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C002-EC090122-F1

ENGINEERING CRITICAL COMPONENT SPECIFICATION

PERFORMANCE/DESIGN AND
PRODUCT CONFIRMATION REQUIREMENTS

FOR

BYPASS CONTROL
VALVE & ACTUATOR

FORMING A PART OF
CEI NUMBER 090290A

PRELIMINARY PROPOSAL ISSUE

DATED 12-15-69

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AEROJET-GENERAL CORPORATION

SACRAMENTO, CALIFORNIA

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Part I of Two Parts
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PERFORMANCE/DESIGN AND QUALIFICATION REQUIREMENTS FOR

~~for~~

BY-PASS CONTROL VALVE & ACTUATOR

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.

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1. SCOPE

1.1 Scope.- This specification establishes the performance, design, test and qualification requirements for equipment identified as By-Pass Control Valve and Actuator, hereinafter referred to as BCV Assembly, consisting of a valve and an electro-mechanical actuator system. The BCV assembly is to regulate the flow of propellant delivered to the turbine in response to control system demands during engine operation.

2. APPLICABLE DOCUMENTS

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

SPECIFICATIONS

EC-90218

Propellant Feed Subsystem

CP-90290

Engine, NERVA, 75K, Full Flow

(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.- Except as otherwise specified herein, performance requirements for this equipment shall be in accordance with EC-90218, Propellant Feed Subsystem, of which this equipment is a part. The BCV assembly shall be capable of meeting these requirements within the environmental conditions specified in 3.1.2.4 and using fluids specified in CP-90290.

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3.1.1 Functional characteristics.- The BCV assembly shall respond to commands for position changes and shall be capable of holding any commanded position within the limits specified herein in the absence of a position change command.

3.1.1.1 Full-open position characteristics.- The BCV assembly shall be capable of remaining in a fully open position without the use of electrical power for a period not exceeding 6 months or until commanded to close.

3.1.1.2 Closing characteristics.- The BCV assembly shall be capable of closing from a fully opened, or any intermediate position, to a fully closed position within two seconds after receipt of a "CLOSE" command signal when the following conditions prevail.

3.1.1.2.1 Inlet conditions.- The BCV assembly shall be capable of closing as specified in 3.1.1.2 with the inlet conditions of Table I, all cases.

3.1.1.2.2 Electrical supply conditions.- The BCV assembly shall be capable of closing as specified in 3.1.1.2 or opening as specified in 3.1.1.3 over the pressure and temperature range specified when provided with 28 ± 2 VDC at the electrical connector interface.

3.1.1.2.3 Flow and fluid conditions.- The BCV assembly shall be capable of flowing hydrogen at the rates and conditions specified in Table I, all cases.

3.1.1.3 Opening characteristics.- The BCV assembly shall be capable of opening within two seconds after receipt of an "OPEN" command signal.

3.1.1.4 Closed position characteristics.- After responding to a "CLOSE" command signal, the BCV assembly shall be capable of remaining in a fully closed position for a period not exceeding 30 minutes or until

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commanded to open. The BCV assembly shall be capable of fully closing after having been open for a period not in excess of 6 months.

3.3.1.5 Pressure loss limitations.- While flowing hydrogen at a rate of 37.6 pounds per second under the pressure and temperature conditions specified in Table I, Case II, the pressure loss through the valve shall not exceed 55 psi when in the full open position.

3.3.1.6 Intermediate position characteristics.- The BCV assembly shall be capable of remaining in any position between the fully opened and fully closed position in response to control system demands, and shall be capable of responding to commands for position changes under the conditions specified below:

3.1.1.6.1 Response conditions.- With the inlet conditions specified in Table I, Case III, the BCV assembly shall be capable of responding to control system demands such that the following criteria are achieved:

3.1.1.6.1.1 Frequency response.- The closed loop frequency response to a sinusoidal input signal having an amplitude corresponding to 1.5 percent (3 percent peak-to-peak) of valve full travel shall fall within the limits of Figure 1.

3.1.1.6.1.2 Step response.- The BCV assembly shall be designed to respond to a step command at an amplitude corresponding to 50 percent of full valve displacement such that the valve position shall fall within the limits of Figure 2.

3.1.1.6.1.2.1 Overshoot.- When responding to the step command as specified in 3.1.1.6.1.2, the valve shall not overshoot the commanded position by more than 25 percent of the total commanded change of position.

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3.1.1.6.1.2.2 Settling time.- When responding to the step command as specified in 3.1.1.6.1.2, the valve shall achieve the commanded position within ± 5 percent of the commanded change of position within 1.75 seconds.

3.1.1.6.1.2.3 Final valve error.- When responding to a step command as specified in 3.1.1.6.1.2, the final position of the valve shall be at the commanded position within ± 0.3 percent of full valve displacement.

3.1.1.6.1.3 Step response (below system saturation).- The BCV assembly shall be capable of responding to a step command at an amplitude below system saturation (but not greater than 10 percent of full valve displacement) such that the valve position shall fall within the limits of Figure 3. This response characteristic shall be achieved when there is no flow through the valve and when the valve is commanded to travel in either the opening or closing direction at ambient conditions.

3.1.1.6.1.3.1 Overshoot (below system saturation).- When responding to a step command as specified in 3.1.1.6.1.3, the valve shall not overshoot the commanded position by more than 25 percent of the total commanded change of position.

3.1.1.6.1.3.2 Settling time (below system saturation).- When responding to a step command as specified in 3.1.1.6.1.3, the valve shall achieve the commanded position within 1.05 seconds and shall be within the limits of 3.1.1.6.1.3.3.

3.1.1.6.1.3.3 Final valve error (below system saturation).- When responding to a step command as specified in 3.1.1.6.1.3, the final position of the valve shall be at the commanded position within ± 0.3 percent of the full valve displacement.

3.1.1.6.1.4 Threshold.- The BCV assembly shall achieve a measurable response from a low frequency (0.1 cps, maximum) sinusoidal command signal

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having an amplitude corresponding to an output displacement of less than ± 0.1 percent of the full valve displacement.

3.1.1.6.2 Command signal conditions.- The BCV assembly shall be capable of executing all commands specified herein when the command signal has an amplitude of 0 to 10 VDC and is proportional to valve positions of 0 to 100 percent open, respectively.

3.1.2 Operability.-

3.1.2.1 Reliability.- The reliability requirement of the BCV assembly shall be 999732 or greater.

3.1.2.2 Maintainability.- The BCV assembly shall be capable of being maintained within the following time allocations.

(a) Removal from engine, checkout and replacement time -- the time required shall not exceed three hours.

(b) Active maintenance time -- the maximum time required for preventive and corrective maintenance shall not exceed 0.1 man-hours per hour during engine assembly and operations.

3.1.2.2.1 Maintenance and repair cycles.-

(a) Periodic maintenance, other than an inert gas purge, shall not be required during storage.

(b) Periodic maintenance or repair shall not be used to attain specified reliability or operating life requirements.

3.1.2.2.2 Service and access.-

(a) Capability for remote malfunction detection and fault isolation shall be provided.

(b) Capability for remote and manual replacement of the BCV assembly shall be provided for ground test engines and space operations. Replacement will be accomplished by replacing a module containing two BVC and two BBV assemblies.

(c) The BCV module shall be capable of being manually maintained and replaced with the use of standard hand tools.

(d) Provisions shall be made for purging the BCV assembly with inert gas through the engine purge system.

3.1.2.3 Useful life.- The useful life of the BCV assembly shall include the rated and non-rated operating life and the non-operating life as specified below.

(a) Rated Operating Life: Subsequent to non-rated operating life and non-operating life (3.1.2.3 b&c) the BCV assembly shall be capable of completing operating steps 7 through 17 as shown on Table II which expose the BCV assembly to 10 hours of cyclic operation simulating the maximum flight life requirement.

(NOTE: The rated operating life shall occur during a three-year space storage period)

(b) Non-Rated Operating Life: The BVC assembly shall be capable of completing operating steps 1 through 6 as shown on Table II which constitute 10 hours of operation simulating the maximum acceptance and pre-installation and pre-launch checkout.

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(c) Non-Operating Life:

(1) Engine assembly to launch pad (less ground storage, months:	6
(2) Launch pad, months:	6
(3) Maximum accumulated space storage time, years:
(Space storage between firings - 6 months)	3
(4) Ground storage, years:	5

3.1.2.4 Environmental.- The environments experienced by the BCV assembly shall be as specified in EC-90218 in addition to the following:

(a) Internal temperature, °K	See Table I
(b) Internal pressure, psia	See Table I
(c) Radiation	
(1) Gamma dose, RADS, max (10 hours)	4.8×10^7
(2) Fast neutron fluence, N/cm^2 ($E > 1$ Mev), max.	2.5×10^{16}

3.1.2.4.1 Dynamic Loads.- The BCV assembly shall withstand dynamic loads resulting from launch vehicle operations and from engine operation as specified below:

(a) <u>Launch Vehicle Operations</u>	
(1) Longitudinal dynamic amplitude over
Frequency range from 3 to 35 Hz.	$\pm 6.75g$ Max.
(2) Lateral dynamic amplitude over
Frequency range from 0.1 to 15 Hz.	$\pm 4.5g$ Max.

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(b) Engine Operation - Random vibration along each of three mutually perpendicular axes at levels indicated below for thirty minutes in each axis:

<u>20 to 200 Hz</u>	<u>200 to 800 Hz</u>	<u>800 to 2000 Hz</u>
Linear Increase	At $1.5g^2/Hz$	Linear Decrease
From 0.03 to		From 1.5 to
$1.5g^2/Hz$		$0.06g^2/Hz$
(3db/Octave)		(3db/Octave)

3.1.2.4.2 Static Loads. - The BCV assembly shall withstand static loads resulting from launch vehicle acceleration for a minimum of five minutes along the following axes:

<u>Along X-Axis</u>	<u>Along Y-Axis</u>	<u>Along Z-Axis</u>
5.2g - 1.0g	$\pm 1.0g$	$\pm 1.0g$

NOTE: The X-Axis shall be parallel with the vehicle longitudinal axis.

3.1.2.5 Transportability. - The BCV assembly shall be capable of meeting the transportability requirements specified in EC-90218.

3.1.2.6 Human performance. - The BCV assembly shall be capable of meeting the human performance requirements specified in EC-90218.

3.1.2.7 Safety. - The BCV assembly shall be capable of complying with the safety requirements specified in EC-90218. The BCV assembly shall open in the event of an electrical power failure.

3.2 Contract end item definition. - Not applicable.

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3.3 Design and construction.- Except as otherwise specified herein, design and construction of the BCV assembly shall be in accordance with EC-90218 of which this equipment is a part. The BCV assembly shall be designed and constructed in a manner such that the functional characteristics of 3.1.1 and the operability requirements of 3.1.2 can be achieved.

3.3.1 General design features.- The BCV assembly shall be designed to satisfy the following criteria.

3.3.1.1 Dimensional.- The envelope dimensions of the BCV assembly shall not exceed the dimensions shown in Figure 4.

3.3.1.2 Weight.- The weight of the BCV assembly shall not exceed 90 pounds.

3.3.1.3 Position indication.- The BCV assembly shall be equipped with a position indicator to provide position indication over the full range of valve travel.

3.3.1.4 Leakage.-

3.3.1.4.1 Internal leakage.- While in the closed position and with fluid pressure and temperature conditions as specified in Table I, the BCV assembly shall not leak between the inlet to the outlet of the valve in excess of 2000 standard cubic feet per minute of GH_2 .

3.3.1.4.2 External leakage.- The external joint leakage shall not exceed 0.01 standard cubic centimeter per second per inch joint diameter of static seal, or 20 standard cubic centimeters per second per inch joint diameter of dynamic seal, at the pressure and temperature conditions specified in Table I for all cases. Hydrogen leakage rate is defined as equivalent to a helium leakage rate at $520 \pm 50^\circ\text{R}$.

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3.3.1.5 Electrical power.- The electrical power consumption shall not exceed the values specified below:

<u>Valve Operational Mode</u>	<u>Table I Fluid Conditions</u>	<u>Power Consumption</u>
(a) Closing (see 3.1.1.2)	Case II	300 watts
(b) Opening (see 3.1.1.3)	Case II	300 watts
(c) Fixed Position (see 3.1.1.6)	Case III	300 watts
(d) Cycling (see 3.1.1.6)	Case III	450 watts
(e) Cycling (see 3.1.1.6)	Case V	600 watts
(f) Closed Position (see 3.1.1.4)	Case II	100 watts

3.3.1.6 Electrical interface.- The BCV assembly shall be equipped with an electrical connector to interface with an electrical power supply, position command signal, and position instrumentation harness.

3.3.1.7 Cleanliness.- The BCV assembly shall satisfy the cleanliness requirements of CP-90290 and shall be designed to permit a flow rate with fluid containing particles no larger than 600 microns in size, 200 grams in weight, and 168 pounds per cubic foot in density.

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.

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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.- As specified in CP-90290.

3.3.10 Identification and marking.- As specified in CP-90290.

3.3.11 Storage.- The BCV 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

PRESSURE, TEMPERATURE, AND FLOW CONDITIONS
IN
BCV ASSEMBLY
FOR
VARIOUS ENGINE OPERATING CONDITIONS

	Case I	Case II	Case III TPA Malfunction Operation	Case IV Throttling Operation	Case V Maximum Expected Operation	Case VI Normal Shutdown
	<u>Chilldown</u>	<u>Normal Operation</u>	<u>Malfunction Operation</u>	<u>Throttling Operation</u>	<u>Maximum Expected Operation</u>	<u>Normal Shutdown</u>
Inlet Pressure, psia - valve closed	-	1239.0	1551.0	620.0	2026.0	-
Outlet Pressure, psia - valve closed(*)	-	676	676	431	690	-
Inlet Temperature, °R	100	262.0	269.0	273.9	280.0	100
Flow Rate, lb/sec	1	13.5	13.0	22.0	20.0	10.0
Inlet Pressure, psia - with above flow rate	30	1239.0	1551.0	620.0	2026.0	100
Outlet Pressure, psia - with above flow rate	-	688.0	687.5	463.1	722.0	-

* BBV, in series with BCV, open

TABLE II
BCV ASSEMBLY USEFUL LIFE CYCLE

OPERATING STEP	TYPICAL INLET CONDITION		VALVE POSITION (NOTE: Flow rate associated with inlet conditions and valve positions indicated produce valve loads.)	OPERATING MODE	AMPLITUDE (° P-P)	FREQ. (CPS)	OPERATING TIME		
	TEMP (°R)	PRESS (PSIA)							
1	650	975	VARIABLE	SIMULATES ACCEPTANCE TESTS			1.5 HRS		
2	100	975	VARIABLE				1.5 HRS		
3	530	15	FROM 100 TO X % OPEN	SIMULATES PRE-LAUNCH CHECK-OUT	RAMP	- -	-	2 SEC	
4	530	15	AT X % OPEN		RAMP	4	1.0	1 HR	
5	530	15	FROM X TO 100% OPEN		RAMP	-	-	2 SEC	
6	REPEAT STEPS 3 THRU 5 FOR A TOTAL OF SEVEN TIMES WITH X = 90, 80, 65, 50, 35, 20, & 10%, RESPECTIVELY.								
7	285	975	FROM 100 TO 90% OPEN	SIMULATES ENGINE CHILL-DOWN CYCLE	RAMP	- -	-	2 SEC	
8	285	975	AT 90% OPEN		RAMP	4	1.0	10 SEC	
9	285	975	FROM 90 TO 100% OPEN		RAMP	- -	-	2 SEC	
10	100	**	FROM 100 TO 50% OPEN	SIMULATES ENGINE START-UP CYCLE	RAMP	- -	-	2 SEC	
11			AT 50% OPEN		RAMP	4 -	1.0	30 SEC	
12		1100	FROM 50 TO 90% OPEN		RAMP	- -	-	15 SEC	
13		*	1100	AT 90% OPEN	SIMULATES ENGINE STEADY STATE OPERATION	RAMP	4	1.0	475 SEC
14	650		FROM 90 TO 30% OPEN	RAMP		- -	-	4 SEC	
15	650	***	AT 30% OPEN	SIMULATES ENGINE SHUT-DOWN CYCLE	RAMP	4	1.0	30 SEC	
16	650		FROM 30 TO 100% OPEN		RAMP	- -	-	30 SEC	
17	REPEAT STEPS 7 THRU 16 FOR A TOTAL OF 60 TIMES.								
* INLET TEMPERATURE UNIFORMLY INCREASES FROM 100°R TO 650°R IN 210 SECONDS DURING THESE STEPS.									
** INLET PRESSURE UNIFORMLY INCREASES FROM 15 PSIA TO 1100 PSIA IN 32 SECONDS DURING THESE STEPS.									
*** INLET PRESSURE UNIFORMLY DECREASES FROM 1100 PSIA TO 15 PSIA IN 64 SECONDS DURING THESE STEPS.

Amplitude Ratio and Phase Lag of Valve Position vs. Frequency

Figure 2

Figure 3

Step Response To Command Displacement vs. Time

NOTE: 6.00 inch I.D.
Inlet-Outlet
Welded Interfaces

Figure 4

BCV Assembly Dimensional Envelope

ERRATA SHEET

BYPASS CONTROL VALVE AND ACTUATOR

THE FOLLOWING CHANGES HAVE BEEN MADE TO THIS SPECIFICATION
 THROUGH REVISION EC-6.

The following requirements have been identified as OBJECTIVES:

<u>Page No.</u>	<u>Paragraph No.</u>	<u>Requirement</u>
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The following requirements have been changed as follows:

<u>Page No.</u>	<u>Paragraph No.</u>	<u>Correction</u>
6	3.1.2.1	Add "point" to 999732
7	3.1.2.3(b)	Non-Rated Operating Life
8	3.1.2.3(c)	Non-Operating Life