TID/SNA--274

F004-CP090290-F1

ENGINE TEST STAND NO. 1 (ETS-1) FACILITY REQUIREMENTS DOCUMENT

NERVA Program, Contract SNP-1

February 1971

DISCLAIMER

F004-CP090290-F1

ENGINE TEST STAND NO. 1 (ETS-1)
FACILITY REQUIREMENTS DOCUMENT

NERVA Program

Contract SNP-1

February 1971

Classification Category
UNCLASSIFIED

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F004-

TITLE: ENGINE TEST STAND-1 FACILITY REQUIREMENTS

RELEASE AND CHANGE CONTROL RECORD

Release	Date	Replace Page Numbers	Page Additions

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Space Nuclear Propulsion Office - Cleveland

CONTENTS

CONTENTS (cont.)

CONTENTS (cont.)

CONTENTS (cont.)

TABLES

FIGURES

1.0 INTRODUCTION

1.1 SCOPE

This document has been prepared to present the basic facility requirements necessary to support the NERVA program for the development and qualification engine test program at Engine Test Stand Number One (ETS-1), Nuclear Rocket Development Station (NRDS), Jackass Flats, Nevada.

A reference engine has been established with sufficient definition to prepare facility requirements for design, procurement, scheduling, and budgetary purposes since facility considerations primarily involve the test article envelope and interfaces.

All changes to this document require SNPO-C approval and will be accomplished in accordance with NERVA Configuration Management Plan C-018.

1.2 OBJECTIVE

The objective of this document is: (1) to identify the requirements for the development of the ETS-1 Trade Studies and Concepts and the Facility Design Criteria; (2) to describe a facility capable of testing the NERVA engine described in Section 2.0 of this document; and (3) to accomplish the test program and operations objectives specified in Section 3.0 of this document.

It is intended that this document may be used for the initiation of design and procurement of long-lead items.

1.3 FACILITY PROGRAM PLAN

The evaluation of the NERVA engine will progress through two stages of maturity (i.e., development hardware, and prequalification and qualification hardware). This in turn will allow ETS-1 to be modified in two phases from its present capabilities to its ultimate required capabilities. The assignment of test objectives to test articles is discussed in Section 3.

1.3.1 Facility Phasing - The improvement in ETS-1 capabilities shall be completed in two phases (Phase A and Phase B) and shall be coupled with test articles DE-1 and DE-2.

1.3.1.1 Phase A Requirements - Phase A modifications of ETS-1 shall be completed and activated to support the DE-1 test program. The basic facility capabilities shall allow for test durations of up to 15 min at full power, significant pulse cooldown simulation, 30 min of SGDS operation at full design flow, the addition of the NERVA Effluent Scrubber System downstream of NASS, and 15-day turnaround between experimental plans insofar as constrained by data analysis and test fluid replenishment. Phase A facility requirements shall be provided as shown in the ETS-1 and E/STS-2 Facility Logic Chart.

1.3.1.2 Phase B Requirements - Phase B modifications of ETS-1 shall be completed and activated to support the DE-2 and all subsequent engine test programs. The total requirements of this document constitute the capabilities of ETS-1 following the Phase B modifications. Phase B modifications will reduce the turnaround time between tests to 2 to 3 days (as defined by Paragraph 3.3.1) and increase the full-power test duration to 60 min. Phase B facility requirements shall be provided as shown in the ETS-1 and E/STS-2 Facility Logic Chart.

1.3.2 Relationship to Other Facilities - ETS-1 will share fluid storage, transfer, and replenishment systems; I&C systems; data processing systems; and control point systems with E/STS-2. In addition, the ETS-1 and E/STS-2 complex will share the automatic data processing (ADP) systems with other NRDS facilities and possibly with other NERVA facilities located at other than NRDS. As a result, the cost of modifing ETS-1 to achieve the ultimate capabilities shall be shared by E/STS-2. The ADP system required to support ETS-1 and other NRDS facilities shall be provided in accordance with the NERVA ADP program plan.

1.3.2.1 E/STS-2 - Since ETS-1 capabilities will in part be provided by E/STS-2 and E/STS-2 construction and activation must be accomplished in parallel with ETS-1 modification, activation, and operation, it is mandatory that an integrated logic be utilized to interface ETS-1 and E/STS-2 activities.

1.3.2.2 Central Data Processing Facility - ETS-1 automatic data processing requirements stated herein shall be utilized to size and design the ADP facilities required to support the NERVA program. The central data processing facility must be available to support the ETS-1 ADP checkout and operations.

1.4 MAJOR ASSUMPTIONS

The following is a list of major assumptions used in the preparation of this document. Any modification to this list may have a major impact on the facility requirements.

1.4.1 Fluids logistics. (All fluids are available as required.)

1.4.2 The maximum envelope dimensions of the test article shall be used for facility design criteria.

1.4.3 The engine lifetime is a minimum of 10 hr at rated conditions, utilizable in multiple cycles (up to 60) of varying lengths totaling a minimum of 600 min.

1.4.4 The nozzle expansion ratio will be 28.65:1.

1.4.5 All portions of ETS-1 shared with E/STS-2 shall be capable of being returned to ETS-1 operational use within 48 hr.

1.4.6 ETS-1 shall have the ability to support two tests in a given week on an intermittant basis to allow an average of one test per week. The reliability of the fluid replenishment system and the data processing equipment for accomplishing the 2 to 3 day turnaround can be less than 100%. The 2-day turnaround applies to all systems except the water which is 3 days.

1.4.7 The test schedule does not allow for any weather constraints.

1.4.8 Maintainability demonstration requirements on a given engine will be before or after a test series but not during.

2.0 TEST ARTICLE DESCRIPTION

2.1 SCOPE

This section defines the test article and describes its operating characteristics to the extent necessary for the development of facility concepts and the ETS-1 Facility Design Criteria. The exact test article configuration to be tested at ETS-1 has not been fully defined; however, sufficient definition is available for the purposes of this document. Facility requirements are based primarily on the test article interface and envelope requirements. The information present is not complete, but it is the latest available and will be updated and supplemented as the design developes.

2.2 ENGINE DESCRIPTION

2.2.1 The engine to be tested is the ground test configuration of the variable thrust, turbopump-fed, full-flow cycle, nuclear powered rocket engine designed to operate at 75,000 lb thrust. The NERVA engine envelope (full flow) is presented in Figure 2-1.

2.2.2 The reference engine specification number is C002-CP090290-AF1, dated 8 September 1970, hereinafter referred to as the Engine Specification.

2.2.3 The concept depicted in the engine flow diagram, Figure 2-2, includes a dual-turbopump assembly, propellant feed system, pressure-vessel/nuclear subsystem, thrust structure, external disc shield, and a nozzle assembly with a skirt and skirt extension to give an expansion ratio of 28.65:1. A cooldown system utilizes propellant tank fluid for the cooling medium. Included in the nuclear subsystem is a structural support coolant assembly and an internal shield. A thrust vector control system provides for engine gimballing forward of the dual-turbopump assembly. For tests in ETS-1 the gimbal system shall be locked at 0° gimbal from the engine axis.

2.2.4 The engine is capable of operating without degradation after six months of pad environment.

2.2.5 The engine shall be designed to handle any unlimited flow (rate) of 600 micron or less particles throughout its operating life. The design and construction of parts, components, subsystems, and systems will satisfy the requirements of Data Item S021-CP090290-F1 (NERVA Contamination and Corrosion Control Plan). The above requirements are also applicable to self-contamination. The estimated weight to be handled is 220 gm of material with the density of aluminum.

2.2.6 The engine is designed and tested to satisfy the requirements of the latest revision of Mil-Spec MIL-E-6051, "Electromagnetic Interference."

2.2.7 All engine valves, gimbal, and control-drum actuators will be electrically powered.

2.3 FUNCTIONAL CHARACTERISTICS

The following engine characteristics are listed with the appropriate paragraph, table, or figure number from the Engine Specification* underscored.

2.3.1 Operational Modes - Para. 3.1.1.1.1

2.3.2 Vacuum Performance Rating - Para. 3.1.1.1.2

2.3.3 Operational Constraints - Para. 3.1.1.1.3 (see Figure 2-3)

*The underscored paragraph, table, and figure numbers refer to Engine Specification C002-CP090290A-F1 dated 8 September 1970. Those paragraph, table, and figure numbers not underscored are provided in this report.

2.3.4 Impulse and Controllability - Para. 3.1.1.1.5

2.3.5 Restart Requirements - Para. 3.1.1.1.6

2.3.6 Engine Communication - Para. 3.1.1.1.7

2.3.7 Propellant Conditioning - Para. 3.1.1.1.8

2.3.8 Propellant Pressurization - Para. 3.1.1.1.9

2.3.9 Thrust Vector Control - Para. 3.1.1.1.10

2.3.10 Nuclear Radiation Shielding - Para. 3.1.1.1.11

2.3.11 Malfunction Detection and Recovery - Para. 3.1.1.1.12

2.3.12 Engine Assembly, Checkout, and Acceptance Operations - Para. 3.1.1.1.13

2.3.13 Nuclear Stage Assembly and Checkout Operations - Para. 3.1.1.1.14

2.3.14 Vehicle Transfer Operations - Para. 3.1.1.1.17

2.3.15 Vehicle Checkout Operations - Para. 3.1.1.1.16

2.3.16 Trend Data System - Para. 3.1.2.1.1

2.3.17 Maintainability - Para. 3.1.2.2

2.3.18 Useful Life - Para. 3.1.2.3

2.3.19 The engine shall be capable of being remotely installed, checked, tested, and removed from the stage/test stand.

2.3.20 Engine State Points - Para. 3.2.1.3

2.4 ENGINE/FACILITY INTERFACES

2.4.1 Engine fluid requirements are as stated in Table 2-1.

2.4.2 The hydrogen delivered upstream of the PSOV must be in accordance with Para. 3.1.1.1.8 of the Engine Specification.

2.4.3 The ground test engine is provided with an interface for an emergency cooldown system, as shown on ANSC Drawing Number 1137421, Ground Test NERVA Engine ICD, reproduced as Figure 2-4 in this document.

2.4.4 All maintainability demonstrations will be performed at E-MAD except for remote installation and removal of the entire test article.

2.4.5 The structural, fluid, electrical, dimensional, and induced environment interfaces are defined in paragraph 3.2.1.2 and Figure 10 of the Engine Specification.

2.4.6 Fluids procured for use as propellant, purge, or coolant shall conform to the following specifications.

A. Liquid hydrogen - MSFC-Spec-356
B. Gaseous nitrogen - MSFC-Spec-234
C. Gaseous helium - MSFC-Spec-364

2.4.7 The engine system, while operating at rated conditions will produce the radiation field described in Tables X and XI of the Engine Specification. Figures 2-5, -6, -7, and -8 are specification extreme isokerma maps. These data represent specification extreme values without the self-shielding and scattering perturbations introduced by the components. The gamma plots include an estimate of component secondary gamma production.

2.5 NERVA ENGINE I&C SYSTEM

The NERVA I&C subsystem is composed of the necessary electrical power source (EPS), power distribution equipment, transducers, and NERVA Digital Instrumentation and Controls Electronics; i.e., multiplexers, signal conditioning, harness, etc., to accomplish on-board measurement, real-time computation, diagnostic analysis, and control of the NERVA engine. The system will also transmit to and receive control information and command signals from the ground test control system (GTCS). The I&C subsystem requirements are delineated in AGC Specification EC 90214.

2.5.1 The first engine I&C subsystem will be a breadboard design for functional operation. The flight configuration will be an evolutionary system based on the ground test design.

2.5.2 The facility will interface electrically and mechanically with the engine I&C system. Initially some parts of the system shall be located in the test cell building. As the design matures into a flight configuration, the system will be moved to a location "on board" the run tank or engine.

2.5.3 The I&C subsystem will contain a power conditioning system capable of operating all flight instrumentation and controls functions. The facility shall provide 120/208v, 3-phase, 4-wire, 60-cps and 28-vdc power to the engine I&C subsystem for conditioning and distribution.

2.5.4 A wiring harness will be provided between the I&C subsystem and the engine.

2.5.5 The engine I&C subsystem will process the engine and nuclear subsystem instrumentation necessary for flight. Required measurements are (TBD).

2.5.6 A method of checkout and calibration will be incorporated in the I&C system design.

2.5.7 The engine I&C subsystem is designed to fulfill the following functional requirements:

A.	Engine control	(TBD)
B.	Instrumentation	(see Table 2-2, Flight Operational Channels)
C.	Power conditioning	(TBD)
D.	I&C sequencing	(TBD)

2.6 GROUND TEST ONLY (GTO) MEASUREMENTS AND CONTROLS

2.6.1 The measurement and control capability necessary to develop the engine system and demonstrate its qualification shall be included as part of the ground test engine.

2.6.2 The instrumentation hardware shall include all transducers, wiring, and connectors provided with the engine. The controls hardware shall include special control equipment (located on the engine side of all facility to engine interfaces) necessary for the ground testing of the engine as defined in Paragraph 7.5.5 B.5.

2.6.3 The GTO measurements shall be as delineated in the measurements requirements list (MRL), with breakdown of channels as presented in Table 2-3 (Ground Test Channels).

TABLE 2-1

ENGINE FLUID REQUIREMENTS

Fluid	Use	Pressure, psia	Temperature, °R	Flow Rate, lb/sec	Duration (max) min.	Specification
LH_2	Propellant	30*	Sat. Vapor	90-100	60	MSFC Spec 356A
LH_2	Cooldown	460 (max)*	40(min) 50(max)*	55 (max)*	2*	
GH_2	Cooldown	1200 (max)*	Ambient	16 (max)*	1*	
GH_2	Warm-Up/Purge	350*	Ambient	0.1*	60*	
He	Emergency Cooldown	1200 (max)*	Ambient	64 (max)*	1.5*	MSFC Spec 364
GN_2-He	Engine Purge	65	530-620	15-60 SCFM	Cont.	MIL-STD-1246
GN_2	Cooldown	35*	Ambient	0.1*	60*	MSFC Spec 234
GN_2	Remote Engine	300*	Ambient	0.5*	5*	
LN_2	Engine Cooldown	300 (max)*	Sat. Vapor	100 (max)*	125 (hrs)*	

NOTE: * Indicates requirement is estimate; requirement to be determined by Trade Study/Design.

TABLE 2-2

OPERATIONAL FLIGHT ENGINE
MEASUREMENT DATA REQUIREMENTS LIST (MDRL)

MEASUREMENT SUMMARY

ABBREVIATIONS

AC/SP - Active/Spare or Redundant Measurement
BS - Binary Switch
DT - Position Transducer
E. - Current
EN - Freq., Speed
MG - Strain Gage
NC - Neutronics
HT - Vibration
P. - Average Pressure
PD - Differential Pressure
PT - Pressure
T. - Average Temperature
TD - Differential Temperature
GE - Heat Flux
TE - Temperature
TT - Resistance Thermometer
PFS - Propellant Feed Subsystem
DS - Destruct Subsystem
NAS - Nozzle Assembly Subsystem
I&CS - Instrumentation & Controls Subsystem
TSS - Thrust Structure Subsystem
ESS - External Shield Subsystem
GAS - Gimbal Actuator Subsystem
PV/CS - Pressure Vessel/Closure Subsystem
NSS - Nuclear Subsystem

MEASUREMENT SUMMARY

SUBSYSTEM SENS LOC.	BS AC/SP	DT AC/SP	E. AC/SP	EN AC/SP	MG AC/SP	NC AC/SP	HT AC/SP	P. AC/SP	PD AC/SP	PT AC/SP	T. AC/SP	TD AC/SP	GE AC/SP	TE AC/SP	TT AC/SP	SYS. TOTAL
PFS	50/0	10/0	0/0	4/0	0/0	0/0	0/0	0/0	7/0	30/0	0/0	2/0	0/0	18/0	9/0	130/0
DS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NAS	0/0	0/0	0/0	0/0	0/0	0/0	0/0	2/0	2/0	6/0	2/0	1/0	0/0	6/0	0/0	19/0
TSS	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	6/0	6/0
ESS	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
GAS	4/0	4/0	10/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	18/0
PV/CS	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
NSS	0/0	21/0	0/0	0/0	0/0	0/0	0/0	0/0	3/0	4/0	3/0	0/0	0/0	20/0	0/0	54/0
SUB-TOTAL	54/0	35/0	10/0	4/0	0/0	3/0	0/0	2/0	12/0	40/0	5/0	3/0	0/0	42/0	15/0	227/0

	TOTAL	227
1.	Minimum Operational Flight Control Parameters	227
2.	Trend Parameters Not Related to Control	TBD
3.	Additional Requirements for Emergency Malfunction Detection System	TBD
4.	Self-Check I&C Parameters	TBD
5.	Calculated Parameters (Other than Averages)	TBD
6.	Input Command Signals from Stage/Vehicle	TBD
7.	Generated Commands from the Engine System Programmer/ Computer	TBD
	GRAND TOTAL	TBD

TABLE 2-3

MEASUREMENT DATA REQUIREMENT LIST (MDRL)

MEASUREMENT SUMMARY

ABBREVIATIONS

AC/SP	- Active/Spare (Redundant)	HT	- Vibration
BC	- Binary Command	P.	- Average Pressure
BS	- Binary Switch	PD	- Differential Pressure
DR	- Position - Remote Shut-Off Valve	PT	- Pressure
DT	- Position Transducer	T.	- Average Temperature
D.	- Position Average	TD	- Differential Temperature
E.	- Current	TE	- Temperature (Self Gen.)
EN	- Frequency, Speed	TT	- Resistance Thermometer
GE	- Heat Flux	FO	- Flight Operational
MG	- Strain	FT	- Flight Test
NC	- Neutronics	GT	- Ground Test

Sensor Location By Subsystem		BC AC/SP	BS AC/SP	DR AC/SP	DT AC/SP	D. AC/SP	E. AC/SP	EN AC/SP	GE AC/SP	HT AC/SP	MG AC/SP	NC AC/SP	P. AC/SP	PD AC/SP	PT AC/SP	T. AC/SP	TD AC/SP	TE AC/SP	TT AC/SP	[illegible] Total
PFS	FO	50			10		0/0	4/0	0/0	0/0	0/0	0/0	0/0	7/0	30/0	0/0	2/0	18/0	9/0	130
	FT		97/60				0/0	4/0	0/0	6/0	0/0	0/0	0/0	7/0	38/0	0/0	2/0	44/0	[illegible]/0	267
	GT	47/7	62/0	0/0	26/18	0/0	0/0	4/0	0/0	8/0	0/0	0/0	0/0	18/0	83/0	0/0	4/0	68/0	20/0	356
DS	FO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]
	FT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]
	GT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]
NAS	FO	0/0			0/0		0/0	0/0	0/0	0/0	0/0	0/0	2/0	2/0	6/0	2/0	1/0	6/0	0/0	19
	FT	0/0			0/0		0/0	0/0	0/0	8/0	0/0	0/0	1/0	2/0	12/0	1/0	1/0	32/0	1/0	58
	GT	0/0			0/0		0/0	0/0	0/0	21/0	8/0	0/0	2/0	4/0	16/0	2/0	2/0	68/0	2/0	125
TSC	FO	0/0			0/0		0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	6
	FT	0/0			0/0		0/0	0/0	8/0	4/0	12/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	30
	GT	0/0			0/0		0/0	0/0	0/0	6/0	12/0	0/0	0/0	0/0	0/0	0/0	0/0	21/0	12/0	51
ECS	FO	0/0			0/0		0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0
	FT	0/0			0/0		0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	16/0	0/0	16
	GT	0/0			0/0		0/0	0/0	0/0	8/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	27/0	0/0	35
GAS	FO	4/0		4/0			10/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	18
	FT	4/0		4/0			12/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	2/0	0/0	0/0	3/0	0/0	25
	GT	4/0		4/0			12/0	0/0	0/0	6/0	0/0	0/0	0/0	0/0	4/0	0/0	0/0	6/0	0/0	36
PV/CS	FO	0/0			0/0		0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0
	FT	0/0			0/0		0/0	0/0	0/0	2/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	4/0	0/0	6
	GT	0/0			0/0		0/0	0/0	0/0	9/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	8/0	0/0	25
NSS	FO	0/0			21/0		0/0	0/0	0/0	0/0	0/0	3/0	0/0	3/0	4/0	3/0	0/0	20/0	0/0	54
	FT	0/0			68/0		0/0	0/0	0/0	3/0	6/0	14/0	0/0	16/0	16/0	2/0	0/0	117/0	0/0	242
	GT	TBD			TBD		TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	*472
[illegible] SUB-TOT.	FO	54/0			35/0		10/0	4/0	0/0	0/0	0/0	3/0	2/0	12/0	40/0	5/0	3/0	42/0	15/0	227
	FT		173/60				12/0	4/0	8/0	2[illegible]0	18/0	14/0	1/0	25/0	68/0	3/0	3/0	237/0	16/0	669
	GT		TBD				TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	1100

1.	Total Parameter/Channels Listed	628
*2.	Estimated NSS Parameter/Channels by ANSC/WANL	472
3.	Calculated Parameters (Other than Averages)	TBD
4.	Input Command Signals from ETS-1/Engine System	TBD
5.	Generated Commands from the Engine System Programmer/Computer	TBD
	GRAND TOTAL	TBD

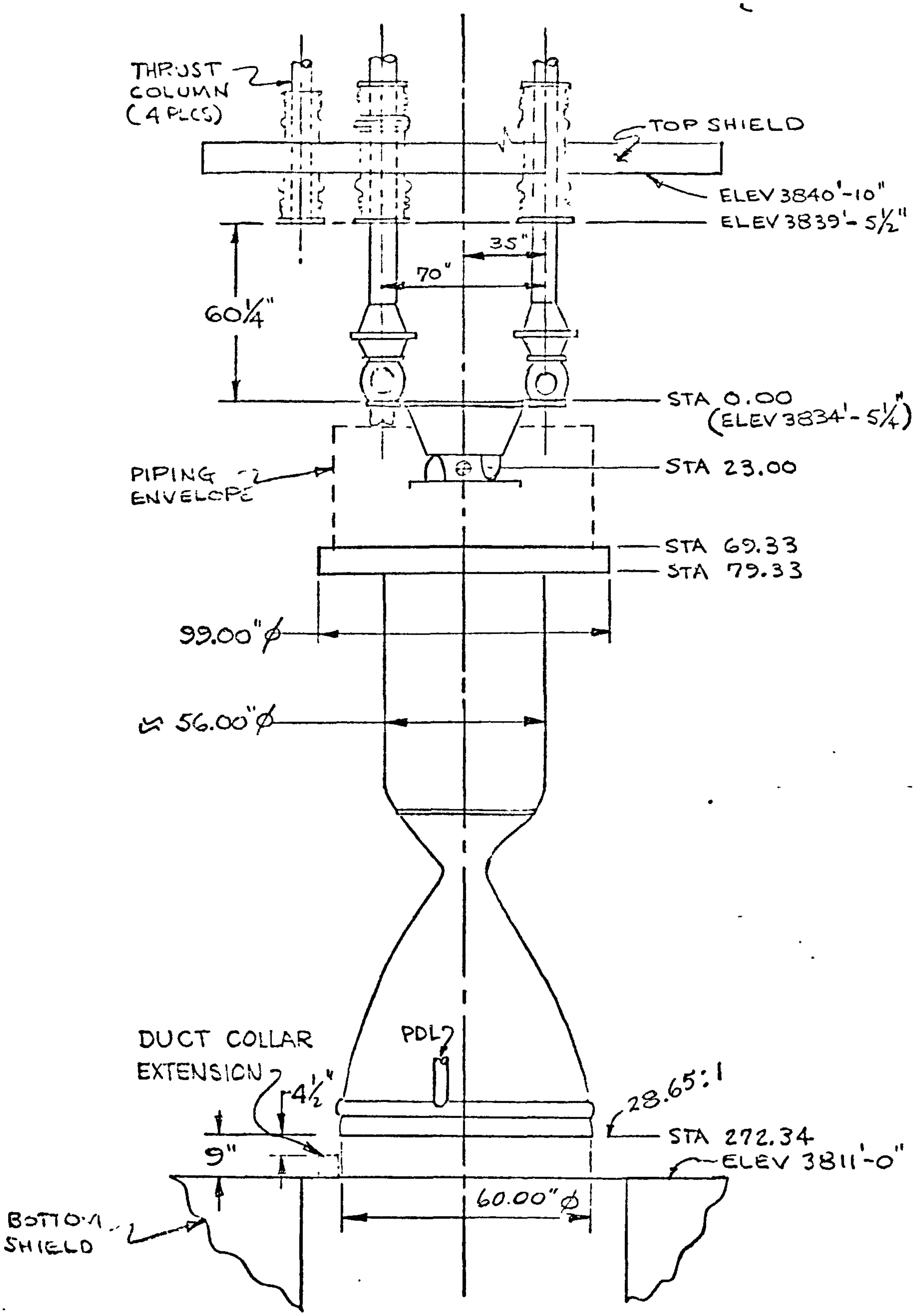


Figure 2-1 - NERVA Engine Envelope (Full Flow)

8-19-70
H.A.B.

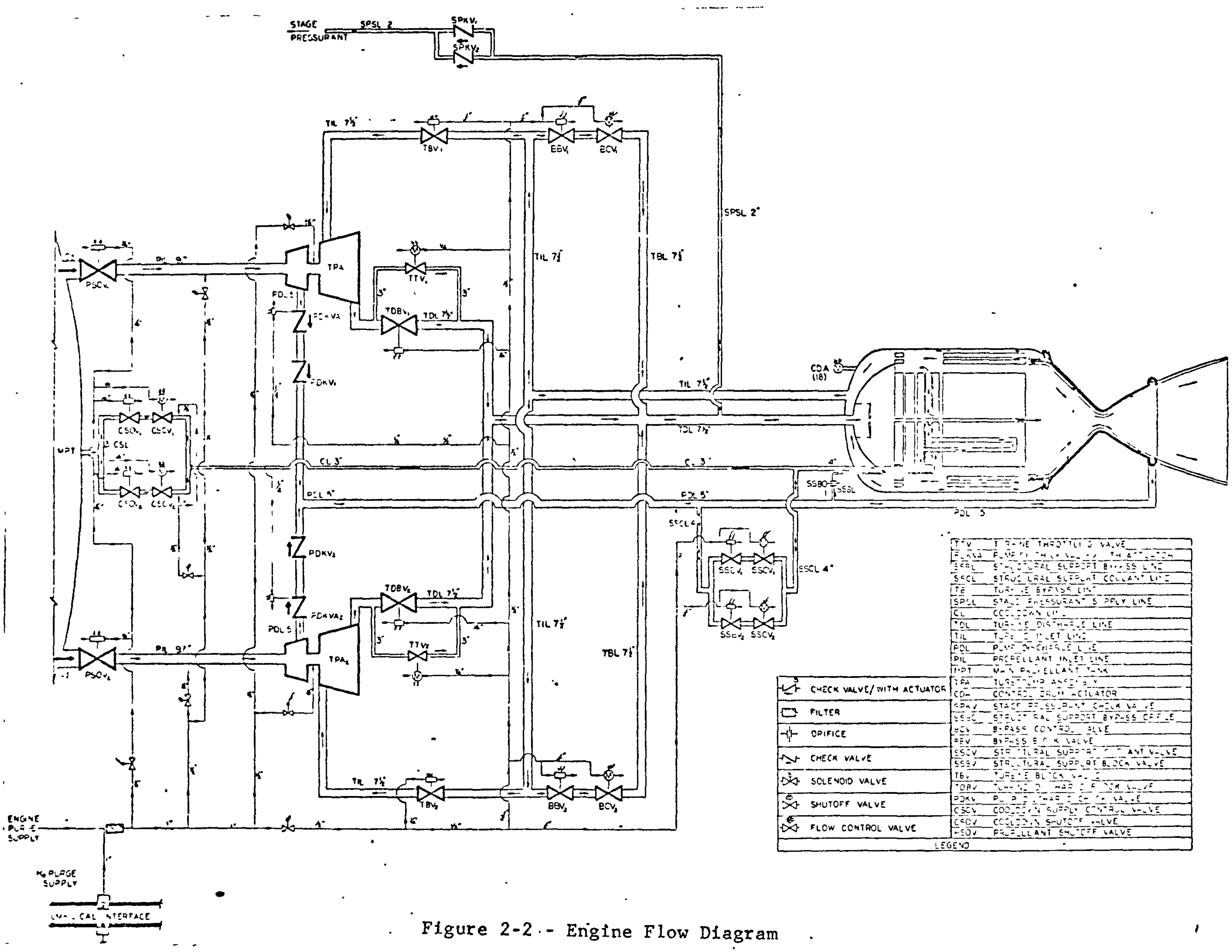


Figure 2-2 - Engine Flow Diagram

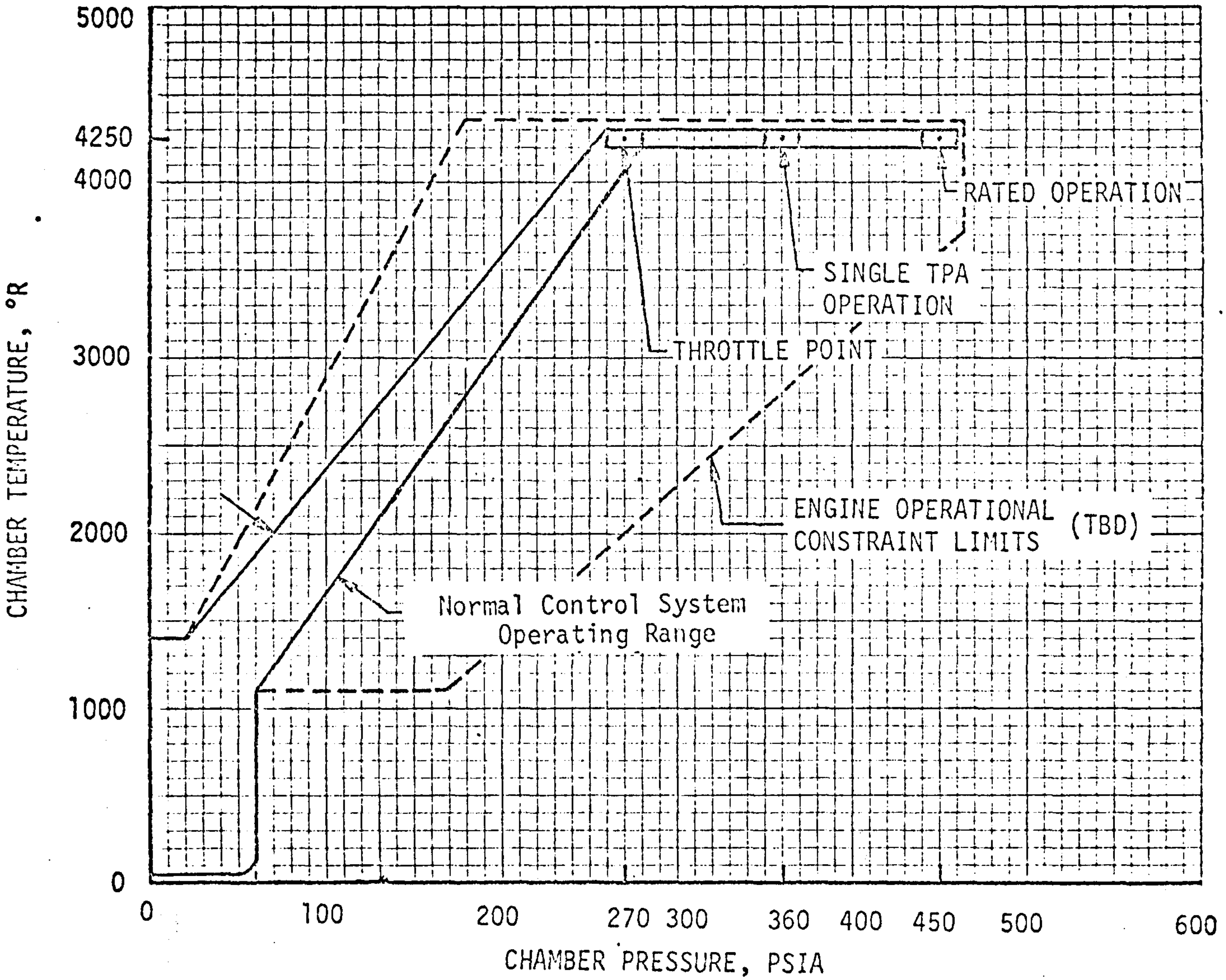


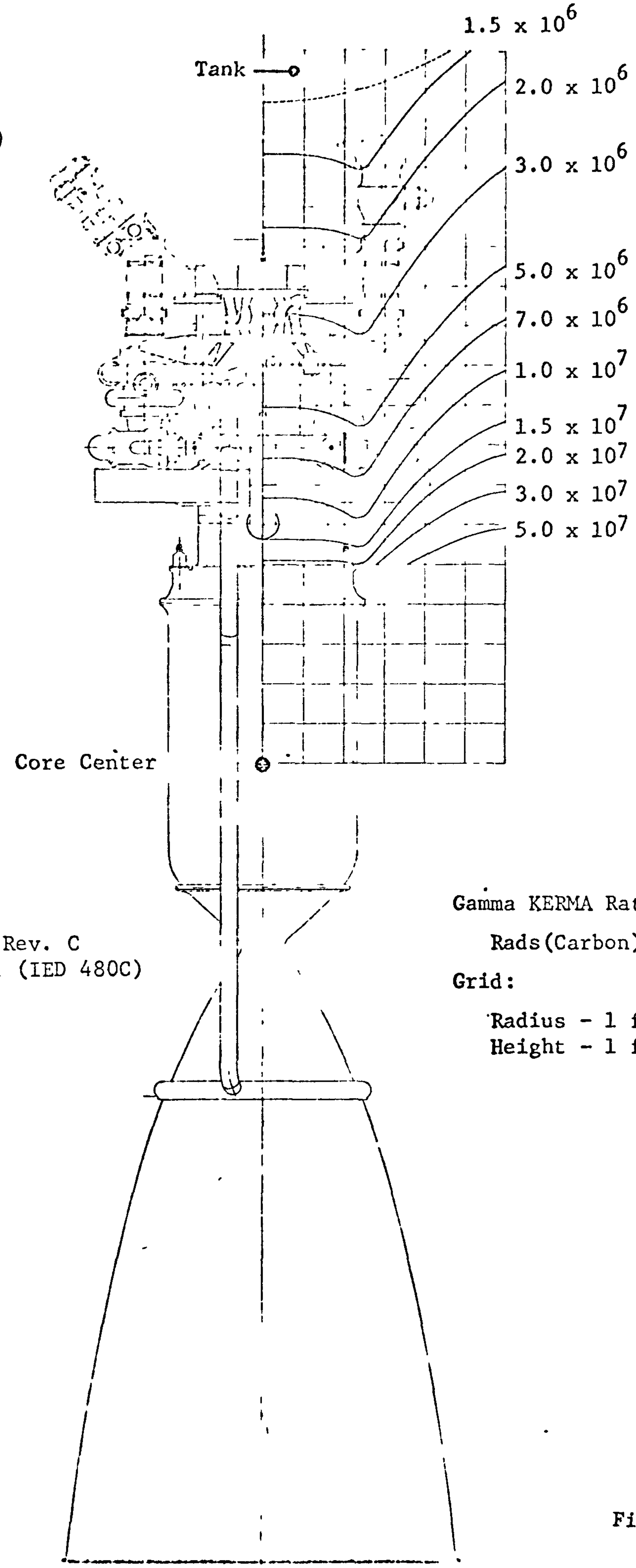
Figure 2-3 - NERVA Engine Operational Constraint Map

FIGURE 2-4

EMERGENCY COOLDOWN SYSTEM REQUIREMENTS

(TBD)

UNPERTURBED PVARA
GAMMA KERMA RATE
(SPECIFICATION EXTREME)



NOTES:

(1) Engine Dwg 1137400 Rev. C
(2) July 1970 NSS Model (IED 480C)

Gamma KERMA Rate:

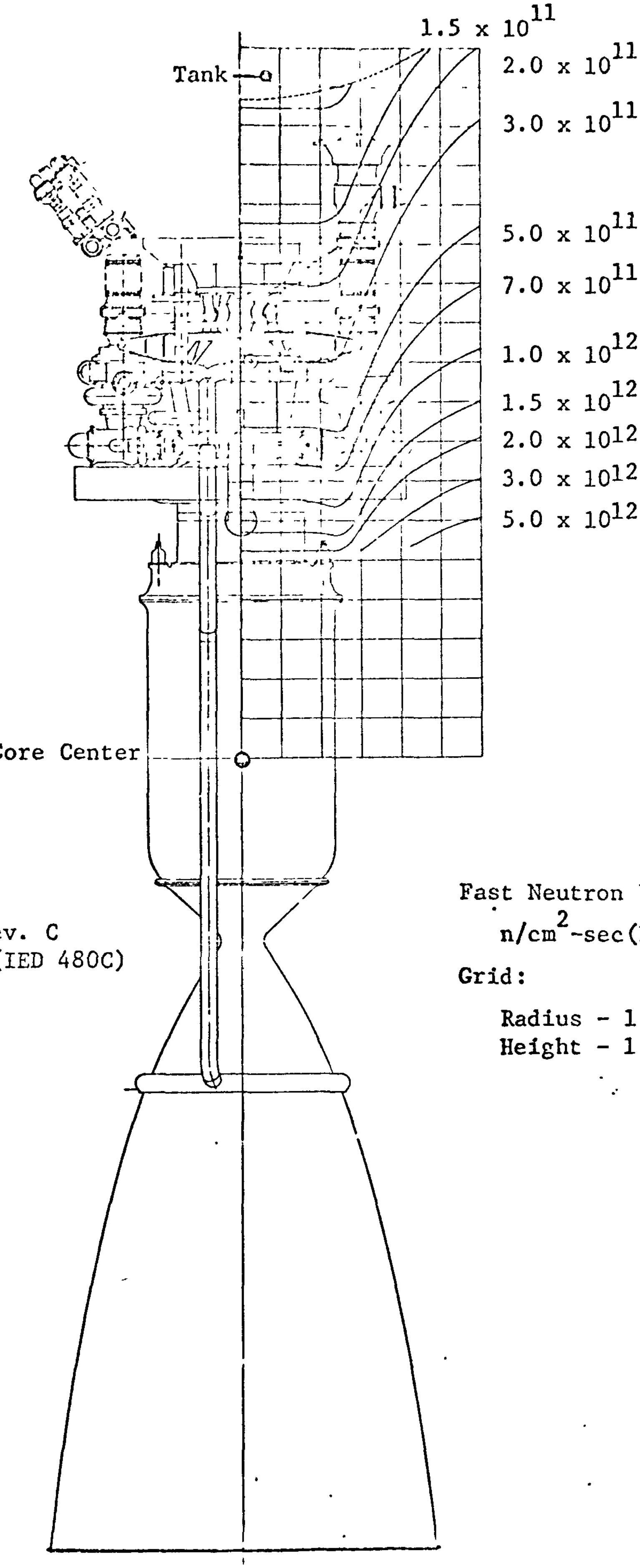
Rads(Carbon)/hr

Grid:

Radius - 1 ft
Height - 1 ft

Figure 2-5

UNPERTURBED FAST NEUTRON FLUX (SPECIFICATION EXTREME)



NOTES:

(1) Engine Dwg 1137400 Rev. C
(2) July 1970 NSS Model (IED 480C)

Fast Neutron Flux:

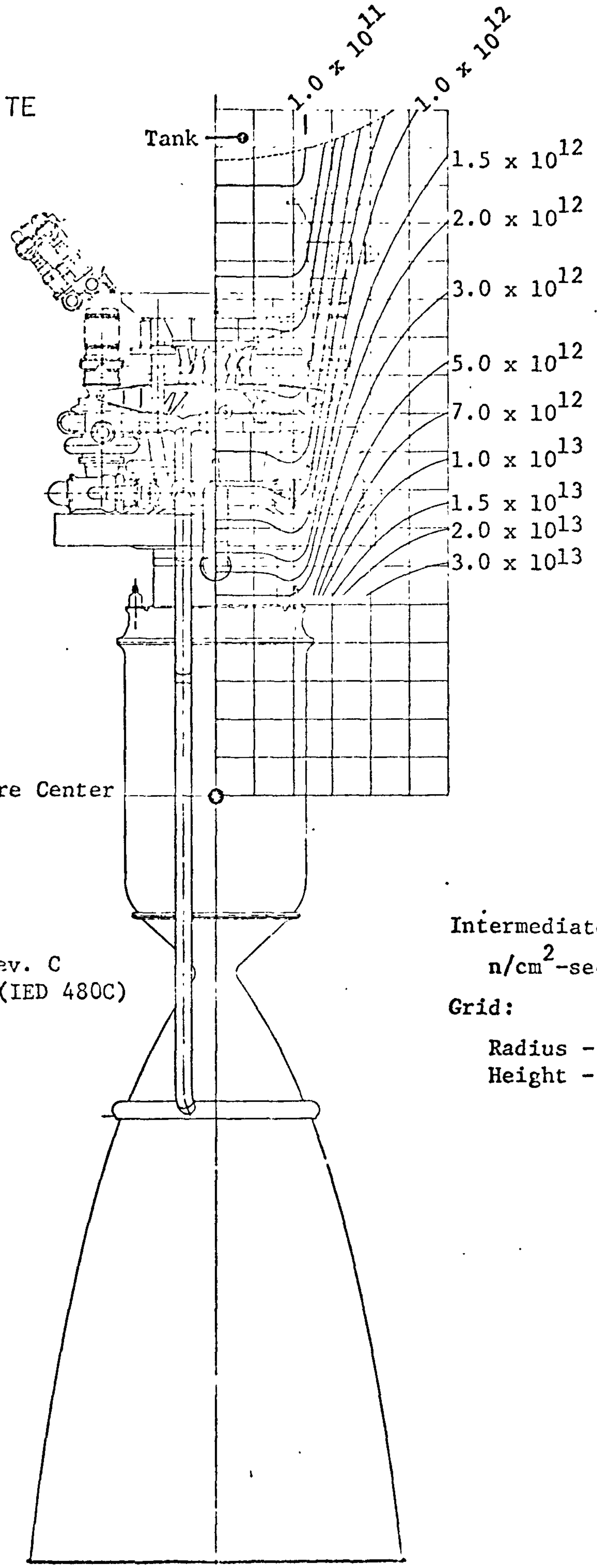
n/cm^2-sec(E_N > 0.9 MeV)

Grid:

Radius - 1 ft
Height - 1 ft

Figure 2-6

UNPERTURBED INTERMEDIATE NEUTRON FLUX (SPECIFICATION EXTREME)



NOTES:

(1) Engine Dwg 1137400 Rev. C
(2) July 1970 NSS Model (IED 480C)

Intermediate Neutron Flux:

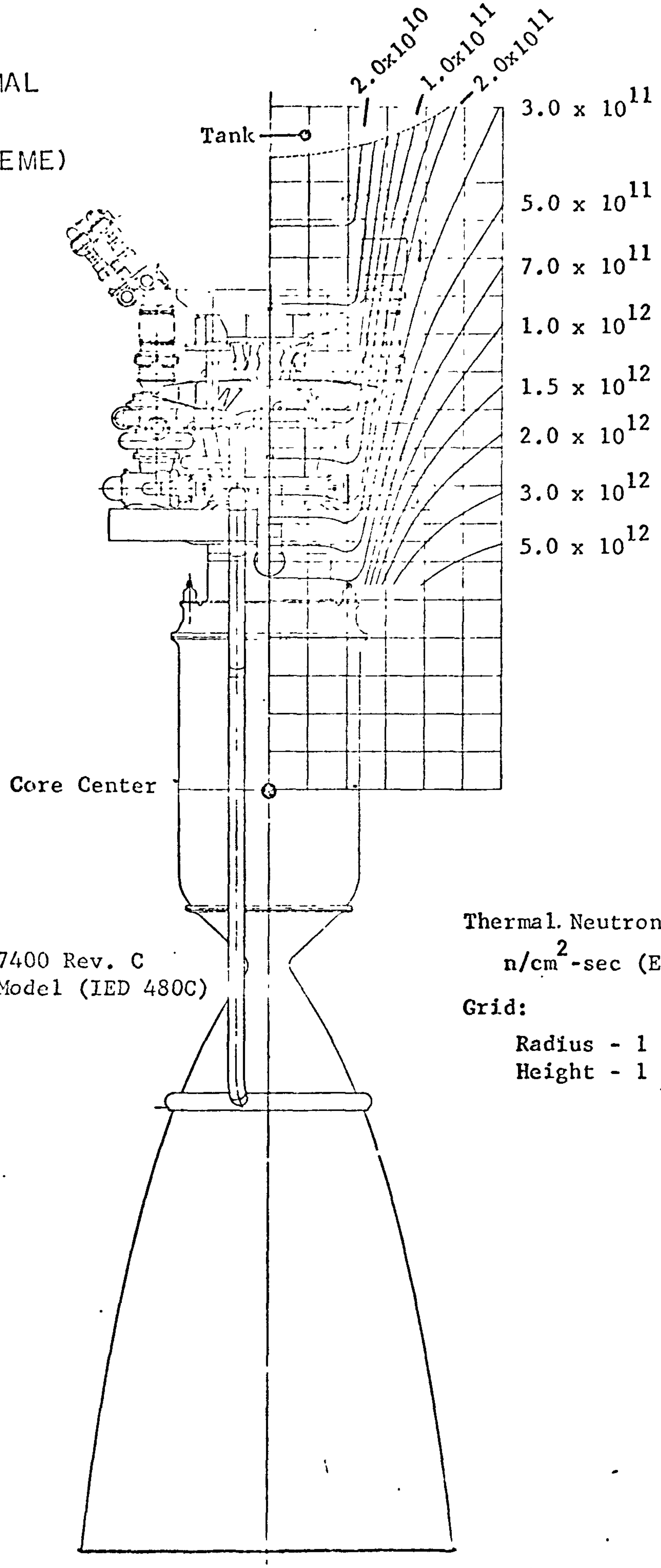
n/cm^2-sec (0.4 eV<E<0.9 MeV)

Grid:

Radius - 1 ft
Height - 1 ft

Figure 2-7

UNPERTURBED THERMAL NEUTRON FLUX (SPECIFICATION EXTREME)



NOTES:

(1) Engine Dwg 1137400 Rev. C
(2) July 1970 NSS Model (IED 480C)

Thermal Neutron Flux:
n/cm^2-sec ($E_N < 0.4$ eV)

Grid:
Radius - 1 ft
Height - 1 ft

Figure 2-3

3.0 TEST PROGRAM AND OPERATIONS

3.1 INTRODUCTION AND SCOPE

The purpose of this section is to establish operational requirements in support of the NERVA test program. The engine test sequence supports delivery of a fully qualified man-rated flight engine. Figure 3-1 provides the engine testing logic and anticipated span times. This logic is independent of a specific point in time and indicates the relationship between engines.

3.2 TEST PLANS

Plans for development and qualification engines are shown in Figures 3-2 and 3-3. Span times are assigned to each run or EP, and a total time is assigned for each test series.

3.2.1 Development Engines (DE-1 and DE-2) - The major test objectives for the development engines are:

1. Reactor and engine physics and reactivity effects.
2. Start-up, shutdown, and cooldown characteristics
3. Engine system characteristics after extended duration and multiple-cycling firing
4. Final ETS-1 qualification is to be accomplished during early development testing
5. Malfunction recovery demonstration
6. Steady-state operation at any point within the operating map (see Figure 2-2)

3.2.2 Prequalification and Qualification Engines (PQE-1 through QE-3)

Qualification engines shall be tested for 10 hours and 60 cycles. The test plans for these engines are provided in Figure 3-3.

3.3 TEST PROGRAM OPERATIONAL REQUIREMENTS

3.3.1 ETS-1 shall have the ability to support two tests in a given week on an intermittant basis to allow an average of one test per week. The reliability of the fluid replenishment systems and the data processing equipment for accomplishing the 2 to 3 day turnaround can be less than 100%. The 2-day turnaround applies to all systems except the water system which is 3 days.

3.3.2 All portions of ETS-1 shared with E/STS-2 shall be capable of being returned to ETS-1 operational use for test within 48 hr.

3.3.3 Sufficient fluids shall be provided to satisfy the engine requirements and all fluids required to conduct the engine test program.

3.3.4 System design and operational analysis shall be based on a maximum of four hour each for run-day setup and shutdown activities. Run-day setup and shutdown activities are defined as those activities leading up to and following power operation where full operating crew participation is required.

3.3.5 ETS-1 staffing shall be consistent with the 2 to 3 day turnaround time. Staffing for the following NTO functional areas shall be as follows:

Operating Crew, Analysis, Test Engineering	4 Teams	
Program Control	3 Shifts	7 Day/Week
Facility Operations	3 Shifts	7 Day/Week
Product Assurance	3 Shifts	7 Day/Week
Safety	3 Shifts	7 Day/Week

3.3.6 ETS-1 shall be capable of receiving a new engine six weeks after the removal of a tested engine.

3.3.7 A codification system shall be used for establishing a coherent system of nomenclature. The codification system shall include all facility hardware and instrumentation.

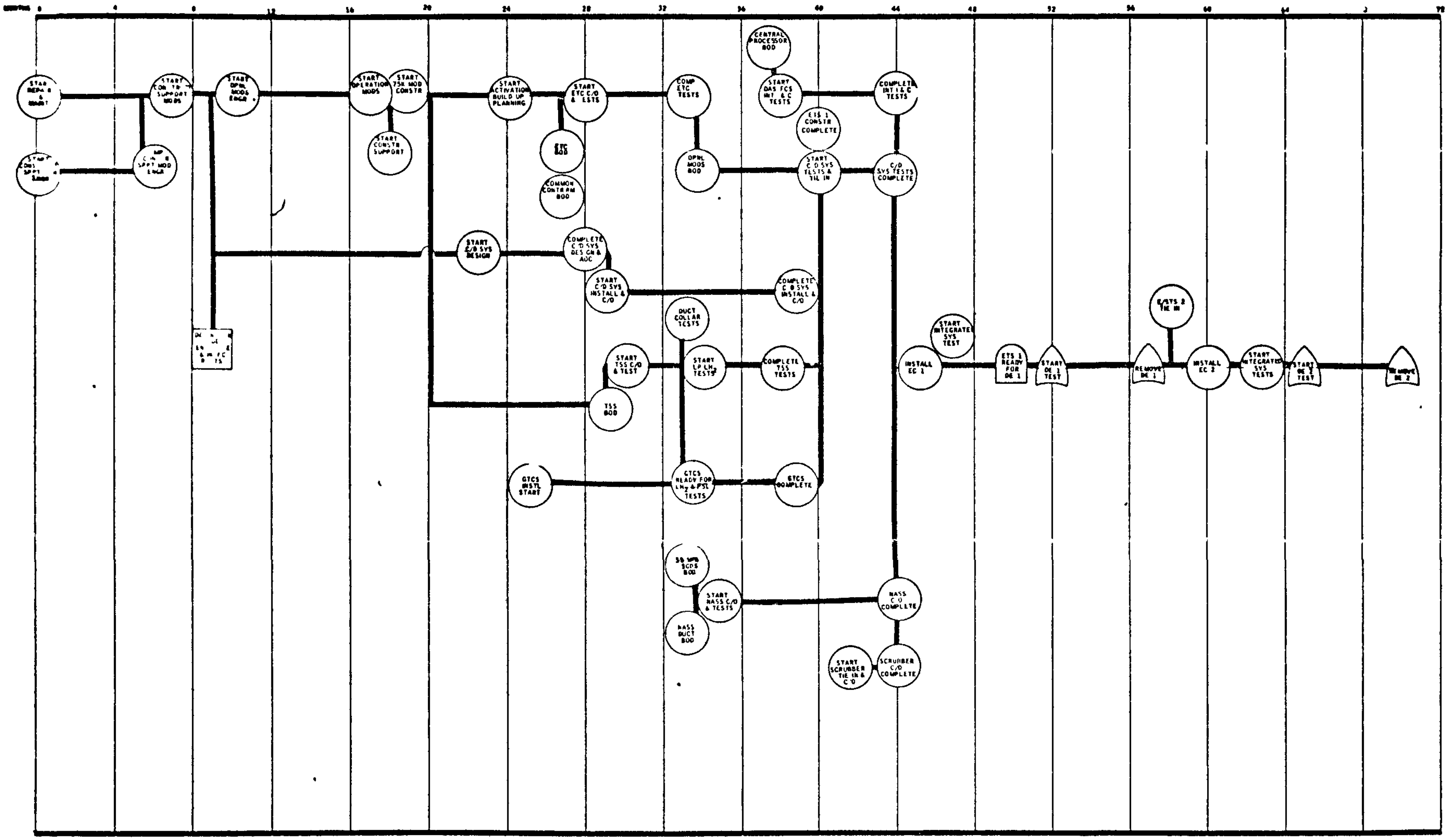


Figure 3-1 - ETS-1 and Associated Testing Logic Plan

Runs	Description	DE-1	Elapsed Time	DE-2	Elapsed Time
EP-1 E	Initial Criticality	X	1	X	1
EP-2	Reactivity Effects	X	2	X	1/2
EP-3	Cold Flow Bootstrap	X	1	0	--
EP-4	Cold Flow Bootstrap	X	2	0	--
EP-5	Powered Bootstraps	X	2	X	2
EP-6	Powered Bootstraps	X	2	X	2
EP-7	Powered Bootstraps	X	2	X	2
EP-8	Powered Bootstraps	X	2	X	2
EP-5 to 8	Startup Malfunctions	X	--	X	--
EP-9	Intermediate Power	X	3	X	2
EP-10	Intermediate Power	X	2	X	2
EP-11	Full-Power	X	2	X	2
EP-12	Full-Power	X	1	0	--
EP-13 to 16/22	Duration and Cyclic Testing	X	2	X	5
EP-16/ 22	Emergency Mission	X	--	X	--
			24 weeks		20-1/2 weeks

Figure 3-2 - Development Engine Test Program

		Prequal and Qual					Elapsed Time (Weeks)
		PQE-1	PQE-2	QE-1	QE-2	QE-3	
EP-1	Initial Criticality	X	X	X	X	X	2
EP-2	Bootstrap to Intermediate Power, Restart	X	X	X	X	X	2
	Perform Engine Dynamics Tests						
	Verify Safety Devices						
	Chilldown						
EP-3	Rated Power	X	X	X	X	X	2
	System Dynamics						
	Low NPSP Start						
	Emergency Mission*						
	Throttleability						
	Verify Cooldown						
	Spec Extreme Performance						
EP-4	Rated Power	X	X	X	X	X	2
	Verify Safety Devices						
	TVC Performance						
	Restart						
	Spec Extreme Performance						
	Maintainability						
	System Dynamics						
EP-5	Rated Power	X	X	X	X	X	5-1/2
to	System Dynamics						13 weeks
EP-14	Restart						
	Spec Extreme Performance						
	Duration						

*Qual only

Figure 3-3 - Prequalification and Qualification Engine Test Program

4.0 NUCLEAR RADIATION AND SHIELDING

4.1 SCOPE

This section defines the nuclear shielding requirements for the Engine Test Compartment shields and other local shielding as required in the facility in terms of personnel access, engine environment, nuclear heating, and material damage requirements.

4.2 ENVIRONMENTAL SIMULATION REQUIREMENTS

4.2.1 The Engine Test Compartment shields shall limit the resultant radiation of components above the engine shield to a level of 125% of the anticipated in-flight radiation levels.

4.2.2 The Engine Test Compartment shields shall not perturb the reactivity of the reactor by more than $0.50.

4.3 ACCESS REQUIREMENTS

Sufficient shielding shall be provided to meet the facility access requirement listed in Table 4-1.

4.4 FACILITY HARDWARE PROTECTION

4.4.1 Analysis for nuclear heating and material damage of facility components and equipment shall be based on whichever of the following provides the more severe case.

A. Ten separate 5.4 x 10^6 Mw-sec runs within 29 days (ten runs of 1500 Mw for 60 min).

B. Six each 0.9 x 10^6 Mw-sec runs (6 runs at 1500 Mw for 10 min) followed 48 hr later by 6 each 0.9 x 10^6 Mw-sec runs.

C. One each 5.4×10^6 Mw-sec run followed 48 hr later by a 5.4×10^6 Mw-sec run.

4.4.2 Maximum effort shall be made to select materials and components for the facility which have high enough threshold damage properties to withstand their individual environment for 10 complete engine test series. In the event that this goal is not attainable for a selected few components they must at least survive the life of 1 engine (6×10^7 Mw-sec) and be replaceable within the facility turnaround time between engines as stated in Section 3.0.

4.4.3 Radiation intensity, neutron activation, accumulated dose, and fission-products contamination shall be considered in the design and location of components used at ETS-1. Local shielding shall be provided in lieu of radiation-hardened equipment or excessive replacement of nonhardened equipment, when shown to be cost effective.

4.5 SOURCE TERM DEFINITION

A. Nuclear analysis shall be based on the current NERVA radiation spectra defined in Tables X and XI of the Engine Specification.

B. The source term to be considered is that associated with 10 each 60 min rated power tests, conducted in a 29 day time period.

TABLE 4-1

ETS-1 ACCESS REQUIREMENTS

Shields Position	Closed	Closed	Closed	Closed	Open	Open	If Maximum Credible Accident Occurs	During NERVA Power Testing
Time after Test	1 Hr	1 Hr	1 Hr	1 Hr	7 Days	8 Days*		
Test Duration	10 Min	1 Hr	5 Hr in 15 Days	10 Hr in 29 Days	10 Hr in 29 Days	10 Hr		
Power Level	1500 Mw or Equiv.	1500 Mw or Equiv.	1500 Mw or Equiv.	1500 Mw or Equiv.	1500 Mw or Equiv.	1500 Mw or Equiv.		
ETS-1 Control Room	A	A	A	A	A	A	EP	A
E/STS-2 Control Room	A	A	A	A	A	A	EP	A
ETS-1 and ETS-2 Control Room Exits	A	A	A	A	A	A	EP	N/E
Fill Station	A	A	A	A	A	A	EP	N/A
Pipe Chase	B	C	C	C	B	A	EP	N/A
Hot Side of Shadow Wall @ Elev 3810	D	D	D	D	D	C	EP	N/A
Cold Side of Shadow Wall	B	B	B	B	B	A	EP	N/A
T.S. Superstructure above Elev 3844	C	D	D	D	C	A	EP	N/A
SCDS Area	B	B	B	B	B	A	EP	N/A
LH_2 Storage Area	B	B	B	B	A	A	EP	N/A
High Pressure Gas Storage Area	B	B	B	B	A	A	EP	N/A
Test Stand Equipment Room	A	A	A	A	A	A	EP	N/A
TCB and FCR's	A	A	A	A	A	A	EP	A
Mechanical Equipment Room (TCB)	A	A	A	A	A	A	EP	A
H.V. and A.C. Equipment Areas (UEB)	A	A	A	A	A	A	EP	N/A
Compressor Room	A	A	A	A	A	A	EP	N/A
ETS-1 Shop and Spares Storage Building	A	A	A	A	A	A	EP	N/A
Diesel Generators	A	A	A	A	A	A	EP	N/A
Substation	A	A	A	A	A	A	EP	N/A
Duct Vault - Under Duct Elbow	D	D	D	D	D	C	EP	N/A
DV Ditch Bottom of Stairs	B	C	C	C	C	B	EP	N/A
DV Ditch Front of DV Door	C	D	D	D	C	A	EP	N/A
E STS-2 Test Stand	A	A	A	A	A	A	EP	N/A
Life Support Area	A	A	A	A	A	A	EP	A
High Pressure LH_2 Dewar	B	B	B	C	B	A	EP	N/A

EP = Emergency Procedure
N/A = No Access
N/E = No Exit

A = Less than 10 MR/Hr
B = 10 MR Hr to 300 MR Hr
C = 300 MR Hr to 5 R Hr
D = Greater than 5 R Hr

*Engine Removed

5.0 RELIABILITY, MAINTAINABILITY, AND QUALITY ASSURANCE

5.1 SCOPE

This section identifies the reliability, maintainability, and quality-assurance requirements to be applied in the design, fabrication, installation, qualification, and testing of a maintainable and reliable facility.

5.2 GUIDELINES

5.2.1 The following documents shall be utilized in the preparation of the reliability, maintainability, and quality assurance plans for ETS-1.

a. SNPO-C-4; Quality Assurance Requirements for Facility and Test Support Equipment
b. FEO Reliability, Maintainability, and Quality Plans for ETS-1
c. SNPO . Maintainability Program Requirements for Facility and Test Support Equipment.
d. NHB-5300.4(1A): Reliability Program Provisions for Aeronautical and Space Systems Contractors.
e. NPC-325-1: Design Criteria and Construction Standards
f. SNPO-C-1: Structural Design Requirements
g. MIL-STD-470 (Maintainability)

NOTE: In the event a conflict occurs between documents, the problem will be resolved on an individual basis.

5.2.2 Reliability, Maintainability, and Quality-Assurance plans shall be prepared to be compatible with the safety requirements specified in Section 6.0 of this document.

5.2.3 All systems shall be designed to "fail safe" in the condition that will do the least damage to personnel, facility, and test article in descending order of importance.

5.2.4 NPC-325-1 shall be applied to all design and construction.

5.2.5 SNPO-C-4 shall be applied to the design, fabrication, construction, installation, qualification, and testing of all functional elements. (Functional elements include the TSS, NASS, I&C, and shielding structures.)

5.2.6 All systems shall be highly reliable as determined through an analysis and design process of identifying and eliminating, where possible, and controlling critical components of which single failures would render the system inoperative. Systems shall have a low probability of failure during a test and, consistent with a scheduled maintenance program, be reliable throughout their useful life.

5.3 REQUIREMENTS

5.3.1 The FEO shall prepare a reliability and quality-assurance plan which defines and describes the program to be implemented upon initiation of facility design.

5.3.2 Design contractor(s) shall be required to prepare implementation procedures to satisfy the reliability, maintainability, and quality-assurance plan.

5.3.3 The FEO shall prepare a maintainability plan that defines and describes the program to be implemented upon initiation of facility design. The plan shall be developed around but not limited to the following criteria:

A. Identify the maintainability requirements to be applied in the design, fabrication, installation, qualification, and testing of the ETS-1 complex.

B. Systems designed shall consider the following:

1. 2-3 day turnaround for testing.
2. Facility and equipment accessibility for repair and troubleshooting.
3. Reduction of complexity for maintenance.
4. Minimize downtime, number of personnel and human errors.
5. Minimize design - dictated maintenance support cost.
6. Rapid replacement or repair of malfunctioning equipment.
7. System and component self-check.
8. Redundancy and/or control on critical components and/or subsystems.
9. Adequate work space in accessible work areas.
10. Test points in accessible work areas.
11. Standardize circuits, components, and equipment where possible.
12. Spare parts.
13. Remote removal of equipment as applicable.

6.0 SAFETY

6.1 SCOPE

This section identifies the safety requirements and to some extent the safety techniques to be applied in the design, fabrication, installation, qualification operations, and testing of facility and test support equipment.

6.2 STANDARDS

6.2.1 Philosophy - The basic philosophy shall be that all facilities, appurtenants, support equipment, etc., are designed and operated so that no single failure or credible combination of errors, malfunctions, or accidents can cause personnel injury, and/or serious facility damage or test article loss. This philosophy requires the use of a formal hazards analysis which results in a categorization of potential hazards and documents the analysis and proposed procedures to reduce any undue consequences to acceptable levels. The hazards analysis technique is further described in Section 6.3.2.

6.2.2 Documents -

A. The following documents shall be complied with:

1. SNPO-C Safety Plan (TBD)

2. AEC Manual Chapters 0500 Series; Health and Safety

3. SNPO-N NRDS Safety Requirements

B. The following document shall be used as a guide:

1. NASA Safety Manual NHB-1700.1 (V 1)

6.3 REQUIREMENTS

Safety requirements are generated by various techniques. Certain basic requirements or standards come from the documents listed above. Other safety requirements come from safety analyses such as the hazard analysis technique listed below:

6.3.1 General Requirements - The following safety requirements, listed in order of preference, will be applied to the designs:

A. Design for Minimum Hazards

Major effort shall be made throughout all phases of design to insure inherent safety through the selection of appropriate specifications, design features, and qualified components. This effort shall include a thorough review of system configuration compatibility with maintenance and test operations, and other test requirements to minimize the probability of system degradation because of personnel error.

B. Protective Systems

In all instances where known hazards exist and cannot be eliminated, appropriate protective systems shall be employed consistent with program goals and objectives.

C. Warning Devices

Where it is not possible to preclude the existence or occurrence of a known hazard, reliable devices shall be employed for timely detection of the condition and the generation of an adequate warning signal. Responses to warning signals shall be delineated in emergency plans. Warning signals shall be standardized within like types of systems, in accordance with existing NRDS directives, to minimize the probability of improper personnel reaction to the signal(s).

D. Special Procedures

Where it is not possible to reduce the magnitude of existing or potential hazards through design, protective systems, or the use of warning devices, appropriate emergency procedures shall be developed.

6.3.2 Special Requirements -

A documented hazards analysis of facility design modifications or new facilities will be performed utilizing the following hazard categories:

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.

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

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.

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.

Category III or IV hazard conditions shall be precluded from designs to the maximum practical extent. Any design which includes a Category III or Category IV hazard condition which cannot be eliminated will require review by SNPO-C. The analysis of Category III or Category IV hazard conditions will be documented together with a proposed procedure for reducing the consequences of the hazard to an acceptable level.

Certain special safety problems are peculiar to the Nuclear Rocket Program. These include site related considerations such as test induced seismic loads, flooding and earthquakes, effluent release, an underground personnel and equipment area, etc. Obviously, certain safety requirements will stem from analysis of these special problems.

7.0 FACILITY SYSTEMS

7.1 SCOPE

This section defines the specific facility performance requirements and constraints for ETS-1 to support the NERVA engine test operations described in Section 3.0. This section has been divided into seven elements as follows:

1. Test Support Systems
2. NERVA Effluent Handling System
3. Instrumentation and Controls
4. Structures
5. Buildings
6. Utilities
7. Site Work

7.2 GUIDELINES

7.2.1 The facility shall provide normal work accessibility to the engine for operations prior to testing.

7.2.2 All systems specified within this section shall have the capacity and capability of providing the required support to accomplish the test program specified in Section 3.0 for the test article described in Section 2.

7.2.3 The facility shall be designed so that normal testing operations can be accomplished on a three shift basis within a basic 7-day work-week without exceeding the personnel exposure limits established in AEC Manual 0524.

7.2.4 Facility Systems Maintenance - Facility design shall be such that maintenance requirements are minimized. Maintenance practices shall be compatible with the 2 to 3 day turnaround requirements. Access shall be provided consistent with Table 4-1 to areas where scheduled maintenance will be required. Access to facility areas for unscheduled maintenance purposes will be considered to the extent practicable.

7.2.5 Environmental Conditions - Upon selecting equipment and components for use in the various areas, specific attention shall be given as to the environment in which the equipment or component is to function. In considering nontest, test, and environment created by testing, also consider that the desert region is subject to extreme heat (120°F +), extreme cold (20°F -), high winds (above 70 mph), snow, rain, fine desert sand, and sand storms (see Table 7-1). Sand and dust environmental control shall be in accordance with NASA-TNX-53872.

7.2.6 During initial activation and checkout of the facility, controlled access shall be provided to all parts of the facility.

7.2.7 Installation and removal of a tested engine will be by remote means.

7.2.8 Seismic Loads - The design of equipment and equipment supports shall be in accordance with FEO-1 "NERVA Facility Structural Design Standards", and FEO-2 "NERVA Facility Seismic Design Standards".

7.2.9 Control consoles shall be designed to include a separate power switch for each console, bulb test and indicator test circuits, and standardization of switch and indicator lamp logic.

7.3 TEST SUPPORT SYSTEMS (TSS)

7.3.1 Scope - This subsection defines the requirements and the applicable functions of the TSS for the ETS-1 facility. The TSS is comprised of the liquid hydrogen, liquid nitrogen, high-pressure gas, process water, and ancillary systems.

7.3.2 Requirements

A. The design of the TSS shall be based on the latest editions of the applicable commercial codes and standards used for design in present day industrial practices.

B. The replenishment systems for all consumable test fluids shall be designed to meet the most exacting condition specified in Paragraph 3.3.

C. Sufficient operating fluid storage and systems capacity shall be provided for prefiring chilldown, ramp to full power, full power durations, normal shutdown, postfiring cooldown, systems warmup and purging, and for emergency or fast shutdown. Capacities shall include allowances for operational transfer losses, delivery contingencies, chilldown of cryogenic components, purge and vent usages, and nontest period operations.

D. Liquid storage vessels shall have a gas ullage of 10% when full and provide a minimum of 5% of capacity margin upon completion of a test.

E. All systems shall be provided with the necessary instrumentation and control systems, valves, flow elements, filters, and safety systems to meet all operational requirements of the facility and the engine.

7.3.3 Liquid Hydrogen (LH_2) System - The LH_2 system shall include provisions for:

A. Chilling, filling, topping, cooldown, and replenishing the run tank at rates dictated by the engine characteristics.

B. A separate high-pressure Dewar for emergency or fast cooldown.

C. A separate storage vessel for replenishment of the GH_2 system.

7.3.4 Liquid Nitrogen (LN_2) System - Provide an LN_2 system for post-test engine cooling and capacity to recharge the GN_2 system during the turnaround time.

7.3.5 High-Pressure Gas Systems - High-pressure gas systems shall be provided for all engine gas requirements at the facility-to-engine interfaces and for all facility gas requirements.

A. Gaseous Hydrogen (GH_2) System

GH_2 shall be provided for: (1) LH_2 system purging, pressurization, and transfer operations; (2) engine cooldown; and (3) pressurization of the LH_2 cooldown system.

B. Gaseous Nitrogen (GN_2) System

GN_2 shall be provided for: (1) pressurization of the LN_2 cooldown system; (2) ETC purge and seals; (3) NASS duct and scrubber; (4) flare systems; (5) actuation of valves and motors; (6) inerting; and (7) engine purge.

C. Gaseous Helium (GHe) System

GHe shall be provided for the emergency safety systems, various purge gas flows, engine purges, and actuation of selected valves and regulators.

7.3.6 Process Water System - Process water shall be provided for:

A. Cooling to the NASS exhaust duct.

B. NASS steam generation and delivery system (SGDS).

C. Cooling the ETC shields.

D. Protection of the test stand and other equipment and structures from thermal radiation.

E. Deluge for protection of structures, storage vessels, and equipment.

F. Decontamination of structures, storage vessels, and equipment.

G. NESS for cleaning the engine effluent.

7.3.7 Ancillary Systems - The following ancillary systems shall be provided:

A. Flare systems with igniters for the disposal of LH_2, GH_2, propane, and other similar fluids.

B. Plant air and propane for flare stack operations.

C. An igniter system for the NASS exhaust duct.

D. A vacuum system for evacuating and maintaining storage vessels and vacuum jacketed piping systems and Dewars.

E. A hydraulic system for hydraulically operated valves and other systems as required.

F. Cryogenic fluid and gas unloading stations shall be compatible with requirements specified in Section 3.0.

7.4 NERVA EFFLUENT HANDLING SYSTEM

This section defines the performance requirements for the NERVA Altitude Simulation System (NASS) and the NERVA Effluent Scrubber System (NESS).

7.4.1 Nerva Altitude Simulation System

7.4.1.1 Scope - This subsection defines the performance requirements for a NERVA Altitude Simulation System (NASS). The NASS consists of an exhaust duct (comprised of a diffuser, a plenum, and an ejector/ejectors) and a steam generation and delivery system (SGDS).

7.4.1.2 Guidelines - The NASS shall be designed for a minimum of 1000 engine test firings of 60 minutes each at full power when operated within the operation design values shown below.

Engine Parameters	Design Values
Gas Temperature (T_c), ^oR	4385
Thrust (F), lb	83,300
Propellant Flow Rate ($\dot{W}$), lb/sec	100
Chamber Pressure (P_c), psia	500
Nozzle Exit ID, in.	60
Area Ratio	28.65:1
Throat Area, in.^{2} (Nominal)	98.7
Engine Nozzle-to-Duct Inlet Gap, (Axial), in.	4 max.

7.4.1.3 Requirements

The NASS, installed in ETS-1, shall be capable of the following:

A. Permit the NERVA engine nozzle to flow full for engine chamber pressure above 350 psia without using the secondary ejector steam supply system.

B. Permit the engine nozzle to flow full for an engine chamber pressure of 200 to 350 psia using the secondary steam ejector.

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.

E. Provide capability for safe operation during cooldown testing of the engine.

F. Provide safe operation under malfunction shutdown of the engine.

G. Operate at an engine chamber temperature of 5000°R at a reduced cyclic life.

H. Operational requirements for the NASS are as follows:

Requirement	Engine Regime	NASS Requirement
Safety flow for engine standby condition	No power - but with H_2 on the stand	Low $\dot{W}$, no altitude, duration - 2 hr
200-350 psi (P_c) testing for controls and emergency mission	Engine nozzle must flow full	Minimum secondary ejector flow to flow nozzle full for 40 min duration.
Cooldown controllability demonstration	$\dot{W}$ = 1 - 10 lb/sec T_c = 1000-2000°R	0.4 psia for 6 min duration

I. The exhaust duct seals and ETC seals shall preclude the entry of air into the duct or ETC under all conditions of NASS flow.

J. The SGDS shall have a cyclic life of 2000 startup and shutdown cycles. The transient time (from zero flow to full flow or reverse) shall not exceed 15 sec.

K. Prevent the entrance of any foreign matter into the test article which may cause degradation of the test article or accidental criticality under normal or malfunction conditions.

L. The system shall be capable of recycling within the 2-to-3-day turnaround period.

7.4.2 NERVA Effluent Purification System

7.4.2.1 Scope

This subsection defines the performance requirements for a NERVA Effluent Scrubber System (NESS).

7.4.2.2 Requirements

7.4.2.2.1 The NESS shall have a designed life of a minimum of 2000 engine test firings of 60 min duration at full power.

7.4.2.2.2 The NESS shall service both ETS-1 and E/STS-2 consistent with the turnaround requirements of Paragraphs 3.3.1, 3.3.2, and 3.3.6 and access requirements of Figure 4-1 of this document.

7.4.2.2.3 The NESS shall not prevent the NASS from achieving its performance requirements.

7.4.2.2.4 The NESS shall treat the NERVA engine effluent as it is discharged from NASS (including any additional mass flows added to the effluent by NASS).

7.4.2.2.5 The NESS shall remove in excess of 99% of the isotopes of Sn, Sb, Te and I and a minimum 80% of all other isotopes except the noble gasses (i.e., xenon, krypton, etc.) from the NERVA effluent prior to releasing the effluent to the atmosphere.

7.4.2.2.6 The NESS shall be designed such that combustible mixtures of H_2 and O_2 within the NEPS are precluded at all times.

7.4.2.2.7 The NESS shall safely burn the engine effluent H_2, after treatment for radioactive contaminant removal, as it is released to the atmosphere.

7.4.2.2.8 The NESS shall include a waste disposal system. The waste disposal system shall be capable of removing and concentrating radioactive materials contained in any liquid used in NESS. Provision shall also be made for the safe removal, storage, and ultimate disposal of radioactive materials removed from the effluent stream by filters, ion exchange beds, chemical reactor, etc., which are part of NESS.

7.4.2.2.9 The concentrated radioactive materials shall be stored for future burial and/or controlled release. The radioactive material released to the environment by the waste disposal system shall be as low as practicable, and in no case shall exceed the limits listed in AECM 0524, "Standards for Radiation Protection".

7.5 INSTRUMENTATION AND CONTROLS

7.5.1 Scope - This subsection identifies the systems required to monitor and record all test data and perform the controls functions not provided with the test article as defined in Paragraphs 2.5 and 2.6. The data processing and display requirements are defined in Section 8.0. The ETS-1 I&C system is comprised of the following subsystems:

A. Data Acquisition System (DAS)
B. Facility Control System (FCS)
C. Ground Test Control System (GTCS)
D. Communication system (including television and photography)
E. Safety system
F. Electrical Power Distribution System for I&C.

7.5.2 Guidelines

A. The DAS shall be designed as a system to operate independently of the GTCS or FCS. These systems shall be physically and electrically isolated from each other to the extent practical. Connections between the systems must be made through suitable isolation devices. The GTCS shall be designed as a system to operate independent of, and isolated from, other facility I&C systems and shall be provided by the engine supplier.

B. Diagnostic signals shall be patchable from the DAS to the control system. Signals and parameters from the control system shall be patchable to the DAS for recording and display.

C. Simulation of engine controls, test controls, and facility controls functions shall be provided.

D. The test and facility control systems shall be operated remotely from the control center during setup, checkout, and operation. Limited local controls shall be provided.

E. Automatic checkout and calibration equipment shall be provided to the extent required to assure the capability to meet the 2 to 3 day turnaround time requirements.

F. The various systems will input the following channels to the DAS.

1. Engine I&C Subsystem - DAS to accept both digital and analog buffered signals for recording and display purposes to consist of 500 channels from the test article.

2. Ground Test Only Diagnostics - 400 channels of test article diagnostic data requiring signal conditioning and recording.

3. Facility Control Systems - Data channels requiring signal conditioning, amplification, recording and display.

   a. ETS-1/E/STS-2 Facility; 200 channels
   b. NASS Duct; 100 channels
   c. NASS SGDS; 100 channels
   d. NESS; 150 channels
   e. Shields; 100 channels

4. Ground Test Control System - Data channels requiring signal conditioning, recording and display:

   a. Facility; 100 channels
   b. Process System; 100 channels
   c. Cooldown System; 100 channels

G. Grounding and Shielding

The grounding system shall be an overall coordinated system and shall provide the following:

1. Compatibility with the test article.
2. Maximum suppression of noise and common mode voltages.
3. Maximum protection to personnel and equipment.

All equipment and cabling shall be shielded to minimize noise, cross talk, etc. The grounding and shielding approach shall be an integrated design. See also paragraph 7.7.7.

7.5.3 Data Acquisition System (DAS) - The DAS shall accept, condition, display (as required), and record all measurements from the test article and the facility systems. The system shall accept both unconditioned signals from transducers and signals that have been conditioned and buffered by other systems. The DAS shall i terface with the automatic data processing system (ADPS). The DAS shall include the following:

A. Transmission and distribution cabling system, including cables, cable trays, terminal columns, boxes, cable-termination racks, switching and patching equipment, patch panels, and miscellaneous system hardware.

B. Transducers, signal-conditioning system, including signal conditioners, amplifiers, checkout and setup equipment and calibration (both manual and automatic) system.

C. Digital recording system including multiplexers, digitizers, buffering and formatting equipment, recorders, operator consoles, displays, and readout devices. Incorporation of input ranging, scaling, and conversion is required. This system shall be designed to handle 1500 channels of data at 0.2% accuracy.

D. Analog recording system, magnetic tape recorders, recording-playback, duplication verification and tape-search electronics, operator consoles or stations, displays and readout devices. Strip charts (single and multiple channels) and optical oscillographs with direct writing capability. This system shall be designed to handle 150 channels of narrow and wide band data at 1.0% accuracy.

E. Event-recording system, including multichannel event records and edge markers on strip charts and oscillographs.

F. Provisions for the addition of a telemetry ground receiving station at a later date.

G. Timing systems capable of producing coded digital and analog signals for recording systems, support systems, control systems, and other applications.

7.5.4 Facility Control System (FCS)

A. The system shall provide the operational controls for all facility systems that do not functionally interface with the NERVA engine. The major systems are:

1. NERVA Altitude Simulation System (NASS), and associated subsystems.

a. Exhaust duct and plenum
b. Steam Generator and Distribution System (SGDS)
c. Engine Test Compartment (ETC)

2. NERVA Effluent Scrubber System (NESS)

3. Test Support System (TSS) and associated subsystems.

   a. Process water system
   b. Duct vault and pipe chase inerting system
   c. Fluid service and storage systems (gas and liquid)

4. Facility operations uspport systems

5. Test operations support consoles

B. The system will consist of transducers, signal conditioning, and operating/display consoles.

C. The system shall provide a means for subsystem checkout, testing, and operator training.

D. The FCS shall be capable of providing signals to the GTCS for logic and interlocking.

E. The FCS shall interface with ADP as necessary to support digital control systems.

7.5.5 Ground Test Control System (GTCS)

A. The system shall provide the operational controls for systems which functionally interface with the NERVA engine and are required to perform simulation, checkout, and testing of the test articles.

B. The Auxiliary Engine Control System (AECS) will control and monitor the test article by providing the following functions:

1. Provide engine I&D with simulated-stage digital test commands.
2. Provide engine I&C with simulated-stage digital calculated parameters.
3. Provide display of engine I&C status and analysis of engine control performance.
4. Provide backup engine and reactor safety system for ground test safety.
5. Provide engine control not provided by the engine I&C.
6. Provide test consoles required for support of the test article and the AECS.
7. Provide the test stand neutronic instrumentation system.

C. The Test Control System (TCS) equipment that controls those systems that directly interface with the performance of the test article consists of the controls for the following:

1. LH_2 run tank.
2. Emergency cooldown systems (liquid and gas).
3. Engine purge and actuation.

4. Test control consoles associated with these systems.
5. Equipment for intersystem controls.
6. Stage tank pressurization simulation system.

D. The GTCS shall provide simulation equipment for support, checkout, and operator training of the GTCS and AECS systems.

E. The GTCS shall include patching through suitable isolation devices for interfacing with the engine I&C, FCS, and DAS.

F. The GTCS shall provide test stand nuclear instrumentation. The nuclear instrumentation shall monitor the reactor nuclear radiation over the complete range of reactor operation and shall provide neutronic control and display signals required for the test stand control system. The test stand nuclear instrumentation shall include the following:

1. Startup channels that monitor reactor power levels from source level to five decades above source level. Also provide count rate and log count rate signals to the LRE console for display.

2. Linear channels that monitor power levels of multiranges. Range linear output signal (1 decade/range) and a range indication to the LRE for console display.

3. Logarithmic channels that monitor power levels and provide single range displays over wide power level ranges.

4. Calibration capabilities that provide positioning a source at multiple positions and the means of calibration checkout when the shields are separated.

7.5.6 Communication System - The system shall be capable of providing the communication link via operational intercom, public address, radio, telephone, closed-circuit television, and photographic systems for the operation of the facility during the test program.

A. For the operational intercom, headsets shall be of a lightweight configuration. Particular attention is to be given to the strength of the wiring, connections, and plug configuration. Extension cords with molded plugs and jacks shall be provided. Explosion proof headsets with cut-off switches shall be provided for outside use.

B. For the radio system, three RF channels shall be provided. Portable two-way radios shall be provided in sufficient quantity to support facility and test operations.

C. The closed-circuit television systems shall be provided with camera outlets at strategic locations. Camera outlets shall be installed in a manner to allow quick installations.

D. The public address system must be heard from any location in the facility complex.

E. For the photographic system, bunker and camera locations shall be provided as required.

F. Telephone systems and stations shall be provided as required.

7.5.7 Safety Systems - The system shall be capable of monitoring, detecting, and activating alarms for such parameters as radiation, fire, smoke, hazardous gases, and O_2 content during the facility and NERVA engine operations.

A. Fire protection systems shall provide inerting and/or deluge where required.

B. The systems shall include a visual and aural warning system.

C. All readouts from safety monitoring devices shall be located in the immediate area of the LSE console, or on the Lead Safety Engineer console.

D. The meteorological monitoring system shall include sensors and indicators for wind velocity and direction, and ambient temperature (to be displayed in the LSE console).

7.5.8 Electrical Power Distribution for Instrumentation and Controls - This system will be divided into the following three separate categories:

A. Instrument bus which will supply power during test period to the data acquisition system, the signal conditioning equipment, and other systems sensitive to harmonics or voltage fluctuations.

B. Essential bus which will supply power during test period to control circuits, rectifiers, certain motor loads and other such vital loads, and back-up power to the engine I&C.

C. Utility bus which will supply power to the remaining loads during test periods, and to the entire ETS-1 area during non-test periods.

7.6 STRUCTURES

7.6.1 Scope - This subsection defines the performance requirements for major structures required to support the test program described in Section 3.0.

Major structures are defined as:

1. Test stand substructure
2. Test stand superstructure
3. Engine Test Compartment (ETC)
4. Exhaust duct cover shield (S-3)

7.6.2 Guidelines -

A. Selection of materials, surface finishes, shapes, and arrangement of structural systems in exposed locations shall be designed to minimize activation and contamination and to facilitate decontamination.

B. All structures and their contained equipment shall be designed to withstand the ground motion conditions produced by NTS underground testing and natural environment at NRDS.

C. All major structures shall be designed in accordance with FEO-1 "NERVA Facility Structural Design Standards".

D. The anticipated thermal and acoustical environment induced by the engine during full-power operation is (TBD) and (TBD).

7.6.3 Test Stand Substructures - The test stand substructure shall accept the static and dynamic, acoustic, and thermal loads imposed by the exhaust duct, test stand superstructure, soil, and duct vault inerting wall with the protection of added systems for deluge, inerting, etc.

7.6.4 Test Stand Superstructures - The test stand superstructure shall accept the static and dynamic, acoustic, and thermal loads imposed by the NERVA engine, exhaust duct, cabling, piping, and vessels supported within the superstructures with the aid of added systems for deluge, inerting, etc.

7.6.5 Engine Test Compartment (ETC) -

A. The shield system shall have the capability of closing to form the ETC by means of remote control from the Control Point.

B. The shield system shall have the capability of opening by means of remote control from the Control Point, to allow removal of the test article from the test stand.

C. Shield seals, seal purges, and penetration purges shall be provided to preclude entry of air into the ETC during periods when the ETC is at less than atmospheric pressure.

D. The ETC seals shall be established by means of remote control from the Control Point. Remote control of the seal purge pressure ranges shall be provided.

E. Audio, visual, and timing aids shall be provided to assist in remote operation of the shield system and installation and removal of the test article.

F. The ETC shall be capable of being opened, moved away from the engine, returned to test position, and sealed consistent with the 2 to 3 day turnaround requirements.

G. The ETC (shield system) shall be capable of an operating range of 0 to 12.8 psia and be able to withstand an over-pressure of 2 psig.

H. Shield coolant water control valves shall be remotely operated from the control point.

I. Shield coolant water flow rates shall be sufficient to maintain ETC shield internal water temperatures below 150°F.

J. Intermediate Shield interface - (TBD)

7.6.6 Exhaust Duct Cover Shield (S3) - The S3 shield shall attenuate radiation above the exhaust duct (after the hot engine and the collar have been removed) to a normally acceptable working level as defined in Table 4-1, Access Requirements.

The S3 shield shall serve as a base for the engine work platform, providing access to the engine TSA, and top shield penetrations.

7.7 BUILDINGS

7.7.1 Scope - This subsection defines requirements for the buildings needed to support the test program described in Section 3.0.

Major building geographical areas are defined as:

Area 10	Control center
Area 20	Substation
Area 30	Tank farm and forward control
Area 40	Test cell building
Area 50	Test stand

7.7.2 Guidelines - Buildings are defined as above- or below-grade, enclosed, functional areas.

All buildings shall be designed in accordance with FEO-1 "NERVA Facility Structural Standards".

All buildings shall be provided shielding as required in accordance with Table 4-1, Access Requirements.

7.7.3 Area 10 Control Center - A below-grade control center shall be provided for the facility and engine control systems, data recording processing and display, television control and monitoring, communications, life-support refuge area, cable termination, and decontamination facilities for personnel and equipment. The design population requirements for each building in Area 10 are shown in Table 7-2. The below-grade complex shall include, but is not limited to, the following rooms:

A. A common control room shall be allocated below grade for central control of the facility during non-run periods. The room will contain, but is not limited to, the following equipment:

1. Control consoles to allow refilling of Dewars and vessels with hydrogen, nitrogen, and other fluids. The pumping and conversion of liquid to gases shall be controlled from this area.

2. A series circuit RSV-SV safe/operate switching panel.

3. The LSE, EPC, and television Consoles.

4. A pressure level, temperature, special parameter, and communications console.

5. Systems status and conditions panel.

6. A series circuit power-on switch for each control-room console, and a control-room isolation switching circuit for simulator operation.

7. Immediately adjacent to the common control room there will be:

   a. A chart room for scheduling and status boards.
   b. Safety systems graphic display panels, and all alarm indicators.
   c. Other equipment or controls as considered necessary for central control of the facility.
   d. This room should be separated with full partitions from the common control room.

8. Layout of the common control room shall be such that access is easily controlled.

NOTE: It is considered that this common control center will be shared with E/STS-2 and will contain equipment and controls for systems which are common to both ETS-1 and E/STS-2.

B. An ETS-1 control room shall be allocated for control of engine tests at ETS-1.

1. This room shall contain the appropriate control consoles for those systems used only during engine tests, including the test director consoles, and appropriate control monitoring and display systems.

2. Layout of the ETS-1 control room will be such that access is easily controlled.

C. Engineering offices located below grade shall be allocated for engineers and shall contain space for desks, files, and other appropriate equipment. Space shall be provided for a complete set of facility blueprints, procedures, and check-lists.

D. Space shall be allocated below grade for a re-entry team staging and equipment room for re-entry team preparation. The room is to be equipped with appropriate radio, headset, headset extension cords, television monitors, and tool kits.

This room will be used for safety/rescue team standby during engine tests, for rad-safe standby, and underground access control personnel during engine tests. It should be a separately partitioned section of the life support area.

E. Space shall be allocated below grade for personnel decontamination. The room is to be appropriately equipped for this purpose and located in such a manner as to allow direct access from the outside area by re-entry personnel without entering other parts of the underground complex.

F. A Test Diagnostic Center (TDC) shall be provided to support the facility and test article operations.

G. Space for an operator team briefing room shall be allocated for use by the operator team for briefing, read through test discussion, critique and preparation for actual tests.

H. A life-support refuge area shall be located underground (large enough for the entire operating crew) and contain smoke protection devices, carbon dioxide removal equipment, breathing air supply, and various means of communication. This area will be used for other functions (i.e., staging room etc).

I. Space for a facility operations staging room shall be allocated for use by the facility operations crews in preparing for normal work, preparing necessary paper-work, and as a life-support refuge area.

J. Building space for above grade equipment facilities shall be provided for facility steam supply, heating and air conditioning, I&C equipment air conditioning, and 28-vdc battery systems.

K. A building space for above grade facilities, shops, and personnel shall be provided for the following:

1. Technicians lockers room with wash facilities and lavatories.
2. Technicians tool box and equipment room
3. Electrical shop
4. Electronics shop

5. Weld shop and minor mechanical repair shop
6. Heavy usage spare parts provisioning room (bonded stores).
7. Tool crib
8. Cryo-technicians tube shop, equipped with appropriate tube benders, flaring tools, vises, drill press, work benches, and associated equipment.
9. Technicians break room
10. Technical operations building (Engineering)
11. Technical service building

7.7.4 Area 20 - Substation - An above-grade building shall be provided for stationary diesel generators.

7.7.5 Area 30 - Tank Farm and Forward Control Rooms

A. Below grade forward control and termination rooms shall be provided for analog-to-digital conversion equipment, multiplexing and cable patching, and termination.

B. An above-grade building shall be provided for a local motor control center, high-pressure gas compressors, and air compressors.

7.7.6 Area 40 - Test Cell Building

A. Below grade electronics and terminal rooms shall be provided for I&C diagnostic signal conditioning and calibration equipment, cable patching, cable termination, and certain engine I&C equipment as required.

B. A below grade mechanical- and electrical-equipment room shall be provided for local heating and air-conditioning equipment and motor control center.

7.7.7 Area 50 - Test Stand

A. Below-grade vaults shall be provided in the test stand substructure for the exhaust duct, duct I&C cable terminating, and process-water piping manifolds.

B. A below-grade equipment room adjacent to the test stand shall be provided for installation of vacuum pumps, hydraulic pumps, local motor control center, elevator drive mechanism, and terminal boxes.

C. Building grounding grids of driven rods and buried bare-copper conductors shall be provided. Items that shall be connected to the grounding system include (but are not limited to) structural steel, reinforcing steel, metal sliding doors, window frames, gratings, handrails, crane rails, tracks, tanks, pipelines, motor frames, pumps, compressors, machine tools, cranes, welders, lightning protection systems, static wires, neutral wires, transformer cases, lightning arrestors, cable sheaths, cable shields, stress cones, potheads, dc minus, switchgear, motor control centers, panel boards, equipment racks, consoles, conduits, trays, duct banks, metal towers, propellant and gas unloading stations, low-voltage equipment, appliances, and receptacles. The ground system will be arranged to provide suitable connections for the I&C systems, dc negatives, and other systems as necessary (see also paragraphs 7.5.2G and 7.8.5).

7.8 UTILITIES

7.8.1 Scope - This subsection defines the requirements for the utilities needed to support the test program described in Section 3.0. The utility systems consist of: domestic water, waste disposal, electric power, diesel generator, and compressed air.

7.8.2 Guidelines

A. The utility systems shall be designed in accordance with the latest edition of applicable commercial codes and standards used for design in current industrial practices and pertinent requirements of NPC-325-1.

B. The design population for ETS-1 is 200 people per shift.

7.8.3 Domestic Water System - System storage shall be provided for domestic consumption and fire protection and equipment cooling not supplied as part of process water system.

7.8.4 Waste Disposal Systems

A. The sanitary waste system shall provide for the disposal of all domestic waste within the ETS-1 complex.

B. The contaminated waste system shall provide for the collection, conveyance and disposal of all contaminated waste water from the thermal spray protection and facility decontamination.

7.8.5 Electrical Power System - The electrical power and distribution system shall provide electrical power, as required, to all facility systems, the ground test control systems, and the test article during both test and nontest periods and under both normal and emergency conditions. Redundancy shall be incorporated into the system as necessary to ensure a highly reliable source of continuous power during engine test periods and an emergency source of power for safe termination of engine testing under emergency shutdowns. Selective tripping (tripping nearest the fault) shall be incorporated for efficient localizing of any possible fault. The electrical power system shall maintain a grounding system which is compatible with the I&C grounding system. The electrical power will be distributed from the following three separate buses:

A. Essential power bus for supplying power to control circuits, vital motor loads, the 28 vdc system rectifiers, and to any other load that requires a high degree of reliability. The essential bus will be supplied from diesel generators in parallel with the utility bus during test periods and from the utility bus only during nontest periods.

The 28 vdc system will also have appropriate battery banks floating on line, capable of supplying power required for engine shutdown in the event of a power system emergency.

B. Instrumentation bus for supplying power to such loads as data-acquisition and signal-conditioning equipment, pressure and flow controllers, and to vital loads that are sensitive to transient harmonics or voltage fluctuations. The instrumentation bus will be supplied from diesel generators during test periods and from the utility bus during nontest periods.

C. Utility bus for supplying power to facility support items such as motors, fans, air conditioner, compressors and lighting, and also, for supplying a backup source of power to the essential bus. The utility bus will supply power to the entire ETS-1 complex during nontest periods. The facility bus will be supplied with commercial power through the ETS-1 substation.

D. A system shall be provided, including load banks and breakers, to allow checkout of the diesel generators under simulated full-load conditions.

E. The neutral or negative leg of each system shall be grounded at, and only at, its point of origin (i.e., generator, transformer secondary, or battery bank). See also paragraph 7.7.7.

7.8.6 Diesel Generation Systems - Separate diesel generator systems shall supply the primary power to the essential and instrumentation buses during engine test periods.

7.8.7 Electrical Equipment - All electrical equipment shall comply with the applicable codes.

7.8.8 Compressed Air System - The system shall supply air for the operations of facility safety instruments, air-conditioning control systems, pneumatic tools, and flare systems.

7.9 SITE WORK

7.9.1 Scope - This subsection delineates the requirements for the roads, grading, drainage, railroads, and soil investigations required to support the test program.

7.9.2 Guidelines - The site work design shall be based upon the latest editions of the applicable commercial codes and standards used for design in current industrial practices and pertinent requirement of NPC-325-1.

7.9.3 Requirements

A. The road system shall provide access to all areas of the test complex for the mobile equipment required to operate, maintain, and repair ETS-1, and shall consider separation distance between vehicle access and personnel in hazardous areas (i.e., fill station, etc.).

B. The railroad system shall provide access to the test stand for all standard gauge railroad equipment required.

C. The grading and drainage system shall intercept and direct all water away from the test complex to natural drainage and collect drainage to prevent off-site damage. Specific provisions shall be made for directing and handling contaminated waste water.

TABLE 7-1

FIVE-YEAR CLIMATOLOGICAL SUMMARY (1962-1966)
YUCCA WEATHER STATION, NEVADA TEST SITE, NEVADA*

Latitude 36° 57' N
Longitude 116° 03' W
Elevation 3,924 Ft

Nevada State Grid (Central)
E 680,500
N 803,550

MONTH	Temperature (°F) Averages Daily Maximum	Temperature Averages Daily Minimum	Temperature Averages Monthly	Temperature Extremes Highest	Temperature Extremes Lowest	Degree Days (65°F Base)	Precipitation (Inches) Average	Precipitation Greatest Monthly	Precipitation Least Monthly	Precipitation Greatest Daily	Snow Average	Snow Greatest Monthly	Snow Greatest Daily	Relative Humidity % 4:00 AM PST	RH 10:00 AM PST	RH 4:00 PM PST	RH 10:00 PM PST	Wind(a) Average Speed (MPH)	Wind Prevailing Direction	Station Pressure (Inches) Average	Station Pressure Highest	Station Pressure Lowest	(b) Average Sky Cover Sunrise to Sunset	Avg. No. of Days Sunrise to Sunset Clear	Partly Cloudy	Cloudy	Precipitation ≥ 0.01 Inch	≥ 0.10 Inch	≥ 0.50 Inch	≥ 100 Inch	Thunderstorms	Temperature Max. ≥ 90°F	Max. ≤ 32°F	Min. ≤ 32°F	Min. ≤ 0° F
Jan	52.0	19.0	33.5	70	0	908	0.12	0.18	0.01	0.18	1.4	4.3	4.3	61	44	30	54	10.0	360	25.11	26.54	25.42	4.1	15	9	7	2	*	0	0	*	0	1	29	*
Feb	56.6	24.4	40.5	77	5	683	0.47	1.21	T	0.73	0.2	1.0	1.0	63	41	28	50	10.6	010	26.05	26.38	25.56	4.4	13	7	8	3	1	*	0	0	0	*	24	0
Mar	60.3	26.0	43.2	87	10	668	0.33	0.47	0.02	0.23	2.4	6.7	4.0	56	28	21	42	11.5	350	25.98	26.35	25.48	5.1	12	9	10	4	1	0	0	1	0	0	26	0
Apr	69.8	35.7	52.8	89	13	362	0.66	2.57	0.04	1.08	0.6	3.0	3.0	49	26	19	34	12.1	010	25.99	26.39	25.50	5.1	11	9	10	3	1	*	*	1	0	0	10	0
May	78.7	43.0	60.9	94	26	130	0.12	0.23	0.01	0.21	T	T	T	42	19	15	27	10.9	200	25.94	26.21	25.61	4.4	13	12	6	2	*	0	0	1	3	0	3	0
Jun	87.0	49.0	68.0	101	34	34	0.11	0.19	0.02	0.16	0.0	0.0	0.0	36	17	12	24	11.7	210	25.92	26.20	25.56	3.2	17	9	4	2	*	0	0	2	13	0	0	0
Jul	95.2	54.1	74.7	104	40	0	0.53	1.34	0.0	0.56	0.0	0.0	0.0	32	16	12	22	11.0	200	25.39	26.19	25.80	2.5	21	6	4	3	2	*	0	2	29	0	0	0
Aug	94.3	56.3	75.3	104	43	0	0.37	1.04	0.0	0.35	0.0	0.0	0.0	40	20	14	27	10.7	200	25.00	28.22	26.71	2.4	22	7	2	3	2	0	0	4	26	0	0	0
Sep	86.3	45.8	65.1	98	31	47	0.66	2.30	0.0	0.76	0.0	0.0	0.0	42	21	13	31	10.3	360	26.00	26.26	23.59	2.0	23	5	2	2	1	1	0	1	12	0	1	0
Oct	78.9	38.3	58.6	94	22	202	0.13	0.25	0.0	0.25	0.0	0.0	0.0	45	22	17	35	9.8	360	26.08	26.39	25.59	2.6	21	6	4	2	1	0	0	*	3	0	8	0
Nov	61.7	27.7	44.7	82	13	603	0.84	3.02	0.0	0.80	1.0	4.8	2.3	62	39	33	53	8.5	360	26.07	26.39	25.94	5.1	12	8	10	4	3	1	0	*	0	0	24	0
Dec	53.5	21.8	37.7	70	1	841	0.84	2.65	T	1.31	0.1	0.5	0.5	66	46	37	61	8.7	360	26.00	26.52	26.49	4.4	14	7	10	2	1	1	*	*	0	0	29	0
Ann.	72.9	36.8	54.8	104	0	4498	5.16	3.02	0.0	1.31	5.7	5.7	4.3	50	28	21	38	10.5	350	26.02	26.54	23.42	3.8	194	94	77	32	13	3	1	13	36	1	154	*

*One or more occurrences during the period of record but average less than 0.5 day.

T Trace, an amount too small to measure.

(a) Average wind speed is based on observations on the hour from towers of varying height during the period of record (9JY 100' tower 1/1/62 - 11/8/64, Yucca 9' tower 11/9/64 - 7/5/66, Yucca 30' tower 7/6/66 - 12/31/66). Prevailing wind direction was taken from the summary of 1-hr average winds for the BJY100 tower for the period 7/11/57 - 12/31/64.

(b) Sky cover is expressed in the range from 0 for no clouds to 10 for complete sky cover. Clear, partly cloudy, and cloudy days are based on average daytime cloudiness 0-3, 4-7, and 8-10 baths, respectively.

TABLE 7-2

POPULATION REQUIREMENTS AREA 10 CONTROL CENTER

	Location	Estimated Population
A.	Common Control Room Including Chart Room Meetings	30
B.	ETS-1 Control Room Runday	30
C.	Engineering Offices	22
D.	Reentry Team Staging and Equipment Room	24
E.	Personnel Decontamination	12
F.	Test Diagnostic Center	8
G.	Operating Team Briefing Room	58
H.	Life-Support Refuge Area	80
I.	Facility Operations Staging Room	10
J.	Above Grade Equipment Facilities	--
K.	Above Grade Shop and Personnel Facilities	
	1. Technicians Lockers Room	100
	2. Technicians Tool Box Room	--
	3. Electrical Shop	8
	4. Electronics Shop	12
	5. Weld Shop	10
	6. Spare Parts	--
	7. Tool Crib	--
	8. Cryo-Tech and Mech Shop	12
	9. Technicians Break Room	60
	10. Tech Ops Bldg (Engrg)	75
	11. Tech Services Bldg.	55

8.0 AUTOMATIC DATA PROCESSING

8.1 SCOPE

Automatic data processing (ADP) as defined herein encompasses computer equipment (hardware) and programs and procedures (software). The function of ADP will be to accumulate, process, make real time computations, and display in various formats the test procedures, test performance predictions, test data, system performance evaluations, and other programmatic information. The ETS-1, E/STS-2, and TCC ADP requirements as defined in other F004 data items should all be interrelated to provide consistent operation and maximum flexibility.

8.2 GUIDELINES AND DESCRIPTION

8.2.1 The primary purpose of the ADP system is to make the engine system and facility data available for interpretation and evaluation by human observers; consequently, presentation of information processed by the ADP system shall be in the most readily understandable form possible, normally in real time and utilizing cathode-ray-tube (CRT) displays.

8.2.2 The data processed by the ADP system shall be made available in the control room as a direct source of information for the test director and the operating crew.

8.2.3 A test diagnostic center (TDC) shall be provided in which processed engine and facility data are displayed so as to permit the evaluation of performance by properly trained and experienced personnel. Capability shall be provided to permit presentation of processed data in real time and by recall from recorded data.

8.2.4 Since the testing schedule requires 2-3 day turnaround, the post-test evaluation of performance must be accomplished during and immediately after the test operations are completed with recommendations no later than 16 hr after the run. To accommodate these requirements, the immediate replay and capability for random access and display of the processed test data shall be provided.

8.2.5 The ADP system shall interface with I&C systems (see Sections 7.5.3, 7.5.4, and 7.5.5) such that all ETS-1 I&C channels can be accepted, processed, and displayed in real time as required by any specific test. Digital control systems shall be supported as necessary.

8.2.6 The ADP system and the I&C system shall be independent (buffered) such that failure of any component in one system will not impede the proper functioning of the other system.

8.2.7 Accomplishment of all data processing activities that are routine is to be undertaken by the ADP system insofar as practicable.

8.2.8 The ADP system shall be installed on a schedule and in such a manner that support of the activation evaluation, checkout, and acceptance testing of the facility shall be provided.

8.2.9 Failure of the ADP shall not preclude the safe shutdown and cooldown of the test article.

8.3 REQUIREMENTS

8.3.1 Introduction

A. Processing of data and information by computer is required to support the operation and the evaluation of the NERVA engine and reactor tests to be performed at NRDS over the next decade. The ADP system requirements are governed by the general requirements of rapid turnaround between tests and the immediate (on line) interpretation of the test article and facility performance data as the results of one test influence subsequent tests.

B. The basic features of the ADP system will include a computer to which the test data are delivered. These data must be converted to engineering units, processed as necessary, and delivered to appropriate graphic display units for evaluation both during (i.e., in real time) and after the test operations. Insofar as possible the ADP system must be arranged to accomplish those performance evaluation operations that are or become routine in nature. Specifically the ADP system shall consist of the hardware and software necessary to accommodate the following functional and display requirements.

8.3.2 Real-Time Engineering Analysis - All data produced by the test article and the facility shall be delivered to the computer in real time. These data include the output of the narrow-band digital data system (1700 channels), the wide-band system (130 channels), and the events (2000 channels). Capability shall be provided to convert this raw data to engineering units in real time and for making engineering calculations using the engineering unit data as necessary. These engineering calculations will be performed by a library of up to one-hundred FORTRAN subroutines and that the actual set of calculations performed for any one test will be variable.

8.3.3 Data Recording - Record all data in raw form as specified in paragraph 7.5.3 prior to delivery to the computer. Provision shall be made to recall the raw data by replay into the ADP system. In addition, the computer processed data-engineering unit data, as well as calculated data shall be recorded in rapid access device which shall be of sufficient size to permit the collection of a minimum of 300 channels of test data during one hour of operation. Data compression techniques will be used. Accessibility in real time shall be provided to all data in the rapid access devices.

8.3.4 Post-test Analysis Support - Accessibility to data from the rapid access devices during the periods between tests shall be provided. Availability of the processed and stored information shall be in the same forms or modes as were available during the tests. This availability shall be accomplished by time sharing or in some manner such that significant interference with computer usage in support of preparation for subsequent tests shall not occur.

8.3.5 Console Displays - All real-time data processed by the computer shall be available for graphic display. In addition, the data in the rapid access devices shall be available for graphic display in the test diagnostic center and for graphic, digital or analog display in the control room. Six CRT display units (including two provided by E/STS-2) with full graphic capability are required in the test diagnostic center. Three CRT display units are required in the ETS-1 control room, and one unit (supplied by E/STS-2) is required in the common control room.

8.3.6 Test Limits Monitoring - Capability for the identification of up to 200 channels of engineering units or calculated parameters for comparison with predetermined limits shall be provided. Approach to the limit and the reaching or exceeding of the limit shall be signaled and presented automatically on one or more of the graphic display units. In addition, provision to introduce an audible signal into the communication net (e.g., a recorded voice warning of the approach to the test limit) shall be provided.

8.3.7 Chronology - Capability to collect, store, and display on demand a list of significant events in chronological order with the associated run time of the event shall be provided. The individual events shall be taken from the predetermined list of approximately 100 occurrences. The particular occurrence or event shall be identified automatically with the specific data channel which experienced the change.

8.3.8 Data Calibration and Performance Analysis - The ADP system shall be capable of performing a prerun calibration of the data system associated with the test article and facility systems. Anomalous performance shall be displayed on a CRT and/or printed out to serve as a record in maintenance files. The ADP system shall be capable of postrun calibration and analysis of the data system performance.

8.3.9 Channel Engineering - In addition to the rapid access devices for the storage of test data, a random access storage device shall be provided in which all data channel information is stored. This information shall be retrievable on CRT display units. Updating capability shall be provided directly from the CRT console, and provision shall be made for adequate control and approval of changes to the stored information. The large quantity and type of information associated with each channel will require retrieval and display in more than one mode.

8.3.10 Maintenance Record Storage - The ADP system shall be capable of accepting, recording, and retrieving corrective and preventative maintenance data and trend data information for the facility and test system.

8.3.11 Wide-Band Data Processing - The ADP system shall be capable of receiving the wide-band data signals, processing these data, and presenting the processed result for display as transfer functions. Vibration shall be processed and displayed as functions of time and frequency. In addition, capability for the reduction of accelerator output to displacement shall be provided.

8.3.12 Engineering Data Processing - The ADP system shall be used to provide a processing capability for personnel at NRTO to perform engineering calculations.

8.3.13 Digital Control Systems - The ADP system shall be capable of processing data and providing control signals as necessary in support of FCS and GTCS.

9.0 SPECIAL TEST EQUIPMENT (STE)

9.1 SCOPE

This section contains the currently identified Special Test Equipment (STE) required to support the NERVA engine test program at ETS-1.

9.2 GUIDELINES

For the purpose of this document, STE is defined as that equipment required to verify that the facility is qualified for, and capable of supporting the test program specified in Section 3.0. STE is further defined as that equipment required to install and connect the test article to the facility, and that equipment needed to assist in facility checkout, and is not required during normal operations.

9.3 REQUIREMENTS

The following STE shall be provided:

9.3.1 Engine Flow Test Device - A device used to checkout the facility gas system, and the turbopump drive gas for the engine simulator, and to demonstrate the reliability and adequacy of the facility including the NASS exhaust duct system.

9.3.2 Top Shield Bypass Line - A bypass line is required on the test stand above the top shield level. This line will be used to permit flow testing of engine fluids without interferring with the top shield and run-tank modifications. The engine fluids which will be flow tested with this device are the cooldown gases (GH_2 and GHe) and the LN_2 and LH_2 emergency cooldown supply. The device is not STE in that it is a permanent part of the facility. It will interface downstream of LF 7. Fluid will pass from there through a spectacle blind flange and a control valve to FS-5001, or the duct bypass (temporary flare stack).

9.3.3 Propellant Supply Line Test Device - This temporary STE will be used only if the engine flow test device is not ready in time. The propellant supply line test device will connect the two propellant supply lines below the top shield to a common line which will connect to the duct bypass flare stack.

9.3.4 Duct Bypass Flare Stack - The existing temporary flare stack will be reactivated and PCV-750 returned from Test Cell C. This flare stack will accept LH_2, LN_2, GH_2, and GHe from the engine flow test device.

9.3.5 Duct Collar Plug - A duct collar plug will be required for ETC leak testing. It is to be designed to withstand a pressure differential of 13 psia. Modification of the existing plug will be considered.

9.3.6 NASS Steam Line Simulator - A "tee" to be installed downstream of the SGDS to provide checkout of the steam generator system without flow through the steam line.

9.3.7 Side Shield I&C Checkout Cables - Cables for connecting from remote connector panels to the side shields in parked (open) position for checkout of the channels prior to bringing shields to test position.

9.3.8 Facility Activation Test (FAT) Console - A separate console (located in the control room) will be utilized for the controls and indications which are used only for facility test.

9.3.9 TSA and T... hrust Structure - The structures between Station 0.00 and ... e interface. It supports the engine weight, acts as a thru... ission device, contains the fluid, gas, and electrical ... ects, the propellant lines and shutoff valves, the coold... and valves, and environmental instrumentation.

9.3.10 Weight/E... ck-up (WEMU) - A device used to verify the engine/ TSA inter... installation and removal clearances; the facilities capabili... pting the test article; and the capability of the EIV/MCC ... and remove the test article at ETS-1.

9.3.11 ETC Test ... Pump Setup - A high-capacity vacuum pump(s) will be requi... cuate the ETC to conduct ETC mechanical seal and leak tes... quipment used for the XE program will be utilized to the e... tical. Pumps, piping, bracing, and control are included

9.3.12 EIV/MCC - ... ne Installation Vehicle (EIV) and Manned Control Car (MCC) ... to install and remove the test article at the ETS-1 facility.

9.3.12 Scrubber ... Device - A device used to verify the scrubbers system c... to meet its design criteria.

9.3.14 Tempora... eld - A device to be used during facility tests with ET... pen to protect the test stand and ETC.

9.3.15 I&C Tr... nal Simulators - A device used to simulate transducer or othe... or use in data ranging, operator training, and facilit...

10.0 FACILITY QUALIFICATION REQUIREMENTS

10.1 SCOPE

The ETS-1 facility will be reactivated, checked out, and qualified by a set of parallel and serial subsystem tests. This section covers the activities leading up to final facility qualification by hot engine firing during DE-2. The final ETS-1 qualification will not occur until after the first DE-2 rated power test.

10.2 GUIDELINES AND ASSUMPTIONS

10.2.1 The NERVA Altitude Simulation System (NASS) and the Test Support System (TSS) will be activated and tested in parallel, with neither test dependent on the other.

10.2.2 Facility capability will be demonstrated to support the following engine testing requirements.

A. Six 10 minute full power runs per test.
B. Two three day turnaround per test.
C. Six-week turnaround between engines.
D. Forty-eight hour turnaround between stands.

10.2.3 The effluent scrubber will be checked out in conjunction with the NASS.

10.3 SPECIFIC QUALIFICATION REQUIREMENTS

Section 7.0 of this document describes the ETS-1 facility system requirements. There are four major facility elements: (1) Test Support Systems; (2) NERVA Altitude Simulation System; (3) Interface System; and (4) Instrumentation and Controls. This section will describe the specific qualification requirements of these four facility elements.

10.3.1 Test Support Systems (TSS) - Qualification of the Test Support Systems will require testing of the propellant supply, high-pressure LH_2, high-pressure gas (H_2, N_2, and He), LN_2, process H_2O, and supporting auxiliary systems (i.e., facility hydraulic, facility pneumatic, TSER inerting, and purge systems). Simulation of engine flow dynamics and impedance (pump and valve) will also be required. The test will flow each fluid in the sequence and at the conditions required to support the engine test program described in Section 3.0 and shall qualify the test support systems and demonstrate the following specific requirements:

A. Provide sufficient coolant flow to protect the engine so it may be restarted if the normal propellant supply is lost.

B. The individual systems do not interact adversely when operated in the required sequence.

C. The individual system setup and operating procedures provide sequencing flexibility and usage within the inventory capability. Prior to the qualification test, each subsystem will have been tested separately to meet the following requirements or objectives.

1. Blowdown to verify cleanliness.
2. Leak and pressure test (cryogenic lines will be cryo-soaked first).
3. Functional test of valves, controllers, flow meters, etc.
4. Flow test to verify:

   a. That system modifications as designed satisfy functional requirements.
   b. That procedures are adequate.
   c. Operating characteristics, such as pressurization/vent characteristics, pressure/flow relationships, chill and chill maintenance logic, etc.

5. Demonstrate data handling techniques and analytical methods.
6. Demonstrate operator proficiency.

10.3.2 NERVA Altitude Simulation System (NASS)

A. Steam Generator Delivery System (SGDS)

1. Water Supply System - Proof and leak test; functional check of all valves for correct direction of travel, stroke length, stroke/time relationship seal capability, and failure mode; instrumentation; pressure drop vs flow rate capabilities, pressure surge/water hammer, and other transient performance.

2. Hot-Water System - Proof and leak test; functional test valves as described in 1. above; instrumentation; heatup times; establish steam delivery efficiency; flow rate capabilities, pressure surge/water hammer effects; and verify pressurization and system vent characteristics.

3. Steam Generation - Proof and leak test, function test of valves and components as described in 1. above; startup/transient characteristics; steady-state operation parameters; pressure/flow relationships; heat-transfer characteristics; and shutdown characteristics.

B. Steam Line - Proof and leak test; pressure/flow characteristics; heat-transfer data; thermal loading and dynamic effects.

C. Duct

1. Water Flow - Determine pressure drop/flow distribution; flow balance; and spray patterns satisfy design criteria.

2. Gas Flow - Verify aerodynamic performance to the extent possible with ambient gas; verify proper flare operation under inert then combustible gas flow.

3. Steam Ejectors - Secondary ejector/ETC pull down performance characteristics; steam heat load on the duct; effect on flare.

D. Engine Test Compartment (ETC)

1. Water Flow - Proof and leak test; valve functional test; flow-rate/pressure-drop relationships; control-valve position/inlet pressure/flow-rate relationships; instrumentation and connectors.

2. Seal - ETC seal and seal cavity purge test, H_2 and detectors check.

E. NERVA Effluent Scrubber System (NESS)

1. Water Flow - Determine flow distribution and balance as required.

2. Gas Flow - Determine aerodynamic performance and particle scrubbing efficiency by artificial particle and gas injection.

10.3.3 Interface Systems (IFS) - The following test stand and auxiliary systems will be reactivated and tested in conjunction with the TSS and NASS. In many cases these test stand systems are required to support other tests so that it will be necessary to activate these systems early.

A. Hydraulic

B. Purge - GHe and GN_2

   1. Cryogenic systems purge.
   2. ETC purge
   3. UTS purge
   4. Engine purge

C. Facility Valve Pneumatic Actuation System

D. Top Shield Penetration System

E. Vent System

F. Space Inerting Systems

G. Safety

   1. Fire protection
   2. Gas detectors (Propane, H_2, O_2)
   3. Radiation, gas and particulate
   4. Criticality

H. Electrical Power

NOTE: The various systems mentioned above will not necessarily be qualified on a subsystem basis. The actual qualification of these systems will be the result of the TSS and NASS qualification tests.

10.3.4 Instrumentation, Controls and Automatic Data Processing - These qualification tests will verify the accuracy, integrity, and system characteristics of all subsystems, components, and elements of the I&C system. Upon completion of these tests, an integration systems checkout and qualification test will be performed to qualify the systems for facility activation and NERVA engine testing.

A. Instrumentation

1. Digital Data System
2. Analog recording system

    a. Wide-band data
    b. Narrow-band data

3. Signal conditioning
4. Transducer and cabling

B. Controls

These qualification tests pertain to facility control system, and ground test control system.

1. Component and channel verification
2. System functional test
3. Component qualification test, (e.g., valve response test)
4. Electronic simulator checkout

C. Automatic Data Processing (ADP)

These qualification tests pertain to both the software and hardware elements of the system:

1. Digital data interface
2. Data link interface
3. Test diagnostic center (TDC)
4. Quick-look data processing
5. Operator console displays
6. Control systems interface

10.4 INTEGRATED ETS-1 TESTS

The final phase of facility qualification prior to E-engine installation consists of a series of tests where the facility is operated in an engine test configuration. It is anticipated that there will be four tests over a period of six weeks, with the last two tests conducted on a 48-hr turnaround basis. The objective of these tests is to demonstrate the following:

10.4.1 All facility systems operating in unison without system interactions.

10.4.2 Facility evaluation team capability (a precursor to the SPEAR team).

10.4.3 Facility operating team readiness.

10.4.4 Facility operating duration (six 10-minute tests).

10.4.5 Fluid restock capability (2-3 day turnaround).

10.4.6 Facility can be maintained in a ready state for extended periods of time.

10.4.7 Final verification of facility setup procedures.

10.4.8 Demonstrate multi-team operating concept.

10.5 FACILITY ACTIVATION AND QUALIFICATION LOGIC

The ETS-1 facility activation and qualification will be a serial effort between BOD and E-1 installation. A consistent activation logic will be developed as early as possible. The purpose of this logic is to identify from the testing standpoint those systems required earliest. Long-term planning of this nature is essential to effectively modify and activate ETS-1. The activation logic will be a precursor to the detailed engineering and scheduling of modification work.