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TEST REPORT
NUCLEAR EXHAUST SYSTEM
DESIGN DEMONSTRATION
TEST PROGRAM
PHASE I

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MASTER

NERVA TEST OPERATIONS
Jackass Flats, Nevada

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TEST REPORT

NUCLEAR EXHAUST SYSTEM

DESIGN DEMONSTRATION

TEST PROGRAM

PHASE I

NTO-R-0127

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October 1967

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1.0 OBJECTIVES

The objectives of the NES Phase I test program, using the Temporary Engine Compartment (TEC), are as follows:

- 1.1 Demonstrate that steam generator operation is not adversely affected by steam discharging through the NES Duct ejector orifices.
- 1.2 Investigate relative degree of altitude simulation, with no primary flow, during one-module and two-module full steam operation.
- 1.3 Determine TEC repressurization rates during SGS shutdown of one module at a time.
- 1.4 Evaluate the capability of the SGS in normal two-module operation, to maintain TEC altitude simulation with a GN_2 purge of 30 lb/sec.
- 1.5 Determine the adequacy of the TEC purge system prior to and after hydrogen flow through the NES to provide adequate inerting.
- 1.6 With the SGS operating, verify duct "pull-in" characteristics by increasing primary nozzle flow.
- 1.7 Without the SGS, verify duct "drop-out" characteristics by decreasing primary nozzle flow.
- 1.8 Evaluate, at a primary chamber pressure of 210 psia, the effect of high GN_2 purge flow on TEC pressure, and primary nozzle flow separation.
- 1.9 Determine if minimum purge flow is required to avoid pressure fluctuation in the TEC during primary nozzle flow.
- 1.10 Evaluate ability of propane flare system to ignite and burn small quantities of GH_2 .
- 1.11 Demonstrate duct performance at full nozzle thrust conditions, design turbine exhaust flow of 7.0 lbs/sec., 1-1/2 lb/sec GN_2 purge flow and design flow of duct coolant water of 38,000 gpm.

- 1.12 Evaluate, at a primary chamber pressure of 550 psia, the effect of design turbine exhaust flow, and excess GN_2 purge flow on TEC pressure, and primary nozzle flow separation.
- 1.13 Verify ability of the SGS to prohibit back flow into the NES Duct following a rapid termination of primary flow (simulating an engine malfunction).
- 1.14 Evaluate, at a primary chamber pressure of 550 psia and with design seal leakage, the effects of excess turbine exhaust flow on TEC pressure, primary nozzle flow and possible nozzle flow separation.
- 1.15 With single module operation, verify ability of the SGS to prohibit back flow into the NES Duct following a rapid termination of primary flow.

Objectives 1.14 and 1.15 were subsequently deferred until Phase II test program to be conducted using the Engine Test Compartment (ETC) and the design turbine exhaust flow of objective 1.12 was increased to 8-1/2 lb/sec.

2.0 SUMMARY

- 2.1 The ETS-1 NES Phase I Design Demonstration Test Program was conducted between 19 January and 7 February 1967 with a total of five tests being conducted.
- 2.2 These tests were conducted using the Temporary Engine Compartment (TEC) to provide a reduced pressure containment chamber for the simulated engine and turbine nozzles since the Engine Test Compartment (ETC) was not operational. This represented the first combined operation of the Steam Generator System (SGS), with simulated engine flow through the NES Duct.

The tests were performed to evaluate the structural integrity and dynamic performance capabilities of the Duct. Ambient temperature GN_2

was utilized for simulating the engine primary nozzle flow and for the TEC and Duct inerting and purging flow. Ambient temperature GH_2 was utilized for simulating turbine exhaust fluid. These nozzles were positioned in the proposed XE engine location.

- 2.3 The performance during this Test Program of the Steam Generator System and Steam Line is detailed in report NTO-R-0125, and the water coolant flow through the NES Duct is detailed in report NTO-R-0106. This report covers the aerodynamic and inerting performance of the NES System.
- 2.4 Generally the performance of the NES was within the predicted values. Single Steam Generator module operation pulled the TEC pressure down to 10 psia and two steam generator module operation pulled the TEC pressure down in the range of 7.0 to 8.0 psia. The NES duct "pulled-in" at approximately 160 psia with two steam generator module operation. Problem areas were experienced in the permanent O_2/H_2 detection system and in the FS-5002 flare system that will require additional evaluation and modification prior to initiating the Phase II test program.
- 2.5 The test program was concluded after test NEP-IV and the objectives of paragraph 1.14 and 1.15 were deferred until Phase II to allow for completion of the ETC and permit necessary steam line modifications.

3.0 CONCLUSIONS AND RECOMMENDATIONS

- 3.1 Steam Generator operation was not affected by the NES Duct secondary ejector nozzles, which indicates that the previously used single orifice to provide steam generator system backpressure was a satisfactory approximation. (Objective 1.1)
- 3.2 With one steam generator module operating the TEC pressure was reduced to approximately 10 psia and was further reduced in the range of 7.0 to 8.0 psia depending on steam temperature when two modules were operating at full steam. (Objective 1.2)

- 3.3 The TEC repressurized from 8.0 psia to 10 psia in 3.0 seconds and from 10 psia to 12.5 psia in 3.0 seconds when the modules were singularly terminated. No overpressurization or rise in O_2 concentration was noted in the TEC during the shutdown. (Objective 1.3)
- 3.4 With two steam generator modules operating and no primary flow, the TEC pressure (approximately 7.5 psia) was not affected by the introduction of 30 lb/sec GN_2 . (Objective 1.4)
- 3.5 The TEC purge system was adequate in reducing the O_2 content below 3% prior to the introduction of GH_2 and after the conclusion of testing, was adequate in reducing the H_2 concentration to less than 2%. (Objective 1.5)
- 3.6 With two modules operating at full steam conditions, the duct "pull-in" occurred at 160 psia primary chamber pressure. A region of "buzzing" occurred from 140 psia to 160 psia. During TEC repressurization the "buzzing" occurred between 172 and 128 psia. A TEC pressure of 0.32 psia was experienced at a primary nozzle pressure of 195 psia. (Objective 1.6)
- 3.7 Duct "drop-out" occurred with the primary chamber pressure at 195 psia when the last module at full steam was shutdown. A peak-to-peak pressure oscillation of 1.6 psi at a frequency of 1.5 CPS occurred until the primary chamber pressure was decreased to 175 psia.

A TEC overpressure spike of 0.37 psi above atmospheric was observed from the data at the end of the repressurization. It is concluded that an operating regime exists as a function of number of steam generators operating at full steam in which TEC pressure fluctuations will be experienced. (Objective 1.7)

It is recommended that the engine operating profile be evaluated in this region and additional testing be conducted to define the curve for one generator and confirm the curve for no generator operation.

- 3.8 When operating at the primary nozzle chamber pressure of 195 psia, a 17 lb/sec GN_2 TEC purge increased the TEC pressure from 0.21 to 0.89 psia. The primary chamber nozzle exit pressure was unaffected and remained at 1.5 psia. At the same primary nozzle conditions of 195 psia, when the GH_2 turbine flow increased to 2 lb/sec the TEC pressure increased from 0.25 to 0.49 psia. The TEC pressure momentarily peaked during this rise to 0.59 psia. (Objective 1.8)
- 3.9 It is concluded that the engine operation will be substantially unaffected by any excess GN_2 purge up to 17 lb/sec. (Objective 1.8)
- 3.10 There was no noticeable pressure fluctuations in the TEC when the GN_2 purge flow was reduced to zero. It is, therefore, concluded that a minimum purge flow to stabilize the primary flow is not required. (Objective 1.9)
- 3.11 The flare system (FS-5002) adequately demonstrated its ability to ignite and burn small quantities of GH_2 up to 7.0 lb/sec. Problems were experienced in maintaining flare ignition probably due to nitrogen aspiration into the burner circuit and poor operating mixture ratio. It is recommended that additional effort be expended to overcome these deficiencies prior to initiating the Phase II test program. (Objective 1.10)
- 3.12 Satisfactory duct performance was demonstrated at the following design conditions:

Primary Chamber Pressure	= 550 psia
Turbine Exhaust Flow	= 7.0 lb/sec
Duct Coolant Flow	= 39,600 GPM

After achieving the primary chamber pressure conditions, the TEC pressure increased from 0.6 to 0.80 psia as the turbine exhaust flow was increased to its design value. The TEC pressure momentarily peaked during this rise to 1.7 psia.

The separation distance of 13" between the nozzle exit and the duct inlet appears to provide for adequate duct operation. Rated duct coolant flow had no apparent adverse effect on NES operation.
(Objective 1.11)

3.13 The primary objectives of section 1.12 (that of maximum chamber pressure maximum GN_2 flow and above design turbine flow) were not achieved due to a failure of the chamber pressure transducer (PT-905) which caused a premature but most rapid closure of PCV-449, the valve controlling the primary flow. The rapid termination of primary flow fortunately achieved objective 1.13 with a decay rate of 665 psi/sec being achieved between primary chamber pressures of 300 and 100 psia. No TEC overpressure or O_2 re-entry occurred as the SGS was still operational.

3.14 The permanent O_2 - H_2 detector operation in the region below approximately 8 psia was unacceptable. The system should be evaluated to determine if any air backflow can occur which would give erroneous readings.

A thorough evaluation should be instituted to determine its calibration as a function of compartment pressure.

3.15 The duct internal surface was dented by a 7/8" steel nut being blown through the duct. An evaluation indicated that the dents could be repaired by surface treatment only.

It is recommended that for all future operations whether NES, XECT or XE-1 all bolts be "double nutted", safety wired, welded or secured by any other acceptable method which will preclude their loosening.

4.0 TECHNICAL DISCUSSION

4.1 General

Phase I of the NES Design Demonstration Test program was initiated on 19 January 1967 and was completed on 7 February 1967. The test program was conducted in accordance with the following documents:

- 1) NES Design Demonstration Test Plan with Temporary Engine Compartment, NRO Report No. RN-S-0286.
- 2) NRO Test Specification No. 201, Nuclear Exhaust System Design Demonstration Tests, Phase I.
- 3) Support Operational Requirements Document for NES Experimental Plan I, NTO-I-0157, included in this report as Appendix I.
- 4) Dry Run Checklist for NES Experimental Plan I, NTO-I-0174.
- 5) Control Room Operating Procedure for NES Experimental Plan I, NTO-I-0166.
- 6) Dry Run Checklist for NES Experimental Plan, Tests No. 3, 4, 5, 6, and 7, NTO-I-0175.
- 7) Control Room Operating Procedure for NES Experimental Plan II, NTO-I-0169.
- 8) Control Room Operating Procedure for Phase I NES Experimental Plan III, IV and V, NTO-I-0170.
- 9) Control Room Operating Procedure for NES Experimental Plan IV, NTO-I-0199.

4.2 System Description

4.2.1 Function

The exhaust system built into ETS-1 for testing of the NERVA Engine is designed to accomplish the following:

- 1) To direct the engine exhaust gases away from the NERVA Engine and ETC for safe burning in the atmosphere.
- 2) To prevent air from entering the exhaust system and engine test compartment during normal or malfunction engine operating conditions, thereby preventing a possible hydrogen fire or detonation.
- 3) To provide altitude simulation within the ETC by aerodynamic pumping action of the engine exhaust gases.

4.2.2 NES Description

The NERVA Exhaust System is comprised of two major sub-systems; the exhaust duct, and the steam generator system (SGS).

1) Exhaust Duct

The exhaust duct mates with the engine compartment bottom shield to direct the NERVA exhaust gases vertically downward for approximately 50 feet and outward horizontally away from the stand for approximately 54 feet, and finally into the atmosphere at an angle of approximately 45° upward from the horizontal plane.

As indicated in Figure 1, the duct consists of three sections. The first is a vertical section called the Primary Duct, consisting of an entrance cone, throat section, and subsonic diffuser. The next section consists of a 90° elbow joined to an offset cone contraction element. The last section, called the Secondary Duct, is a straight horizontal section with a steam ejector (for safety purge) and a 45° exit elbow.

The three sections of the duct together with their supporting truss members constitute the duct-truss assembly. The duct is fabricated from type 347 stainless steel and the truss from type 304. The elbow section of the duct is constructed from round tubes welded together, while the straight sections are constructed of sheet and angle sections welded together to provide rectangular channels.

These longitudinal channels and tubes are used to flow cooling water through the duct during engine operation.

In addition, the elbow section has a water-filled secondary jacket to provide protection against cooling water loss in the event of penetration damage or weld failure in that section.

The duct-truss assembly is housed in a concrete vault below the engine in the ETS-1. The concrete walls of the vault surround three sides of the duct-truss assembly, the exhaust side being open during engine tests. The concrete walls of the vault are three (3) ft. thick to provide radiation shielding for personnel and equipment in the adjacent pipe chase and equipment vaults after test firing and engine removal.

After firing, an aluminum-covered concrete door may be closed to cover the vault opening for personnel protection against radiation

emission from activated duct components. During an engine test, the NES vault area will be sprayed with water for cooling of the structural members of the NES Duct Support.

2) Steam Generator System

The Steam Generator System (SGS) delivers steam through a sonic ejector into the NES secondary duct at approximately 125 psia and 1460° R. The flow rate is designed to be equal to the sum of:

- a) The choked flow rate (92 pounds per second) required to fill the duct in the event of an instantaneous termination of the engine working fluid, and
- b) The flow rate (23 pounds per second) required to prevent entry of 35 mph air into the duct.

The SGS pulls a partial vacuum (approximately 7.5 psia) in the primary duct and engine compartment prior to engine startup.

The chemical steam generator produces steam on command from a high rate combustion of propane with oxygen. Water is injected into the combustion products to reduce their temperature and provide additional steam. There are three identical steam generator modules connected to a common plenum mixing and discharge chamber.

Each module is capable of independent operation. Normally two units operate concurrently with the third on standby. In the event an operating module shuts down due to malfunction, the standby module will come onstream within five seconds.

4.2.3 Facility Support Systems

The facility systems required to support NES operation include the Process Water System, the Propane Flare System, and the Facility Gas Supply System.

1) Process Water System

Water is used at ETS-1 for cooling and shielding in the Engine Test Compartment (ETC), for cooling the NES Duct, for operation and cooling of the Steam Generator System, for fire-fighting, and for the test stand deluge systems.

This water is supplied from a well to a storage tank north of the CP Area. A demineralizer plant in the CP Area reduces mineral content and adds a rust inhibitor, and the water is then pumped to a 2,750,000 gallon storage tank on a slope North of ETS-1, approximately 500 feet above the test stand.

The demineralized water is gravity fed through 42-inch diameter supply line from the storage tank to ETS-1. The process water system provides sufficient cooling water through the duct walls such that the maximum duct inner wall temperature in the elbow section will not exceed $1,640^{\circ}\text{R}$, and in the straight sections, will not exceed $1,460^{\circ}\text{R}$.

Cooling water flows in separate circuits through each of the three duct sections; i.e., primary (counter flow) elbow (parallel flow) and secondary (counter flow). All cooling water is eventually dumped into an open drain.

2) Duct Flare System

Propane flares are provided for safe burning of hydrogen gas at the exhaust duct outlet, the duct drain pipe outlet, the LH_2 storage area, the steam generator and the LH_2 run tank. These flares are remotely ignited from the control area and are supplied from the same 15,000 gallon 400 psig propane storage tank (V-3401) that feeds the SGS.

3) Facility Gas Supply System

Storage and supply systems for gaseous nitrogen, gaseous hydrogen and gaseous helium are available for ETS-1.

Gaseous nitrogen is utilized for general facility purge, buffer zone pressure for flange seals, flare stack molecular seals, pressurization of the LN_2 , IO_2 and propane storage vessels, remote valve operation and engine cooldown following a test run. Nitrogen is procured and stored in liquid form and may be converted to gas by the LN_2 vaporizer as required. Gaseous nitrogen is normally stored in three 1750 cubic feet, 2500 psig storage vessels (V-3201, -2 and -3).

Gaseous hydrogen is utilized for engine cooldown and LH_2 dewar pressurization. Hydrogen is procured and stored in liquid form and may be converted to gas by the LH_2 vaporizer as required. GH_2 is normally stored in three 2,400 cubic feet, 2,500 psig storage vessels (V-3207, -8 and -9).

Gaseous helium is utilized for engine purge, for facility purge in LH_2 areas, for remote valve operation in LH_2 systems and for engine cooldown. It is also, of course, a valuable medium for leak tests. GHe is normally stored in three 1,750 cubic feet, 2,500 psig storage vessels (V-3204, -5 and -6).

Storage vessels V-3201 through V-3206 may be utilized for GN_2 and/or GHe storage in any combination, depending on test requirements. Manifolding allows connection of any of these bottles into either the GHe or GN_2 facility gas supply headers.

Special flow rate demands of NEP III and NEP IV ($P_c = 550$ psia) required the combined capacity of the GH_2 (6") GN_2 (8") GHe (6") headers for primary fluid supply to PCV-449. For these tests, the three gas headers (GN_2 , GH_2 , GHe) were connected in parallel by manifolds in the gas storage area and at the PCV449 inlet.

4.3 Test Arrangement

Figure 2 shows the arrangement of the simulated engine and turbine exhaust chambers and nozzles inside the TEC. Additional 1.5- and 3-inch nozzle inlet flange spacers were available in the event it was necessary to decrease the 13.0 inch critical distance between the nozzle exit and the top of the duct. GN_2 for purge and simulated leakage was provided through a drilled ring in the top of the TEC. GN_2 primary fluid was supplied from seven of the facility gas storage bottles pressurized to 2475 psig through one 8-inch and two 6-inch gas headers which were interconnected at the gas storage area and at PCV-449 inlet. This valve metered the flow through a 12" temporary

line into the primary chamber. A closed loop pressure feedback from the primary chamber (P-905) controlled PCV-449 operation to provide preset up-ramps, hold levels and down-ramps of primary flow.

The GH_2 turbine exhaust fluid was stored at a maximum pressure of 1390 psig, at ambient temperature in V-5002, the 592 cubic ft. high pressure LH_2 storage dewar. The GH_2 was transferred to the turbine exhaust chamber via 4-LH-6 and PCV-472. This valve was controlled by position demand potentiometers which were manually adjusted by visual indication of P-901.

Purge and simulated leakage from the 8-inch GN_2 header take-off upstream of PCV-449 through PCV-446 (2") and PCV-447 (1") connected in parallel. Mass flow was then measured by FE-426 (4"), respectively, and delivered to the TEC purge ring via line 201 GN 6. These pressure control valves were controlled by position demand potentiometers which were manually set by visual indications of FE-426 and FE-427 on-line calculators.

4.4 Test Parameter Measurements

Appendix A of the NEP I Support Operational Requirements Document, Appendix I to this report, lists all parameters which were recorded during the Phase I tests. Interrelationship of SGS, duct, process water system and test fixtures, and locations of test parameter transducers and system components are shown schematically in Figure 3.

4.5 Test Results

Table I is a tabulation of the pertinent data pertaining to each of the five tests discussed hereafter.

The turbine flow was determined from the NRO curves shown as figure 4. The primary nozzle flow was determined from the curves shown in figure 5. It should be noted that the ordinate of figure 5 is the static pressure measured at P906 and accounts for the velocity of approach.

4.5.1 NEP-I

This test, conducted on January 19, 1967, was performed to verify that steam generator operation is unaffected by back pressure when discharging into the NES Duct as compared with the temporary orifice plate used

during SGS development testing, to determine TEC pull-down with one and two module operation, to determine repressurization rates during shutdown of one module at a time and to determine the effects of 30 lb/sec GN_2 purge flow on TEC pressure during SGS operation. All of these test objectives were met.

In preparation for full steam operation, the TEC was purged with GN_2 to reduce the O_2 concentration to less than 3.5%, and the three SGS modules were started to idle steam.

The test chronology is delineated in Appendix II, Section 1. Module #1 was brought to full steam conditions and the steam pressure increased to 43 psig at an initial rate of 23 psi/sec; the steam temperature was then adjusted to 1560°R. The resultant TEC pressure was reduced from 12.4 psia to 10.3 psia at a rate of 0.8 psi/sec for the 485 ft³ TEC volume and the approximate 800 ft³ duct section I & II volume.

The startup of the single SGS module to full steam temperature conditions resulted in a high temperature shutdown after 109 seconds which was caused by too rapid adjustment of the steam temperature controller. The rate used was normal for two unit operation, however, with the additional cooling water from the second unit at idle continuously being supplied, extremely high operating module temperatures were being experienced. For a more complete discussion of the malfunction and its effects, see report NIO-R-0125, "Steam Generator Product Improvement Test Program." The high steam temperature shutdown reduced steam pressure at 21 psi/sec resulting in a TEC pressure rise to 12.3 psi (ambient) at 1 psi/sec with no overpressure. The TEC pressure changes lagged the steam pressure changes by 0.1 sec.

During the second SGS startup, modules 2 and 3 were brought up to full steam within 18 seconds. The module 2 startup increased steam pressure from zero to 42 psig, (with a 10 psi overshoot), at an initial rate of 27 psi/sec; the module 3 startup then increased pressure from 42 to 85 psig at an initial ramp of 38 psi/sec, with a 9 psi overshoot. TEC pressure was reduced from 12.4 to 10.3 psia at 2.1 psi/sec during module 2 startup and from 10.3 to 8.1 psia at 1.3 psi/sec during module 3 startup. Equilibrium TEC pressure with two SGS modules operating was 8.1 psia.

This pressure remained unchanged and stable within ± 0.1 psi during the subsequent 33 lb/sec GN_2 purge flow. During this purge flow, both SGS modules were shutdown to idle within 20.0 seconds. The module 2 shutdown reduced steam pressure from 95 to 46 psig at 14 psi/sec; TEC pressure increased from 8.0 to 10.1 psia at 0.7 psi/sec. When the second operating SGS module (SG-3) was shutdown, steam pressure was reduced from 45.4 to 1.4 psig at 12.5 psi/sec from a steam temperature of 1365°R . TEC pressure then increased from 10.1 to 12.3 psia (ambient atmospheric pressure) at 0.7 psi/sec with no overpressure. On review of the digital data, no increase in TEC oxygen concentration was noted. The pulldown and repressurization of the TEC is shown in Figure 5.

Since the ratio of the volumes of the ETC and duct sections I & II (6950 ft^3) to the TEC and duct sections I & II (1280) is approximately 5.5, the momentum of the re-entering gas could result in an overpressure of the ETC and/or O_2 reentry. This should be investigated during the NES Phase II test series which utilizes the ETC.

4.5.2 NEP II

This experimental plan consisted of two tests which were conducted on 26-27 January 1967. Test No. 1 was performed to evaluate duct pull-in from zero to 200 psia primary chamber pressure at a 9.0 psi/sec ramp-up rate and to demonstrate safe shutdown on an 8 psi/sec ramp-down rate without SGS operation.

Test No. 2 was to evaluate, at P_c - 200 psia, the effects of excess seal leakage on TEC pressure and primary nozzle flow characteristics, to determine if a minimum seal leakage was required to avoid TEC pressure fluctuations during primary nozzle flow and to evaluate the ability of FS-5002 to burn small quantities of GH_2 . All of these test objectives were met.

4.5.2.1 NEP II-I Test Phase

The test chronology is delineated in Appendix II, Section 2. Sixty-four seconds after SGS flow was established at 127.0 lb/sec of steam at 1715°R and 119 psia, the PCV-449 up ramp of 9.0 psi/sec was initiated at a range time of 78573.5. TEC pressure decreased from 7.0 psia to 0.37 psia, then slowly diminished to 0.32 psia during continued nozzle flow at a P_c of 195 psia. During pull-in, a region of TEC pressure instability (buzzing) was observed between primary chamber pressures of 140 and 160 psia. These oscillations were 0.9 psi peak-to-peak amplitude at 1.6 cps frequency. The pull-in point at this up ramp was 160 psia P_c . At a range time of 78616.1, one of the operating SGS modules, SG-2, was shutdown to idle steam. No change in TEC pressure or primary nozzle exhaust pressures was observed. However, severance plane pressure (P-805) increased to 12.3 psia from 11.3 psia. At range time 786259, the second SGS operating module (SG-1) was also shutdown to idle steam. The TEC pressure then began a 1.6 psi oscillation at a frequency of 1.5 cycles per second. These oscillations continued until the P_c decreased to 175 psia on the down ramp at which point the TEC pressure had increased to 1.5 psia. On shutdown of the second SG module, the severance plane pressures (P805 & P806) increased from 12.3 psia to 13.7 psia.

The TEC repressurized at a rate of 0.5 psi/sec at a P_c down ramp of

8 psi/sec. A peak overpressure of 0.37 psi above atmospheric pressure was observed. The pertinent parameters are shown in Figure 7.

4.5.2.2 NEP II-2 Test Phase

The test chronology is delineated in Appendix II, Section 3. In preparation for the primary flow test, TEC purge flow was established at 0.8 lb/sec and two steam generator modules were increased to full steam and adjusted to provide 1760°R steam at 118 psia to the NES Duct. With a 16.7 psi/sec up ramp, the primary nozzle pull-in point was determined to be 170 psia. Prior to pull-in at primary chamber pressures between 140 and 157 psia, 0.7 to 1.2 psi TEC pressure oscillations were observed at an approximate frequency of 1.5 cps. At the pull-in point ($P_c = 170$ psia), the TEC pressure was reduced to 0.32 psia. This pressure decreased to 0.25 psia as equilibrium was achieved prior to turbine exhaust flow initiation.

As hydrogen flow was ramped up through the simulated turbine exhaust nozzles, the TEC pressure increased from 0.25 psia to 0.59 psia at 1 lb/sec GH_2 . The TEC pressure then decreased to 0.49 psia at 2 lb/sec GH_2 flow. A similar pressure increase was also apparent on the TEC pressure as the GH_2 turbine flow was ramped to zero flow.

A TEC pressure change from 0.21 to 0.890 to 0.200 psia resulted from a subsequent 0 to 16.9 to 0 lb/sec GN_2 purge flow through the TEC purge ring during the 195 psia primary chamber pressure operation. As shown in Figure 8, the primary nozzle exit pressure was unaffected by the above TEC pressure variations and remained at approximately 1.5 psia.

During the 300 lb/sec ($P_c = 195$ psia) GN_2 primary flow, duct severance plane pressure increased from 7.5 to 11.2 psia. This pressure remained unchanged during the simulated turbine exhaust and purge gas flow operations as shown on Figure 9.

During duct "drop out", the TEC pressure oscillations (buzzing) reoccurred between primary chamber pressures of 172 and 128 psia as shown on Figure 10.

4.5.3 NEP III

This test was performed on February 2, 1967 to demonstrate duct performance at full nozzle thrust conditions, design turbine exhaust flow, and duct coolant water of 38,000 gpm; and to observe the adequacy of post-fire purging following H_2 flow through the simulated turbine exhaust nozzles. All of these test objectives were met.

As a result of TRB action, see Appendix III, the steam temperature was reduced from $1760^{\circ}R$ to $1350^{\circ}R$ to protect the steam line.

In preparation for the primary flow test, the TEC and duct were purged and duct water flow was established at 39,600 gpm. Purge flow was then adjusted to 1.5 lb/sec and two steam generator modules were started to full steam with the third unit put on standby. This provided 137 lb/sec of $1430^{\circ}R$ steam to the duct ejector nozzles and reduced the TEC pressure to 7.0 psia. The test chronology is delineated in Appendix II, Section 4.

Primary flow was then ramped up at 18 psi/sec to 532 psia and held for seven seconds as shown in Figure 11 after which decaying supply bottle pressure reduced the chamber pressure to 450 psi in the subsequent 17 seconds, prior to initiation of a 16 psi/sec down ramp. During primary flow the TEC purge flow varied from 2 to 0.1 lb/sec and this turbine exhaust GH_2 flow was ramped from 0 to 7 to 0 lb/sec in 14 seconds. Figure 12 shows the TEC pressure as a function of SGS operation, primary flow and turbine flow. The TEC pressure during initial pull-in was reduced to 0.3 psia at a P_c of 160 psia. As P_c was increased above the pull-in point, TEC pressure increased to 0.65 psia at 530 psia P_c as shown in Figure 13. These TEC pressures are one-half psi lower than predictions from scale model tests. The repressurization curve as shown in Figure 14 followed the pull-in curve within 0.05 psi; this difference is probably due to system hysteresis or difference between transient and steady state conditions.

During pull-in and repressurization, TEC pressure oscillations (buzzing) were evident between primary chamber pressures of 135 and 155 psia. One oscillation of 0.87 amplitude for a 0.5 second duration occurred on the 18 psi/sec up ramp whereas three oscillations of 1.3

psi amplitude at 1.8 cps occurred on the 16 psi/sec down ramp as shown in Figure 15. The severance plane pressures as shown in Figure 16 increased from approximately 7.5 psia to a maximum of 18 psia during primary flow conditions.

When GH_2 simulated turbine exhaust flow was introduced, TEC pressure fluctuated from 0.6 to 1.7 to 0.8 psia as GH_2 flow was increased from zero to 7.0 lb/sec. A similar change from 0.8 to 1.4 to 0.6 was experienced on the down ramp from 7 to zero lb/sec. During steady state turbine exhaust flow, TEC pressure was stable 0.2 psi higher than pre and post-flow conditions, as shown in Figures 12 and 17.

Comparing primary nozzle exit pressure of Figure 18 with the TEC pressure shown in Figure 12 or 17 reveals that for the approximately 500 psi chamber pressure, the 10:1 nozzle is underexpanded. Figure 19, based on Equation 1, is a curve of static chamber pressure versus the nozzle exit pressure. The chamber pressure parameter, however, reflects the velocity of approach.

Equation 1

$$\frac{A_c}{A^*} = \sqrt{\frac{k-1}{2}} \left(\frac{k+1}{2}\right)^{\frac{k+1}{2-2k}} \left[\left(\frac{p}{p_{t1}}\right)^{\frac{2}{k}} - \left(\frac{p}{p_{t1}}\right)^{\frac{k+1}{k}} \right]^{-\frac{1}{2}}$$

A = Exit Area

A* = Throat Area

k = Ratio of Specific Heat

p = Static Exit pressure

p_{t1} = Total Pressure

Good correlation is obtained when comparing the nozzle chamber pressure and nozzle exit pressure from Figures 11 and 18, respectively, with the theoretical curve, Figure 19, as shown below.

Range Time Seconds	P _c Psia	P _e (Average) Psia	P _e (Theoretical) Psia
73920	260	2.0	2.08
73930	440	3.4	3.50
73940	530	4.1	4.20

4.5.4 NEP IV

This test was performed on February 7, 1967 to evaluate, at a primary chamber pressure of 550 psia, the effects of excess turbine exhaust flow, and GN_2 purge on TEC pressure, and primary nozzle flow separation and to verify the ability of the SGS to prohibit back flow into the NES Duct following a rapid termination of primary flow which simulates an engine malfunction. The excess turbine flow requirement was reduced from 15 lb/sec to 8.5 lb/sec GH_2 and included in NEP IV as a result of TRB action, see Appendix IV.

In preparation for the test, the TEC and duct were purged with GN_2 to reduce O_2 concentration to less than 3.5% and duct water flow was established at approximately 39,000 gpm. Purge flow was then reduced to 1.5 lb/sec. Two steam generator modules were started to full steam and the third unit was put on standby. This provided 135 lb/sec of 1350°R steam to the duct ejection nozzles which reduce the TEC pressure to 7.7 psia. The test chronology is delineated in Appendix II, Section 5.

A primary GN_2 flow up-ramp of 82 psi/sec was then initiated simultaneously with a GH_2 simulated turbine exhaust ramp up to 8.5 lb/sec. At a P_c of 439 psia and a TEC pressure of 1.1 psia, the P-905 transducer which provided the primary chamber pressure feedback signal for the PCV-449 controller, failed to a full scale indication, thereby inducing the controller to close the valve. The primary nozzle chamber pressure decayed at a rate of 665 psi/sec between 300 and 100 psia P_c .

This action was immediately followed by manual switching of the PCV-449 "mode of operation" selector switch from the "Program" mode to the "Manual" mode which was preset at 5% open position demand. The valve was then closed with the manual demand pot.

This manual switching procedure was a pre-arranged, evasive action to prevent repeated impacting of the plug upon the seat in the event of an intermittent malfunction and to step the valve to 5% open from any position for subsequent manual closure. Figures 20 and 21 shown the TEC pressure and primary nozzle exit pressure during the "pull-down" and rapid repressurization since the SGS was still operating. No increase in O_2 concentration was noted on evaluation of the data from

the temporary O_2 sensors. The permanent sensors did not work correctly as is discussed in section 4.6.1.

Following the PT-905 malfunction, purge flow was increased to 37 lb/sec and GH_2 flow was terminated. The GN_2 purge was reduced to 1.5 lb/sec for a 265 sec. hold. During this time, the cause of the malfunction was determined to be in the PT-905 transducer which was located inside the TEC. Since the only redundant primary chamber pressure transducer, PT-906, was ranged only to 300 psia, the test was aborted and the SGS Duct, coolant and facility systems were shut down.

During the TRB (meeting No. 3, see Appendix V) the Phase I program was terminated and the objectives scheduled for the remaining tests were deferred until the NES Phase II program.

4.5.5 Summary of Test Results

With the SGS operating no TEC overpressure or O_2 intrusion was experienced during ramp down of primary nozzle pressure even at the maximum rate of 665 psi/sec. A 0.37 psi TEC overpressure was observed during the 8 psi/sec ramp down of primary nozzle pressure after termination of SGS operation.

The TEC GN_2 purge proved adequate in inerting the TEC to exclude oxygen and after testing to exclude hydrogen. Purges up to 30 lb/sec appear to have little or no effect on TEC pressure.

At ramp rates less than 82 psi/sec both with and without SGS operation, a region of buzzing is experienced during duct "pull-in" and "drop-out". With SGS operation this region occurred between primary chamber pressures of 130 to 170 psia and without SGS operation the buzzing region is at higher chamber pressures.

At ramp rates of 82 psi/sec and higher with SGS operation no buzzing was evident.

Figure 22 shows the actual duct operating curves superimposed on the NES project supplied curve. During SGS operation the steam flow was 127 lb/sec at 1715°R and resulted in a 105 psig pressure at the duct secondary ejector. The ramp up rate with the SGS in operation was 9 psi/sec and the ramp down rate without the SGS system was 8.8 psi/sec. Good agreement was found with the predicted curve during the pull-down but the TEC pull-in pressure was found to be lower than the predicted curve. Figure 22 also shows the operating curve without SGS operation.

Figures 23 and 24 show TEC pull down and repressurization versus primary chamber pressure respectively for various ramp rates. These curves tend to show the effect of TEC volume on ramp rate. In figure 23 for the 82 psi/sec ramp rate the pull-in point is not pronounced and buzzing was not evident probably because gas was still evacuating from the TEC as the buzzing region and pull-in point was reached and past.

Lag in repressurization is very evident in figure 24 for the 665 psi/sec ramp rate, which indicates that some period of time is required to repressurize the TEC.

A point is shown on each figure which depicts the same steady state point which was obtained during NEP IV. It can be seen that slow ramp rates during pull-in approximates steady state operation.

4.6 Special Topics

4.6.1 Flare System (FS-5002)

During the Phase I test program difficulty was experienced in maintaining FS-5002 lighted during all test operating conditions. Figure 25 is a schematic of the flare system at the start of the Phase I test program. Subsequently it was determined that 0.050 inch diameter orifices were missing from each burner fuel supply line. Burner operation appeared to be better after this modification but snuffing out of the one or more of the burners was still occurring occasionally. The test program was successfully concluded in this configuration and gaseous hydrogen when introduced into the NES was ignited and burned without incident.

It was ascertained that GN_2 issuing from the NES could be aspirated into the Duct Vault boom openings. It is recommended that these openings be closed and air be introduced at some location in the Duct Vault to supply the required air.

4.6.2 Permanent O₂ - H₂ Detection System

During the test program, the permanent O₂ analyzers appeared to operate satisfactorily at TEC pressures down to approximately 8.0 psia, it's design condition, when compared to the temporary O₂ detectors actually installed within the TEC.

During primary nozzle operation, when the TEC pressure was quickly reduced to the range of about 0.5 psia, O₂ spikes and excessive O₂ concentrations were noted on the permanent O₂ detection system which was not apparent on the temporary system.

It is postulated that the O₂ indications were due to air back flow into the sensor system coupled with the inadequacy of the installed pumping system to supply samples to the sensor during simulated high altitude operation. Figure 26 is a schematic of the permanent O₂- H₂ detection system.

Prior to the initiation of Phase II, the permanent O₂ - H₂ system should be thoroughly evaluated to determine the effect on the system at various altitude conditions with known sample compositions of:

- a) actual indication of sample concentration;
- b) electronic response time; and
- c) sample transport time to the sensor.

4.6.3 Duct Internal Surface Damage

Subsequent to the last test (NEP IV) of Phase I of the NES Design Demonstration Test Program a series of dents and nicks were found on the internal surfaces of the NES duct. It was determined that the damage was caused by a 7/8" I.D. steel nut weighing $4\frac{1}{2}$ oz. being blown at high speed through the duct. Since then an investigation has been completed evaluating the extent of damage and its affect on the duct serviceability. Based mainly on the results of heat transfer and strength analyses, it has been concluded that the duct is entirely satisfactory for use provided the surface is smoothed and polished in the damaged areas. The findings of the investigation leading to this conclusion are summarized hereafter: Evidence was found of five separate "hits" made as the nut was blown through the duct. The first two were in the elbow section where the coolant passage construction is tubular. The other three hits were in the secondary section where the duct has a continuous cylindrical inner shell and the coolant passages are formed from welded-on angle sections. Hit number 4 caused no damage of significance and was disregarded in further evaluation.

Dye penetrant tests were performed on all defects to determine if the sudden impact by the nut had caused cracking of the material. No cracks were present.

Plaster impressions were then made of each defect and brought to Sacramento for further evaluation. Wax positives were made of the worst defects, evaluated under a comparator, and plotted at 10 x magnification. The maximum dent depth was where a depth of 0.155" was measured in the 3/4" dia. tube.

A study was then made of the tube-to-tube variation in coolant flow caused by the worst dents to see if the damage could cause significant flow starvation. The maximum variation was calculated to be of the order of 2% of nominal, and this is deemed well within acceptable limits. This statement is based on other calculations which show a margin of at least 3.3 between normal and burnout heat flux for

the pertinent local conditions at the site of the #1 defect.

Two heat transfer analyses were performed for the defect judged as the area of damage worst from a cooling standpoint. One analysis was made assuming the dent to be left in the as-is condition (with surface smoothing only), and another analysis was made assuming the dent to be filled with weld material and polished smooth to the original surface contour. The local gas side wall temperature calculated for both cases is slightly under 1900°R , an acceptable value which compares with 1640° for the normal undented condition. The increased material thickness of the filled case seems to negate the improvement in gas side coefficient, although some slight (approximately 60°R) improvement in liquid side temperature is obtained.

Finally a strength analysis was performed considering the elevated temperatures in the vicinity of the defects. The original analysis (Reference (a)) required an elasto-plastic method to show a positive margin of safety on ultimate strength in the undamaged elbow and secondary sections. The present evaluation indicates that large positive margins on ultimate (± 0.56 for the worst case) remain even in the areas of the defects.

As a result of the foregoing investigation which indicates duct wall temperatures and stresses in the vicinity of the defects to be within acceptable limits, and considering the questionable gains of weld filling as well as danger of burn through or cracking of adjacent welds, repair will be limited to surface treatment only.

NOTES.

1. DIMENSIONS ARE IN INCHES.
2. DIAMETERS ARE INTERNAL

Figure 1

NES DUCT ASSEMBLY

FIGURE 2: Test Arrangement

DATE	10/13/43
BY	J101343
CHKD	
APP'D	
REVIEWED	
REVISION	
DESCRIPTION	PERMANENT LIFE SUPPORT AIR RECycler SYSTEM
PROJECT	ET-1
WORK ORDER	20780
FIGURE	3

FIGURE 3

FLOW CURVE
NES/DDT TURBINE EXHAUST ASSEMBLY
4.38 INCH THROAT

NOTE:

$$\dot{W}_{TOT} = 2 \dot{W}_{CORR}$$

$$\dot{W}_{TOT} = 1915 \text{ PS} \sqrt{\frac{520}{T_0}}$$

Turbine Nozzle Flow Vs Supply Pressure

FIGURE 5

N.I.O.-EIS-1
TEST NEP-1-1 2 DATE 1-19-67

1 -x- PT806 -x- PSIA
2 -x- PT908 -x- PSIA

N.I.B. HE S-I
TEST NEP2-2 DATE 1-26-67

1 -■- PT805 -■- PSIA
2 -■- PT806 -■- PSIA

FIGURE 9

N.T.O.-ETS-I
TEST NEP-2-2-4 DATE 1-26-67

1 - * - PT 907 - * - PSIA

2 - X - PT 906 - X - PSIA

1 - PT 907
PRESSURE PSIA

2 - PT 906
PRESSURE PSIA

2.04 PPS TURBINE EXHAUST - CH₂

INCREASE RESULTING FROM
16.9 PPS CH₂ FUEL FLOW

0

6680.0

6700.0

6720.0
RANGE TIME-SECS.

6740.0

6760.0

6780.0

FIGURE 10

N.T.O.-ETS-1
TEST WP-3-1 DATE 2-2-67

1 -■- PT905 -■- PSIA

FIGURE 11

N.T.O.-ETS-1
TEST NEP-3-1 2 DATE 2-2-67

1 -■- PT908 -■- PSIA

FIGURE 12

NEP-III

2 FEBRUARY 1967

PT-908 V6 PI-905

T E C FULL - IN

FIGURE 13

NEP-111 2 FEBRUARY 1967

PT-908 VS PT-905

T E C REPRESSURIZATION

FIGURE 14

TEC PRESSURE OSCILLATIONS DURING NEPTII REPRESSURIZATION

CURVE 1 YEC PRESS - PSIA (P907)

16
14
12
10
08
06
04
02

739765

739790

739715

739750

739785

RANGE TIME - SEC/10

CURVE 2 - P2 - PSIA (P906)

160
155
150
145
140
135
130
125

FIGURE 15

FIGURE 16

FIGURE 17

FIGURE 18

STATIC CHAMBER PRESSURE - PSIA

THEORETICAL
PRIMARY NOZZLE
EXIT PRESSURE

800

700

600

500

400

300

200

100

0

1

2

3

4

5

NOZZLE EXIT PRESSURE - PSIA

NOTES:

1. NOZZLE THROAT
CHOKED

2. NOZZLE EXIT
Full No Boundary
Separation.

3. $A_c/A_e = 10:1$

FIGURE 20

FIGURE 22

EFFECT OF RAMP RATE ON TEC REPRESSURIZATION

- O - NEP II-1, P RAMP = 8.8 ψ /SEC,
P(TEC) RAMP = 0.57 ψ /SEC, NO STEAM
- Δ - NEP II-2, P RAMP = 16 ψ /SEC,
P(TEC) RAMP = 0.7 ψ /SEC, STEAM
FLOW 129 PPS @ 105 PSIG / 170° R
- ∇ - NEP II, P RAMP = 16 ψ /SEC,
P(TEC) RAMP = 0.84 ψ /SEC, STEAM
FLOW 135 PPS @ 98 PSIG / 1420° R
- ∇ - NEP II - P MALFUNCTION
RAMP = 665 ψ /SEC, P(TEC)
LAGGED AS INDICATED BY
DASHED LINE. STEAM
FLOW 135 PPS.
- DASHED LINE - P(TEC) LAGGED

NOTES:

1. FS-5002 has 2 Booms - Upper and Lower
2. There are 3 Burners
 - #1 Lower Boom
 - #2 End of Upper Boom
 - #3 Inside of Upper Boom
3. All Components located in area 50
For Identification Purposes

DUCT VAULT FLARE SYSTEM - ETS-1
(FS-5002)

FIGURE 25

FLOW SCHEMATIC
Typical
 O_2 - H_2 Detection System
Two Complete Systems Required.

TABLE I
1 of 4

NEE
DESIGN DEMONSTRATION TEST
PROGRAM
DATA TABULATION

		PRIMARY NOZZLE GASEOUS NITROGEN FLOW																			
Test Number	Range Time	P 1 psig	T 489 °R	P 4 psig	T 490 °R	P 7 psig	T 491 °R	P 815 psig	P 2 psig	P 904 psig	CP449 %	DP449 % open	P 813 psig	P 905 °R	P 906 psia	T 903 °R	P 909 psia	P 910 psia	P 911 psia	P 912 psia	Wp LB/sec
NEP-I	80715	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0
NEP-I	80815	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0
NEP-I	80840	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0
NEP-I	80860	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0
NEP-II-1	78550	1741	535	1668	544	1669	DI	*	1752	1713	4.9	0	*	NR	*	463	6.77	OR	6.64	OR	0
NEP-II-1	78593	1607	527	1545	538	1550	DI	*	1583	1468	57.8	47.3	*	NR	201.8	462	1.68	1.663	1.28	1.454	323
NEP-II-1	78620	1376	506	1328	519	1329	DI	*	1349	1225	62.6	51.2	*	NR	197.9	464	1.61	1.612	1.23	1.412	312
NEP-II-1	78630	1297	498	1253	511	1257	DI	*	1268	1141	63.9	52.5	*	NR	195.7	464	1.6	1.591	1.23	1.399	308
NEP-II-1	78670	1191	484	1147	500	1146	DI	*	1202	1165	101	0	*	NR	13.5	459	12.58	OR	12.63	OR	0
NEP-II-2	06670	1253	536	1197	547	1208	DI	*	1265	1236	12.8	0	*	NR	8.2	492	7.51	OR	7.43	OR	0
NEP-II-2	06690	1152	530	1107	544	1119	DI	*	1130	991	66.7	56.4	*	NR	196.7	471	1.63	1.558	1.23	1.420	307
NEP-II-2	06714	995	511	961	529	971	DI	*	966	817	71.4	60.4	*	NR	194	471	1.6	1.521	1.21	1.38	304
NEP-II-2	06736	867	492	837	510	846	DI	*	827	657	76.7	65.3	*	NR	194	469	1.59	1.541	1.21	1.391	304
NEP-II-2	06745	802	484	841	503	787	DI	*	760	585	79.4	67.3	*	NR	190	469	1.55	1.501	1.18	1.370	300
NEP-II-2	06770	777	475	847	505	750	DI	*	785	756	- .5	0	*	NR	8.1	458	7.28	OR	0	OR	0
NEP-III	73900	2127	547	2130	555	2130	DI	2128	2136	2117	-9.7	0	1957	*	7.3	536	7.11	OR	NR	OR	0
NEP-III	73934	1828	531	1840	545	1847	DI	1863	1692	1140	+86.1	71.7	1896	513.6	OR	507	3.86	4.123	NR	3.785	784
NEP-III	73942	1678	520	1689	536	1700	DI	1715	1509	751	+100.0	100	1894	532.6	OR	510	4.05	4.284	NR	3.917	812
NEP-III	73970	1342	486	1358	501	1356	DI	1351	1295	1117	+68.6	56.9	1853	264.6	262.5	498	1.94	2.059	NR	1.856	404
NEP-III	73995	1312	480	1318	495	1310	DI	1310	1318	1291	-100.0	0	1933	8.5	8.1	491	7.54	OR	NR	OR	0
NEP-IV	71430	2153	551	2156	558	2157	550	2154	2162	2147	- 8.5	0	1688	5	7.8	508	7.74	OR	DI	OR	0
NEP-IV	71439	2094	550	2098	557	2103	549	2117	2018	1682	63.5	60.8	1766	439	OR	476	3.32	3.479	DI	3.172	687
NEP-IV	71450	2085	547	2088	556	2089	547	2088	2092	2065	81	4.8	1671	*	55.9	475	5.58	OR	DI	OR	0
NEP-IV	71465	2084	546	2087	554	2087	546	2082	2092	2070	0	0	1782	*	8.2	473	7.79	OR	DI	OR	0
NEP-IV	71610	2077	546	2078	553	2079	546	2075	2084	2067	0	0	2920	*	8.6	499	8.34	OR	DI	OR	0

* Instrumentation Malfunction
NR Not Recorded
OR Overranged

DI Data not valid

NES
DESIGN DEMONSTRATION TEST
PROGRAM
DATA TABULATION

TEC AND NES DUCT GASEOUS NITROGEN PURGE FLOW																
Test Number	Range Time	CP446 %	DP447 %	CP447 %	DP447 % open	P796 psig	P602-1 psid	F426 LB/SEC	F426 LB/SEC	P797 psig	P603-1 psid	F427 LB/SEC	F427 LB/SEC	T901 °R	P474 psig	P801 psig
NEP-I	80715	0	1.3	NR	*	0	0	*	0	0	0	NR	0	490	NR	0
NEP-I	80815	48.5	1.3	NR	*	69.9	39.5	*	33.7	52.7	0	NR	0	477	NR	39
NEP-I	80840	49.3	1.4	NR	*	68.3	38.8	*	32.9	50.8	0	NR	0	474	NR	39
NEP-I	80860	50.1	1.3	NR	*	69.3	39.4	*	34.7	50.8	0	NR	0	474	NR	40
NEP-II-1	78550	NR	0	18.9	4.6	.4	3.47	1	4	7.4	8.76	NR	2.07	463	.4	-6.2
NEP-II-1	78593	NR	0	20	6	.5	3.31	1	4	7.4	9.41	NR	2.07	462	.5	-9.2
NEP-II-1	78620	NR	0	21.4	7.2	-.3	2.58	0.7	3.4	6.6	9.63	NR	2.09	462	.6	-9.4
NEP-II-1	78630	NR	0	23	8.3	.1	3.01	0.8	3.7	7.1	9.93	NR	2.15	463	.4	-9.4
NEP-II-1	78670	NR	0	23.9	9.5	2.9	5.96	2.8	5.7	9.8	8.99	NR	2.16	470	1.0	2.5
NEP-II-2	06670	NR	0	21.4	4.7	-1.2	1.01	.4	2	3.3	7.14	NR	1.62	470	0.7	-6.6
NEP-II-2	06690	NR	0	21.4	7.9	-.5	2.32	1.	3.2	4.9	6.63	NR	1.64	467	0.5	-9.8
NEP-II-2	06714	NR	0	21.4	7.8	-2.1	.2	.8	.9	2.5	5.61	NR	1.4	467	0.7	-10
NEP-II-2	06736	NR	31.9	21.4	7.7	22.4	23.2	16.8	16.9	20	2.12	NR	1.38	471	0.5	33.8
NEP-II-2	06745	NR	0	21.3	7.7	-6.4	-5.82	2.5	0	-1.2	6.81	NR	1.34	471	0.7	-10
NEP-II-2	06770	NR	0	22.2	8.6	-3.7	-1.92	1.4	0	1.2	7.49	NR	1.1	475	0.6	-7.4
NEP-III	73900	0	0	24	5.1	5.9	5.32	1.75	DI	16.8	10.94	1.89	2.7	468	DI	-2.8
NEP-III	73934	0	0	24	5.5	-0.6	-0.17	.19	DI	6.2	7.23	.19	1.82	460	DI	-4.7
NEP-III	73942	0	0	24	5.6	-2.6	-2.16	.63	DI	1.3	4.89	.19	1.25	461	DI	-4.8
NEP-III	73970	0	0	24	5.7	-2	-1.30	.53	DI	4.7	7.3	.51	1.67	470	DI	-4.7
NEP-III	73995	0	0	27	8.9	4.6	4.21	1.08	DI	15.4	11.62	1.85	2.81	474	DI	-2.8
NEP-IV	71430	0	DI	23.7	4.3	5.3	4.59	1.66	5.39	15.2	10.51	1.85	2.65	473	DI	-2.6
NEP-IV	71439	0	DI	23.7	5.4	2.5	2.8	.88	3.87	13	10.71	1.51	2.57	472	DI	-4.2
NEP-IV	71450	37.7	DI	23	5.3	5.1	4.55	1.63	5.35	18	13	2.16	3.09	472	DI	-3.3
NEP-IV	71465	0	DI	23.8	5.3	2.0	2.41	.84	3.54	17.1	15.87	2.44	3.38	470	DI	-2.4
NEP-IV	71610	0	DI	22.9	4.2	2.1	2.06	.50	3.29	12.2	11.16	1.49	2.59	472	DI	-2.4

* Instrumentation Malfunction

NR Not Recorded

OR Overranged

DI Data not valid

NES
DESIGN DEMONSTRATION TEST
PROGRAM
DATA TABULATION

TURBINE EXHAUST GASEOUS HYDROGEN FLOW													
Test Number	Range Time	P 97 psig	T 28 °R	P 101 psig	P 601 psid	W _T LB/SEC	CP472 %	DP472 % open	P 484 psig	T 902 °R	P 901 psia	P 902 psia	P 903 psia
NEP-I	80715	NR	NR	NR	NR	0	NR	NR	NR	NR	NR	NR	NR
NEP-I	80815	NR	NR	NR	NR	0	NR	NR	NR	NR	NR	NR	NR
NEP-I	80840	NR	NR	NR	NR	0	NR	NR	NR	NR	NR	NR	NR
NEP-I	80860	NR	NR	NR	NR	0	NR	NR	NR	NR	NR	NR	NR
NEP-II-1	78550	523	500	-4	0	0	3.8	0	*	489	6.9	OR	OR
NEP-II-1	78593	522	500	-4	0	0	3.8	0	*	488	0.5	0.310	0.33
NEP-II-1	78620	522	500	-3	0	0	3.8	0	*	488	0.5	0.28	0.313
NEP-II-1	78630	522	500	-5	0	0	3.8	0	*	488	1.7	1.489	1.39
NEP-II-1	78670	522	500	-3	0	0	3.8	0	*	488	12.2	OR	OR
NEP-II-2	06670	423	499	426	*	0	3.8	0	*	489	7.8	OR	OR
NEP-II-2	06690	423	499	426	*	0	3.7	0	*	488	.3	0.223	0.275
NEP-II-2	06714	401	411	405	*	1.78	13.7	13	*	487	11.4	0.276	0.435
NEP-II-2	06736	389	449	393	*	0	3.8	0	*	485	1	0.840	9.878
NEP-II-2	06745	390	461	394	*	0	3.8	0	*	486	.3	0.158	0.211
NEP-II-2	06770	391	476	393	*	0	3.8	0	*	487	7.6	OR	OR
NEP-III	73900	1346	526	1346	*	0	0	0	DI	498	7.3	OR	OR
NEP-III	73934	1346	526	1346	*	0	1.1	0	DI	496	0.6	0.620	0.653
NEP-III	73942	1285	488	1283	*	7.07	13.5	12.7	DI	500	36.1	1.690	1.660
NEP-III	73970	1213	497	1213	*	0	0	0	DI	496	0.3	0.255	0.298
NEP-III	73995	1215	507	1215	*	0	0	0	DI	496	7.7	OR	OR
NEP-IV	71430	1192	525	1190	0	0	3.8	0	-3	505	7.8	OR	OR
NEP-IV	71439	1104	487	1101	0.77	5.74	13.1	14.4	69	504	29.5	1.32	1.294
NEP-IV	71450	709	442	704	1.52	6.45	18.6	23.0	78	480	33.1	4.965	4.924
NEP-IV	71465	504	433	505	0	0	3.8	0	-3	473	7.8	OR	OR
NEP-IV	71610	564	468	0	0	0	3.8	0	-4	482	8.5	OR	OR

* Instrumentation Malfunction
NR Not Recorded
OR Overranged
DI Data not valid

TABLE I
4 of 4

NES
DESIGN DEMONSTRATION TEST
PROGRAM
DATA TABULATION

TEMPORARY ENGINE COMPARTMENT																	NES DUCT			
Test Number	Range Time	P 907 psia	P 908 psia	O A1 % O ₂	O A 2 % O ₂	HA 3 % H ₂	HA 4 % H ₂	OA 701 % O ₂	OA 706 % O ₂	OA 707 % O ₂		P 805 psia	P 806 psia	P 239 psig	T 534 °R	T 159	W LB/SEC			
NEP-1	80715	or	8.03	NR	NR	NR	NR	0	NR	NR		7.73	7.7	93	*	1258	127			
NEP-I	80815	or	7.99	NR	NR	NR	NR	0	NR	NR		7.81	7.81	95.4	*	*	135.8			
NEP-I	80840	or	10.16	NR	NR	NR	NR	0	NR	NR		9.96	9.99	46.4	*	*	87			
NEP-I	80860	or	12.34	NR	NR	NR	NR	0	NR	NR		12.33	12.34	0	*	*	1.2			
NEP-II-1	78550	or	6.54	-.78	DI	*	DI	*	DI	NR		7.91	8.03	104.2	1,653	*	129.7			
NEP-II-1	78593	0.376	0.87	8.82	DI	*	DI	*	DI	NR		11.09	11.05	107	1,715	*	128.5			
NEP-II-1	78620	0.338	0.78	1.88	DI	*	DI	*	DI	NR		12.04	12.14	56.4	1,193	*	89			
NEP-II-1	786.30	1.492	1.79	5.75	DI	*	DI	*	DI	NR		13.78	13.65	0	.823	*	1.8			
NEP-II-1	78670	or	12.6	-.5	DI	*	DI	*	DI	NR		12.67	12.79	0	648	*	1.8			
NEP-II-2	06670	or	7.08	-.72	DI	*	DI	*	DI	NR		7.47	7.63	105	1.753	1772	127.1			
NEP-II-2	06690	2.71	0.72	1	DI	*	DI	*	DI	NR		11.03	11.1	106.6	1.751	1774	127			
NEP-II-2	06714	0.509	0.85	19	DI	*	DI	*	DI	NR		11.02	11.5	107.1	1.745	1772	128.3			
NEP-II-2	06736	0.872	1.22	19	DI	*	DI	*	DI	NR		10.72	10.89	107	1.740	1768	128.6			
NEP-II-2	06745	0.19	0.49	16	DI	*	DI	*	DI	NR		11.14	11.42	107	1.737	1766	129.7			
NEP-II-2	06770	or	6.56	6	DI	*	DI	*	DI	NR		7.34	7.5	107.6	1.738	1767	129.3			
NEP-III	73900	or	7.04	DI	DI	0	1.5	*	DI	NR		7.02	7.06	101	1.421	1450	138.3			
NEP-III	73934	0.640	0.48	DI	DI	0	1.6	*	DI	NR		15.17	14.97	100.9	1.382	1405	137			
NEP-III	73942	0.808	0.67	DI	DI	7.7	> 2.5	*	DI	NR		16.65	17.32	100.1	1.389	1414	137.4			
NEP-III	73970	0.261	0.14	DI	DI	>2.5	> 2.5	*	DI	NR		11.36	11.27	101.1	1.384	1411	138			
NEP-III	73995	or	7.58	DI	DI	4.6	8.8	*	DI	NR		7.49	7.48	102.9	1.399	1422	138.2			
NEP-IV	71430	or	7.63	DI	DI	2.3	0	.8		NR		7.59	7.59	99	1.344	1369	135.5			
NEP-IV	71439	1.123	0.92	DI	DI	6.4	.4	1.2	.7	NR		13.73	13.64	98.9	1.328	1355	137.2			
NEP-IV	71450	or	5.51	DI	DI	>2.5	21.5	1.2	.8	NR		8.82	8.79	99.6	1.337	1362	134.6			
NEP-IV	71465	or	7.71	DI	DI	>2.5	15.9	1.3	.8	NR		7.65	7.66	97.4	1.333	1357	138.2			
NEP-IV	71610	or	8.34	DI	DI	3.5	1.1	1.2	.8	NR		8.26	8.29	88	820	831	159.9			

* Instrumentation Malfunction
NR Not Recorded
OR Overranged
DI Data not valid

SUPPORT OPERATIONAL
REQUIREMENTS DOCUMENT
FOR
NES EXPERIMENTAL PLAN I

NES DESIGN DEMONSTRATION TEST
PHASE I (GN₂)

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22 December 1966

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I. INTRODUCTION

A. GENERAL

Phase I of the NERVA Exhaust System (NES) Design Demonstration Test represents the first operation of the NES Duct and all duct sub-systems at simulated engine operating conditions. Although it is impractical to simulate actual engine temperatures, these tests will demonstrate the performance capabilities and structural integrity of the NES by flowing cold gaseous nitrogen at mass flows and pressures required for equivalent engine thrust conditions. Phase I will investigate mass flows and pressures required to obtain duct pull-in; that is, the point where engine compartment pressure no longer decreases with increasing nozzle chamber pressure. In addition, the effects of excessive engine test compartment (ETC) seal leakage and excessive turbine exhaust flow will be investigated.

Steam Generator System (SGC) operation will be demonstrated during Phase I of the NES Design Demonstration Tests.

To avoid constraint imposed by the checkout of the ETC, a temporary engine compartment (TEC) will be utilized during Phase I while the ETC shields and associated seals are installed and checked out. The test arrangement with TEC installed is presented in Figures 1 and 2.

B. NERVA EXHAUST SYSTEM

1. Function

The exhaust system built into ETS-1 for testing of the NERVA Engine is designed to accomplish the following:

- a. Direct the engine exhaust gases away from the NERVA Engine and ETC for safe burning in the atmosphere.
- b. Prevent air from entering the exhaust system and engine test compartment during normal or malfunction engine operating conditions, thereby preventing a possible hydrogen fire or detonation.
- c. Provide altitude simulation within the ETC by aerodynamic pumping action of the engine exhaust gases.

2. NES Description

The NERVA Exhaust System is comprised of two major sub-systems; the exhaust duct, and the steam generator system (SGS).

a. Exhaust Duct

The exhaust duct mates with the engine compartment bottom shield to direct the NERVA exhaust gases vertically downward for approximately 50 feet and outward horizontally away from the stand for approximately 54 feet, and finally into the atmosphere at an angle of approximately 45° upward from the horizontal plane.

As indicated in Figure 3, the duct consists of three sections. The first is a vertical section called the Primary Duct, consisting of an entrance cone, throat section, and subsonic diffuser. The next section consists of a 90° elbow joined to an offset cone contraction element. The last section, called the Secondary Duct, is a straight horizontal section with a steam ejector (for safety purge) and a 45° exit elbow.

The three sections of the duct together with their supporting truss members constitute the duct-truss assembly (See Figure 4). The duct is fabricated from type 347 stainless steel and the truss from type 304. The elbow section of the duct is constructed from round tubes welded together, while the straight sections are constructed of sheet and angle sections welded together to provide rectangular channels as shown in Figure 5.

These longitudinal channels and tubes are used to flow cooling water through the duct during engine operation.

In addition, the elbow section has a water-filled jacket to provide protection against cooling water loss in the event of penetration damage or weld failure in that section.

The duct-truss assembly is housed in a concrete vault below the engine in the ETS-1. The concrete walls of the vault surround three sides of the duct-truss assembly, the exhaust side being open during engine tests. The concrete walls of the vault are three (3) feet thick to provide radiation shielding for personnel and equipment in the adjacent pipe chase and equipment vaults after test firing and engine removal.

After firing, an aluminum-covered concrete door may be closed to cover the vault opening for personnel protection against radiation emission from activated duct components. During an engine

test, the NES vault area will be sprayed with water for cooling of the structural members of the NES Duct Support.

b. Steam Generator System

The Steam Generator System (SGS) delivers steam through a sonic ejector into the NES secondary duct at approximately 125 psia and 1,760°R. The flow rate is designed to be equal to the sum of:

1. The choked flow rate (92 lbs. per second) required to fill the engine compartment without allowing air to enter the duct in the event of an instantaneous termination of the engine working fluids, and
2. The flow rate (23 lbs. per second) required to prevent penetration of 35 mph air into the duct. In addition, operation of the SGS pulls a partial vacuum (approximately 7.5 psia) in the primary duct and engine compartment prior to engine startup.

The chemical steam generator produces steam on command from a high rate chemical combustion of propane with oxygen. Water is injected into the combustion products to reduce their temperature and provide additional steam. There are three identical steam generator modules connected to a common plenum mixing and discharge chamber.

Each module is capable of independent operation. Normally two units operate concurrently with the third on standby. In the event an operating module shuts down due to malfunction, the standby module will come onstream.

Liquid oxygen required for the Steam Generator System is stored in a 22,000 gallon, 400 psig dewar (V-2801). Propane supply for the SGS is stored in a 15,000 gallon, 400 psig tank (V-3401).

Fluid transfer is accomplished in each case by controlled pressurizing of the storage vessels with GN_2 .

3. Facility Support Systems

The facility systems required to support NES operation include the Process Water System, the Propane Flare System, and the Facility Gas Supply System.

a. Process Water System

Water is used at ETS-1 for cooling and shielding in the test cell shields, for cooling the NES Duct, for operation and cooling of

the Steam Generator System, for fire-fighting, and for the test stand deluge systems. This water is supplied from a well to a storage tank north of the C.P. area. A demineralizer plant in the C.P. Area reduces mineral content and adds a rust inhibitor, then the water is pumped to a 2,750,000 gallon storage tank on a slope north of ETS-1, 500 feet above the test stand.

The demineralized water is gravity fed through a 42 inch supply line from the storage tank to ETS-1. The process water system provides sufficient cooling water through the duct walls such that the maximum duct inner wall temperature in the elbow section will not exceed 1,540°R, and in the straight sections, will not exceed 1,460°R.

Cooling water flows in separate circuits through each of the three duct sections; i.e., primary (counter flow) elbow (parallel flow) and secondary (counter flow). All cooling water is eventually dumped into an open drain.

b. Duct Flare System

Propane flares are provided for the safe burning of hydrogen gas at the exhaust duct outlet, the duct drain pipe outlet, the LH₂ storage area, the steam generator and the LH₂ run tank. These flares are remotely ignited from the control area and are supplied from the same 15,000 gallon 400 psig propane storage tank (V03401) that feeds the SGS.

c. Facility Gas Supply System

Storage and supply systems for gaseous nitrogen, gaseous hydrogen and gaseous helium are available for ETS-1.

Gaseous nitrogen is utilized for general facility purge, buffer zone pressure for flange seals, flare stack molecular seals, pressurization of the LN₂, LO₂ and propane storage vessels, remote valve operation and engine cooldown following a test run. Nitrogen is procured and stored in liquid form and may be converted to gas by the LN₂ vaporizer as required. Gaseous nitrogen is normally stored in three (3) 1,750 cubic feet, 2500 psig storage vessels (V-3201, -2 and -3).

Gaseous hydrogen is utilized for engine cooldown and LH_2 dewar pressurization. Hydrogen is procured and stored in liquid form and may be converted to gas by the LH_2 vaporizer as required. GH_2 is normally stored in three (3) 2,400 cubic feet, 2,500 psig storage vessels (V-3207, -8 and -9).

Gaseous helium is utilized for engine purge, for facility purge in LH_2 areas, for remote valve operation in LH_2 systems and for engine cooldown. It is also, of course, a valuable medium for leak tests. GHe is normally stored in three (3) 1,750 cubic feet, 2,500 psig storage vessels (V-3204, -5 and -6).

Storage vessels V-3201 through V-3206 may be utilized for GN_2 and/or GHe storage in any combination, depending on test requirements. Jumpers are available to allow connection of any of these bottles into either the GHe or GN_2 facility gas supply headers.

Special conditions arising during NES tests ($P_c = 550$ psia) may dictate a requirement for the use of the GH_2 , GHe and GN_2 headers for GN_2 flow.

The three gas headers (GN_2 , GH_2 , GHe) may be combined in any arrangement using an existing manifold in conjunction with spectacle blinds.

II. TEST OBJECTIVES

The primary purpose of Phase I of the NES Design Demonstration Test is to prove the ability of the NES Duct to perform its intended function at design and off-design conditions of primary engine nozzle chamber pressure (P_c) prior to XE Engine testing. Cold gaseous nitrogen will be flowed through the simulated primary engine nozzle in quantities sufficient to provide for primary nozzle chamber pressures up to 55- psia (XE design), resulting in a gas momentum equivalent to hot hydrogen exhaust gas at XE design temperature. Cold gaseous hydrogen will be flowed through twin nozzles to simulate engine turbine exhaust flow. Cold gaseous nitrogen will be flowed through a supply line to the TEC purge ring to simulate seal leakage. As stated earlier, the TEC will be utilized due to the constraints imposed by checkout of the ETC seals.

- A. TEST NO. 1 - STEAM GENERATOR TEST WITH NORMAL SEAL LEAKAGE
1. Verify that steam generator operation is unaffected by back pressure when discharging into the NES Duct, as compared to the temporary orifice plate used during SGS development testing.
 2. Investigate relative degree of altitude simulation (TEC pressure) during one-module and two-module operation.
 3. Determine ETC repressurization rates during SGS shutdown of one module at a time.
- B. TEST NO. 2 - STEAM GENERATOR TEST WITH EXCESSIVE SEAL LEAKAGE
1. Evaluate the capability of the SGS in normal two-module operation to pump down the TEC with excessive seal leakage of 30 lb/sec.
- C. TEST NO. 3 - PRIMARY FLOW TEST, $P_c = 200$ PSIA, NO TURBINE EXHAUST AND NORMAL SEAL LEAKAGE
1. Determine the adequacy of the TEC purge system prior to hydrogen flow through the NES.
 2. Demonstrate duct pull-in at primary chamber pressure $P_c = 200$ psia.
 3. Demonstrate, without the SGS, safe shutdown on a normal XE Ramp (no H_2 flow and using TEC).
- D. TEST NO. 4 - PRIMARY FLOW TEST, $P_c = 200$ PSIA, DESIGN TURBINE EXHAUST AND EXCESS SEAL LEAKAGE
1. Evaluate, at an intermediate level of primary flow, the effects of excess seal leakage on TEC pressure, primary nozzle flow and possible nozzle flow separation.
 2. Determine if minimum seal leakage (flow stabilization) is required to avoid pressure fluctuation in the TEC during primary nozzle flow.
 3. Evaluate ability of propane flare system to ignite and burn small quantities of GH_2 .
- E. TEST NO. 5 - PRIMARY FLOW TEST, $P_c = 550$ PSIA, DESIGN TURBINE EXHAUST AND NORMAL SEAL LEAKAGE
1. Demonstrate duct performance at full nozzle thrust conditions, design turbine exhaust flow of 7.0 lbs/sec., normal seal leakage and design flow of duct coolant water of 38,000 gpm.

2. Observe adequacy of post-fire purging following H_2 flow through simulated turbine exhaust.

F. TEST NO. 6 - PRIMARY FLOW TEST, $P_c = 550$ PSIA, DESIGN TURBINE EXHAUST AND EXCESS SEAL LEAKAGE

1. Evaluate, at a primary chamber pressure of 550 psia and with design turbine exhaust flow, the effects of excess seal leakage on TEC pressure, primary nozzle flow and possible flow separation.
2. Verify ability of the SGS to prohibit back flow into the NES Duct following a rapid termination of primary flow (simulating an engine malfunction).

G. TEST NO. 7 - PRIMARY FLOW TEST, $P_c = 550$ PSIA, EXCESS TURBINE EXHAUST AND NORMAL SEAL LEAKAGE

1. Evaluate, at a primary chamber pressure of 550 psia and with design seal leakage, the effects of excess turbine exhaust flow on TEC pressure, primary nozzle flow and possible nozzle flow separation.
2. With single module operation, verify ability of the SGS to prohibit back flow into the NES Duct following a rapid termination of primary flow.

III. TEST DESCRIPTION

A. GENERAL

A summary description of all tests to be conducted during Phase I is presented in Figure 6. In order to meet the primary chamber pressures, gas flow rates and operating ramps required and at the same time prevent unnecessary constraint of other facility activities, three gas system configurations will be employed as indicated in Figure 7, a simplified schematic of the NES gas system.

For Tests 1 and 2, primary flow, purge flow and simulated seal leakage will be supplied by three (3) GN_2 storage vessels and one (1) supply header, GN-8-inch. Tests 1 and 2 involve steam generator operation and simulated seal gas leakage, but no primary nozzle gas flow or turbine exhaust gas flow.

For Tests 3 and 4, primary flow will be supplied by six (6) GN_2 storage vessels and two (2) headers, GN-8-inch and GH_2 -6-inch. Test 3 will involve primary nozzle gas flow but no turbine exhaust flow. Gaseous hydrogen turbine exhaust flow will be included in Test 4. The primary objective in using this configuration for Tests 3 and 4 is to determine if six (6) storage vessels and two (2) headers are adequate for Test 5, 6 and 7 at primary nozzle chamber pressure (P_c) of 550 psia. Calculations indicate that this is a marginal possibility.

Should the $P_c=550$ psia tests require a greater nitrogen storage and supply capability than is available in this configuration, Test 5, 6 and 7 will utilize nine (9) GN_2 storage vessels and three (3) supply headers, GN-8-inch, GHe -6-inch for primary flow. Gaseous hydrogen turbine exhaust will be included in these tests.

During both design and off-design flow tests, the simulated primary nozzle chamber pressure will be the controlling parameter. This pressure will be indicated on meters of the temporary NES (TN) Console. Primary flow is controlled by PCV-449 through a feedback loop from PT-905, primary chamber pressure. The valve controller includes a ramp generator for automatic startup and shutdown. At a P_c of 200 psia, the cold nitrogen gas through the engine nozzle is approximately 284 lbs/sec., at 550 psia nozzle flow is approximately 780 lbs/sec.

Gaseous nitrogen for TEC purge and simulated seal leakage will be supplied from line GN-8-inch. This flow will be indicated by flow elements FE-426 and 427 and controlled by PCV-446 and -447.

Simulated turbine exhaust flow will be supplied by GH_2 stored in high pressure run tank V-5002. The GH_2 will flow through line 4LH-6-inch to exhaust nozzle chamber pressure utilizing PCV-472. Flow as a function of chamber pressure is presented in Figure 8.

During all tests involving GH_2 simulated turbine exhaust flow, the hydrogen will be flared at the duct exit. The flares will be lighted before the start of GH_2 flow and will continue for 60 seconds after the flare goes out at the duct exit.

Cooling water will flow through the NES Duct during each test. Flow will be at either design (40,000 GOM) or low (4,300 GOM) rate, depending on water availability; however, design flow rate will be mandatory for Test No. 5, and is desirable for Tests No. 6 and 7. Water height in the process water tank shall be checked and recorded before and after each test.

During periods when gaseous nitrogen is flowing through the primary nozzle, a minimum simulated seal leakage into the TEC may be required to avoid pressure fluctuations. Scale model tests have indicated that approximately 1.5 lbs/sec. of GN_2 flow is required to avoid these fluctuations.

Pressure in the TEC shall be closely monitored at all times during each test. Should this pressure rise to one (1) atmosphere during primary or turbine exhaust flow, flow shall be terminated. If turbine exhaust was flowing, a post-fire purge shall be accomplished.

B. TEST 1 AND 2 - STEAM GENERATOR

Test 1 consists of a checkout of the SGS when discharging into the NES Duct. With the SGS propellant tank pressures as required for nominal steam flow, one steam module will be started and injection water regulated to obtain $1,560^{\circ} \pm 50^{\circ}\text{R}$ steam line temperature. After 60 seconds at this temperature, a second steam module will be started and injection water regulated to obtain $1,760^{\circ} \pm 50^{\circ}\text{R}$ with two (2) modules operating. Operation at this temperature will continue for 60 seconds and data recordings will be obtained of TEC pressure to evaluate altitude simulation.

Post-fire purge will be established prior to initiation of SGS shutdown. One steam module will be shut down and operation continued until the TEC pressure stabilizes; then the second module will be shut down. Post-fire purge will then be terminated. Data will be obtained to evaluate post-fire purge and TEC repressurization rates during the SGS shutdown.

NOTE: Method of SGS shutdown established during this test will be the normal method used for Tests 2 through 6.

Test 2 is designed to evaluate TEC pump down and altitude simulation with excessive seal leakage simulated in the TEC. Figure 9 is a graphic presentation of this test. The SGS will be started normally and brought up to full steam operation. When the TEC has stabilized at a minimum pressure, 1.5 lbs/sec. simulated seal leakage will be introduced into the TEC

and pressure again allowed to stabilize. Seal leakage (purge) will then be increased from 1.5 to 30 lbs/sec. in approximately 10 seconds, then reduced to 0 in approximately 10 seconds. Seal leakage (purge) will be increased to 30 lbs/sec. in approximately 10 seconds, held at that rate until O_2 concentration is less than 4%. Shut down SGS in a normal manner and terminate simulated seal leakage (purge). TEC and duct severance plane pressures, simulated seal leakage flow and O_2 concentration will be recorded throughout this test.

NOTE: Test 1 and 2 may be accomplished consecutively without shutdown of SGS.

C. TEST 3 - PRIMARY FLOW, P_c = PSIA, NO TURBINE EXHAUST AND NORMAL SEAL LEAKAGE

NOTE: Filter elements from 50-GF-15 and 50-GF-432 will be removed and flow elements 50-FE-415 and 50-FE-15 will be spooled out as appropriate prior to conduct of Tests 3 through 7.

This will be the first test conducted with gas flow through the primary nozzle. Figure 10 is a graphic presentation of this test. TEC purge will be initiated at approximately 15 lbs/sec. GN_2 flow. The Test Director may vary flow to obtain a more efficient purge.

The flow rate which produces the most efficient purge of the TEC will be defined as "normal purge flow" for the tests that follow. TEC purge is considered complete when O_2 concentration is reduced to 4% by volume.

Following TEC purge, the SGS will be started and brought up to full steam operation and simulated seal leakage set at 1.5 lbs/sec. Primary GN_2 flow will be established using an 11 second start ramp to P_c = 200 psia. Operation will continue at these conditions for approximately 20 seconds, followed by shutdown of the SGS. Primary flow will continue for an additional 10 seconds, and then terminated with a 12.5 second shutdown ramp. Primary chamber pressure, seal leakage flow, TEC and duct severance plane pressures, and O_2 concentration data will be recorded through this test. Sensor locations on the TEC and NES test device are shown in Figure 2.

D. TEST 4 - Pc=200 PSIA, DESIGN TURBINE EXHAUST AND EXCESS SEAL LEAKAGE

This will be the first test conducted with gaseous hydrogen turbine exhaust flow through the NES. For this reason, duct flare operation will be required. A graphic presentation of this test is included as Figure 11. A normal TEC purge will be conducted, followed by SGS operation to normal full steam operation. Primary flow will be initiated, with 0 seal leakage using a 6-second startup ramp to Pc=200 psia. Turbine exhaust flow will then be initiated to 2.5 lbs/sec within 5 seconds and reduced to 0 within 5 seconds. Simulated seal leakage will be increased to 15 lbs/sec within 5 seconds and reduced to 0 within 5 seconds. Primary flow and turbine exhaust flow will be terminated on a 6-second shutdown ramp, the SGS shutdown then post-fire purge completed.

Data recorded during this test will include TEC and duct severance plane pressures; primary and turbine exhaust nozzle pressures; primary, turbine exhaust, and seal leakage flows; primary nozzle pressure; O₂ and H₂ concentrations; and gas storage vessel pressures and temperatures.

E. TEST 5 - Pc=550 PSIA, DESIGN TURBINE EXHAUST AND NORMAL SEAL LEAKAGE

This will be the first test conducted at the design primary nozzle chamber pressure of Pc=550 psia. All tests conducted at design primary chamber pressure will require a minimum of 2,475 psig GN₂ storage vessel pressure. Gas storage temperature should not exceed 560°R at initiation of each test.

Figure 12 is a graphic presentation of Test 5. Normal TEC purge and SGS startup to full steam operation will be accomplished. Simulated seal leakage will be set at normal rate. Primary flow will be initiated using a 30-second startup ramp to Pc=550 psia. Turbine exhaust flow will then be initiated to 7.0 lbs/sec in approximately 8 seconds, then decreased to 0 in approximately 8 seconds. Primary flow termination will be accomplished with a 35-second shutdown ramp. The SGS will be shut down and a normal post-fire purge will be accomplished.

Data recorded during this test will include TEC and duct severance plane pressure; primary and turbine exhaust nozzle chamber pressures; primary, turbine exhaust, and seal leakage flows; O₂ and H₂ concentrations; and gas storage vessel pressures and temperatures.

F. TEST 6 - $P_c=550$ PSIA, DESIGN TURBINE EXHAUST AND EXCESS SEAL LEAKAGE

This test will investigate the effects of excess seal leakage into the TEC and also the ability of the SGS to prevent backflow into the duct following a simulated engine malfunction; i.e., rapid termination of primary flow.

Figure 13 is a graphic presentation of Test 6. Normal TEC purge and SGS startup to full steam operation will be accomplished. Simulated seal leakage will be set at the normal rate. Primary and turbine exhaust flows will be initiated simultaneously using a 6-second startup ramp, to $P_c=550$ psia and $W_t = 7.0$ lbs/sec respectively. Simulated seal leakage will then be increased to 30 lbs/sec in 5 seconds and reduced to normal flow rate in 5 seconds. Turbine exhaust flow will be terminated and then primary nozzle flow will be terminated as rapidly as possible. Normal SGS shutdown and post-fire purge will be accomplished.

Data requirements are the same as for Test 5.

G. TEST 7 - $P_c=550$ PSIA, EXCESS TURBINE EXHAUST AND NORMAL SEAL LEAKAGE

This test will investigate the effects of excess turbine exhaust and rapid primary flow termination with single module operation of the SGS. Figure 14 is a graphic presentation of this test. Normal TEC purge will be completed and seal leakage set at normal flow rate followed by startup of one module of the SGS. Injection water will be regulated to obtain $1,560^\circ \pm 50^\circ R$ steam temperature. Primary flow will be established at $P_c=550$ psia using a 6-second startup ramp. Turbine exhaust flow will then be initiated, increased to 15 lbs/sec in approximately 5 seconds and then decreased to 0 in approximately 5 seconds. Primary flow will then be terminated as rapidly as possible. Normal shutdown of SGS (one module) and post-fire purge will be accomplished.

Data requirements are the same as for Test 5.

H. FLOW PROFILE

The anticipated gas flow profiles for the NES Design Demonstration Tests are presented in Figures 9 through 14.

IV. TEST LIMITSA. OPERATING LIMITS

<u>FUNCTION</u>	<u>CONDITION</u>	<u>ACTION</u>
TEC Pressure	Increases to 1 Atmosphere during Run.	Terminate Primary and Turbine Exhaust Flows. Purge if Turbine Exhaust was flowing.
Primary Chamber Pressure	Exceeds 550 psia	Switch "Function" to "Auto". If Pc continues to rise, switch to "Manual." If Pc does not close to 5% stroke, turn on "Fast Shutoff" on Function Generator Panel.
TEC O ₂ Concentration	Greater than 6% by volume prior to GH ₂ flow introduction.	Increase GN ₂ pre-fire purge flow rate.
TEC O ₂ Concentration	Greater than 5% by volume prior to discontinuing post-fire purge.	Continue GN ₂ purge and increase flow rate as required.
TEC O ₂ Concentration	Greater than 5% by volume prior to SGS shutdown.	Continue GN ₂ purge and increase flow rate as required.
Propane Flow	Decreases to 90% of nominal flow after steady state.	Terminate Primary and Turbine Exhaust Flows, initiate purge and shutdown SGS.
Propane Manifold	Exceeds 525°R	Terminate Primary and Turbine Exhaust Flows, initiate purge and shutdown SGS.
Module Chamber Pressure	Exceeds 160 psig	Terminate Primary and Turbine Exhaust Flows, initiate purge and shutdown SGS.

A. OPERATING LIMITS - Continued

<u>FUNCTION</u>	<u>CONDITION</u>	<u>ACTION</u>
Steam Line Temperature	Exceeds 1860°R	Terminate Primary and Turbine Exhaust Flows, initiate purge and shutdown SGS.
Combustion Chamber Coolant Water Jacket Outlet Temperature	Approaches 672°R	Terminate Primary and Turbine Exhaust Flows, initiate purge and shutdown SGS.
Plenum Coolant Water Jacket Outlet Temperature	Approaches 672°R	Terminate Primary and Turbine Exhaust Flows, initiate purge and shutdown SGS.

V. SAFETY REQUIREMENTS

- A. The area surveillance and warning system will be in operation during each test.
- B. All zones of the Fire Protection System will be completely automated prior to hydrogen testing.
- C. The NRDS Fire Department will have hoses charged in the ETS-1 Facility prior to hydrogen flow. The Fire Department shall remain ready and on standby at the main roadblock during all hydrogen tests.
- D. Remote hydrogen detectors in the LH₂ dewar area, high pressure gas storage area and test stand equipment room shall be operating and calibrated prior to each test involving GH₂. A portable hydrogen detector will be maintained at the LSE Console.
- E. Oxygen concentration in all operating flare stacks shall be continuously monitored prior to, during, and following hydrogen flow.
- F. All GH₂ lines, compartment and chambers shall be purged of air with GHe or GN₂ prior to and following GH₂ flow through them.
- G. The safety requirements for steam generator testing are specified in NTO-SOP-0068.
- H. The ETS-1 tunnel blast valve shall be locked closed prior to hydrogen testing.
- I. A sweep of the facility piping systems shall be made with infrared TV cameras to locate any small hydrogen fires prior to any re-entry.
- J. All personnel re-entries following hydrogen flow shall be accomplished only after the systems involved have been evacuated and/or inerted, the systems are at ambient pressure, and a safe condition has been established between this portion of the system and any source of hydrogen.
- K. ETS-1 Lock and Tag procedures will be in force as applicable.

- L. All areas of potentially reduced oxygen content shall be cleared for access by NTO Health & Safety prior to personnel entry.
- M. Area Control will be according to Figure 15.

VI. TEST SCHEDULE

To be determined.

VII. STATUS BOARD AND AREA CONTROL

- A. A Status Board will be established for each run and will assume control of the facility at 1400 on R-1. Input to the Status Board will be submitted to Test Planning by R-7 Day.
- B. Area Control will be established at 1700 hours of each R-Day per Figure 15; the access lists will be prepared on R-1 Day.

VIII. PRODUCT ASSURANCE

- A. Before the start of testing, it shall be verified that current calibrations exist for all test equipment.
- B. Quality Assurance shall document the serial numbers of the SGS main stage injectors, ignitors, and combustion chambers.
- C. Quality Assurance shall maintain a discrepancy log for all systems utilized in the conduction of this test series (NTO-A-0013).
- D. Following each EP, a complete visual examination shall be made of the entire duct inside and out. Particular attention shall be given to inspection of the weld of the primary section inner shell to the lower end cap. In addition, this weld shall be dye-penetrant inspected following completion of the last test of this series.

C. TELEVISION REQUIREMENTS

Television coverage will be required for test observation and surveillance of the facility for safety considerations. The following television cameras will be used to monitor this test:

<u>Monitor No.</u>	<u>Camera No.</u>	<u>Location</u>	<u>Observation</u>
1	3 (Infrared)	W. of Ditch	NES Duct, Flare Stack
2	13	N.E. of Steam Generator	SG Enclosure
3	1	N. of Ditch	NES Duct, Duct Vault
4	20	N. of LOX Dewar	LO ₂ Tank, Pipe Line, Bottle Shed
5	6	Top of 3801 LH ₂ Storage	East Face of Test Stand and Mix Station
6	16	N. of Bottle Shed	Bottle Shed and Propane Tank *
7	14	S. Corner of Test Stand	Gas Supply Lines, PCV-449
8	10	In Duct Vault	Duct

Other cameras will be operational in the event substitution is required. Auxiliary illumination of the SGS enclosure, duct vault, and pipe chase will be provided by search lights and flood lamps. Kinescope capability will be available during all phases of the test operation.

D. COMMUNICATIONS

1. The ETS-1 communication system will be operational and audio tape recording of selected trunk lines will be required.
2. RF communications will be required.

E. PHOTOGRAPHIC SUPPORT REQUIREMENTS

1. Pipe chase steam line motion picture coverage using 16MM film at 200 frames per second (FPS).

2. Steam Generator Enclosure motion picture coverage using 16MM film at 24 FPS (Color).
3. NES Duct infrared motion picture coverage using 16MM film at 24 FPS. .
4. Still photographs shall be taken to show details of any portion of the NES which fails during testing.

IX. OPERATIONAL REQUIREMENTS

A. CONTROL POINT

The following consoles and their associated equipment will be operational for the conduction of Phase I of the NES Design Demonstration Tests:

Test Director	Gas Fill and Service
Deputy Test Director	Electrical Power
Temporary NES	Lead Safety Engineer
Test Stand Engineer	Lead Instrument Engineer
Assistant Stand Engineer	Digital Data
Lead Facility Engineer	Remote Recorder
Facility Engineer Right	Television
Facility Engineer Left	Remote Installation

B. FACILITY AND TEST STAND

The following systems and their associated equipment will be operational for the conduction of Phase I of the NES Design Demonstration Tests:

- Gas Fill and Storage System
- Gas Distribution System
- Gaseous Helium Purge System
- Steam Generator System
- Fire Protection System
- Area Surveillance and Warning System
- Utility and Process Water Systems
- Duct Exhaust Igniter System
- NES Duct Support Systems
- Combustible Gas Detection System (H_2/C_3H_8)
- Oxygen Detection System
- Facility H_2/O_2 Detection System

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IX. OPERATIONAL REQUIREMENTS (Continued)C. FLUID REQUIREMENTS

1) Tests 1 & 2

V-3201, 3202, 3203, pressurized to minimum of 1600 psig with GN_2 .

Utility water tank minimum level of 10 ft.

Process water tank minimum level of 22 ft.

Propane tank (V-3401) minimum level of 12000 gals.

Liquid Oxygen Storage tank (V-2801) minimum level of 20,000 gallons.

2) Test 3 & 4

V-3201, 3202, 3203, 3207, 3208, 3209, pressurized to minimum of
2000 psig with GN_2 .

Utility water tank minimum level of 10 ft.

Process water tank minimum level of 22 ft.

Propane tank (V-3401) minimum level of 12000 gals.

Liquid Oxygen Storage tank (V-2801) minimum level of 20,000 gallons.

Turbine exhaust supply (V-5002) GH_2 pressurized to minimum of
600 psig.

3) Test 5 or 6 or 7

V-3201, 3202, 3203

3204, 3205, 3206

3207, 3208, 3209

} pressurized to a minimum of 2475 psig.

Utility water tank minimum level of 10 ft.

Process water tank minimum level of 20 ft.

Propane tank (V-3401) minimum level of 12000 gals.

Liquid Oxygen Storage tank (V-2801) minimum level of 18,000 gallons.

Turbine Exhaust Supply (V-5002) GH_2 pressurized to minimum of
1490 psig.X. REPORT REQUIREMENTS

A preliminary reporting will be issued following completion of Phase I of the NES Design Demonstration Tests.

FIGURE 1: Test Arrangement

FIGURE 2 - TEC INSTRUMENTATION
NES DESIGN DEMO. TESTS

Figure 3
NES Duct
Principal Sections

Figure 4
NES Duct
Truss Assembly

TYPICAL ELBOW SECTION 2

TYPICAL STRAIGHT SECTION 1 & 3

Figure 5
NES Duct
Coolant Passage Configurations

**NES DESIGN DEMONSTRATION
TEST SUMMARY**

TEST		SYSTEMS REQUIRED EACH TEST														
NO.	DESCRIPTION	S G S	H ₂ O DUCT COOLANT		GN ₂			PRIMARY FLOW				GH ₂ TURBINE EXHAUST		DUCT PROPANE FLARE	O ₂ DETECT	H ₂ DETECT
			LOW	DESIGN	ENGINE COMPT. PURGE	PRESSURE STABILIZE	SIMULATE EXCESS LEAKAGE	FLUID		START RAMP	STOP RAMP	DESIGN	EXCESS			
								GN ₂ (1)	GH ₂ (1)							
1	SGS C/O& TEC PULL DOWN TEST	X	X													
2	SGS PULL DOWN TEST OF TEC WITH SIMULATED EXCESS LEAKAGE	X	X		X	X	X									
3	PRIMARY FLOW TEST P _C = 200 PSIA	X	X		X	X		10		XE	XE ⁽²⁾				X	
4	PRIMARY FLOW TEST P _C = 200 PSIA	X	X		◆		X	30		6 SEC	6 SEC	◆		◆	◆	◆
5	PRIMARY FLOW TEST P _C = 550 PSIA	X		X	◆	X		10		XE	XE	◆		◆	◆	◆
6	PRIMARY FLOW TEST P _C = 550 PSIA	X	X		◆	X	X	10		6 SEC	MALF.	◆		◆	◆	◆
7	PRIMARY FLOW TEST P _C = 550 PSIA	X (4)	X		◆	X		10		6 SEC	MALF.		◆	◆	◆	◆

- NOTES: (1) NUMBERS SHOWN IN THESE COLUMNS ARE STEADY
STATE RUN DURATION IN SEC
- (2) SHUTDOWN W/O SGS
- (3) ◆ THIS SYMBOL IS USED FOR QUICK IDENTIFICATION
OF H₂ FLOW OR SYSTEM REQUIRED BECAUSE H₂ IS FLOWING
- (4) ONE MODULE ONLY OF SGS OPERATED FOR THIS TEST

FIG. 5

CONFIGURATION CHART

Spectacle Lids	Tests 1,2	Tests 3,4	Tests 5,6,7
1	Closed	Open	Open
2	Closed	Closed	"
3.	Closed	Open	"
4	Open	Open	"
5	Closed	Closed	"
6	Closed	Open	"
Vessels			
V-3201, 2, 3	2	2	2
V-3204, 5, 6	2	2	2
V-3207, 8, 9	2	2	2

FLOW CURVE
NES/DDT TURBINE EXHAUST ASSEMBLY
4.38 INCH THROAT

W_{MODEL} = 3.56 NPS
W_{TEST} = 2.00 NPS

FIGURE 8

NES DESIGN DEMONSTRATION TESTS
APPROX FLOWS & PRESSURES VS TIME

NES DESIGN DEMONSTRATION TESTS
APPROX. FLOWS & PRESSURES VS TIME

TEST NO 3
FIG NO 10

NES DESIGN DEMONSTRATION TESTS
APPROX FLOWS & PRESSURES VS TIME

TEST NO 4
FIG NO 11

NES DESIGN DEMONSTRATION TESTS
APPROX FLOWS & PRESSURE VS TIME

NES DESIGN DEMONSTRATION TESTS
APPROX. FLOWS & PRESSURES VS TIME

NES DESIGN DEMONSTRATION TESTS
APPROX FLOWS & PRESSURES VS TIME

ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	*01*02*03*	*R*R*R*R*R*R*R	*R	*D*D*D*	*F*F*S	*S*L*M*CON-	*W*	*SOLF*
BC701W.FSG	SG1 START SEQUENCE	NA		X	X					
MN L02 OPN	SG1 START SEQUENCE	NA			X					
MN PRO OPN	SG1 START SEQUENCE	NA			X					
BC701X.FSG	SG2 START SEQUENCE	NA		X	X					
MN L02 OPN	SG2 START SEQUENCE	NA			X					
MN PRO OPN	SG2 START SEQUENCE	NA			X					
BC701Y.FSG	SG3 START SEQUENCE	NA		X	X					
MN L02 OPN	SG3 START SEQUENCE	NA			X					
MN PRO OPN	SG3 START SEQUENCE	NA			X					
BS480W.FSG	SG1 CMBJS CHBR PRESS SW	NA		X						
BS480X.FSG	SG2 CMBJS CHBR PRESS SW	NA		X						
BS480Y.FSG	SG3 CMBJS CHBR PRESS SW	NA		X						
CF030..OFND	DCT A20 FLW CTL-OPEN 1.5	NA						P		LF
CF031..OFND	DCT H20 FLW CTL-OPEN 6	NA				X		P		LF
DF031..FND	DCT H20 FLW CTL-POS 6	NA				X			X	LF
CF032..OFND	DCT H20 FLW CTL-OPEN 20	NA				X		P		LF
DF032..FND	DCT H20 FLW CTL-POS 20	NA				X			X	LF
CF423W.FSG	SG1 H20 THROTTLE VLV-CTI	NA		X				X		XFL
DF423WMFSG	SG1 H20 THROTTLE VLV-POS	0-100PC		X		X				X FL

FTS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MFAS * RANGE	*01*02*03*	*R*R*R*R*R*R*R	*R	*D*D*D*	*E*F*S	*S*L*M*	*CON-*	*A*B*C*D*E*F*FC*CS*L*M*H*	*W*	*SOLE*
CF423X.FSG	SG2 H2O THROTTLE VLV-CTI	NA		X							X	FL
DF423X.MFSG	SG2 H2O THROTTLE VLV-POS	0-100PC		X		X						X FL
CF423Y.FSG	SG3 H2O THROTTLE VLV-CTI	NA		X							X	FL
DF423Y.MFSG	SG3 H2O THROTTLE VLV-POS	0-100PC		X		X						X FL
CP250..RLC	V5002 LH RTNK PG PCV-CTI	0-100 %				X					P	AS
DP250..MRLC	V5002 LH RTNK PG PCV-POS	0-100 %				X						X AS
DP250..RRLC	V5002 LH RTNK PG PCV-DMND	0-1500PSIG				X						
CP251..RGH	GH CD PCV-MAN CTL VI V	0-100 %				X					P	TS
DP251..MRGH	GH CD PCV-VLV POS	0-100 %				X						X TS
DP251..RRGH	GH CD PCV-PRESS/FLW DEMAND	0-1000PSIG				X						
CP446..F50	PRG TEST FLOW CNTL (2#)	0-100 %				X		X			P	TN
DP446..MF50	PRG TEST FLOW CNTL (2#)	0-100 %				X		X				X TN
CP447..F50	PRG TEST FLOW CNTL (1#)	0-100 %				X		X			P	TN
DP447..MF50	PRG TEST FLOW CNTL (1#)	0-100 %				X		X				X TN
CP449..RLC	EMER CD PCV	NA				X		X			P	TN
DP449..MRL	EMER CD PCV	NA				X		X				X TN
DP449..RRLC	EMER CD PCV-CNTI											
CP472..RLC	LH CD PCV-CTL	NA				X		X			P	TN
DP472..MRLC	LH CD SYS-VLV POS	NA				X		X				X TN

ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

CHANNEL NUMBER	CHANNEL TITLE	MEAS RANGE	*01*02*03*R*R*R*R*R*R*R*R	*D*D*D*E*F*S	*S*L*M*CON-	*SOLE
FT012..RLC	LH CD SYS-FLOW-COMPUTED	0-15 PPS		R3	X	X TN
FT031..FWS	DCT H2O SPLY-PART 12IN IN	0-5 PSID			X	X LF
FT032..FWS	DCT H2O SPLY-TOTAL	0-5 PSID	6		X	X LF
FT054..FND	DCT SEC1 LT H2O IN FLO	0-50 PSID			X	X LF
FT055..FND	DCT SEC1 RT H2O IN FLO	0-50 PSID			X	X LF
FT056..FND	DCT SEC2 LT CLG H2O IN FLO	0-25 PSID			X	X LF
FT057..FND	DCT SEC2 RT CLG H2O IN FLO	0-25 PSID			X	X LF
FT058..FND	DCT SEC3 LT CLG H2O IN FLO	0-50 PSID			X	X LF
FT059..FND	DCT SEC3 RT CLG H2O IN FLO	0-50 PSID			X	X LF
FT060..FND	DCT SEC2 JKT H2O IN FLO	+5 PSID			X	X LF
FT072..FND	DCT SEC1 LT H2O OUT FLO	0-200 PSID			X	B18RI
FT073..FND	DCT SEC1 RT H2O OUT FLO	0-200 PSID			X	B19RI
FT074..FND	DCT SEC2 UPR LT H2O OTLT	0-25 PSID			X	B20RI
FT075..FND	DCT SEC2 LWR LT H2O OTLT	0-10 PSID			X	B21RI
FT078..FND	DCT SEC2 LWR RT H2O OTLT	0-10 PSID			X	B24RI
FT079..FND	DCT SEC2 UPR RT H2O OTLT	0-25 PSID			X	B25RI
FT087..FND	SEC3 CLVG H2O-3IN LN	0-200 PSID	5		X	
FT405W.FSG	SG1 3RD STG FUEL VNTR P-FL	0-500PSIG	X	6	X	X FL
FT405X.FSG	SG2 3RD STG PRO VNTR P-FLW	0-500PSIG	X	6	X	X FL

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ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	*01*02*03*	*R*R*R*R*R*R*R	*R	*D*D*D*E*F*S	*S*L*M*CON-	*SOLE
FT405Y.FSG	SG3 3RD ST PRO VNTR PR-FLW	0-500PSIG		X	6	X		X FL
FT406W.FSG	SG1 H2O VNTR DP(FLW)	0-250PSID		X	5	X		X FL
FT406X.FSG	SG2 H2O VNTR DP(FLW)	0-250PSID		X	5	X		X FL
FT406Y.FSG	SG3 H2O VNTR DP(FLW)	0-250PSID		X	5	X		X FL
FT409W.FSG	SG1 3RD ST L02 VNTR PR-FLW	0-500PSIG		X	3	X		X FL
FT409X.FSG	SG2 3RD ST L02 VNTR PR-FLW	0-500PSIG		X	3	X		X FL
FT409Y.FSG	SG3 3RD ST L02 VNTR PR-FLW	0-500PSIG		X	3	X		X FL
F.426..FPF	FLO FE426 AT 60 F (CAL)	0-40 PPS				R1	X	X TN
F.427..FPF	FLO FE427 AT 60F (CAL)	0-10 PPS				R2	X	X TN
FT428..FSG	SG1 L02 FLOW RATE	0-500CPS		X			X	
FT701..FSG	FUEL FLOW RATE	0-500CPS		X	8	X		
GG004..FND	DCT REAR LT TRUN STR	0-1500					X	B37RI
GG005..FND	DCT RT REAR TRUN STR	0-1500					X	B38RI
GG006..FND	DCT FRNT LT TRUN STR	0-1500					X	B39RI
GG007..FND	DCT FRNT RT TRUN STR	0-1500					X	B40RI
GG008..FND	DCT SEC1 BLWS LS STR	0-1500					X	B41RI
GG009..FND	DCT SEC1 BLWS RS STR	0-1500					X	B43RI
GG011..FND	DCT SEC2 CONE BOT STR	0-1500					X	B44RI
GG012..FND	DCT SEC2 CONE RS STR	0-1500					X	

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ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

★ CHANNEL ★ NUMBER	★ CHANNEL TITLE	★ MFAS ★ RANGE	★01★02★03★R★R★R★R★R★R★R★R★R★D★D★D★E★F★S★S★L★M★CON-★ ★A★B★C★D★E★F★FC★CS★L★M★H★★★W★★★SOLE★
GG013..FND DCT SEC2 CONE TOP STR	0-1500	X	B45RI
GG014..FND DCT SEC2 CONE LS STR	0-1500	X	B46RI
GG015..FND DCT SEC3 BOT STR	0-1500	X	B47RI
GG016..FND DCT SEC3 RS STR	0-1500	X	
GG017..FND DCT SEC3 TOP STR	0-1500	X	B48RI
GG018..FND DCT SEC3 LS STR	0-1500	X	
GG019..FND DCT SEC3 FWD HOR TRUSS STR	0-1500	X	
GG901..FND SECT 1 FRONT-TOP	0-1000		X
GG902..FND SECT 1 REAR-TOP	0-1000		X
GG903..FND SECT 1 FRONT-MIDSPAN	0-1000		X
GG904..FND SECT 1 REAR-MIDSPAN	0-1000		X
GG905..FND SECT 1 FRONT-BOTTOM	0-1000		X
GG906..FND SECT 1 REAR-BOTTOM	0-1000		X
GG907..FND ELBOW H2O JKT-FRT-TOP	0-1000		X
GG908..FND ELBOW H2O JKT-REAR-TOP	0-1000		X
GG909..FND ELBOW H2O JKT-FRONT-BOTTOM	0-1000		X
GG910..FND ELBOW H2O JKT REAR-BOTTOM	0-1000		X
GG911..FND SECT3 MIDSPAN-TOP	0-1000		X
GG912..FND SECT3 MIDSPAN-BOTTOM	0-1000		X

ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	*01*02*03*R*R*R*R*R*R*R*R * * * *A*R*C*D*E*F*FC*CS*L*M*H* * *	*R *D*D*D*E*F*S *S*L*M*CON- * * * *W* * *SOLE *
GG913..FND	SFC3-45DEG ELBOW-TOP	0-1000		X
GG914..FND	SFC3-45DEG ELBOW-BOTTOM	0-1000		X
HT001..FND	DCT SEC1 SEAL TABLE-1X VIR	0-15 G		X
HT002..FND	DCT SEC1 SEAL TABLE-2Y VIR	0-15 G		X
HT003..FND	DCT SEC1 SEAL TABLE-3Z VIR	0-15 G		X
HT004..FND	DCT SEC2 ELR-1X VIB	0-15 G		X
HT005..FND	DCT SEC2 ELROW-2Y VIB	0-15 G		X
HT006..FND	DCT SEC2 ELROW-3Z VIB	0-15 G		X
HT007..FND	DCT SEC3 MIDSPAN-1X VIR	0-15 G		X
HT008..FND	DCT SEC3 MIDSPAN-2Y VIR	0-15 G		X
HT009..FND	DCT SEC3 MIDSPAN-3Z VIR	0-15 G		X
HT901..FND	SECT 1 MIDSPAN SPT RING	0-15 G		X
HT902..FND	SECT 1 MIDSPAN SPT RING	0-15 G		X
HT903..FND	SECT 1 MIDSPAN SPT RING	0-15 G		X
HT904..FND	ELBOW H2O JACKET-FRONT	0-15 G		X
HT905..FND	ELBOW H2O JACKET-FRONT	0-15 G		X
HT906..FND	ELBOW H2O JACKET-FRONT	0-15 G		X
HT907..FND	SECT 3 420 INLET M	0-15 G		X
HT908..FND	SECT 3 420 INLT MNFLD	0-15 G		X

ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MFAS * RANGE	*01*02*03*R*R*R*R*R*R*R*R	*R	*D*D*D*E*F*S	*S*L*M*CON-	*A*B*C*D*E*F*FC*CS*L*M*H*	*W*	*SOLE*
HT909..FND	SFCX 420 INLT MNFLD	0-15 G							X
HT910..FND	REAR TRJN MIDSPAN	0-15 G							X
HT911..FND	REAR TRJN MIDSPAN	0-15 G							X
HT912..FND	REAR TRJN MIDSPAN	0-15 G							X
HT913..FND	FRONT TRJN MIDSPAN	0-15 G							X
HT914..FND	FRONT TRJN MIDSPAN	0-15 G							X
HT915..FND	FRONT TRJN MIDSPAN	0-15 G							X
KT001..FPE	02 CON ETC CHAN 1	0-10 MV		5			X		
KT001.MFPE	02 CON ETC CHAN 1	0-5 0-25 %							X X LFE
KT002..FPE	02 CON ETC CHAN 2	0-10 MV		6			X		
KT002.MFPE	02 CON ETC CHAN 2	0-5 0-25 %							X X LFE
KT003..FPE	H2 CON ETC CHAN 1	0-10 MV		7			X		
KT003.MFPE	H2 CON ETC CHAN 1	0-5 0-100%							X X LFE
KT004..FPE	H2 CON ETC CHAN 2	0-10 MV		8			X		
KT004.MFPE	H2 CON ETC CHAN 2	0-5 0-100%							X X LFE
KT700..FPF	OXYGEN CONCENTRATION 1	0-5 0-25 %				C1			X TN
KT701..FPF	OXYGEN CONCENTRATION 2	0-5 0-25 %				C2 X			X TN
KT702..FPF	OXYGEN CONCENTRATION 3	0-5 0-25 %				C3 X			X TN
KT703..FPF	OXYGEN CONCENTRATION 4	0-5 0-25 %				C4 X			X TN

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ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MFAS * RANGE	* 01*02*03*R*R*R*R*R*R*R *R *D*D*D*E*F*S *S*I*M*CON- * * * * *A*B*C*D*F*F*FC*CS*L*M*H* * * *W* * *SOLF *
KT704..FPF	OXYGEN CONCENTRATION 5	0-5 0-25 %	C5 X X TN
KT705..FPF	OXYGEN CONCENTRATION 6	0-5 0-25 %	C6 X X TN
KT706..FPF	OXYGEN CONCENTRATION 7	0-5 0-25 %	D1 X X TN
KT707..FPF	OXYGEN CONCENTRATION 8	0-5 0-25 %	C7 X X TN
KT708..FPF	OXYGEN CONCENTRATION 9	0-5 0-25 %	C8 X X TN
LT001..FSG	LO V-2801 TNK LVL	0-10PSID	X FL
LT011..FSG	PRO V3401 TNK LVL	0-25PSID	X FL
LT015..FWS	PROCESS H2O SPLY TNK-LVI	0-50 FFET	X X LF
PT001..FGF	GF V3201 TNK PR	0-3000PSIG	X X GF
PT002..FGS	GS DIST HDR (1-GN) PR	0-3000PSIG	X X GF
PT004..FGF	GF V3202 TNK PR	0-3000PSIG	X X GF
PT007..FGF	GF V3203 TNK PR	0-3000PSIG	X X GF
PT049..FSG	LO V2801 TNK PRESS	0-500PSIG	X X FL
PT097..RLC	V5002 HP LH DEWR PR	0-2000PSIG	1 X X AS
PT101..RLC	LH CD SPLY PRESS	0-1500PSIG	X X
PT118..FSG	PRO V3401 TNK PRESS	0-500PSIG	X X FL
PT168..FWS	PROCESS H2O HDR PRESS	0-300PSIG	4 X X LF
PT203..FND	DCT SEC1 RT H2O IN PRESS	0-250 PSIG	X
PT204W..FND	DCT SEC 1 LT H2O OTIT PRES	0-300PSIG	X B27R1

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ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL *	CHANNEL TITLE	* MFAS	*01*02*03*R*R*R*R*R*R*R *R *D*D*D*E*F*S *S*L*M*CON- *
* NUMBER *		* RANGE	* * * *A*B*C*D*E*F*FC*CS*L*M*H* * * *W* * *SOLE *
PT204X.FND	DCT SEC 1 LT H2O OTLT PRES	0-100PSIG	X
PT205W.FND	DCT SEC2 LT VPR H2O OTLT P	0-300PSIG	X B29RI
PT205X.FND	DCT SEC2 LT VPR H2O OTLT P	0-100PSIG	X
PT206..FND	DCT SEC2 RT H2O IN PRESS	0-250 PSIG	X
PT207..FND	DCT SEC3 RT H2O IN PRESS	0-250 PSIG	X
PT208..FND	DCT SEC3 RT H2O OTLT PRESS	0-250 PSIG	X B34RI
PT209W.FND	DCT SEC2 RT LWR H2O OTLT P	0-300PSIG	X B 33RI
PT209X.FND	DCT SEC2 RT LWR H2O OTLT P	0-100PSIG	X
PT210W.FND	DCT SEC2 RT UPR H2O OTLT P	0-300PSIG	X B30RI
PT210X.FND	DCT SEC2 RT UPR H2O OTLT P	0-100PSIG	X
PT221..FND	DCT SEC1 LT H2O IN PRESS	0-250 PSIG	X
PT222..FND	DCT SEC3 RT H2O OTLT PRESS	0-250 PSIG	X B35RI
PT223W.FND	DCT SEC1 RT H2O OTLT PRES	0-300PSIG	X B28RI
PT223X.FND	DCT SEC1 RT H2O OTLT PRES	0-100PSIG	X
PT224..FND	DCT SEC2 LT H2O IN PRESS	0-250 PSIG	X
PT225..FND	DCT SEC3 LT H2O IN PRESS	0-300 PSIG	X
PT226W.FND	DCT SEC2 LT LWR H2O OTLT P	0-300PSIG	X B31RI
PT226X.FND	DCT SEC2 LT LWR H2O OTLT P	0-100PSIG	X
PT239..FND	DCT STM HDR PRESS	0-250PSG	X L3 M LF

ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DFC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	*01*02*03*R*R*R*R*R*R*R *R *D*D*D*E*F*S *S*L*M*CON- *	*A*B*C*D*E*F*FC*CS*L*M*H* * *	*W* * *SOLE *
PT290..	FSS ETC PRESS - TOP SHLD	0-20 PSIA			X
PT292..	FSS BOT CHBR PRESS	0-20 PSIA			X
PT407W.	FSG SG1 1ST STG PRO INJTN PRES	0-500PSIG	X	1	X
PT407X.	FSG SG2 1ST STG PRO INJTN PRES	0-500PSIG	X	1	X
PT407Y.	FSG SG3 1ST STG PRO INJTN PRES	0-500PSIG	X	1	X
PT408W.	FSG SG1 2ND STG PRO VNTR IN PR	0-500PSIG	X	2	X
PT408X.	FSG SG2 2ND STG PRO VNTR IN PR	0-500PSIG	X	2	X
PT408Y.	FSG SG3 2ND STG PRO VNTR IN PR	0-500PSIG	X	2	X
PT410W.	FSG SG1 CHBR JKT H2O DSCH PR	0-200PSIG			X
PT410X.	FSG SG2 CHBR JKT H2O DSCH PR	0-200PSIG			X
PT410Y.	FSG SG3 CHBR JKT H2O DSCH PR	0-200PSIG			X
PT416W.	FSG SG1 1ST STAGE IG PRESS	0-250PSIG	X		X FL
PT416X.	FSG SG2 1ST STAGE IG PRESS	0-250PSIG	X		X FL
PT416Y.	FSG SG3 1ST STAGE IG PRESS	0-250PSIG	X		X FL
PT417W.	FSG SG1 2ND STAGE IG PRESS	0-250PSIG	X		X FL
PT417X.	FSG SG2 2ND STAGE IG PRESS	0-250PSIG	X		X FL
PT417Y.	FSG SG3 2ND STAGE IG PRESS	0-250PSIG	X		X FL
PT420..	FSG SG PRO IN PRESS	0-500PSIG	X	7	X FL
PT421..	FSG SG LO MV FLD PRESS	0-500PSIG	X	7	X FL

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ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	*01*02*03*	*R*R*R*R*R*R*	*R	*D*D*D*	*E*S	*S*L*M*CON-	* *W* * *SOLE *
PT425..FSG	SG PLEN STM NO.1 PR	0-250PSIG	X			L2	X		X FL
PT426..FSG	SG PLEN STM NO2 PR	0-250PSIG	X				X		X FL
PT427..FSG	SG MN H2O MN FLD PRESS	0-300PSIG	X			7	X		X FL
PT428..FSG	SG GN PRG SPLY PRESS	0-500PSIG							X FL
PT438W.FSG	SG1 LWR 3RD STG PRESS PR	0-250PSIG	X		4		X		X FL
PT438X.FSG	SG2SLWR 3RD STG PRESS	0-250PSIG	X		4		X		X FL
PT438Y.FSG	SG3 LWR 3RD STG PRESS PR	0-250PSIG	X		4		X		X FL
PT439	FSG PRO TANK DOME REG-PRESS	0-500PSIG							X FL
PT440..FSG	RMT LOR LO2 TANK PRESS	0-500PSIG							X FL
PT474..FPF	PRESS DWNSTRM CHV-1722	0-300 PSIG		3			X		
PT484..RLC	LH CD SYS PRESS	0-1500PSIG					X	X	X TS
PT574..FSG	150IB GN SPLY PRESS	0-250PSIG							X FL
PT596..FWS	DCT CLNT OLT-PRESS	0-300 PSIG		8			X		X LF
PT597..FWS	DCT CLNT INLT-PRESS	0-300 PSIG		7			X		X LF
PT600..FWS	DCT CLNT FCV OTIT-PRESS	0-30 PSIA					X		
PT601..RLC	50FF012 DELTA PRESS	0-25 PSID							
PT602W.FPT	DELTA PRESS - FE426	0-50 PSID		1			X	X	
PT602X.FPT	DELTA PRESS - FE426 COMP	0-50PSID							
PT603W.FPF	DELTA PRESS - FF427	0-50 PSID					X	X	

ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

★ CHANNEL ★ NUMBER	★ CHANNEL TITLE	★ MEAS ★ RANGE	★ 01★02★03★R★R★R★R★R★R★R★R★R★R★D★D★D★F★F★S★S★L★M★CON-★ ★ A★B★C★D★E★F★F★C★CS★L★M★H★ ★ ★ ★W★ ★ ★SOLE ★
PT603X.FPF	DELTA PRESS - FF427 COMP	0-50PSID	
PT606..FGF	V-3204 STATIC PRESS	0-3000PSIG	X X
PT607..FGF	V-3205 STATIC PRESS	0-3000PSIG	X X
PT707W.FSG	SG1 MV STG CHBR DP	0-200PSID	X
PT707X.FSG	SG2 MV STG CHRR DP	0-200PSID	X
PT707Y.FSG	SG3 MV STG CHBR DP	0-200PSID	X
PT787..FSG	SG PLENUM CLNT H2O ORF DP	0-100PSID	X
PT789W.FSG	SG1 1-2 ST CMBUS CHRR DP	0-200PSID	X
PT789X.FSG	SG2 1-2 ST CMBUS CHRR DP	0-200PSID	X
PT789Y.FSG	SG3 1-2 ST CMBUS CHRR DP	0-200PSID	X
PT790W.FSG	SG1 2/MV STG CMBUS CHRR DP	0-200PSID	X
PT790X.FSG	SG2 2/MV STG CMBUS CHRR DP	0-200PSID	X
PT790Y.FSG	SG3 2/MV STG CMBUS CHRR DP	0-200PSID	X
PT791..F	GN SPLY LV ORF	0-2500PSIG	X
PT792..F	GN SPLY OR DP	0-1000PSID	X
PT796..FPF	50FE426 PRG/LKG STAT PRS	0-300 PSIG	2 X X
PT797..FPF	50FF427 PRG/LKG STAT PRES	0-300PSIG	X X
PT800..FSS	ETC DELTA P TOP-BTM SHLD	0-5 PSID	X
PT801..FPF	PRESS UPSTRM 50-R0-45	0-300 PSIG	4 X X TN

ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	*01*02*03*R*R*R*R*R*R*R*R *R *D*D*D*E*F*S *S*L*M*CON- *	* * * *A*B*C*D*F*F*FC*CS*L*M*H* * * *W* * *SOLE *
PT802W.FPF PRESS PURGE RING A	0-300 PSIA		X	X TN
PT802X.FPF PRESS PURGE RING B	0-300 PSIA		X	
PT802Y.FPF PRESS PURGE RING C	0-300 PSIA		X	
PT804..FND DUCT SEVERANCE PLANE	0-30 PSIA		X	X
PT805..FND DUCT SEVERANCE PLANE	0-30 PSIA		X	X
PT901..FND TURB EXHST CHMBR PTC-1	0-100 PSIA	R4	X	X TN
PT902..FND TURB EXHST NOZ-1 PTF-1	0-5 PSIA		X	X
PT903..FND TURB EXHST NOZ-2 PTF-2	0-5 PSIA		X	X
PT904..FND PRI GAS SPLY LINE PS	0-3000PSIG	3	X	X TN
PT905..FND PRI CHMBR-1	0-1000PSIA	R5	X	X TN
PT906..FND PRI CHMBR-2 PPC-2	0-300 PSIA	2	X	X TN
PT907..FND TEC PV-1	0-5 PSIA		X	X
PT908..FND TEC PV-2	0-30 PSIA	R6	X	X TN
PT909..FND PRI NOZ EXIT-1 PE-1	0-30 PSIA	R8	X	X
PT910..FND PRI NOZ EXIT-2 PE-2	0-5 PSIA		X	X TN
PT911..FND PRI NOZ EXIT-3 PE-3	0-30 PSIA	R7	X	X TN
PT912..FND PRI NOZ EXIT-4 PE-4	0-5 PSIA		X	X
S.701W.FSG SG1 1ST STG MAN SHUTOFF			X X	X LF
S.701X.FSG SG2 1ST STG MAN SHUTOFF			X X	X LF

ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	* 01*02*03*P*R*R*R*R*R*R *R *D*D*D*F*F*S *S*L*M*CON- * * * *A*B*C*D*E*F*FC*CS*L*M*H* * * *W* * *SOLE *
S.701Y.FSG	SG3 1ST STG MAN SHUTOFF		X X X LF
SR001..FGF	V3201 TNK MN BLK VLV	NA	X GF
BR001..CFGF	V3201 TNK MN BLK VLV	NA	X GF
BR001..DFGF	V3201 TNK MN BLK VLV	NA	X GF
SR002..FGF	V3201 TNK BLK VLV BYPASS	NA	X GF
BR002..CFGF	V3201 TNK BLK VLV BYPASS	NA	X GF
BR002..DFGF	V3201 TNK BLK VLV BYPASS	NA	X GF
SR006..FGF	V3202 MV BLK VLV	NA	X GF
BR006..CFGF	V3202 MV BLK VLV	NA	X GF
BR006..DFGF	V3202 MV BLK VLV	NA	X GF
SR007..FGF	V3202 BLK VLV BYPASS	NA	X GF
BR007..CFGF	V3202 BLK VLV BYPASS	NA	X GF
BR007..DFGF	V3202 BLK VLV BYPASS	NA	X GF
SR011..FGF	V-3203 TNK MN BLK VLV	NA	X GF
BR011..CFGF	V-3203 TNK MN BLK VLV	NA	X GF
BR011..DFGF	V-3203 TNK MN BLK VLV	NA	X GF
SR012..FGF	V3203 BLK VLV BYPASS	NA	X GF
BR012..CFGF	V3203 BLK VLV BYPASS	NA	X GF
BR012..DFGF	V3203 BLK VLV BYPASS	NA	X GF

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ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	*01*02*03*R*R*R*R*R*R*R *R *D*D*D*E*F*S *S*L*M*CON- * * * *A*B*C*D*F*F*FC*CS*L*M*H* * * *W* * *SOLE *
SR016..FGF	V3204 MV BLK VLV	NA	X GF
BR016.CFGF	V3204 MV BLK VLV	NA	X GF
BR016.OFGF	V3204 MV BLK VLV	NA	X GF
SR017..FGF	V3204 B_K VLV BYPASS	NA	X GF
BR017.CFGF	V3204 B_K VLV BYPASS	NA	X GF
BR017.OFGF	V3204 B_K VLV BYPASS	NA	X GF
SR021..FGF	V3205 MV BLK VLV	NA	X GF
BR021.CFGF	V3205 MV BLK VLV	NA	X GF
BR021.OFGF	V3205 MV BLK VLV	NA	X GF
SR022..FGF	V3205 B_K VLV BYPASS	NA	X GF
BR022.CFGF	V3205 B_K VLV BYPASS	NA	X GF
BR022.OFGF	V3205 B_K VLV BYPASS	NA	X GF
SR026..FGF	V3206 MV BLK VLV	NA	X GF
BR026.CFGF	V3206 MV BLK VLV	NA	X GF
BR026.OFGF	V3206 MV BLK VLV	NA	X GF
SR027..FGF	V3206 B_K VLV BYPASS	NA	X GF
BR027.CFGF	V3206 B_K VLV BYPASS	NA	X GF
SR053..FGS	106-HE HDR SOV	NA	X FR
BR053.CFGS	106-HE HDR SOV	NA	X FR

ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NFS INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	*01*02*03*R*R*R*R*R*R*R *R *D*D*D*E*F*S *S*L*M*CON- * * * * *A*B*C*D*E*F*F*FC*CS*L*M*H* * * *W* * *SOLE *
BR053.0FGS	106-HE HDR SOV	NA	X FR
SR054..FGS	106-HE HDR BYPASS VLV	NA	X FR
BR054.0FGS	106-HE HDR BYPASS VLV	NA	X FR
BR054.0FGS	106-HE HDR BYPASS VLV	NA	X FR
SR059..FGF	C3001 CCM SUCT VLV	NA	X GF
BR059.0FGF	C3001 CCM SUCT VLV	NA	X GF
BR059.0FGF	C3001 CCM SUCT VLV	NA	X GF
SR068..FSG	V2801 L3 TNK PG VLV	NA	X FL
BR068.0FSG	V2801 L3 TNK PG VLV	NA	X FL
BR068.0FSG	V2801 L3 TNK PG VLV	NA	X FL
SR105..RLC	LH CD TSFR LN HE PRG SOV	NA	X TS
BR105.0RLC	LH CD TSFR LN HE PRG SOV	NA	X TS
BR105.0RLC	LH CD TSFR LN HE PRG SOV	NA	X TS
SR106..RLC	V5002 LH DEWR FILL VLV	NA	X FR
BR106.0RLC	V5002 LH DEWR FILL VLV	NA	X FR
BR106.0RLC	V5002 LH DEWR FILL VLV	NA	X FR
SR107..RLC	V5002 LH DEWR TSFR VLV	NA	X TS
BR107.0RLC	V5002 LH DEWR TSFR VLV	NA	X TS
BR107.0RLC	V5002 LH DEWR TSFR VLV	NA	X TS

ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	*01*02*03*R*R*R*R*R*R*R *R *D*D*D*E*F*S *S*L*M*CON- *A*R*C*D*E*F*FC*CS*L*M*H* * * *W* * *SOLE *
SR188..RLC	EMER LH TSFR VAC LVV	NA	X TS
BR188.CRLC	EMER LH TSFR VAC LVV	NA	X TS
SR194..FGS	GH HDR (1-GH) VV	NA	X GF
BR194.CFGS	GH HDR (1-GH) VV	NA	X GF
BR194.OFGS	GH HDR (1-GH) VV	NA	X GF
SR201..RGH	GH CD LV	NA	X TS
BR201.CRGH	GH CD LV	NA	X TS
BR201.JRGH	GH CD LV	NA	X TS
SR222..FPF	ENG CMPT GN PRG SOV	NA	X LF
BR222.CFPF	ENG CMPT GN PRG SOV	NA	X X LF
BR222.OFPF	ENG CMPT GN PRG SOV	NA	X X LF
SR245..FGS	GS HDR (1-GN) SOV	NA	X GF
BR245.CFGS	GS HDR (1-GN) SOV	NA	X GF
BR245.OFGS	GS HDR (1-GN) SOV	NA	X GF
SR246..FGS	GS HDR (1-GN) SOV	NA	X GF
BR246.CFGS	GS HDR (1-GN) SOV	NA	X GF
BR246.OFGS	GS HDR (1-GN) SOV	NA	X GF
SR273..FGS	GS HDR (1-GN) BPASS VLV	NA	X FR
BR273.CFGS	GS HDR (1-GN) BPASS VLV	NA	X FR

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ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	*01*02*03*R*R*R*R*R*R*R *R *D*D*D*E*F*S *S*I*M*CON- * * * *A*R*C*D*F*F*FC*CS*L*M*H* * * *W* * *SOLE *
BR273.OFGS	GS HDR (1-GN) BPASS VLV	NA	X FR
SR274..FGS	GS HDR (1-GH) BPASS VLV	NA	X FR
BR274.OFGS	GS HDR (1-GH) BPASS VLV	NA	X FR
BR274.OFGS	GS HDR (1-GH) BPASS VLV	NA	X FR
SR276..FLS	V3801 L4 DEWR PG SOV	NA	X FR
BR276.OFLS	V3801 L4 DEWR PG SOV	NA	X FR
SR283..RLP	V5001 L4 RTNK PG SOV V	NA	X TS
BR283.CRLP	V5001 L4 RTNK PG SOV V	NA	X TS
SR286..RLC	V5002 L4 DEWR PG SOV	NA	X FR
BR286.CRLC	V5002 L4 DEWR PG SOV	NA	X FR
SR296..FND	DCT H2O SPLY LOW FLW-CMD	NA	X LF
BR296.CFND	DCT H2O SPLY LOW FLW-CLOSE	NA	X LF
BR296.CFND	DCT H2O SPLY LOW FLW-OPEN	NA	X LF
SR297..FND	DCT H2O SPLY MED FLW-CMD	NA	X LF
BR297.CFND	DCT H2O SPLY MED FLW-CLOSE	NA	X LF
BR297.CFND	DCT H2O SPLY MED FLW-OPEN	NA	X LF
SR298..FND	DCT H2O SPLY HI FLW-CMD	NA	X LF
BR298.CFND	DCT H2O SPLY HI FLW-CLOSE	NA	X LF
BR298.CFND	DCT H2O SPLY HI FLW-OPEN	NA	X LF

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ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	*01*02*03*R*R*R*R*R*R*R *R *P*D*D*E*F*S *S*L*M*CON- * * * * *A*B*C*D*E*F*FC*CS*L*M*H* * * *W* * *SOLF *
SR322..RGH GH CD LINE HE PRG SOV	NA		X TS
BR322.CRGH GH CD LINE HE PRG SOV	NA		X TS
BR322.ORGH GH CD LINE HE PRG SOV	NA		X TS
SR324..RGH GH CD SYS GN PRG SOV	NA		X TS
BR324.CRGH GH CD SYS GN PRG SOV	NA		X TS
SR330..FSG V3401 PRO TNK PG VLV	NA		X FL
BR330.CFSG V3401 PRO TNK PG VLV	NA		X FL
BR330.CFSG V3401 PRO TNK PG VLV	NA		X FL
SR384..RLC LH CD TSFR LVV	NA		X TS
BR384.CRLC LH CD TSFR LVV	NA		X TS
BR384.ORGH LH CD TSFR LVV	NA		X TS
SR456..RLC LH CD TSFR LVV	NA		X TS
BR456.CRLC LH CD TSFR LVV	NA		X TS
BR456.ORGH LH CD TSFR LVV	NA		X TS
SR457..RLC CD SYS LVV	NA		X TS
BR457.CRLC CD SYS LVV	NA		X TS
BR457.ORGH CD SYS LVV	NA		X TS
SR458..RLC LH CD PBASS VLV	NA		X TS
BR458.CRLC LH CD PBASS VLV	NA		X TS

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ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NFS INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	*01*02*03*R*R*R*R*R*R*R *R *D*D*D*E*F*S * * * *A*B*C*D*E*F*FC*CS*L*M*H* * *	*S*L*M*CON- * *W* * *SOLE *
SR459..RLC	LH CD BPASS VLV	NA		X TS
BR459.CRLC	LH CD BPASS VLV	NA		X TS
SR515..FGF	GF V-3207 TNK BLK VI V BPAS NA			X GF
BR515.CFGF	GF V-3207 TNK BLK VI V BPAS NA			X GF
BR515.CFGF	GF V-3207 TNK BLK VI V BPAS NA			X GF
SR516..FGF	GF V-3207 TNK MN BLK VLV NA			X GF
BR516.CFGF	GF V-3207 TNK MN BLK VLV NA			X GF
BR516.CFGF	GF V-3207 TNK MN BLK VLV NA			X GF
SR519..FGF	GF V-3208 TNK BLK VI V BPAS NA			X GF
BR519.CFGF	GF V-3208 TNK BLK VI V BPAS NA			X GF
BR519.CFGF	GF V-3208 TNK BLK VI V BPAS NA			X GF
SR520..FGF	V-3209 TNK MN BLK VI V NA			X GF
BR520.CFGF	V-3209 TNK MN BLK VI V NA			X GF
BR520.CFGF	V-3209 TNK MN BLK VI V NA			X GF
SR523..FGF	GF V3209 TNK BLK VLV BPASS NA			X GF
BR523.CFGF	GF V3209 TNK BLK VLV BPASS NA			X GF
BR523.CFGF	GF V3209 TNK BLK VLV BPASS NA			X GF
SR524..FGF	GF V-3209 TNK MN BLK VLV NA			X GF
BR524.CFGF	GF V-3209 TNK MN BLK VLV NA			X GF

ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	*01*02*03*R*R*R*R*R*P*R *R *D*D*D*F*F*S *S*L*M*CON- * * * *A*B*C*D*E*F*FC*CS*I*M*H* * * *W* * *SOLE *
BR524..DFGF	GF V-3209 TNK MN RLK VLV	NA	X GF
SR545..RLN	LN CD SYS SOV	NA	X TS
BR545..CRLN	LN CD SYS SOV	NA	X TS
SR550..RLC	CD SYS LVV-CMD	NA	X TS
BR550..CRLC	CD SYS LVV-CLOSE	NA	X TS
BR550..CRLC	CD SYS LVV-OPEN	NA	X TS
SR727..FND	PURGE RING SOV-CMD	NA	X LF
BR727..CFND	PURGE RING SOV-CLOSE	NA	X I F
TE057..FND	DCT SEC1 RT H2O OTLT TEMP	492-711	X X LF
TE058..FND	DCT SEC2 LT LWR H2O OTLT	492-711	X X LF
TE059..FND	DCT SEC3 RT CLG H2O OTLT	492-711	X X LF
TE060..FND	DCT SEC2 RT LWR H2O OTLT	492-711	X
TE061..FND	DCT SEC2 RT UPR H2O OTLT	492-711	X
TE066..FND	DCT SEC1 LFT H2O OTLT	492-711	X X LF
TE067..FND	DCT SEC2 LFT H2O OTLT	492-711	X X LF
TE068..FND	DCT SEC3 LFT H2O OTLT	492-711	X X LF
TE075..FND	DCT SEC2 STA529 H2O	492-711	X B5 RI
TE076..FND	DCT SEC2 STA539 H2O	492-711	X B7 RI
TE077..FND	DCT SEC2 STA554 H2O	492-711	X X LF

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ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MEAS * RANGE	*01*02*03*R*R*R*R*R*R*R *R *D*D*D*F*F*S *S*I*M*CON- *	* * * *A*B*C*D*E*F*F*G-CS*L*M*H* * * *W* * *SOLE *
TE078..FND	DCT SEC2 STA563 H2O	492-711		X B8 RI
TE079..FND	DCT SEC2 STA579 H2O	492-711		X B9 RI
TE083..FND	DCT SEC2 STA596 H2O	492-711		X B13RI
TE084..FND	DCT SEC2 STA598 H2O	492-711		X B14RI
TE085..FND	DCT SEC2 STA588 H2O	492-711		X B10RI
TE086..FND	DCT SEC2 STA590 H2O	492-711		X B11RI
TE087..FND	DCT SEC1 STA63 H2O	492-711		X B1 RI
TE088..FND	DCT SEC1 STA280 H2O	492-711		X B2 RI
TE089..FND	DCT SEC1 STA358 H2O	492-711		X B3 RI
TE090..FND	DCT SEC1 STA422 H2O	492-711		X B4 RI
TE158..FND	DCT SEC3 DRAIN H2O TEMP	492-711		X B15RI
TF159..FND	STM HDR TEMP	460-2460	X	L1 X X LF
TF164..FND	DCT SEC1 RT TRS H2O TEMP	492-711		X
TE165..FND	DCT SEC1 LFT TRS H2O TEMP	492-711		X
TE166..FND	DCT SEC3 JPR TRS STA 823	492-711		X
TE167..FND	DCT SEC3 LWR TRS STA 823	492-711		X
TE210..FND	DCT FLARE IG EXHST TEMP	NA		X FL
TE211..FND	DCT FLARE IG EXHST TEMP	NA		X FL
TE212..FND	DCT FLARE IG EXHST TEMP	NA		X FL

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ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NFS INTEGRATED TEST PHASE 1 (GM2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL * NUMBER	* CHANNEL TITLE	* MFAS * RANGE	*01*02*03*R*R*R*R*R*R*R *R *D*D*D*E*F*S *S*L*M*CON- *	* * * *A*B*C*D*E*F*F*G*CS*L*M*H* * * *W* * *SOLE *
TE320..FND DCT SEC3 H2O DRAIN TEMP	492-711		X	B14RI
TE438WPFSG SG1 STM DSCHG AVG TEMP	492-2760		X	X FL
TE438XPFSG SG2 STM DSCHG AVG TEMP	492-2760		X	X FL
TE438YPFSG SG3 STM DSCHG AVG TEMP	492-2760		X	X FL
TE435W.FSG SG1 STM DSCHG T1				
TE435X.FSG SG2 STM DSCHG T1				
TE435Y.FSG SG3 STM DSCHG T1				
TE436W.FSG SG1 STM DSCHG T2				
TE436X.FSG SG2 STM DSCHG T2				
TE436Y.FSG SG3 STM DSCHG T2				
TE437W.FSG SG1 STM DSCHG T3				
TE437X.FSG SG2 STM DSCHG T3				
TE437Y.FSG SG3 STM DSCHG T3				
TE480..FSG LO2 LPLY TOMATMOS TEMP	65-654			X FL
TE534..FND STM HDR TEMP	492-2760	X	X	X FL
TE902..FND TURR EXHST CHMBR TTC	135-610		X	X TN
TE903..FND PRI CHMBR TPC	492-771		X	X
TE904..FND TEST STAND-1	0-444		X	
TE905..FND TEST STAND-2	0-444		X	

ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL *	CHANNEL TITLE	* MEAS *	*01*02*03*R*R*R*R*R*R*R*R *	*D*D*D*E*F*S *	*S*L*M*CON- *
* NUMBER *		* RANGE *	* * * *A*R*C*D*E*F*FC*CS*L*M*H* * *	*W* * *	*SOLE *
TE906..	FND TEST STAND-3	0-444			X
TE907..	FND TEST STAND-4	492-1960			X
TF901..	FND THERM RAD-H2 EXHST PLUMF	0-158/FT2S			X
TF902..	FND THERM RAD-H2 EXHST PLUMF	0-258/FTSC			X
TT028..	RLC LH CD SPLY TEMP	135-610			X X
TT047..	FWS DCT CLNT INLT-TEMP	460-560			X X LF
TT048..	FWS DCT CLNT OTLT-TEMP	492-711			X X LF
TT431..	FSG SG PLEN H2O JKT TEMP	460-610		L5	X X FL
TT434W.	FSG SG1 CHBR JKT H2O DSCHG T	460-610		L6	X
TT434X.	FSG SG2 CHBR JKT H2O DSCHG T	460-610		L7	X
TT434Y.	FSG SG3 CHBR JKT H2O DSCHG T	460-610		L8	X
TT478..	FSG SG FUEL MNFLD TEMP	460-560	X	B	X X FL
TT479..	FSG LO2 MNFLD TEMP	70-290		B	X X FL
TT483..	FSG PRO V3401 TANK TEMP	460-560			X
TT489..	FGF V3201 TNK TEMP	360-610			X X GF
TT490..	FGF V-3202 TNK TEMP	360-610			X X GF
TT491..	FGF V-3203 TNK TEMP	360-610			X X GF
TT509..	FUEL BLEAD IN TEMP	460-560			X AC
TT765..	GN SPLY LN TEMP	460-610			X

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ETS-1 MEASUREMENTS AND CONTROL REQUIREMENTS NES INTEGRATED TEST PHASE 1 (GN2 PRIMARY) - FINAL
DEC 21, 1966

* CHANNEL *	CHANNEL TITLE	* MEAS	*01*02*03*R*R*R*R*R*R*R *R *D*D*D*E*F*S	*S*L*M*CON-	*
* NUMBER *		* RANGE	* * * *A*B*C*D*E*F*G*CS*L*M*H* * *	*W* * *	*SOLE *
TT901..FPF TEMP OF FE426		492-771		X	X TN

[[

NUMBER OF CHANNELS LISTED IS 458.
THE END

A P P E N D I X A

NES DESIGN DEMONSTRATION TESTS PHASE I
MEASUREMENT AND CONTROL REQUIREMENTS

NEP-II-1

EVENTS

RANGE TIME

EVENTS	RANGE	TIME	
1. Before the data system was turned on, FCV-30 was OPEN fully and FCV-31 was OPENED such that F-31 indicated 4.5 PSID.			
2. Idle steam SG-1	782300	- 85.9	
3. Idle Steam SG-2	782391	- 76.8	
4. Idle steam SG-3	782468	- 69.1	
5. Increase flow F-427 = 1.5 lb/sec	782878	- 28.1	
6. Full steam SG-3	783159	0	
7. Full steam SG-2	783373	21.4	
8. Start to adjust FCV-423-2 & 3 until F-406-2 & 3 indicates 110 PSID.	783544	38.5	
9. Achieved 110 PSID on F-406-2 & 3	783889	73.0	
0. Start to adjust steam temperature to 1760° R	784279	112.0	
1. Achieved 1760°R steam temperature	784736	157.7	
12. Shutdown to idle steam SG-3	785060	190.1	
3. Full steam SG-1	785098	193.9	
4. Adjust FCV-423-1 & -2 until steam temperature is 1760° R	785255	209.6	
15. Initiated ramp up on PCV-449	785735	257.6	0
6. Achieved 188 PSIA on P-905	785927	276.8	19.2
7. Shutdown to idle steam SG-2	786161	300.2	42.6
18. Shutdown to idle steam SG-1	786259	310.0	52.4
9. Initiated ramp down on PCV-449	786380	322.1	64.5
20. PCV-449 CLOSED.	786600	344.1	86.5
1. Stop SG-1	787014	385.5	
2. Stop SG-2	787035	387.6	
3. Stop SG-3	787046	388.7	
4. CLOSE FCV-31*	787530	437.1	

EVENTS	RANGE TIME			
25. CLOSE FCV-30	No Instrumentation			
26. CLOSE PCV-447**				
* FCV-31 increased from 31% (r.t. 787120) to 78% OPEN (r.t. 787160) then started to CLOSE.				
** Data Pass 2 - Not Complete				

EVENTS

RANGE TIME

EVENTS	RANGE TIME
OPEN FCV-31	800030
OPEN FCV-32 until F-56 and F-57 indicate 15.7 PSID	800250
Achieved 15.7 PSID on F-56	800800
Idle steam SG-1	801618
Idle steam SG-2	801708
Idle steam SG-3	801792
Shut off first stage SG-1	802195
Shutoff first stage SG-2	802214
Shutoff first stage SG-2	802233
CLOSE PCV-447	
Full steam SG-1	802658
Started to adjust FCV-423-1 until F-406-1 indicates 110 PSID	802871
Achieved 110 PSID on F-406-1	803000
Started to adjust FCV-423-1 until T-534 indicates 1560° R	803552
High temperature shutdown SG-1	803751
Full steam SG-2	806231
Full steam SG-3	806509

EVENTS	RANGE TIME			
Started to adjust FCV-423-2 and -3 until F-406-2 and -3 indicates 110 PSID	806808			
Achieved 110 PSID on F-406-s and -3.	807107			
OPEN PCV-447 to obtain 1b/sec.				
Initiate ramp up on PCV-446	807748			
Initiate ramp down on PCV-446 and PCV-447.	807836			
PCV-446 and PCV-447 CLOSED	807909			
Initiate ramp up on PCV-446	808041			
Achieved 30 lb/sec through PCV-446	808123			
Shutdown to idle SG-2	808366			
Shutdown to idle SG-3	809156			
Initiate ramp down on PCV-446	808712			
PCV-446 CLOSED	808838			
Stop SG-2	809134			
Stop SG-3	809156			
Initiate closure of FCV-32	809264			
FCV-32 CLOSED	809906			
FCV-31 CLOSED	810441			

SECTION 3 NEP-II-2

EVENTS	RANGE TIME			
1. Before data system was turned on, purge flow (F-426) was established (0.8 lb/sec.)				
2. Open FCV-31 to 4 psid.	062643	-246.7		
3. Idle steam SG-1	064439	- 67.1		
4. Idle steam SG-2	064521	- 58.9		
5. Idle steam SG-3	064597	- 51.3		
6. Full steam SG-1	065110	0		
7. Full steam SG-3	065306	19.6		
8. Start to adjust FCV-423-1 and -3 until F-406-1 and -3 indicates 110 PSID	065510	40.0		
9. Achieved 110 PSID on F-406-1 and -3	065714	60.4		
10. Achieved 1760°R steam temperature	066620	151.0		
11. Initiated ramp up on PCV-449	066722	161.2	0	
12. Achieved 195 PSIA on P-906	066828	171.8	10.6	
13. Initiated ramp up on PCV-472	067070	196.0	31.8	
14. Initiated ramp down on PCV-472	067144	203.4	42.2	
15. PCV-472 CLOSED	067187	207.7	46.5	
16. Initiated ramp up on PCV-446	067313	220.3	59.1	
17. Initiated ramp down on PCV-446	067360	225.0	63.8	
18. PCV-446 CLOSED	067397	228.7	67.5	

EVENTS	RANGE TIME			
19. Initiated ramp down on PCV-449	067474	236.4	75.2	
20. PCV-449 CLOSED	067587	247.7	86.5	
21. Shutdown to idle steam SG-1	068850	374.0		
22. Shutdown to idle steam SG-3	068922	381.2		
23. Stop SG-1	069134	402.4		
24. Stop SG-2	069152	404.2		
25. Stop SG-3	069163	405.3		
26. CLOSE PCV-447	069540	443.0		
27. Started to OPEN FCV-32 to achieve 15.7 PSID on F-56 and F-57	071200	609.0		
28. Achieved 15.7 PSID on F-56	071860	675.0		
29. Start to CLOSE FCV-32	072066	695.6		
30. FCV-32 CLOSED	072656	754.6		
31. CLOSE FCV-31	072900	779.0		

NEP-III

SECTION 4

EVENTS	RANGE TIME			
1. Before data system was turned on, purge flow was established at 0.5 lb/sec.				
2. OPEN FCV-31	733132	-331.2		
3. OPEN FCV-32 until F-56 and F-57 indicate 15.7 PSID	733442	-290.6		
4. Achieved 15.7 PSID on F-56	734062	-228.6		
5. Idle Steam SG-1	735477	- 87.1		
6. Idle Steam SG-2	735563	- 78.5		
7. Idle Steam SG-3	735644	- 70.4		
8. Increase TEC purge to 2.0 lb/sec.	736049	- 29.9		
9. Full Steam SG-1	736348	0		
10. Full steam SG-2	736550	20.2		
11. Started to adjust FCV-423-1 and -2 until F-406-1 and -2 indicates 120 PSID	736716	36.8		
12. Achieved 120 PSID on F-406-1 & -2	736945	59.7		
13. Shutdown to idle SG-1	738080	173.2		
14. Full steam SG-3	738118	177.0		
15. Initiate ramp up on PCV-449	739064	271.6	0	
16. Achieved 512 PSIA on P-905	739340	299.2	27.6	
17. Initiate ramp up on PCV-472	739340	299.2	27.6	
18. Reached 100% OPEN on PCV-449	739413	306.5	34.9	
19. Initiate ramp down on PCV-472	739426	307.8	36.2	
20. PCV-472 CLOSED	739484	313.6	42.0	
21. Initiate ramp down on PCV-449	739594	324.6	53.0	

EVENTS	RANGE TIME		
22. PCV-449 CLOSED	739860	351.2	79.6
23. OPEN FCV-423-2 and -3 to full OPEN	739980	363.2	
24. Reduce TEC purge to 1 lb/sec.	740030	368.2	
25. Initiate closure of FCV-32	740075	372.7	
26. FCV-32 CLOSED	740636	428.8	
27. Shutdown to idle SG-2	741216	486.8	
28. Shutdown to idle SG-3	741293	494.5	
29. Stop SG-1	741473	512.5	
30. Stop SG-2	741492	514.4	
31. Stop SG-3	741505	515.7	
32. FCV-31 CLOSED	742073	572.5	
33. TEC purge stopped (PCV-447 CLOSED)	742232	588.4	

NEP-IV
SECTION 5

EVENTS	RANGE TIME		
1. OPEN FCV-31	709225	-290.5	
2. OPEN FCV-32 until F-56 and F-57 indicate 15.7 PSID	709625	-250.5	
3. Achieved 15.7 PSID on F-57	710215	-191.5	
4. Idle steam SG-1	711183	- 94.7	
5. Idle steam SG-2	711262	- 86.8	
6. Idle steam SG-3	711347	- 78.3	
7. OPEN FCV-447 to purge flow rate of 1.5 lb/sec.	711823	- 30.7	
8. Full steam SG-2	712130	0	
9. Full steam SG-3	712384	25.4	
10. Started to adjust PCV-423-2 and -3 until F-406-2 and -3 indicates 130 PSID	712631	50.1	
11. Achieved 130 PSID on F-406-2 and -3	712848	71.8	
12. Initiate ramp up on PCV-449	714343	221.3	0
13. Initiate ramp up on PCV-472	714343	221.3	0
14. P-905 failure	714390	226.0	4.7
15. PCV-449 CLOSED	714398	226.8	5.5
16. Achieved 7 lb/sec. on P-901	714400	227	5.7
17. Switch to manual PCV-449	714407	227.7	6.4
18. PCV-449 CLOSED	714500	237	15.7
19. Started to increase TEC purge flow (F-426)	714517	238.7	17.4
20. Initiated ramp down on PCV-472	714562	243.2	21.9
21. PCV-472 CLOSED	714590	246.0	24.7
22. Achieved 37.6 lb/sec. purge flow (F-426) and started to CLOSE	714623	249.3	28.0

EVENTS	RANGE TIME			
23. Reduced TEC purge flow to 1.5 lb/sec.	714637	250.7	29.4	
24. OPEN FCV-423-2 and -3 to full OPEN	714902	277.2		
25. Initiate closure of FCV-32	715015	288.2		
26. FCV-32 CLOSED	715550	342.0		
27. Shutdown to idle SG-2	716123	399.3		
28. Shutdown to idle SG-3	716198	406.8		
29. STOP SG-1	716437	430.7		
30. STOP SG-2	716459	432.9		
31. STOP SG-3.	716479	434.9		
32. FCV-31 CLOSED	717102	497.2		
33. FCV-447 CLOSED	717410	528.0

P.O. BOX 2027, JACKSON FLATS, NEVADA-89022

MEETING NO. 1

NES/TRB

DATE: 1 February 1967

NTO-M-14110

JRD:gg

MEMBERS:

J. R. DaVolio (REON)
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R. E. Branstrom (REON)
S. McManus (SNPO-C)
D. J. McDonald (WANL) ✓
C. K. Soppet (NTO) ✓
W. D. Wayne (NTO) ✓
H. Henze (NTO) ✓

PURPOSE:

The meeting was convened at NRDS to review and discuss the NES Design Demonstration Test Program and, in particular, Phase I Series Test (i.e., NEP-III, NEP-IV and NEP-V).

MINUTES:

The following items were discussed in detail:

1. In reviewing the NES DDT Specification #201 dated November, 1966, it was felt that NEP-V (Excess Turbine Leakage Test) could possibly be deleted and the specifications be incorporated in NEP-IV. Furthermore, it was recommended that the excess turbine flow rate of 15 lbs/sec. be reduced to 8.5 lbs/sec. to more closely simulate an XE turbine over-speed condition. All the specifications of NEP-V will be met by NEP-IV.
2. Mr. W. D. Wayne, NTO, recommended that the steam generator full steam operating temperature be reduced from 1760°R to 1400°R. This reduction was requested in order to minimize apparent thermal stresses to the steam pipe pending the outcome of the steam pipe investigation.
3. NTO further recommended that the Phase II NES Tests (GH₂ Primary Flow) be preceded by a GN₂ Test to safely checkout the Engine Test Compartment.
4. The DEP portion (Water Flow Test) of the NEP Test Series will be deleted pending investigation of the flow measurement devices. It is anticipated that a Water Flow Test to checkout the final duct balance will be conducted as a separate test.

MEETING NO. 1

DATE: 1 February 1967
NTO-M-14110
JRD:gg

ACTION:

Pending the favorable outcome of NEP-III, it is expected that the proposed specification change mentioned in Item #1, above, will be submitted to the TRB for approval.

A formal TRB has convened and approved reduction of full steam temperature noted in Item #2, above, and there will be no immediate action taken on Item #3.

ENCLOSURE: (1) Change No. 1

J. R. DaVolio, AGC/REON
FTRB/NES TRB Chairman

S. McManus, TRB/SNPO-C

P. W. Davison, TRB/WANL

CHANGE AUTHORIZATION FORM

DOCUMENT NO. (Or Title as Applicable):

NES Design Demonstration Tests SORD NTO-I-0157

NES Experimental Plans CROP NTO-I-0170 (NEP-III, NEP-IV and NEP-V)

CHANGE NO.

1

REQUESTED BY:

W. D. Wayne, NTO

DATE:

31 January 1967

REQUIRED CHANGE:

1. Change NES Design Demonstration Test SORD NTO-I-0157 to specify the maximum NES duct steam line temperature of 1400°R at 50-TT-159 and 50-TT-534 for tests NEP-III, NEP-IV and NEP-V.
2. Change NEP-III, NEP-IV and NEP-V CROP NTO-I-0170 to require steam generator system (SGS) temperature control adjustment to maintain NES duct steam line temperature of $1350 \pm 50^{\circ}\text{R}$ at thermocouples 50-TT-159 and 50-TT-534.

REASON:

Changes above initiated to decrease stress conditions in NES duct steam line during NEP-III, NEP-IV and NEP-V tests. Evaluation of the steam line operating stress and configuration is in progress, and results will determine future specified operating steam temperatures.

APPROVED NTO:

BOARD APPROVAL
REQUIRED

NO

☐

YES

☒

CHAIRMAN:

J. R. DaVolio☐

TS & PRB

☒

TRB

SOURCE ENGINEERING APPROVAL REFERENCES:

P. O. BOX 2027, JACKASS FLATS, NEVADA-89023

MEETING NO. 2
NES TRBDATE: 7 February 1967
NTO-M-14112
JRD:ggMEMBERS:J. R. DaVolio (REON)
S. McManus (SNPO-C)
D. J. McDonald (WANL - Alternate)PARTICIPANTS:C. K. Soppet (NTO)
H. Henze (NTO)
R. E. Branstrom (REON)PURPOSE:

A meeting was convened at NRDS to review and discuss the NEP-IV Test.

MINUTES:

The following items were discussed:

1. It was the consensus of the members that NEP-V of Phase I DDT be deleted and the turbine leakage test be incorporated into NEP-IV at a reduced rate of 8.5 lbs/sec. as recommended in Meeting No. 1.
2. REON recommended that the two duct drain valves (GLV-2469 and GLV-2470) be closed during the NEP-IV Test. This action will eliminate the necessity of requiring personnel to enter the duct vault during countdown.
3. REON recommended that since NEP-V will be deleted, the sudden stoppage of primary flow with one generator operating (instead of two generators as in NEP-IV) be deferred to Phase II.
4. REON recommended that the idle generator module be placed on standby to duplicate actual operation.

ACTION:

f1.c

In reviewing the data of NEP-III, all of the objectives were met (except the operation of the propane flow system) and therefore Items 1, 2, 3 and 4 are approved as shown in Enclosure (1).

MEETING NO. 2
NES TRB

DATE: 7 February 1967
NTO-M-14112
JRD:gg

ENCLOSURE: (1) Change No. 2

J. R. DaVolio, REON
FTRB/NES TRB Chairman

S. McManus, TRB/SNPO-C

for P. W. Davison, TRB/WAIL

CHANGE AUTHORIZATION FORM

DOCUMENT NO. (Or Title as Applicable):
NES Design Demonstration Tests SORD NTO-IO157
NES Experimental Plans CROP NTO-I-0199 (NEP-IV)

CHANGE NO.

2

REQUESTED BY:

J. R. DaVolio, REON

DATE:

2 February 1967

REQUIRED CHANGE:

1. The requirement for conduct of Test NEP-V is deleted.
2. The NEP-IV conditions will be modified so that during simulated excess leakage flow of 30 lbs/sec GN_2 , the turbine exhaust flow will be momentarily increased from 7.0 lbs/sec. to 8.5 lbs/sec. GH_2 to simulate an excess XE engine turbine exhaust flow rate.
3. Duct drain valves (GLV-2469 and GLV-2470) are to be kept closed thru the NEP-IV Test.
4. The third SGS module shall be placed on standby after two modules are brought to full steam.

REASON:

Changes 1 & 2 accomplish a time saving in the ETS-1 testing schedule. By combining the excess leakage requirement into NEP-IV Test conditions, all test objectives of NEP-V will then be accomplished by NEP-IV with the exception of sudden termination of primary flow during single generator operation. Since it is presently intended to add a GN_2 Test prior to Phase II, this objective can be satisfied on that test.

Change 3 - Minimize access required to duct vault.

Change 4 - More nearly duplicate the expected mode of operation during future XE Testing.

APPROVED NTO:

C. K. Soppet
Manager - ETO

BOARD APPROVAL
REQUIRED

NO

YES

CHAIRMAN:

J. R. DaVolio

TS & PRB

TRB

SOURCE ENGINEERING APPROVAL REFERENCES:

P. O. BOX 2027, JACKASS FLATS, NEVADA-89023

MEETING NO. 3
NES TRBDATE: 8 February 1967
NTO-M-14113
JRD:ggMEMBERS:

J. R. DaVolio (RECN)
S. McManus (SNPO-C)
D. J. McDonald (WANL - Alternate)

PARTICIPANTS:

W. D. Stinnett (RECN)
W. H. Robbins (SNPO-C)
(i.e. Telecon 2/8/67)

PURPOSE:

A meeting of the NES TRB was held at 0945 on 8 February 1967 to review results of NEP-IV, conducted the previous evening, and to determine the need for additional testing during Phase I of the NES Design Demonstration Test Program.

MINUTES:

1. During the ramp-up to rated engine nozzle chamber pressure the test was aborted when PT-905 (nozzle chamber pressure) failed, causing a full-scale pressure indication which, via feedback circuitry, caused PCV-449 to close at its maximum rate. At the time of the failure, main nozzle chamber pressure had reached approximately 440 psig and turbine flow was approximately 7 lbs/sec. Simulated seal leakage flow was at its nominal value of 1.5 lbs/sec. Testing was terminated because PT-905 could not be repaired or replaced within a reasonable period of time. Also, the available water supply had reached its minimum permissible value.
2. A review of the test results indicates that the following test objectives were met.
 - a. The ability of the FS-5002 flare system at the duct mouth to ignite a GH_2 /steam exhaust flow mixture was partially demonstrated (one flare failed after the run).
 - b. An adequate demonstration of system performance during rapid shutdown conditions (simulating a malfunction) was achieved.
 - c. Approximately 80% of the fast startup ramp of the primary nozzle was obtained.

However, the primary test objective was not achieved. This objective was the acquisition of system performance data during full-chamber pressure conditions, maximum seal leakage, and maximum turbine flow.

3. Discussions with REON indicate a desire to study the interaction of the main exhaust and the turbine exhausts, with the latter at maximum pressure. This can be done conservatively, with the main nozzle chamber pressure at any value greater than 30 psi above the pull-in value.

ACTIONS:

1. After discussion with the appropriate home office personnel (REON - Stinnett; SNPO-C - Robbins; WANL - Davison), it was decided that any information still required could be obtained during Phase II of the NES DDT and that Phase I of this program may be terminated.
2. REON (DaVolio/Patmor) will review the available Phase I Test results to determine what knowledge can be gained from them regarding the interactions between the main exhaust and the turbine exhausts and will specify, in detail, the associated testing to be conducted during Phase II of the NES DDT.
3. NTO will perform indicated test stand work, particularly:
 - a. Improvement of FS-5002 performance.
 - b. Inspection of main steam line inside the duct vault.
 - c. Investigation of PT-905 failure with view to ascertaining likelihood of similar failures during future testing.

J. R. DaVolio, REON
FTRB/NES TRB Chairman

S. McManus, TRB/SNPO-C

P. W. Davison, TRB/WANL

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