

SSME A/CIL
REDUNDANCY SCREEN

Component Group: Ducts and Lines
CIL Item: K103-01
Part Number: RS007037
Component: LPFTP Turbine Discharge Duct
FMEA Item: K103
Failure Mode: Fails to contain hydrogen.

Prepared: D. Early
Approved: T. Nguyen
Approval Date: 7/25/00
Change #: 1
Directive #: CCBD 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

**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 AND INCOLOY 903 FORGINGS FOR THE FLANGE AND FITTING DETAILS. INCOLOY 903 WAS SELECTED BECAUSE OF ITS STRENGTH, WELDABILITY, RESISTANCE TO STRESS CORROSION CRACKING, AND CORROSION RESISTANCE. MATERIALS ARE HEAT TREATED TO DEVELOP FULL MATERIAL STRENGTH AND HARDNESS (2). INCOLOY 903 IS NOT SIGNIFICANTLY EFFECTED BY HYDROGEN IN THIS ENVIRONMENT (2). FLANGE SECTIONS INCORPORATE RADIUS JOINTS TO REDUCE STRESS CONCENTRATIONS. OFFSET LIMIT REQUIREMENTS ARE ESTABLISHED TO REDUCE STRESS CONCENTRATIONS AND IMPROVE WELD GEOMETRY.

(1) RS007037; (2) RSS-8582

FAILURE CAUSE: B: Flex joint assemblies structural failure of: Pin, Caps, Ring, Yokes, Stabilizer (N/A to RS008761 short), Bellows assembly, inlet/outlet sleeves/tubes, Liners (RS008761 short only), 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 (8). THE RING (3) IS MANUFACTURED UTILIZING TITANIUM TI-6AL-6V-2SN AND WAS SELECTED FOR STRENGTH TO DENSITY RATIO. MATERIALS ARE HEAT TREATED TO DEVELOP FULL MATERIAL STRENGTH AND HARDNESS (8). THE STABILIZER (4), BELLOWS ASSEMBLY (5), AND INLET AND OUTLET SLEEVES (4) ARE MANUFACTURED UTILIZING INCOLOY 903, WHICH WAS SELECTED FOR ITS STRENGTH, WELDABILITY AND RESISTANT TO STRESS CORROSION CRACKING (8). THE LINER (6) IS MANUFACTURED FROM A-286 WHICH WAS SELECTED FOR ITS STRENGTH, DUCTILITY, AND ELASTIC MODULUS (8). THE TUBE (6) IS MANUFACTURED FROM ARMCO 21-6-9 WHICH WAS SELECTED FOR ITS STRENGTH, CORROSION RESISTANCE, AND RESISTANCE TO STRESS CORROSION CRACKING (8). THESE MATERIALS ARE NOT SIGNIFICANTLY EFFECTED BY HYDROGEN IN THIS ENVIRONMENT (8). THE WELDS ARE CONTROLLED BY DRAWING REQUIREMENTS DEFINING CLASS AND SPECIFICATION REQUIREMENTS (7). 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, 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 INLET AND OUTLET SLEEVES OR LINERS 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. BELLOWS ARE MANUFACTURED OF MULTIPLE PLIES 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 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 (9).

(1) RS008742, RS008762; (2) RS008745, RS008765; (3) RS008744, RS008764; (4) RS008741, RS008761; (5) RS008890, RS008891; (6) RS008761; (7) RS008741, RS008761, RS008890, RS008891; (8) RSS-8582; (9) 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

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FAILURE CAUSE: ALL CAUSES

INSTALLATION IS CONTROLLED FOR ANGULARITY AND OFFSET (1). THE MINIMUM FACTORS OF SAFETY FOR THE BELLOWS 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). THE FLEX JOINTS ARE HIGH CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (4). THE DUCT ASSEMBLY PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY RISK ASSESSMENT (5). TABLE K103 LISTS ALL 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 DUCT ASSEMBLY HAS SUCCESSFULLY COMPLETED PRESSURE CYCLING AND ULTIMATE PRESSURE DVS TESTING (7). THE VISUAL BELLOWS INSPECTION, HE MASS LEAK, AND ACCESSIBLE BELLOWS WELDS DYE PENETRANT INSPECTION TEST HAVE BEEN SUCCESSFULLY COMPLETED ON ENGINES 2010 (8) AND 2014 (9) FLEX JOINTS. NO ANOMALIES WERE FOUND. THE 2010 DUCT HAD ACCUMULATED 59 STARTS AND 17,431 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) DAR 2123; (5) NASA TASK 117; (6) RSS-8756; (7) RSS-511-43; (8) CD#2-0152; (9) CD#2-87-0031; (10) DAR 2139

SSME FMEA/CIL INSPECTION AND TEST

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference	
A	LPFTP DISCHARGE DUCT		RS007037	
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS007037	
		THE RING, FLANGE, AND MANIFOLD FORGING ARE PENETRANT AND EITHER ULTRASONIC OR RADIOGRAPHIC INSPECTED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RA0115-116 RA0115-012 MIL-I-8950 RA0115-006	
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020	
	ASSEMBLY INTEGRITY	THE DUCT DETAILS ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116	
		THE DUCT IS PROOF PRESSURE TESTED PER DRAWING REQUIREMENTS.	RS007037	
	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	
		THE DUCT WELDS ARE PENETRANT INSPECTED AND LEAK TESTED PER DRAWING AND SPECIFICATION REQUIREMENTS AFTER PROOF PRESSURE TESTED.	RS007037 RA0115-116	
	B	PIN		RS008742
		PIN		RS008762
MATERIAL INTEGRITY		MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008742 RS008762	
		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.	RS008742 RS008762	
CAP			RS008745	
CAP			RS008765	
MATERIAL INTEGRITY		MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008745 RS008765	
		THE CAP IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116	
HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020		
SURFACE FINISH	THE CAP DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008745 RS008765		

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
B	RING		RS008744
	RING		RS008764
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008744 RS008764
		THE FORGING IS PENETRANT AND ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116 RA0115-012
		THE FORGING TENSILE TEST IS VERIFIED PER DRAWING REQUIREMENTS.	RS008781
		THE RING IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	RING HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0111-024
	SURFACE FINISH	RING DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008744 RS008764
	YOKE		RS008741
	YOKE		RS008761
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008741 RS008761
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	YOKE DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008741 RS008761
	STABILIZER		RS008741
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008741
		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.	RS008741
	ASSEMBLY INTEGRITY	INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008741
	BELLOWS		RS008891
	BELLOWS		RS008890
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008891 RS008890
		THE BELLOWS GRAINS DIRECTION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008891 RS008890
		THE BELLOWS SEAM WELD DIRECTION AND LOCATION ARE VERIFIED PER DRAWING REQUIREMENTS.	RS008891 RS008890
	CLEANLINESS OF COMPONENTS	THE BELLOW PLIES ARE VERIFIED CLEAN PER SPECIFICATION REQUIREMENTS PRIOR TO ASSEMBLY AND CONVULUTING.	RA1610-044
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020 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 RS008891 RS008890 RL00078
	SLEEVE		RS008741
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008741
	HEAT TREAT	THE SLEEVE BAR MATERIAL IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	SURFACE FINISH	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	ASSEMBLY INTEGRITY	THE SLEEVE DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008741
	SLEEVE	INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008761
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008761
	HEAT TREAT	THE SLEEVE BAR MATERIAL IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	TUBE/RING	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	MATERIAL INTEGRITY		RS008761
	HEAT TREAT	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008761
	SURFACE FINISH	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	ASSEMBLY INTEGRITY	THE TUBE IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	LINER	THE TUBE DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008761
	MATERIAL INTEGRITY	INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008761
	SURFACE FINISH		RS008761
	ASSEMBLY INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008761
	WELDS	THE LINER DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008761
	WELDS	INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008761

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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 RA0115-116 RA0115-006 RA1115-001 RA0115-127
	FLEX JOINT FLEX JOINT		RS008741 RS008761
	ASSEMBLY INTEGRITY	THE FLEX JOINT IS GIMBAL TESTED PER DRAWING REQUIREMENTS.	RS008741 RS008761
		THE FLEX JOINT ACCEPTANCE TESTS ARE VERIFIED PER SPECIFICATION REQUIREMENTS.	RL00378 RL00379
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.	RS007037
ALL CAUSES	DUCT		RS007037
	CLEANLINESS OF COMPONENTS	COMPONENTS ARE VERIFIED CLEANED 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 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	RS007037	6	GTAW	I		X		
DUCT	RS007037	7	GTAW	I	X	X		
DUCT	RS007037	8	GTAW	I		X		
DUCT	RS007037	21	GTAW	I	X	X	X	
DUCT	RS007037	22	GTAW	I	X	X	X	
DUCT	RS007037	23	GTAW	I		X	X	
DUCT	RS007037	25	GTAW	I	X	X	X	
DUCT	RS007037	26	GTAW	I		X		
DUCT	RS007037	27	GTAW	I		X		
DUCT	RS007037	28	GTAW	I	X	X		
DUCT	RS007037	29-31	GTAW	I	X			
DUCT	RS007037	32	GTAW	I	X			
DUCT	RS007037	33	GTAW	I		X		
DUCT	RS007037	34	GTAW	I		X	X	
DUCT	RS007037	35	GTAW	I		X		
DUCT	RS007037	36	GTAW	I		X		
DUCT	RS007037	37	GTAW	I		X		
FLEX JOINT	RS008741	1,2	EBW	II	X			
FLEX JOINT	RS008741	3,4	EBW	I				
FLEX JOINT	RS008741	5-8	EBW	I	X			
FLEX JOINT	RS008761	5,6	EBW	I	X			
FLEX JOINT	RS008761	7,8	EBW	I		X		
FLEX JOINT	RS008761	9,10	EBW	II				
BELLOWS	RS008890	1-4	GTAW	I				
BELLOWS	RS008890	5,6	EBW	I				
BELLOWS	RS008891	1-4	GTAW	I			X	
BELLOWS	RS008891	5,6	EBW	I				