.

4.2.2.2 NES Checkout

Checkout tests shall be conducted to establish satisfactory NES operation when using the permanent engine compartment prior to conducting tests at design conditions. GN_2 primary and GH_2 turbine exhaust shall be used. SGS shall be operated 50 seconds preceding, during and 50 seconds following primary duct flow. Pre-fire purge shall be operated for 50 seconds preceding and 50 seconds following primary duct flow. Flow 200 to 300 lb/sec of coolant water through the duct when the SGS is operating. Perform test at 275 psia P_{pc} , with SGS and pre-fire purge only. The startup and shutdown shall be per the startup (to 275 P_{pc}) and shutdown shown in Figures 4 and 5 respectively. Oxygen concentration in the engine compartment shall be recorded.

4.2.2.2.1 Objective

- a. Verify NES operation with the permanent engine compartment.
- b. Verify adequacy of the pre-fire purge system.

4.2.2.2.2 Tests Conducted

- a. Number of tests 1
- b. Duration of run 10 sec steady-state, primary flow

4.2.2.3 NES Duct Tests at Design Conditions

A series of tests shall be conducted to confirm the prototype duct design. The tests shall be divided into two groups; the first will use GN_2 as the primary gas and the second group GH_2 as the primary gas. All tests shall use GH_2 as the turbine exhaust. See Figure 8 for the sequence of operation.

4.2.2.3.1 Nitrogen Flow Tests

Perform tests with SGS, pre-fire GN_2 purge, and design GH_2 turbine exhaust (for maximum P_{pc}). The startup (to maximum P_{pc}) and shutdown of primary flow shall be in accordance with the startup and shutdown shown in Figures 4 and 5 respectively.

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4.2.2.3.1.1 Objective

- a. Verify satisfactory NES operation at design conditions.

4.2.2.3.1.2 Tests Conducted

- a. Number of tests 2
- b. Duration of run 10 sec. steady-state, primary flow

4.2.2.3.2 Hydrogen Flow Tests

Perform tests with SGS, pre-fire purge and design GH_2 turbine exhaust (for maximum P_{pc}). The startup of the primary flow shall be in accordance with the startup (to maximum P_{pc}) shown in Figure 4. The shutdown shall simulate an XE-engine malfunction. The primary system must be purged with GN_2 prior to flowing GH_2 . Oxygen concentration in the engine compartment shall be recorded.

4.2.2.3.2.1 Objective

- a. Verify GN_2 primary test results
- b. Evaluate exhaust plume thermal radiation
- c. Simulate operating conditions

4.2.2.3.2.2 Tests Conducted

- a. Number of tests 2
- b. Duration of run 10 sec. steady-state, primary flow

4.2.2.4 NES Duct Test at Off-Design Conditions

Perform test, using GH_2 primary, in accordance with Figure 7 sequence of operation. Set P_{pc} at maximum, with maximum expected seal leakage, and increase the GH_2 turbine exhaust in 5 to 10 seconds until flow separation occurs in the primary nozzle or the GH_2 flow rate is 15 lb/sec. The primary system must be purged with GN_2 prior to flowing GH_2 .

4.2.2.4.1 Objective

- a. Verify GN_2 primary test results.

4.2.2.4.2 Tests Conducted

- a. Number of tests 1
- b. Duration of run 10 sec. steady-state

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5.0 TEST FLUID

5.1 TEST GASES

5.1.1 The test gases shall be filtered nitrogen, hydrogen, and air.

5.2 TEST LIQUIDS

5.2.1 The test liquids shall be demineralized water per Volume I of Specifications for Test Stand Process Systems, Para. 29.5.24.3.

6.0 INSTRUMENTATION REQUIREMENTS

6.1 The required instrumentation shall be per Section J of Report No. 2630 for the NES duct and Figure 9 for the test cell and NES test device. All instrumentation shall be compatible with the permanent I&C system.

7.0 TEST DATA

7.1 The following data on each NES tests is required as applicable. This data shall be listed on reproducible forms and approved by the cognizant Test Engineer.

7.2 TABULATED DATA

All data noted in Paragraph 6.1 shall be presented in tabulation form at specified data points. The data points will be specified for each test.

7.3 PLOTTED DATA (Required on Tests as Specified)

7.3.1 Plot permanent engine compartment oxygen concentration vs time.

7.3.2 Plot ρ vs chamber pressure (in atmospheres) at nozzle flow separation. (See Figures 10 and 11 for sample.)

7.3.3 Plot chamber pressure vs cell pressure. (See Figures 12 and 13 for sample.)

7.4 RECORDED DATA

7.4.1 Photostats or equivalent shall be provided of the records, as required. Original records shall be kept on file for the duration of the contract and for a period of two years thereafter.

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The records shall be identified prior to reproduction as follows:

- a. Calibration scale factors
- b. Functions
- c. NES serial number
- d. Test number
- e. Test data

8.0 PHOTOGRAPH REQUIREMENTS

8.1 STILL PHOTOGRAPHS

8.1.1 Each initial test setup shall be photographed.

8.1.2 Photographs shall be taken of any significant component failure or damage during the test series.

8.2 MOTION PICTURES

8.2.1 24 FPS color documentary motion pictures shall be taken of each initial test setup and operation.

8.2.2 24 FPS color motion pictures shall be taken as specified where major test hardware changes have been made.

9.0 SCHEMATICS

9.1 A flow diagram for the facility-NES duct testing is shown in Figure 14. A schematic of the facility piping and wiring, as installed, to the NES test device shall be furnished prior to test.

ESTIMATE FLUID REQ. - LBS	TYPE OF TEST	OBJECTIVE	NO. OF TESTS	TIME (WEEKS)			TEST DURATION (SECONDS) PRIMARY FLOW	DESCRIPTION	NOTES	REQUIRED HARDWARE	
				TOTAL	DATA RED.	GN ₂ , GN ₂ & WATER TANK REFILL				NES	FACILITY
	I. ACCEPTANCE (AT NRDS) $\Delta \Delta$										
	A. PHASE I (VENDOR)										
	1. ASSEMBLY	PREPARE FOR INSTALLATION	NOT APPLICABLE	1			NOT APPLICABLE	INSTALL SEALS & ASSEMBLE DUCT SECTIONS ON TRAILER; CHECK INTERFACE & TRAILER OPERATION	SEE NDC - 69	DUCT	CRANE, TRAILER, PRIME MOVER & GENERAL SUPPORT EQUIPMENT
	2. INSTALLATION	VERIFY INSTALLATION PROCEDURE		3				ALIGN DUCT TO VAULT WELD TRANSIONS & WATER HEADERS. INSTALL INSTRUMENTATION HARNESS & TRANSDUCERS	SEE NDC - 69	SLCT, HARNESS, TRANSDUCERS & SEALS	PORTABLE STANDS, WELDING EQUIPMENT, GN ₂
	3. PROOF & LEAK (DUCT)	VERIFY STRUCTURAL & SEAL INTEGRITY		1	1/8			PROOF TEST DUCT AT 860 $\pm$ 15 PSIG & LEAK TEST AT 240 PSIG. VISUAL INSPECTION.	SEE PROCESS SPECIFICATION (TO BE DETERMINED)	DUCT & INSTRUMENTATION	1 C, PROCESS WATER, GN ₂
800,000* H ₂ O	4. CALIBRATE	CALIBRATE DUCT		3	4	1 (FILL WATER TANK)		FLOW & BALANCE DUCT TO PROVIDE DESIGN FLOW RATES THRU EACH DUCT SECTION.	SEE PROCESS SPECIFICATION (TO BE DETERMINED)	DUCT, INSTRUMENTATION & ORIFICES	1 C, PROCESS WATER GN ₂
	5. REMOVAL	VERIFY REMOTE REMOVAL PROCEDURE		1				REMOVELY REMOVE DUCT & CHECK ALL INTERFACE CONNECTIONS TO SIMULATE NOT REMOVAL.	SEE NDC - 69	DUCT	1 C, GN ₂ , TRAILER, PRIME MOVER
	B. PHASE II (NTO)										
	1. INSTALLATION	REINSTALL DUCT FOR TEST PROGRAM - INTERFACE CHECK		2 3/8				CHECK INSTALLATION PROCEDURE & ALIGNMENT	SEE NDC - 69	DUCT & SEALS	1 C, GN ₂ , TRAILER PRIME MOVER
2,000,000* H ₂ O	2. WATER SYSTEM CHECKOUT	VERIFY THAT WATER SYSTEM IS READY FOR USE	NOT APPLICABLE	2 3/8	1/8		NOT APPLICABLE	PROOF & LEAK AT 240 PSIG & FUNCTIONAL CHECK ON WATER SYSTEM VALVES.	SEE PROCESS SPECIFICATION (TO BE DETERMINED)		1 C, GN ₂ , PROCESS WATER
	II. DESIGN DEMONSTRATION	ACCEPTANCE PROGRAM TOTAL		12 3/8	4 3/8						
	A. PHASE I										
	Δ 1. FINAL SYSTEM CHECK	VERIFY THAT ALL SYSTEMS ARE READY FOR USE	1	3/8			NOT APPLICABLE	VERIFY SEAL INTEGRITY, FUNCTIONAL CHECK ON GAS SUPPLY VALVES & NES INSTR. & CHECK FLARE SYSTEM		TEMPORARY ENGINE COMPARTMENT DUCT	WATER SYSTEM GN ₂ FOR TURBINE EXHAUST ONLY (4 TRAILERS)
5,000* N ₂ 25,000* H ₂ O	Δ 2. STEAM GEN SYSTEM CHECK	DEMONSTRATE SATISFACTORY S.G.S. OPERATION & ESTABLISH EFFECTS OF LEAKAGE ON CELL PRESS.	1	3/8	3/8		100	TEST FIRE S.G.S. ONLY. INDUCE LEAKAGE TO DETERMINE THE EFFECT OF CELL PRESSURE		DUCT FLARE SYSTEM	
18,000* N ₂ 42,000* H ₂ O	3. NES CHECKOUT (GN ₂ PRIMARY)	ESTABLISH NES DUCT PULL-IN & VERIFY STRUCTURAL INTEGRITY	1	1	3/8	4/5 (GN ₂)	35 (10 SEC. STEADY STATE)	S.G.S. PRE-FIRE PURGE, PRIMARY GN ₂ FLOW ONLY, DESIGN START-UP TO 275 PSIA & SHUT-DOWN. PRE-FIRE PURGE SYSTEM ADEQUACY WILL BE VERIFIED WITH THIS TEST.			
51,000* N ₂ 150* H ₂ 1,700,000* H ₂ O	4. NES CHECKOUT WITH FULL WATER FLOW (GN ₂ PRIMARY)	CONFIRM PREVIOUS TEST RESULTS & DEMONSTRATE SATISFACTORY OPERATION AT FULL-FLOW CONDITIONS	1	1	4/5	4/5 (GN ₂)	70 (10 SEC. STEADY STATE)	S.G.S. PRE-FIRE PURGE, DESIGN TURBINE EXHAUST, PRIMARY GN ₂ & DESIGN H ₂ O FLOW DESIGN STARTUP (TO MAX. Ppc) & SHUT-DOWN.			
	5. NES DUCT OFF-DESIGN TEST (GN ₂ PRIMARY)	NOTED BELOW						DESIGN START-UP & SHUT-DOWN NOT REQUIRED FOR THESE, HOWEVER THE SHUT-DOWN ON TESTS (c) & (d) SHALL SIMULATE A NEPA ENGINE MALFUNCTION.			
24,000* N ₂ 160* H ₂ 80,000* H ₂ O	Δ a. Ppc AT 275 PSIA & EXCESSIVE SEAL LEAKAGE	DETERMINE AMOUNT OF LEAKAGE TO CAUSE FLOW SEPARATION	2	2	1	1 1/8 (GN ₂)	25 (10 SEC. STEADY STATE)	S.G.S. PRE-FIRE PURGE, DESIGN TURBINE EXHAUST, GN ₂ PRIMARY & EXCESSIVE SIMULATED SEAL LEAKAGE			
48,000* N ₂ 300* H ₂ 80,000* H ₂ O	Δ b. Ppc AT MAX. & EXCESSIVE SEAL LEAKAGE	DETERMINE AMOUNT OF LEAKAGE TO CAUSE FLOW SEPARATION	2	2	1	1 1/8 (GN ₂)	25 (10 SEC. STEADY STATE)	"			
24,000* N ₂ 300* H ₂ 80,000* H ₂ O	Δ c. Ppc AT 275 PSIA & EXCESSIVE TURBINE LEAKAGE	DEMONSTRATE NES DUCT WILL MAINTAIN FUL FLOW WITH ABOVE DES GN TURBINE EXHAUST	2	2	1	1 1/8 (GN ₂)	25 (10 SEC. STEADY STATE)	S.G.S. PRE-FIRE PURGE, EXPECTED SEAL LEAKAGE, ABOVE DESIGN TURBINE EXHAUST, & GN ₂ PRIMARY			
48,000* N ₂ 400* H ₂ 80,000* H ₂ O	Δ d. Ppc AT MAX. & EXCESSIVE TURBINE EXHAUST	"	2	2	1	1 1/8 (GN ₂)	25 (10 SEC. STEADY STATE)	"			
12,000* N ₂ 150* H ₂ 42,000* H ₂ O	Δ e. Ppc AT 275 PSIA & EXCESSIVE TURBINE EXHAUST (12:1 NOZZLE)	"	1	1	3/8	4/5 (GN ₂)	25 (10 SEC. STEADY STATE)	SAME AS (c) EXCEPT USE 12:1 NOZZLE		SAME AS ABOVE EXCEPT USE 12:1 NOZZLE	
24,000* N ₂ 200* H ₂ 40,000* H ₂ O	Δ f. Ppc AT MAX. PSIA & EXCESSIVE TURBINE EXHAUST (12:1 NOZZLE)	"	1	1/8		CONCURRENT WITH COMPARTMENT LEAK CHECK	25 (10 SEC. STEADY STATE)	SAME AS (d)			
	PERMANENT ENGINE COMPARTMENT CHECKOUT	TEC & FACILITY ACTIVATION		2				PERMANENT ENGINE COMPARTMENT LEAK CHECK	NTO		
	COMPLETE DATA REDUCTION & REMOVE THE OF PROTOTYPE ENGINE COMPARTMENT & REINSTALL NES TEST DEVICE			2							
	PHASE I SUB-TOTAL		14	12 3/8							
	PHASE I TOTAL		14	16 3/8							
	B. PHASE II										
7,000* N ₂ 60,000* H ₂ O	1. PURGE TEST	ESTABLISH SATISFACTORY OPERATION OF THE PERMANENT PRE-FIRE PURGE SYS.	3 (MIN)	1	1		50-100 SECONDS	TEST FIRE THE S.G.S. ONLY; INDUCE GN ₂ PURGE AT 20, 30 & 60 LBS/SEC.		SAME AS PHASE I EXCEPT USE 12:1 NOZZLE & ENGINE SHIELD; WITHOUT TEC	SAME AS PHASE I EXCEPT USE PROTOTYPE ENGINE COMPARTMENT
51,000* N ₂ 40,000* H ₂ O	2. NES CHECKOUT (GN ₂ PRIMARY)	VERIFY OPERATION IN PERMANENT ENGINE COMPARTMENT	1	1	4/5	4/5 (GN ₂)	70 (10 SEC. STEADY STATE)	S.G.S. PRE-FIRE PURGE & PRIMARY GN ₂ ONLY ADEQUACY OF THE PERMANENT PRE-FIRE PURGE SYSTEM WILL BE ESTABLISHED DURING THE TEST			
102,000* N ₂ 800* H ₂ 80,000* H ₂ O	3. NES TEST AT DESIGN CONDITIONS (GN ₂ PRIMARY)	VERIFY SATISFACTORY NES OPERATION AT DESIGN CONDITIONS	2	2	4/5	2 (GN ₂)	70 (10 SEC. STEADY STATE)	S.G.S. PRE-FIRE PURGE, DESIGN TURBINE EXHAUST, PRIMARY GN ₂ FLOW, DESIGN START-UP (TO MAX. Ppc) & SHUT-DOWN. (PRE-FIRE PURGE SYSTEM SHALL BE VERIFIED DURING THESE TESTS)			
12,000* N ₂ 2,000* H ₂ 80,000* H ₂ O	4. NES TEST AT DESIGN CONDITIONS (GN ₂ PRIMARY)	VERIFY SATISFACTORY NES OPERATION AT DESIGN CONDITIONS & CHECK THERMAL RADIATION	2	2	4/5	2 (GN ₂)	35 (10 SEC. STEADY STATE)	S.G.S. PRE-FIRE PURGE, DESIGN TURBINE EXHAUST, PRIMARY GN ₂ FLOW, DESIGN START-UP (TO MAX. Ppc) & SHUT-DOWN		CALORIMETER / RADIOMETER	
5,000* N ₂ 7,500* H ₂ 40,000* H ₂ O	5. NES OFF DESIGN TEST (GN ₂ PRIMARY)	DEMONSTRATE NES DUCT WILL MAINTAIN FULL FLOW WITH ABOVE DESIGN TURB EXHAUST	1	1	4/5		75	S.G.S. PRE-FIRE PURGE, EXPECTED SEAL LEAKAGE, ABOVE DESIGN TURBINE EXHAUST, / GN ₂ PRIMARY, USE 12:1 NOZZLE			
	PHASE II SUB-TOTAL		9	8							
	III. REMOVAL OF NES TEST DEVICE & CLEANUP			3							
TOTALS	429,000* N ₂ 12,460* H ₂ 12,163,000* H ₂ O	DESIGN DEMONSTRATION TEST PROGRAM TOTALS	23	27 3/8							
USE FACTOR	2 FOR N ₂ 3 FOR H ₂										
GRAND TOTALS	858,000* N ₂ 37,380* H ₂ 12,163,000* H ₂ O										

Δ S.G.S. OPERATION REQUIRES 700 LB/SEC. THRU DUCT

Δ DUCT AVAILABLE AT ETS-1 SITE - JUNE, 1965

Δ TEC AVAILABLE AT ETS-1 SITE - 3, APRIL, 1965

DATE	TIME	BY	REMARKS

4

3

2

1

REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVED

- NOTES:
- 1 512 PSIA (DESIRED)
255 PSIA (MIN) GN₂ & H₂ AMBIENT TEMP
 - 2 92 PSIA (MAX REQUIRED)
 - 3 FOR INSTRUMENTATION LISTINGS
SEE MEMO 793: MO 123 ENCL (1)
TEST PLAN DATED 22 JAN 1964

PURGE SYSTEM FLOW RATE 40*/SEC. GN₂ PRESSURE IS NOT SIGNIFICANT. (10'-0" DIA PERFORATED RING, 6" PIPE WITH 50 - 0.8125" DIA HOLES, 25 ON HORIZONTAL ¢, ID ONLY, AND 25 ON VERTICAL ¢, TOP SIDE ONLY).

SOUTH ELEVATION AT ¢ OF DUCT

QTY REQD	SYM	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	UNIT WT.	ZONE	ITEM NO.
LIST OF MATERIALS									
UNLESS OTHERWISE SPECIFIED					DRAWN D. SCALES	DATE	AEROJET-GENERAL CORPORATION AZUSA, CALIFORNIA		
CHECK					DESIGN	3-26-64	TITLE		
DESIGN					STRUCTURE/STRESS		NES DUCT DESIGN TEST		
TREATMENT					MATERIALS		DEMONSTRATION HARDWARE		
					PRODUCTION		CONCEPT NO 4		
FINISH					DESIGN ACTIVITY APPD		CODE IDENT NO		
ON THRU PART NEXT FINAL NEXT ASSY USED ON							70143		
EFFECTIVE SERIAL NO. USAGE DATA					SIMILAR TO	ACT WT	CALC WT	CUSTOMER	DWG NO. SK-TD-1203
DRAWING LEVEL					SCALE 1/2"=1'-0"		RELEASE DATE		SHEET

Figure 2

2

1

4

3

COPY SK-TD-1203

STARTUP TRANSIENT FOR NES DESIGN
DEMONSTRATION TESTS

Figure 4

SHUTDOWN TRANSIENT FOR NES DESIGN
DEMONSTRATION TESTS

Figure 5

Figure 6

GN₂ PRIMARY OFF-DESIGN TESTS
EXCESSIVE TURBINE EXHAUST & EXPECTED LEAKAGE

GN₂ PRIMARY OFF-DESIGN TESTS - EXCESSIVE SIMULATED
LEAKAGE & DESIGN TURBINE EXHAUST
SEQUENCE OF OPERATION

TESTS AT DESIGN CONDITIONS
SEQUENCE OF OPERATION

Figure 8

NES PROTOTYPE ENGINE TEST CELL INSTRUMENTATION LIST

SYMBOL	PARAMETER	PRIMARY ELEMENT LOCATION	RECORDER			CALC. PARA-METER	PRIMARY ELEMENT			REMARKS
			OSCILL.	PEN TYPE	COMPUTER PRINT-OUT		PRESS RANGE	OPER. TEMP.	QUANT.	
P _{pc} - 1	Primary Chamber Pressure	Primary Chamber	X	X	X		15-1000 PSIA	AMB.	1	
P _{pc} - 2	Primary Chamber Pressure	Primary Chamber			X		15-1000 PSIA	AMB.	1	
P _v - 1	Engine Environmental Cell Pressure	Environmental Cell	X	X	X		0-3 PSIA	AMB.	1	
P _v - 2	Engine Environmental Cell Pressure	Environmental Cell	X				0-15 PSIA	AMB.	1	
P _v - 3	Engine Environmental Cell Pressure	Environmental Cell	X				0-3 PSIA	AMB.	1	
P _v - 4	Engine Environmental Cell Pressure	Environmental Cell	X				0-3 PSIA	AMB.	1	
P _E - 1	Engine Nozzle Exit Pressure	Approx. 1/4" Upstream from Nozzle Exit Plane	X				0-15 PSIA	AMB.	1	
P _E - 2	Engine Nozzle Exit Pressure	Same Plane, but 90° from P _E - 1	X				0-3 PSIA	AMB.	1	
P _E - 3	Engine Nozzle Exit Pressure	Approx. 1" Upstream from Nozzle Exit Plane	X				0-3 PSIA	AMB.	1	
P _E - 4	Engine Nozzle Exit Pressure	Same Plane, but 90° from P _E - 3	X				0-3 PSIA	AMB.	1	
T _{PC} -1	Primary Chamber Temperature	Primary Chamber		X	X			AMB.	1	
T _{PC} -2	Primary Chamber Temperature	Primary Chamber			X			AMB.	1	
W _{N/H}	Primary Gas Flowrate	--				X				
W _L	Simulated Leakage					X				
ΔP _L	Simulated Leakage Flow Tube Differential Pressure	Leakage Gas Supply Flow Tube	X	X	X		200 PSID	AMB.	1	
W _p	Pre-fire purge flow rate					X				
ΔP _p	Purge flow tube differential pressure	Purge supply flow tube		X	X					
W _T	Turbine Exhaust Flowrate					X				
ΔP _T	Turbine Flow Tube Differential Pressure	Turbine Gas Supply Flow Tube	X	X	X		0-100 PSIA	AMB.	1	
P _{TC} - 1	Turbine Exhaust Chamber Pressure	Turbine Exhaust Chamber			X		100 PSIA	AMB.	1	
P _{TC} - 2	Turbine Exhaust Chamber Pressure	Turbine Exhaust Chamber			X		100 PSIA	AMB.	1	

Figure 9
Sheet 1 of 2

NES PROTOTYPE ENGINE TEST CELL INSTRUMENTATION LIST

SYMBOL	PARAMETER	PRIMARY ELEMENT LOCATION	RECORDER			CALC. PARA-METER	PRIMARY ELEMENT			REMARKS
			OSCILL.	PEN TYPE	COMPUTER PRINT-OUT		PRESS RANGE	OPER. TEMP.	QUANT.	
P _{TN} -1	Turbine Exhaust Nozzle Exit Pressure	Turbine Exhaust Nozzle Exit			X		0-3 PSIA	AMB.	1	
P _{TN} -2	Turbine Exhaust Nozzle Exit Pressure	Turbine Exhaust Nozzle Exit			X		0-3 PSIA	AMB.	1	
P _{TN} -3	Turbine Exhaust Nozzle Exit Pressure	Turbine Exhaust Nozzle Exit			X		0-3 PSIA	AMB.	1	
P _{TN} -4	Turbine Exhaust Nozzle Exit Pressure	Turbine Exhaust Nozzle Exit			X		0-3 PSIA	AMB.	1	
P _S -1	Engine Gas Supply Line Pressure	Common Supply Line at Engine		X	X		0-1000 PSIA	AMB.	1	
P _S -2	Engine Gas Supply Line Pressure	Common Supply Line at Engine			X		0-1000 PSIA	AMB.	1	
O ₂ -1	Oxygen Content Inside Shields	Environmental Cell		X			(Later)	AMB.		
O ₂ -2	Oxygen Content Inside Shield	Environmental Cell		X			(Later)	AMB.	1	
O ₂ -3	Oxygen Content Inside Shield	Environmental Cell		X			(Later)	AMB.		
O ₂ -4	Oxygen Content Inside Shield	Environmental Cell		X			(Later)	AMB.		
FS-1	Fire Switch Trace		X		X				1	
T _L	Simulated leakage gas Temperature	Simulated Leakage Supply Line			X			AMB.	1	
T _L	Turbine Exhaust Gas Temperature	Turbine Exhaust Supply Line			X			AMB.	1	
T _p	Pre-fire Purge Gas Temperature	Pre-Fire Purge Supply Line			X			AMB.	1	
Q _{PR}	Thermal Radiation of H ₂ Exhaust Plume	To be determined			X				1	Radiometer - 20 Btu/Ft ² Sec
Q _{PT}	Thermal Radiation of H ₂ Exhaust Plume minus Local Convection	To be determined			X				1	Calorimeter - 20 Btu/Ft ² Sec

Figure 9
Sheet 2 of 2

Figure 9

10:1 NOZZLE $\psi = 1.66$ $\alpha = 8^\circ$

$$\beta = \frac{\dot{w}_T \sqrt{(T/M)_T}}{\dot{w}_{PC} \sqrt{(T/M)_{PC}}} = \frac{\dot{w}_{LC} \sqrt{(T/M)_{LC}}}{\dot{w}_{PC} \sqrt{(T/M)_{PC}}}$$

β VS P_{PC} AT NOZZLE FLOW SEPARATION FOR 10:1 NOZZLE

Figure 10

12:1 NOZZLE

$\psi = 1.66$

$\alpha = 8^\circ$

$$\beta = \frac{\dot{w}_T \sqrt{(T/M)_T} + \dot{w}_{LC} \sqrt{(T/M)_{LC}}}{\dot{w}_{PC} \sqrt{(T/M)_{PC}}}$$

β VS P_{PC} AT NOZZLE FLOW SEPARATION FOR 12:1 NOZZLE

Figure 11

10:1 Nozzle $\psi = 1.66$ $\angle = 8^\circ$

1. Turbine Exhaust Flow at Engine Design Values.

2. Safety Purge = $P_{sc} = 100$ psia; $T_{sc} = 1650^\circ R$; $\dot{W}_s = 120$ lbs/sec.

3. Seal Leakage Flow = 1.5 lbs/sec amb. H_2

4. $P_{amb} = 12.8$ psia.

Engine Compartment Pressure, P_v , vs Nozzle Chamber Pressure, P_c , for 10:1 Conical Nozzle in ETS-1, NES

12:1 NOZZLE $\psi = 1.66$ $\alpha = 8^\circ$

1. Turbine Exhaust Flow at Engine Design Value.

2. Safety Purge $P_{sc} = 100$ psia; $T_{sc} = 1650^\circ R$; $\dot{W}_s = 120$ lbs/sec.

3. Seal Leakage Flow = 1.5 lbs/sec. amb. H_2 .

4. $P_{amb} = 12.8$ psia.

Engine Compartment Pressure, P_v , vs Nozzle Chamber Pressure, P_c , for 12:1 Contoured Nozzle in ETS-1, NES.

1 BOTTLES 1 THRU 6 FILLED WITH GN₂ FOR GN₂ TEST
2 BOTTLE NO. 7-10 FILLED WITH GH₂ & NO. 6
FILLED WITH GN₂ FOR GH₂ TEST

Figure 14