

SSME A/CIL
REDUNDANCY SCREEN

Component Group: Ducts and Lines
 CIL Item: K202-01
 Part Number: RS007035
 Component: LPOTP Turbine Drive Duct
 FMEA Item: K202
 Failure Mode: Fails to contain oxidizer.

Prepared: D. Early
 Approved: T. Nguyen
 Approval Date: 7/25/00
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 Page: 1 of 1

Phase	Failure / Effect Description	Criticality Hazard Reference
PSMCD 4.1	Oxidizer leakage into aft compartment. Overpressurization of aft compartment. Loss of vehicle. Redundancy Screens: SINGLE POINT FAILURE: N/A	1 ME-C3P,D, ME-C3S, ME-C3A,C, ME-C3M

SSME FMEA/CIL DESIGN

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Design / Document Reference

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 AND DUCT SECTIONS INCORPORATE RADIUS JOINTS TO REDUCE STRESS CONCENTRATIONS. OFFSET LIMIT REQUIREMENTS ARE ESTABLISHED TO REDUCE STRESS CONCENTRATIONS AND IMPROVE WELD GEOMETRY.

(1) RS007035; (2) RSS-8582, RSS-8575

FAILURE CAUSE: B: Flex joint structural failure of: Pins, Ring, Yokes, Stabilizer, Bellows, Inlet and outlet sleeves.

THE FLEX JOINTS ARE DOUBLE BELLOWES WITH EXTERNAL GIMBAL LINKAGE. PINS (1), YOKES (3), STABILIZER (3), BELLOWES (4), AND INLET/OUTLET SLEEVES (3) ARE MANUFACTURED UTILIZING INCONEL 718. INCONEL 718 WAS SELECTED FOR ITS STRENGTH, RESISTANCE TO STRESS CORROSION CRACKING, CORROSION RESISTANCE, HIGH/LOW CYCLE FATIGUE CHARACTERISTICS AND WELDABILITY (5). RING (2) IS MANUFACTURED UTILIZING TITANIUM TI-6AL-6V-2SN AND WAS SELECTED FOR STRENGTH TO DENSITY RATIO. MOVING PARTS INCORPORATE RADIUS ON ENDS TO PREVENT NARROW CONTACT POINTS AND LOADING THAT MAY CAUSE HEAT GENERATION. DURING OPERATION, PRESSURE SEPARATING LOADS APPLIED TO THE BELLOWES 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 BELLOWES ASSEMBLY AND PROVIDE LAMINAR FLOW WHICH INHIBITS FLOW INDUCED VIBRATION. VENT HOLES ARE MANUFACTURED IN THE STABILIZERS TO EQUALIZE PRESSURE ACROSS THE SURFACE. SCREENS KEEP CONTAMINATION FROM COLLECTING IN THE CONVOLUTION AREA IN ADDITION TO EQUALIZING PRESSURE. BELLOWES ARE MANUFACTURED OF MULTIPLE PLIES EVENLY SPACED, AND ANNULAR TO IMPROVE FATIGUE LIFE, REDUCE STRESS/STRAIN CONCENTRATIONS, AND MAINTAIN CONSTANT SPRING RATE. BELLOWES ARE WELDED AT THE PLY ENDS PRIOR TO HYDROFORMING TO PREVENT OIL CONTAMINATION BETWEEN BELLOWES PLIES. WELDED PLIES 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 (6).

(1) RS008662, RS008642; (2) RS008644, RS008664; (3) RS008641, RS008661; (4) RS008895, RS008896; (5) RSS-8582, RSS-8575; (6) 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). THE MINIMUM FACTORS OF SAFETY FOR DUCT MEET CEI REQUIREMENTS (3). LOW CYCLE FATIGUE LIFE FOR THE BELLOWES MEET CEI REQUIREMENTS (4). THE RS008641 AND RS008661 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 MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH, SINCE THEY ARE NOT FRACTURE CRITICAL PARTS (6). TABLE K202 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 BELLOWES INSPECTION, HE MASS LEAK, AND ACCESSIBLE BELLOWES WELDS DYE PENETRANT INSPECTION TEST HAVE BEEN 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, CP320R003B; (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 2120

**SSME FME CIL
INSPECTION AND TEST**

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Page: 1 of 3

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	DUCT		RS007035
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS007035
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	SURFACE FINISH IS VERIFIED PER DRAWING REQUIREMENTS.	RS007035
	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
		ALL DUCT WELDS ARE PENETRANT INSPECTED AFTER PROOF PRESSURE TEST PER SPECIFICATION REQUIREMENTS.	RA0115-116
	ASSEMBLY INTEGRITY	DUCT IS PROOF PRESSURE TESTED PER DRAWING REQUIREMENTS.	RS007035
B	PIN		RS008662
	PIN		RS008642
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008662 RS008642
		PIN IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	THE PIN DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008662 RS008642
	RING		RS008644
	RING		RS008664
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008644 RS008664
		THE RING IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS. THE FORGING TENSILE TEST IS VERIFIED PER DRAWING REQUIREMENTS.	RA0611-020 RS008781
SURFACE FINISH	THE RING DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS	RS008644 RS008664	
YOKE		RS008661	
YOKE		RS008641	
MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008661 RS008641	

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Page: 2 of 3

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B	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	YOKE DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008661 RS008641
	STABILIZER STABILIZER		RS008661 RS008641
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008661 RS008641
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RA0611-020 RS008641 RS008661
	SURFACE FINISH	STABILIZER DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008661 RS008641
	ASSEMBLY INTEGRITY	INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008661 RS008641
	BELLOWS BELLOWS		RS008895 RS008896
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008895 RS008896
		THE BELLOWS GRAIN DIRECTION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008895 RS008896
	CLEANLINESS OF COMPONENTS	THE BELLOWS PLYS ARE VERIFIED CLEAN PER SPECIFICATION REQUIREMENTS PRIOR TO ASSEMBLY AND CONVOLUTING.	RA1610-044
	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/RA1607-079 RA0115-116 RA0115-006 RA1115-001 RA0115-127
		THE BELLOWS SEAM WELD DIRECTION AND LOCATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008895 RS008896
	ASSEMBLY INTEGRITY	THE BELLOWS ECCENTRICITY, CONVOLUTE HEIGHTS, CROWN AND ROOTS RADIUS, PLY THICKNESS, AND SURFACE IRREGULARITY ARE VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS008896 RS008895 RL00078
	SLEEVES SLEEVES		RS008641 RS008661
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008641 RS008661

Component Up: Ducts and Lines
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Page: 3 of 3

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B	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	THE SLEEVE DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008641 RS008661
	ASSEMBLY INTEGRITY	INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008641 RS008661
	FLEX JOINT FLEX JOINT		RS008641 RS008661
	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.	RS008641 RS008661
		THE FLEX JOINT IS ACCEPTANCE TESTED PER SPECIFICATION REQUIREMENTS.	RL00210 RL00211
ALL CAUSES	DUCT		RS007035
	CLEANLINESS OF COMPONENTS	ASSEMBLY IS VERIFIED CLEAN PER SPECIFICATION REQUIREMENTS.	RA1610-002 RA1610-004
	FLIGHT FLOW TESTING	THE EXTERNAL SURFACE IS VISUALLY INSPECTED PRIOR TO EACH LAUNCH. A HELIUM SIGNATURE LEAK TEST IS PERFORMED PRIOR TO EACH LAUNCH. (LAST TEST)	OMRSD V41BU0.030 OMRSD S00000.950

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.

SSME EA/CIL
WELD JOINTS

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 Page: 1 of 1

Component	Basic Part Number	Weld Number	Weld Type	Class	Root Side Not Access	Critical Initial Flaw Size Not Detectable		Comments
						HCF	LCF	
DUCT	RS007035	1	GTAW	I		X		
DUCT	RS007035	2	GTAW	I				
DUCT	RS007035	3,4	GTAW	I	X			
DUCT	RS007035	5	GTAW	I				
DUCT	RS007035	7-13	GTAW	I				
DUCT	RS007035	14	GTAW	I	X	X		
DUCT	RS007035	15	GTAW	I				
DUCT	RS007035	16	GTAW	I	X			
DUCT	RS007035	17	GTAW	I				
DUCT	RS007035	18,20,21	GTAW	I				
DUCT	RS007035	19	GTAW	I	X	X		
DUCT	RS007035	22	GTAW	I	X			
FLEX JOINT	RS008641	1-4	EBW	I	X			
FLEX JOINT	RS008641	5,6	GTAW	I	X			
FLEX JOINT	RS008641	16 PLCS	GTAW	III	X			
FLEX JOINT	RS008661	1-4	EBW	I	X			
FLEX JOINT	RS008661	4 PLCS	EBW	I	X			
FLEX JOINT	RS008661	5,6	GTAW	I	X			
FLEX JOINT	RS008661	16 PLCS	GTAW	III	X			
BELLOWS	RS008895	1-4	GTAW	I				
BELLOWS	RS008895	5,6	EBW	I				
BELLOWS	RS008896	1-4	GTAW	I				
BELLOWS	RS008896	5,6	EBW	I				