C002

AEROJET NUCLEAR SYSTEMS COMPANY

A DIVISION OF AEROJET-GENERAL

NERVA

Data Item No.
C002-CP090290A-F1

Specification No. CP-90290A

Part 1 of 2 Parts
Page 1 of 89 Pages

DETAIL SPECIFICATION

PART 1

PERFORMANCE/DESIGN AND QUALIFICATION REQUIREMENTS

FOR

ENGINE, NERVA, 75K, FULL FLOW

BASIC ISSUE APPROVED BY:

W. O. Wetmore 9/8/70
W. O. Wetmore — DATE
Vice President and
NERVA Program Director

BASIC ISSUED APPROVED BY:

SNPO-C — DATE

SNPO — DATE

Classification Category
UNCLASSIFIED

9/8/70
Classifying Officer — Date

AEROJET NUCLEAR SYSTEMS COMPANY

A DIVISION OF AEROJET-GENERAL

NERVA

Data Item No.
C002-CP090290A-F1

Specification No. CP-90290A

Part 1 of 2 Parts
Page i of i Pages

DETAIL SPECIFICATION

PART 1

PERFORMANCE/DESIGN AND QUALIFICATION REQUIREMENTS

for

ENGINE, NERVA, 75K, FULL FLOW

	Replace page(s) with the latest revised page(s) noted below. Revised paragraph(s) are annotated with the latest revision in the margin.
	REV LTR A
Page	DATE
No.	ECP
1 thru 89	
I-1	
II-1 thru II-18	

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

LIST OF TABLES

LIST OF TABLES (Cont.)

LIST OF FIGURES

ATTACHMENTS

Section 1. SCOPE

This part of this specification defines the requirements for the performance, design, and qualification of equipment identified as the NERVA Nuclear Rocket Engine, Contract End Item (CEI) No. 90290 as established by the NERVA Program Requirements Document, SNPO-NPRD-1. This CEI, hereinafter referred to as the engine, is used as a source of primary propulsive power for both manned and unmanned space vehicle applications. The engine is designed to operate at a vacuum thrust level of 75,000 lbs and a specific impulse of 825 seconds and shall be man rated. The engine requires externally supplied liquid hydrogen, command signals, and electrical power. Rated thrust is achieved at a nominal thrust chamber pressure of 450 psia and a nominal design thrust chamber temperature of 4250° Rankine and with a nozzle having an expansion ratio of 100:1. Endurance at rated temperature shall be 600 accumulated minutes. The operating time is utilizable in multiple cycles up to 60 with durations of varying lengths up to 60 minutes.

1.1 Mission Definitions - The following missions are used in the definition of NERVA requirements. Payloads shall be maximized consistent with the engine performance requirements of this specification.

(a) Reusable Interorbit Shuttle - To shuttle payloads (manned and unmanned) between a 262 nautical mile earth orbit and a space station in lunar or geosynchronous earth orbit and return for reuse.

(b) Unmanned Deep-Space Injection - To place a large unmanned payload on a deep space trajectory using the reusable nuclear shuttle from 262 nautical mile earth orbit and returning the shuttle vehicle to earth orbit for reuse.

1.2 Launch Vehicle Definition - The engine shall be capable of being launched into earth orbit by an INT-21 (SIC/SII) launch vehicle modified for a nuclear third stage.

1.3 Support Systems Definition - The engine shall be compatible with the following support systems:

a. Orbiting Propellant Depot
b. Space Stations (Lunar and Geosynchronous)
c. Spacecrafts and Space Vehicles
d. Operational Ground Facilities
e. Aerospace Ground Equipment
f. Aerospace Space Equipment

1.4 Man Rating Definition - The engine shall be defined as man rated when it has met the requirements of this specification. (1)

Section 2. APPLICABLE DOCUMENTS

2.1 Government Documents - The following documents form a part of this specification to the extent specified herein. The issue used shall be that controlled by the latest approved contractor's controlled documents list. When the requirements of this specification and other documents are in conflict, the following precedence shall apply:

(a) NERVA Program Requirements Document
(b) This Specification
(c) Other documents referenced herein
(d) Documents subsidiary to those referenced herein

SPECIFICATIONS

Military

MIL-D-1000	Drawing, Engineering and Associated Lists
MIL-B-5087	Bonding, Electrical, and Lightning Protection, for Aerospace Systems
MIL-E-6051	Electromagnetic Compatibility Requirements, Systems
MIL-I-6866	Inspection, Penetrant Method of
MIL-I-6868	Inspection Process, Magnetic Particle
MIL-W-8160	Wiring, Guided Missile, Installation of, General Specification for
MIL-E-8189	Electronic Equipment, Missiles Boosters and Allied Vehicles, Specification for
MIL-I-8500	Interchangeability and Replaceability of Component Parts for Aircraft and Missiles
MIL-I-8950	Inspection, Ultrasonic, Wrought Metals, Process for

National Aeronautics and Space Administration

MSFC-SPEC-234	Nitrogen, Space Vehicle Grade
MSFC-SPEC-356	Hydrogen, Liquid
MSFC-SPEC-364	Helium

Space Nuclear Propulsion Office

SNPO - C-1	Structural Design Specification
SNPO - C-6	External Environments - Definitions and Requirements

STANDARDS

Military

MIL-STD-100	Engineering Drawing Practices
MIL-STD-130	Identification Marking of US Military Property
MIL-STD-143	Specifications and Standards Order of Precedence for the Selection of
MIL-STD-171	Finishing of Metal and Wood Surfaces
MIL-STD-453	Inspection, Radiographic
MIL-STD-1247	Marking, Functions and Hazard Designations of Hose, Pipe, and Tube Lines for Aircraft, Missiles, and Space Systems
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities

PUBLICATIONS

Department of Defense

DOD 5220.22-M	Industrial Security Manual for Safeguarding Classified Information

Air Force

AFETRM 127-1	Air Force Eastern Test Range Manual

Atomic Energy Commission

Manual Chapter 0529	Safety Standard for the Packaging of Radioactive and Fissile Materials
CG-RR-3	Rover Classification Guide

Space Nuclear Propulsion Office

SNPO-NPRD -1	NERVA Program Requirements Document

2.2 Other Publications - Not applicable.

2.3 Aerojet/Westinghouse Documents -

2.3.1 Aerojet Nuclear Systems Company Documents. - The following documents form a part of this specification to the extent specified herein. The issue used shall be that controlled by the latest approved contractor's controlled documents list. When the requirements of this specification and other subsidiary documents are in conflict, the following precedence shall apply:

(a) This Specification.
(b) Other documents referenced herein.
(c) Documents subsidiary to those referenced herein.

SPECIFICATIONS

EC-90117	Propellant Shutoff Valve & Actuator
EC-90121	Turbine Block Valve & Actuator
EC-90122	Bypass Control Valve & Actuator
EC-90149	Turbopump Assembly
EC-90151	Nozzle Assembly Subsystem
EC-90152	Thrust Structure Subsystem
EC-90154	Pressure Vessel and Closure Subsystem
EC-90192	Structural Support Coolant Valve
EC-90214	Instrumentation and Control Subsystem
EC-90218	Propellant Feed Subsystem
EC-90242	Destruct Subsystem
EC-90243	External Shield Subsystem
EC-90244	Gimbal Assembly Subsystem
EC-90246	Pump Discharge Check Valves
EC-90257	Bypass Block Valve and Actuator
EC-90258	Cooldown Supply Control Valve and Actuator
EC-90261	Structural Support Block Valve and Actuator

EC-90276	Cooldown Shutoff Valve and Actuator
EC-90281	Turbine Discharge Block Valve and Actuator
EC-90283	Turbine Throttle Valve and Actuator
DS-90176	Nozzle Extension
DS-90196	Nozzle
DS-90251	Gimbal Actuator
DS-90263	Stage Tank Pressurization Line and Check Valve
DS-90264	Engine Purge Unit
DS-90267	Upper Thrust Structure
DS-90269	Lower Thrust Structure
DS-90284	Propellant Lines

STANDARDS

AGC-STD-1004	NERVA Program Terminology (1)
AGC-STD-4004	Engineering Acceptance Criteria for Castings
AGC-STD-4005	Engineering Acceptance Criteria for Welds
AGC-STD-4006	Engineering Acceptance Criteria for Wrought and Forged Products
AGC-STD-9012	Wiring, Routing and Termination of
ASD-5229	Metals, Dissimilar, Definition and Use of

PUBLICATIONS

Reports

2275	Materials Properties Data Book

Data Item

C103-CP090290-F1	Measurement Design Requirements (1)
P017-SS090205-F1	Product Assurance Program Plan
R101-CP090290-F1	Reliability Program Plan (1)
S007-CP090290-F1	Electromagnetic Compatability Plan
S019-CP090290-F1	Safety Plan
S021-CP090290-F1	Contamination and Corrosion Control Plan
S131-CP090290-F1	Materials Plan

DRAWINGS

1136393	NERVA Flight Engine Nuclear/Non Nuclear Interface Control Drawing
1137401	75K NERVA Flight Engine Flow Diagram
1136403	NERVA Engine Module/Stage
1137101	NERVA Engine Specification Tree
1137400	75K NERVA Flight Engine Layout, Full Flow

2.3.2 Westinghouse Astronuclear Laboratory Documents - The following documents form a part of this specification to the extent specified herein. The issue used shall be that controlled by the latest approved contractor's controlled documents list. When the requirements of this specification and other subsidiary documents are in conflict, the following precedence shall apply:

(a) This Specification.
(b) Other documents referenced herein.
(c) Documents subsidiary to those referenced herein.

SPECIFICATIONS

CP-677555	Nuclear Subsystem
EC-677558	Cluster Hardware
EC-677559	Reflector Assembly
EC-677561	Support Plate and Plena
EC-677562	Internal Shield
EC-677564	Core Periphery
EC-677565	Nuclear Subsystem Instrumentation
EC-677566	Fuel Elements
EC-677575	Structural Support Coolant Assembly
EC-677576	Structural Support Coolant Valve Actuator
EC-677585	Control Drum Drive Assembly

Section 3. REQUIREMENTS

3.1 Performance - The engine shall be capable of meeting the performance requirements specified herein.

3.1.1 Functional Characteristics.- The engine shall be capable of performing operational functions specified herein.

3.1.1.1 Primary Performance Characteristics.-

3.1.1.1.1 Operational Modes - The engine shall be capable of performance as specified in 3.1.1.1.5, (Impulse and Controllability Requirements) while operating in the following modes: (See Section 6.2 for definition of operational modes.)

(a) Normal Mode
(b) Malfunction Mode
    (1) Single Turbopump Operation
    (2) Component Malfunction
(c) Emergency Modes

(1)

3.1.1.1.2 Vacuum Performance Rating - The engine performance rating is based on nominal vacuum thrust using liquid hydrogen as specified in MSFC Specification 356 with a 100:1 nozzle area ratio as follows:

(a) Thrust - 75,000 ± 2000 lb which includes a ± ~~TBD~~ 1500 lb controllability tolerance. (Thrust considered parallel to the pressure vessel axis).

(b) Specific Impulse - 825 sec ± 0.75% (which includes a ± TBD % controllability tolerance but does not include allowable operating H_2 leakage nor H_2 required for tank/ STAGE OPERATION ~~pressurization~~.) Minimum Specific Impulse - ~~TBD~~. 819 WITH FLIGHT VEHICLE Isp TRIM SIGNAL.

(c) Nominal Chamber Pressure - 450 psia (The nominal chamber pressure is the stagnation pressure).

(d) Nominal Chamber Temperature - 4250°R (The nominal chamber temperature is the stagnation temperature).

(e) Normal Mode Endurance - 600 minutes at rated temperature (accumulated in up to 60 cycles of varying duration up to 60 minutes maximum per cycle).

(f) In meeting the thrust and impulse requirements all components must perform within their specified tolerances.

3.1.1.1.3 Operational Constraints - The engine shall be capable of operating at any selected point within the operational constraint map shown in Figure 1.

During thrust buildup and retreat, the engine shall be capable of chamber temperature ramp rates of 150 ± 25°R/sec and chamber pressure ramp rates of TBD psi/sec at a pressure less than 293 psia and at a rate of 50 ± 10 psi/sec at a pressure greater than 293 psia.

3.1.1.1.4 Attitude, Altitude and Temperature - The engine shall start, operate, and shutdown satisfactorily independent of engine gimballed position and attitude and with exposure to the external environmental conditions specified in Column 1 of Table V. The engine shall start satisfactorily in a zero-g field when liquid hydrogen is supplied in accordance with the requirements of 3.1.1.1.8 (Propellant Conditioning).

3.1.1.1.5 Impulse and Controllability Requirements - The specific impulse shall be maximized during engine operation consistent with the restrictions of 3.1.1.1.3 (Operational Contraints), with propellant supplied as specified in 3.1.1.1.8 (Propellant Conditioning) in the environments specified in 3.1.2.4 (Environments) and when operating over the duty cycles specified in 3.1.2.3 (Useful Life).

3.1.1.1.5.1 Normal Mode Impulse - The engine shall be capable of meeting the following performance requirements when operating in the normal mode. The normal operating cycle shall be initiated by a vehicle command signal to depart from a coast (shutdown) condition or previous operating cycle and is completed upon termination of cooldown flow, post operational status checks and coast preparation, i.e., system power-down, or the receipt of a command signal for restart. The normal operating cycle is shown in Figure 2.

3.1.1.1.5.1.1 Prestart - The engine shall be capable of performing function and status check operations as commanded to assure readiness for startup. There shall be no propellant flow other than permitted by 3.3.1.8 (Leakage) during prestart operations except as required for cooldown during restart. Prestart time shall be TBD ± TBD minutes.

3.1.1.1.5.1.2 Startup.- Startup consists of temperature conditioning, nuclear startup, bootstrap, and thrust buildup. Startup is initiated upon receipt of a command signal to initiate propellant flow or nuclear startup and is completed when rated performance has been achieved within the specified controllability limits. The engine shall be capable of accomplishing temperature conditioning and nuclear startup simultaneously or sequentially depending on prior operating history. The engine shall be capable of meeting the following requirements during normal startup operations.

3.1.1.1.5.1.2.1 Temperature Conditioning and Nuclear Startup.-

3.1.1.1.5.1.2.1.1 Temperature Conditioning - Temperature Conditioning is initiated at engine startup and consists of non-nuclear component and reactor thermal conditioning. These operations may be conducted separately or simultaneously depending on engine thermal conditions at startup. The engine shall be capable of being temperature conditioned for the initiation of bootstrap within TBD seconds and shall consume less than TBD lbs of propellant during this time. The time required for this function shall be predictable within ± TBD seconds and propellant consumption shall be predictable within ± TBD lb.

3.1.1.1.5.1.2.1.2 Nuclear Startup.- Nuclear startup may occur separately or simultaneously with temperature conditioning. During nuclear startup reactor criticality shall be achieved and temperature control shall be established. The time required for this function shall not exceed TBD sec and shall be predictable within ± TBD sec for each nuclear startup.

3.1.1.1.5.1.2.2 Bootstrap.- Bootstrap startup begins with initiation of flow through the turbines, and ends when program control has been achieved to initiate thrust buildup. Temperature control shall be maintained during bootstrap, and the engine shall be brought under program control when chamber pressure has increased to TBD ± TBD psia. The engine shall be capable of completing bootstrap startup within TBD sec and shall consume less than TBD lb of propellant during this time. These parameters shall be predictable to within ± TBD sec and ± TBD lb propellant for each bootstrap startup throughout the engine operating life.

3.1.1.1.5.1.2.3 Thrust Buildup - The engine shall be capable of thrust buildup through the engine throttle point, and shall maintain rated specific impulse from the throttle point to steady state operations. For each thrust buildup cycle during the engine useful life, the thrust and specific impulse shall be predictable as a function of time and engine history. These parameters shall be controllable to ± TBD percent thrust and ± TBD percent specific impulse of instantaneous predicted values.

3.1.1.1.5.1.3 Steady State Operation - Steady State Operation is initiated when rated performance has been achieved within specified controllability limits, and is terminated by receipt of a command signal to begin retreat from this condition. During Steady State Operation the engine shall be capable of providing the vacuum performance specified in 3.1.1.1.2 (Vacuum Performance Rating).

3.1.1.1.5.1.4 Shutdown and Cooldown - Shutdown consists of throttling, throttle hold, temperature retreat and pump tailoff, and is initiated by a command signal to depart from rated conditions and is completed upon termination of powered pump operation. During shutdown the engine shall be capable of steady-state hold at the engine throttle point. Cooldown is initiated upon completion of engine shutdown and is completed upon termination of propellant flow or the receipt of a command signal for restart. Cooldown propellant is supplied at tank pressure conditions as defined in 3.1.1.1.8, (Propellant Conditioning). The total delivered impulse during shutdown and cooldown shall be predictable within ± TBD percent of the total startup and steady state impulse as a function of engine operating history and shall be controllable as a function of time after initiation of shutdown. Provision shall be made for a TBD sec steady state hold at the throttle point, and for each shutdown cycle during the engine operating life the thrust and specific impulse shall be controllable to ± TBD percent thrust and ± TBD percent specific impulse of instantaneous predicted values from initiation of shutdown to termination of steady state hold at the throttle point. The total impulse delivered after termination of the steady state hold at the throttle point shall be controllable to within ± 20,000 lb sec at termination of cooldown. The time of termination of cooldown impulse shall be predictable within ± 15 sec. Cooldown thrust shall be not less than 30 lb and average cooldown specific impulse shall be not less than 400 sec.

3.1.1.1.5.1.5 Post Operations - The post operation period begins with the termination of cooldown and ends when the engine is powered-down for coast or space storage. During this period, the engine shall be capable of functional and status check operations. The time for this operation shall not exceed TBD minutes. There shall be no propellant flow other than permitted in 3.3.1.8 (Leakage).

3.1.1.1.5.1.6 Coast - The coast operation period is initiated upon completion of the post operation period and continues until receipt of a signal to initiate restart operations. During coast operations the engine thrust (due to allowable non-operating leakage) shall not exceed TBD lb.

3.1.1.1.5.2 Malfunction Mode Impulse - The engine shall be capable of meeting the following performance requirements when operating under the following malfunction conditions. The engine shall be capable of direct transition to the malfunction modes during any phase of engine operation.

3.1.1.1.5.2.1 Single Turbopump Operation Impulse - The engine shall be capable of operating with one Propellant Feed Subsystem leg inoperative. Operation in this mode shall be initiated or completed as specified in 3.1.1.1.5.1 (Normal Mode Impulse), or by receipt of a command signal demanding the engine to switch to this mode of operation from the normal mode startup, steady state or shutdown functions.

3.1.1.1.5.2.1.1 Prestart - There shall be no propellant flow other than permitted in 3.3.1.8 (Leakage) during prestart operations except as required for cooldown during restart. Prestart time shall be TBD $\pm$ TBD minutes.

3.1.1.1.5.2.1.2 Startup - The engine shall be capable of the following requirements during single Turbopump startup operation.

3.1.1.1.5.2.1.2.1 Temperature Conditioning and Nuclear Startup.- (2)

3.1.1.1.5.2.1.2.1.1 Temperature Conditioning - The engine shall be capable of being temperature conditioned for the initiation of bootstrap within TBD seconds and shall consume less than TBD lb of propellant. The time required for this function shall be predictable within $\pm$ TBD sec.

3.1.1.1.5.2.1.2.1.2 Nuclear Startup.- Nuclear startup may occur separately or simultaneously with temperature conditioning. During nuclear startup reactor criticality shall be achieved and temperature control shall be established. The time required for this function shall not exceed TBD sec and shall be predictable within $\pm$ TBD sec for each nuclear startup.

3.1.1.1.5.2.1.2.2 Bootstrap.- Bootstrap startup begins with initiation of flow through the operational turbine, and ends when program control has been achieved to initiate thrust buildup. Temperature control shall be maintained during bootstrap, and the engine shall be brought under program control when chamber pressure has increased to TBD ± TBD psia. The engine shall be capable of completing bootstrap startup within TBD sec and shall consume less than TBD lb of propellant during this time. These parameters shall be predictable to within ± TBD sec and ± TBD lb propellant for any Single Turbopump bootstrap startup occurring throughout the engine operating life.

3.1.1.1.5.2.1.2.3 Thrust Buildup - For each thrust buildup cycle during the engine useful life, the thrust and specific impulse shall be predictable as a function of time and engine history. These parameters shall be controllable to ± TBD percent thrust and ± TBD percent specific impulse of instantaneous predicted values.

3.1.1.1.5.2.1.3 Steady State Operation - The engine when operating with one PFS leg shall provide the vacuum specific impulse specified in 3.1.1.1.2 (Vacuum Performance Rating) and a nominal vacuum thrust of 60,000 lb. The engine shall be capable of operation at extended duration as required to deliver a single burn total impulse equivalent to that which would have been required for normal mode operation.

3.1.1.1.5.2.1.4 Shutdown and Cooldown - The engine shutdown and cooldown requirements for this mode of operation shall be as specified in 3.1.1.1.5.1.4 (Shutdown and Cooldown) for normal mode operation.

3.1.1.1.5.2.1.5 Post Operation - The engine post operation requirements shall be as specified in 3.1.1.1.5.1.5 (Post Operations) for normal mode operation.

3.1.1.1.5.2.1.6 Coast - During coast operations the engine thrust (due to allowable non-operating leakage) shall not exceed TBD lb.

3.1.1.1.5.2.2 Component Malfunction Impulse - When operating with component malfunctions other than those which would cause operation with a single PFS leg as specified in 3.1.1.1.5.2.1 (Single Turbopump Operation Impulse), or emergency operation as specified in 3.1.1.1.5.3 (Emergency Mode Operation), the engine shall be capable of operating under the conditions specified in 3.1.1.1.5.1 (Normal Mode Impulse).

3.1.1.1.5.3 Emergency Mode Operation - The engine shall be capable of operation in an emergency operating mode. No more than one emergency cycle shall be required of the engine. The emergency operating modes shall be initiated manually or by a command from the malfunction detection and control system or the trend data system demanding the engine to an emergency mode of operation from any point on the engine operating map. The engine shall be capable of a transition to the emergency operating mode during any portion of startup or steady state operation. For emergencies occurring during shutdown, the engine shall be capable of cooldown for up to five hours prior to entering the emergency operating mode. The engine shall be preserved in a restartable condition if it can be done at no additional risk to the population, passengers or crew. The engine shall be capable of providing emergency mode impulse at selected points (TBD) within the operational constraint map shown in Figure 1. Emergency mode impulse requirements shall be determined during the engine development program. The minimum emergency mode impulse and thrust shall be 10^8 lb.sec. and 30,000 lb. respectively, as specified in 3.1.2.7.1.3 (Malfunction Operation). Minimum emergency mode specific impulse shall be 500 sec. A summary of the emergency mode operating conditions is shown in Table TBD. (The format of this table is provided as Attachment I to this specification.)

3.1.1.1.6 Restart Requirements - The engine shall be capable of entering the engine prestart phase for restart at any time after completing the shutdown phase of a previous operating cycle.

3.1.1.1.7 Engine Communication - The engine shall be capable through the Engine/Stage interface of receiving, processing, and distributing command signals for engine operation and checkout functions through normal input channels from the stage, spacecraft, vehicle instrumentation unit (I.U.), the Vehicle Emergency Detection System (V.E.D.S.), and the range safety decoder. The engine shall provide engine output data through the Engine/Stage interface to the I.U. and stage systems, the V.E.D.S., and to the spacecraft and spacecraft systems display equipment as specified in 3.2.1.2 (Detailed Interface Definition).

3.1.1.1.8 Propellant Conditioning - The engine shall be capable of operating at the conditions stated herein when supplied with liquid hydrogen as specified in MSFC Specification 356 delivered at the tank outlet (upstream of the main propellant shutoff valve). The pressure and vapor quality shall be as follows:

	Tank Pressure psia	Saturation Pressure psia	Vapor, Percent
(a) Normal Operation			
(1) Startup	TBD to 30	TBD	0
(2) Rated Condition	28	28	0
(3) Cooldown	TBD	TBD	TBD
(b) Single Turbopump Operation			
(1) Startup	TBD to 30	TBD	0
(2) Rated Condition	30	28	0
(3) Cooldown	TBD	TBD	TBD
(c) Component Malfunction Operation			
(1) Startup	Same as Normal Operation		
(2) Rated Condition	Same as Normal Operation		
(3) Cooldown	TBD	TBD	TBD
(d) Emergency Operation			
(1) Startup	TBD to 30	TBD	0
(2) Emergency Point	30	28	0
(3) Cooldown	TBD	TBD	TBD

3.1.1.1.9 Propellant Pressurization - The engine shall be capable of providing hydrogen gas for propellant tank pressurization. The gas delivered to the interface shall have properties as shown in Figure 3.

3.1.1.1.10 Thrust Vector Control - The engine gimbal system shall be capable of providing the following thrust vector control in all directions:

(a)	Angle from null, degree (°),	0 - 3.0
(b)	Angular velocity, °/sec,	0 - 0.25
(c)	Angular acceleration, °/sec^2,	0 - 0.5

3.1.1.1.11 Nuclear Radiation Shielding - Engine components shall be protected from radiation emitted from the nuclear subsystem by a shield internal to the reactor pressure vessel. The engine shall be capable of incorporating an external radiation shield to reduce the dose due to engine radiation to permissable levels within manned spacecraft. The engine design shall minimize the sources of radiation and thereby reduce the penalty for meeting crew protection requirements.

3.1.1.1.11.1 Unmanned Configuration - In the unmanned configuration (no external shield) the internal shield (internal to the pressure vessel) shall be no larger than is necessary to prevent radiation damage or heating of engine components which would preclude meeting their specified performance requirements. The internal shield shall limit Pressure Vessel and Reactor Assembly (PVARA) radiation leakage through a plane located at a height of 63 inches forward of core center, perpendicular to the engine axis, to the levels shown in Table I, within the radius defined by the pressure vessel outside radius. Additionally, the PVARA leakage radiation at critical locations in the engine system shall be limited to the levels shown in Table II.

The internal shield shall be limited to an envelope within the inside radius of the pressure vessel and an overall thickness not to exceed 18 inches (including structural and coolant regions).

3.1.1.1.11.2 Manned Configuration - In the manned configuration the engine shall be capable of providing external shielding which in conjunction with vehicle and spacecraft shielding reduces the dose per round-trip to 10 rem at the location of each passenger and 3 rem at the location of each flight crew member in the spacecraft. The manned shield (external shield) shall be capable of being removed in space for unmanned flight and replaced for manned flight. Variations in crew shielding attenuation capability, based on mission requirements, shall be possible with minimum redesign. (1)

3.1.1.1.12 Malfunction Detection and Recovery - The engine shall be capable of detecting malfunctions and providing corrective action as established by the analysis techniques specified in 3.1.2.7 (Safety). The engine control system shall be capable of evaluating the malfunction condition and directing the appropriate malfunction recovery action.

3.1.1.1.13 Engine Assembly, Checkout, and Acceptance Operations - The engine shall be capable of manual assembly using AGE and facility equipment as specified in 3.2.1.2 (Detailed Interface Definition). The engine shall be capable of functional checks to assess engine operational status. Capability for poison wire insertion subsequent to engine acceptance shall be TBD. (1)

3.1.1.1.14 Nuclear Stage Assembly and Checkout Operations - The engine shall be capable of the procedural requirements as specified in 3.2.1.2 (Detailed Interface Definition) and shall be capable of remote functional testing and checkout of all engine operational parameters using stage control system circuits. The engine shall be capable of monitoring and self-check operations to provide assessment of engine reliability safety and operational status. Other specific requirements are TBD. (1)

3.1.1.1.15 Nuclear Stage/Vehicle Mating Operations - The engine shall be capable of the procedural requirements specified in 3.2.1.2 (Detailed Interface Definition), and shall be capable of monitoring to provide assessment of engine safety. The engine shall be capable of peripheral poison wire removal prior to nuclear stage/vehicle mating operations. Other specific requirements are TBD.

3.1.1.1.16 Vehicle Checkout Operations - The engine shall be capable of functional testing and checkout of all engine operational parameters using vehicle control system circuits. The engine shall be capable of monitoring and self-check operations during vehicle checkout to provide assessment of engine reliability safety and operational status. Other specific requirements are TBD.

3.1.1.1.17 Vehicle Transfer Operations - The engine shall be capable of withstanding the loads and environments specified in 3.1.2.4 (Environments) during vehicle transfer to the launch pad. During this operation the engine shall be capable of monitoring all functional parameters critical to engine safety, and shall be capable of interfacing with AGE/Facility equipment as specified in 3.2.1.2 (Detailed Interface Definition). Other specific requirements are TBD.

3.1.1.1.18 Vehicle Countdown Operations - During pre-launch (vehicle countdown) operations for the operational period specified in 3.1.2.3 (Useful ife) the engine shall be capable of the following:

(a) Being exposed to the natural environments specified in 3.1.2.4 (Environments) without degradation.

(b) Interfacing with AGE and facility equipments as sp cified in 3.2.1.2 (Detailed Interface Definition).

(c) Maintenance and functional testing as specified in 3.1.2.2 (Maintainability).

(d) Installation of destruct system detonators.

(e) Attachment and removal of radiation monitoring equipment.

(f) Reactor central poison wire removal.

(g) Monitoring all functional engine parameters required to assess engine reliability, operational and safety status.

(h) Reactor central poison wire reinsertion TBD.

(i) Other requirements TBD.

3.1.1.1.19 Launch and Boost Operation - The engine shall have the following capabilities during launch and boost:

(a) Exposure to the natural and induced environments of 3.1.2.4 (Environments) without degradation of performance potential.

(b) Response to a destruct signal and fragmentation and disposal of the reactor fuel elements in accordance with 3.1.2.7 (Safety).

(c) Response to a signal to render the engine destruct system inoperative (safe) after completion of launch and boost operations.

(d) Monitor all engine parameters required to assess engine safety and reliability.

(e) Other requirements TBD.

3.1.1.1.20 Space Station Operation - The engine shall be capable of functional testing and checkout while the nuclear stage is docked at the lunar space station or the geosynchronous space station. The specific requirements of this operation are TBD.

3.1.1.1.21 Propellant Depot Operations - The engine shall be capable of the following functional requirements while the nuclear stage is docked at the 262 nautical mile earth orbit propellant depot.

(a) Removal of the expendable equipment required for launch, including the anticriticality destruct subsystem, launch support structure and gimbal locking devices, and central poison wires.

(b) Installation, removal, and replacement of the external radiation shield.

(c) Engine maintenance functions as specified in 3.1.2.2 (Maintainability).

(d) Functional testing and checkout as required to assess engine condition and verify engine operability and reliability.

(e) Other requirements TBD. (1)

3.1.1.1.22 Coast Operations - The engine shall be capable of maintaining a restartable condition during coast periods not to exceed TBD days with exposure to the natural and induced environments of 3.1.2.4 (Environments). The engine shall provide capability for monitoring all functional engine parameters required for assessment of engine safety and restart capability. Engine electrical power requirements during coast operations shall be minimized and shall not exceed the power consumption levels specified in 3.3.1.10 (Electrical Power). (1)

3.1.1.1.23 Spent Stage Disposal Operation - Except after emergency mode operation the engine shall be capable of providing impulse for spent stage disposal. Disposal operation shall be conducted within the operational modes specified in 3.1.1.1.5.1, (Normal Mode Impulse) and 3.1.1.1.5.2, (Malfunction Mode Impulse) and the engine useful life specified in 3.1.2.3, (Useful Life.) During disposal operation the engine shall retain the following capabilities:

(a) Command override of engine control functions.

(b) Control reactor coolant to prevent core vaporization following the final engine thrust cycle.

(c) Remote monitoring of all engine operating functions.

(d) Other requirements TBD.

3.1.1.2 Secondary Performance Characteristics - No secondary performance characteristics have been established for the engine.

3.1.2 Operability -

3.1.2.1 Reliability.- TBD

3.1.2.1.1. Trend Data System - The engine shall have the capability such that its operational status or capability may be assessed at any time during its service life. Trend characteristics or parameters with operating limits shall be selected during the design process and monitored during the engine service life to provide an effective status indication of the system and system performance factors subject to wearout and/or deterioration. The engine control system shall be capable of calculating the probability of mission success at any time during a mission, using trend data and appropriate reliability analyses.

3.1.2.2 Maintainability - The engine shall be capable of being maintained by redundancy, adjustment, and/or replacement of key components. Maintenance action except for switching to redundant components shall be limited to ground or earth orbit. The design of the engine for maintainability shall not compromise reliability (mission success) and the effect of maintainability on engine weight and performance shall be minimized. The engine shall be designed to meet the following repair time allocations.

(a) Space - The time allowed for engine repair including engine removal and replacement shall be in accordance with vehicle turn-around time allocation TBD.

(b) Launch Pad - The time allowed for engine maintenance shall be in accordance with time allocation as follows:

1. Prior to propellant servicing TBD.
2. Subsequent to propellant servicing TBD.

(c) Engine/Vehicle Assembly - The time allowed for engine maintenance shall be in accordance with the assembly/checkout maintenance allocation TBD.

3.1.2.2.1 Maintenance and Repair Cycle -

3.1.2.2.1.1 Maintenance Classification and Usage -

3.1.2.2.1.1.1 Routine - There shall be no routine engine maintenance required. Routine inspection shall be permitted.

3.1.2.2.1.1.2 Preventive - No scheduled maintenance or repair cycles shall be required. Preventive maintenance shall be limited to checkout and purge requirements.

3.1.2.2.1.1.3 Corrective - Corrective maintenance shall be performed when check-out and trend data indicate that maintenance (replacement) is required. Component replacement shall be limited to those components and assemblies specified in 3.1.2.2.1.3 (Engine Maintainability Requirements).

3.1.2.2.1.2 Maintenance Modes -

3.1.2.2.1.2.1 Manual - The engine shall be capable of manual maintenance during ground operations. Manual maintenance shall not be required where radiation dose levels exceed those established by radiation guides TBD.

3.1.2.2.1.2.2 Remote - The engine shall be capable of remote maintenance in hostile environments.

3.1.2.2.1.3 Engine Maintainability Requirements - Engine maintainability capability shall be limited to the following:

(a) The engine shall be capable of manual assembly and disassembly to the stage during ground operations, and remote separation from and reassembly to the stage while in earth orbit. Additionally, stage mounted engine components shall be capable of remote replacement when located in hostile environments, and may be capable of manual replacement when maintained in a non-hostile environment.

(b) Engine component valve assemblies, drum actuators, gimbal actuators, external shield, turbomachinery and electronic logic packages external to the reactor pressure vessel and nozzle shall be remotely maintained by replacement or substitution (switching or redundancy) when in a hostile environment, and may be capable of manual replacement when maintained in a non-hostile environment.

(c) The reactor, pressure vessel and nozzle including physically associated instrumentation shall not be replaced.

(d) Corrective maintenance on the NERVA Digital Instrumentation and Control Electronics (NDICE). (4)

(e) For module and component remote replacement requirements see 3.3.1.5 (Module and Component Remote Replacement).

3.1.2.2.1.4 Maintenance Design Requirements -

3.1.2.2.1.4.1 System Constraints - The engine shall be designed to withstand the angular and offset axial misalignment and the docking load impact when installing the engine to the stage during space maintenance operation as follows:

(a) Angular Misalignment - TBD
(b) Offset Axial Misalignment - TBD
(c) Docking Load Impact - TBD

3.1.2.2.1.4.2 Checkout and Test - All components shall be capable of remotely conducted functional and electrical checks after engine assembly or maintenance.

3.1.2.2.1.4.3 Complexity - The engine components/modules design for maintenance shall be as simple as possible. Where maintenance design guidelines cause undue complexity or weight, consideration shall be given to adding complexity to the support equipment rather than to flight components, and to the use of single components rather than modules. Safety and reliability analysis techniques shall be used to establish maintenance design guidelines. (4)

3.1.2.2.1.4.4 Human Performance - The maintainability features of the engine for human performance shall be as specified in 3.1.2.6 (Human Performance).

3.1.2.2.2 Service and Access - Access shall be provided for remote removal, reinstallation, and checkout of replaceable modules or components.

3.1.2.3 Useful Life - The engine shall have a minimum useful life as defined in the following subparagraphs.

3.1.2.3.1 Service Life -

3.1.2.3.1.1 Space Service Life - The engine shall be capable of meeting the performance requirements of this specification for a minimum of 3 years under the in-space environmental conditions specified in 3.1.2.4 (Environments).

3.1.2.3.1.1.1 Operating Service Life - The engine shall be capable of operating for a minimum of 600 minutes accumulated in multiple burn cycles up to 60 of varying length up to one hour for normal mode operations and TBD hour for single turbopump operation, at a nominal thrust chamber temperature of 4250°R. The engine shall be capable of the duty cycles as specified in Table IV. The engine shall be capable of completing any single mission as specified in 1.1 (Mission Definitions) under the malfunction conditions specified in 3.1.1.1.1.2 (Malfunction Mode).

3.1.2.3.2 Engine Storage Life - The assembled engine shall have a minimum ground storage and pre-launch operational life as follows:

(a) Storage (controlled environment) 5 years
(b) Launch Pad Environment 6 months

3.1.2.3.3 Subsystem/Component Storage Life - Engine subsystems and components shall have a minimum ground storage life of TBD months under controlled storage environments.

3.1.2.4 Environment - The engine shall meet all performance requirements of this specification during or after exposure to the following environments as applied to the engine or its protective container for the service and storage durations specified in 3.1.2.3 (Useful Life).

3.1.2.4.1 Natural Environment - Extreme values of the natural environment are specified in Tables V through IX and Figures 4 through 7.

3.1.2.4.2 Induced Environments -

3.1.2.4.2.1 Nuclear Environment - The engine induced nuclear environment is specified in Tables X, XI, and XII. The isoflux nuclear environment contour map is specified in Figure 8 TBD. (1)

3.1.2.4.2.2 Acoustic Environment.- The acoustic environment applied at the engine boundaries is specified in Figure 9.

3.1.2.4.2.3 Thermal Environment - TBD.

3.1.2.4.2.4 Vibration and Acceleration Environments - Vibration and acceleration environments and the interface locations where applied are specified in Table XIII TBD.

3.1.2.4.2.5 Electromagnetic Environment - Extreme values either radiated or conducted, of the externally induced electromagnetic radiation environment and the vehicle/stage induced electromagnetic environment are specified in Tables XIV TBD and XV TBD. The engine induced electromagnetic environment resulting from engine (nuclear) operation shall not exceed the values specified in Table XVI TBD.

3.1.2.4.2.6 Atmosphere Environment - The atmosphere environments which may be developed as a result of permissable hydrogen leakage are specified in Table XVII TBD.

3.1.2.4.3 Combined Environments - The performance requirements of this specification shall be met when the environments specified in 3.1.2.4.1 (Natural Environment) and 3.1.2.4.2 (Induced Environments) are applied sequentially and in combination to produce augmented environmental stresses.

3.1.2.5 Transportability - The engine shall be capable of performing as specified herein subsequent to the following transportation and handling conditions.

3.1.2.5.1 Modes of Transport and Handling - - The engine and its subsystems shall be capable of being handled and transported by land, sea, or air after final checkout when suitably packaged. Specific requirements are TBD.

3.1.2.5.2 Transportation Attitude - The engine shall be capable of transportation in any attitude when suitably packaged and shall be capable of being handled in the horizontal, rotational, and vertical (nozzle up and nozzle down) attitudes during assembly. The engine shall be capable of transportation in the vertical (nozzle down) or horizontal attitude when attached to the stage/airframe.

3.1.2.5.3 Transportation Loads - Engine allowable loads as specified in 3.1.2.4.2.4 (Vibration and Acceleration Environments) will not be exceeded during transport and handling. (2) (4)

3.1.2.5.4 Interface Requirements - The engine shall be capable of providing for the attachment of fixtures required for assembly and transport. These interfaces shall be as specified in 3.2.1.2 (Detailed Interface Definition).

3.1.2.5.5 Environmental Requirements - The engine shall be capable of allowing internal environmental control during transport and handling.

3.1.2.6 Human Performance - Design practices for the engine shall integrate man into the system in such areas as maintenance, training, and system operation by means of human engineering design principles and practices as specified in MIL-STD-1472.

3.1.2.6.1 Maintenance - Engine design shall take into account the special human performance factors associated with maintenance. Engine design shall consider: (1) malfunction identification; (2) ease of component removal, replacement, and repair; (3) manual and remote operation where required; (4) alignment aids where necessary; and (5) incorporation of calibration techniques with related test and checkout points.

3.1.2.6.2 Training - The engine shall be designed to minimize requirements for personnel training programs required to develop human performance necessary in the operational maintenance, support, and control of the engine system in a specified environment.

3.1.2.6.2.1 Number of Skills Required.- The engine shall be designed to minimize the level and extent of personnel skills required for assembly, maintenance, and system operations.

3.1.2.6.2.2 Reliability/Safety Through Performance - The engine shall be designed such that personnel shall have the capability to override automatic devices which control their lives and engine performance.

3.1.2.6.2.3 Environmental Conditions - Those parameters conducive or restrictive to man, and which have a strong influence on his reliability, shall be considered in the engine design.

3.1.2.6.3 System Operation - A systematic method shall be developed for determining optimum manned design solutions to engine system problems. Functions will be allocated between operating personnel and the engine system to promote optimum capability between equipment and human performance.

3.1.2.6.3.1 Operating Procedures - The engine shall be designed such that effective procedures may be written for each level of tasks to be performed during inspection, checkout, maintenance, and trouble shooting. These procedures shall be prepared and validated during development of the engine system.

3.1.2.6.3.2 Control Displays - The man relationship to control displays shall be as specified in MIL-STD-1472.

3.1.2.6.3.3 Psychophysiological Stress and Fatigue - The interface between the engine design and man shall consider ease of operation and promotion of decision making. (1)

3.1.2.6.3.4 Adequate Emergency Systems - The selection of emergency systems shall take into consideration the potential for human error in the operation of the system under emergency conditions.

3.1.2.7 Safety - Maximum effort shall be directed toward elimination of single failures or credible combinations of errors and/or failures which preclude mission completion or endanger successful mission termination, ground personnel, space crews, launch crew, general public; or which cause serious facility damage or engine loss. The following order of precedence of safety criteria shall be applied to engine design:

(a) 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, test and mission operations, and other test requirements to minimize the probability of system degradation because of personnel error.

(b) In all instances where known hazards exist and cannot be eliminated, appropriate protective systems shall be employed.

(c) 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. Warning signals shall be standardized within like types of systems to minimize the probability of improper personnel reaction to the signal(s).

(d) Where it is not possible to reduce the magnitude of existing or potential hazards through design change or the use of safety warning devices, appropriate emergency procedures shall be developed.

(e) The engine shall be designed using reliability and safety analysis techniques of hazard analysis, contingency analysis and fault tree analysis in accordance with Safety Plan S019-CP090290-F1 and Reliability Program Plan R-101-CP090290-F1. Failures shall be categorized according to failure effects as defined in Section 6.2(h) using the guidelines in 3.1.2.7.1.3, (Malfunction Operation). To the extent feasible, all single failures shall be reduced by appropriate design to Category I or Category II in stated order of preference (3.1.2.7.1.3). Where it is not feasible to reduce such failures to Category I, it is mandatory that the trend data and the malfunction detection systems include provisions to detect the failure (or approach thereof) and provide appropriate action. The detection and warning systems for Category II, III, and IV failures shall consist of at least two completely independent circuits.

(f) Means shall be provided to prevent accumulation of combustible or explosive mixtures of hydrogen and air in the engine during ground acceptance test, prelaunch operations, and the ascent phase. The engine design shall minimize the use of materials that will support combustion in the event of fire. Where such materials are required, fire resistant protective coverings shall be utilized as appropriate.

3.1.2.7.1 Flight Safety -

3.1.2.7.1.1 Failure Identification - Single failures or errors shall be identified and categorized as to their effects on the system. Multiple failures which lead to Category III or IV failure effects shall be identified and their effects on the system shall be assessed. (1)

3.1.2.7.1.2 Malfunction Detection and Control - The engine shall incorporate means for detection of Category II, III, and IV failures. Control logic shall be provided to permit engine operation at maximum performance capabilities consistent with the nature of the malfunction or failure. (1)

3.1.2.7.1.3 Malfunction Operation - The engine shall be capable of operation under malfunction conditions resulting from single or multiple failures in accordance with the following guidelines.

(a) Category I - No additional functions required

(b) Category II - Operation in the Component Malfunction Mode specified in 3.1.1.1.5.2.2 (Component Malfunction Impulse) for all Category II failures.

(c) Category IIIA - Operation with only one leg of the propellant feed system operational as specified in 3.1.1.1.5.2.1 (Single Turbopump Operation Impulse).

(d) Category IIIB - Operation in Emergency Mode Operation in a manner consistent with the control philosophy of 3.1.2.7.1.2 (Malfunction Detection and Control). Minimum engine performance in an Emergency Mode shall be established considering the nature of the failure, the reliability of retreating to and operating at an Emergency Mode point, and using optimumly the remaining propellant. Minimum engine performance in any Emergency Mode Operation shall be not less than:

(1) 30,000 pounds thrust.

(2) 500 seconds specific impulse.

(3) 10^8 lb-sec. total impulse, including cooldown.

(e) Category IV - Retention of maximum capability to protect vehicle and crew consistent with the control philosophy of 3.1.2.7.1.2 (Malfunction Detection and Control).

(f) The ability to override the engine programmer remotely by the crew and ground control, and the capability for remote thrust cutdown independent of the engine program shall be incorporated.

3.1.2.7.1.4 Spent Engine Disposal - TBD

3.1.2.7.2 Ground Safety - The reactor and the engine shall be capable of being shipped in accordance with AEC Manual Chapter 0529.

3.1.2.7.3 Nuclear Safety - The engine shall include provisions for preventing the inadvertent attainment of reactor criticality through any single or credible multiple failures, malfunctions, or operations during all ground, launch, flight, and space operations in accordance with the following:

(a) During reactor assembly and for all subsequent shipping, storage, engine assembly, and handling operations prior to movement to the launch pad, the reactor shall be provided with a poison wire system such that the effective neutron multiplication factor shall not exceed 0.95 if the reactor is flooded with water or liquid hydrogen.

(b) The poison wire system shall remain effective if the reactor or engine as packaged for shipment is subjected to the Hypothetical Accident Conditions set forth in Annex 2 of AEC Manual Chapter 0529 Appendix.

(c) The central poison wires alone shall be capable of retaining the reactor in a subcritical state if all control drums are rotated to their most reactive position or if the reactor is subjected to a compaction accident.

(d) For ground operations which are conducted with poison wires removed, as well as for engine use in space flight, protection against inadvertent criticality shall be provided both by safety measures that prevent inadvertent roll-out of control drums; and safety measures that prevent valve operations that could permit LH_2 to flow from the propellant tank to the reactor through either the normal flow path or the cooldown flow path. The safety measures applied to the PFS valves shall also prevent inadvertent flow of LH_2 to the reactor following propellant loading and during launch, boost, and space operations.

(e) The engine shall provide a means of destruct during launch and ascent so as to assure sufficient dispersion of the reactor fuel upon earth impact to prevent nuclear criticality with the fuel fully immersed in water. The destruct system shall be capable of removal prior to initial reactor startup in space.

(f) The engine shall include provisions for the safe determination of sub-critical multiplication when all poison wires have been removed.

(g) The engine shall have a minimum reactivity shutdown margin (no H_2 flow, poison wires out, control drums full-in position) of $1.50 at 540°R at all times.

(h) The engine shall include provisions for monitoring the neutron flux during engine non-operating periods during space flight. The monitor shall provide an appropriate alarm signal to indicate an abnormal increase in the neutron level.

3.1.2.7.4 Personnel Safety - Maximum practical provisions for personnel safety shall be incorporated in the engine and its components so that assembly, checkout, acceptance test, transport, storage, maintenance, inspection, repair and replacement shall be accomplished with minimum hazard to personnel. Particular consideration should be given to the safety aspects of required personnel access to the engine. The hazards to be considered include but are not limited to the following:

(a) Electrical Shock
(b) Sharp protrusions
(c) Release and/or entrapment of inert fluids to confined spaces
(d) Exposure to cryogenic temperature
(e) Release of projectiles
(f) High pressure fluid releases
(g) Unguarded moving machinery
(h) Excessive radiation levels

3.1.2.7.5 Explosive and/or Ordnance Safety - All ordnance, including associated power supplies and circuity, shall be capable of meeting the requirements of Section C, Paragraph 8 of AFETRM 127-1.

3.2 CEI Definition - This section defines the components and subsystems which constitute the NERVA Engine CEI, including the Nuclear Subsystem CEI. The following paragraphs specify the interface requirements and component identification of the Engine CEI.

3.2.1 Interface Requirements - The engine as delivered for assembly to the nuclear stage shall consist of the following separate assemblies:

(a) NERVA Digital Instrumentation and Control Electronics (NDICE) Assemblies
(b) Two Propellant Shutoff Valve (PSOV) Assemblies
(c) One Cooldown Supply Module Assembly
(d) One Engine Module Assembly
(e) One Destruct Subsystem

The functional, dimensional, physical and procedural interfaces between the engine assemblies and other system equipment and facilities shall be as specified in the following subparagraphs.

3.2.1.1 Schematic Arrangement.- The schematic diagram identifying engine assembly interfaces with related system equipments is shown in Figure 10. The schematic diagram identifying engine assembly interfaces with the Nuclear Subsystem CEI is shown in Figure 11. Graphic portrayal of the engine interfaces shall be as shown in the following drawings and diagrams:

(a) 75K NERVA Flight Engine Layout, Full Flow, Dwg. No. 1137400
(b) 75K NERVA Flight Engine Electrical Schematic, Dwg. No. TBD
(c) 75K NERVA Flight Engine Assembly, Dwg. No. TBD
(d) 75K NERVA EPIC Assembly, Dwg. No. TBD
(e) 75K NERVA PSOV Assembly, Dwg. No. TBD
(f) 75K NERVA Cooldown Supply Module Assembly, Dwg. No. TBD
(g) 75K NERVA Flight Engine Flow Diagram, Dwg. No. 1136401
(h) 75K NERVA Destruct Subsystem, Dwg. No. TBD

3.2.1.2 Detailed Interface Definition.- Detailed definitions and design requirements for the physical, functional, and procedural characteristics of the interfaces shown in 3.2.1.1 (Schematic Arrangement) shall be as provided in the following Interface Control Drawings:

(a) NERVA Flight Engine Nuclear/Non-Nuclear Interface Control, Dwg. No. 1136393 (2)
(b) NERVA Engine Module/Stage, Dwg. No. 1136403
(c) PSOV/Stage, Dwg. No. TBD
(d) Cooldown Supply Module/Stage, Dwg. No. TBD.
(e) EPIC/Stage, Dwg. No. TBD
(f) NERVA Engine/AGE, Dwg. No. TBD
(g) NERVA Engine/Facility, Dwg. No. TBD
(h) NERVA Engine/Propellant Depot, Dwg. No. TBD
(i) NERVA Engine/Space Station, Dwg. No. TBD
(j) Destruct Subsystem/Stage, Dwg. No. TBD (1)

3.2.1.3 Engine State Points.- The schematic diagram identifying engine state point locations, and a tabulation of flow rates, temperatures, and pressures at these locations is provided as Attachment II to this specification.

3.2.2 Component Identification.-

3.2.2.1 Government Furnished Property List.- TBD. (1)

3.2.2.2 Engineering Critical Components List.- Components of the engine are individually specified as subsystems and as engineering critical (EC) or Design (DS) components. These components and their categorization are as shown on Drawing 1137101 and are identified as follows:

EC-90218	Propellant Feed Subsystem	
	EC-90149	Turbopump Assembly
	EC-90117	Propellant Shutoff Valve & Actuator

EC-90122	Bypass Control Valve & Actuator
EC-90257	Bypass Block Valve & Actuator
EC-90121	Turbine Block Valve & Actuator
EC-90246	Pump Discharge Check Valves
EC-90258	Cooldown Supply Control Valve & Actuator
EC-90276	Cooldown Shutoff Valve & Actuator
EC-90281	Turbine Discharge Block Valve and Actuator
EC-90261	Structural Support Block Valve & Actuator
EC-90283	Turbine Throttle Valve and Actuator
DS-90263	Stage Tank Pressurization Line and Check Valve
DS-90264	Engine Purge Unit
DS-90284	Propellant Lines
EC-90242	Destruct Subsystem
EC-90151	Nozzle Assembly Subsystem
DS-90196	Nozzle
DS-90176	Nozzle Extension
EC-90214	Instrumentation & Control Subsystem
EC-90152	Thrust Structure Subsystem
DS-90267	Upper Thrust Structure
DS-90269	Lower Thrust Structure
EC-90243	External Shield Subsystem
EC-90244	Gimbal Assembly Subsystem
DS-90251	Gimbal Actuator
EC-90154	Pressure Vessel & Closure Subsystem
CP-677555	Nuclear Subsystem
EC-677575	Structural Support Coolant Assembly
EC-90192	Structural Support Coolant Valve
EC-677576	Structural Support Coolant Valve Actuator

(4)

EC-677566	Fuel Elements
EC-677558	Cluster Hardware
EC-677564	Core Periphery
EC-677561	Support Plate & Plena
EC-677562	Internal Shield
EC-677559	Reflector Assembly
EC-677585	Control Drum Drive Assembly
EC-677565	Nuclear Subsystem Instrumentation

3.2.2.3 Logistics Critical Components List.- There are no logistics critical components in the engine.

3.3 Design and Construction.-

3.3.1 General Design Features.- The engine shall be designed as a single module (engine) utilizing a full flow cycle to drive the engine turbopumps.

3.3.1.1 Structural Criteria.- The structural criteria for engine design shall be in accordance with the requirements of SNPO-C-1.

3.3.1.2 Electrical Criteria.- The NERVA engine electrical systems shall meet the requirements of MIL-E-8189. All wiring installations shall comply with requirements of MIL-W-8160. Bonding shall comply with the requirements of MIL-B-5087. Grounding requirements for all electrical systems shall be based on a controlled approach which permits optimum performance. Wherever possible, a single path-to-ground (i.e., only one path from any point in a circuit to ground) grounding philosophy shall be utilized. The ground reference shall be the structure ground points in the vehicle and the power source interface with the facility ground system in the AGE. Where redundancy or EMI/EMC requirements dictate, they shall take precedence over single-path requirements.

3.3.1.3 Nuclear Criteria.- The engine shall be capable of withstanding the engine induced nuclear radiation environments as specified in 3.1.1.1.11, (Nuclear Radiation Shielding), and 3.1.2.4.2.1 (Nuclear Environment).

3.3.1.4 Dry Weight of Engine.-

3.3.1.4.1 Engine Weight with External Shield (Manned Configuration).- The target dry weight of the engine with a graphite core and consisting of the engine module, NDICE, two PSOV's and a cooldown supply module, shall be 32,400 lbs. The weight breakdown shall be:

(a)	Engine Module	31,600 lbs.
(b)	NDICE	500
(c)	PSOV's (two)	200
(d)	Cooldown Supply Module	100

3.3.1.4.2 Engine Weight Without External Shield (Unmanned Configuration).- The target dry weight of the engine with a graphite core and consisting of the engine module, NDICE, two PSOV's and a cooldown supply module shall be 22,400 lbs. The weight breakdown shall be: (1)

(a)	Engine Module	21,600 lbs.
(b)	NDICE	500
(c)	PSOV (two)	200
(d)	Cooldown Supply Module	100

3.3.1.4.3 Weight of Additional Equipment.-

3.3.1.4.3.1 Destruct Subsystem.- The target weight of the Destruct Subsystem shall be 300 lb, including the support structure and attached devices.

3.3.1.4.3.2 Stage Mounted NERVA Engine I&C Cable (Supplied by Stage Contractor).- The target weight of the cable, including connectors to NDICE and engine module wiring harness and mounting devices to the stage, shall be 2500 lbs.

3.3.1.4.4 Launch Weight of Engine (Manned Configuration).- The target launch weight of the engine with a graphite core shall be 35,200 lbs. consisting of:

(a)	Engine Module	31,600 lbs.
(b)	NDICE	500
(c)	PSOV (two)	200
(d)	Cooldown Supply Module	100
(e)	Destruct Subsystem	300
(f)	Stage Mounted NERVA Engine I&C Cable (Supplied by Stage Contractor)	2,500

3.3.1.5 Module and Component Remote Replacement.- The engine shall be designed to meet the maintainability requirements specified in 3.1.2.2.1.3, (Engine Maintainability Requirements). The following modules and components as shown on drawing 1137400 shall be designed and packaged for remote removal and replacement:

(a) TPA and valves module
(b) Turbine bypass module
(c) Structural Support Module
(d) Cooldown Module
(e) Propellant Shutoff Valves
(f) Gimbal Actuators
(g) Control Drum Actuators
(h) Miscellaneous Valves
(i) NERVA Digital Instrumentation and Control Electronics
(j) External Shield

3.3.1.6 Gimballed Mass Characteristics.- Characteristics for the gimballed portion of the engine with graphite core and 10,000 lb external shield, and excluding the Destruct Subsystem, shall be as specified in the following subparagraphs.

3.3.1.6.1 Moment of Inertia About Gimbal Point.- The moments of inertia about the three principal axes of the engine without propellant shall not exceed the following:

Roll Axis:	6000 slug-feet squared
Pitch Axis:	120,000 slug-feet squared
Yaw Axis:	120,000 slug-feet squared

3.3.1.6.2 Gimballed Weight (Operating).- The target weight including propellant shall be 31,200 lb.

3.3.1.6.3 Center of Gravity.- The center of gravity without propellant shall not exceed 144 inches from Engine Station Zero.

3.3.1.7 Engine Natural Frequency.- The TBD engine natural frequencies during launch and boost operations shall be TBD Hz and during the nuclear space operation phase TBD Hz.

3.3.1.8 Leakage.- The engine shall be designed to minimize fluid joints where leakage could occur. Maximum leakage during all non-operating periods shall not exceed 400 standard cubic inches of hydrogen per minute. Maximum leakage during all operating periods shall not exceed TBD lb of hydrogen per minute. The engine shall be capable of handling leakage without incurring problems such as ice formation, including solidified hydrogen, in any place in the engine or engine valving. (1)

3.3.1.9 Cleanliness.- Engine components shall be designed to minimize blind passages that reduce assurance of effective contamination control and cleaning. The engine shall be designed to handle any unlimited flow (rate) of 600 micron or less particles throughout its operating life. The estimated weight to be handled is 220 grams of material with the density of aluminum. The design and construction of the engine shall satisfy the requirements of Data Item S021-CP090290-F1, (Contamination and Corrosion Plan). All requirements of this paragraph also apply to self-contamination.

3.3.1.10 Electrical Power.- The engine, including NDICE, shall be designed for operation with an instantaneous electrical power consumption not to exceed 10,000 watts at 28 ± 2 VDC. This power requirement shall be minimized as a design goal. The engine operating power profile shall be as shown in Figure 12.

3.3.1.11 Checkout and Calibration.- The engine shall be capable of preoperational checkout and calibration tests as specified in 3.1.1.1.13, (Engine Assembly, Checkout, and Acceptance Operations), 3.1.1.1.14, (Nuclear Stage Assembly and Checkout Operations), and 3.1.1.1.16, (Vehicle Checkout Operations). Checkout and calibration tests shall be performed prior to launch and subsequent to ground and space maintenance operations. Additionally, the engine shall be capable of complete functional and status checks to establish engine operational status throughout the engine operational life.

Functional and status checks shall satisfy the prestart and post operation requirements of 3.1.1.1.1.1, (Normal Mode); 3.1.2.1.1, (Trend Data System); 3.1.2.6, (Human Performance); and 3.1.2.7, (Safety). The requirements of 3.1.1.1.7, (Engine Communication), shall apply to the conduct of functional and status checks.

3.3.1.12 Engine Purge and Vent.- The engine shall be capable of venting and purging as required to prevent the accumulation of explosive concentrations of Hydrogen and to provide environmental protection to sensitive engine components. The engine shall be capable of inert gas purging as preventive maintenance during all ground, launch and boost operations. Specific requirements for engine vent and purge capability shall be TBD. (i)

3.3.1.13 Fluid Compatibility.-

3.3.1.13.1 Propellant.- The engine propellant shall be as specified in MSFC-SPEC-356.

3.3.1.13.2 Gaseous Nitrogen.- Gaseous nitrogen shall be as specified in MSFC-SPEC-234.

3.3.1.13.3 Gaseous Helium.- Gaseous helium shall be as specified in MSFC-SPEC-364.

3.3.1.14 Thrust Nulling.- The engine shall be designed with internal features as required for the possible future addition of a thrust nulling system capable of cancelling engine thrust between TBD and TBD lb.

3.3.1.15 Security.- The engine shall be designed, packaged and protected, such that all items identified in Rover Classification Guide CG-RR-3, shall be protected from disclosure to unauthorized persons at all times in accordance with the provisions of DoD Industrial Security Manual DoD 5220.22-M. (1)

3.3.1.16 Thrust Vector Misalignment.- TBD. (1)

3.3.1.17 Growth.- The reactor and nozzle design will incorporate such features as necessary (exclusive of fuel element features) to allow growth as shown by analysis to operation at 4500°R nominal mixed mean chamber temperature for two hours duration (12 cycles) at TBD thrust, based on a reactor and nozzle design optimized for nominal operation at 4250°R chamber temperature and 450 psia chamber pressure.

3.3.1.18 Measurements Criteria.- The engine shall include provisions for the measurement of all parameters essential to engine operation and to the determination of engine operational and safety status. Instrumentation shall be provided in accordance with the provisions of C103-CP090290-F1, (Measurement Design Requirements). (5)

3.3.2 Selection of Specifications and Standards.- MIL-STD-143 shall be used for criteria and order of precedence in the selection of specifications and standards to be used for the design and construction of the NERVA engine.

3.3.3 Materials, Parts, and Processes.-

3.3.3.1 Materials and Parts.- Materials shall be selected on the basis of resistance to degradation of properties in the predicted NERVA environments (SNPO-C-6 External Environments - Definitions and Requirements), and as required by design and reliability. Design properties of materials shall be taken from ANSC Report 2275 and Data Release Memoranda in accordance with S131-CP090290-F1. Parts having multiple applications, such as fasteners, shall be standardized whenever possible.

3.3.3.1.1 Hydrogen Embrittlement.- Materials shall be selected to avoid degradation due to hydrogen embrittlement and shall be compatible with mission environment.

3.3.3.1.2 Radiation.- Materials shall be selected and qualified by appropriate tests to be compatible with the radiation environment specified in 3.1.2.4 (Environments).

3.3.3.1.3 Material Activation.- The use of materials which become radioactive when used in a nuclear environment shall be minimized.

3.3.3.2 Processes.- Fabrication processes shall be selected with the intent of using techniques that assure the most reliable performance and reproducible results. Materials fabrication procedures, such as forming, welding, heat treating, service finishes and coatings, shall be incorporated into the component design documentation. Protective coatings shall be selected and applied as necessary to protect the engine from deterioration when subjected to the environment specified in 3.1.2.4 (Environments). MIL-STD-171 shall be used in the selection and application of protective treatments and surface finishes. Cleaning procedures and solutions shall conform to S021-CP090290-F1, (Contamination and Corrosion Control Plan). An assembly process (including welding) of an unusual nature shall be demonstrated by a suitable mockup prior to initiation of fabrication. Proprietary processes may be used only if the NERVA contractor reviews and understands the process and controls it through the vendor's quality program or through other means such as a resident in-plant quality monitor.

3.3.3.2.1 Training.- A training program shall be maintained for quality assurance, purchasing, manufacturing, and other disciplines whose decisions or actions affect achievement, measurement or maintenance of product quality.

3.3.3.2.2 Certification.- Contractor and subcontractor personnel responsible for controlling and/or performing special processes (such as welding, soldering, wiring, heat treating, non-destructive testing, etc.,) having an effect upon quality of NERVA hardware shall be certified by standard codes, subject to the approval of the procuring agency.

3.3.3.3 Non-Destructive Testing.- Non-destructive testing requirements and standards shall be incorporated into the component design documentation as specified in P017-SS-090205-F1, (Product Assurance Program Plan). MIL-STD-453 shall be used for radiographic inspection, MIL-I-6866 for penetrant inspection, MIL-I-6868 for magnetic particle inspection and MIL-I-8950 for ultrasonic inspection. The standards for castings shall be in accordance with AGC-STD-4004, for weldments AGC-STD-4005 and forgings and wrought metals AGC-STD-4006. Specialized requirements and standards for non-destructive testing shall be defined in the component design documents. Definitive nondestructive testing procedures shall be prepared to insure the implementation of these inspections and interpretation of tests resulting in accordance with the design intent. All non-destructive test operations and inspectors shall be qualified by standard codes subject to the approval of the procuring activity.

3.3.4 Standard and Commercial Parts.- Standard and commercial parts as defined in AGC-STD-1004 may be used only if an appropriate standard cannot be selected as specified in 3.3.2 (Selection of Specifications & Standards) and if it is not economically or logistically feasible to prepare a contractor drawing or standard. All standard and commercial parts shall be controlled by specification or source control drawings in accordance with MIL-STD-100. Proprietary parts may be used only if:

(a) The vendor agrees to reveal his design and design analysis through some medium such as a protective agreement; or,

(b) The vendor agrees to divulge his Failure Mode Analysis data which must be of the same level of detail and technical quality as the NERVA Contractor's Failure Mode Analysis or which can be carried to such level of detail and technical adequacy.

3.3.4.1 Drawings.- The requirements to be incorporated on the control drawing shall be determined from a review of the supplier drawings supplemented by inspection and test requirements.

3.3.4.2 Qualification.- A source control drawing shall be used when qualification is a requirement. The drawing will include the requirement: "Only the item(s) described on this drawing when procured from the supplier(s) listed hereon are approved by Aerojet Nuclear System Company (ANSC) for use on the NERVA Program". All changes to supplier drawings, specifications, materials, and methods of fabrication, processing, inspection and testing shall require approval and effectivity established by ANSC.

3.3.5 Moisture and Fungus Resistance.- Requirements for moisture and fungus resistance shall be as defined in S021-CP090290-F1 (Contamination and Corrosion Control Plan).

3.3.6 Corrosion of Metal Parts.- Use of dissimilar metals as defined in ASD-5229 in intimate contact with each other shall be minimized. All metal parts shall be finished to provide protection from corrosion throughout their expected life or protected by an inert purge during ground operations, including storage. The selection, control and application of finishes shall be in general accordance with the requirements specified in S021-CP090290-F1 (Contamination and Corrosion Control Plan) consistent with the constraints of 3.1.2.4, (Environments) and 3.3.1.13, (Fluid Compatibility).

3.3.7 Interchangeability and Replaceability.- All major assemblies, subassemblies and components having the same manufacturers part number shall be physically and functionally interchangeable within the engine. Changes in manufacturer's part numbers shall be governed by the requirements of MIL-D-1000 on interchangeability and replaceability to the extent required by MIL-I-8500.

3.3.8 Workmanship.- All details of workmanship, unless defined by specific standards, shall be consistent with the design intent, as represented by the other quality requirements, such as the dimensional tolerances and surface finish standards, considering the function or use of the product. When the quality imparted in the process of fabrication could have an effect on reliability, strength or function, a standard for workmanship shall be incorporated into the design documentation. The general workmanship requirements for electrical/electronic equipment shall be in accordance with AGC-STD-9012.

3.3.9 Electromagnetic Interference.- The engine shall be electromagnetically compatible with all associated vehicle, propellant depot, space station, and other operational systems, equipment, and related electromagnetic radiation environments. The engine shall comply with the requirements of MIL-E-6051 as specified in S007-CP090290-F1 (Electromagnetic Compatibility Plan.)

3.3.10 Identification and Marking.- Parts of the NERVA Engine shall be marked with the applicable suppliers code identification number and part number in accordance with the requirements of MIL-STD-130. Pipes, hoses and fluid lines shall be identified as to fluid contents and direction of flow as required by MIL-STD-1247.

3.3.11 Storage.- The engine shall be capable of meeting all performance requirements of this specification subsequent to storage while protected from the ground environmental conditions specified in 3.1.2.4, (Environments), for the ground storage life specified in 3.1.2.3, (Useful Life).

Section 4. QUALITY ASSURANCE PROVISIONS

This section will be prepared at a later date.

Section 5. PREPARATION FOR DELIVERY

This section is not applicable to this specification.

Section 6. NOTES

6.1 Tolerances.- Unless otherwise stated, all tolerances and limits are 2.326 standard deviations ($\pm$ 2.326 sigma).

6.2 Definitions.-

(a) Normal Mode - The operation of the engine when all subsystems and components are capable of being operated as designed.

(b) Malfunction Mode

(1) Single Turbopump Operation - The operation of the engine with only one leg of the propellant feed subsystem.

(2) Component Malfunction Mode - The operation of the engine when a component has malfunctioned, other than one which would require single turbopump operation or emergency operation or results in a Category IV failure effect. This mode of operation allows the engine to operate the same as in the normal mode, but without the advantage of the normal mode redundancy.

(c) Emergency Mode - The operation of the engine at a level to effect safe crew return or to prevent danger to the earth's population subsequent to a failure effect Category III failure.

(d) Single Failure Point - Any single mode of failure occuring at the part, component or subsystem level that can be attributed to a specific internal failure mechanism at the part level and that results in inability of the engine to meet its normal-mode performance or service life requirements.

(e) System Power Down - Reduction of engine power to a minimum level consistent with the operating requirements for that particular phase of operation.

(f) Prestart - The phase of an operating mode where all functions of the engine are performed prior to initiating propellant flow other than that required for cooling from a previous operation.

(g) Startup - The process of conditioning and bringing the engine to the first steady state operating point.

(h) Failure Effects

(1) Category I - Failures which produce no significant performance or safety degradation of the system, allow continued operation in the normal mode throughout the rated engine life, and do not result in an increase in the number of Single Failure Points.

(2) Category II - Failures from which the engine can recover and still meet its normal mode performance and service life requirements by switching to or reverting to a recovery mode, but which do result in an increase in the number of Single Failure Points. Failures in this category are further subdivided as follows:

a IIA - Failures which degrade the safety of continued operations but which do not produce transient effects and, at the time of failure, do not require automatic or manual action for the recovery mode. Failures of safety systems and standby-redundant components fall within this category.

b IIB - Failures which are compensated for automatically by the normal control mode or which produce transient effects which can be tolerated by the system and which permit time for human judgement to be exercised on the method and desirability of the recovery mode. Failures which require the functioning of safety systems or redundant components to preclude Category IIIB effects fall within this category.

c IIC - Failures which require immediate malfunction detection and subsequent action to remove or lessen the transient effect and to preclude system damage. Switching to the recovery mode is usually accomplished automatically by the malfunction detection system or by the engine control system. Failures which require the automatic functioning of safety systems or redundant components to preclude Category IV effects fall within this category.

(3) Category III - Failures which result in inability of the engine to meet its normal-mode performance and service-life requirements but which allow Emergency Mode Operation or Single Turbopump Operation. Failures in this category are further subdivided as follows:

a IIIA - Failures which require Single Turbopump Operation.

b IIIB - Failures which require Emergency Mode Operation.

(4) Category IV - Failures which result in direct injury to the crew, endanger the earth's population, or damage the spacecraft or other stage modules upon which crew survival depends, and/or which preclude Emergency Mode Operation. This category includes failures which produce one or more of the following system effects:

a Uncorrectable thrust vector misalignment.

b Loss of thrust to less than that required to effect Emergency Mode Operation.

c Inability to reduce thrust or unsuccessful shutdown and/or cooldown which precludes engine restart.

d Unsuccessful startup to attain thrust equal to or greater than that required for Emergency Mode Operation.

(i) Kerma - A term used to describe the energy deposited by radiation. It is an acronym for Kinetic Energy Released in Material. In this document it is used to describe the intensity of gamma radiation. (4)

TABLE I

SPECIFICATION EXTREME* RADIATION LEAKAGE LIMITS AT PVARA PLANE

(Plane is 63 inches Forward of Core Center)

TYPE OF RADIATION	RADIATION LEAKAGE LIMITS WITHIN PRESSURE VESSEL OUTSIDE RADIUS
Gamma Carbon KERMA Rate	1.8×10^{7} Rad(c)/hr
Fast Neutron Flux	2.0×10^{12} n/cm^2-sec, $E_n > 1.0$ Mev
Intermediate Neutron Flux	3.0×10^{12} n/cm^2-sec, 0.4 ev $\leq E_n \leq 1.0$ MeV
Thermal Neutron Flux	6.0×10^{11} n/cm^2-sec, $E_n < 0.4$ ev

* NOTE: These radiation limits are specification extreme values in that engine component designs are based directly on these limits, with no identifiable factors of uncertainty involved in the use of these data. Component design is based directly on these induced radiation environments and has overall component reliability limits of 2.326 σ.

(1)

TABLE II

SPECIFICATION EXTREME* PVARA RADIATION LEAKAGE LIMITS AT CRITICAL COMPONENT LOCATIONS

Component	Location: Radius (Inches)	Location: Distance Fwd of Core Center (in.)	Gamma KERMA Rate Rads(carbon)/hr.	Neutron Flux (n/cm^2-sec): Thermal $E < .4$ ev	Neutron Flux (n/cm^2-sec): Intermediate $.4\ ev < E < 1$ MeV	Neutron Flux (n/cm^2-sec): Fast $E > 1$ MeV
Lower Thrust Structure-1	19.5	65.5	2.1×10^7	-	-	2.8×10^{14}
-2	19.5	67.5	1.8×10^7	-	-	2.8×10^{14}
-3	19.5	76.5	1.8×10^7	-	-	2.8×10^{14}
Turbopump Assembly-1	36.0	107.0	7.0×10^6	1.0×10^{12}	5.0×10^{12}	1.0×10^{12}

* NOTE: These radiation limits are specification extreme values in that engine component designs are based directly on these limits, with no identifiable factors of uncertainty involved in the use of these data. Component design is based directly on these induced radiation environments and has overall component reliability limits of 2.326 σ.

TABLE III

ENGINE RELIABILITY ASSESSMENT PARAMETERS

Normal or Component Malfunction (Spec.Para.No.)	Single Turbopump Operation (Spec.Para.No.)	Title	Response Variable
3.1.1.1.3		Thrust Build-up and Thrust Retreat	Chamber Pressure Change Rate, psi/sec. Chamber Temperature Change Rate, °R/sec.
3.1.1.1.2	3.1.1.1.5.2.1.3	Steady State Operation	Isp (vacuum), sec. Thrust (vacuum), lb.
3.1.1.1.5.1.4		Cooldown	Isp (vacuum), sec. Thrust, vacuum lb.
3.1.1.1.10		Thrust Vector Control	Angle from null, degree Angular Velocity, °/sec Angular Acceleration, $°/sec^2$

TABLE IV

NERVA ENGINE DUTY CYCLES

Burn Number	Manned Interorbit Shuttle – Normal Mode – Duration (Minutes)	Manned Interorbit Shuttle – Normal Mode – Time Between Burns (Hours)	Manned Interorbit Shuttle – Single TPA Mode – Duration (Minutes)	Manned Interorbit Shuttle – Single TPA Mode – Time Between Burns (Hours)	Unmanned Interorbit Shuttle – Normal Mode – Duration (Minutes)	Unmanned Interorbit Shuttle – Normal Mode – Time Between Burns (Hours)	Unmanned Interorbit Shuttle – Single TPA Mode – Duration (Minutes)	Unmanned Interorbit Shuttle – Single TPA Mode – Time Between Burns (Hours)	Deep-Space Injection – Normal Mode – Duration (Minutes)	Deep-Space Injection – Normal Mode – Time Between Burns (Hours)	Deep-Space Injection – Single TPA Mode – Duration (Minutes)	Deep-Space Injection – Single TPA Mode – Time Between Burns (Hours)
1.	24	72	TBD	TBD	31	64	TBD	TBD	15	4	TBD	TBD
2.	2	8	TBD	TBD	7	107	TBD	TBD	21	0	TBD	TBD
3.	1	8	TBD	TBD	3	65	TBD	TBD	10	5	TBD	TBD
4.	2	48	TBD	TBD	8		TBD		3		TBD	
5.	2	8	TBD	TBD								
6.	1	8	TBD	TBD								
7.	1	72	TBD	TBD								
8.	10		TBD									

TABLE V

OPERATIONAL PHASE/NATURAL ENVIRONMENT MATRIX

Environment	1 Space Operations	2 Flight Vehicle Boost (ETR)	3 Vehicle Assembly and Checkout Launch Operations (KSC and ETR)	4 Transportation (Ground)	5 Engine, Subsystem and Component (Assy and Storage) - Stage Assy
Geographic Locations	In space between 262 NM earth orbit and 60 NM lunar orbit.	Eastern Test Range	Kennedy Space Center and Eastern Test Range	Sacramento to Michoud and Large, Large to Michoud and Gulf Transportation.	Sacramento, Large, Michoud and MTF.
Altitude	262 to 60 NM lunar orbit	S.L. to 262 NM	Sea Level	Seal Level to 7000 ft.	Sea Level to 890 ft
Atmospheric Pressure, psia	2×10^{-10} at 262 NM orbit. 1.5×10^{-15} at 60 NM lunar orbit.	See column 1 and 3 $\Delta P/\Delta t$ max =	Min 14.4 Max 15.0 ΔP max = 0.09 lb/in.^{2} in 1 hour.	Min. 11.0 Max 15.2 ΔPmax = 0.09 lb/in.^{2} in 1 hour	Min 13.1 Max 15.2 ΔP max = 0.09 lb/in.^{2} in 1 hour.
Atmospheric Temperature °R (Kinetic)	2700 at 262 NM orbit	See Column 1 and 3	Min. 488 - Max 559	Min 420 Max 585	Min 420 Max 575
Atmospheric Composition	Primarily, H and H+ with trace of H_e at extreme altitudes.	See Table VI	See Table VI	Same as column 3.	Same as column 3.
Atmospheric Humidity	Negligible	Negligible	See Figures 4 and 5 inclusive	Same as column 3	Same as column 3.
Solar Radiation Btu/ft²/hr (Thermal)	442	442	Max normal to surface I_H = 400 Diffuse sky radiation I_{dH} = 166	Same as column 3	Same as column 3.
Rain	Not Applicable	No boost during rain.	Max rate in/hr 30 Wind speed, ft/sec 55	Same as column 3	Same as column 3
Snow	Not Applicable	None	None	Max snow load = 20 lb/ft^2	Max snow load = 10 lb/ft^2
Hail	Not Applicable	No boost during hail	Max size 1 inch diameter probability one in 30 years. Velocity of fall 66 ft/sec. Hail density 50 lb/ft^3.	Max size 2 inch diameter Probability once in 15 years. Velocity of fall 100 ft/sec. Hail density = 50 lb/ft^3.	Same as column 4

TABLE V (CONTINUED)

OPERATIONAL PHASE/NATURAL ENVIRONMENT MATRIX

Phase	1	2	3	4	5
Environment	Space Operations	Flight Vehicle Boost (ETR)	Vehicle Assembly and Checkout-Launch Operations (KSC and ETR)	Transportation (Ground)	Engine Subsystem and Component (Assy and Storage) - Stage Assy
Wind, ft/sec	Not Applicable	Max 246 ft/sec	Max 150 ft/sec	Max peak wind 77 ft/sec	Same as column 4
Sand and Dust	Not Applicable	Negligible	See Table VII	See Table VII	See Table VII
Salt Spray	Not Applicable	See Table VIII	See Table VIII	Negligible	Negligible
Fungi and Bacteria	Not Applicable	TBD	TBD	TBD	TBD
Atmospheric Electricity	Not Applicable	Rise to 100,000 amps in 10 μsec. Decay to 50,000 amps in 20 μsec.	Same as column 2	Same as column 2	Same as column 2
Seismic Environment	Not Applicable	Not Applicable	TBD	TBD	TBD
Magnetic Field, avg. Total Gauss, max.	0.35 at 262 NM to $< 10^{-4}$ 60 NM lunar orbit	0.52	0.52	0.52	0.52
Meteoroids	See Figures 6 and 7	See Figures 6 and 7	Not Applicable	Not Applicable	Not Applicable
Radiation-High Energy Particle	1.24×10^9 particles/in^2/yr with energy $<$ 30 MEV. 9.3×10^7 particles/in^2/yr with energy $<$ 100 MEV.	Negligible	Not Applicable	Not Applicable	Not Applicable
Radiation-Trapped Particles/in^2/flight	TBD protons with energy $<$ 30 MEV. TBD electrons with energy $<$ __ MEV.	Negligible	Not Applicable	Not Applicable	Not Applicable
Radiation - ultra violet and X-ray watts/ft^2	Ultra violet 2.4×10^{-4} max. X-ray 8.6×10^{-4} max.	Same as column 1	Not Applicable	Not Applicable	Not Applicable

TABLE V (CONTINUED)

OPERATIONAL PHASE/NATURAL ENVIRONMENT MATRIX

Phase / Environment	1 Space Operations Space Operations	2 Flight Vehicle Boost (ETR)	3 Vehicle Assembly and Checkout Launch Operations (KSC and ETR)	4 Transportation (Ground)	5 Engine Subsystem and Component (Assy and Storage) - Stage Assy
Radiation - Earth Thermal, $\bar{E}$, $Btu/ft^2/hr$	$\bar{E} = 63.4 \left(\frac{3442}{3442+Alt_E}\right)^2$ Alt_E = Altitude above earth in NM	See column 1	Not Applicable	Not Applicable	Not Applicable
Radiation - Earth albedo $\bar{a}_E$ = $Btu/ft^2/hr$	$\bar{a}_E = 173.4 \left(\frac{3442}{3442+Alt_E}\right)^2$	See column 1	Not Applicable	Not Applicable	Not Applicable
Radiation - Lunar thermal, L, $Btu/ft^2/hr$	$\bar{L} = 210 \left(\frac{938}{938+Alt_L}\right)^2$	Negligible	Not Applicable	Not Applicable	Not Applicable
Radiation - Lunar albedo, $\bar{a}_L$, $Btu/ft^2/hr$	$\bar{a}_L = 56 \left(\frac{938}{938+Alt_L}\right)^2$	Negligible	Not Applicable	Not Applicable	Not Applicable
Ionosphere - ionized electron density $N/in.^3$	5×10^6 at 262 NM decreasing to < 5700 at 60 NM lunar orbit	Max 5×10^7 at 190 NM Altitude, $< 10^4$ below 50 NM	Not Applicable	Not Applicable	Not Applicable
Solar Radio Noise	See Table IX	See Table IX	See Table IX	Not Applicable	Not Applicable
Solar Illumination $lumens/ft^2$	1.27×10^4	Not significant	Not significant	Not significant	Not significant

TABLE VI

NORMAL ATMOSPHERIC COMPOSITION FOR CLEAN,
DRY AIR AT ALL LOCATIONS
(VALID TO 48.6 NAUTICAL MILE GEOMETRIC ALTITUDE)

Gas	Percent by Volume	Percent by Weight
Nitrogen (N_2)	78.084	75.520
Oxygen (O_2)	20.9476	23.142
Argon (Ar)	0.934	1.288
Carbon dioxide (CO_2)	0.0314	0.048
Neon (Ne)	1.818×10^{-3}	1.27×10^{-3}
Helium (He)	5.24×10^{-4}	7.24×10^{-5}
Krypton (Kr)	1.14×10^{-4}	3.30×10^{-4}
Xenon (Xe)	8.7×10^{-6}	3.9×10^{-5}
Hydrogen (H_2)	5×10^{-5}	3×10^{-6}
Methane (CH_4)	2×10^{-4}	1×10^{-5}
Nitrous Oxide (N_2O)	5×10^{-5}	8×10^{-5}
Ozone (O_3) summer	0 to 7×10^{-6}	0 to 1.1×10^{-5}
winter	0 to 2×10^{-6}	0 to 3×10^{-6}
Sulfur dioxide (SO_2)	0 to 1×10^{-4}	0 to 2×10^{-4}
Nitrogen dioxide (NO_2)	0 to 2×10^{-6}	0 to 3×10^{-6}
Ammonia (NH_3)	0 to trace	0 to trace
Carbon monoxide (CO)	0 to trace	0 to trace
Iodine (I_2)	0 to 1×10^{-6}	0 to 9×10^{-6}

TABLE VII

SAND AND DUST

	Sand	Dust
Size of Particles Diameter, in.	0.0031 to 0.039 90% between 0.0031 and 0.012	3.9×10^{-6} to 3.1×10^{-3} 90% between 3.9×10^{-6} and 7.9×10^{-6}
Hardness and Shape	>50% of particles composed of angular quartz or harder, 7 to 8 on MOH's scale	
Number, Distribution and Associated Conditions	1.2 lb/ft^3 during sand storm 10% between 0.079 and 3.3 ft above ground 90% below 0.079 ft	3.7×10^{-7} lb/ft^3 uniform distribution
	Relative humidity 30% or less wind velocity 32.8 ft/sec at 10 ft altitude	

TABLE VIII

SALT SPRAY

Salt Spray Exposure	**TBD**
Salt Accumulation (Extremes) Particle Size, inches	3.94×10^{-6} to 7.87×10^{-4} 98% of total greater than 3.15×10^{-5}
Accumulation (Fallout) lb/ft^2/day, Max	10.2×10^{-7} During Rain Storm
Min	5.12×10^{-8} Unevenly Distributed.

TABLE IX

SOLAR RADIO NOISE

Quiet Sun Noise Power watts/ft^2/caps	Varies from 10^{-20} at 0.4 in. wavelength to 10^{-23} at 160 inch wavelength
Solar Storm Noise Power Increase (orders of magnitude)	1 to 8
Variation with Sunspot Between 2.5 and 80 inch wavelength Orders of Magnitude	Up to 4

Noise Power Flux = $3.0 \times 10^{-34} f^{1.1}$ watts/in. ^{2}/cps

where f = frequency in cps

TABLE X

INDUCED RADIATION ENVIRONMENT OF NERVA ENGINE OPERATING AT FULL POWER
(GRAPHITE CORE REACTOR)

Location			Gamma	Neutron Flux (n/cm^2-sec)		
Polar Angle	Direction	Distance from Core Center	KERMA Rate Rads(Carbon)/hr.	Thermal*** E < .4 eV	Intermediate .4 ev < E < 1 MeV	Fast E > 1 MeV
0°	Forward*	6 Feet	1.8×10^7	6.0×10^{11}	3.0×10^{12}	2.0×10^{12}
90°	Radial Outward** at Core Midplane	10 Feet	$(1.2 \pm 0.4) \times 10^8$	$(1.2 \pm 0.7) \times 10^{13}$	$(4.0 \pm 4.0) \times 10^{13}$	$(9.0 \pm 4.5) \times 10^{12}$
180°	Aft**	5 Feet	$(3.2 \pm 1.0) \times 10^8$	$(3.0 \pm 1.8) \times 10^{12}$	$(1.4 \pm 1.4) \times 10^{14}$	$(9.0 \pm 4.5) \times 10^{13}$

Radiation environment at distances greater than 10 ft is proportional to $\frac{1}{r^2}$, where r is the distance from the core center.

*Radiation levels in the forward direction are controlled by the specification for the Internal Shield.

**These are nominal levels ± the maximum anticipated calculational uncertainty ($\sim 3\sigma$). The uncertainties are not necessarily symmetric about the nominal value. That is, negative radiation levels have no physical meaning.

***The thermal neutron flux shown at 90° is appropriate for a radial not in line with a control drum.

TABLE XI

INDUCED UNPERTURBED RADIATION ENVIRONMENT OF NERVA ENGINE FOLLOWING 30 MINUTE FULL POWER FIRING

(GRAPHITE CORE REACTOR)

Polar Angle	Location	Distance From Core Center	Gamma KERMA Rate* (Rads (Carbon)/hr) 1 Day After Firing	1 Week After Firing	1 Month After Firing
0°	Forward	10 Feet	(79 ± 119)	(8.6 ± 12.9)	(1.8 ± 2.7)
90°	Radial Outward at Core Mid-plane	10 Feet	$(1.7 \pm 0.5) \times 10^4$	$(1.9 \pm 0.6) \times 10^3$	$(3.8 \pm 1.1) \times 10^2$
180°	Aft	10 Feet	$(1.3 \pm 0.4) \times 10^4$	$(1.5 \pm 0.5) \times 10^3$	$(3.0 \pm 0.9) \times 10^2$

Radiation environment at distances greater than 10 ft is proportional to $\frac{1}{r^2}$, where r is distance from core center.

*Gamma KERMA Rates are the nominal level $\pm$ the maximum anticipated calculational uncertainty ($\sim 3\sigma$). The uncertainties are not necessarily symmetric about the nominal value. That is, negative KERMA rates have no physical meaning.

TABLE XII

INDUCED RADIATION ENVIRONMENT OF NERVA ENGINE OPERATING AT 80% OF FULL POWER
(GRAPHITE CORE REACTOR)

Location			Gamma	Neutron Flux (n/cm^2-sec)		
Polar Angle	Direction	Distance from Core Center	KERMA Rate Rads (Carbon)/hr.	Thermal*** $E < .4$ eV	Intermediate $.4\ \text{ev} < E < 1$ MeV	Fast $E > 1$ MeV
0°	Forward*	6 Feet	1.4×10^{7}	4.8×10^{11}	2.4×10^{12}	1.6×10^{12}
90°	Radial Outward** at Core Midplane	10 Feet	$(9.6 \pm 0.3) \times 10^{7}$	$(9.6 \pm 0.6) \times 10^{12}$	$(3.2 \pm 3.0) \times 10^{13}$	$(7.2 + 3.6) \times 10^{12}$
180°	Aft**	5 Feet	$(2.6 \pm 0.8) \times 10^{8}$	$(2.4 \pm 1.4) \times 10^{12}$	$(1.1 \pm 1.1) \times 10^{14}$	$(7.2 \pm 3.6) \times 10^{13}$

Radiation environment at distances greater than 10 ft is proportional to $\frac{1}{r^2}$, where r is the distance from the core center.

*Radiation levels in the forward direction are controlled by the specification for the Internal Shield.

**These are nominal levels ± the maximum anticipated calculational uncertainty ($\sim 3\sigma$). The uncertainties are not necessarily symmetric about the nominal value. That is, negative radiation levels have no physical meaning.

***The thermal neutron flux shown at 90° is appropriate for a radial not in line with a control drum.

The table is appropriate for single TPA operation.

The above data is applicable to a graphite core reactor.

(4)

(4)

TABLE XIII

DESIGN ACCELERATIONS, NUCLEAR ENGINE-TO-STAGE INTERFACE

Operational Phase and Event	Time or Time Interval (Seconds)	Longitudinal Static Acceleration (g)	Longitudinal Dynamic Acceleration (g)	Lateral Dynamic Acceleration (g)	Acoustics (Yes/No)	Acoustics Vibrations (Yes/No)
Ground Handling	Handling accelerations shall not exceed Flight Design Acceleration					
Transportation	Transportation acceleration shall not exceed Flight Design Acceleration					
Launch and Boost						
Ignition 1st Stage	T-4/T-0	1.0	0	0	Yes	Yes
Release/Liftoff	T-0/T+10	1.4	±2.25* (3 - 35 Hz)	± 1.5*★ (0.1 - 15 Hz)	Yes	Yes
1st Stage Steady State	T+10/T+65	1.4/2.0	±0.3 (3 - 35 Hz)	± 0.3* (0.1 - 15 Hz)	Yes	Yes
Mach I Transonic	T+65/T+75	2.0/2.2	±0.3 (3 - 35 Hz)	± 0.3* (0.1 - 15 Hz)	Yes	Yes
Max Q	T+75/T+85	2.2/2.4	±0.3 (3 - 35 Hz)	± 0.3* (0.1 - 15 Hz)	Yes	Yes
Max Acceleration	T+150/T+160	5.0/5.2	±0.3 (3 - 35 Hz)	± .10* (0.1 - 15 Hz)	No	No
Cutoff/Separation 1st Stage	T+160/T+165	0	±2.25* (3 - 35 Hz)	± .0.3* (0.1 - 15 Hz)	No	No
Ignition 2nd Stage	T+170	0.75	Small	Small	No	No
Boost 2nd Stage	T+170/T+470	1.50	Small	Small	No	No
Space Operations (TBD)						
Docking/Undocking						
Start						
Steady State Thrust						
Shutdown						
Cooling						
Coast						
TVC						

NOTE:

* These Transient Accelerations decay to zero within 6 seconds.

★ The peak acceleration occurring during this transient motion is ± 1.5g as listed below. Decomposition into the individual Lateral modes of the frequency band 0.1 Hz. - 15 Hz. results in the following modal peak accelerations:

Mode No.	Natural Frequency (Hertz)	Peak Acceleration (g)
1	1.15	± 0.05
2	2.46	± 0.38
3	4.50	± 0.79
4	5.37	± 0.49
5	6.22	± 0.01
6	6.47	± 0.01
7	7.32	± 0.00
8	7.99	± 0.11
9	9.30	± 0.26
10	11.2	± 0.15
11	13.2	± 0.07
12	14.6	± 0.01

TABLE XIV

EXTERNAL INDUCED ELECTROMAGNETIC RADIATION ENVIRONMENT

OPERATION	RADIATION SPECTRUM ≤ 1 MHz	1 MHz - 10 MHz	10 MHz - 100 MHz	100 MHz - 1 GHz	≥ 1 GHz
Engine Assembly & Checkout	IPL(1) ______ MED(2) ______ MRR(3) ______				
Engine Acceptance Test					
Transportation and Storage					
Vehicle Assembly					
Pre-Launch Operations					
Launch and Boost					
Propellant Depot					
262 nm Orbit					
Translunar Trajectory					
Lunar Orbit					
Space Stations					

(1) Incident power level, watts/ft^2 (at engine boundary)
(2) Maximum exposure duration
(3) Maximum repetition rate, exposures/hr

TABLE XV

VEHICLE/STAGE INDUCED ELECTROMAGNETIC ENVIRONMENT

A. Radiation

Frequency	Power Level	Max. Duration	Repetition Rate

B. Conduction

Frequency	Voltage	Power Level	Max. Duration	Repetition Rate

TABLE XVI

ENGINE INDUCED ELECTROMAGNETIC ENVIRONMENT

Frequency	POWER LEVEL			Decay Rate
	Rated Thrust	80% Thrust	60% Thrust	

TABLE XVII

NERVA FLIGHT ENGINE
EXPLOSIVE ATMOSPHERE ENVIRONMENT

OPERATION	AVERAGE H_2 CONCENTRATION(Vol.%)	MAX H_2 CONCENTRATION (Vol.%) AND LOCATION
Engine Acceptance Testing		
Pre-Launch Operations		
Launch and Boost		

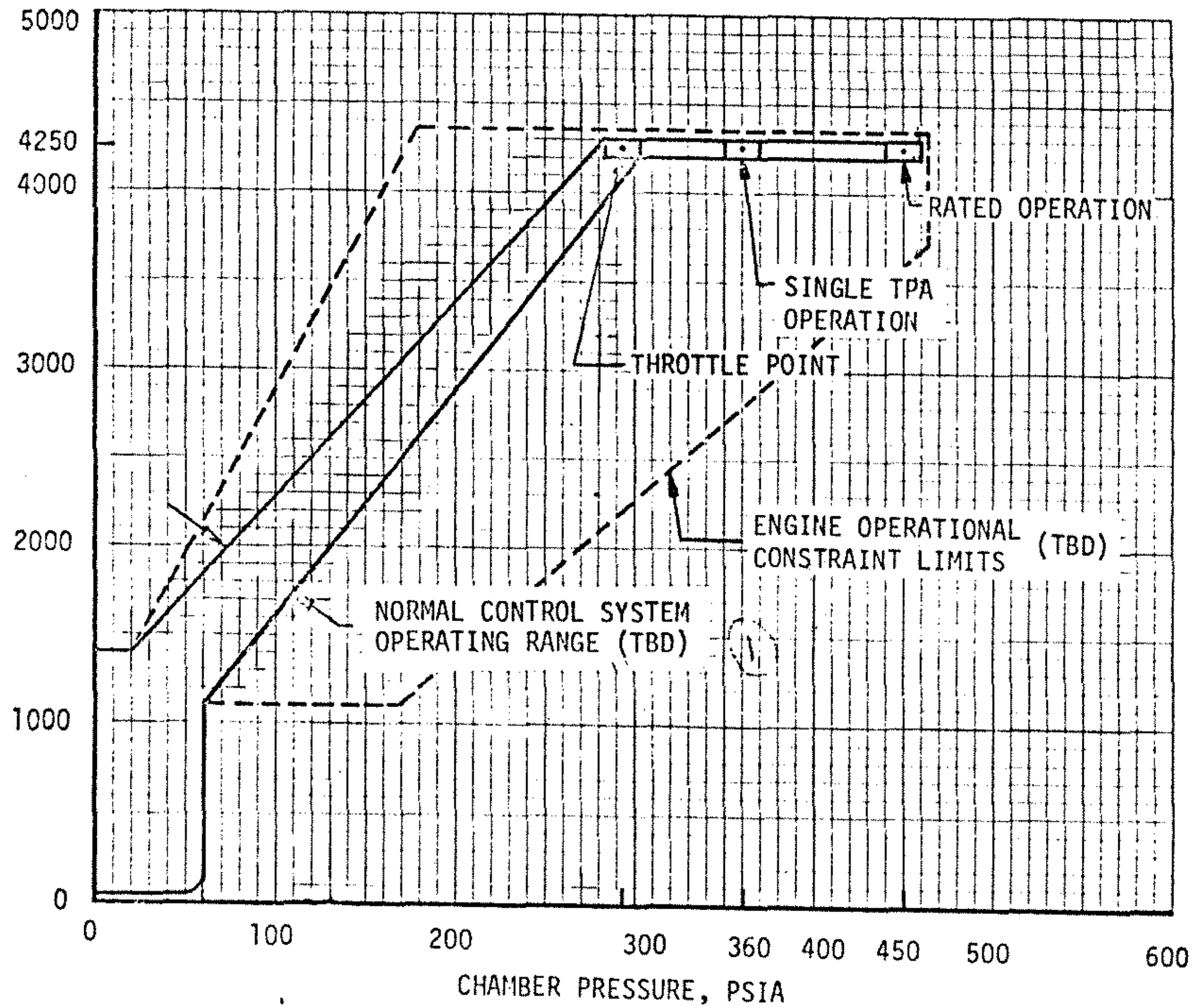


Figure 1

NERVA ENGINE OPERATIONAL CONSTRAINT MAP

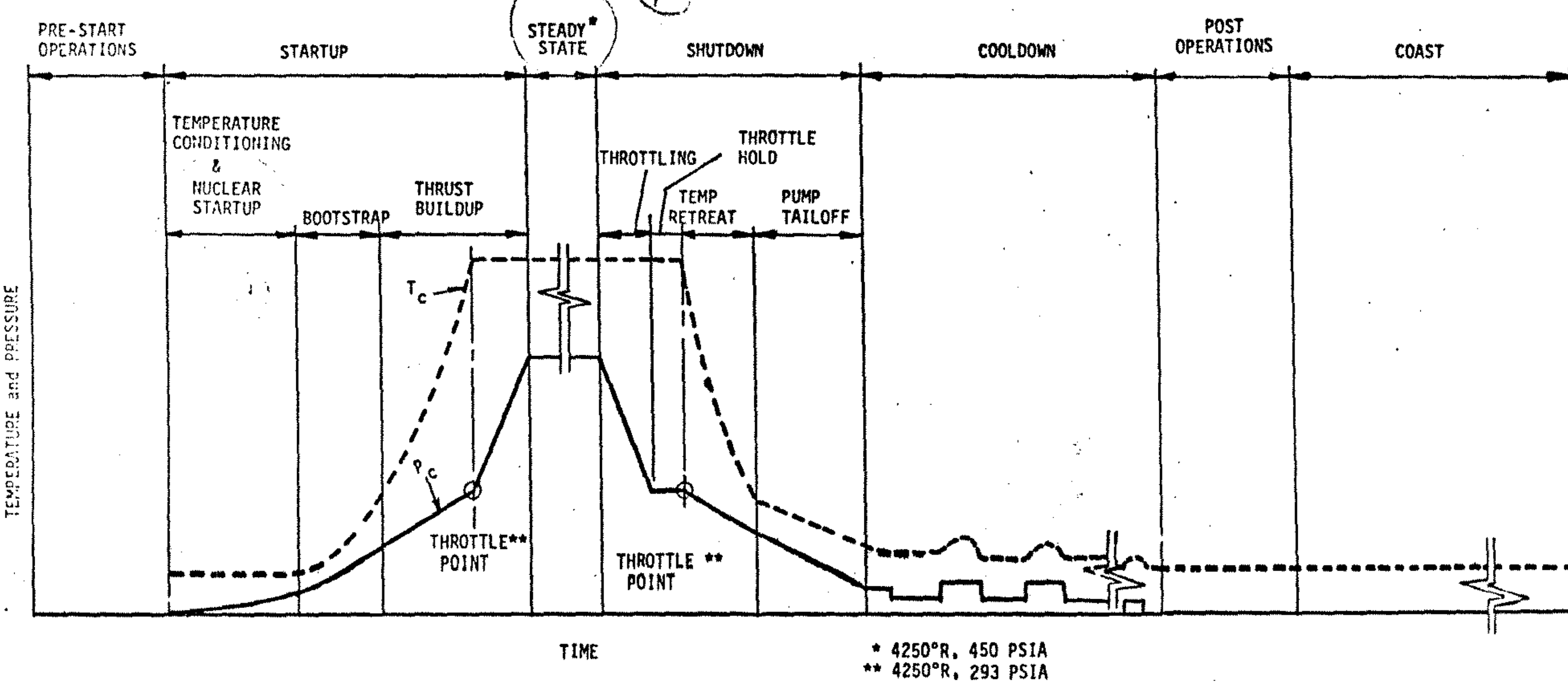


Figure 2 - NERVA Engine Operational Phases

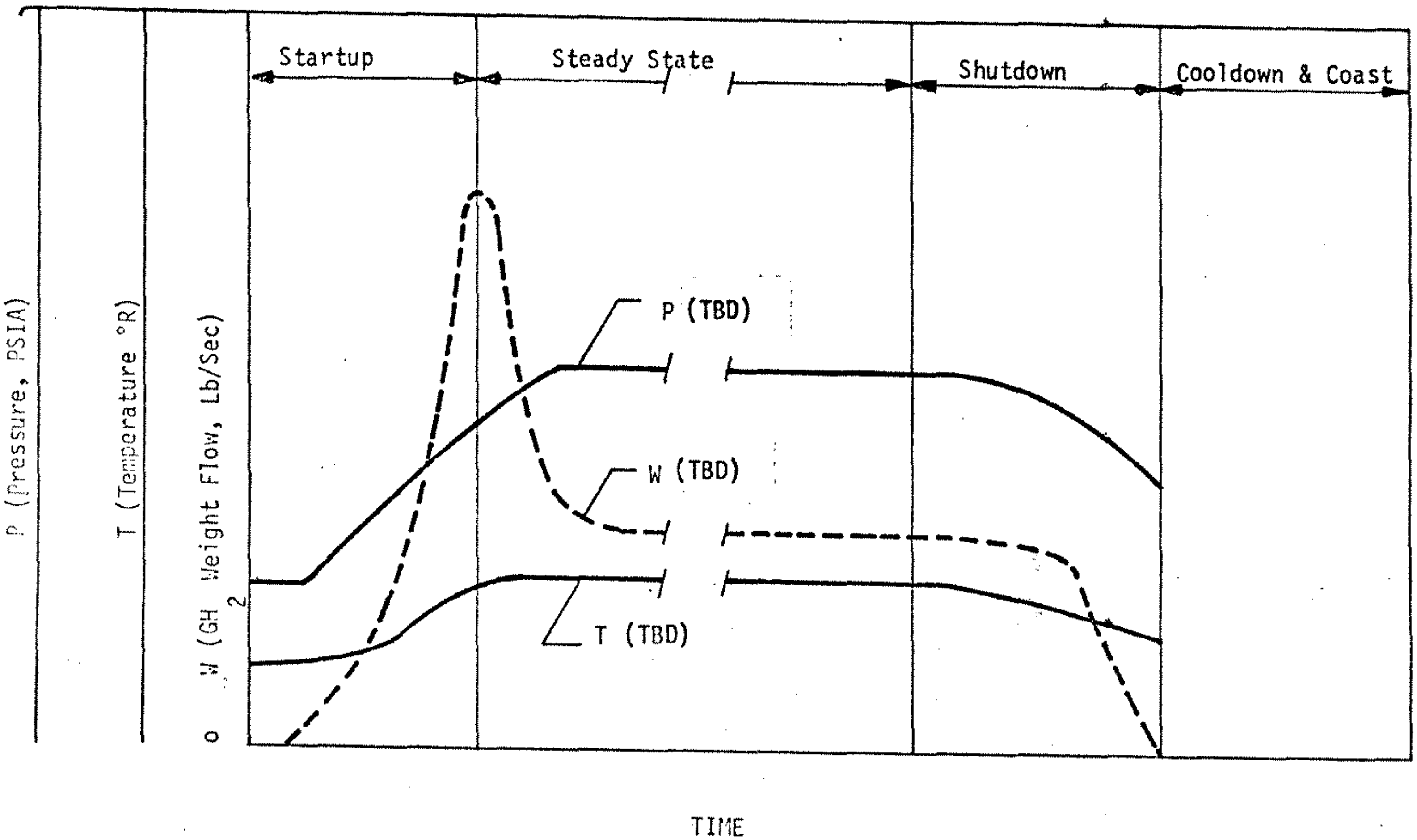


Figure 3

Normal Mode Interface Gas Requirements
for Propellant Tank Pressurization

Figure 4

Extreme Humidity Cycle - 15 Day Exposure

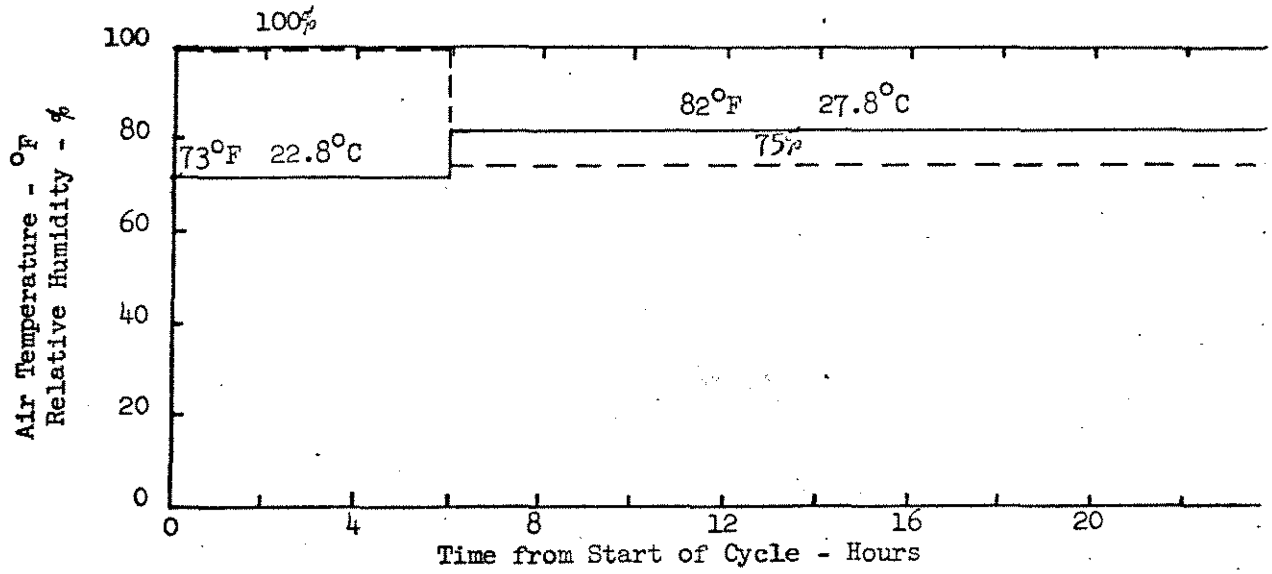
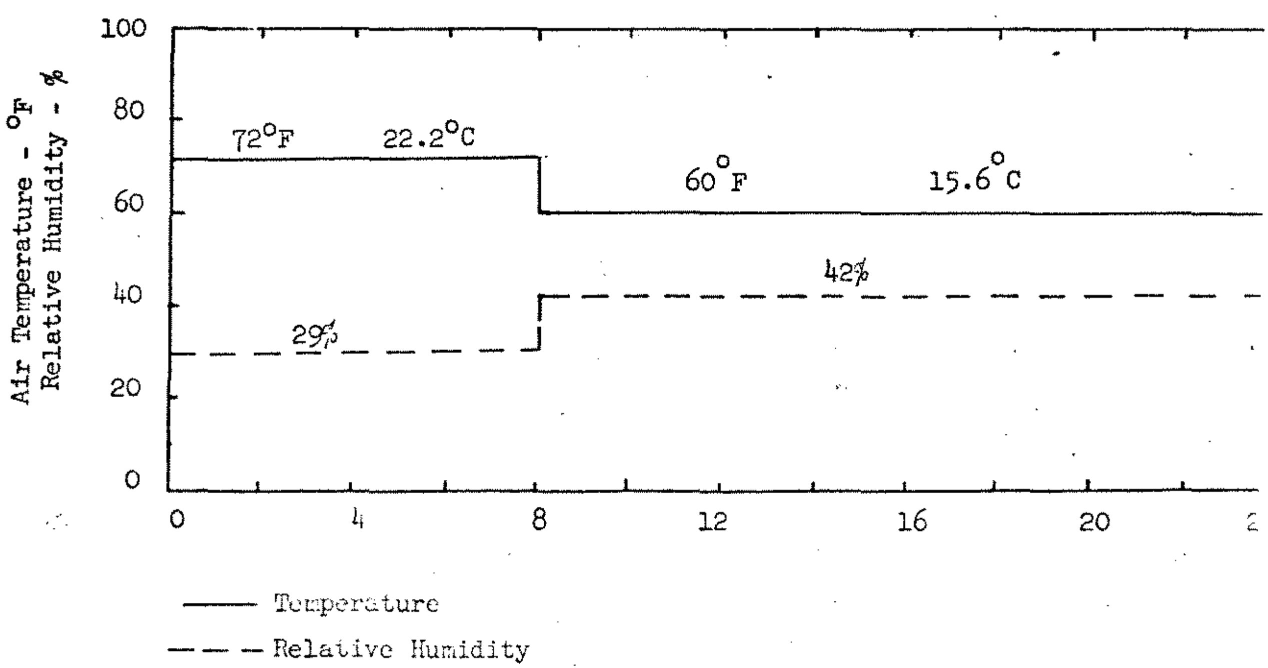


Figure 5

Low Humidity Cycle - 10 Day Exposure



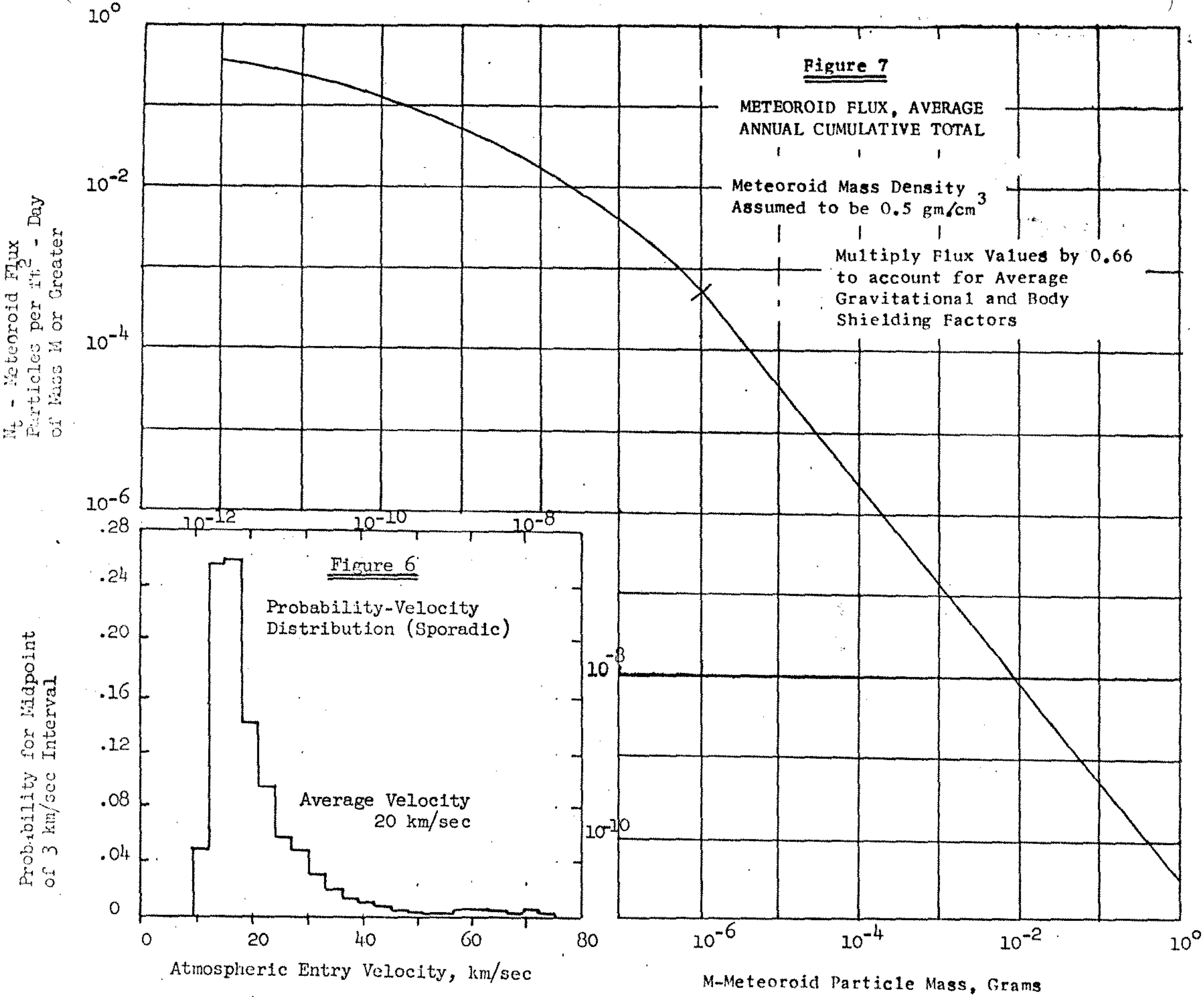


Figure 7
METEOROID FLUX, AVERAGE ANNUAL CUMULATIVE TOTAL
Meteoroid Mass Density Assumed to be 0.5 gm/cm3
Multiply Flux Values by 0.66 to account for Average Gravitational and Body Shielding Factors
Nt - Meteoroid Flux Particles per ft2 - Day of Mass M or Greater
M-Meteoroid Particle Mass, Grams
10^0
10^-2
10^-4
10^-6
10^-8
10^-10
10^-12
10^-6
10^-4
10^-2
10^0
Figure 6
Probability-Velocity Distribution (Sporadic)
Average Velocity 20 km/sec
Probability for Midpoint of 3 km/sec Interval
Atmospheric Entry Velocity, km/sec
.28
.24
.20
.16
.12
.08
.04
0
0
20
40
60
80

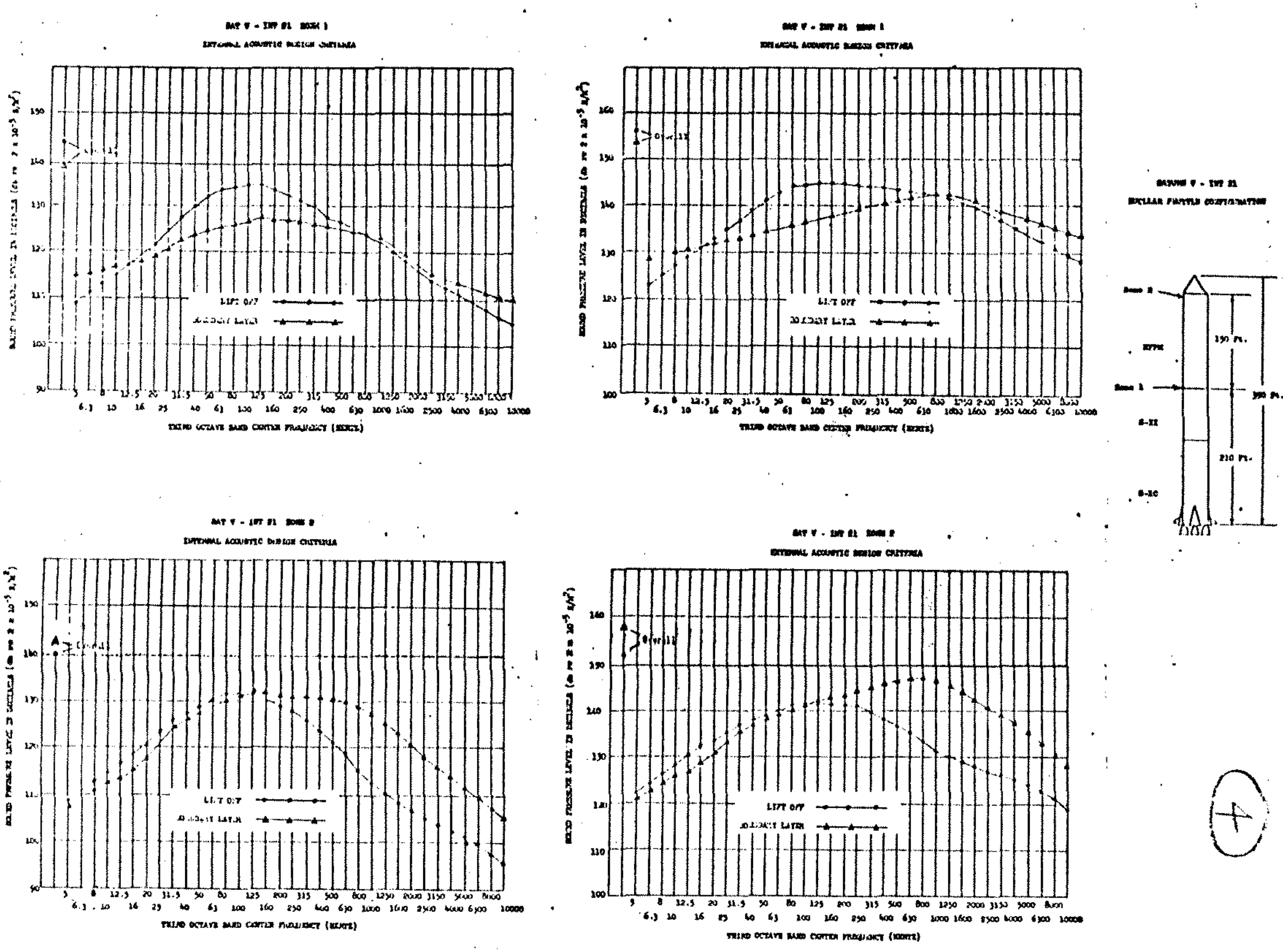
TBD

Note: KERMA Rate and Flux Contours are based on a Graphite Core Reactor

Figure 8

Isokerma Rate and Isoflux Nuclear Environment Contour Map (Full Power)

Figure 9 NERVA Acoustic Environment Data



Specification No. CP-9290 A

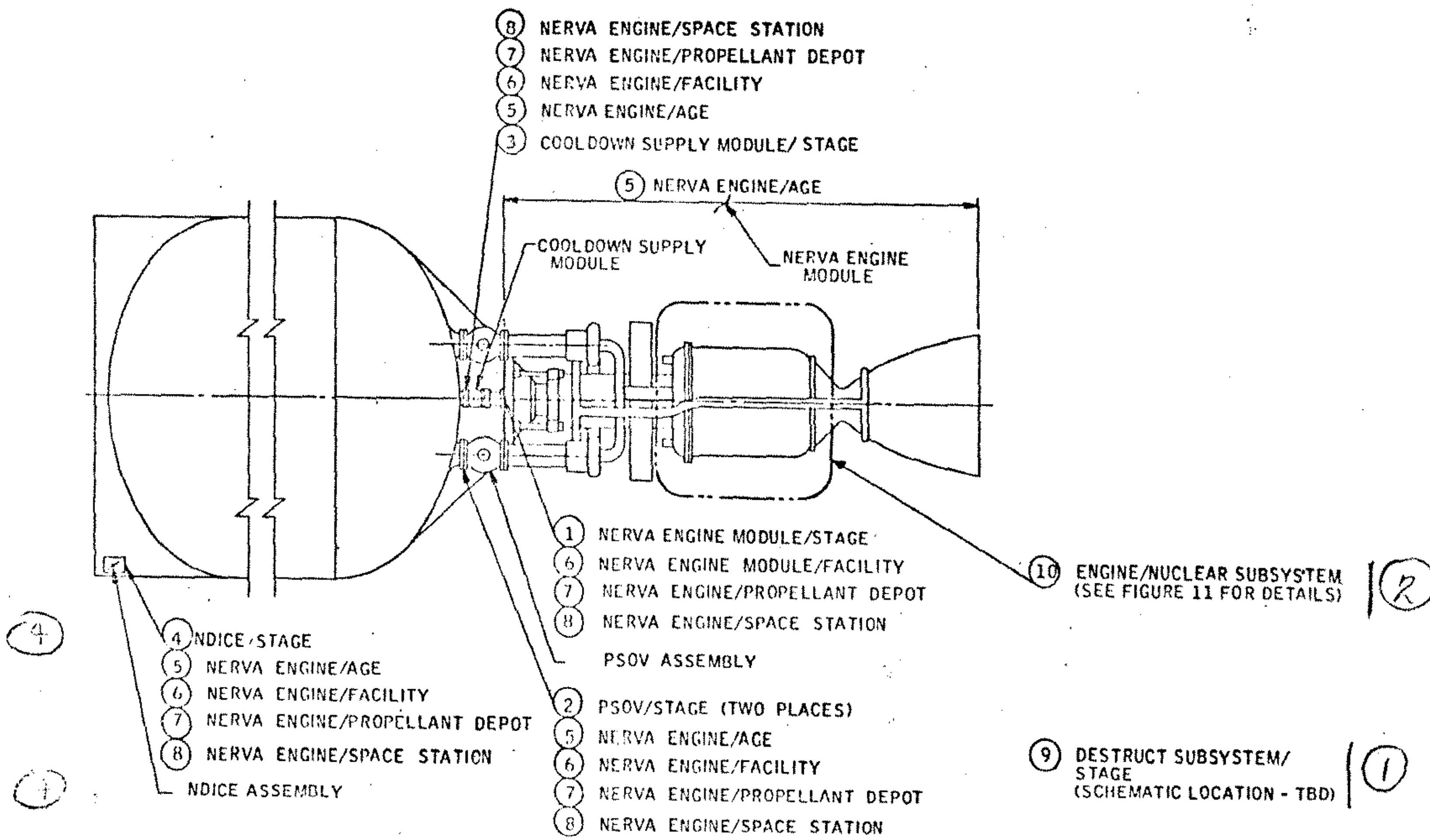
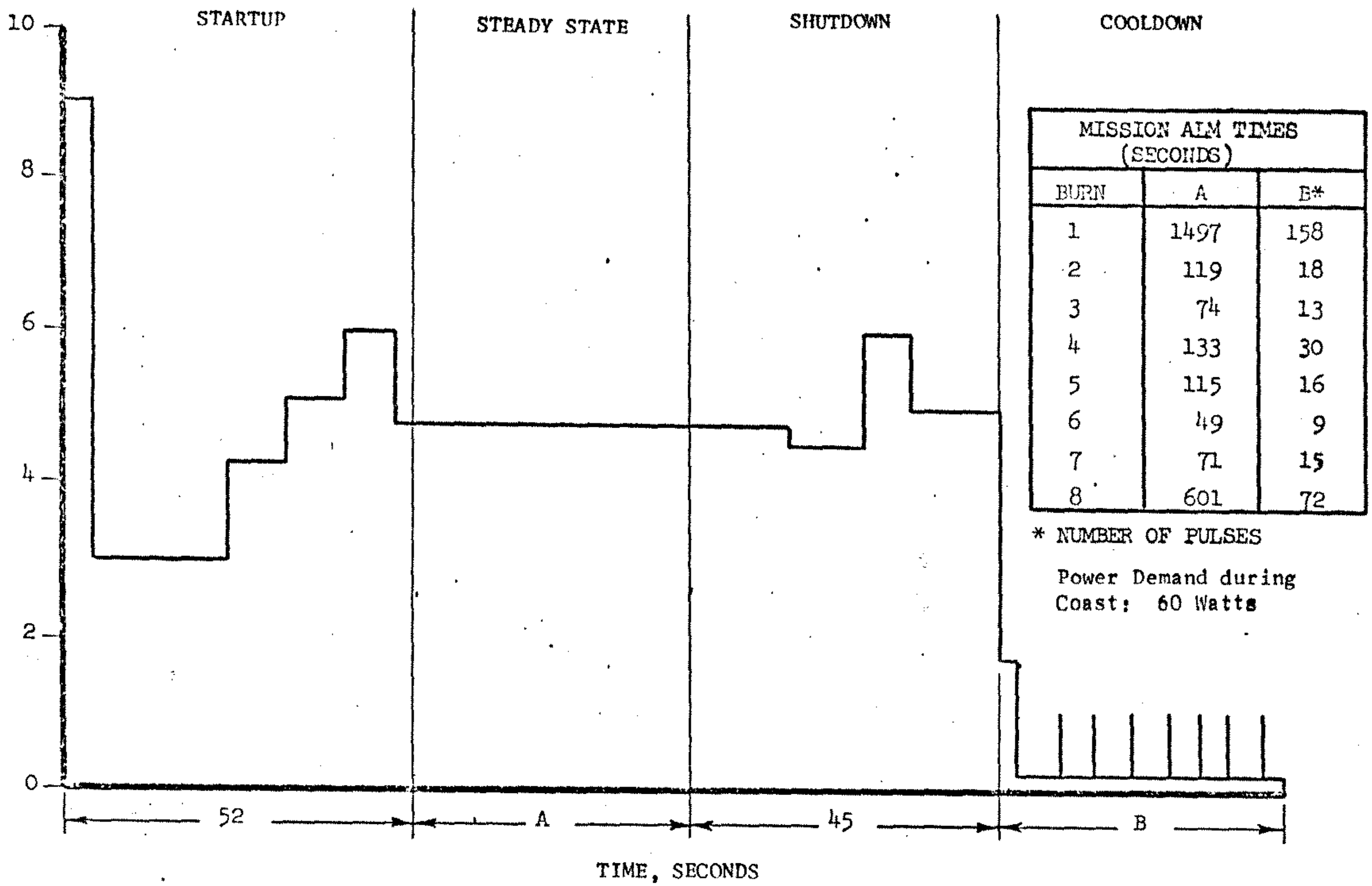


Figure 10. Schematic Arrangement

(2)

(TBD)

Figure 11 - Engine-Nuclear Subsystem Interfaces



MISSION AIM TIMES (SECONDS)		
BURN	A	B*
1	1497	158
2	119	18
3	74	13
4	133	30
5	115	16
6	49	9
7	71	15
8	601	72

* NUMBER OF PULSES

Power Demand during Coast: 60 Watts

Figure 12 NORMAL OPERATION POWER PROFILE

ATTACHMENT I

(1)

Format for Emergency Mode Operation Summary

For each selected Emergency Mode Operation, the following information shall be included as a minimum in tabular form:

A. Prestart
   1. Time
B. Startup (from all applicable normal operating modes)
   1. Time
   2. Propellant
   3. Impulse
   4. Chamber Temperature Ramp Rate
   5. Chamber Pressure Ramp Rate
C. Retreat from Normal Mode Steady-State
   1. Time
   2. Propellant
   3. Impulse
   4. Chamber Temperature Ramp Rate
   5. Chamber Pressure Ramp Rate.
D. Steady-State
   1. Time
   2. Specific Impulse
   3. Thrust
   4. Chamber Temperature
   5. Chamber Pressure
   6. Impulse
E. Shutdown and Cooldown
   1. Time
   2. Propellant
   3. Impulse
   4. Chamber Temperature Ramp Rate
   5. Chamber Pressure Ramp Rate
F. Total Impulse

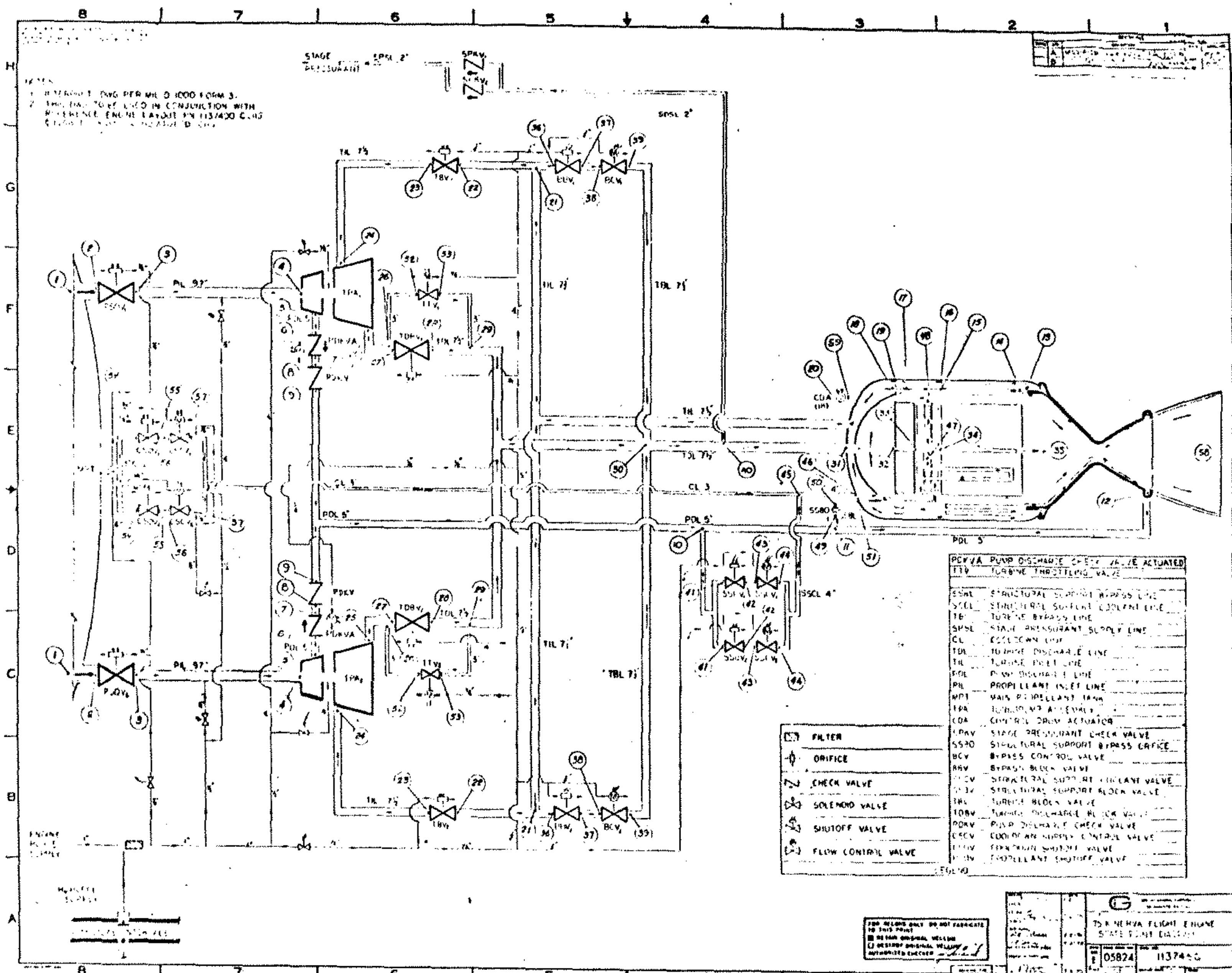
Each selected Emergency Mode shall be displayed graphically on an engine operational map such as Fig. 1 and Fig 2.

5

ATTACHMENT II

ENGINE STATE POINTS

The attached figure and tables provide state point data for the NERVA Flight Engine with a graphite core reactor.


PCKVA PUMP DISCHARGE CHECK VALVE ACTUATED
TURBINE THROTTLING VALVE
TURBINE BYPASS LINE
STAGE PRESSURANT SUPPLY LINE
TURBINE DISCHARGE LINE
TURBINE INLET LINE
PROPELLANT INLET LINE
MAIN PROPELLANT TANK
CONTROL DRUM ACTUATOR
STAGE PRESSURANT CHECK VALVE
STRUCTURAL SUPPORT BYPASS ORIFICE
BYPASS CONTROL VALVE
BYPASS BLOCK VALVE
STRUCTURAL SUPPORT COOLANT VALVE
STRUCTURAL SUPPORT BLOCK VALVE
TURBINE BLOCK VALVE
PUMP DISCHARGE CHECK VALVE
FILTER
ORIFICE
CHECK VALVE
SOLENOID VALVE
SHUTOFF VALVE
FLOW CONTROL VALVE
75 K NERVA FLIGHT ENGINE
05824
1137450

GRAPHITE CORE

STATE POINT CONDITIONS A SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

1137400C PDR ENGINE (GRAPHITE - 9%) AT DESIGN - NORMAL START OF LIFE

PC = 451. PSIA TBCV POSITION = 16.1 DEGREES THRUST = 75500. LBF TURBINE EFFICIENCY = 88.5 % PUMP EFFICIENCY = 68.1 %
TC = 4247. DEGREES R SSCV POSITION = 3.1 DEGREES ISP = 821.9 SEC BYPASS FRACTION = 8.0 % PUMP SPEED = 24014. RPM

NETAP RESTART TAPE 5997 AT 256. SECONDS PLOTTED AT 256. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	46.2	44.9	47.5	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	46.2	44.9	47.5	30.0	29.3	30.8	40.6	40.3	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	46.2	44.9	47.5	29.9	29.2	30.7	40.6	40.3	41.0
4 - PUMP INLET	46.2	44.9	47.5	29.8	29.1	30.6	40.6	40.3	41.0
5 - PUMP OUTLET	45.9	44.6	47.2	1395	1335	1454	59.2	56.8	60.6
6 - PUMP DISCHARGE CHECK VALVE INLET	45.9	44.6	47.2	1394	1335	1454	59.2	56.8	60.6
7 - PUMP DISCHARGE CHECK VALVE OUTLET	45.9	44.6	47.2	1389	1330	1448	59.2	56.8	60.6
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	45.9	44.6	47.2	1388	1329	1447	59.2	56.8	60.6
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	45.9	44.6	47.2	1382	1324	1441	59.2	56.8	60.6
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	7.50	6.10	8.90	1382	1324	1441	59.2	56.8	60.6
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	3.19	2.99	3.39	1373	1316	1431	59.2	56.8	60.6
12 - NOZZLE TUBES INLET	81.2	76.9	85.5	1359	1303	1415	59.2	56.8	60.6
13 - NOZZLE TUBES OUTLET	81.2	76.9	85.5	1169	1129	1209	191	177	205
14 - REFLECTOR INLET	74.3	70.4	78.2	1169	1129	1209	191	177	205
15 - REFLECTOR OUTLET	74.3	70.4	78.2	1111	1074	1148	254	231	277
16 - REFLECTOR PRESSURE VESSEL OUTLET	6.89	6.49	7.29	1111	1074	1148	265	240	289
17 - EXTENSION SHIELD INLET	66.7	64.8	68.6	1111	1074	1148	293	264	322
18 - EXTENSION SHIELD OUTLET	66.7	64.8	68.6	1101	1064	1137	293	264	322
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	25.2	24.5	25.9	1101	1064	1137	293	264	322
20 - DOME TURBINE LINE INLET	91.9	89.3	94.5	1101	1064	1137	293	264	322
21 - TURBINE BYPASS LINE INLET	7.35	2.05	12.7	1068	1034	1103	293	264	322
22 - TURBINE BLOCK VALVE INLET	42.3	39.5	45.1	1068	1034	1103	293	264	322
23 - TURBINE BLOCK VALVE OUTLET	42.3	39.5	45.1	1061	1026	1095	293	264	322
24 - TURBINE INLET	42.3	39.5	45.1	1060	1026	1094	293	264	322
25 - TURBINE OUTLET	42.5	39.7	45.3	742	725	758	269	245	294
26 - TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	741	724	758	269	245	294

Table II-1, Normal Mode State Points - Start of Life

GRAPHITE CORE

STATE POINT CONDITIONS AND SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

1137400C PDR ENGINE (GRAPHITE - 8%) AT DESIGN - NORMAL START OF LIFE

PC = 451. PSIA TBCV POSITION = 13.1 DEGREES THRUST = 75500. LBF TURBINE EFFICIENCY = 88.5 % PUMP EFFICIENCY = 68.1 %
TC = 4247. DEGREES R SSCV POSITION = 3.1 DEGREES ISP = 821.9 SEC BYPASS FRACTION = 8.0 % PUMP SPEED = 24014. RPM

NETAP RESTART TAPE 5997 AT 256. SECONDS PLOTTED AT 256. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	42.5	39.7	45.3	741	724	758	269	245	294
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	42.5	39.7	45.3	729	712	745	269	245	294
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	729	712	745	269	245	294
30 - TURBINE BYPASS LINE OUTLET	7.35	2.05	12.7	708	692	725	272	248	297
31 - DOME INLET LINE OUTLET	91.9	89.3	94.5	695	679	710	272	248	297
32 - CENTRAL SHIELD INLET	91.9	89.3	94.5	671	655	686	272	248	297
33 - CORE SUPPORT PLATE INLET	91.9	89.3	94.5	636	622	651	272	248	297
34 - CORE INLET	91.9	89.3	94.5	624	609	638	277	252	301
35 - THRUST CHAMBER	91.9	89.3	94.5	451	443	459	4247	4180	4315
36 - TURBINE BYPASS BLOCK VALVE INLET	3.68	1.03	6.33	1068	1034	1103	293	268	317
37 - TURBINE BYPASS BLOCK VALVE OUTLET	3.68	1.03	6.33	1068	1034	1103	293	268	317
38 - TURBINE BYPASS CONTROL VALVE INLET	3.68	1.03	6.33	1068	1034	1103	293	268	317
39 - TURBINE BYPASS CONTROL VALVE OUTLET	3.68	1.03	6.33	711	695	727	293	268	317
40 - STAGE PRESSURANT LINE INLET	0.48	0.44	0.52	708	692	725	272	248	297
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	3.75	2.70	4.80	1382	1323	1440	59.2	56.8	60.6
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	3.75	2.70	4.80	1382	1323	1440	59.2	56.8	60.6
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	3.75	2.70	4.80	1382	1323	1440	59.2	56.8	60.6
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	3.75	2.70	4.80	1164	1127	1201	59.2	56.8	60.6
45 - COOLDOWN SUPPLY LINE OUTLET	7.50	5.40	9.60	1164	1127	1200	59.2	56.8	60.6
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	7.50	5.40	9.60	1164	1127	1200	59.2	56.8	60.6
47 - STEM OUTLET	7.50	5.40	9.60	1112	1076	1149	863	732	993
48 - STRUCTURAL SUPPORT OUTLET	10.7	8.39	13.0	1111	1074	1148	595	509	681
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	3.19	2.99	3.39	1371	1314	1429	59.2	56.8	60.6
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	3.19	2.99	3.39	1133	1095	1170	59.2	56.8	60.6
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	3.19	2.99	3.39	1124	1087	1160	59.2	56.8	60.6
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	741	724	758	269	245	294

Table II-1, Normal Mode State Points - Start of Life

GRAPHITE CORE

STATE POINT CONDITIONS AND SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

1137400C PDR ENGINE - 1 TPA (GRAPHITE - [illegible]) AT 80% THRUST - START OF LIFE

PC = 359. PSIA TBCV POSITION = 24.6 DEGREES THRUST = 60200. LBF TURBINE EFFICIENCY = 88.3 % PUMP EFFICIENCY = [illegible]
TC = 4247. DEGREES R SSCV POSITION = 13.4 DEGREES ISP = 822.2 SEC BYPASS FRACTION = 38.1 % PUMP SPEED = 25?54. RPM

NETAP RESTART TAPE 4824 AT 272. SECONDS PLOTTED AT 272. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	73.7	71.1	76.3	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	73.7	71.1	76.3	30.0	29.3	30.8	40.6	40.3	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	73.7	71.1	76.3	29.8	29.1	30.6	40.6	40.3	41.0
4 - PUMP INLET	73.7	71.1	76.3	29.6	28.9	30.4	40.6	40.3	41.0
5 - PUMP OUTLET	73.2	70.6	75.8	1286	1226	1346	61.2	58.8	62.6
6 - PUMP DISCHARGE CHECK VALVE INLET	73.2	70.6	75.8	1285	1225	1344	61.2	58.8	62.6
7 - PUMP DISCHARGE CHECK VALVE OUTLET	73.2	70.6	75.8	1271	1213	1328	61.2	58.8	62.6
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	73.2	70.6	75.8	1269	1212	1326	61.2	58.8	62.6
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	73.2	70.6	75.8	1254	1199	1310	61.2	58.8	62.6
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	8.20	6.80	9.60	1253	1197	1309	61.4	59.0	62.8
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	2.58	2.39	2.76	1249	1194	1304	61.4	59.0	62.8
12 - NOZZLE TUBES INLET	62.4	58.1	66.7	1240	1185	1295	61.4	59.0	62.8
13 - NOZZLE TUBES OUTLET	62.4	58.1	66.7	1110	1070	1150	204	190	218
14 - REFLECTOR INLET	57.1	53.2	61.0	1110	1070	1150	204	190	218
15 - REFLECTOR OUTLET	57.1	53.2	61.0	1071	1034	1108	272	248	295
16 - REFLECTOR PRESSURE VESSEL OUTLET	5.31	4.91	5.71	1071	1034	1108	279	255	303
17 - EXTENSION SHIELD INLET	53.2	51.3	55.1	1071	1034	1108	313	284	342
18 - EXTENSION SHIELD OUTLET	53.2	51.3	55.1	1064	1027	1101	313	284	342
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	20.0	19.3	20.7	1064	1027	1101	313	284	342
20 - CORE TURBINE LINE INLET	73.2	70.6	75.8	1064	1027	1101	312	283	341
21 - TURBINE BYPASS LINE INLET	27.9	22.6	33.2	1040	1005	1075	312	283	341
22 - TURBINE BLOCK VALVE INLET	45.3	39.7	50.9	1040	1005	1075	312	283	341
23 - TURBINE BLOCK VALVE OUTLET	45.3	39.7	50.9	1030	996	1065	312	283	341
24 - TURBINE INLET	45.3	39.7	50.9	1030	995	1064	312	283	341
25 - TURBINE OUTLET	45.8	40.2	51.4	604	588	621	276	251	300
26 - TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	603	586	620	276	251	300

Table II-2, Single TPA Mode State Points - Start of Life

GRAPHITE CORE

STATE POINT CONDITIONS / SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 11374J0C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

11374CCC FOR ENGINE - 1 TPA (GRAPHITE - [illegible]) AT [illegible] THRUST - START OF LIFE

PC = 359. PSIA TBCV POSITION = 24.6 DEGREES THRUST = 60200. LBF TURBINE EFFICIENCY = 88.3 % PUMP EFFICIENCY = [illegible] %
TC = 4247. DEGREES R SSCV POSITION = 13.4 DEGREES ISP = 822.2 SEC BYPASS FRACTION = 39.1 % PUMP SPEED = [illegible] RPM

NETAP RESTART TAPE 4924 AT 273. SECONDS PLOTTED AT 273. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	45.8	40.2	51.4	603	586	620	276	251	300
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	45.8	40.2	51.4	585	569	602	276	251	300
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	585	569	602	276	251	300
30 - TURBINE BYPASS LINE OUTLET	27.9	22.6	33.2	575	559	591	291	266	315
31 - DOME INLET LINE OUTLET	73.3	70.7	75.9	563	548	579	291	266	315
32 - CENTRAL SHIELD INLET	73.3	70.7	75.9	544	528	559	291	266	315
33 - CORE SUPPORT PLATE INLET	73.3	70.7	75.9	515	500	529	291	267	316
34 - CORE INLET	73.3	70.7	75.9	504	489	518	295	271	320
35 - THRUST CHAMBER	73.3	70.7	75.9	359	351	367	4247	4179	4315
36 - TURBINE BYPASS BLOCK VALVE INLET	13.9	11.3	16.6	1039	1004	1074	312	286	337
37 - TURBINE BYPASS BLOCK VALVE OUTLET	13.9	11.3	16.6	1038	1003	1073	312	286	337
38 - TURBINE BYPASS CONTROL VALVE INLET	13.9	11.3	16.6	1039	1004	1074	312	286	337
39 - TURBINE BYPASS CONTROL VALVE OUTLET	13.9	11.3	16.6	624	608	640	312	288	337
40 - STAGE PRESSURANT LINE INLET	0.38	0.34	0.42	575	559	591	291	266	315
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	4.10	3.05	5.15	1252	1293	1308	61.4	59.0	62.8
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	4.10	3.05	5.15	1252	1293	1308	61.4	59.0	62.8
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	4.10	3.05	5.15	1252	1293	1308	61.4	59.0	62.8
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	4.10	3.05	5.15	1127	1090	1164	61.4	59.0	62.8
45 - COOLDOWN SUPPLY LINE OUTLET	8.20	6.10	10.3	1127	1090	1164	61.4	59.0	62.8
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	8.20	6.10	10.3	1127	1090	1164	61.4	59.0	62.8
47 - STEM OUTLET	8.20	6.10	10.3	1073	1036	1111	753	623	883
48 - STRUCTURAL SUPPORT OUTLET	10.8	8.48	13.1	1071	1034	1108	565	479	651
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	2.58	2.38	2.78	1248	1286	1303	61.4	59.0	62.8
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	2.58	2.38	2.78	1087	1053	1125	61.4	59.0	62.8
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	2.58	2.38	2.78	1081	1044	1118	61.4	59.0	62.8
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	603	586	620	276	251	300

Table II-2, Single TPA Mode State Points - Start of Life

[illegible]

STATE POINT CONDITIONS AND SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

1137400C   POR ENGINE (GRAPHITE - 8%) AT THROTTLING - NORMAL START OF LIFE

PC = 2[illegible]. PSIA   TBCV POSITION = 27.6 DEGREES   THRUST = 49109. LBF   TURBINE EFFICIENCY = 87.0 %   PUMP EFFICIENCY = 65.9 %
TC = 424[illegible]. DEGREES R   SSCV POSITION = 44.5 DEGREES   ISP = 822.7 SEC   BYPASS FRACTION = 28.0 %   PUMP SPEED = 18040. RPM

NETAP RESTART TAPE 6780 AT 280. SECONDS PLOTTED AT 250. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	30.1	28.8	31.4	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	30.1	28.8	31.4	30.0	29.3	30.8	40.6	40.2	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	30.1	28.8	31.4	30.0	29.3	30.8	40.6	40.3	41.0
4 - PUMP INLET	30.1	28.8	31.4	29.9	29.2	30.7	40.6	40.3	41.0
5 - PUMP OUTLET	29.9	28.6	31.2	831	771	890	52.5	50.1	53.9
6 - PUMP DISCHARGE CHECK VALVE INLET	29.9	28.6	31.2	830	771	890	52.5	50.1	53.9
7 - PUMP DISCHARGE CHECK VALVE OUTLET	29.9	28.6	31.2	828	769	887	52.5	50.1	53.9
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	29.9	28.6	31.2	828	769	887	52.5	50.1	53.9
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	29.9	28.6	31.2	825	767	884	52.5	50.1	53.9
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	10.7	9.30	12.1	825	767	884	52.5	50.1	53.9
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	2.36	2.16	2.56	822	764	880	52.5	50.1	53.9
12 - NOZZLE TUBES INLET	46.7	42.4	51.0	817	760	875	52.5	50.1	53.9
13 - NOZZLE TUBES OUTLET	46.7	42.4	51.0	708	669	748	210	196	224
14 - REFLECTOR INLET	42.7	38.8	46.6	708	669	748	210	196	224
15 - REFLECTOR OUTLET	42.7	38.8	46.6	673	636	711	289	265	313
16 - REFLECTOR PRESSURE VESSEL OUTLET	4.00	3.60	4.40	673	636	711	292	266	317
17 - EXTENSION SHIELD INLET	43.3	41.4	45.2	673	636	711	325	296	354
18 - EXTENSION SHIELD OUTLET	43.3	41.4	45.2	666	629	702	325	296	354
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	16.4	15.7	17.1	666	629	702	325	296	354
20 - DOME TURBINE LINE INLET	59.7	57.1	62.3	666	629	702	325	296	353
21 - TURBINE BYPASS LINE INLET	16.7	11.4	22.0	641	607	676	325	296	353
22 - TURBINE BLOCK VALVE INLET	21.5	18.7	24.3	641	607	676	325	296	353
23 - TURBINE BLOCK VALVE OUTLET	21.5	18.7	24.3	638	603	672	325	296	353
24 - TURBINE INLET	21.5	18.7	24.3	637	603	672	324	295	353
25 - TURBINE OUTLET	21.7	18.9	24.5	491	475	508	304	280	329
26 - TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	491	474	508	304	280	329

Table II-3, Normal Mode Throttling State Points - Start of Life

GRAPHITE CORE

STATE POINT CONDITIONS   SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

1137400C   PDR ENGINE (GRAPHITE - 8%) AT THROTTLING - NORMAL START OF LIFE

PC = 293. PSIA   TBCV POSITION = 27.6 DEGREES   THRUST = 49160. LBF   TURBINE EFFICIENCY = 87.0 %   PUMP EFFICIENCY = 65.9 %
TC = 4249. DEGREES R   SSCV POSITION = 44.5 DEGREES   ISP = 822.7 SEC   BYPASS FRACTION = 28.0 %   PUMP SPEED = 18040. RPM

NETAP RESTART TAPE 6788 AT 280. SECONDS PLOTTED AT 280. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	21.7	18.9	24.5	491	474	508	304	280	329
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	21.7	18.9	24.5	486	469	502	304	280	329
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	486	469	502	304	280	329
30 - TURBINE BYPASS LINE OUTLET	16.7	11.4	22.0	477	460	493	310	286	335
31 - CORE INLET LINE OUTLET	59.8	57.2	62.4	467	451	483	310	286	335
32 - CENTRAL SHIELD INLET	59.8	57.2	62.4	450	434	465	310	286	335
33 - CORE SUPPORT PLATE INLET	59.8	57.2	62.4	425	410	440	310	286	335
34 - CORE INLET	59.8	57.2	62.4	416	401	430	315	290	339
35 - THRUST CHAMBER	59.8	57.2	62.4	293	285	301	4249	4181	4316
36 - TURBINE BYPASS BLOCK VALVE INLET	8.35	5.70	11.0	641	606	675	325	300	349
37 - TURBINE BYPASS BLOCK VALVE OUTLET	8.35	5.70	11.0	640	606	675	325	300	349
38 - TURBINE BYPASS CONTROL VALVE INLET	8.35	5.70	11.0	640	606	675	325	300	349
39 - TURBINE BYPASS CONTROL VALVE OUTLET	8.35	5.70	11.0	499	483	516	325	300	349
40 - STAGE PRESSURANT LINE INLET	0.31	0.27	0.35	477	460	493	310	286	335
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	5.35	4.30	6.40	824	766	893	52.5	50.1	53.9
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	5.35	4.30	6.40	824	766	883	52.5	50.1	53.9
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	5.35	4.30	6.40	824	766	833	52.5	50.1	53.9
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	5.35	4.30	6.40	768	731	805	52.5	50.1	53.9
45 - COOLDOWN SUPPLY LINE OUTLET	10.7	8.60	12.8	768	731	805	52.5	50.1	53.9
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	10.7	8.60	12.8	768	731	805	52.5	50.1	53.9
47 - STEM OUTLET	10.7	8.60	12.8	678	641	715	560	430	690
48 - STRUCTURAL SUPPORT OUTLET	13.1	10.8	15.4	673	636	711	459	373	545
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	2.36	2.16	2.56	821	763	879	52.5	50.1	53.9
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	2.36	2.16	2.56	689	651	727	52.5	50.1	53.9
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	2.36	2.16	2.56	684	647	721	52.5	50.1	53.9
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	491	474	508	304	280	329

Table II-3, Normal Mode Throttling State Points - Start of Life

GRAPHITE CORE

STATE POINT CONDITIONS AND SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE · DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS ·

1137400C PDR ENGINE — 1 TPA (GRAPHITE — 8%) AT THROTTLING — START OF LIFE

PC = 293. PSIA TBCV POSITION = 28.9 DEGREES THRUST = 49200. LBF TURBINE EFFICIENCY = 87.7 % PUMP EFFICIENCY = [illegible] %
TC = 4249. DEGREES R SSCV POSITION = 35.7 DEGREES ISP = 822.7 SEC BYPASS FRACTION = 47.6 % PUMP SPEED = 21594. RPM

NETAP RESTART TAPE 5723 AT 280. SECONDS PLOTTED AT 280. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 — PROPELLANT TANK OUTLET	60.1	57.5	62.7	30.0	29.3	30.8	40.6	40.3	41.0
2 — PROPELLANT SHUTOFF VALVE INLET	60.1	57.5	62.7	30.0	29.3	30.8	40.6	40.3	41.0
3 — PROPELLANT SHUTOFF VALVE OUTLET	60.1	57.5	62.7	29.9	29.2	30.7	40.6	40.3	41.0
4 — PUMP INLET	60.1	57.5	62.7	29.7	29.0	30.5	40.6	40.3	41.0
5 — PUMP OUTLET	59.7	57.1	62.3	964	904	1024	55.6	53.2	57.0
6 — PUMP DISCHARGE CHECK VALVE INLET	59.7	57.1	62.3	964	903	1023	55.6	53.2	57.0
7 — PUMP DISCHARGE CHECK VALVE OUTLET	59.7	57.1	62.3	954	896	1012	55.6	53.2	57.0
8 — PUMP DISCHARGE CHECK VALVE 2 INLET	59.7	57.1	62.3	953	895	1010	55.6	53.2	57.0
9 — PUMP DISCHARGE CHECK VALVE 2 OUTLET	59.7	57.1	62.3	943	887	999	55.6	53.2	57.0
10 — STRUCTURAL SUPPORT COOLANT INLET LINE	9.85	8.45	11.3	942	885	999	55.7	53.3	57.1
11 — STRUCTURAL SUPPORT BYPASS LINE INLET	2.26	2.06	2.46	940	884	996	55.7	53.3	57.1
12 — NOZZLE TUBES INLET	47.6	43.3	51.9	935	880	990	55.7	53.3	57.1
13 — NOZZLE TUBES OUTLET	47.6	43.3	51.9	834	794	874	212	198	226
14 — REFLECTOR INLET	43.5	39.6	47.4	834	794	874	212	198	226
15 — REFLECTOR OUTLET	43.5	39.6	47.4	803	766	840	288	264	312
16 — REFLECTOR PRESSURE VESSEL OUTLET	4.07	3.67	4.47	803	766	840	292	267	316
17 — EXTENSION SHIELD INLET	43.3	41.4	45.2	803	766	840	327	298	356
18 — EXTENSION SHIELD OUTLET	43.3	41.4	45.2	796	760	833	328	299	357
19 — EXTENSION SHIELD PRESSURE VESSEL OUTLET	16.4	15.7	17.1	796	760	833	327	299	356
20 — COMP TURBINE LINE INLET	59.7	57.1	62.3	796	760	833	327	298	356
21 — TURBINE BYPASS LINE INLET	28.4	23.1	33.7	774	740	809	327	298	356
22 — TURBINE BLOCK VALVE INLET	31.3	25.7	36.9	774	740	809	327	298	356
23 — TURBINE BLOCK VALVE OUTLET	31.3	25.7	36.9	768	734	803	327	298	356
24 — TURBINE INLET	31.3	25.7	36.9	768	733	802	327	298	355
25 — TURBINE OUTLET	31.7	26.1	37.3	496	479	512	294	270	319
26 — TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	495	478	512	294	270	319

Table II-4, Single TPA Mode Throttling State Points - Start of Life

STATE POINT CONDITIONS A SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

1137400C POR ENGINE - 1 TPA (GRAPHITE - 8%) AT THROTTLING - START OF LIFE

PC = 293. PSIA TBCV POSITION = 24.9 DEGREES THRUST = 49200. LBF TURBINE EFFICIENCY = 87.7 % PUMP EFFICIENCY = 62.2 %
TC = 4249. DEGREES R SSCV POSITION = 36.7 DEGREES ISP = 822.7 SEC BYPASS FRACTION = 47.6 % PUMP SPEED = 21994. RPM

NETAP RESTART TAPE 5723 AT 280. SECONDS PLOTTED AT 280. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	31.7	26.1	37.3	495	478	512	294	270	319
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	31.7	26.1	37.3	484	467	500	294	270	219
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	484	467	500	294	270	319
30 - TURBINE BYPASS LINE OUTLET	28.4	23.1	33.7	477	461	494	310	285	334
31 - DOME INLET LINE OUTLET	59.8	57.2	62.4	467	451	483	310	285	334
32 - CENTRAL SHIELD INLET	59.8	57.2	62.4	450	435	466	310	285	334
33 - CORE SUPPORT PLATE INLET	59.8	57.2	62.4	425	411	440	310	286	335
34 - CORE INLET	59.8	57.2	62.4	416	402	431	314	290	339
35 - THRUST CHAMBER	59.8	57.2	62.4	293	285	301	4249	4161	4316
36 - TURBINE BYPASS BLOCK VALVE INLET	14.2	11.6	16.9	774	739	808	327	303	352
37 - TURBINE BYPASS BLOCK VALVE OUTLET	14.2	11.6	16.9	772	737	807	327	303	352
38 - TURBINE BYPASS CONTROL VALVE INLET	14.2	11.6	16.9	772	738	807	327	303	352
39 - TURBINE BYPASS CONTROL VALVE OUTLET	14.2	11.6	16.9	539	522	555	327	303	352
40 - STAGE PRESSURANT LINE INLET	0.31	0.27	0.35	477	461	494	310.	285	334
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	4.93	3.88	5.98	941	984	997	55.7	53.3	57.1
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	4.93	3.88	5.98	941	984	997	55.7	53.3	57.1
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	4.93	3.88	5.98	941	984	997	55.7	53.3	57.1
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	4.93	3.88	5.98	880	844	916	55.7	53.3	57.1
45 - COOLDOWN SUPPLY LINE OUTLET	9.85	7.75	12.0	880	843	917	55.7	53.3	57.1
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	9.85	7.75	12.0	880	843	917	55.7	53.3	57.1
47 - STEM OUTLET	9.85	7.75	12.0	806	769	843	607	476	737
48 - STRUCTURAL SUPPORT OUTLET	12.1	9.81	14.4	803	766	840	491	404	577
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	2.26	2.06	2.46	939	990	995	55.7	53.3	57.1
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	2.26	2.06	2.46	817	782	855	55.7	53.3	57.1
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	2.26	2.06	2.46	812	775	849	55.7	53.3	57.1
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	495	478	512	294	270	319

Table II-4, Single TPA Mode Throttling State Points - Start of Life

GRAPHITE CORE

STATE POINT CONDITIONS AN PECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

1137400C PDR ENGINE (GRAPHITE = 8%) AT DESIGN - NORMAL END OF LIFE

PC = 449. PSIA THCV POSITION = 17.3 DEGREES THRUST = 75100. LBF TURBINE EFFICIENCY = 88.5 % PUMP EFFICIENCY = 68.2 %
TC = 4243. DEGREES R SSCV POSITION = 17.7 DEGREES ISP = 821.9 SEC BYPASS FRACTION = 9.3 % PUMP SPEED = 23881. RPM

NETAP RESTART TAPE 5794 AT 268. SECONDS PLOTTED AT 268. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	46.1	44.8	47.4	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	46.1	44.8	47.4	30.0	29.3	30.8	40.6	40.3	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	46.1	44.8	47.4	29.9	29.2	30.7	40.6	40.3	41.0
4 - PUMP INLET	46.1	44.8	47.4	29.8	29.1	30.6	40.6	40.3	41.0
5 - PUMP OUTLET	45.8	44.5	47.1	1370	1311	1430	58.8	56.4	60.2
6 - PUMP DISCHARGE CHECK VALVE INLET	45.8	44.5	47.1	1370	1311	1429	58.8	56.4	60.2
7 - PUMP DISCHARGE CHECK VALVE OUTLET	45.8	44.5	47.1	1364	1305	1423	58.8	56.4	60.2
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	45.8	44.5	47.1	1364	1305	1422	58.8	56.4	60.2
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	45.8	44.5	47.1	1358	1300	1416	58.8	56.4	60.2
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	11.8	10.4	13.2	1358	1300	1416	58.9	56.5	60.3
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	3.07	2.87	3.27	1350	1292	1407	58.9	56.6	60.3
12 - NOZZLE TUBES INLET	76.8	72.5	81.1	1337	1281	1393	58.9	56.5	60.3
13 - NOZZLE TUBES OUTLET	76.8	72.5	81.1	1159	1119	1199	196	182	210
14 - REFLECTOR INLET	70.3	66.4	74.2	1159	1119	1199	196	182	210
15 - REFLECTOR OUTLET	70.3	66.4	74.2	1105	1068	1142	265	241	289
16 - REFLECTOR PRESSURE VESSEL OUTLET	6.53	6.13	6.93	1105	1068	1142	273	248	298
17 - EXTENSION SHIELD INLET	66.7	64.8	68.6	1105	1068	1142	297	268	326
18 - EXTENSION SHIELD OUTLET	66.7	64.8	68.6	1095	1058	1131	298	269	326
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	25.0	24.3	25.7	1095	1058	1131	297	268	326
20 - DOME TURBINE LINE INLET	91.7	89.1	94.3	1095	1058	1131	297	268	326
21 - TURBINE BYPASS LINE INLET	8.49	3.19	13.8	1062	1027	1096	297	268	326
22 - TURBINE BLOCK VALVE INLET	41.6	38.8	44.4	1062	1027	1096	297	268	326
23 - TURBINE BLOCK VALVE OUTLET	41.6	38.8	44.4	1054	1020	1089	297	268	326
24 - TURBINE INLET	41.6	38.8	44.4	1054	1019	1088	297	268	326
25 - TURBINE OUTLET	41.9	39.1	44.7	741	724	758	273	249	298
26 - TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	740	724	757	273	249	298

Table II-5, Normal Mode State Points - End of Life

GRAPHITE CORE

STATE POINT CONDITIONS AND ECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

1137400C PDR ENGINE (GRAPHITE - 8%) AT DESIGN - NORMAL END OF LIFE

PC = 449. PSIA TBCV POSITION = 17.3 DEGREES THRUST = 75300. LBF TURBINE EFFICIENCY = 88.5 % PUMP EFFICIENCY = 68.2 %
TC = 4248. DEGREES R SSCV POSITION = 19.7 DEGREES ISP = 821.9 SEC BYPASS FRACTION = 9.3 % PUMP SPEED = 23821. RPM

NETAP RESTART TAPE 5794 AT 268. SECONDS PLOTTED AT 268. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	41.9	39.1	44.7	740	724	757	273	249	298
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	41.9	39.1	44.7	728	712	745	273	249	298
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	728	712	745	273	249	298
30 - TURBINE BYPASS LINE OUTLET	8.49	3.19	13.8	708	692	725	276	252	301
31 - DOME INLET LINE OUTLET	91.7	89.1	94.3	694	679	710	276	252	301
32 - CENTRAL SHIELD INLET	91.7	89.1	94.3	670	655	686	276	252	301
33 - CORE SUPPORT PLATE INLET	91.7	89.1	94.3	635	621	650	277	252	301
34 - CORE INLET	91.7	89.1	94.3	623	608	637	281	256	305
35 - THRUST CHAMBER	91.7	89.1	94.3	449	441	457	4248	4180	4315
36 - TURBINE BYPASS BLOCK VALVE INLET	4.24	1.59	6.89	1062	1027	1096	297	273	322
- TURBINE BYPASS BLOCK VALVE OUTLET	4.24	1.59	6.89	1062	1027	1096	297	273	322
- TURBINE BYPASS CONTROL VALVE INLET	4.24	1.59	6.89	1062	1027	1096	297	273	322
- TURBINE BYPASS CONTROL VALVE OUTLET	4.24	1.59	6.89	711	695	727	297	273	322
40 - STAGE PRESSURANT LINE INLET	0.47	0.43	0.51	708	692	725	276	252	301
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	5.90	4.85	6.95	1357	1298	1415	58.9	56.5	60.3
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	5.90	4.85	6.95	1357	1298	1415	58.9	56.5	60.3
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	5.90	4.85	6.95	1357	1298	1415	58.9	56.5	60.3
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	5.90	4.85	6.95	1184	1147	1221	58.9	56.5	60.3
45 - COOLDOWN SUPPLY LINE OUTLET	11.8	9.70	13.9	1183	1146	1220	58.9	56.5	60.3
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	11.8	9.70	13.9	1183	1146	1220	58.9	56.5	60.3
47 - STEM OUTLET	11.8	9.70	13.9	1108	1071	1145	586	456	716
48 - STRUCTURAL SUPPORT OUTLET	14.9	12.6	17.2	1105	1068	1142	465	379	551
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	3.07	2.87	3.27	1348	1290	1405	58.9	56.5	60.3
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	3.07	2.87	3.27	1127	1089	1165	58.9	56.5	60.3
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	3.07	2.87	3.27	1119	1082	1156	58.9	56.5	60.3
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	740	724	757	273	249	298

Table II-5, Normal Mode State Points - End of Life

STATE POINT CONDITIONS AND SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

1137400C   PDR ENGINE - 1 TPA (GRAPHITE - [illegible]) AT [illegible] THRUST - END OF LIFE

PC = 360. PSIA   TBCV POSITION = 23.0 DEGREES   THRUST = 66400. LBF   TURBINE EFFICIENCY = [illegible] %   PUMP EFFICIENCY = 60.2 %
TC = 4252. DEGREES R   SSCV POSITION = 33.3 DEGREES   ISP = 822.8 SEC   BYPASS FRACTION = 30.7 %   PUMP SPEED = [illegible] RPM

NETAP RESTART TAPE 6566 AT 279. SECONDS PLOTTED AT 279. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	73.8	71.2	76.4	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	73.8	71.2	76.4	30.0	29.3	30.6	40.6	40.3	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	73.8	71.2	76.4	29.8	29.1	30.6	40.6	40.3	41.0
4 - PUMP INLET	73.8	71.2	76.4	29.6	28.9	30.4	40.6	40.3	41.0
5 - PUMP OUTLET	73.3	70.7	75.9	1271	1211	1331	61.1	59.7	62.5
6 - PUMP DISCHARGE CHECK VALVE INLET	73.3	70.7	75.9	1270	1210	1329	61.1	59.7	62.5
7 - PUMP DISCHARGE CHECK VALVE OUTLET	73.3	70.7	75.9	1255	1197	1313	61.1	59.7	62.5
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	73.3	70.7	75.9	1253	1195	1311	61.1	59.7	62.5
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	73.3	70.7	75.9	1239	1184	1294	61.1	59.7	62.5
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	12.3	10.9	13.7	1238	1183	1293	61.4	59.0	62.8
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	2.46	2.26	2.66	1234	1179	1289	61.4	59.0	62.8
12 - NOZZLE TUBES INLET	58.5	54.2	62.8	1226	1171	1281	61.4	59.0	62.8
13 - NOZZLE TUBES OUTLET	58.5	54.2	62.8	1107	1067	1146	211	197	225
14 - REFLECTOR INLET	53.5	49.6	57.4	1107	1067	1146	211	197	225
15 - REFLECTOR OUTLET	53.5	49.6	57.4	1071	1034	1108	265	241	310
16 - REFLECTOR PRESSURE VESSEL OUTLET	5.00	4.60	5.40	1071	1034	1108	290	265	315
17 - EXTENSION SHIELD INLET	53.3	51.4	55.2	1071	1034	1106	317	288	345
18 - EXTENSION SHIELD OUTLET	53.3	51.4	55.2	1064	1027	1101	317	288	346
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	20.0	19.3	20.7	1064	1027	1101	317	288	346
20 - LOWER TURBINE LINE INLET	73.3	70.7	75.9	1064	1027	1101	316	287	345
21 - TURBINE BYPASS LINE INLET	28.4	23.1	31.7	1039	1004	1074	316	287	345
22 - TURBINE BLOCK VALVE INLET	44.9	39.3	50.5	1039	1004	1074	316	287	345
23 - TURBINE BLOCK VALVE OUTLET	44.9	39.3	50.5	1030	996	1064	316	287	345
24 - TURBINE INLET	44.9	39.3	50.5	1029	995	1063	315	287	344
25 - TURBINE OUTLET	45.4	39.8	51.0	606	590	623	279	255	304
26 - TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	605	589	622	279	255	304

Table II-6, Single TPA Mode State Points - End of Life

GRAPHITE CORE

STATE POINT CONDITIONS AT SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

1137400 C POR ENGINE - 1 TPA (GRAPHITE - 6%) AT 80% THRUST - END OF LIFE

PC = 360. PSIA TBCV POSITION = 23.0 DEGREES THRUST = 60400. LBF TURBINE EFFICIENCY = 88.3 % PUMP EFFICIENCY = 66.3 %
TC = 4252. DEGREES R SSCV POSITION = 39.3 DEGREES ISP = 822.8 SEC BYPASS FRACTION = 38.7 % PUMP SPEED = 25808. RPM

NETAP RESTART TAPE 6566 AT 279. SECONDS PLOTTED AT 279. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	45.4	39.8	51.0	605	588	622	279	255	304
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	45.4	39.8	51.0	588	571	604	279	255	304
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	588	571	604	279	255	304
30 - TURBINE BYPASS LINE OUTLET	28.4	23.1	33.7	577	561	593	294	270	319
31 - CORE INLET LINE OUTLET	73.4	70.8	76.0	566	550	581	294	270	319
32 - CENTRAL SHIELD INLET	73.4	70.8	76.0	545	530	561	294	270	319
33 - CORE SUPPORT PLATE INLET	73.4	70.8	76.0	516	501	531	295	270	319
34 - CORE INLET	73.4	70.8	76.0	505	491	520	299	274	323
35 - THRUST CHAMBER	73.4	70.8	76.0	360	352	368	4252	4184	4320
36 - TURBINE BYPASS BLOCK VALVE INLET	14.2	11.5	16.8	1039	1004	1074	316	292	341
37 - TURBINE BYPASS BLOCK VALVE OUTLET	14.2	11.5	16.8	1038	1003	1073	316	292	341
38 - TURBINE BYPASS CONTROL VALVE INLET	14.2	11.5	16.8	1038	1003	1073	316	292	341
39 - TURBINE BYPASS CONTROL VALVE OUTLET	14.2	11.5	16.8	628	612	644	316	292	341
40 - STAGE PRESSURANT LINE INLET	0.38	0.34	0.42	577	561	593	294	270	319
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	6.15	5.10	7.20	1236	1275	1291	61.4	59.0	62.8
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	6.15	5.10	7.20	1236	1275	1291	61.4	59.0	62.8
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	6.15	5.10	7.20	1236	1275	1291	61.4	59.0	62.8
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	6.15	5.10	7.20	1150	1113	1197	61.4	59.0	62.9
45 - COOLDOWN SUPPLY LINE OUTLET	12.3	10.2	14.4	1149	1112	1187	61.4	59.0	62.8
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	12.3	10.2	14.4	1149	1112	1197	61.4	59.0	62.8
47 - STEM OUTLET	12.3	10.2	14.4	1074	1036	1111	532	402	662
48 - STRUCTURAL SUPPORT OUTLET	14.8	12.5	17.1	1071	1034	1108	446	360	537
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	2.46	2.26	2.66	1233	1270	1298	61.4	59.0	62.8
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	2.46	2.26	2.66	1086	1052	1124	61.4	59.0	62.8
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	2.46	2.26	2.66	1081	1043	1118	61.4	59.0	62.5
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	605	588	622	279	255	304

Table II-6, Single TPA Mode State Points - End of Life

GRAPHITE CORE

STATE POINT CONDITIONS AT SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

1137400C PDR ENGINE (GRAPHITE - 8%) AT THROTTLING - NORMAL END OF LIFE

PC = 293. PSIA TBCV POSITION = 29.1 DEGREES THRUST = 49100. LBF TURBINE EFFICIENCY = 86.9 % PUMP EFFICIENCY = 66.1 %
TC = 4248. DEGREES R SSCV POSITION = 79.2 DEGREES ISP = 822.6 SEC BYPASS FRACTION = 29.0 % PUMP SPEED = 17663. RPM

NETAP RESTART TAPE 6372 AT 283. SECONDS PLOTTED AT 283. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	30.0	28.7	31.3	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	30.0	28.7	31.3	30.0	29.3	30.8	40.6	40.3	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	30.0	28.7	31.3	30.0	29.3	30.8	40.6	40.3	41.0
4 - PUMP INLET	30.0	28.7	31.3	29.9	29.2	30.7	40.6	40.3	41.0
5 - PUMP OUTLET	29.8	28.5	31.1	814	755	873	52.2	49.8	53.6
6 - PUMP DISCHARGE CHECK VALVE INLET	29.8	28.5	31.1	814	754	873	52.2	49.8	53.6
7 - PUMP DISCHARGE CHECK VALVE OUTLET	29.8	28.5	31.1	811	752	870	52.2	49.8	53.6
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	29.8	28.5	31.1	811	752	870	52.2	49.8	53.6
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	29.8	28.5	31.1	809	750	867	52.2	49.8	53.6
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	14.7	13.3	16.1	809	750	867	52.3	49.9	53.7
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	2.23	2.03	2.43	806	748	864	52.3	49.9	53.7
12 - NOZZLE TUBES INLET	42.8	38.5	47.1	802	745	859	52.3	49.9	53.7
13 - NOZZLE TUBES OUTLET	42.8	38.5	47.1	703	663	743	222	208	236
14 - REFLECTOR INLET	39.1	35.2	43.0	703	663	743	222	208	236
15 - REFLECTOR OUTLET	39.1	35.2	43.0	672	634	709	309	282	335
16 - REFLECTOR PRESSURE VESSEL OUTLET	3.66	3.28	4.08	672	634	709	310	283	336
17 - EXTENSION SHIELD INLET	43.3	41.4	45.2	672	634	709	328	299	357
18 - EXTENSION SHIELD OUTLET	43.3	41.4	45.2	664	627	701	328	299	357
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	16.4	15.7	17.1	664	627	701	328	299	357
20 - DOME TURBINE LINE INLET	59.7	57.1	62.3	664	627	701	328	299	356
21 - TURBINE BYPASS LINE INLET	17.3	12.0	22.6	639	604	674	327	299	356
22 - TURBINE BLOCK VALVE INLET	21.2	18.4	24.0	639	604	674	327	299	356
23 - TURBINE BLOCK VALVE OUTLET	21.2	18.4	24.0	636	601	670	327	299	356
24 - TURBINE INLET	21.2	18.4	24.0	635	601	670	327	298	356
25 - TURBINE OUTLET	21.4	18.6	24.2	492	475	508	307	283	332
26 - TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	491	475	508	307	283	332

Table II-7, Normal Mode Throttling State Points - End of Life

GRAPHITE CORE

STATE POINT CONDITIONS AND S[illegible]IFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

1137400C PDR ENGINE (GRAPHITE - 8%) AT THROTTLING - NORMAL END OF LIFE

PC = 293. PSIA TBCV POSITION = 28.1 DEGREES THRUST = 49100. LBF TURBINE EFFICIENCY = 86.9 % PUMP EFFICIENCY = 66.1 %
TC = 4248. DEGREES R SSCV POSITION = 79.2 DEGREES ISP = 822.6 SEC BYPASS FRACTION = 29.0 % PUMP SPEED = 17863. RPM

NETAP RESTART TAPE 6372 AT 283. SECONDS PLOTTED AT 283. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	21.4	18.6	24.2	491	475	508	307	283	332
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	21.4	18.6	24.2	486	469	503	307	283	332
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	486	469	503	307	283	332
30 - TURBINE BYPASS LINE OUTLET	17.3	12.0	22.6	477	461	494	313	288	337
31 - DOME INLET LINE OUTLET	59.7	57.1	62.3	467	451	483	313	288	337
32 - CENTRAL SHIELD INLET	59.7	57.1	62.3	450	435	466	313	288	337
33 - CORE SUPPORT PLATE INLET	59.7	57.1	62.3	425	410	440	313	288	337
34 - CORE INLET	59.7	57.1	62.3	416	401	430	317	292	341
35 - THRUST CHAMBER	59.7	57.1	62.3	293	285	301	4248	4180	4316
36 - TURBINE BYPASS BLOCK VALVE INLET	8.65	6.00	11.3	639	604	673	327	303	352
37 - TURBINE BYPASS BLOCK VALVE OUTLET	8.65	6.00	11.3	638	604	673	327	303	352
38 - TURBINE BYPASS CONTROL VALVE INLET	8.65	6.00	11.3	638	604	673	327	303	352
39 - TURBINE BYPASS CONTROL VALVE OUTLET	8.65	6.00	11.3	502	486	519	327	303	352
40 - STAGE PRESSURANT LINE INLET	0.31	0.27	0.35	477	461	494	313	288	337
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	7.35	6.30	8.40	807	748	865	52.3	49.9	53.7
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	7.35	6.30	8.40	807	748	865	52.3	49.9	53.7
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	7.35	6.30	8.40	807	748	865	52.2	49.8	53.6
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	7.35	6.30	8.40	794	756	833	52.2	49.8	53.6
45 - COOLDOWN SUPPLY LINE OUTLET	14.7	12.6	16.8	793	756	831	52.2	49.8	53.6
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	14.7	12.6	16.8	793	756	831	52.2	49.8	53.6
47 - STEM OUTLET	14.7	12.6	16.8	677	640	715	427	297	557
48 - STRUCTURAL SUPPORT OUTLET	16.9	14.6	19.2	672	634	709	378	291	464
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	2.23	2.03	2.43	805	747	863	52.3	49.9	53.7
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	2.23	2.03	2.43	688	650	726	52.3	49.9	53.7
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	2.23	2.03	2.43	683	646	720	52.2	49.8	53.6
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	491	475	508	307	283	332

Table II-7, Normal Mode Throttling State Points - End of Life

STATE POINT CONDITIONS AND SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

1137400C   PDI ENGINE - 1 TPA (GRAPHITE - 8%) AT THROTTLING - END OF LIFE

PC = 292. PSIA   TRCV POSITION = 23.3 DEGREES   THRUST = 40100. LBF   TURBINE EFFICIENCY = 97.7 %   PUMP EFFICIENCY = [illegible] %
TC = 4247. DEGREES R   SSCV POSITION = 75.4 DEGREES   ISP = 822.5 SEC   BYPASS FRACTION = 46.3 %   PUMP SPEED = [illegible] RPM

NETAP RESTART TAPE 5553 AT 284. SECONDS PLOTTED AT 284. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	60.1	57.5	62.7	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	60.1	57.5	62.7	30.0	29.3	30.8	40.6	40.3	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	60.1	57.5	62.7	29.9	29.2	30.7	40.6	40.3	41.0
4 - PUMP INLET	60.1	57.5	62.7	29.7	29.0	30.5	40.6	40.3	41.0
5 - PUMP OUTLET	59.7	57.1	62.3	949	890	1008	55.4	53.0	56.8
6 - PUMP DISCHARGE CHECK VALVE INLET	59.7	57.1	62.3	948	889	1007	55.4	53.0	56.8
7 - PUMP DISCHARGE CHECK VALVE OUTLET	59.7	57.1	62.3	938	880	[illegible]	55.4	[illegible]	[illegible]
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	59.7	57.1	62.3	937	879	995	55.4	53.0	[illegible]
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	59.7	57.1	62.3	927	871	983	55.4	53.0	[illegible]
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	13.8	12.4	15.2	927	871	983	55.5	53.1	[illegible]
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	2.14	1.94	2.34	925	870	980	55.5	53.1	56.9
12 - NOZZLE TUBES INLET	43.8	39.5	48.1	920	865	975	55.5	53.1	[illegible]
13 - NOZZLE TUBES OUTLET	43.8	39.5	48.1	829	769	869	223	209	[illegible]
14 - REFLECTOR INLET	40.0	36.1	43.9	825	[illegible]	859	223	209	237
15 - REFLECTOR OUTLET	40.0	36.1	43.9	801	763	838	307	282	[illegible]
16 - REFLECTOR PRESSURE VESSEL OUTLET	3.75	3.35	4.15	800	763	838	309	283	324
17 - EXTENSION SHIELD INLET	43.3	41.4	45.2	601	763	838	331	302	360
18 - EXTENSION SHIELD OUTLET	43.3	41.4	45.2	794	757	831	332	303	361
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	16.4	15.7	17.1	794	757	831	331	302	360
20 - PUMP TURBINE LINE INLET	59.7	57.1	62.3	794	757	831	331	302	360
21 - TURBINE BYPASS LINE INLET	28.8	23.5	34.1	772	737	806	331	302	360
22 - TURBINE BLOCK VALVE INLET	30.9	25.3	36.5	772	737	806	331	302	360
23 - TURBINE BLOCK VALVE OUTLET	30.9	25.3	36.5	765	731	300	331	302	360
24 - TURBINE INLET	30.9	25.3	36.5	765	730	799	331	302	359
25 - TURBINE OUTLET	31.3	25.7	36.9	496	479	513	298	274	323
26 - TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	495	479	512	298	274	323

Table II-8, Single TPA Mode Throttling State Points - End of Life

GRAPHITE CORE

STATE POINT CONDITIONS (SPECIFICATION EXTREMES)

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1127400C

REFER TO DRAWING NUMBER 1137456A FOR STATE POINT LOCATIONS

1137400C PDR ENGINE - 1 TPA (GRAPHITE - 8%) AT THROTTLING - END OF LIFE

PC = 293. PSIA TOCV POSITION = 23.3 DEGREES THRUST = 49100. LBF TURBINE EFFICIENCY = 67.7 % PUMP EFFICIENCY = 62.0 %
TC = 4247. DEGREES R SSCV POSITION = 73.4 DEGREES ISP = 622.5 SEC BYPASS FRACTION = 48.3 % PUMP SPEED = 21059. RPM

NETAP RESTART TAPE 5963 AT 284. SECONDS PLOTTED AT 284. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	31.3	25.7	36.9	495	479	512	298	274	323
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	31.3	25.7	36.9	484	468	501	298	274	323
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	484	468	501	298	274	323
30 - TURBINE BYPASS LINE OUTLET	28.8	23.5	34.1	478	462	494	314	289	338
31 - CORE INLET LINE OUTLET	59.8	57.2	62.4	468	452	484	314	289	338
32 - CENTRAL SHIELD INLET	59.8	57.2	62.4	451	435	466	314	289	338
33 - CORE SUPPORT PLATE INLET	59.8	57.2	62.4	426	411	440	314	289	338
34 - CORE INLET	59.8	57.2	62.4	416	402	431	318	294	343
35 - THRUST CHAMBER	59.8	57.2	62.4	293	285	301	4247	4179	4314
36 - TURBINE BYPASS BLOCK VALVE INLET	14.4	11.8	17.1	771	736	806	331	307	356
37 - TURBINE BYPASS BLOCK VALVE OUTLET	14.4	11.8	17.1	769	734	804	331	307	356
38 - TURBINE BYPASS CONTROL VALVE INLET	14.4	11.8	17.1	769	735	804	331	307	356
39 - TURBINE BYPASS CONTROL VALVE OUTLET	14.4	11.8	17.1	523	507	539	331	307	356
40 - STAGE PRESSURANT LINE INLET	0.31	0.27	0.35	478	462	494	314	289	338
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	6.90	5.85	7.95	924	965	980	55.5	53.1	56.9
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	6.90	5.85	7.95	924	965	980	55.5	53.1	56.9
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	6.90	5.85	7.95	924	965	980	55.5	53.1	56.9
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	6.90	5.85	7.95	903	867	941	55.5	53.1	56.9
45 - COOLDOWN SUPPLY LINE OUTLET	13.8	11.7	15.9	902	865	940	55.5	53.1	56.9
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	13.8	11.7	15.9	902	865	940	55.5	53.1	56.9
47 - STEM OUTLET	13.8	11.7	15.9	805	767	842	454	324	584
48 - STRUCTURAL SUPPORT OUTLET	15.9	13.6	18.2	801	763	838	399	313	485
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	2.14	1.94	2.34	924	963	979	55.5	53.1	56.9
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	2.14	1.94	2.34	814	780	852	55.5	53.1	56.9
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	2.14	1.94	2.34	810	773	847	55.5	53.1	56.9
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	495	479	512	298	274	323

Table II-8, Single TPA Mode Throttling State Points - End of Life

AEROJET NUCLEAR SYSTEMS COMPANY

A DIVISION OF AEROJET-GENERAL

NERVA

Data Item No.
C002-CP090290/10A-EA

Specification No. CP-90290/10A

APPENDIX SPECIFICATION

PART 1

PERFORMANCE/DESIGN AND QUALIFICATION REQUIREMENTS

for

ENGINE, NERVA, GROUND TEST

Forming a Part of

CP-90290

ENGINE, NERVA, 75K, FULL FLOW

BASIC ISSUE APPROVED BY:

W. O. Wetmore
Vice President and
NERVA Program Director

9/8/70
DATE

BASIC ISSUE APPROVED BY:

SNPO-C DATE

SNPO DATE

Classification Category
UNCLASSIFIED

Classification Officer 9/8/70
Date

AEROJET NUCLEAR SYSTEMS COMPANY

A DIVISION OF AEROJET-GENERAL

NERVA

Data Item No.
C002-CP090290/10A-EA

Specification No. CP-90290/10A

APPENDIX SPECIFICATION

PART 1

PERFORMANCE/DESIGN AND QUALIFICATION REQUIREMENTS

for

ENGINE, NERVA, GROUND TEST

Replace page(s) with the latest revised page(s) noted below.
Revised paragraph(s) are annotated with the latest revision in the margin.

Page No.	
	REV LTR A
	DATE
	ECP
1 thru 5	

APPENDIX SPECIFICATION

Section 1. SCOPE

1.1 Scope.- This specification establishes the exceptions or deviations to the performance, design, test and qualification requirements specified in CP-90290 defining the flight design of the NERVA Engine. These exceptions specify those requirements which are different because of the different ground test conditions experienced by the development version of this equipment.

Section 2. APPLICABLE DOCUMENTS

2.1 Government Documents.- This subsection is the same as in CP-90290.

2.2 Other Publications.- This subsection is the same as in CP-90290.

2.3 Aerojet/WANL Documents.- This subsection is the same as in CP-90290.

Section 3. REQUIREMENTS

3.1 Performance.- This subsection is the same as in Specification CP-90290 except for individual paragraphs shown hereunder.

3.1.1.1.2 Vacuum Performance Rating.- The nozzle expansion ratio for the ground test engine shall be 24:1. Numerical values of thrust and specific impulse from the basic specification are not applicable to the ground test engine.

3.1.1.5 Impulse and Controllability Requirements.- The nozzle expansion ratio for the ground test engine shall be 24:1. All numerical values from all paragraphs of the basic specification relating to impulse and controllability requirements are not applicable to the ground test engine for the following parameters:

(a) Thrust
(b) Specific impulse
(c) Impulse
(d) Controllability values for (a), (b) and (c) above.

Verification for the above performance parameters will be by analytical methods (see Section 4) based on measured chamber pressure, temperature and flow. Therefore values for parameters (a), (b), (c) and (d) are not specified for the test engine.

3.1.1.1.10 Thrust Vector Control.-

(a) Mechanical stops shall be provided to limit the angle from null to 1/2° maximum.

3.1.1.1.13 Engine Assembly, Checkout, and Acceptance Operations.- N/A

3.1.1.1.14 Nuclear Stage Assembly and Checkout Operations.- N/A

3.1.1.1.15 Nuclear Stage/Vehicle Mating Operations.- N/A

3.1.1.1.16 Vehicle Checkout Operations.- N/A

3.1.1.1.17 Vehicle Transfer Operations.- N/A

3.1.1.1.18 Vehicle Countdown Operations.- N/A

3.1.1.1.19 Launch and Boost Operation.- N/A

3.1.1.1.20 Space Station Operation.- N/A

3.1.1.1.21 Propellant Depot Operations.- N/A

3.1.1.1.22 Coast Operations.- N/A (4)

3.1.1.1.23 Spent Stage Disposal Operation.- N/A

3.1.2.2.1.3 Engine Maintainability Requirements.- The engine shall be [...]le of manual and remote assembly and disassembly to the test stand.

3.1.2.4.1 Natural Environment.- In addition to applicable environments [speci]fied in the basic specification the test engine shall be capable of [with]standing the ground test natural environments as specified in Table TBD.

3.1.2.4.2.1 Nuclear Environment.- The test engine shall be designed to [with]stand nuclear radiation TBD percent in excess of the values of the basic [speci]fication, Tables X, XI and XII, when measured at a point TBD feet forward [of th]e core center line. (4)

3.1.2.4.2.2 Acoustic Environment.- The engine shall be capable of [withs]tanding the ground test acoustic loads applied at the engine boundaries as [...] in TBD.

3.1.2.4.2.3 Thermal Environment.- TBD

3.1.2.4.2.4 Vibration and Acceleration Environments.- In addition to [appli]cable environments specified in the basic specification, the test engine [shall] be capable of withstanding the ground test vibration and acceleration [enviro]nments specified in Table TBD.

3.1.2.4.2.5 Electromagnetic Environment.- In addition to applicable [envir]onments specified in the basic specification, the test engine shall be [capab]le of withstanding the ground test electromagnetic environment specified [in Ta]ble TBD.

3.1.2.7.2 Ground Safety.- The system shall be capable of utilizing facility supplied fluids for engine shutdown and cooldown in the event of an emergency during ground tests which prevents reactor cooling with LH_2 supplied through the normal propellant flow path. (1)

3.3.1.7 Engine Natural Frequency.- The test engine when installed in the test stand shall have natural frequencies as specified in Table TBD.

AEROJET NUCLEAR SYSTEMS COMPANY
A DIVISION OF AEROJET-GENERAL

NERVA

Data Item No.
C002-CP090290/20A-F1

Specification No. CP-90290/20A

APPENDIX SPECIFICATION
PART 1
PERFORMANCE/DESIGN AND QUALIFICATION REQUIREMENTS
for
ENGINE, NERVA, COMPOSITE CORE

Forming a Part of

CP-90290

ENGINE, NERVA, 75K, FULL FLOW

BASIC ISSUE APPROVED BY:

W. O. Wetmore 9/8/70
Vice President and
NERVA Program Director
DATE

BASIC ISSUE APPROVED BY:

SNPO-C DATE

SNPO DATE

Classification Category
UNCLASSIFIED

Classification Officer 9/8/70
Date

AEROJET NUCLEAR SYSTEMS COMPANY

A DIVISION OF AEROJET-GENERAL

NERVA

Data Item No.
C002-CP090290/20A-F1

Specification No. CP-90290/20A

Part 1 of 2 Parts
Page i of i Pages

APPENDIX SPECIFICATION

PART 1

PERFORMANCE/DESIGN AND QUALIFICATION REQUIREMENTS

for

ENGINE, NERVA, COMPOSITE CORE

Replace page(s) with the latest revised page(s) noted below.
Revised paragraph(s) are annotated with the latest revision in the margin.

Page No.	REV LTR A
	DATE
	ECP
1 thru 8	
II-1 thru II-18	

Specification No. CP-90290/20A

APPENDIX SPECIFICATION

Section . SCOPE

1.1 Scope.- This specification establishes the deviations to the performance, design, and qualification requirements specified in CP-90290 defining the flight design of the NERVA Engine. These deviations specify those requirements which are different because of the performance characteristics of the engine with a composite core, whereas CP-90290 specifies the design and performance characteristics of an engine with a graphite core.

Section 2. APPLICABLE DOCUMENTS

2.1 Government Documents.- This subsection is the same as in CP-90290.

2.2 Other Publications.- This subsection is the same as in CP-90290.

2.3 Aerojet/WANL Documents.- This subsection is the same as in CP-90290.

Section 3. REQUIREMENTS

3.1 Performance.- This subsection is the same as in Specification CP-90290 except for individual paragraphs shown hereunder.

3.1.2.4.2.1 Nuclear Environment.- The engine induced nuclear environment shall be as specified in Table X, XI and XII. The isoflux nuclear environment contour map shall be as specified in Figure 8.

3.2.1.3 Engine State Points.- The schematic diagram identifying engine state point locations, and a tabulation of flow rates, temperatures, and pressures at these locations is provided as Attachment II to this specification. (5)

3.3.1.4.1 Engine Weight with External Shield (Manned Configuration).- The target dry weight of the engine with a composite core and consisting of the engine module, NDICE, two PSOV's, and a cooldown supply module, shall be 33,500 lbs. The weight breakdown shall be: (4)

(a)	Engine Module	32,700 lbs (4)
(b)	NDICE	500
(c)	PSOV's (two)	200
(d)	Cooldown Supply Module	100

3.3.1.4.2 Engine Weight without External Shield (Unmanned Configuration).- The target dry weight of the engine with a composite core and consisting of the engine module, NDICE, two PSOV's, and a cooldown supply module shall be 23,500 lbs. The weight breakdown shall be: (4)

(a)	Engine Module	22,700 lbs (4)
(b)	NDICE	500
(c)	PSOV's (two)	200
(d)	Cooldown Supply Module	100

3.3.1.4.4 Launch Weight of Engine (Manned Configuration).- The target launch weight of the engine with a composite core shall be 36,300 lbs consisting of: (4)

(a)	Engine Module	32,700 lbs (4)
(b)	NDICE	500
(c)	PSOV's (two)	200
(d)	Cooldown Supply Module	100
(e)	Destruct Subsystem	300
(f)	Stage Mounted NERVA Engine I&C Cable (Supplied by Stage Contractor)	2,500

3.3.1.6 Gimballed Mass Characteristics.- Characteristics of the gimballed portion of the engine with composite core and 10,000 lb external shield, and excluding the Destruct Subsystem, shall be as specified in the following subparagraphs.

3.3.1.6.1 Moment of Inertia About Gimbal Point.- The moments of inertia about the three principal axes of the engine without propellant shall not exceed the following:

Roll Axis	6,000 slug-feet squared
Pitch Axis	100,000 slug-feet squared
Yaw Axis	100,000 slug-feet squared

(4)

3.3.1.6.2 Gimballed Weight (Operating).- The target weight including propellant shall be 32,300 lbs. (4)

3.3.1.6.3 Center of Gravity.- The center of gravity without propellant shall not exceed 120 inches from Engine Station Zero. (4)

TABLE X

INDUCED RADIATION ENVIRONMENT OF NERVA ENGINE
OPERATING AT FULL POWER
(Composite Core Reactor)

To Be Determined

TABLE XI

INDUCED UNPERTURBED RADIATION ENVIRONMENT
OF NERVA ENGINE FOLLOWING 30 MINUTE FULL POWER FIRING

(Composite Core Reactor)

To Be Determined

TABLE XII

INDUCED RADIATION ENVIRONMENT OF NERVA ENGINE OPERATING AT 80 PERCENT POWER

(Composite Core Reactor)

To Be Determined

1

TBD

Note: KERMA Rate and Flux Contours are based on a Composite Core Reactor

Figure 8

Isokerma Rate and Isoflux Nuclear Environment Contour Map (Full Power)

Specification No. CP-90290/20 A

(5)

ATTACHMENT II

ENGINE STATE POINTS

The attached figure and tables provide state point data for the NERVA Flight Engine with a composite core reactor.

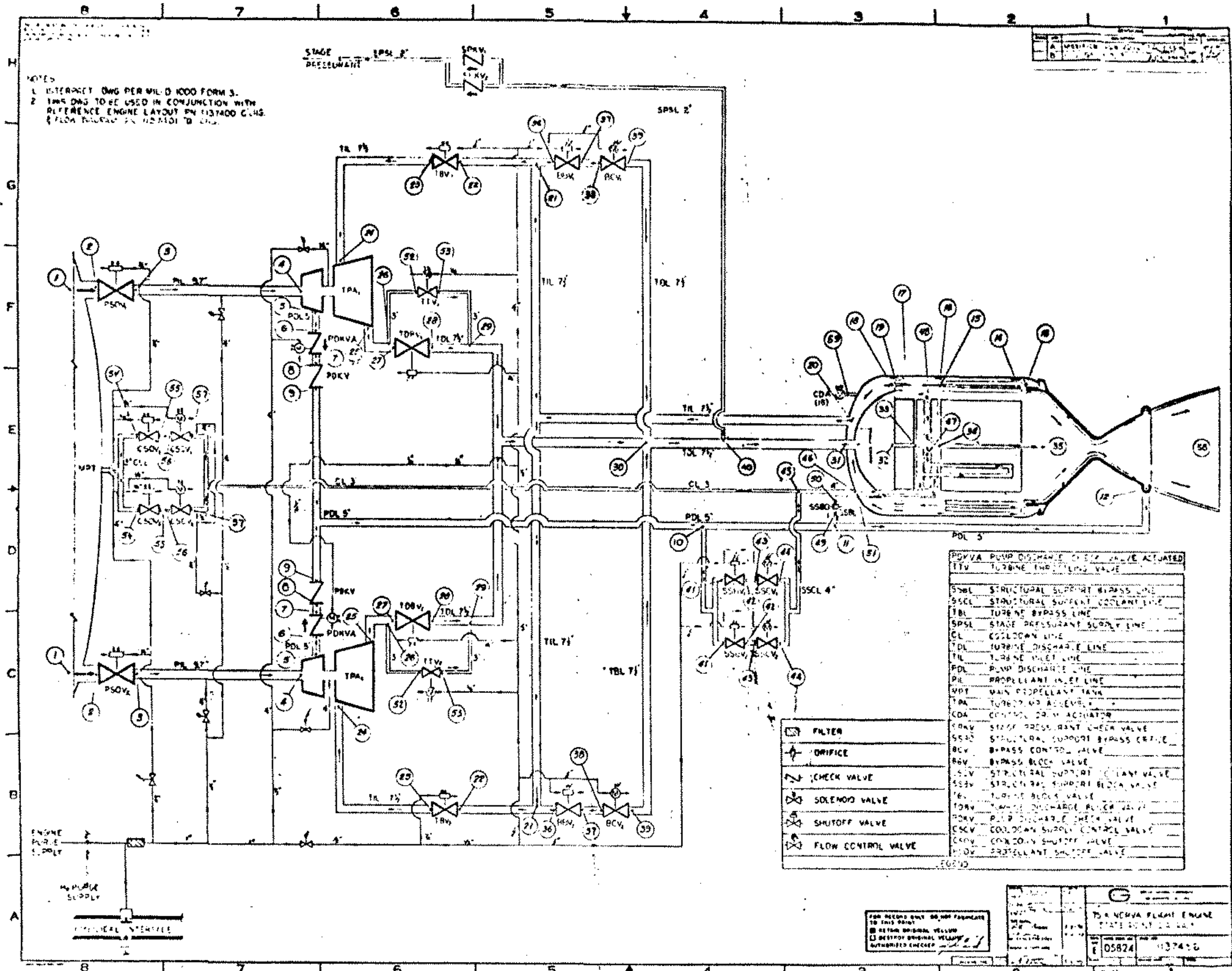


Figure II-1, 75K NERVA Flight Engine State Point Diagram

STATE POINT CONDITIONS AT SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456B FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (8%) AT DESIGN - NORMAL START OF LIFE

PC = 451. PSIA THCV POSITION = 15.6 DEGREES THRUST = 756[illegible]. LBF TURBINE EFFICIENCY = 98.5 % PUMP EFFICIENCY = 68.1 %
TC = 4251. DEGREES R SSCV POSITION = 1.0 DEGREES ISP = 822.3 SEC BYPASS FRACTION = 8.0 % PUMP SPEED = 24079. RPM

NETAP RESTART TAPE 1556 AT 252. SECONDS PLOTTED AT 252. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	46.2	44.9	47.5	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	46.2	44.9	47.5	30.0	29.3	30.8	40.6	40.3	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	46.2	44.9	47.5	30.0	29.3	30.8	40.6	40.3	41.0
4 - PUMP INLET	46.2	44.9	47.5	29.9	29.2	30.7	40.6	40.3	41.0
5 - PUMP OUTLET	46.0	44.7	47.3	1403	1344	1462	59.3	56.9	60.7
6 - PUMP DISCHARGE CHECK VALVE INLET	46.0	44.7	47.3	1402	1343	1462	59.3	56.9	60.7
7 - PUMP DISCHARGE CHECK VALVE OUTLET	46.0	44.7	47.3	1397	1338	1456	59.3	55.9	60.7
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	46.0	44.7	47.3	1396	1337	1455	59.3	56.9	60.7
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	46.0	44.7	47.3	1391	1332	1449	59.3	56.9	60.7
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	7.10	5.67	8.53	1390	1332	1449	59.4	57.0	60.9
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	3.20	3.00	3.40	1381	1324	1439	59.4	57.0	60.9
12 - NOZZLE TUBES INLET	81.7	77.4	86.0	1367	1311	1423	59.4	57.0	60.9
13 - NOZZLE TUBES OUTLET	81.7	77.4	86.0	1175	1136	1215	191	177	205
14 - REFLECTOR INLET	74.7	70.8	78.6	1175	1136	1215	191	177	205
15 - REFLECTOR OUTLET	74.7	70.8	78.6	1117	1080	1154	243	221	265
16 - REFLECTOR PRESSURE VESSEL OUTLET	6.95	6.55	7.35	1117	1080	1154	252	238	275
17 - EXTENSION SHIELD INLET	66.8	64.9	68.7	1117	1080	1154	279	251	308
18 - EXTENSION SHIELD OUTLET	66.8	64.9	68.7	1107	1071	1144	280	251	309
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	25.2	24.5	25.9	1107	1071	1144	279	251	303
20 - DOME TURBINE LINE INLET	92.0	89.4	94.6	1107	1071	1144	280	251	309
21 - TURBINE BYPASS LINE INLET	7.36	2.06	12.7	1077	1042	1111	280	251	309
22 - TURBINE BLOCK VALVE INLET	42.3	39.5	45.1	1077	1042	1111	280	251	309
23 - TURBINE BLOCK VALVE OUTLET	42.3	39.5	45.1	1069	1035	1104	280	251	309
24 - TURBINE INLET	42.3	39.5	45.1	1069	1034	1103	280	251	309
25 - TURBINE OUTLET	42.6	39.8	45.4	735	718	751	256	232	281
26 - TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	734	717	751	256	232	281

Table II-1, Normal Mode State Points - State of Life

COMPOSITE E

STATE POINT CONDITIONS AND SPECIFICATION EXTR ES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456B FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (8%) AT DESIGN - NORMAL START OF LIFE

PC = 451. PSIA THCV POSITION = 15.6 DEGREES THRUST = 75600. LBF TURBINE EFFICIENCY = 98.5 % PUMP EFFICIENCY = 59.1 %
TC = 4251. DEGREES R SSCV POSITION = 1.0 DEGREES ISP = 822.3 SEC BYPASS FRACTION = 8.0 % PUMP SPEED = 24079. RPM

NETAP RESTART TAPE 1556 AT 252. SECONDS PLOTTED AT 252. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	42.6	39.8	45.4	734	717	751	256	232	281
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	42.6	39.8	45.4	722	705	739	256	232	281
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	722	705	739	256	232	281
30 - TURBINE BYPASS LINE OUTLET	7.36	2.06	12.7	703	687	719	260	236	285
31 - DOME INLET LINE OUTLET	92.0	89.4	94.6	689	674	705	260	235	285
32 - CENTRAL SHIELD INLET	92.0	89.4	94.6	667	651	682	260	236	285
33 - CORE SUPPORT PLATE INLET	92.0	89.4	94.6	634	619	648	261	236	285
34 - CORE INLET	92.0	89.4	94.6	621	607	636	264	240	289
35 - THRUST CHAMBER	92.0	89.4	94.6	451	443	459	4251	[illegible]	4319
36 - TURBINE BYPASS BLOCK VALVE INLET	3.68	1.03	6.33	1077	1042	1111	280	255	304
37 - TURBINE BYPASS BLOCK VALVE OUTLET	3.68	1.03	6.33	1077	1042	1111	280	255	304
38 - TURBINE BYPASS CONTROL VALVE INLET	3.68	1.03	6.33	1077	1042	1111	280	255	304
39 - TURBINE BYPASS CONTROL VALVE OUTLET	3.68	1.03	6.33	706	690	722	280	255	304
40 - STAGE PRESSURANT LINE INLET	0.48	0.44	0.52	703	687	719	260	236	285
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	3.55	2.50	4.60	1390	1332	1448	59.4	57.0	60.9
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	3.55	2.50	4.60	1390	1332	1448	59.4	57.0	60.9
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	3.55	2.50	4.60	1390	1332	1448	59.4	57.0	60.9
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	3.55	2.50	4.60	1164	1128	1201	59.4	57.0	60.8
45 - COOLDOWN SUPPLY LINE OUTLET	7.10	5.00	9.20	1164	1127	1201	59.4	57.0	60.9
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	7.10	5.00	9.20	1164	1127	1201	59.3	56.9	60.7
47 - STEM OUTLET	7.10	5.00	9.20	1119	1082	1156	833	703	953
48 - STRUCTURAL SUPPORT OUTLET	10.3	8.00	12.6	1117	1080	1154	564	478	650
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	3.20	3.00	3.40	1379	1322	1437	59.4	57.0	60.9
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	3.20	3.00	3.40	1139	1102	1177	59.4	57.0	60.9
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	3.20	3.00	3.40	1130	1093	1167	59.4	57.0	60.9
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	734	717	751	256	232	281

Table II-1, Normal Mode State Points - State of Life

COMPOSITE CORE

STATE POINT CONDITIONS AND SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456B FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (1 TPA) AT 80% THRUST - START OF LIFE

PC = 360. PSIA TBCV POSITION = 23.7 DEGREES THRUST = 60403. LBF TURBINE EFFICIENCY = 89.5 % PUMP EFFICIENCY = [illegible]0.3 %
TC = 4251. DEGREES R SSCV POSITION = 11.3 DEGREES ISP = 822.7 SEC BYPASS FRACTION = 37.5 % PUMP SPEED = 26132. RPM

NETAP RESTART TAPE 2052 AT 270. SECONDS PLOTTED AT 270. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	73.9	71.3	76.5	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	73.9	71.3	76.5	30.0	29.3	30.8	40.6	40.3	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	73.9	71.3	76.5	30.0	29.3	30.8	40.6	40.3	41.0
4 - PUMP INLET	73.9	71.3	76.5	29.9	29.2	30.7	40.6	40.3	41.0
5 - PUMP OUTLET	73.3	70.7	75.9	1305	1245	1364	61.3	59.9	62.7
6 - PUMP DISCHARGE CHECK VALVE INLET	73.3	70.7	75.9	1303	1244	1363	61.3	59.9	62.7
7 - PUMP DISCHARGE CHECK VALVE OUTLET	73.3	70.7	75.9	1289	1231	1346	61.3	58.9	62.7
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	73.3	70.7	75.9	1287	1230	1344	61.3	58.9	62.7
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	73.3	70.7	75.9	1272	1217	1328	61.3	59.5	62.7
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	8.00	7.6	9.4	1271	1216	1327	61.5	59.1	62.9
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	2.58	2.38	2.78	1267	1212	1322	61.5	59.1	62.9
12 - NOZZLE TUBES INLET	62.8	58.5	67.1	1259	1204	1313	61.5	59.1	62.9
13 - NOZZLE TUBES OUTLET	62.8	58.5	67.1	1128	1089	1168	204	190	218
14 - REFLECTOR INLET	57.4	53.5	61.3	1128	1089	1168	204	190	218
15 - REFLECTOR OUTLET	57.4	53.5	61.3	1089	1052	1127	259	236	282
16 - REFLECTOR PRESSURE VESSEL OUTLET	5.35	4.95	5.75	1090	1052	1127	266	242	290
17 - EXTENSION SHIELD INLET	53.3	51.4	55.2	1089	1052	1127	297	268	326
18 - EXTENSION SHIELD OUTLET	53.3	51.4	55.2	1083	1046	1119	297	269	325
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	20.0	19.3	20.7	1083	1046	1119	297	263	326
20 - DOME TURBINE LINE INLET	73.3	70.7	75.9	1083	1046	1119	297	268	326
21 - TURBINE BYPASS LINE INLET	27.5	22.2	32.8	1060	1025	1095	297	269	325
22 - TURBINE BLOCK VALVE INLET	45.9	40.3	51.5	1060	1025	1095	297	269	325
23 - TURBINE BLOCK VALVE OUTLET	45.9	40.3	51.5	1051	1017	1085	297	269	325
24 - TURBINE INLET	45.9	40.3	51.5	1050	1016	1085	297	268	325
25 - TURBINE OUTLET	46.4	40.8	52.0	600	583	616	262	237	286
26 - TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	599	582	615	262	237	285

Table II-2, Single TPA Mode State Points - Start of Life

STATE POINT CONDITIONS AND SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456B FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (1 TPA) AT 90% THRUST - START OF LIFE

PC = 360. PSIA TBCV POSITION = 23.7 DEGREES THRUST = 60400. LBF TURBINE EFFICIENCY = 88.5 % PUMP EFFICIENCY = 60.0 %
TC = 4251. DEGREES R SSCV POSITION = 11.3 DEGREES ISP = 822.7 SEC BYPASS FRACTION = 37.5 % PUMP SPEED = 26133. RPM

NETAP RESTART TAPE 2052 AT 270. SECONDS PLOTTED AT 270. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	46.4	40.8	52.0	599	582	615	263	237	285
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	46.4	40.8	52.0	581	565	597	262	237	296
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	581	565	597	262	237	285
30 - TURBINE BYPASS LINE OUTLET	27.5	22.2	32.8	571	555	587	277	253	302
31 - DOME INLET LINE OUTLET	73.5	70.9	76.1	560	544	576	277	253	302
32 - CENTRAL SHIELD INLET	73.5	70.9	76.1	541	525	556	277	253	302
33 - CORE SUPPORT PLATE INLET	73.5	70.9	76.1	513	498	528	279	253	302
34 - CORE INLET	73.5	70.9	76.1	503	488	517	281	257	306
35 - THRUST CHAMBER	73.5	70.9	76.1	360	352	368	4251	4184	4319
36 - TURBINE BYPASS BLOCK VALVE INLET	13.7	11.1	16.4	1060	1025	1095	297	273	322
37 - TURBINE BYPASS BLOCK VALVE OUTLET	13.7	11.1	16.4	1059	1024	1094	297	273	322
38 - TURBINE BYPASS CONTROL VALVE INLET	13.7	11.1	16.4	1059	1024	1094	297	273	322
39 - TURBINE BYPASS CONTROL VALVE OUTLET	13.7	11.1	16.4	617	601	633	297	273	322
40 - STAGE PRESSURANT LINE INLET	0.33	0.34	0.42	617	555	587	277	253	302
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	4.00	2.95	5.05	1271	1215	1326	61.5	59.1	62.9
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	4.00	2.95	5.05	1271	1215	1326	61.5	59.1	62.9
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	4.00	2.95	5.05	1271	1215	1326	61.5	59.1	62.9
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	4.00	2.95	5.05	1140	1103	1177	61.5	59.1	62.9
45 - COOLDOWN SUPPLY LINE OUTLET	8.00	5.90	10.1	1139	1102	1176	61.5	59.1	62.9
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	8.00	5.90	10.1	1139	1102	1176	61.5	59.1	62.9
47 - STEM OUTLET	8.00	5.90	10.1	1091	1054	1128	700	579	830
48 - STRUCTURAL SUPPORT OUTLET	10.6	8.28	12.9	1089	1052	1127	528	442	615
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	2.58	2.38	2.78	1266	1211	1321	61.5	59.1	62.9
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	2.58	2.38	2.78	1105	1067	1143	61.5	59.1	62.9
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	2.58	2.38	2.78	1099	1062	1135	61.5	59.1	62.9
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	599	582	615	262	237	286

Table II-2, Single TPA Mode State Points - Start of Life

COMPOSIT[illegible] PRE

STATE POINT CONDITIONS AND C[illegible]CATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137453 FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (8%) AT THROTTLE-NORMAL START OF LIFE

65% THRUST

PC = 293. PSIA TBCV POSITION = 26.8 DEGREES THRUST = 49100. LBF TURBINE EFFICIENCY = 87.9 % PUMP EFFICIENCY = 55.9 %
TC = 4251. DEGREES R SSCV POSITION = 38.2 DEGREES ISP = 823.0 SEC BYPASS FRACTION = 27.2 % PUMP SPEED = 19055. RPM

NETAP RESTART TAPE 3664 AT 277. SECONDS PLOTTED AT 277. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	30.0	28.7	31.3	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	30.0	28.7	31.3	30.0	29.3	30.8	40.6	40.3	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	30.0	28.7	31.3	30.0	29.3	30.8	40.6	40.3	41.0
4 - PUMP INLET	30.0	28.7	31.3	29.9	29.2	30.7	40.6	40.3	41.0
5 - PUMP OUTLET	29.9	28.6	31.2	832	772	891	52.5	50.1	53.0
6 - PUMP DISCHARGE CHECK VALVE INLET	29.9	28.6	31.2	831	772	891	52.5	50.1	53.0
7 - PUMP DISCHARGE CHECK VALVE OUTLET	29.9	28.6	31.2	829	770	888	52.5	50.1	53.0
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	29.9	28.6	31.2	829	770	888	52.5	50.1	53.0
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	29.9	28.6	31.2	826	768	885	52.5	50.1	53.0
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	10.5	9.1	11.9	826	768	885	52.6	50.2	54.0
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	2.37	2.17	2.57	823	765	881	52.6	50.2	54.0
12 - NOZZLE TUBES INLET	46.8	42.5	51.1	818	761	875	52.5	50.1	53.0
13 - NOZZLE TUBES OUTLET	46.8	42.5	51.1	709	669	749	210	195	224
14 - REFLECTOR INLET	42.8	38.9	46.7	709	669	742	210	195	224
15 - REFLECTOR OUTLET	42.8	38.9	46.7	674	637	711	272	249	296
16 - REFLECTOR PRESSURE VESSEL OUTLET	4.02	3.62	4.42	674	637	711	270	254	303
17 - EXTENSION SHIELD INLET	43.3	41.4	45.2	674	637	711	305	277	335
18 - EXTENSION SHIELD OUTLET	43.3	41.4	45.2	666	630	703	305	277	335
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	16.4	15.7	17.1	666	630	703	306	277	335
20 - DOME TURBINE LINE INLET	59.7	57.1	62.3	666	630	703	305	277	335
21 - TURBINE BYPASS LINE INLET	16.2	10.9	21.5	643	609	678	305	277	335
22 - TURBINE BLOCK VALVE INLET	21.7	18.9	24.5	643	609	678	306	277	335
23 - TURBINE BLOCK VALVE OUTLET	21.7	18.9	24.5	640	606	674	306	277	335
24 - TURBINE INLET	21.7	18.9	24.5	640	605	674	306	277	335
25 - TURBINE OUTLET	21.9	19.1	24.7	487	470	503	288	263	312
26 - TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	486	469	503	288	263	312

Table II-3, Normal Mode Throttling State Points - Start of Life

COMPOSITE CORE

STATE POINT CONDITIONS AND SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456B FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (8%) AT THROTTLE-NORMAL START OF LIFE

65% THRUST

PC = 293. PSIA TBCV POSITION = 26.8 DEGREES THRUST = 49100. LBF TURBINE EFFICIENCY = 87.9 % PUMP EFFICIENCY = 65.9 %
TC = 4251. DEGREES R SSCV POSITION = 38.2 DEGREES ISP = 823.0 SEC BYPASS FRACTION = 27.2 % PUMP SPEED = 19055. RPM

NETAP RESTART TAPE 3664 AT 277. SECONDS PLOTTED AT 277. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	21.9	19.1	24.7	486	469	503	295	263	312
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	21.9	19.1	24.7	481	464	499	289	263	312
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	481	464	498	289	263	312
30 - TURBINE BYPASS LINE OUTLET	16.2	10.9	21.5	472	456	489	294	270	319
31 - DOME INLET LINE OUTLET	59.8	57.2	62.4	463	447	479	294	270	319
32 - CENTRAL SHIELD INLET	59.8	57.2	62.4	447	431	462	294	270	319
33 - CORE SUPPORT PLATE INLET	59.8	57.2	62.4	423	408	438	295	270	319
34 - CORE INLET	59.8	57.2	62.4	414	399	428	298	274	323
35 - THRUST CHAMBER	59.8	57.2	62.4	293	285	301	4251	4194	4310
36 - TURBINE BYPASS BLOCK VALVE INLET	8.12	5.47	10.8	643	608	678	306	282	331
37 - TURBINE BYPASS BLOCK VALVE OUTLET	8.12	5.47	10.8	642	608	677	306	282	331
38 - TURBINE BYPASS CONTROL VALVE INLET	8.12	5.47	10.8	642	608	677	305	282	331
39 - TURBINE BYPASS CONTROL VALVE OUTLET	8.12	5.47	10.8	493	477	509	306	282	331
40 - STAGE PRESSURANT LINE INLET	0.31	0.27	0.35	472	456	489	294	270	319
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	5.25	4.20	6.30	825	767	884	52.6	50.3	54.0
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	5.25	4.20	6.30	825	767	894	52.6	50.2	54.0
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	5.25	4.20	6.30	825	767	884	52.5	50.1	53.9
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	5.25	4.20	6.30	761	724	798	52.5	50.1	53.9
45 - COOLDOWN SUPPLY LINE OUTLET	10.5	8.40	12.6	760	723	797	52.5	50.1	53.9
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	10.5	8.40	12.6	760	723	797	52.5	50.1	53.9
47 - STEM OUTLET	10.5	8.40	12.6	677	640	714	523	392	653
48 - STRUCTURAL SUPPORT OUTLET	12.9	10.6	15.2	674	637	711	428	341	511
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	2.37	2.17	2.57	822	764	880	52.5	50.2	54.0
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	2.37	2.17	2.57	689	651	727	52.6	50.2	54.0
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	2.37	2.17	2.57	684	647	721	52.5	50.1	53.9
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	486	469	503	288	263	312

Table II-3, Normal Mode Throttling State Points - Start of Life

COMPOST CORE

STATE POINT CONDITIONS AND ECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456B FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (1 TPA) AT THROTTLING - START OF LIFE (65% THRUST)

PC = 293. PSIA TOCV POSITION = 28.3 DEGREES THRUST = 49100. LBF TURBINE EFFICIENCY = 87.7 % PUMP EFFICIENCY = 62.3 %
TC = 4250. DEGREES R SSCV POSITION = 33.0 DEGREES ISP = 822.9 SEC BYPASS FRACTION = 46.6 % PUMP SPEED = 22046. RPM

NETAP RESTART TAPE 1786 AT 279. SECONDS PLOTTED AT 279. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	60.1	57.5	62.7	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	60.1	57.5	62.7	30.0	29.3	30.8	40.6	40.3	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	60.1	57.5	62.7	30.0	29.3	30.8	40.6	40.3	41.0
4 - PUMP INLET	60.1	57.5	62.7	29.9	29.2	30.7	40.6	40.3	41.0
5 - PUMP OUTLET	59.7	57.1	62.3	972	912	1031	55.6	53.2	57.0
6 - PUMP DISCHARGE CHECK VALVE INLET	59.7	57.1	62.3	971	911	1030	55.6	53.2	57.0
7 - PUMP DISCHARGE CHECK VALVE OUTLET	59.7	57.1	62.3	961	903	1019	55.6	53.2	57.0
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	59.7	57.1	62.3	960	902	1017	55.6	53.2	57.0
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	59.7	57.1	62.3	950	894	1006	55.6	53.2	57.0
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	9.70	8.3	11.1	950	893	1006	55.8	53.4	57.2
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	2.26	2.06	2.46	947	891	1003	55.8	53.4	57.2
12 - NOZZLE TUBES INLET	47.7	43.4	52.0	942	887	997	55.8	53.4	57.2
13 - NOZZLE TUBES OUTLET	47.7	43.4	52.0	841	801	881	212	198	226
14 - REFLECTOR INLET	43.6	39.7	47.5	841	801	881	212	198	226
15 - REFLECTOR OUTLET	43.6	39.7	47.5	810	773	847	272	249	296
16 - REFLECTOR PRESSURE VESSEL OUTLET	4.08	3.68	4.48	810	773	847	279	254	303
17 - EXTENSION SHIELD INLET	43.3	41.4	45.2	810	773	847	308	280	337
18 - EXTENSION SHIELD OUTLET	43.3	41.4	45.2	804	767	841	309	280	338
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	16.4	15.7	17.1	804	767	841	309	280	337
20 - DOME TURBINE LINE INLET	59.7	57.1	62.3	804	767	841	308	280	337
21 - TURBINE BYPASS LINE INLET	27.8	22.5	33.1	784	749	818	309	280	337
22 - TURBINE BLOCK VALVE INLET	31.9	26.3	37.5	783	749	818	309	280	337
23 - TURBINE BLOCK VALVE OUTLET	31.9	26.3	37.5	777	743	812	308	280	337
24 - TURBINE INLET	31.9	26.3	37.5	777	743	811	308	279	337
25 - TURBINE OUTLET	32.3	26.7	37.9	490	473	507	278	253	302
26 - TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	489	473	506	279	253	302

Table II-4, Single TPA Mode Throttling State Points - Start of Life

COMPOSIT ORE

STATE POINT CONDITIONS AND CIFICATION EXTREMES

175K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456B FOR STATE POINT LOCATIONS

65% THRUST

1137400C PRELIMINARY DESIGN REVIEW ENGINE (1 TPA) AT THROTTLING - START OF LIFE

PC = 293. PSIA TBCV POSITION = 28.3 DEGREES THRUST = 49100. LBF TURBINE EFFICIENCY = 87.7 % PUMP EFFICIENCY = 62.3 %
TC = 4250. DEGREES R SSCV POSITION = 33.0 DEGREES ISP = 822.9 SEC BYPASS FRACTION = 45.6 % PUMP SPEED = 22945. RPM

NETAP RESTART TAPE 1786 AT 279. SECONDS PLOTTED AT 279. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	32.3	26.7	37.9	489	473	506	278	253	302
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	32.3	26.7	37.9	478	462	495	278	253	302
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	478	462	495	278	253	302
30 - TURBINE BYPASS LINE OUTLET	27.8	22.5	33.1	472	456	488	294	269	319
31 - DOME INLET LINE OUTLET	59.8	57.2	62.4	463	447	479	294	269	318
32 - CENTRAL SHIELD INLET	59.8	57.2	62.4	446	431	462	294	269	318
33 - CORE SUPPORT PLATE INLET	59.8	57.2	62.4	423	408	437	294	270	319
34 - CORE INLET	59.8	57.2	62.4	414	399	428	298	273	322
35 - THRUST CHAMBER	59.8	57.2	62.4	293	285	301	4250	4183	4318
36 - TURBINE BYPASS BLOCK VALVE INLET	13.9	11.2	16.5	783	748	818	309	284	333
37 - TURBINE BYPASS BLOCK VALVE OUTLET	13.9	11.2	16.5	781	747	816	308	284	333
38 - TURBINE BYPASS CONTROL VALVE INLET	13.9	11.2	16.5	782	747	816	308	284	333
39 - TURBINE BYPASS CONTROL VALVE OUTLET	13.9	11.2	16.5	529	512	545	308	284	333
40 - STAGE PRESSURANT LINE INLET	0.31	0.27	0.35	472	456	488	294	269	318
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	4.85	3.80	5.90	948	892	1004	55.9	53.4	57.2
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	4.85	3.80	5.90	948	892	1004	55.9	53.4	57.2
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	4.85	3.80	5.90	948	892	1004	55.9	53.4	57.2
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	4.85	3.80	5.90	881	844	919	55.9	53.4	57.2
45 - COOLDOWN SUPPLY LINE OUTLET	9.70	7.60	11.8	881	844	918	55.8	53.4	57.2
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	9.70	7.60	11.8	881	844	918	55.9	53.4	57.2
47 - STEM OUTLET	9.70	7.60	11.8	813	776	850	563	432	[illegible]
48 - STRUCTURAL SUPPORT OUTLET	12.0	9.66	14.3	810	773	847	455	369	541
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	2.26	2.06	2.46	946	890	1002	55.9	53.4	57.2
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	2.26	2.06	2.46	824	786	861	55.8	53.4	57.2
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	2.26	2.06	2.46	819	782	856	55.9	53.4	57.2
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	489	473	506	278	253	302

Table II-4. Single TPA Mode Throttling State Points - Start of Life

NP

COMPC CORE

STATE POINT CONDITIONS AND SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456B FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (8%) AT DESIGN - NORMAL END OF LIFE

PC = 450. PSIA TBCV POSITION = 17.1 DEGREES THRUST = 75400. LBF TURBINE EFFICIENCY = 88.5 % PUMP EFFICIENCY = 68.2 %
TC = 4251. DEGREES R SSCV POSITION = 17.1 DEGREES ISP = 822.3 SEC BYPASS FRACTION = 9.3 % PUMP SPEED = 23873. RPM

NETAP RESTART TAPE 868 AT 265. SECONDS PLOTTED AT 265. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	46.1	44.8	47.4	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	46.1	44.8	47.4	30.0	29.3	30.8	40.6	40.3	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	46.1	44.8	47.4	30.0	29.3	30.8	40.6	40.3	41.0
4 - PUMP INLET	46.1	44.8	47.4	29.9	29.2	30.7	40.6	40.3	41.0
5 - PUMP OUTLET	45.8	44.5	47.1	1379	1320	1433	58.9	55.5	60.3
6 - PUMP DISCHARGE CHECK VALVE INLET	45.8	44.5	47.1	1379	1319	1438	58.9	56.5	60.3
7 - PUMP DISCHARGE CHECK VALVE OUTLET	45.8	44.5	47.1	1373	1314	1432	58.9	56.5	60.3
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	45.8	44.5	47.1	1372	1314	1431	58.9	56.5	60.3
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	45.9	44.5	47.1	1367	1309	1425	58.9	56.5	60.3
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	11.1	9.7	12.5	1367	1308	1425	59.0	55.6	60.4
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	3.08	2.88	3.28	1358	1301	1416	59.0	56.6	60.4
12 - NOZZLE TUBES INLET	77.5	73.2	81.8	1346	1289	1402	59.0	56.6	60.4
13 - NOZZLE TUBES OUTLET	77.5	73.2	81.8	1166	1126	1205	195	181	209
14 - REFLECTOR INLET	70.9	67.0	74.8	1166	1126	1205	195	181	209
15 - REFLECTOR OUTLET	70.9	67.0	74.8	1111	1074	1147	253	220	275
16 - REFLECTOR PRESSURE VESSEL OUTLET	6.61	6.21	7.01	1111	1074	1147	259	235	284
17 - EXTENSION SHIELD INLET	66.7	64.8	68.6	1111	1074	1147	284	256	313
18 - EXTENSION SHIELD OUTLET	66.7	64.8	58.6	1101	1064	1137	285	256	314
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	25.0	24.3	25.7	1101	1065	1137	284	256	313
20 - DOME TURBINE LINE INLET	91.7	89.1	94.3	1101	1064	1137	285	256	314
21 - TURBINE BYPASS LINE INLET	8.55	3.26	13.9	1070	1035	1104	285	256	314
22 - TURBINE BLOCK VALVE INLET	41.6	38.8	44.4	1070	1035	1104	285	256	314
23 - TURBINE BLOCK VALVE OUTLET	41.6	38.8	44.4	1062	1028	1097	285	256	314
24 - TURBINE INLET	41.6	38.8	44.4	1062	1028	1096	285	256	314
25 - TURBINE OUTLET	41.8	39.0	44.6	735	718	751	261	236	295
26 - TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	734	717	751	261	236	295

Table II-5, Normal Mode State Points - End of Life

STATE POINT CONDITIONS AND SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456B FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (8%) AT DESIGN - NORMAL END OF LIFE

PC = 450. PSIA TBCV POSITION = 17.1 DEGREES THRUST = 75400. LBF TURBINE EFFICIENCY = 88.5 % PUMP EFFICIENCY = 68.2 %
TC = 4251. DEGREES R SSCV POSITION = 17.1 DEGREES ISP = 822.3 SEC BYPASS FRACTION = 9.3 % PUMP SPEED = 23872. RPM

NETAP RESTART TAPE 868 AT 265. SECONDS PLOTTED AT 265. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	41.8	39.0	44.6	734	717	751	261	236	285
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	41.8	39.0	44.6	722	706	739	261	236	285
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	722	706	739	261	236	285
30 - TURBINE BYPASS LINE OUTLET	8.56	3.26	13.9	703	687	719	265	240	289
31 - DOME INLET LINE OUTLET	91.7	89.1	94.3	690	674	706	265	240	289
32 - CENTRAL SHIELD INLET	91.7	89.1	94.3	667	651	682	265	240	289
33 - CORE SUPPORT PLATE INLET	91.7	89.1	94.3	633	618	648	266	241	290
34 - CORE INLET	91.7	89.1	94.3	621	606	635	269	245	294
35 - THRUST CHAMBER	91.7	89.1	94.3	450	442	459	4251	4183	4310
36 - TURBINE BYPASS BLOCK VALVE INLET	4.28	1.63	6.93	1070	1035	1104	285	260	309
37 - TURBINE BYPASS BLOCK VALVE OUTLET	4.28	1.63	6.93	1069	1035	1104	285	260	309
38 - TURBINE BYPASS CONTROL VALVE INLET	4.28	1.63	6.93	1069	1035	1104	285	260	309
39 - TURBINE BYPASS CONTROL VALVE OUTLET	4.28	1.63	6.93	707	691	723	285	260	309
40 - STAGE PRESSURANT LINE INLET	0.47	0.43	0.51	703	687	719	265	240	289
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	5.55	4.50	6.60	1366	1307	1424	59.0	56.6	60.4
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	5.55	4.50	6.60	1365	1307	1424	59.0	56.6	60.4
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	5.85	4.50	6.60	1365	1307	1424	59.0	56.6	60.4
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	5.55	4.50	6.60	1184	1147	1221	59.0	56.6	60.4
45 - COOLDOWN SUPPLY LINE OUTLET	11.1	9.00	13.2	1184	1147	1220	59.0	56.6	60.4
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	11.1	9.00	13.2	1184	1147	1220	59.0	56.6	60.4
47 - STEM OUTLET	11.1	9.00	13.2	1115	1078	1152	573	449	710
48 - STRUCTURAL SUPPORT OUTLET	14.2	11.9	16.5	1111	1074	1147	453	367	539
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	3.08	2.88	3.28	1356	1299	1414	59.0	56.6	60.4
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	3.08	2.88	3.28	1134	1097	1172	59.0	56.6	60.4
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	3.08	2.88	3.28	1126	1099	1163	59.0	56.6	60.4
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	734	717	751	261	236	285

Table II-5, Normal Mode State Points - End of Life

COMPOSITE CORE

STATE POINT CONDITIONS AND SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456B FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (1 TPA) AT 80% THRUST - END OF LIFE

PC = 360. PSIA   TBCV POSITION = 24.2 DEGREES   THRUST = 60400. LBF   TURBINE EFFICIENCY = 38.A %   PUMP EFFICIENCY = 60.6 %
TC = 4250. DEGREES R   SSCV POSITION = 32.4 DEGREES   ISP = 822.5 SEC   BYPASS FRACTION = 38.2 %   PUMP SPEED = 26005. RPM

NETAP RESTART TAPE 2837 AT 276. SECONDS PLOTTED AT 276. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	73.8	71.2	76.4	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	73.8	71.2	76.4	30.0	29.3	30.8	40.6	40.3	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	73.8	71.2	76.4	30.0	29.3	30.8	40.6	40.3	41.0
4 - PUMP INLET	73.8	71.2	76.4	29.9	29.2	30.7	40.6	40.3	41.0
5 - PUMP OUTLET	73.3	70.7	75.9	1288	1228	1347	61.2	53.8	62.6
6 - PUMP DISCHARGE CHECK VALVE INLET	73.3	70.7	75.9	1286	1227	1345	61.2	53.8	62.6
7 - PUMP DISCHARGE CHECK VALVE OUTLET	73.3	70.7	75.9	1272	1214	1329	61.2	53.8	62.6
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	73.3	70.7	75.9	1270	1212	1327	61.2	53.8	62.5
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	73.3	70.7	75.9	1255	1200	1311	61.2	53.8	62.5
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	11.5	10.1	12.9	1254	1199	1310	61.4	53.0	62.8
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	2.48	2.28	2.68	1250	1195	1305	61.4	59.0	62.8
12 - NOZZLE TUBES INLET	59.3	55.0	63.6	1243	1188	1297	61.4	59.0	62.8
13 - NOZZLE TUBES OUTLET	59.3	55.0	63.6	1121	1092	1161	210	196	224
14 - REFLECTOR INLET	54.3	50.4	58.2	1121	1092	1161	210	196	224
15 - REFLECTOR OUTLET	54.3	50.4	58.2	1085	1048	1122	270	245	294
16 - REFLECTOR PRESSURE VESSEL OUTLET	5.07	4.67	5.47	1085	1048	1122	275	250	300
17 - EXTENSION SHIELD INLET	53.2	51.3	55.1	1085	1048	1122	301	272	330
18 - EXTENSION SHIELD OUTLET	53.2	51.3	55.1	1079	1042	1115	301	272	330
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	20.1	19.4	20.8	1079	1042	1115	301	272	330
20 - DOME TURBINE LINE INLET	73.3	70.7	75.9	1079	1042	1115	301	272	330
21 - TURBINE BYPASS LINE INLET	28.0	22.7	33.3	1056	1021	1091	301	272	330
22 - TURBINE BLOCK VALVE INLET	45.3	39.7	50.9	1056	1021	1091	301	272	330
[illegible] VALVE OUTLET	45.3	39.7	50.9	1047	1012	1081	301	272	330
24 - TURBINE INLET	45.3	39.7	50.9	1046	1011	1080	301	272	329
25 - TURBINE OUTLET	45.0	40.2	51.4	601	584	617	265	241	290
[illegible] VALVE LINE INLET	0.0	0.0	0.0	600	593	615	265	241	290

Table II-6, Single TPA Mode State Points - End of Life

COMPOS[illegible] CORE

STATE POINT CONDITIONS AN[illegible] [illegible]PECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456B FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (1 TPA) AT 80% THRUST - END OF LIFE

PC = 360. PSIA TBCV POSITION = 24.2 DEGREES THRUST = 60400. LBF TURBINE EFFICIENCY = 88.6 % PUMP EFFICIENCY = 70.5 %
TC = 4250. DEGREES R SSCV POSITION = 32.4 DEGREES ISP = 822.5 SEC BYPASS FRACTION = 38.2 % PUMP SPEED = 26005. RPM

NETAP RESTART TAPE 2837 AT 276. SECONDS PLOTTED AT 276. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	45.8	40.2	51.4	600	583	616	265	241	290
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	45.8	40.2	51.4	582	566	599	265	241	290
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	582	566	599	265	241	290
30 - TURBINE BYPASS LINE OUTLET	28.0	22.7	33.3	572	556	588	281	256	305
31 - DOME INLET LINE OUTLET	73.5	70.9	76.1	561	545	577	281	256	305
32 - CENTRAL SHIELD INLET	73.5	70.9	76.1	542	526	557	281	256	305
33 - CORE SUPPORT PLATE INLET	73.5	70.9	76.1	514	499	529	281	257	305
34 - CORE INLET	73.5	70.9	76.1	503	489	518	285	260	309
35 - THRUST CHAMBER	73.5	70.9	76.1	360	352	368	4250	4182	4319
36 - TURBINE BYPASS BLOCK VALVE INLET	14.0	11.4	16.7	1055	1020	1090	301	276	325
37 - TURBINE BYPASS BLOCK VALVE OUTLET	14.0	11.4	16.7	1054	1019	1089	301	276	325
38 - TURBINE BYPASS CONTROL VALVE INLET	14.0	11.4	16.7	1054	1019	1089	301	276	325
39 - TURBINE BYPASS CONTROL VALVE OUTLET	14.0	11.4	16.7	622	606	638	301	276	325
40 - STAGE PRESSURANT LINE INLET	0.38	0.34	0.42	572	556	388	281	256	305
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	5.75	4.70	6.80	1252	1197	1308	61.4	59.0	62.9
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	5.75	4.70	6.80	1252	1197	1308	61.4	59.0	62.3
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	5.75	4.70	6.80	1252	1197	1308	61.4	59.0	62.9
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	5.75	4.70	6.80	1156	1119	1193	61.4	59.0	62.9
45 - COOLDOWN SUPPLY LINE OUTLET	11.5	9.40	13.6	1155	1118	1193	61.4	59.0	62.9
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	11.5	9.40	13.6	1155	1118	1193	61.4	59.0	62.9
47 - STEM OUTLET	11.5	9.40	13.6	1098	1051	1125	524	394	554
48 - STRUCTURAL SUPPORT OUTLET	14.0	11.7	16.3	1085	1048	1122	434	348	520
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	2.48	2.28	2.68	1249	1194	1304	61.4	59.0	62.9
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	2.48	2.28	2.68	1101	1063	1139	61.4	59.0	62.9
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	2.48	2.28	2.68	1095	1058	1132	61.4	59.0	62.8
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	600	583	616	265	241	290

Table II-6, Single TPA Mode State Points - End of Life

COMPOSITE CORE

STATE POINT CONDITIONS AT SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456B FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (8%) AT THROTTLE - *65% THRUST* - NORMAL END OF LIFE

PC = 293. PSIA TBCV POSITION = 27.5 DEGREES THRUST = 49200. LBF TURBINE EFFICIENCY = 87.8 % PUMP EFFICIENCY = 66.1 %
TC = 4250. DEGREES R SSCV POSITION = 76.4 DEGREES ISP = 822.9 SEC BYPASS FRACTION = 28.4 % PUMP SPEED = 17878. RPM

NETAP RESTART TAPE 5117 AT 290. SECONDS PLOTTED AT 280. SECONDS

	FLOW RATE (LBS/SEC) NOMINAL	MIN	MAX	PRESSURE (PSIA) NOMINAL	MIN	MAX	TEMPERATURE (DEGREES R) NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	30.0	28.7	31.3	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	30.0	28.7	31.3	30.0	29.3	30.8	40.5	40.3	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	30.0	28.7	31.3	30.0	29.3	30.8	40.6	40.3	41.0
4 - PUMP INLET	30.0	28.7	31.3	29.9	29.2	30.7	40.6	40.3	41.0
5 - PUMP OUTLET	29.9	28.6	31.2	816	757	875	52.2	49.8	53.6
6 - PUMP DISCHARGE CHECK VALVE INLET	29.9	28.6	31.2	816	756	875	52.2	49.8	53.6
7 - PUMP DISCHARGE CHECK VALVE OUTLET	29.9	28.6	31.2	813	754	872	52.2	49.9	53.6
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	29.9	28.6	31.2	813	754	872	52.2	49.9	53.
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	29.9	28.6	31.2	811	752	869	52.2	49.8	53.6
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	14.5	13.1	15.9	811	752	869	52.3	49.9	53.7
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	2.24	2.04	2.44	808	750	866	52.3	49.9	53.7
12 - NOZZLE TUBES INLET	43.0	38.7	47.3	804	747	861	52.3	49.9	53.7
13 - NOZZLE TUBES OUTLET	43.0	38.7	47.3	704	664	744	222	208	235
14 - REFLECTOR INLET	39.3	35.4	43.2	704	664	744	222	208	236
15 - REFLECTOR OUTLET	39.3	35.4	43.2	672	635	709	291	266	317
16 - REFLECTOR PRESSURE VESSEL OUTLET	3.70	3.30	4.10	672	635	710	295	269	322
17 - EXTENSION SHIELD INLET	43.3	41.4	45.2	672	635	709	309	281	338
18 - EXTENSION SHIELD OUTLET	43.3	41.4	45.2	665	628	701	310	281	339
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	16.5	15.8	17.2	665	628	701	309	281	338
20 - CORE TURBINE LINE INLET	59.8	57.2	62.4	665	628	701	309	281	338
21 - TURBINE BYPASS LINE INLET	17.0	11.7	22.3	641	607	676	309	281	338
22 - TURBINE BLOCK VALVE INLET	21.4	18.6	24.2	641	607	676	309	281	338
23 - TURBINE BLOCK VALVE OUTLET	21.4	18.6	24.2	638	604	672	309	281	333
24 - TURBINE INLET	21.4	18.6	24.2	638	604	672	309	280	338
25 - TURBINE OUTLET	21.6	18.8	24.4	488	471	504	291	266	315
26 - TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	487	471	504	291	266	315

Table II-7, Normal Mode Throttling State Points - End of Life

COMPOSI ORE

STATE POINT CONDITIONS AND SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137454B FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (8%) AT THROTTLE - NORMAL END OF LIFE

65% THRUST

PC = 293. PSIA TDCV POSITION = 27.5 DEGREES THRUST = 49200. LBF TURBINE EFFICIENCY = 87.3 % PUMP EFFICIENCY = 55.1 %
TC = 4250. DEGREES R SSCV POSITION = 76.4 DEGREES ISP = 822.9 SEC BYPASS FRACTION = 29.4 % PUMP SPEED = 17878. RPM

NETAP RESTART TAPE 5117 AT 280. SECONDS PLOTTED AT 280. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	21.6	18.8	24.4	487	471	504	291	266	315
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	21.6	18.8	24.4	482	466	499	291	265	315
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	482	466	499	291	266	315
30 - TURBINE BYPASS LINE OUTLET	17.0	11.7	22.3	474	457	490	297	273	322
31 - DOME INLET LINE OUTLET	59.8	57.2	62.4	464	448	480	297	273	322
32 - CENTRAL SHIELD INLET	59.8	57.2	62.4	448	432	463	297	273	322
33 - CORE SUPPORT PLATE INLET	59.8	57.2	62.4	424	409	438	298	273	322
34 - CORE INLET	59.8	57.2	62.4	415	400	429	301	277	325
35 - THRUST CHAMBER	59.8	57.2	62.4	293	285	301	4250	4183	4318
36 - TURBINE BYPASS BLOCK VALVE INLET	8.48	5.83	11.1	641	607	676	303	295	334
37 - TURBINE BYPASS BLOCK VALVE OUTLET	8.48	5.83	11.1	641	606	675	309	295	334
38 - TURBINE BYPASS CONTROL VALVE INLET	8.48	5.83	11.1	641	606	675	309	295	334
39 - TURBINE BYPASS CONTROL VALVE OUTLET	8.48	5.83	11.1	496	480	513	309	295	334
40 - STAGE PRESSURANT LINE INLET	0.31	0.27	0.35	474	456	490	297	273	322
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	7.25	6.20	9.30	809	750	867	52.3	49.9	53.7
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	7.25	6.20	8.30	809	750	867	52.3	49.9	53.7
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	7.25	6.20	8.30	809	750	867	52.3	49.9	53.7
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	7.25	6.20	8.30	789	751	827	52.3	49.9	53.7
45 - COOLDOWN SUPPLY LINE OUTLET	14.5	12.4	16.6	788	751	825	52.3	49.9	53.7
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	14.5	12.4	16.6	788	751	825	52.4	50.0	53.8
47 - STEM OUTLET	14.5	12.4	16.6	678	640	715	402	272	532
48 - STRUCTURAL SUPPORT OUTLET	16.7	14.4	19.0	672	635	709	355	269	441
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	2.24	2.04	2.44	807	749	865	52.3	49.9	53.7
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	2.24	2.04	2.44	688	650	726	52.3	49.9	53.7
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	2.24	2.04	2.44	684	646	721	52.3	49.9	53.7
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	487	471	504	291	266	315

Table II-7, Normal Mode Throttling State Points - End of Life

COMPOSIT[illegible]RE

STATE POINT CONDITIONS AND [illegible]PECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456B FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (1 TPA) AT THROTTLING 65% THRUST - END OF LIFE

PC = 293. PSIA   TBCV POSITION = 28.5 DEGREES   THRUST = 49200. LBF   TURBINE EFFICIENCY = 87.7 %   PUMP EFFICIENCY = 62.1 %
TC = 4248. DEGREES R   SSCV POSITION = 72.7 DEGREES   ISP = 822.6 SEC   BYPASS FRACTION = 47.2 %   PUMP SPEED = 21949. RPM

NETAP RESTART TAPE 2561 AT 291. SECONDS PLOTTED AT 291. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
1 - PROPELLANT TANK OUTLET	60.2	57.6	62.8	30.0	29.3	30.8	40.6	40.3	41.0
2 - PROPELLANT SHUTOFF VALVE INLET	60.2	57.6	62.8	30.0	29.3	30.8	40.6	40.3	41.0
3 - PROPELLANT SHUTOFF VALVE OUTLET	60.2	57.6	62.8	30.0	29.3	30.8	40.6	40.3	41.0
4 - PUMP INLET	60.2	57.6	62.8	29.9	29.2	30.7	40.6	40.3	41.0
5 - PUMP OUTLET	59.7	57.6	62.8	959	899	1018	55.5	53.1	56.9
6 - PUMP DISCHARGE CHECK VALVE INLET	59.7	57.6	62.8	958	898	1017	55.5	53.1	55.9
7 - PUMP DISCHARGE CHECK VALVE OUTLET	59.7	57.6	62.8	948	890	1006	55.5	53.1	56.9
8 - PUMP DISCHARGE CHECK VALVE 2 INLET	59.7	55.6	62.8	947	889	1004	55.5	53.1	56.9
9 - PUMP DISCHARGE CHECK VALVE 2 OUTLET	59.7	55.6	62.8	937	881	993	55.5	53.1	56.9
10 - STRUCTURAL SUPPORT COOLANT INLET LINE	13.6	12.2	15.0	936	891	992	55.6	53.2	57.0
11 - STRUCTURAL SUPPORT BYPASS LINE INLET	2.14	1.94	2.34	934	879	990	55.6	53.2	57.0
12 - NOZZLE TUBES INLET	44.0	39.7	48.3	930	875	985	55.6	53.2	57.0
13 - NOZZLE TUBES OUTLET	44.0	39.7	48.3	838	798	878	222	209	236
14 - REFLECTOR INLET	40.2	36.3	44.1	838	798	878	222	209	236
15 - REFLECTOR OUTLET	40.2	36.3	44.1	810	773	847	290	264	315
16 - REFLECTOR PRESSURE VESSEL OUTLET	3.78	3.38	4.18	810	773	847	294	269	320
17 - EXTENSION SHIELD INLET	43.3	41.4	45.2	810	773	847	312	283	341
18 - EXTENSION SHIELD OUTLET	43.3	41.4	45.2	804	767	841	312	284	341
19 - EXTENSION SHIELD PRESSURE VESSEL OUTLET	16.4	15.7	17.1	804	767	841	312	283	341
20 - DOME TURBINE LINE INLET	59.7	57.1	62.3	804	767	841	312	283	341
21 - TURBINE BYPASS LINE INLET	28.2	22.9	33.5	783	748	818	312	283	341
22 - TURBINE BLOCK VALVE INLET	31.6	26.0	37.2	783	748	818	312	283	341
23 - TURBINE BLOCK VALVE OUTLET	31.6	26.0	37.2	777	743	812	312	283	341
24 - TURBINE INLET	31.5	26.0	37.2	777	742	811	311	283	340
25 - TURBINE OUTLET	32.0	26.4	37.6	492	475	508	281	256	305
26 - TURBINE THROTTLE VALVE LINE INLET	0.0	0.0	0.0	491	474	508	281	256	305

Table II-8, Single TPA Mode Throttling State Points - End of Life

STATE POINT CONDITIONS AND SPECIFICATION EXTREMES

75K FULL FLOW NERVA ENGINE - DRAWING NUMBER 1137400C

REFER TO DRAWING NUMBER 1137456B FOR STATE POINT LOCATIONS

1137400C PRELIMINARY DESIGN REVIEW ENGINE (1 TPA) AT THROTTLING - END OF LIFE (65% THRUST)

PC = 293. PSIA   TDCV POSITION = 28.5 DEGREES   THRUST = 49000. LBF   TURBINE EFFICIENCY = 37.7 %   PUMP EFFICIENCY = 52.1 %
TC = 4248. DEGREES R   SSCV POSITION = 72.7 DEGREES   ISP = 822.5 SEC   BYPASS FRACTION = 47.2 %   PUMP SPEED = 21948. RPM

NETAP RESTART TAPE 2561 AT 291. SECONDS PLOTTED AT 291. SECONDS

	FLOW RATE (LBS/SEC)			PRESSURE (PSIA)			TEMPERATURE (DEGREES R)		
	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX	NOMINAL	MIN	MAX
27 - TURBINE DISCHARGE BLOCK VALVE INLET	32.0	26.4	37.6	491	474	508	281	256	305
28 - TURBINE DISCHARGE BLOCK VALVE OUTLET	32.0	26.4	37.6	480	464	496	281	256	305
29 - TURBINE THROTTLE VALVE LINE OUTLET	0.0	0.0	0.0	480	464	496	281	256	305
30 - TURBINE BYPASS LINE OUTLET	28.2	22.9	33.5	474	458	490	297	272	321
31 - DOME INLET LINE OUTLET	59.9	57.3	62.5	464	448	480	297	272	321
32 - CENTRAL SHIELD INLET	59.9	57.3	62.5	448	432	463	297	272	321
33 - CORE SUPPORT PLATE INLET	59.9	57.3	62.5	424	409	438	297	272	322
34 - CORE INLET	59.9	57.3	62.5	415	400	429	301	276	325
35 - THRUST CHAMBER	59.9	57.3	62.5	293	285	301	4248	4180	4315
36 - TURBINE BYPASS BLOCK VALVE INLET	14.1	11.4	16.7	782	747	817	312	287	336
37 - TURBINE BYPASS BLOCK VALVE OUTLET	14.1	11.4	16.7	781	746	816	312	287	336
38 - TURBINE BYPASS CONTROL VALVE INLET	14.1	11.4	16.7	781	746	816	312	287	336
39 - TURBINE BYPASS CONTROL VALVE OUTLET	14.1	11.4	16.7	534	518	550	312	287	336
40 - STAGE PRESSURANT LINE INLET	0.31	0.27	0.35	474	458	490	297	272	321
41 - STRUCTURAL SUPPORT BLOCK VALVE INLET	6.80	5.75	7.85	934	878	990	55.6	53.2	57.0
42 - STRUCTURAL SUPPORT BLOCK VALVE OUTLET	6.80	5.75	7.85	934	878	990	55.6	53.2	57.0
43 - STRUCTURAL SUPPORT CONTROL VALVE INLET	6.80	5.75	7.85	934	878	990	55.6	53.2	57.0
44 - STRUCTURAL SUPPORT CONTROL VALVE OUTLET	6.80	5.75	7.85	907	869	944	55.6	53.2	57.0
45 - COOLDOWN SUPPLY LINE OUTLET	13.6	11.5	15.7	906	869	943	55.6	53.2	57.0
46 - STRUCTURAL SUPPORT COOLANT LINE OUTLET	13.6	11.5	15.7	906	868	943	55.6	53.2	57.0
47 - STEM OUTLET	13.6	11.5	15.7	814	777	851	429	299	559
48 - STRUCTURAL SUPPORT OUTLET	15.7	13.4	18.0	810	773	847	376	290	462
49 - STRUCTURAL SUPPORT BYPASS ORIFICE INLET	2.14	1.94	2.34	933	878	989	55.6	53.2	57.0
50 - STRUCTURAL SUPPORT BYPASS ORIFICE OUTLET	2.14	1.94	2.34	823	786	861	55.5	53.2	57.0
51 - STRUCTURAL SUPPORT BYPASS LINE OUTLET	2.14	1.94	2.34	819	782	857	55.5	53.2	57.0
52 - TURBINE THROTTLE VALVE INLET	0.0	0.0	0.0	491	474	508	281	256	305

Table II-8, Single TPA Mode Throttling State Points - End of Life