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Engineering Design Sheet
DESIGN AND TEST REQUIREMENTS

for

NASS EXHAUST DUCT SYSTEM

Forming a Part of
CEI Number 090221A

JANUARY 1970

MASTER

NUCLEAR ROCKET OPERATIONS

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Basic Approved By:

W. D. Wayne
W. D. Wayne, Manager
Engine Test Operations
Nuclear Rocket Operations

Basic Approved By:

B. J. Billings
B. J. Billings, Director
Facility Engineering Office
SNPO-Nevada Extension
Jackass Flats, Nevada

Date

7 Jan 70

Date

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J. H. Yetto
J. H. Yetto, Supervisor
NRO Specifications and Standards
Sacramento

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Section 1. SCOPE

This document defines the design requirements for the Exhaust Duct System (EDS) of the NERVA Altitude Simulation System (NASS) as installed in Engine Test Stand -1 (ETS-1) at the Nuclear Rocket Development Station (NRDS), Jackass Flats, Nevada. The relationship of this document to the ETS-1 Modification Program for the NERVA engine is described in F007-CP090219-EA, "ETS-1 Design Criteria".

Section 2. APPLICABLE DOCUMENTS

2.1 Government Documents.- The following documents, of the exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced herein and other detail content of Sections 3 and 4 the detail requirements of Section 3 and 4 shall be considered a superseding requirement.

SPECIFICATIONS

Military

MIL-E-6051D	7 Sept 1967	Electromagnetic Capability Requirements Systems

National Aeronautics and Space Administration

NHB-1700.1(VI)	July 1969	NASA Safety Manual

Space Nuclear Propulsion Office

SNPO-C-1	19 Dec 1968	Structural Design Requirements
SNPO-C-4 Revision 1	Sept 1969	Quality Assurance Requirements for Facility and Ground Support Equipment

STANDARDS

Military

MIL-STD-100A	1 Oct 1967	Engineering Drawing Practices
MIL-STD-130C	29 Sept 1967	Identification Marking of U.S. Military Property
MIL-STD-143A	14 May 1963	Specifications and Standards, Order of Precedence
MIL-STD-171B	16 Mar 1965	Finishing of Metal and Wood Surfaces
MIL-STD-1246A	18 Aug 1967	Product Cleanliness Levels and Contamination Control Program
MS-33586A	16 Dec 1958	Metals, Definition of Dissimilar

2.2 Other Publications.- The following documents, of the exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced herein and other detailed content of Sections 3 and 4 the detail requirements of Sections 3 and 4 shall be considered a superseding requirement.

American Welding Society

AWS A2.0-68	Standard Welding Symbols
AWS A2.2-58	Nondestructive Testing Symbols
AWS A3.0-61	AWS Definitions, Welding and Cutting

American Society of Mechanical Engineers

ASME Boiler and Pressure Vessel Code

Section III 1968 & Summer Addenda 1968	Nuclear Vessels
Section VIII 1968	Pressure Vessels
Section IX 1968 & Summer Addenda 1968	Welder Qualifications

Other

"Shock and Vibration Handbook" by Harris and Crede, Volume III, (McGraw-Hill 1961)

"Stresses in Skin Panels Subjected to Random Acoustic Loading" by Brian L. Clarkson, Institute of Sound and Vibration Research, University of South Hampton, dated June 1967

Blume, John A. and Associates, Engineers, "Seismic Design Manual for The Lateral Force Design of Mechanical Equipment for the Nuclear Rocket Development Station," January 1967

"Wind Forces and Structures," ASCE Paper No. 3269, Transactions of The American Society of Chemical Engineers, Vol. 126, 1961

"The CSI Format for Construction Specifications," The Construction Specifications Institute, 1964

National Electric Code

2.3 Aerojet-General Corporation Documents.- The following documents, of the exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced herein and other detailed content of Sections 3 and 4, the detailed requirements of Sections 3 and 4 shall be considered a superseding requirements.

STANDARDS

AGC-STD-9012   26 May 1967   Wiring, Routing and Termination of

PUBLICATIONS

NTU-A-0022, VI-3	18 June 1965	Pressure Equipment and Systems
NTU-A-0022, VI-9	4 Aug 1967	Electrical Design and Installation Guide Applicable to Fire/Explosion Hazard Locations
NTU-SUP-0047	14 Dec 1965	Compatible Lubricants, Sealants, Gaskets, Cleaning Fluids and Materials at ETS-1
RN-S-0504	(Not Released)	NASS-Scale Model Test Report

(Copies of above documents required by suppliers in connection with specific procurement functions should be obtained from the procuring activity)

Section 3. REQUIREMENTS

3.1 Performance3.1.1 Functional Characteristics.-

3.1.1.1 Primary Performance Characteristics.- The EDS, installed in the ETS-1, shall be capable of achieving the following performance:

(a) Permit the NERVA engine nozzle to flow full for engine chamber pressure above 270 psia without using the secondary ejector steam supply system.

(b) Permit the NERVA engine nozzle to flow full for an engine chamber pressure of 200 to 270 psia using the secondary steam ejector with dry saturated steam supplied at the following conditions:

(1) Pressure, psia	100
(2) Flow Rate, lb/sec	TBD

(c) Safely dispose of the engine exhaust gas during engine testing operation.

(d) Provide safe conditions under engine standby test conditions using N_2 purge or the secondary ejector with steam available at (TBD) lb/sec, (TBD) psia, and (TBD) °R.

(e) Provide capability for safe operation during pulse cooldown testing of the engine using a supplementary secondary ejector with steam available at (TBD) lb/sec, (TBD) psia, and (TBD) °R.

(f) Provide safe operation under malfunction shutdown of the engine utilizing the existing ETC helium Safety Purge System.

(g) The EDS shall be capable of operation at the NERVA engine operating conditions listed in Table I. The EDS shall also be capable of operation at an engine chamber temperature of 5000°R at a reduced cyclic life.

3.1.2 Operability.-

3.1.2.1 Reliability.- The reliability of the EDS shall be such that no single failure will prevent startup, operation or shutdown of an engine test. The design of the system, subsystem, components and parts shall inherently eliminate all potential failure including:

(a) Structural failures which would affect the conductance of hot hydrogen gas away from the test stand or result in unsatisfactory hydrogen concentrations in the ETC or duct vault. No structural failure shall prevent satisfactory flow of coolant water from the primary ejector.

(b) Component malfunction or failure which would detrimentally affect secondary ejector pumping, hot gas stream cooling or primary ejector cooling.

3.1.2.2 Maintainability.-

3.1.2.2.1 Maintenance and Repair Cycles.- All portions of the EDS located inside the duct vault will not be maintainable for the useful life of the EDS after the initial NERVA engine test(s) due to resultant high nuclear radiation levels. The maintenance cycles required for maintaining system integrity throughout its useful life for those maintainable portions located outside the duct vault shall be specified. All routine maintenance and repair activity shall be compatible with the NASS three day turnaround time. Those parts considered necessary to have as spares at NRDS for replacement purposes shall be identified in a spare parts list.

3.1.2.2.2 Service and Access.- The EDS shall be designed so that all service maintenance can be performed at the organizational level at NRDS. All maintainable portions of the EDS shall be designed for easy access and for decontamination of particulate matter.

3.1.2.3 Useful Life.- The EDS shall meet the reliability requirements of paragraph 3.1.2.1 for an equivalent of a minimum of 1000 full-power NERVA engine test firings (cycles) when operated within the operation design values shown in Table I. It shall be a design goal to achieve up to 2000 full power cycles. A reduction in cyclic life is acceptable if the EDS is operated when the engine chamber temperature is 5000°K.

3.1.2.4 Environmental.- The EDS shall be capable of withstanding the environments listed in Table II throughout its useful life.

3.1.2.4.1 Wind.- All aboveground structures shall be designed to resist wind forces as prescribed in ASCE Paper No. 3269, "Wind Forces on Structures," using a 50 year basic wind velocity of 80 mph.

3.1.2.4.2 Seismic Loads.- The design of equipment and equipment supports shall be in accordance with the John A. Blume design manual. Items of equipment and other structures not within the scope of the John A. Blume design

manual shall be designed using current structural dynamic techniques. Mode shapes and periods shall be determined for as many modes as are required to adequately determine the total response of the structure. A minimum of 10 natural modes or all frequencies under 4 times the frequency of the fundamental mode shall be determined. The effects of modes having periods of vibration less than 0.05 second shall be neglected. In addition, a dynamic analysis shall be performed for all structures and equipment that are in resonance with the basic ground motion or with adjacent structures. This response spectra is shown in Figure 1a and the ground motion time history is shown in Figure 1b.

3.1.2.5 Transportability.- The transportability of each component to ETS-1 for assembly and installation shall be a design constraint.

3.1.2.6 Human Performance.- All personnel activities during EDS operation shall be capable of being performed from the ETS-1 control room.

3.1.2.7 Safety.- To the maximum practical extent, the EDS shall be designed so that no single failure or credible combination of errors, malfunctions or accidents can cause personnel injury, and/or facility destruction, facility damage, test article or test data loss, in that order of priority. (i.e. Category III or IV hazard conditions as defined in 3.1.2.7.2 shall be precluded from designs to the maximum practical extent.)

3.1.2.7.1 Order of Preference.- Actions for satisfying the above criteria shall be in the following order of preference.

(a) Design for Minimum Hazard.- Maximum practical effort shall be made during all phases of design to ensure the optimum degree of inherent safety through the selection of appropriate design features and qualified components.

(b) Safety Devices. - Known hazards which cannot be eliminated by design selection shall be reduced where possible to an acceptable minimum through use of appropriate safety devices as part of the system, subsystem, or equipment.

(c) Warning Devices. - For those instances where it becomes impossible to preclude occurrence of a known hazardous condition, appropriate devices shall be employed for detection of the condition and generation of an adequate warning signal.

(d) Special Emergency Procedures. - For those instances where design consideration or use of safety and warning devices fail to reduce the magnitude of a known or potential hazard to an acceptable level, special emergency procedures shall be developed. These procedures shall include identification of the hazardous period time span, actions required if such hazards occur, and, where applicable, special operating procedures to reduce possibility of occurrence.

3.1.2.7.2 Hazards Categories. - Hazardous conditions shall be categorized in accordance with the following criteria:

(a) Category I - Negligible. Condition(s) such that personnel error, environment, design characteristics, procedural deficiencies, or subsystem or component malfunction will not result in damage or personnel injury.

(b) Category II - Marginal. Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem or component malfunction which can be counteracted or controlled without major damage or any injury to personnel.

(c) Category III - Critical. Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem, or component malfunction will cause major equipment damage or personnel injury, or will result in a hazard requiring immediate corrective action for personnel or system survival.

(d) Category IV - Catastrophic. Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem or component malfunction will severely degrade system performance and cause subsequent system loss, or death or severe injuries to personnel.

3.1.2.7.3 Safety Standards. - The design of the EDS shall comply with NTU-A-0022, Sections VI-3 and VI-9 and NHB-1700.1 (VI).

3.2 CEI Definition. -

3.2.1 Interface Requirements. -

3.2.1.1 Schematic Arrangement. - Schematic arrangement of the EDS shall be as shown in Figure 2.

3.2.1.2 Detailed Interface Definition. - The EDS shall conform to the dimensional requirements of Figure 2 and be compatible with the existing ETS-1 facility as shown in Figure 3. When installed, the EDS shall be capable of being remotely removed from the facility. Integrity of the EDS need not be maintained during removal. Location and details of the existing remote operated trunnions are shown in Figures 3 and 4 and shall be used where possible. The EDS/facility interfaces shall be equipped with remote type clamps similar to those used on the existing duct, Figure 5. The EDS design shall define interfaces to the duct vault, water source, steam line, bottom shield, instrumentation and controls and electrical source. The EDS design shall define fasteners, couplings, and seals at the interfaces--except at the vault trunnions for which only the duct portion shall be defined. The primary ejector inlet section shall fit within the inside diameter and seal with the existing bottom shield, Figures 6 and 7. The duct inlet diameter shall be compatible with the engine nozzle size and engine gimbal constraint as indicated in Figure 6.

3.2.2 Component Identification.- The EDS consists of the following components:

- (a) Primary Ejector Collar*
- (b) Primary Ejector
- (c) Turning Plenum
- (d) Water Injection Subsystem
- (e) Plenum Drain Line
- (f) Secondary Steam Ejector
- (g) Supplementary Secondary Steam Ejector*
- (h) Diagnostic and Operational Instrumentation and Controls
- (i) Associated Piping, Structural Members, Supports and Duct-to-Bottom Shield Seal System and Bellows

*Not included in EDS Design Task

3.2.2.1 Government Furnished Property List.- All test support systems; instrumentation and controls, structures, building, utilities, and site preparation as described in the interim ETS-1 baseline drawings and used by the existing duct system will be available for use.

3.2.2.1.1 Water System.- The existing ETS-1 gravity supply process water system is schematically shown in Figure 8. The nominal operating water pressure is 200 psig with a maximum static pressure of 240 psig at test stand pad level, elevation 3810 ft. At 40,000 gpm flow rate, a minimum pressure of 175 psig will be available at pad level. The typical untreated quality of the water available at the test site is indicated in Table III. Any required treatment of the water shall be specified in the design, and shall be consistent with the turn-around time specified in 3.1.2.2.1. A maximum flow of 30,000 gpm will be available for EDS use.

3.2.2.1.2 Electrical Power System.- A 28-VDC system will be available at ETS-1 for all binary valves as well as for certain critical instrumentation and control circuits.

3.2.2.1.3 Nitrogen Gas.- Nitrogen gas for inerting and purging is available at a flow rate of approximately 2 lb/sec and a pressure of 100 psig.

3.2.2.1.4 Installation Vehicle.- The existing engine installation vehicle will be used for collar installation and removal if remote transportability is required.

3.2.2.1.5 Instrumentation and Control Channels.- The I&C channels shown in Table IV are available for use as required, for signal conditioning and amplification.

3.2.2.2 Engineering Critical Components List.- Not applicable.

3.2.2.3 Logistics Critical Components List.- Not applicable.

3.3 Design and Construction.-

3.3.1 General Design Features.- The configuration of the EDS is shown in Figure 2. The components are listed in 3.2.2. The temperature profile of the exhaust gas through the primary ejector and turning plenum as well as the predicted heat flux data shall be obtained from the scale model test program conducted by Aerojet-General Corporation and reported in AGC Report RN-S-0504.

3.3.1.1 Structural Criteria.- Unless otherwise specified herein, the design of the EDS, including structural and dynamic analyses shall be in accordance with SNPO-C-1. In the event of conflict between documents referenced here and SNPO-C-1, the requirements of SNPO-C-1 shall be considered superseding.

3.3.1.1.1 Cyclic Life Analysis.- The cyclic life analysis, as applicable to the EDS, shall utilize methods and data conforming to (To Be Determined).

3.3.1.1.2 Vibrations.- Fatigue stress values shall be calculated for vibrations induced by pressure fluctuations, seismic or "event" shock, and acoustic environment. It shall be assumed that an earthquake or an "event" does not occur while the system is in operation. Vibrations induced by an acoustic environment shall be treated as fatigue stresses based upon a white noise level of 170 db in the range of 0 to 2000 Hz located at the duct exit. The methods given in the Shock and Vibration Handbook shall be used in establishing acoustic loads as well as current state-of-the-art literature, such as, "Stresses in Skin Panels Subjected to Random Acoustic Loading." Natural frequencies shall be determined. Analytical vibrational modeling of the system should be such that the first ten natural modes or all frequencies under four times the frequency of the fundamental mode of all components of the EDS shall be determined. Vibrations induced by a seismic or an "event" shall be calculated based on the criteria of 3.1.2.4.2. The accelerations and stresses for this seismic shall be calculated for the condition of excitation along any one of the three principle axes with no simultaneous combination of these load conditions.

3.3.1.2 Contract Drawings and Specifications.- Design drawings shall be prepared in accordance with MIL-STD-100. Weld symbols used thereon shall be in accordance with AWS A2.0. Nondestructive testing symbols used on the drawings shall be in accordance with AWS A2.2. Fabrication specifications shall be prepared in accordance with the format generated by the Construction Specifications Institute (CSI).

3.3.1.3 Component Design.-

3.3.1.3.1 Primary Ejector Collar.- The primary ejector collar shall fit on top of the primary ejector and shall not interfere with the nozzle exhaust gas stream flow pattern or create hot spots. Facility thrust structure-to-primary ejector centerline misalignment shall be zero inches nominal.

The collar/primary ejector interface shall not be above the top of the facility bottom shield, Figure 6. The collar design shall include provisions to permit the installation and removal of the collar by remote means. Collar coolant water, if required, and instrumentation connections shall be designed for remote installation and removal. Two collar lengths are required, see Figure 6.

3.3.1.3.2 Primary Ejector. - The primary ejector shall be a vertically mounted, water cooled structure consisting of a contracting supersonic diffuser, a supersonic cylindrical throat section and an expanding subsonic diffuser which exits into a turning plenum. The primary ejector shall be designed for a 20.7 maximum starting pressure ratio (ratio of engine chamber pressure to primary ejector exit pressure). The primary ejector shall fit into the existing bottom shield and have an ID of 64 inches maximum and an OD of less than 82 inches, Figure 6. The inlet cylindrical-to-convergent section transition point, relative to the engine nozzle exit, shall be as shown in Figure 6. The top of the primary ejector, including the collar interface flanges and fasteners, shall not extend above the ETC bottom shield. A nuclear-radiation water shield surrounding the primary ejector is not required to protect other facility elements. The primary ejector shall be supported by the turning plenum and restrained by the primary ejector support structure. The coolant water shall be supplied and returned through the existing 36-inch lines located in the duct vault. A remotely disconnecting seal shall be provided between the primary ejector and the bottom shield.

3.3.1.3.3 Turning Plenum. - A subsonic turning plenum shall be used to expand the exhaust gas and to turn it 90 degrees from the vertical to the horizontal direction. The walls of the turning plenum shall not be of coolant-passage type design. The plenum shall withstand internal pressures of 1.0 to 23.0 psia during engine testing.

3.3.1.3.4 Water Injection Subsystem. - The water injection subsystem shall include water injection nozzles and piping. Water injection nozzles shall be designed to inject coolant water into the gas stream at the plenum/primary ejector interface to lower the exhaust gas temperature to a level compatible with the turning plenum wall and secondary ejector designs.

3.3.1.3.5 Plenum Drain Line.- The plenum drain line shall allow complete self draining of the plenum and be designed to handle the total injection flow of water. The design shall prevent the accumulation of water in the turning plenum and the drain line.

3.3.1.3.6 Secondary Steam Ejector.- The secondary ejector, utilizing steam, shall provide auxiliary pumping to provide altitude simulation during engine operation at low chamber pressures. The internal pressure during engine testing is expected to be equivalent to that in the turning plenum. Steam at TBD lb/sec, and 100 psia, is available at the steam line/steam ejector inlet coupling. The secondary ejector shall consist of the following parts:

- (a) Steam ejector nozzle
- (b) Ejector body
- (c) Piping (on the duct side of the duct/steam line interface)
- (d) Supporting structure

The exit end of the ejector shall be provided with a mating flange for attachment of either a 45° exit elbow or for future attachment of a scrubber. The outlet of either the elbow or the scrubber shall have a closure for use during standby conditions. When a scrubber is installed it shall be structurally supported separately from the EDS.

3.3.1.3.6.1 Supplementary Secondary Ejector.- A supplementary secondary ejector shall be designed to provide a low nozzle back pressure during pulse cooldown testing. The use of this device will require a positive sealing of the secondary ejector closure. (A means of obtaining the low nozzle back-pressure may be investigated which would utilize the secondary steam ejector operating at 175 psia.)

3.3.1.3.7 Diagnostic and Operational Instrumentation and Controls.- Various diagnostic and operational parameters of the EDS will require measurement to insure safe and controlled system operation from the ETS-1 control

room. Instrumentation, pass-throughs, bosses and cabling shall be provided. Instrumentation located within the duct vault shall be radiation hardened, waterproofed and have low vibration sensitivity. Where possible, pressure transducers shall be mounted on the vault wall and plumbed from the duct boss.

3.3.1.3.8 Associated Valves, Piping, Structural Members and Supports and Duct-to-Bottom Shield Seal System and Bellows.-

All piping, flanges, and couplings to the duct/facility element interfaces shall be provided by the EDS. Interfacing facility elements shall provide a pipe stub to the interface. Duct/ETC bottom shield interface fasteners, seals and bellows; the duct portion of the vault trunnions; and the electrical and I&C cabling to the specified interfaces shall be provided by the EDS. Facility water valves and control valves are not to be provided by this effort.

3.3.2 Selection of Specifications and Standards.- The selection and use of specifications and standards required for design of the EDS shall be governed by MIL-STD-143.

3.3.3 Materials, Parts, and Processes.-

3.3.3.1 Materials.- Selection of materials shall conform to the criteria given in SNPO-C-1 for facilities and ground support equipment. Electrical materials shall conform to the National Electric Code. Lubricants, sealants, gaskets and cleaning fluids shall be in accordance with NTO-SUP-0047.

3.3.3.2 Processes.- Existing material fabrication processes such as forming, welding, heat treating, surface coating, etc. shall be evaluated for incorporation into the design and procedures prepared for utilization in the fabrication of the EDS. All welding shall conform to the requirements of the ASME Boiler and Pressure Vessel Code, Section III. Welding definitions shall conform to AWS A3.0. Welding symbols shall conform to AWS A2.0. All welders and welding procedures shall be qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX. Welders who are qualified to other standard

codes may be used subject to the approval of the Contracting Officer. Feasibility of joints and sections requiring welding of an unusual nature shall be demonstrated by suitable mock-ups prior to start of fabrication. Each component design shall delineate weld mock-up requirements on the design drawings by the use of an identifying symbol which is defined in the drawing legend. Mock-ups shall be required for any weld in either of the following categories.

- (a) Full penetration welds which cannot be adequately inspected.
- (b) Welds for which accessibility constitutes a major fabrication problem.
- (c) Welds which require unusual operator position to accomplish the weld.

3.3.3.3 Cleanliness.— System cleanliness shall conform to the following requirements:

- (a) All mating surfaces and all surfaces which are in contact with process fluids shall be assigned cleanliness levels in accordance with MIL-STD-1246.
- (b) Assigned levels shall be incorporated on applicable fabrication specifications.

3.3.3.4 Nondestructive Testing.— Nondestructive testing (NDT) requirements and standards shall be incorporated into the design. Radiographic examination shall be made in accordance with N-624 of Section III of the ASME Code. Penetrant inspection shall be performed per N-627 of Section III where required in addition to radiography and also on welds that are not inspectable by radiography. Ultrasonic inspection of welded joints, where required shall be performed per N-625 of Section III. Written procedures for NDT methods shall be required per IX-320 of Appendix IX of Section III. As NDT requirements exceeding the above become evident during the design phase, details

shall be included in the fabrication specifications. These requirements may include: NDT methods other than those listed, critical NDT inspections warranting more restrictive procedures than permitted by referenced codes or acceptance levels differing from code requirements.

3.3.4 Standard and Commercial Parts.- Commercial parts may be used only if an appropriate standard part cannot be selected as specified in 3.3.2 and if it is not economically or logistically feasible to prepare a contractor drawing or standard. Commercial parts shall be controlled by specifications or specification control drawings. Those parts requiring qualification shall be controlled by source control drawings or component specifications containing qualification requirements.

3.3.5 Moisture and Fungus Resistance.- The EDS shall be designed to resist degradation in the environments identified in Table II.

3.3.6 Corrosion of Metal Parts.- Unless protected against electrolytic corrosion, dissimilar metals shall not be used in intimate contact with each other. Dissimilar metals shall be as defined in MS33586. Finish and surface treatments shall be incorporated as necessary to protect the EDS from deterioration during exposure to the environments specified in 3.1.2.4. The selection and application of protective treatments and surface finish shall be in accordance with MIL-STD-171.

3.3.7 Interchangeability and Replaceability.- All parts having the same manufacturers part number shall be directly and completely interchangeable with respect to installation and performance.

3.3.8 Workmanship.- All workmanship for the EDS shall be of a quality consistent with the requirements of this document. Electrical workmanship shall conform to AGC-STD-9012.

3.3.9 Electromagnetic Interference.- Electromagnetic interference for the EDS shall conform to the requirements of MIL-E-6051.

3.3.10 Identification and Marking.- Identification and marking for the EDS shall conform to MIL-STD-130.

3.3.11 Storage.- Not applicable.

Section 4. QUALITY ASSURANCE PROVISIONS

This section defines the general requirements for the verification of performance and design requirements of Section 3. The performance and design requirements of Section 3 are based on the test operating conditions involving hot firings of the NERVA engine. It is not feasible to simulate the pressure, temperature and nuclear radiation conditions that would be experienced during a hot firing. The verification of the EDS shall be based primarily upon review of analytical data for functional characteristics, and inspections and tests for validity of design, fabrication and installation processes. Testing then, is aimed at collecting data under peripheral and simulated operating conditions which will permit an analytical evaluation of its readiness for engine testing. Quality Assurance requirements shall be in accordance with the requirements of SNPO-C-4.

4.1 Category I Test.- The following tests shall be conducted at the component level.

4.1.1 Formal Qualification Tests.-

4.1.1.1 Inspection.- Verification by inspection, as indicated in Table V, shall be performed by a visual and dimensional inspection of the finished article.

4.1.1.2 Analyses. - Verification by analysis, as indicated in Table V, shall be performed by a detailed review of the engineering data which includes drawings, specifications and analytical work.

4.1.1.3 Demonstrations. - Verification by demonstration, as indicated in Table V, shall be performed by a functional checkout of the operating components.

4.1.1.4 Tests. - The following tests, as noted in Table V, shall be performed at the component level:

- (a) Hydrostatic test of collar (if water cooled)
- (b) Hydrostatic test of primary ejector coolant water system
- (c) Hydroflow test of primary ejector coolant water system
- (d) Flow test of water injection system
- (e) Turning plenum leak test
- (f) Steam pipe stub and nozzle hydrotest

4.2 Category II System Test Program. - The following tests shall be conducted at the system level.

4.2.1 Inspection. - Verification by inspection, as indicated in Table V, shall be performed by a visual and dimensional inspection of the assembled and installed EDS.

4.2.2 Analyses. - Verification by analysis, as indicated in Table V, shall be performed by a detailed review of the engineering data which includes drawings, specifications and analytical work.

4.2.3 Demonstrations. - Verification by demonstration, as indicated in Table V, shall be performed by:

(a) Demonstrating that the primary ejector inlet configuration will accept and restrain the NASS collar.

(b) Demonstrating that the maintenance and repair cycle can be accomplished within the three day turnaround time.

4.2.4 Tests.- The following tests, as noted in Table V, shall be performed at the system level.

(a) Hydrostatic test of EDS coolant water system as installed in the ETS-1.

(b) Hydroflow test of EDS coolant water system as installed in the ETS-1.

(c) Leak test all remote EDS and water line remote couplings.

(d) Design demonstration tests performed with a mock-up nozzle and ambient nitrogen or oxygen.

4.2.5 Safety Analyses.- A hazards analysis of the EDS shall be conducted to provide an early comprehensive qualitative assessment of safety. Qualitative fault tree analyses shall be performed as appropriate when needed to provide a realistic assessment of system safety. Hazardous conditions shall be categorized as specified in paragraph 3.1.2.7.2.

4.2.6 Reliability Tests and Analyses.- There shall be no testing of the EDS solely for reliability demonstration. Verification of reliability of the EDS shall be accomplished by:

(a) Performance of a Failure Mode Analysis (FMA) to determine the probable modes of failure. Hazardous conditions shall be categorized as shown in 3.1.2.7. A failure shall be defined as an event which results in a Category III or IV hazard category as defined in 3.1.2.7.2.

(b) Analysis of available test data to determine reliability history.

(c) Review of fabrication, assembly and acceptance procedures to minimize probability of failure.

(d) Review of the subsystem test program and evaluation of the use of peripheral test levels if necessary to improve reliability assessment.

(e) Performance of the FMA shall be made in accordance with procedures provided by the Contracting Officer.

(f) Qualitative assessment of the reliability requirement shall be presented as part of the Final Design Review (FDR).

TABLE I
EDS OPERATIONAL DESIGN VALUES

<u>Engine Parameters</u>	<u>Design Values*</u>
Gas Temperature (Tc), °K	4,385
Thrust (F), lb	83,300
Propellant Flow Rate ($\dot{W}$), lb/sec	100
Chamber Pressure (Pc), psia	500
Test Duration (Full Power), minutes	60
Nozzle Exit I.D. (No Engine Gimballing), Inches	60
Area Ratio (With Engine Gimballing $\pm 1/2^\circ$)	24:1
Throat Area, in. ² (Nominal)	98.7
Engine Nozzle-to-Duct Inlet Gap, in. (Axial)	2 maximum

*Some values are uprated from the engine design values.

TABLE II
ENVIRONMENTS

Environment	Requirements			
	Inside Duct Vault		Outside Duct Vault	
	<u>Non-operating</u>	<u>Operating</u>	<u>Non-operating</u>	<u>Operating</u>
(a) Relative humidity, percent	0-100	0-100	0-100	0-100
(b) Temperature, °F	+ 5 to + 110	+ 70 to + 180	+ 5 to + 110	+ 5 to + 180
(c) Pressure, average, psia	12.8	12.8	12.8	12.8
(d) Atmosphere	Ambient Air	Nitrogen (less than 5.0% O ₂)	Ambient Air	Ambient Air
(e) Sand and Dust	As encountered in desert regions			
(f) Water				
(1) Rainfall, in.***	None	None	3.24	3.24
(2) Deluge	None	14.8 ft/hr*	None	2100 gpm
(g) Wind	Negligible		See 3.1.2.4.1	
(h) Seismic Loads	See 3.1.2.4.2		See 3.1.2.4.2	
(i) Radiation, Max. (full power NERVA engine run)**				
(1) Gamma flux, Rads (C)/nr		5 x 10 ⁸	Negligible	Negligible
Gamma Dose, Rads (C)		4.4 x 10 ⁸	Negligible	Negligible
(2) Fast (E > 1 Mev) neutron flux, neutrons/cm ² /sec		1 x 10 ¹³	Negligible	Negligible
Fast (E < 1 Mev) neutron fluence, neutrons/cm ²		3 x 10 ¹⁶	Negligible	Negligible
(j) Acoustic	-	-	-	170 db at 0 to 2000 hz

*Spray from engine compartment shields

**The maximum radiation levels noted above occur in the vicinity of the exhaust duct inlet. Radiation levels in other locations along the exhaust assembly will be of lower intensity depending on the distance from the reactor core.

***Average annual rainfall.

Radiation levels will exist after the first firing in the non-operating mode but will not contribute significantly to the integrated dose.

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TABLE III
TYPICAL NRDS WATER ANALYSIS

pH at Ambient Temperature

7.45 at 77°F

8.32 at 70°F

8.40 at 60°F

Conductivity

287 micro mho/cm

Chemical Analysis

Cations:	(ppm)
Calcium	13
Magnesium	1.7
Sodium	43
Potassium	4.2

Anions:	
Bicarbonate	120
Sulfate	16
Chloride	8
Fluoride	2.3
Nitrate	10

Carbon Dioxide	7
Hardness (as calcium carbonate)	40
Iron	0.01
Manganese	0.00
Silica (colorimetric test)	40
Boron	0.17
Total Dissolved Minerals by addition: (HCO_3 CO_3)	198

TABLE IV
EXISTING EDS INSTRUMENTATION AND CONTROL CHANNELS
(Radiation Hardened Equipment)

<u>Measurement</u>	<u>Channels</u>	<u>Wires per Channel</u>
Differential Pressure	15	6
Pressure	14	6
Strain	30	6
Vibration	24	6
Temperature (Probe)	26	3
Temperature (Surface)	4	3
Position	7	2
Controls	None	None

TABLE V

VERIFICATION/REQUIREMENT CROSS REFERENCE INDEX

Verification Method Legend:

N/A Not Applicable   2. Inspection
1. Analysis   3. Demonstration
4. Test

SECTION 3 REQUIREMENT		METHOD OF VERIFICATION					SECTION 4 REFERENCE PARAGRAPH	
REFERENCE PARAGRAPH	DESCRIPTION	N/A	1	2	3	4		
3.1	Performance	X						
3.1.1	Functional Characteristics	X						
3.1.1.1	Primary Performance Characteristics			X		X	4.2.2	4.2.4
(a)				X		X	4.2.2	4.2.4
(b)				X		X	4.2.2	4.2.4
(c)				X		X	4.2.2	4.2.4
(d)				X		X	4.2.2	4.2.4
(e)				X		X	4.2.2	4.2.4
(f)				X		X	4.2.2	4.2.4
(g)				X			4.2.2	
3.1.2	Operability	X						
3.1.2.1	Reliability			X			4.2.6	
3.1.2.2	Maintainability	X						
3.1.2.2.1	Maintenance and Repair Cycles			X	X		4.2.2	4.2.3(b)
3.1.2.2.2	Service and Access			X	X		4.2.2	
3.1.2.3	Useful Life			X			4.2.2	
Table II (a)	Humidity			X			4.1.1.2	
Table II (b)	Temperature			X			4.1.1.2	

TABLE V (Cont.)

SECTION 3 REQUIREMENT		METHOD OF VERIFICATION					SECTION 4 REFERENCE PARAGRAPH
REFERENCE PARAGRAPH	DESCRIPTION	N/A	1	2	3	4	
Table II (c)	Pressure			X			4.1.1.2
Table II (d)	Atmosphere			X			4.1.1.2
Table II (e)	Sand and Dust			X			4.1.1.2
Table II (f)	Water			X			4.1.1.2
Table II (g)	Wind			X			4.1.1.2
Table II (h)	Seismic Loads			X			4.1.1.2
Table II (i)	Radiation			X			4.1.1.2
Table II (j)	Acoustic			X			4.1.1.2
3.1.2.4.1	Wind			X			4.2.2
3.1.2.4.2	Seismic Loads			X			4.2.2
3.1.2.5	Transportability			X			4.1.1.2, 4.2.2
3.1.2.6	Human Performance			X	X		4.1.1.2, 4.2.3 (b)
3.1.2.7	Safety			X			4.2.5
3.1.2.7.1	Order of Preference	X		X			4.1.1.2, 4.2.2
3.1.2.7.1(a)	Design for Minimum Hazard			X			4.1.1.2, 4.2.2
3.1.2.7.1(b)	Safety Devices			X	X		4.1.1.2, 4.2.2, 4.2.4
3.1.2.7.1(c)	Warning Devices			X	X		4.1.1.2, 4.2.2, 4.2.4
3.1.2.7.1(d)	Emergency Procedures			X			4.1.1.2, 4.2.2
3.1.2.7.2	Hazards Categories	X					
3.1.2.7.3	Safety Standards			X			4.1.1.2
3.2	CEI Definition	X					
3.2.1	Interface Requirements	X					

TABLE V (Cont.)

SECTION 3 REQUIREMENT		METHOD OF VERIFICATION					SECTION 4 REFERENCE PARAGRAPH
REFERENCE PARAGRAPH	DESCRIPTION	N/A	1	2	3	4	
3.2.1.1	Schematic Arrangement	X					
3.2.1.2	Detailed Interface Definition		X				4.1.1.1, 4.2.1
3.2.2	Component Identification	X					
3.2.2.1	Government Furnished Property List	X					
3.2.2.1.1	Water System			X			4.1.1.2, 4.2.2
3.2.2.1.2	Electrical Power System	X					
3.2.2.1.3	Nitrogen Gas	X					
3.2.2.1.4	Installation Vehicle	X					
3.2.2.1.5	Instrumentation and Control Channels	X					
3.2.2.2	Engineering Critical Components List	X					
3.2.2.3	Logistics Critical Components List	X					
3.3	Design and Construction	X					
3.3.1	General Design Features			X			4.1.1.2
3.3.1.1 & Subpar.	Structural Criteria			X			4.1.1.1.4, 4.2.1.1
3.3.1.2	Contract Drawings and Specifications			X			4.1.1.2, 4.2.2
3.3.1.3	Component Design	X					
3.3.1.3.1	Primary Ejector Collar		X	X	X	X	4.1.1.1, 4.1.1.2 4.1.1.4(a), 4.2.3(a), 4.2.2
3.3.1.3.2	Primary Ejector		X	X		X	4.1.1.1, 4.1.1.2 4.1.1.4(b)&(c), 4.2.4
3.3.1.3.3	Turning Plenum		X	X		X	4.1.1.1, 4.1.1.2, 4.1.1.4(e), 4.2.4
3.3.1.3.4	Water Injection Subsystem		X	X	X	X	4.1.1.1, 4.1.1.2, 4.1.1.4(d), 4.2.4
3.3.1.3.5	Plenum Drain Line		X	X		X	4.1.1.1, 4.1.1.2, 4.2.4
3.3.1.3.6	Secondary Steam Ejector		X	X		X	4.1.1.1, 4.1.1.2, 4.1.1.4(f)

TABLE V (Cont.)

SECTION 3 REQUIREMENT		METHOD OF VERIFICATION					SECTION 4 REFERENCE PARAGRAPH
REFERENCE PARAGRAPH	DESCRIPTION	N/A	1	2	3	4	
3.3.1.3.6.1	Supplementary Secondary Ejector		X	X		X	4.1.1.1, 4.1.1.2, 4.1.1.4(f)
3.3.1.3.7	Diagnostic and Operational Instrumentation & Controls		X	X			4.1.1.1, 4.1.1.2
3.3.1.3.8	Associated Valves, Piping, Structural Members & Supports		X	X			4.1.1.1, 4.1.1.2
3.3.2	Selection of Specifications and Standards			X			4.1.1.1
3.3.3	Materials, Parts and Processes	X					
3.3.3.1	Materials		X				4.1.1.1
3.3.3.2	Processes		X				4.1.1.1
3.3.3.3	Cleanliness		X				4.1.1.1, 4.2.1
3.3.3.4	Nondestructive		X				4.1.1.1
3.3.4	Standard and Commercial Parts		X				4.1.1.1
3.3.5	Moisture and Fungus Resistance			X			4.1.1.2
3.3.6	Corrosion of Metal Parts			X			4.1.1.2
3.3.7	Interchangeability and Replaceability		X	X			4.1.1.1, 4.1.1.2
3.3.8	Workmanship		X				4.1.1.1, 4.2.1
3.3.9	Electromagnetic Interference		X				4.2.1
3.3.10	Identification and Marking		X				4.1.1.1, 4.2.1
3.3.11	Storage	X					

SINGLE DEGREE OF FREEDOM PEAK RESPONSE VS NATURAL PERIOD FOR 2% DAMPING

Figure 1a

For initial Design use

* USE HIGHER VALUE FROM EACH CURVE FOR DESIGN

For Detailed Dynamic Analysis

DESIGN CRITERIA GROUND VELOCITY VS TIME HISTORY

Figure 1b

31 Rev. A

NASS Duct Configuration Control

Figure 2

32 Rev. A

Currently being updated - for information only

Figure 3

Figure 3 Continued
34 Rev. A

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Figure 1
35 Rev. A

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Figure 5
36 REV. A

NOTE: DIMENSIONS ARE CURRENTLY BEING UPDATED -
FOR INFORMATION ONLY

NERVA ENGINE/EXHAUST DUCT SEGMENT/ETS-1 BOTTOM SHIELD INTERFACE DEFINITION

Figure 6

37 Rev. A