

**SSME EA/CIL
REDUNDANCY SCREEN**

Component Group: Actuators
 CIL Item: E140-12
 Part Number: RES1008-6XXX
 Component: Oxidizer Preburner Oxidizer Valve Actuator
 FMEA Item: E140
 Failure Mode: Pneumatic shutdown piston or sequence valve leakage.

Prepared: S. Heater
 Approved: T. Nguyen
 Approval Date: 6/9/00
 Change #: 1
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Phase	Failure / Effect Description	Criticality Hazard Reference
PCD 4.1	Contamination of hydraulic return fluid with helium gas. Loss of vehicle due to loss of hydraulic control of orbiter control surfaces during re-entry.	1 ME-G1P,S,M,C,D
Redundancy Screens: SINGLE POINT FAILURE: N/A		

**SSME FMEA/CIL
DESIGN**

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FAILURE CAUSE: A: Damaged pneumatic piston seals.

THE PNEUMATIC SHUTDOWN ASSEMBLY INCORPORATES DUAL PISTON SEALS WITH A VENT BETWEEN THEM TO PREVENT LEAKAGES PAST THE FIRST SEAL FROM CONTINUING PAST THE SECOND SEAL. THE PISTON SEAL DESIGN INCORPORATES A BUNA-N O-RING (1) WITH A TEFLON RING (2) BETWEEN THE O-RING AND THE PISTON. THE BUNA-N O-RING PROVIDES PRESSURE ACTUATION OF THE SEAL, AND THE TEFLON RING PROVIDES LOW FRICTION WEAR RESISTANT CONTACT WITH THE PISTON (3). THE PNEUMATIC PISTON O.D. (4) AND PNEUMATIC CYLINDER (5) BORE ARE HARD ANODIZED, AND THE SURFACE FINISHES ARE MACHINED FOR DYNAMIC SEALS TO PREVENT WEAR WHICH MAY DAMAGE THE SEALS. THE HARD ANODIZE ALSO PREVENTS CORROSION AND PRECLUDES DAMAGE CAUSED BY CORROSION PRODUCTS ON THE DYNAMIC SEALING SURFACES. THE PISTON L/D GREATER THAN 3 MINIMIZES THE POTENTIAL OF DAMAGE TO THE SEAL CAUSED BY PISTON COCKING. ALL ACTUATOR PARTS ARE CLEANED PRIOR TO ASSEMBLY AND THE ACTUATOR IS ASSEMBLED IN A CONTAMINATION CONTROLLED AREA (5). THE CLEANLINESS OF THE PNEUMATIC AND HYDRAULIC FLUIDS ARE CONTROLLED (5).

(1) MS28775; (2) S13077; (3) RSS-8582; (4) 34001926; (5) RC1008

FAILURE CAUSE: B: Damaged pneumatic piston.

THE PNEUMATIC PISTON IS MADE FROM 6061-T651 ALUMINUM ALLOY (1). THE MATERIAL WAS SELECTED FOR ITS STRENGTH AND THERMAL COMPATIBILITY WITH THE PNEUMATIC CYLINDER AND ACTUATOR HOUSING. THE MATERIAL IS STRESS CORROSION RESISTANT AND IS ANODIZED FOR GENERAL CORROSION RESISTANCE (2). THE PISTON OUTSIDE DIAMETER IS HARD ANODIZED FOR PROTECTION AGAINST WEAR AND DAMAGE. THE L/D OF GREATER THAN 3 FOR THE PISTON PREVENTS DAMAGE CAUSED BY COCKING. ALL ACTUATOR PARTS ARE CLEANED PRIOR TO ASSEMBLY AND THE ACTUATOR IS ASSEMBLED IN A CONTAMINATION CONTROLLED AREA (3). THE CLEANLINESS OF THE PNEUMATIC AND HYDRAULIC FLUIDS ARE CONTROLLED (3).

(1) 34001926; (2) RSS-8582; (3) RC1008, RL10012

FAILURE CAUSE: C: Damaged sequence valve.

THE SEQUENCE VALVE PISTON (1) IS MADE FROM CUSTOM 455. THE MATERIAL IS HEAT TREATED AND AGED TO THE H1000 CONDITION. CUSTOM 455 WAS SELECTED FOR ITS STRENGTH AND WEAR RESISTANCE (2). THE SLEEVE (3) MATERIAL IS ANODIZED 2024-T6 WHICH WAS SELECTED FOR ITS STRENGTH (2). THE SEQUENCE VALVE ROLLER IS HEAT TREATED CUSTOM 455 (4). THE MATERIAL WAS CHOSEN FOR ITS BEARING STRENGTH (2). THE PIN IS A-286 WHICH IS CHROME PLATED (5) FOR ADDITIONAL SURFACE HARDNESS (2). A-286 WAS CHOSEN FOR ITS SHEAR STRENGTH (2). BOTH MATERIALS ARE CORROSION AND STRESS CORROSION RESISTANT. THE PARTS ARE CLEANED PRIOR TO ASSEMBLY; THE ACTUATORS ARE ASSEMBLED IN A CONTAMINATION CONTROLLED AREA. THE HYDRAULIC FLUID IS FILTERED THROUGH A SYSTEM 25-MICRON FILTER AND THE HELIUM IS FILTERED THROUGH A 15-MICRON FILTER TO PREVENT DAMAGE CAUSED BY CONTAMINATION. THE ROLLER ON THE PISTON LIMITS THE SIDE LOADS, AND THE L/D OVER 2 ON THE PISTON PREVENTS DAMAGE CAUSED BY COCKING.

(1) 34000318; (2) RSS-8582; (3) 34000319; (4) 34000395; (5) 34000317

FAILURE CAUSE: D: Damaged sequence valve seals.

THE SEQUENCE VALVE HYDRAULICS AND PNEUMATICS ARE SEPARATED AT THE PISTON AND SLEEVE INTERFACE BY TWO GREENE TWEED SEALS (1). A DRAIN CAVITY BETWEEN THE TWO SEALS VENTS LEAKAGE FROM EITHER THE PNEUMATIC OR THE HYDRAULIC SEAL. THIS PREVENTS LEAKAGE PAST THE FIRST SEAL FROM PRESSURIZING THE SECOND SEAL. THE GREENE TWEED SEALS ARE USED FOR THEIR ABILITY TO SEAL AT LOW PRESSURES, YET NOT SEVERELY DEFORM AT HIGH PRESSURES (2). THE SEQUENCE VALVE SLEEVE TO HOUSING SEALS (3) ARE BUNA-N. THE SEALS ARE SEPARATED BY A DRAIN CAVITY TO PREVENT LEAKAGE PAST THE SECOND SEAL. BUNA-N IS USED FOR ITS ELASTIC CHARACTERISTICS, RESISTANCE TO PERMANENT SET, AND COMPATIBILITY WITH THE HYDRAULIC FLUID AT THE DESIGN OPERATING TEMPERATURE (2). THE SEQUENCE VALVE PISTON (4) IS MADE FROM CUSTOM 455 CRES. THE MATERIAL IS HEAT TREATED AND AGED. CUSTOM 455 CRES IS USED FOR ITS STRENGTH, HARDNESS, AND STIFFNESS (2). THE PISTON SLEEVE (3) MATERIAL IS 2024-T6 ALUMINUM. 2024-T6 ALUMINUM IS USED FOR ITS STRENGTH AND SIMILARITY OF THERMAL PROPERTIES TO THE 7175 ALUMINUM HOUSING (2). THE SLEEVE IS ANODIZED FOR GENERAL CORROSION RESISTANCE (2). DIFFERENTIAL HARDNESS, 2.5 L/D, AND SMALL CLEARANCES BETWEEN THE PISTON AND SLEEVE, AND CORNER CHAMFER MINIMIZE THE POTENTIAL OF WEAR AND GALLING THAT COULD DAMAGE THE SEALS. THE ACTUATOR PARTS ARE CLEANED PRIOR TO ASSEMBLY. THE ACTUATOR IS ASSEMBLED IN A CONTAMINATION CONTROLLED AREA. THE HYDRAULIC FLUID AND HELIUM ARE FILTERED PRIOR TO ENTERING THE ACTUATOR (5). THE CLEANLINESS PROCEDURES MINIMIZE THE POTENTIAL OF SEAL DAMAGE CAUSED BY CONTAMINATION (6).

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FAILURE CAUSE: ALL CAUSES

THE HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE ACTUATOR MEET CEI REQUIREMENTS (1). THE MINIMUM FACTORS OF SAFETY FOR THE ACTUATOR MEET CEI REQUIREMENTS (2). THE ACTUATOR WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH, SINCE IT CONTAINS NO FRACTURE CRITICAL PARTS (3). THE ACTUATOR HAS COMPLETED DESIGN VERIFICATION TESTING (4). DVS TEST RESULTS ARE DOCUMENTED (5). THE OPOVA FROM ENGINE 2010 WAS DISASSEMBLED AND EXAMINED. THE ACTUATOR SHOWED NO DETRIMENTAL DEFECTS OR WEAR. THIS ACTUATOR HAD 28 STARTS AND 10,332 SECONDS HOT FIRE TIME, INCLUDING 6,651 SECONDS AT FPL (6).

(1) RL00532, CP320R0003B; (2) RSS-8546, CP320R0003B; (3) NASA TASK 117; (4) DVS-SSME-512; (5) RSS-512; (6) SSME-82-2316

SSME FMEA/CIL INSPECTION AND TEST

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	PISTON PNEUMATIC CYLINDER		34001926
			34001927
	SEALING SURFACE INTEGRITY	THE PNEUMATIC PISTON AND CYLINDER ASSEMBLY HARD ANODIZE IS VERIFIED TO DRAWING REQUIREMENTS.	34001926
		THE PISTON SURFACES ARE PENETRANT INSPECTED PER DRAWING REQUIREMENTS.	34001927
	O-RING/CAP SEAL ASSEMBLY	THE SURFACE FINISH OF PNEUMATIC PISTON IS INSPECTED.	34001926
		THE O-RING/CAP SEAL SURFACE FINISH IS INSPECTED DURING ASSEMBLY.	34001926
			RC1008
		PISTON AND CAP ASSEMBLY CLEANLINESS IS VERIFIED PER DRAWING REQUIREMENTS.	RC1008
		COMPONENT ASSEMBLY IS VERIFIED TO BE IN A CONTAMINATION CONTROLLED AREA.	RL10012
		FUNCTIONAL TESTING VERIFIES PNEUMATIC PISTON SEAL INTEGRITY.	RC1008
B	PISTON MATERIAL INTEGRITY		34001926
			34001926
		PISTON IS PENETRANT INSPECTED PER DRAWING REQUIREMENTS.	34001926
		ANODIZE AND HARD ANODIZE OF PISTON IS VERIFIED PER DRAWING REQUIREMENTS.	34001926
		THE SURFACE FINISH OF PNEUMATIC PISTON IS INSPECTED.	34001926
		PISTON AND CAP CLEANLINESS IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RC1008
		RL10012	
	COMPONENT ASSEMBLY IS VERIFIED TO BE IN A CONTAMINATION CONTROLLED AREA.	RC1008	
FUNCTIONAL TESTING VERIFIES PNEUMATIC PISTON OPERATION.	RL10012		
C, D	PISTON SLEEVE HOUSING, MACHINED HOUSING ASSY.		34000316
			34000319
	MATERIAL INTEGRITY		34000657
			34000694
		MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	34000316
			34000319
			34000657
	THE PISTON AND HOUSING HEAT TREAT IS VERIFIED PER DRAWING REQUIREMENTS.	34000316	
		34000657	

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C, D	MATERIAL INTEGRITY	THE HOUSING AND SLEEVE ARE PENETRANT INSPECTED AFTER MACHINING.	34000319 34000694	
		SLEEVE ANODIZE IS VERIFIED PER DRAWING REQUIREMENTS.	34000319	
		THE HOUSING, PISTON, AND SLEEVE SURFACE FINISHES ARE VERIFIED PER DRAWING REQUIREMENTS.	34000316 34000319 34000694	
		PISTON IS PENETRANT INSPECTED PER DRAWING REQUIREMENTS.	34000316	
	COMPONENT CLEANLINESS	COMPONENTS ARE VERIFIED TO BE CLEAN PRIOR TO ASSEMBLY.	RC1008 RL10012	
		CONTAMINATION CONTROL OF THE COMPONENT ASSEMBLY IS VERIFIED.	RC1008 RL10012	
	FUNCTIONAL INTEGRITY	SEQUENCE VALVE ALIGNMENT IN THE HOUSING IS VERIFIED.	41003720	
		SEQUENCE VALVE AND ACTUATOR FUNCTIONAL TESTS, INCLUDING PNEUMATIC SHUTDOWN SLEW RATE, VERIFY SEQUENCE VALVE OPERATION.	RC1008	
	ALL CAUSES	COMPONENT CLEANLINESS	ALL ACTUATOR DETAILS ARE VERIFIED TO BE CLEAN PRIOR TO INSTALLATION.	RC1008, RL10012
		FUNCTIONAL INTEGRITY	HOTFIRE TESTING AND SECOND E & M INSPECTIONS VERIFY SATISFACTORY OPERATION.	RL00050-04 RL00056-06 RL00056-07
ACTUATOR OPERATION IS VERIFIED PRIOR TO EACH FLIGHT DURING HYDRAULIC SYSTEM CONDITIONING.			OMRSD S00FA0.211	
ACTUATOR OPERATION IS VERIFIED DURING THE ACTUATOR CHECKOUT MODULE PRIOR TO EACH FLIGHT.			OMRSD V41AS0.010	
PNEUMATIC SEALS ARE LEAK CHECKED EVERY FLIGHT.			OMRSD V41BQ0.170	
ACTUATOR OPERATION IS VERIFIED DURING FLIGHT READINESS CHECKOUT PRIOR TO EACH FLIGHT. (LAST TEST)			OMRSD V41AS0.030	

Failure History: Comprehensive failure history data is maintained in the Problem Reporting database (PRAMS/PRACA)
 Reference: NASA letter SA21/88/308 and Rocketdyne letter 88RC09761.

Operational Use: Not Applicable.

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