

**SSME I A/CIL**  
**REDUNDANCY SCREEN**

Component Group: Ducts and Lines  
CIL Item: K102-01  
Part Number: RS007034  
Component: LPFTP Turbine Drive Duct  
FMEA Item: K102  
Failure Mode: Fails to contain hydrogen.

Prepared: D. Early  
Approved: T. Nguyen  
Approval Date: 7/25/00  
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Directive #: CCBDB ME3-01-5638

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Phase	Failure / Effect Description	Criticality Hazard Reference
SMC 4.1	Fuel leakage into aft compartment. Overpressurization of aft compartment. Possible fire or detonation. Loss of vehicle.  Redundancy Screens: SINGLE POINT FAILURE: N/A	1 ME-D3S,A,M,C

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**SSME FMEA/CIL  
DESIGN**

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

THE DUCT ASSEMBLY (1) IS MANUFACTURED UTILIZING INCOLOY 903 TUBING, BAR, AND FORGING. THE FORGING WAS USED FOR FLANGE AND FITTING DETAILS. INCOLOY 903 WAS SELECTED BECAUSE OF ITS RESISTANCE TO HYDROGEN ENVIRONMENTAL EFFECTS AND ITS STRENGTH, WELDABILITY, RESISTANCE TO STRESS CORROSION CRACKING, AND CORROSION RESISTANCE (2). MATERIALS ARE HEAT TREATED TO DEVELOP FULL MATERIAL STRENGTH AND HARDNESS (2). FLANGE SECTIONS INCORPORATE RADIUS JOINTS TO REDUCE STRESS CONCENTRATIONS. OFFSET LIMIT REQUIREMENTS ARE ESTABLISHED TO REDUCE STRESS CONCENTRATIONS AND IMPROVE WELD GEOMETRY.

(1) RS007034; (2) RSS-8582

**FAILURE CAUSE: B: Flex joint assemblies structural failure of: Pins, Caps, Ring, Yokes, Stabilizer, Bellows assembly, Inlet outlet sleeves/tubes, Welds.**

THE FLEX JOINTS ARE DOUBLE BELLOWS WITH EXTERNAL GIMBAL LINKAGE. THE PINS (1), CAPS (2), AND YOKES (4) 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. THE RING (3) IS MANUFACTURED UTILIZING TITANIUM TI-6AL-6V-2S. IT WAS SELECTED FOR ITS STRENGTH TO DENSITY RATIO. MATERIALS ARE HEAT TREATED TO DEVELOP FULL MATERIAL STRENGTH AND HARDNESS (6). STABILIZER (4), BELLOWS ASSEMBLY (5), AND INLET AND OUTLET SLEEVES (4) ARE MANUFACTURED UTILIZING INCOLOY 903. INCOLOY 903 WAS SELECTED FOR ITS STRENGTH AND ITS RESISTANCE TO HYDROGEN ENVIRONMENT EFFECTS. IT IS WELDABLE AND IS RESISTANT TO STRESS CORROSION CRACKING (6). MOVING PARTS INCORPORATE RADIUS ON ENDS TO PREVENT NARROW CONTACT POINTS AND LOADING. DURING OPERATION, PRESSURE SEPARATING LOADS APPLIED TO THE BELLOWS MAINTAIN A CONSTANT LOADING FORCE ON THE MOVING PARTS. DRY-FILM LUBRICANT IS USED TO REDUCE FRICTION AND GALLING. 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 BELLOWS ASSEMBLY AND PROVIDES 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. BELLOWS ARE MANUFACTURED OF MULTIPLE PLYS EVENLY SPACED, AND ANNULAR TO IMPROVE FATIGUE LIFE, REDUCE STRESS/STRAIN CONCENTRATIONS, AND MAINTAIN CONSTANT SPRING RATE. BELLOWS ARE WELDED AT THE PLY ENDS PRIOR TO HYDROFORMING TO PREVENT OIL CONTAMINATION BETWEEN BELLOWS PLYS. WELDED PLYS 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 (7).

(1) RS008902, RS008922; (2) RS008905, RS008925; (3) RS008904, RS008924; (4) RS008901, RS008921; (5) RS008888, RS008889; (6) RSS-8582; (7) RSS-511-13

**FAILURE CAUSE: C: Parent material failure of plate.**

THE PLATE (1) IS MANUFACTURED FROM INCONEL 718. THIS MATERIAL WAS SELECTED FOR ITS STRENGTH, RESISTANCE TO STRESS CORROSION, CORROSION RESISTANCE, AND HIGH/LOW CYCLE FATIGUE CHARACTERISTICS (2). HYDROGEN ENVIRONMENT EFFECTS ARE NOT A PROBLEM IN THIS ENVIRONMENT (2). THE MATERIAL IS HEAT TREATED TO DEVELOP FULL STRENGTH AND HARDNESS (2). THE PLATE INCORPORATES RADIUS CORNERS TO REDUCE STRESS CONCENTRATIONS.

(1) RS009528; (2) RSS-8582

Component p: Ducts and Lines  
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**FAILURE CAUSE: ALL CAUSES**

INSTALLATION IS CONTROLLED FOR ANGULARITY AND OFFSET (1). MINIMUM FACTORS OF SAFETY FOR THE DUCT MEET CEI REQUIREMENTS (2). LOW CYCLE FATIGUE LIFE FOR THE DUCT MEETS CEI REQUIREMENTS (3). THE DUCT IS HIGH CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (10). FLEX JOINTS ARE LIFE LIMITED BY MAJOR WAIVER (9). THE DUCT ASSEMBLY HAS SUCCESSFULLY COMPLETED PRESSURE CYCLING, ULTIMATE PRESSURE DVS TESTING, AND RECERTIFICATION FOR MCC NICKEL PLATING (4). THE DUCT ASSEMBLY PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY RISK ASSESSMENT (5). TABLE K102 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 (6). THE VISUAL BELLOWS INSPECTION, HE MASS LEAK, AND ACCESSIBLE BELLOWS WELDS DYE PENETRANT INSPECTION TEST HAS BEEN COMPLETED ON ENGINES 2010 (7) AND 2014 (8) FLEX JOINTS (7). 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-8546, CP320R0003B; (3) RL00532, CP320R0003B; (4) RSS-511-43, ECP 872; (5) NASA TASK 117; (6) RSS-8756, MCR 0964; (7) CD#2-0152; (8) CD#2-87-0031; (9) DAR 2122; (10) DAR 2227

**SSME FMEA/CIL**  
**INSPECTION AND TEST**

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	DUCT, TURBINE DRIVE LPFTP		RS007034
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS007034
		FORGING DETAILS ARE ULTRASONIC OR RADIOGRAPHIC INSPECTED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RA0115-012 RA0115-006
		THE DUCT DETAILS ARE PENETRANT INSPECTED AS REQUIRED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	THE DUCT DETAILS SUBASSEMBLIES HEAT TREAT ARE 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
		AFTER PROOF PRESSURE TEST, THE DUCT WELDS ARE PENETRANT INSPECTED AND LEAK TESTED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007034 RA0115-116
ASSEMBLY INTEGRITY	THE DUCT IS PROOF PRESSURE TESTED PER DRAWING REQUIREMENTS.	RS007034	
B	PIN PIN		RS008902 RS008922
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008902 RS008922
		HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.
	SURFACE FINISH	THE PIN IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		THE PIN DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008902 RS008922
	CAP CAP		RS008905 RS008925
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008905 RS008925
		HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.
	SURFACE FINISH	CAP IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		THE CAP DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008905 RS008925

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
B	RING		RS008904
	RING		RS008924
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008904 RS008924
		THE RING IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		THE FORGING TENSILE TEST IS VERIFIED PER DRAWING REQUIREMENTS.	RS008781
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0111-024
		THE RING TENSILE TESTS ARE VERIFIED PER SPECIFICATION REQUIREMENTS AFTER HEAT TREAT.	RB0170-219
	SURFACE FINISH	DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008904 RS008924
	YOKE		RS008901
	YOKE		RS008921
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008901 RS008921
	HEAT TREAT	HEAT TREAT IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS008901 RS008921 RA0611-020
	SURFACE FINISH	THE YOKE DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008901 RS008921
	STABILIZER		RS008901
	STABILIZER		RS008921
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008901 RS008921
		THE INCOLOY BAR IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	THE STABILIZER DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008901 RS008921
	ASSEMBLY INTEGRITY	INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008901 RS008921
BELLOWS		RS008888	
BELLOWS		RS008889	
MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008888 RS008889	
	THE BELLOWS GRAIN DIRECTION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008888 RS008889	
	THE BELLOWS SEAM WELD DIRECTION AND LOCATION ARE VERIFIED PER DRAWING REQUIREMENTS.	RS008888 RS008889	

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
B	CLEANLINESS OF COMPONENTS	THE BELLOWS PLYS ARE VERIFIED CLEAN PER SPECIFICATION REQUIREMENTS PRIOR TO ASSEMBLY AND CONVOLUTING.	RA1610-044
	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 WELD PLANISHING OR GRINDING IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020 RA1611-002
	ASSEMBLY INTEGRITY	THE BELLOWS ECCENTRICITY, CONVOLUTE HEIGHTS CROWN AND ROOTS RADIUS, PLY THICKNESS, AND SURFACE IRREGULARITY ARE VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS008888 RS008889 RL00078
	SLEEVE SLEEVE		RS008901 RS008921
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008901 RS008921
		THE SLEEVE BAR MATERIAL IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020 RA1611-002
	SURFACE FINISH	THE SLEEVE DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008901 RS008921
	ASSEMBLY INTEGRITY	INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008901 RS008921
	WELDS WELDS		RS008901 RS008921
	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
	FLEX JOINT FLEX JOINT		RS008901 RS008921
	ASSEMBLY INTEGRITY	THE FLEX JOINT IS GIMBAL TESTED PER DRAWING REQUIREMENTS.	RS008901 RS008921

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B	ASSEMBLY INTEGRITY	THE FLEX JOINT IS ACCEPTANCE TESTED PER SPECIFICATION REQUIREMENTS.	RL00376 RL00377
C	PLATE		RS009528
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS009528
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	ASSEMBLY INTEGRITY	THE DUCT IS PROOF PRESSURE TESTED PER DRAWING REQUIREMENTS.	RS007034
ALL CAUSES	DUCT		RS007034
	COMPONENT CLEANLINESS	COMPONENT CLEANLINESS IS VERIFIED PER SPECIFICATION REQUIREMENTS.	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 FMEA/CIL**  
**WELD JOINTS**

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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	RS007034	31	GTAW	I	X			
DUCT	RS007034	32	GTAW	I	X	X		
DUCT	RS007034	37	GTAW	I	X			
DUCT	RS007034	38	GTAW	I	X	X		
DUCT	RS007034	42	GTAW	I	X	X		
DUCT	RS007034	43	GTAW	I	X	X		
DUCT	RS007034	44,45,48	GTAW	I	X	X		
DUCT	RS007034	46	GTAW	I	X	X		
DUCT	RS007034	47	GTAW	I	X	X		
DUCT	RS007034	49	GTAW	I		X		
DUCT	RS007034	50	GTAW	I				
DUCT	RS007034	51,52	GTAW	I	X			
DUCT	RS007034	53	GTAW	I	X	X		
BELLOWS	RS008888	1-4	GTAW	I				
BELLOWS	RS008888	5,6	EBW	I				
BELLOWS	RS008889	1-4	GTAW	I				
BELLOWS	RS008889	5,6	EBW	I				
FLEX JOINT	RS008901	1-4	EBW	I				
FLEX JOINT	RS008901	5-8	EBW	I	X			
FLEX JOINT	RS008921	1,2	EBW	I		X		
FLEX JOINT	RS008921	3-6	EBW	I	X			