

**SSME FMEA/CIL**  
**REDUNDANCY SCREEN**

Component Group: Ducts and Lines  
 CIL Item: K204-01  
 Part Number: RS007016  
 Component: Oxidizer Tank Pressurant Duct  
 FMEA Item: K204  
 Failure Mode: Fails to contain oxidizer.

Prepared: D. Early  
 Approved: T. Nguyen  
 Approval Date: 7/25/00  
 Change #: 1  
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Phase	Failure / Effect Description	Criticality Hazard Reference
SMC 4.1	Oxidizer leakage into aft compartment and overpressurization of the aft compartment. Loss of GOX source to the Pogo accumulator. Loss of vehicle.  Redundancy Screens: SINGLE POINT FAILURE: N/A	1 ME-C3S, ME-C3M, ME-C3A,C

**SSME I A/CIL**  
**DESIGN**

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Design / Document Reference

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**FAILURE CAUSE: A: Parent material failure or weld failure.**

THE DUCT ASSEMBLY (1) IS MANUFACTURED UTILIZING INCONEL 718 TUBING AND INCONEL 718 BAR FOR FLANGE AND RING DETAILS. INCONEL 718 WAS SELECTED FOR ITS STRENGTH, RESISTANCE TO STRESS CORROSION, CORROSION RESISTANCE, HIGH/LOW CYCLE FATIGUE CHARACTERISTICS, AND WELDABILITY (2). FLANGE SECTIONS INCORPORATE RADIUS JOINTS TO REDUCE STRESS CONCENTRATIONS. OFFSET LIMIT REQUIREMENTS ARE ESTABLISHED TO REDUCE STRESS CONCENTRATIONS AND IMPROVE WELD GEOMETRY.

(1) RS007016; (2) RSS-8582, RSS-8575

**FAILURE CAUSE: B: Flex joint structural failure of: Caps, Pins, Fasteners, Rings, Yokes, Stabilizer, Bellows, Inlet and outlet sleeves.**

ALL DETAILS ARE MANUFACTURED UTILIZING INCONEL 718. INCONEL 718 WAS SELECTED FOR ITS STRENGTH, RESISTANCE TO STRESS CORROSION, CORROSION RESISTANCE, HIGH/LOW CYCLE FATIGUE CHARACTERISTICS, AND WELDABILITY (6). MOVING PARTS INCORPORATE RADII ON ENDS TO PREVENT NARROW CONTACT POINTS AND LOADING THAT MAY CAUSE HEAT GENERATION. DURING OPERATION, PRESSURE SEPARATING LOADS APPLIED TO THE BELLOW ASSEMBLY MAINTAIN A CONSTANT LOADING FORCE ON THE MOVING PARTS. DRY-FILM LUBRICANT IS USED TO REDUCE FRICTION, GALLING, AND PARTICLE GENERATION. MATING ROTATIONAL SURFACES HAVE TIGHT TOLERANCE CONTROLS TO INCREASE SURFACE CONTACT AREA WHICH REDUCES GALLING, STRESS RISERS, AND OFFSET LOADING. TOLERANCE CONTROLS ALSO DECREASE LUBRICANT WEAR, INCREASING LIFE. INTERNAL STABILIZERS REDUCE TURBULENCE OVER THE BELLOW ASSEMBLY AND PROVIDES LAMINAR FLOW WHICH INHIBITS FLOW INDUCED VIBRATION. VENT HOLES ARE MANUFACTURED IN THE STABILIZERS TO EQUALIZE PRESSURE ACROSS THE SURFACE. VENT HOLES ARE PROVIDED WITH SCREENS TO KEEP CONTAMINATION FROM COLLECTING IN THE CONVOLUTION AREA IN ADDITION TO EQUALIZING PRESSURE. BOLTS ARE SILVER-PLATED TO PROVIDE PROPER RETENTION TORQUE (7). BELLOW ASSEMBLIES ARE MANUFACTURED OF MULTIPLE PLIES EVENLY SPACED, AND ANNULAR TO IMPROVE FATIGUE LIFE, REDUCE STRESS/STRAIN CONCENTRATIONS, AND MAINTAIN CONSTANT SPRING RATE. BELLOW ASSEMBLIES ARE WELDED AT THE PLY ENDS PRIOR TO HYDROFORMING TO PREVENT OIL CONTAMINATION BETWEEN BELLOW ASSEMBLY PLIES. WELDED PLY ENDS ARE SUBSEQUENTLY MACHINED TO A UNIFORM SURFACE BEFORE FINAL WELDING TO THE SUPPORT. THIS IMPROVES THE CONNECTING WELD QUALITY, AND REDUCES PLY DISTORTION. THE FLEX JOINT HAS COMPLETED BENDING MOMENT, FLEXURAL ENDURANCE, ULTIMATE PRESSURE, PROOF PRESSURE, VIBRATION, AND SECTIONING DVS TESTING (8).

(1) RS008705, RS008725; (2) RS008702, RS008722; (3) RS008721, RS008701; (4) RS008704, RS008724; (5) RS008898, RS008899; (6) RSS-8582, RSS-8575; (7) RD111-1012-0407; (8) RSS-511-13

**FAILURE CAUSE: ALL CAUSES**

INSTALLATION IS CONTROLLED FOR ANGULARITY AND OFFSET (1). ALL MATERIALS USED IN THE DUCT FABRICATION ARE LOX COMPATIBLE (2). DUCT AND SUBASSEMBLY MATERIALS ARE HEAT TREATED TO DEVELOP FULL MATERIAL STRENGTH AND HARDNESS. THE MINIMUM FACTORS OF SAFETY FOR THE DUCT MEET CEI REQUIREMENTS (3). HIGH AND LOW CYCLE FATIGUE LIFE FOR THE DUCT MEET CEI REQUIREMENTS (4), EXCEPT THE RS008721 FLEX JOINTS ARE HIGH CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (10). THE DUCT ASSEMBLY HAS SUCCESSFULLY COMPLETED PRESSURE CYCLING AND ULTIMATE PRESSURE DVS TESTING (5). THE DUCT ASSEMBLY PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH, SINCE THEY ARE NOT FRACTURE CRITICAL PARTS (6). TABLE K204 LISTS ALL THE FMEA/CIL WELDS AND IDENTIFIES THOSE WELDS IN WHICH THE CRITICAL INITIAL FLAW SIZE IS NOT DETECTABLE, AND THOSE WELDS IN WHICH THE ROOT SIDE IS NOT ACCESSIBLE FOR INSPECTION. THESE WELDS HAVE BEEN ASSESSED AS ACCEPTABLE FOR FLIGHT BY RISK ASSESSMENT (7). THE VISUAL BELLOW INSPECTION, HE MASS LEAK, AND ACCESSIBLE BELLOW WELDS DYE PENETRANT INSPECTION TESTS HAVE BEEN SUCCESSFULLY COMPLETED ON ENGINE 2010 (8) AND 2014 (9) FLEX JOINTS. NO ANOMALIES WERE FOUND. THE 2010 DUCT HAD ACCUMULATED 65 STARTS AND 19,903 SECONDS. THE 2014 DUCT HAD ACCUMULATED 53 STARTS AND 15,346 SECONDS.

(1) I.L. 0126-8066; (2) RSS-8582; (3) RSS-8546, CP320R0003B; (4) RL00532, CP320R0003B; (5) RSS-511-43; (6) NASA TASK 117; (7) RSS-8756; (8) CD#2-0152; (9) CD#2-87-0031; (10) DAR 2118

**SSME FMEA/CIL  
INSPECTION AND TEST**

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference		
A	DUCT		RS007016		
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS007016		
		THE DETAIL PARTS ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116		
		HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020	
	WELD INTEGRITY	ALL WELDS ARE INSPECTED TO DRAWING AND SPECIFICATION REQUIREMENTS PER WELD CLASS. INSPECTIONS INCLUDE: VISUAL, DIMENSIONAL, PENETRANT, RADIOGRAPHIC, ULTRASONIC, AND FILLER MATERIAL, AS APPLICABLE.	RL10011 RA0607-094 RA0115-116 RA0115-006 RA1115-001 RA0115-127		
		ASSEMBLY INTEGRITY	THE DUCT IS PROOF PRESSURE TESTED PER DRAWING REQUIREMENTS.	RS007016	
			AFTER PROOF PRESSURE TESTING, THE OUTSIDE DIAMETER WELDS ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116	
		B	CAPS		RS008705
			CAPS		RS008725
	MATERIAL INTEGRITY		MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008705 RS008725	
THE CAP IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.			RA0115-116		
HEAT TREAT			HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020	
SURFACE FINISH	CAP DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.		RS008705 RS008725		
PIN			RS008722		
PIN			RS008702		
MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.		RS008722 RS008702		
	THE PIN IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.		RA0115-116		
	HEAT TREAT		HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020	
SURFACE FINISH	PIN DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.		RS008722 RS008702		
BOLTS			RD111-1012-0407		
WASHER			RS008763		
MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION AND DRAWING REQUIREMENTS.		RD111-1012-0407 RS008763		
HEAT TREAT	BOLT HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RD111-1012-0407			

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B	SURFACE FINISH	BOLT SILVER-PLATING IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RD111-1012-0407
	RING		RS008724
	RING		RS008704
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008724
			RS008704
		THE RING IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	RING DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008724
			RS008704
	YOKE		RS008721
	YOKE		RS008701
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008721
			RS008701
	HEAT TREAT	HEAT TREAT IS VERIFIED PER DRAWING REQUIREMENTS.	RS008721
			RS008701
	SURFACE FINISH	YOKE DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008721
			RS008701
	STABILIZER		RS008701
	STABILIZER		RS008721
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008701
			RS008721
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	THE STABILIZER DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008701
			RS008721
	ASSEMBLY INTEGRITY	INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008701
			RS008721
	BELLOWS		RS008899
	BELLOWS		RS008898
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008899
			RS008898
		THE BELLOWS GRAIN DIRECTION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008899
			RS008898
		THE BELLOWS SEAM WELD DIRECTION AND LOCATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008899
			RS008898
	CLEANLINESS OF COMPONENTS	THE BELLOWS PLIES ARE VERIFIED CLEAN PER SPECIFICATION REQUIREMENTS PRIOR TO ASSEMBLY AND CONVOLUTING.	RA1610-044
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENT.	RA1611-002

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B	WELD INTEGRITY	ALL WELDS ARE INSPECTED TO DRAWING AND SPECIFICATION REQUIREMENTS PER WELD CLASS. INSPECTIONS INCLUDE: VISUAL, DIMENSIONAL, PENETRANT, RADIOGRAPHIC, ULTRASONIC, AND FILLER MATERIAL, AS APPLICABLE.	RL10011 RA0607-094/RA1607-079 RA0115-116 RA0115-006 RA1115-001 RA0115-127	
	ASSEMBLY INTEGRITY	WELDS ARE PENETRANT INSPECTED AFTER PLANISHING PER SPECIFICATION REQUIREMENTS. THE BELLOWS ECCENTRICITY, CONVOLUTE HEIGHTS, CROWN AND ROOTS RADIUS, PLY THICKNESS, AND SURFACE IRREGULARITY ARE VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RA0115-116 RS008898 RS008899 RL00078	
	INLET/OUTLET SLEEVE INLET/OUTLET SLEEVE		RS008701 RS008721	
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008701 RS008721	
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020	
	SURFACE FINISH	THE SLEEVE DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008701 RS008721	
	ASSEMBLY INTEGRITY	INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008701 RS008721	
	FLEX JOINT FLEX JOINT		RS008701 RS008721	
	WELD INTEGRITY	ALL WELDS ARE INSPECTED TO DRAWING AND SPECIFICATION REQUIREMENTS PER WELD CLASS. INSPECTIONS INCLUDE: VISUAL, DIMENSIONAL, PENETRANT, RADIOGRAPHIC, ULTRASONIC, AND FILLER MATERIAL, AS APPLICABLE.	RL10011 RA0607-094 RA0115-116 RA0115-006 RA1115-001 RA0115-127	
	ASSEMBLY INTEGRITY	THE FLEX JOINT IS GIMBAL TESTED PER DRAWING REQUIREMENTS. THE FLEX JOINT IS ACCEPTANCE TESTED PER SPECIFICATION REQUIREMENTS.	RS008701 RS008721 RL00212 RL00213	
	ALL CAUSES	DUCT		RS007016
		COMPONENT CLEANLINESS	CLEANLINESS IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1610-002 RA1610-004
		FLIGHT FLOW TESTING	THE EXTERNAL SURFACE IS VISUALLY INSPECTED PRIOR TO EACH LAUNCH. (LAST TEST)	OMRSD V41BU0.030

**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 History:** Not Applicable

**SSME FMEA/CIL**  
**WELD JOINTS**

Component Group: Ducts and Lines  
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Component	Basic Part Number	Weld Number	Weld Type	Class	Root Side Not Access	Critical Initial Flaw Size Not Detectable		Comments
						HCF	LCF	
DUCT	RS007016	7,14,17	GTAW	I	X	X		
DUCT	RS007016	8-13,16	GTAW	I	X			
DUCT	RS007016	15	GTAW	I				
DUCT	RS007016	18	GTAW	I	X			
DUCT	RS007016	19,21	GTAW	I	X	X		
DUCT	RS007016	20	GTAW	I	X	X	X	
DUCT	RS007016	22,23	GTAW	I	X			
FLEX JOINT	RS008701	1-4	EBW	I	X			
FLEX JOINT	RS008701	5,6	EBW	I	X			
FLEX JOINT	RS008701	7-10	EBW	I	X			
FLEX JOINT	RS008701	4 PLCS	GTAW	III				
FLEX JOINT	RS008721	1,2	EBW	I	X			
FLEX JOINT	RS008721	3-6	EBW	I	X			
BELLOWS	RS008898	1-4	GTAW	I			X	
BELLOWS	RS008898	5,6	EBW	I				
BELLOWS	RS008899	1	GTAW	I				
BELLOWS	RS008899	2	GTAW	I				
BELLOWS	RS008899	3	GTAW	I				
BELLOWS	RS008899	4,5	EBW	I				