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RN-DR-0182

EXTERNAL-SHIELD SUBSYSTEM

NERVA Program

Contract SNP-1

December 1969

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RN-DR-0182

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NUCLEAR ROCKET OPERATIONS

December 1969

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W. C. Stephens

CLASSIFYING OFFICER

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AEROJET-GENERAL CORPORATION

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- I. PURPOSE
- II. DESIGN REQUIREMENT SHEETS

I. PURPOSE

This document is one of a series of Departmental Reports which will document NERVA design and performance requirements at engine, sub-system, and component levels. These reports are intended to provide a single source for maintenance and documentation of design criteria and functional performance requirements, and may be used to display a continual assessment of overall design maturity. They also provide the basic data for component specification preparation, and will be used to document traceability of all design and performance criteria.

These reports will be revised and updated periodically to incorporate significant new design and/or performance requirements.

II. DESIGN REQUIREMENTS SHEETS

The Design Requirements Sheets in this document cover the

EXTERNAL SHIELD SUBSYSTEM

as described in the NERVA Engine Specification Tree, ACC Drawing 1137101, "E" Change. The sheets are organized into two principle categories: Section 1.0 provides design requirements criteria generated externally (e.g., environments) to the component; Sections 2.0 through 6.0 provide component functional performance requirements for steady state, startup, throttling, shutdown, and cooldown operations. Requirements are provided for both nominal and malfunction performance conditions.

DESIGN REQUIREMENTS SHEETS

Appended hereto are design criteria and functional performance requirements for the

EXTERNAL SHIELD SUBSYSTEM

EC-90243

The following data are included in this issue:

		<u>Sheet</u>	<u>Revision</u>
1.0	Design Criteria		
1.1	Reliability Allocation	1	0
1.2	Maintainability	2	0
1.3	Useful Life	3	0
1.4	Nuclear Environment	4	0
1.5	Thermal Environment	5	0
1.6	Natural Environment	6	0
1.7	Dimensional Interfaces	7	0
1.8	Mechanical Interfaces	8	0
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5.0	Shutdown Transient Functional Performance	21	0
6.0	Cooldown Functional Performance	22	0

Date: 12-3-69

Rev: 0

Sheet: 1

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem (EC-90243)

DATA SOURCE: Memorandum 7850:M0346, Mihanovich to Varga

1.1 Reliability Allocation

The probability that this component shall successfully fulfill its operating requirements shall be .999999 or greater.

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem

DATA SOURCE: Interpretation of the NPRD-1 Rev 6, M plan and engineering
Evaluation by Klacking/Shoemaker

- 1.2 Maintainability: Maintainability design requirements for the engine shall apply (See RN-DR-0187).
- 1.2.1 Maintenance and Repair Cycles - The shield shall not require periodic maintenance during storage or operational use.
- 1.2.2 Service and Access
 - 1.2.2.1 Access shall be provided to allow remote and manual repair and replacement of all valves, control drum actuators and TPA's for ground test engines and space operation and manual replacement of valves actuators.
 - 1.2.2.2 Removal and replacement of the shield for different mission engine configuration will be by remote means.

Date: 12-3-69
Rev: 0
Sheet: 3

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem

DATA SOURCE: NPRD-1 Revision 6 (Draft)
Dept. 7810 Interpretation of NPRD-1
and Engineering Estimate - Froelich/Paavola

1.3 Useful Life

The External Shield Subsystem shall be capable of satisfying the minimum useful life of the NEKVA Engine, allocated as follows:

1.3.1	Rated Operating Life	600 minutes
(maximum of 60 cycles)
1.3.2	Non-Rated Operating Life
(Transients and In-Flight Checkout)	72 days
1.3.3	Non-Operating Life	
1.3.3.1	Engine Assembly to Launch Pad
(less Storage)	6 months
1.3.3.2	Launch Pad Environment	6 months
1.3.3.3	Space Storage Conditions	3 years
(Including Operational Life)
1.3.4	Storage Life (Ground)	5 years

DATE: 12-3-69

REV: 0

SHEET: 4-1

DESIGN REQUIREMENT SHEET

Component: External Shield Subsystem

Data Source: Engineering Judgement based on nuclear analyses of an idealized configuration, Section 7830 Warman

1.4 Nuclear Environment Flight No External Shield - Unperturbed

Description	Location(In)		γ	γ	In Aluminum γ Heating Rate Btu/in ³ -sec	Thermal Neutron		Fast Neutron		Epi Thermal	
	Station	R	Kerma Rate Rads/Hr	Kerma Rate Rads (10 Hr Exp)		Flux n/cm ² -sec	Nvt n/cm ²	Flux n/cm ² -sec	Nvt n/cm ²	Flux n/cm ² -sec	Nvt n/cm ²
	96.7	0	5.9+6	5.9+7	7.4 - 4	3.4 + 9	1.2+14	7.8+11	2.8+16	3.0+11	1.1+16
	96.7	12	5.3+6	5.3+7	6.6 - 4	3.3 + 9	1.2+14	5.8+11	2.1+16	6.4+11	2.3+16
	96.7	18	4.6+6	4.6+7	5.8 - 4	3.0 + 9	1.1+14	4.7+11	1.7+16	5.3+11	1.9+16
	96.7	24	3.8+6	3.8+7	4.8 - 4	2.8 + 9	1.0+14	4.1+11	1.5+16	4.5+11	1.6+16
	96.7	30	3.5+6	3.5+7	4.4 - 4	8.8 + 9	3.2+14	5.2+11	1.9+16	7.2+11	2.6+16
	96.7	36	5.5+6	5.5+7	6.8 - 4	1.7 + 10	6.1+14	8.0+11	2.9+16	1.6+12	5.8+16
	96.7	40	1.2+7	1.2+7	1.5 - 3	7.2 + 10	2.6+15	1.6+12	5.7+16	4.0+12	1.5+17
	96.7	45	2.0+7	2.0+8	2.4 - 3	1.2 + 11	2.1+12	2.1+12	7.6+16	5.1+12	1.8+17
	96.7	60	2.9+7	2.9+3	3.5 - 3	1.5 + 11	5.4+15	2.5+12	7.2+16	6.6+12	2.4+17

DATE: 12-3-69

REV: 0

SHEET: 4-2

DESIGN REQUIREMENT SHEET

Component: External Shield Subsystem

Data Source:

1.4 Nuclear Environment ETS-1 - No external shield - Unperturbed

Description	Location(In)		γ	γ	In Aluminum γ Heating Rate Btu/in ³ -sec	Thermal Neutron		Fast Neutron		Epi Thermal	
	Station	R	Kerma Rate Rads/Hr	Rads (10 Hr Exp)		Flux n/cm ² sec	Nvt n/cm ²	Flux n/cm ² sec	Nvt n/cm ²	Flux n/cm ² sec	Nvt n/cm ²
1	96.7	0	7.3 + 6	-	9.1 - 4			8.2 + 11			
	96.7	12	6.7 + 6		8.3 - 4			6.2 + 11			
	96.7	18	6.0 + 6		7.5 - 4			5.1 - 11			
	96.7	24	5.2 + 6		6.5 - 4			4.5 + 11			
	96.7	30	4.9 + 6		6.1 - 4			5.6 - 11			
	96.7	36	6.9 + 6		8.5 - 4			8.4 + 11			
	96.7	40	1.3 + 7		1.7 - 3			1.6 + 12			
	96.7	45	2.1 + 7		2.6 - 3			2.1 + 12			
	96.7	60	3.0 + 7		3.7 - 3			2.5 + 12			

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem

DATA SOURCE: K. Sato, Dept. 7730

1.5 Thermal Environment

Data not available at this time.

Date: 12-3-69
Rev: 0
Sheet: 6

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem

DATA SOURCE: NERVA Engine Natural Environment Report Data Item
S023-CP090194-F1 - S. A. Varga, Dept. 7810

1.6 Natural Environment

The natural environments to which the component will be exposed are as specified in Table 1.6-1 thru 1.6-10 and Figures 1.6-1 thru 1.6-8.

Table 1.6-1
NATURAL ENVIRONMENTS SUMMARY
EXTERNAL SHIELD SUBSYSTEM

Phase Environment	Space Operations	Flight Vehicle Boost	Vehicle Assembly and Checkout Pre-launch and Launch Operations
Altitude - Miles	262 to 210,000 N. miles	Sea Level to 262 N. miles	Sea Level
Atmospheric pressure, psia	2×10^{-12} at 262 N.M.	Pressure - Altitude profiles established by Figures 1 and 2	1.7 to 14.4, and 15.0 $\Delta P = 0.01$ to 10^{-12} in 2 hr $\Delta P = -1.0$ to 10^{-12} in 1 hr
Atmospheric temperature (static) °R	2700°R at 262 N.M.	See Figure 3 for nominal profile	Min: 438 Max: 55° (TMR Values)
Atmospheric Density - lb/ft ³	1×10^{-13} at 262 N.M.	Density - Altitude profiles established by Figures 1 and 2	Min: 7.12×10^{-2} Max: 8.2×10^{-2}
Atmospheric composition	See Figure 4	As established from Figure 4 and Table 2	See Table 2
Atmospheric humidity	Negligible	Water vapor concentration at launch: 11.8 gr H ₂ O/lb	Relative 100% rh @ 73° for 6 hrs, 75% rh @ 82°F for 18 hr, 15 day cycle
Solar radiation - Btu/ft ² /hr	442.4	N.A.	1BD
Rain	N.A.	N.A.	See Table 3
Snow	N.A.	N.A.	N.A.
Solar Radio Noise	N.A.	N.A.	N.A.

Phase			Vehicle Assembly and Checkout Pre-launch and Launch Operations
Environment	Space Operations	Flight Vehicle Boost	
Wind, ft/sec	N.A.	N.A.	See Table 9
Sand and dust	N.A.	N.A.	See Table 3
Salt spray	N.A.	N.A.	See Table 4
Fungi and bacteria	N.A.	TBD	TBD
Atmospheric electricity	N.A.	N.A.	See Table 5
Seismic environment	N.A.	N.A.	TBD
Magnetic field avg. total gauss, max	0.53	0.53	0.52
Meteoroids	See Figures 5 and 6. Meteoroid mass density 0.5 gr/cm ³	N.A.	N.A.
Radiation - high energy particle	See Table 6	Negligible	N.A.
Radiation - trapped	See Figures 7 and 8	Negligible	N.A.
Radiation - ultraviolet and X-ray	See Table 7	Negligible	N.A.
Radiation - earth thermal avg., $\bar{E}$, Btu/ft ² /hr	$\bar{E} = 68.4 \left(\frac{3,963}{3,963 + \text{alt}} \right)^2$ alt = altitude location in miles	N.A.	N.A.
Radiation - earth albedo avg., $\bar{a}_E$, Btu/ft ² /hr	$\bar{a}_E = 173.4 \left(\frac{3,963}{3,963 + \text{alt}} \right)^2$	N.A.	N.A.
Ionosphere - ionized electron density - N/in. ³	N.A.	N.A.	N.A.

TABLE 2

NORMAL ATMOSPHERIC COMPOSITION FOR CLEAN,
 DRY AIR AT ALL LOCATIONS
 (VALID TO 55.9 MILLS GEOMETRIC ALTITUDE)

<u>Gas</u>	<u>Percent by Volume</u>	<u>Percent by Weight</u>
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^{-4}
Nitrous Oxide (N ₂ O)	5×10^{-5}	8×10^{-5}
Ozone (O ₃) summer	$0 \text{ to } 7 \times 10^{-6}$	$0 \text{ to } 1.1 \times 10^{-5}$
winter	$0 \text{ to } 2 \times 10^{-6}$	$0 \text{ to } 3 \times 10^{-6}$
Sulfur dioxide (SO ₂)	$0 \text{ to } 1 \times 10^{-4}$	$0 \text{ to } 2 \times 10^{-4}$
Nitrogen dioxide (NO ₂)	$0 \text{ to } 2 \times 10^{-6}$	$0 \text{ to } 3 \times 10^{-6}$
Ammonia (NH ₃)	0 to trace	0 to trace
Carbon monoxide (CO)	0 to trace	0 to trace
Iodine (I ₂)	$0 \text{ to } 1 \times 10^{-6}$	$0 \text{ to } 9 \times 10^{-6}$

TABLE 3

SAND AND DUST

	<u>Sand</u>	<u>Dust</u>
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 4

SALT SPRAY

Salt Spray Exposure

TBD

Salt Accumulation (Extractions)
Particle Size, inches

3.94×10^{-6} to 7.87×10^{-4}
98% of total greater than
 3.15×10^{-5}

Accumulation (Fallout)
lb/ft²/day, Max

10.2×10^{-7}
During Rain Storm

Min

5.12×10^{-8}
Unevenly Distributed.

TABLE 5

CHARACTERISTICS OF LIGHTNING STROKES

	Average	Maximum
Peak Current, A ps	10,000	Not greater than 100,000 90% of time.
Time interval, micro seconds	6	10
Start of stroke to peak current		
Fall from peak current to 1/2 of peak value	24	20
Total stroke charge (Coulombs)	25	100
Transmitted to earth (90% of Current flow)		

TABLE 6

SOLAR HIGH ENERGY PARTICLE RADIATION AT 1 AU

Particle Energy, MEV	>30	>100
Integrated Yearly Particle Flux Protons/in. ²		
Near solar min	7.75×10^7	1.55×10^7
Near solar max	1.24×10^9	9.3×10^7
Composition	Predominantly H ⁺ and He ⁺⁺	
Flux variation with Distance from Sun	$\left[\frac{1 \text{ AU}}{X \text{ AU}} \right]^2$	

TABLE 7

ULTRAVIOLET AND X-RAY RADIATION CHARACTERISTICS

UltravioletPrincipal Line Emission Fluxes (watts/ft²)

Lyman Alpha H [°] I (1216Å)	5×10^{-4}
He II (303.8Å) [°]	2.4×10^{-4}
H I (1026Å) [°]	5.6×10^{-6}
C III (977Å) [°]	4.7×10^{-6}

X-Ray Flux (watts/ft²)

	<u>2-8Å[°]</u>	<u>8-20Å[°]</u>	<u>20-200Å[°]</u>
Sunspot min (quiet sun)	2.8×10^{-10}	3.8×10^{-8}	1.2×10^{-5}
Sunspot max (quiet sun)	1.9×10^{-9}	2.2×10^{-6}	9.5×10^{-5}
Upper Limit During Flare Activity	2.1×10^{-5}	4.2×10^{-5}	8.6×10^{-4}

TABLE 8

DESIGN RAINFALL RATES FOR EASTERN TEST RANGE, MICHOU, MISSISSIPPI TEST FACILITY, GULF TRANSPORTATION, TRANSPORTATION LARGE TO MICHOU, AND TRANSPORTATION SACRAMENTO TO MICHOU

<u>Time Period</u>	<u>1 min</u>	<u>1 hour</u>	<u>24 hours</u>	<u>Year</u>
Total Amount, in.	0.5	4	20	To be determined
Rate, in./hr	30.0	4.0	0.8	
Average Drop Diameter, in.	0.16	0.11	0.07	
Average Rate of Fall, ft/sec	28.8	24.9	20.0	
Peak Wind Speed, ft/sec	98.4	65.6	65.6	
Average Wind Speed, ft/sec	55	19.6	14.7	

TABLE 9

SURFACE WIND SPEED ENVELOPE DURING STRONGEST WIND MONTH FOR ALL LOCATIONS
WINDS BETWEEN SURFACE AND 492 FOOT HEIGHT

Height Above Ground (ft)	Quasi-Steady-State*			Peak Wind**		
	Wind (ft/sec)			(ft/sec)		
	99.9	99	95	99.9	99	95
	Percentile	Percentile	Percentile	Percentile	Percentile	Percentile
9.84	43.9	40.6	31.8	61.6	56.7	44.2
29.5	54.7	50.5	39.3	76.7	70.8	55.4
59.0	62.9	58.0	45.2	88.5	81.3	63.6
100	69.8	64.6	50.1	97.7	90.2	70.5
200	80.0	74.1	57.7	112.2	103.6	80.7
300	86.9	80.3	62.6	121.7	112.5	87.6
400	92.1	84.9	66.2	128.9	119.1	92.8
500	96.4	88.9	69.2	134.8	124.6	97.1

*Two minute average.

**Two minute average (1.4 times Quasi-Steady-State Wind)

TABLE 10

- SOLAR RADIO NOISE

Quiet Sun Noise Power
watts/ft²/cps

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

Figure 1A

FIGURE 1b

ALTITUDE VS TIME FOR MISSION A

TOTALS FOR 3 YEAR LIFE

1. LUNAR ORBIT	360 DAYS
2. IN FLIGHT	70 DAYS
3. EARTH ORBIT	665 DAYS

Figure 2a

Atmospheric Pressure - Height Extremes for all areas of concern
and Density - Height Extremes for the Eastern Test Range

ATMOSPHERIC PRESSURE AND DENSITY VERSUS ALTITUDE
(above 300,000 feet)

FIGURE 3TEMPERATURE VERSUS ALTITUDE
(Eastern Test Range Reference Atmosphere)

FIGURE 4

ESTIMATED MEAN CONCENTRATIONS OF
PRINCIPAL ATMOSPHERIC CONSTITUENTS
ABOVE 37.9 STATUTE MILES

Figure 5

- ATMOSPHERIC ENTRY VELOCITY DISTRIBUTION FOR SPORADIC METEORIODS

Figure ;

FIGURE 7

PROTON OMNIDIRECTIONAL FLUX
AT THE GEOMAGNETIC EQUATOR

FIGURE 3 ELECTRON MAP₂ OMNIDIRECTIONAL FLUX (ELECTRONS/IN² SEC) AT THE GEOMAGNETIC EQUATOR

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem

DATA SOURCE: Enginecring evaluation by
Klackring/Krivanec, Section 7840

1.7 Dimensional Interfaces

The base of the external shield shall be 84.32 inches from reactor core center as shown on Engine Layout Drawing 1136390.

Detailed dimensional interface characteristics will be presented in the 75K NERVA FFE Component Interface Control Drawing 1136408 (in process). Also see Sheet 1.15 Envelope Dimension.

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem
DATA SOURCE: Engineering evaluation by
Klacking/Krivanec, Section 7840

1.8 Mechanical Interfaces

The shield shall be mechanically attached (bolted) to the lower and middle thrust structures.

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem

DATA SOURCE: Engineering Evaluation by
Klackning/Krivanec, Section 7840

1.9 Electrical Interfaces:

Not Applicable.

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem

DATA SOURCE: Engineering Evaluation by
Klackning/Krivanec, Section 7840

1.10 Functional Interfaces:

Not Applicable

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem

DATA SOURCE: Packaging Plan, Varga/McClurkin, Section 7810

1.11 Handling & Shipping

1. This component is shipped installed on the thrust structure module.
2. Attach points for lifting the component should be provided for handling during pre-assembly and assembly.
3. Design should provide for use of the shield as the means of attaching the engine to the assembly stand, remote handling device, and certain transporting devices.

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem

DATA SOURCE: Memorandum 7810:1803M, R. A. Henderson to R. W. Froelich,
dated 11-21-69

1.12 Test

Radiation hardness requirements for components within the engine test compartment will exceed the Flight Engine requirements due to secondary radiation.

For Ground Test requirements see Nuclear Environment Section 1.4.

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem, EC-90243

DATA SOURCE: Engineering Evaluation, Section 7810,

1.12 Checkout

Insufficient Data Available to evaluate

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem

DATA SOURCE: Preliminary loads analysis based on hot bleed port configuration weights, unit shear and bending moment diagram. Kaveney/Kovack, Section 7730

1.13 Static Loads

Preliminary design only - not to be used for design stress approval

External Shield

1. Launch Vehicle Operations: (1.0g lateral, 5.2g axial acceleration)

P_5	= 96,500 lbs	P_6	= 147,000 lbs
V_5	= $\pm 18,500$ lbs	V_6	= $\pm 28,300$ lbs
M_5	= $\pm 1,485,600$ in-lbs	M_6	= $\pm 1,674,000$ in-lbs

Maximum compressive load = $-75,000 \pm 2,000 = 77,000$ lbs.

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem

DATA SOURCE: Engineering estimate, Kaveney/Kovacs, Section 7730

1.14 Dynamic Loads

Load Condition: Launch Vehicle Operations

1. Max. longitudinal dynamic acceleration (3-35HZ freq. range) = $\pm 4.5g's$
2. Max. lateral dynamic acceleration (.1-1.5HZ freq. range) = $\pm 3.0g's$

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem

DATA SOURCE: Engineering evaluation by
Klackning/Krivanec, Section 7840

1.15 Envelope Dimensions

The external shield maximum dimensions shall be 100 in. dia. and 10 in. height except as follows: A channel shall be provided at the base of the shield for TIL and TDL routing with equivalent shielding replaced on top per the Engine Payout Drawing 1136390. No through penetrations of the shield envelope are required.

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield

DATA SOURCE: RN-PD-P-1197, Kaveney/Talbot, Section 7730

1.16 Weight Allocation - 10,000 lbs.

Date: 12-3-69
Rev: 0
Sheet: 17

DESIGN REQUIREMENT SHEET

COMPONENT: External Shield Subsystem

DATA SOURCE: NPRD-1 Revision 6 (Draft) Para. III.B.1.p
(As interpreted by Dept. 7810)

1.17 Safety

Maximum effort shall be placed on a design which eliminates single failures or credible combinations of errors and/or failures which endanger the safety of space and/or ground personnel.

Under degraded conditions component design shall provide for continuous engine operation at approximately 40% thrust and an I of not less than 500 seconds for a minimum of 1 hour at any time^{sp} during the engine's operating life.

DESIGN REQUIREMENT SHEET

Component: External Shield

Data Source: NPRD-1 Rev 6 (Draft) Shielding Trade Study (003 and 023)

2.0 Steady State Functional Performance

The function of the external engine shield is to attenuate radiation so as to limit radiation exposure to 3 Rem for flight crew members and 10 Rem for passengers per mission. This is accomplished with indigenous radiation attenuation in the payload in addition to the external engine shield.

The external shield shall attenuate the radiation such that the dose at the top of the 300,000 lb LH₂ propellant tank will not exceed 30 Rem.

The radiation levels incident on the base of the external engine shield are assumed to be equal or less than those depicted in Figures 2.0-1, -2, and -3 for the shielding requirements established in the preceding paragraphs.

These external engine shield design requirements are based on a full flow engine design which includes an internal shield in the nuclear subsystem sufficient to meet the engine component radiation levels for 10 hours of operation and for an unmanned mission with a continuous firing of 50 minutes duration at full rated power.

OPERATION: *

SHEET: 19 thru 22

[illegible]

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10^{12}

10^{11}

10^{10}

Thermal Neutron Flux ($\frac{n}{cm^2-sec}$)

Thermal Neutron Flux as a Function of
 Disk Shield Radius Dot/Dash
 Calculation

Disk Shield

3300 lb. Internal Shield

Radius (in.)

Figure 2.0-1

EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 340R-L310 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
3 CYCLES X 10 DIVISIONS PER INCH

Figure 2.0-2

FIGURE 2.0-3