T10/SNA--241

C002-EC090151-F1
ENGINEERING CRITICAL COMPONENT SPECIFICATION

PERFORMANCE/DESIGN AND
PRODUCT CONFIRMATION REQUIREMENTS

FOR
NOZZLE ASSEMBLY SUBSYSTEM

FORMING A PART OF
CEI NUMBER 090290A

ORDER

PRELIMINARY PROPOSAL ISSUE
DATED 12-15-69
FOR REVIEW ONLY. DO NOT IMPLEMENT.

AEROJET-GENERAL CORPORATION

SACRAMENTO, CALIFORNIA

TECHNICAL DOCUMENT CENTER
Nuclear Rocket Operations

DISTRIBUTION OF THIS DOCUMENT UNLIMITED

DOC. NO. N-1971

AGCS 0120-48

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

AEROJET-GENERAL CORPORATION

CODE IDENT. NO. 05824

Data Item Identification
No. C002-EC090151-F1

Engineering Critical
Component Specification No. EC-90151

Part I of Two Parts
Page 1 of 16

PERFORMANCE/DESIGN AND QUALIFICATION REQUIREMENTS for

NOZZLE ASSEMBLY SUBSYSTEM

Replace page(s) with the latest revised page(s) noted below. Revised paragraph(s) are identified with the latest revision letter (or number) in the margin.

	REV	LTR
Page	DATE	
No.	ECP	

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

CLASSIFICATION CATEGORY	
UNCLASSIFIED	
<i>Hayes</i>	<i>12-15-69</i>
CLASSIFYING OFFICER	DATE

DISTRIBUTION OF THIS DOCUMENT UNLIMITED

S

1. SCOPE

1.1 Scope.- This specification establishes the performance, design, test and qualification requirements for equipment identified as the Nozzle Assembly Subsystem hereinafter referred to as the nozzle assembly.

2. APPLICABLE DOCUMENTS

2.1 Aerojet-General Corporation documents.- The following documents, of the latest issue, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced herein and other detailed content of Sections 3, 4, 5, and 10 the detailed requirements of Sections 3, 4, 5, and 10 shall be considered a superseding requirement.

SPECIFICATIONS

DS-90176	Nozzle Skirt Extension
DS-90196	Nozzle
CP-90290	Engine, NERVA, 75K, Full Flow

DRAWINGS

1136408	75K NERVA Full Flow Engine Component ICD
---------	--

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

3. REQUIREMENTS

3.1 Performance.- The nozzle assembly shall be capable of performing the following functions at the conditions and in the environments as specified herein.

(a) Collect the hot exit gas from the reactor, accelerate it through the throat, and expand it in an efficient manner to produce a thrust of $75,000 \pm 2,000$ pounds at a nominal specific impulse of 822.8 lbf-sec/lbm. The minimum allowable specific impulse shall be 816 lbf-sec/lbm.

(b) Transmit the generated thrust forces to the pressure vessel.

(c) Receive the propellant from the pump discharge line and transmit the propellant within the temperature rise and pressure drop limits specified herein to the interface between the nozzle and the reflector.

(d) Support the preload, acceleration, and pressure differential loads imparted by the nuclear subsystem and transmit them to the pressure vessel.

(e) Serve as an aft closure to the pressure vessel and nuclear subsystem providing the specified back pressure.

3.1.1 Functional characteristics.-

3.1.1.1 Performance characteristics.- While the engine is operating at a nominal 100 percent power and 100 percent thrust, the nozzle assembly shall be capable of handling the most severe combination of conditions specified in Tables I, II, and III within the design reliability allocation stated in 3.1.2.1.

Specification No. EC-90151

3.1.1.2 Cyclic life.- The nozzle assembly shall be capable of operation as stated in Tables I, II, and III, throughout its rated operating life as defined in 3.1.2.3.

3.1.1.3 Bolt coolant circuit.- If, as a product of design analysis, it is determined that a bolt coolant circuit, parallel to the nozzle coolant circuit is required, it shall flow 3.0 pounds per second under nominal conditions with the same pressure loss as the nozzle coolant circuit.

3.1.1.4 Throttleability.- The nozzle assembly shall be capable of continuous throttling with a chamber pressure range from 450 psia to 270 psia at a constant chamber temperature of 4250°R. The nozzle assembly shall be capable of withstanding loads resulting from a maximum chamber pressure increase or decrease rate of 50 pounds per second.

3.1.1.5 Chamber temperature change.- The nozzle shall be capable of operation with a maximum rate of chamber temperature increase or decrease of 150°R per second.

3.1.2 Operability.-

3.1.2.1 Reliability.- The nozzle assembly shall have a reliability of 0.999746 such that the performance characteristics of 3.1.1.1 shall be met. The apportionment of this reliability to the critical components of the nozzle assembly is as follows:

(a) Nozzle 0.999794

(b) Nozzle Skirt Extension 0.9999515

3.1.2.2 Maintainability.- The nozzle assembly subsystem shall be capable of being maintained within the following time limitations:

	<u>Repair</u>	<u>Inspection</u>
(a) Nozzle, hours	7.0	1.0
(b) Nozzle skirt extension, hours	2.5	0.5

3.1.2.2.1 Maintenance and repair cycles.- There shall be no periodic maintenance required on the nozzle assembly subsystem. If long lead time storage is required, an inspection for cleanliness and bolt torque shall be performed prior to use.

3.1.2.2.2 Service and access.-

3.1.2.2.2.1 Leak test and purge requirements.- The nozzle assembly coolant circuits shall be capable of being purged with an inert gas. The nozzle assembly coolant circuit shall be capable of being tested with gaseous nitrogen or gaseous helium at all pressures through 50 psig. The nozzle assembly shall be capable of a 50 psig leak check after assembly into the engine. This applies only to the coolant passage and the cavity constituted in the convergent portion of the assembly. If a throat plug is used, no special design considerations for the nozzle tubes, will be necessary. No ports, specifically for purge or leak test, shall be required on the nozzle assembly.

3.1.2.3 Useful life.- The nozzle assembly shall be capable of satisfying the useful life of the NLRVA engine, allocated as follows:

3.1.2.3.1 Rated operating life.- The rated operating life of the nozzle assembly shall be 600 minutes with a maximum of 60 cycles to rated conditions. A cycle is defined as engine startup from a no-flow condition,

bootstrap to rated power, hold at rated power for a defined period of time, retreat to less than rated power, shutdown, and cooldown. Any return to rated power after retreat from rated power shall be defined as an additional cycle. The rated operating life shall nominally consist of 60 ten minute cycles.

3.1.2.3.2 Nonrated operating life.- The non rated operating life, i.e., transients and checkouts at less than 60 percent thrust, of the nozzle assembly shall be 72 days. Any run at greater than 60 percent thrust shall, for cycle life consideration, be defined as a run at rated conditions.

3.1.2.3.3 Nonoperating life.-

3.1.2.3.3.1 Engine assembly to launch pad.- The nozzle assembly shall be capable of being in the engine assembly complex and in transit to the launch pad for six months. This shall not include storage time.

3.1.2.3.3.2 Launch pad environment.- The nozzle assembly shall be capable of surviving without degradation in the launch pad environment for six months.

3.1.2.3.3.3 Space storage conditions.- The nozzle assembly shall be capable of withstanding space storage conditions without degradation for three years. This period of time includes the operational life of 3.1.2.3.1 and 3.1.2.3.2.

3.1.2.3.4 Ground storage life.- The nozzle assembly shall be capable of being stored in an approved container either as an assembly or as separate critical components for a combined total storage time of five years under the applicable conditions of 3.1.2.4.

3.1.2.4 Environmental.- The Nozzle Assembly Subsystem shall experience the natural environments as specified in CP-90290 in addition to the following:

3.1.2.4.1 Nuclear environment.- The nozzle assembly shall be capable of operating in all of the nuclear environments specified in Table IV.

3.1.2.4.2 Thermal environment.- The nozzle assembly shall be capable of operation under the most severe condition of combined thermal environments due to operation defined in 3.1.1, nuclear heating due to environments defined in 3.1.2.4.1, and natural environments defined in 3.1.2.4. The maximum temperature allowable at nominal rated operating conditions is 2060°K in the coolant channel crowns. The maximum temperature of the structural portion of the nozzle shell shall be consistent with the strength-temperature relationship for the material of construction and the reliability allocation of 3.1.2.1. The maximum temperature of the nozzle skirt extension shall be consistent with the materials used and the reliability requirements of 3.1.2.1.

3.1.2.4.3 Static loads.- The static loads which shall be used to determine the nozzle assembly design are shown in Table V and Figure 1.

3.1.2.4.4 Dynamic loads (Launch).- During launch operations at the maximum longitudinal dynamic acceleration, within the range of 3 to 35 Hz, shall be ± 4.5 g's. The maximum lateral dynamic acceleration within the range of 0.1 to 15 Hz shall be ± 3.0 g's.

3.1.2.5 Transportability.- The nozzle assembly shall be capable of being handled in any attitude using ground support equipment. The nozzle assembly shall be capable of being shipped by land, sea, or air. Methods for preservation, packaging, and packing, for the assembly shall be developed to provide adequate protection against corrosion, contamination, and physical damage from shock and vibration so that the nozzle assembly may be shipped without degradation. The nozzle assembly, when adequately packaged, shall be capable of being shipped in any attitude.

3.1.2.6 Human performance.- Not applicable.

3.1.2.7 Safety.- The nozzle assembly shall be capable of operating safely within the applicable safety requirements of CP-90290.

3.2 CEI definition.- The nozzle assembly described in this specification shall be physically, mechanically, and functionally suitable for operation with the pressure vessel, nuclear subsystem, and pump discharge line.

3.2.1 Interface requirements.-

3.2.1.1 Schematic arrangement.- The relationship of the nozzle assembly to the pressure vessel, nuclear subsystem, and pump discharge line shall be as shown in Drawing 1136408.

3.2.1.2 Detailed interface definition.- The detailed dimensional, mechanical, electrical, and functional interface characteristics, which the nozzle is required to meet, shall be as shown in Drawing 1136408.

3.2.2 Component identification.-

3.2.2.1 Government furnished equipment list.- The nozzle assembly incorporates no government furnished equipment or materials.

3.2.2.2 Engineering critical component list.- The nozzle assembly incorporates no engineering critical components.

3.2.2.3 Logistics critical component list.- The nozzle assembly uses no logistics critical components.

3.2.2.4 Design critical components list.- Design of the nozzle assembly shall include the following design critical components:

<u>Specification Number</u>	<u>Nomenclature</u>
DS 90196	Nozzle
DS 90176	Nozzle Skirt Extension

3.3 Design and construction.-

3.3.1 General design features.- The nozzle shall contain coolant channels in the interior of the nozzle structural shell. The nozzle skirt extension shall attach to the nozzle in its divergent portion at an area ratio of 24:1. It shall be constructed of graphite material which needs no cooling. After a short cylindrical section extending aft from the core, the nozzle walls shall blend to a 45 degree half angle of convergence toward the throat. The throat area shall be such that the nominal chamber conditions of 3.1.1 are met with a diametrical tolerance of ± 0.010 inch. The upstream radius to the throat shall be one throat radius, and the downstream radius from the throat shall be 0.5 throat radius. The downstream radius shall terminate coincident with and tangent to the divergent contour. The divergent section shall conform to Rao contour design criteria. The exit area ratio shall be 100:1. Design shall be such as to eliminate dead spots where flow will stagnate or gases being purged from the engine will be trapped. The nozzle and nozzle skirt extension flanges shall be capable of being fit to a match plate to determine fitup capability.

3.3.1.1 Weight.- The target dry weight of the nozzle assembly shall be 1930 pounds. The target dry weight of the nozzle shall be 1280 pounds. The target weight of the skirt extension shall be 600 pounds. The maximum weight of the fasteners and seals shall be 50 pounds.

3.3.1.2 Envelope.- The nominal envelope dimensions of the nozzle assembly shall be as shown in Drawing 1136408.

- 3.3.2 Selection of specifications and standards.- As specified in CP-90290.
- 3.3.3 Materials, parts and processes.- As specified in CP-90290.
- 3.3.4 Standard and commercial parts.- As specified in CP-90290.
- 3.3.5 Moisture and fungus resistance.- As specified in CP-90290.
- 3.3.6 Corrosion and metal parts.- As specified in CP-90290.
- 3.3.7 Interchangeability and replaceability.- As specified in CP-90290.
- 3.3.8 Workmanship.- As specified in CP-90290.
- 3.3.9 Electromagnetic interference.- Not applicable.
- 3.3.10 Identification and marking.- As specified in CP-90290.
- 3.3.11 Storage.- The nozzle assembly shall be capable of performing as specified herein subsequent to storage while protected from the ground environmental conditions specified in 3.1.2.4 for a period not exceeding the ground storage life specified in 3.1.2.3.

TABLE I

PROPELLANT FLOW CHARACTERISTICS
(Maximum Conditions)

CHAMBER:

Flow Rate	92.0 lb/sec
Pressure	464 psia
Temperature	4300°R

COOLANT INLET:

Flow Rate	71.0 lb/sec
Pressure	2190 psia
Temperature	67.5°R

COOLANT OUTLET:

Flow Rate	71.0 lb/sec
Pressure	2103 psia
Temperature	220°R

TABLE II

PROPELLANT FLOW CHARACTERISTICS
(Nominal Operating Conditions)

CHAMBER:

Flow Rate	89.2 lb/sec
Pressure	450 psia
Temperature	4250°F

COOLANT INLET:

Flow Rate	65.6 lb/sec
Pressure	1423 psia
Temperature	61.1°R

COOLANT OUTLET:

Flow Rate	65.6 lb/sec
Pressure	1329 psia
Temperature	197°R

TABLE III

PROPELLANT FLOW CHARACTERISTICS
(Malfunction Conditions)

CHAMBER:

Flow Rate	89.3 lb/sec
Pressure	450 psia
Temperature	4250°R

COOLANT INLET:

Flow Rate	66.3 lb/sec
Pressure	1718 psia
Temperature	67.3°R

COOLANT OUTLET:

Flow Rate	66.3 lb/sec
Pressure	1628 psia
Temperature	204°R

TABLE IVa
NUCLEAR ENVIRONMENT
(Flight Engine)

Description	Location Station	(In) R	γ Kerma Rate Rads/Hr	γ Kerma Rate Raas (10 Hr Exp)	* = Hast x ** = SS γ Heating Rate Btu/in ³ -sec	Thermal Neutron		Fast Neutron		Epi Thermal	
						Flux n/cm ² sec	Nev n/cm ²	Flux n/cm ² sec	Nev n/cm ²	Flux n/cm ² sec	Nev n/cm ²
	209.18	20.47	8.1+8	8.1+9	3.0-1*	7.5+12	2.7+17	2.4+14	8.6+18	5.1+14	1.8+19
	211.54	20.47	8.1+8	8.1+9	3.0-1*	7.3+12	2.6+17	2.3+14	8.3+18	5.1+14	1.8+19
	213.9	20.47	7.5+8	7.5+9	2.7-1*	7.2+12	2.6+17	2.3+14	8.3+18	5.1+14	1.8+19
	214.68	21.36	3.0+8	3.0+9	1.3-1*	7.2+12	2.6+17	2.3+14	8.3+18	5.1+14	1.8+19
	214.68	22.25	2.6+8	2.6+9	1.2-1*	7.2+12	2.6+17	2.3+14	8.3+18	5.1+14	1.8+19
	214.68	23.15	2.7+8	2.7+9	1.1-1*	7.2+12	2.6+17	2.3+14	8.3+18	5.1+14	1.8+19
	223.34	12.31	7.5+8	7.5+9	2.7-1*	6.4+12	2.3+17	2.0+14	7.2+18	5.0+14	1.8+19
	225.31	10.36	1.1+9	1.1+10	4.2-1*	6.4+12	2.3+17	2.0+14	7.2+18	5.0+14	1.8+19
	227.28	8.42	1.1+9	1.1+10	4.3-1*	6.2+12	2.2+17	2.0+14	7.2+18	4.7+14	1.7+19
	230.43	6.10	6.2+8	6.2+9	2.2-1*	6.0+12	2.2+17	1.9+14	6.8+18	4.5+14	1.6+19
	235.94	8.38	4.5+8	4.5+9	1.7-1*	5.6+12	12.0+17	1.8+14	6.5+18	4.1+14	1.5+19
	239.88	10.76	2.6+8	2.6+9	1.2-1*	5.3+12	1.9+17	1.7+14	6.1+18	3.9+14	1.4+19
	243.82	15.35	2.6+8	2.6+9	9.4-2*	5.0+12	1.8+17	1.6+14	5.8+18	3.7+14	1.3+19
	261.14	20.19	1.2+8	1.2+9	5.0-2**	3.9+12	1.4+17	1.2+14	4.3+18	2.6+14	9.4+18
	277.72	27.28	8.7+7	8.7+8	3.1-2**	2.9+12	1.0+17	9.5+13	3.4+18	2.0+14	7.2+18
	317.72	39.56	4.0+7	4.0+8	1.7-2**	1.4+12	5.0+16	4.5+13	1.6+18	9.4+13	3.4+18
	367.72	49.88	2.1+7	2.1+8	8.9-3**	6.5+11	2.3+16	2.2+13	4.4+13	1.6+18	
	415.56	55.68	1.3+7	1.3+8	5.6-3**	4.1+11	1.5+16	1.3+13	4.7+17	2.9+13	1.0+18

TABLE IVb
NUCLEAR ENVIRONMENT
(Ground Engine

Description	Location Station	(in) R	γ Kerma Rate Rads/Hr	γ Kerma Rate Rads (10 Hr Exp)	* = Hast x ** = SS γ Heating Rate Btu/in ³ -sec	Thermal Neutron		Fast Neutron		Epi Thermal	
						Flux n/cm ² sec	Nev n/cm ²	Flux n/cm ² sec	Nev n/cm ²	Flux n/cm ² sec	Nev n/cm ²
Subsystem	213.9	20.5	7.9+8		3.0-1*						
	214.7	24.0	3.4+8		1.3-1*						
	223.3	12.3	7.9+8		3.0-1*						
	230.4	6.1	6.6+8		2.5-1*						
	235.9	8.4	4.9+8		1.9-1*						
	243.8	15.4	3.0+8		1.1-1*						
	261.1	20.2	1.5+8		5.2-2**						
	277.7	27.3	1.0+8		3.5-2**						
Ground Engine	223.3	12.3	8.6+8		4.7-1*			2.0+14			
	235.9	8.38	5.6+8		2.1-1*			1.8+14			
	243.8	15.4	3.7+8		1.4-1*			1.6+14			
	214.7	23.2	3.8+8		1.5-1*			2.3+14			
	230.4	6.1	7.3+8		3.1-1*			1.9+14			
	213.9	20.5	8.6+8		3.1-1*			2.3+14			
	277.7	27.3	2.1+8		8.4-2**			9.5+13			
	261.1	20.2	2.4+8		9.8-2**			1.2+14			

TABLE V

STATIC LOADS

STATION	Space Operation			Boost		
	Load			Load		
	F	M	V	F	M	V
	lb	lb-in	lb	lb	lb-in	lb
1	834,000	0	Negligible	-124,890	+ 677,104	+11,902
2	-1,629,000	Product of Design Analysis	Product of Design Analysis	135,062	+ 666,657	+13,859
3	64,000	Product of Design Analysis	154	800	0	154
4	0	0	0	0	0	0