

SSME A/CIL
REDUNDANCY SCREEN

Component Group: Ducts and Lines
 CIL Item: K101-01
 Part Number: RS007018
 Component: LPFTP Discharge Duct
 FMEA Item: K101
 Failure Mode: Loss of Insulating capability.

Prepared: D. Early
 Approved: T. Nguyen
 Approval Date: 7/25/00
 Change #: 1
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Phase	Failure / Effect Description	Criticality Hazard Reference
PSMCD 4.1	Outer bellows leakage causes cryopumping, liquid nitrogen freezes between inner and outer bellows. Flex joint fails during engine gimbaling. Fuel leakage into aft compartment. Overpressurization of aft compartment. Loss of fuel to downstream system. LOX-rich operation. Fuel pump overspeed/cavitation. Loss of vehicle.	1 ME-D3P,D, ME-D3S,A,M,C
Redundancy Screens: SINGLE POINT FAILURE: N/A		
M 4.1	Insulation leakage results in the generation of liquid nitrogen (LN2). LN2 impingement on the MFVA RVDT results in RVDT drift. Controller detects error and switches to channel B (servovalve No. 2) when detected by SEII, or by the RVDT comparison test when HPOTP or HPFTP turbine discharge temperatures are outside blueline limits; continuation of failure, controller initiates hydraulic lockup, all actuators. Mission abort may result when hydraulic lockup occurs during Max Q throttling.	1R ME-G4M
Redundancy Screens: DUCT SYSTEM - SENSOR SYSTEM: UNLIKE REDUNDANCY		
A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround. B: Pass - Loss of a redundant hardware items is detectable during flight. C: Pass - Loss of redundant hardware items could not result from a single credible event.		

SSME FMEA/CIL
DESIGN

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Design / Document Reference

FAILURE CAUSE: A: Insulation debonding, cracks in nickel outer covering.
B: Damaged/debonded overlay.
C: Damaged/debonded overmold.
D: Damaged insulator or cover.
E: Damaged/defective elastomer.

THE INSULATION ON THE DUCT ASSEMBLY (1) IS MANUFACTURED WITH A POLYURETHANE CLOSED-CELL, SELF-EXTINGUISHING FOAM LAYER. THE FOAM IS INSTALLED BY MOLDS TO MAINTAIN AN EVEN LAYER. INSULATION IS PROTECTED FROM DAMAGE AND MOISTURE ABSORPTION BY A NICKEL ELECTRODEPOSITED PLATING (1). NICKEL WAS SELECTED FOR ITS DUCTILITY AND TOUGHNESS. THE NICKEL PLATING ADHESION IS IMPROVED BY AN INITIAL COPPER PLATING AT THE ENDS (2). TO STRENGTHEN THE FORM, AN EPOXY CLOTH AND RESIN COATING IS APPLIED PRIOR TO PLATING. A SILVER CONDUCTIVE COATING IS APPLIED TO ENSURE AN EVEN NICKEL DEPOSIT. EXPANSION JOINTS ARE INCORPORATED IN THE INSULATION JACKET TO REDUCE STRESS IN THE DUCT FORM DISSIMILAR EXPANSION RATES (1). OVERMOLDS ARE APPLIED TO THE EXPANSION JOINTS TO MAINTAIN A SEAL FROM THE INSULATION AND ALLOW MOVEMENT WITH MINOR LOADS. INSULATING OVERMOLDS ARE USED AT VARIOUS JOINTS, SENSOR PORTS, AND INSPECTION PORTS TO MAINTAIN AN INSULATING BARRIER. THE OVERMOLDS ARE SEALED WITH A SILICON ELASTOMER OR TAPE.

(1) RS007018; (2) RS007019, RS008961, RS008981

FAILURE CAUSE: F: Damaged/defective outer bellows.

OUTER (JACKET) BELLOWS ASSEMBLY - THE TUBING (1) AND END RINGS (1) ARE MANUFACTURED UTILIZING INCONEL 718 SHEET. INCONEL 718 WAS SELECTED FOR ITS STRENGTH, RESISTANCE TO STRESS CORROSION CRACKING, CORROSION RESISTANCE, AND HIGH/LOW CYCLE FATIGUE CHARACTERISTICS. DUE TO CRYOGENIC OPERATION, HYDROGEN ENVIRONMENT EFFECTS ARE NOT A FACTOR (2). 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. BELLOWS ARE MANUFACTURED OF MULTIPLE PLIES EVENLY SPACED, AND ANNULAR TO IMPROVE FATIGUE LIFE, REDUCE STRESS/STRAIN CONCENTRATIONS, AND MAINTAIN CONSTANT SPRING RATE. BACKFILL OF THE CAVITY BETWEEN THE TWO BELLOWS DURING MANUFACTURE OF THE ASSEMBLY PROVIDES A LOW-PRESSURE AREA DURING CRYOGENIC OPERATION WHICH IMPROVES INSULATING CHARACTERISTICS. THE FLEX JOINT/BELLOWS HAS COMPLETED DVS TESTING FOR BENDING MOMENT, ENDURANCE, ULTIMATE PRESSURE, AND PROOF PRESSURE SECTIONING (3).

(1) RS008971, RS008991; (2) RSS-8582; (3) RSS-511-13

FAILURE CAUSE: ALL CAUSES

MINIMUM FACTORS OF SAFETY FOR THE DUCT MEET CEI REQUIREMENTS (1). HIGH AND LOW CYCLE FATIGUE LIFE MEET CEI REQUIREMENTS (2). THE DUCT ASSEMBLY HAS COMPLETED PRESSURE CYCLING AND ULTIMATE PRESSURE DVS TESTING (3). THE OUTER BELLOWS PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH, SINCE THEY ARE NOT FRACTURE CRITICAL PARTS (4). TABLE K101 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 (5).

(1) RSS-8546, CP320R0003B; (2) RL00532, CP320R0003B; (3) RSS-511-13; (4) NASA TASK 117; (5) RSS-8756

SSME FM CIL
INSPECTION AND TEST

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A, B, C	DUCT ASSEMBLY		RS007018
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS007018
	SURFACE FINISH	COPPER PLATING AND PLATING THICKNESS IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007019 RS008961 RS008981 RA1609-023
		NICKEL PLATING IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1609-023
	ASSEMBLY INTEGRITY	THE POLYURETHANE FOAM MATERIAL IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0130-087
		THE APPLICATION OF THE POLYURETHANE FOAM IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1106-001
		THE INSULATION IS VISUALLY INSPECTED PER SPECIFICATION REQUIREMENTS.	RL00815
		EPOXY RESIN COATING IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1106-001
		SILVER CONDUCTIVE COATING IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1609-023
		THE OVERLAY ON THE DUCT POLYURETHANE SEAL IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0120-056 RA1606-016
THE OVERMOLD SILICON RUBBER TAPES ARE VERIFIED PER SPECIFICATION REQUIREMENTS.		RA1105-002	
THE SILICON RUBBER TAPE ADHESIVES PREPARATION AND APPLICATION ARE VERIFIED PER SPECIFICATION REQUIREMENTS.		RB0120-005	
D	INSULATOR		RS007241
	INSULATOR		RS007242
	INSULATOR		RS007244
	INSULATOR		RS007248
	INSULATOR		R0010966
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0130-107
COVER	COVER		RS007243
	COVER		RS007246
	COVER		RS007252
	COVER		R0010967
MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0130-108	
	THE COVER BONDING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007018 RB0120-005 RA1606-005	
E	DUCT ASSEMBLY		RS007018
	LIQUID AIR INSTALLATION		RS007008

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E	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0120-056 RB0120-005
	ASSEMBLY INTEGRITY	THE POLYURETHANE SEALANT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1606-016
F	BELLOWS JACKET		RS008971
	BELLOWS JACKET		RS008991
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008971 RS008991
		THE BELLOWS GRAIN DIRECTION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008971 RS008991
		THE BELLOWS SEAM WELD DIRECTION AND LOCATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008971 RS008991
	CLEANLINESS OF COMPONENTS	THE BELLOWS PLIES 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 ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	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. THE BELLOWS IS ACCEPTANCE TESTED PER SPECIFICATION REQUIREMENTS.	RS008971 RS008991 RL00078 RL00215 RL00214
ALL CAUSES	DUCT		RS007018
	ASSEMBLY INTEGRITY	THE DUCT OVALITY IS INSPECTED PER SPECIFICATION REQUIREMENTS.	RL00815
	HOT-FIRE ACCEPTANCE TESTING (GREEN RUN)	THE DUCT ASSEMBLY IS VERIFIED BY ENGINE HOT-FIRE ACCEPTANCE TESTING.	RL00461 RL00050-04 RL00056-06 RL00056-07
	FLIGHT FLOW TESTING	A HELIUM BAG INSPECTION IS PERFORMED PRIOR TO EACH LAUNCH PER SPECIFICATION REQUIREMENTS. THE EXTERNAL SURFACE IS VISUALLY INSPECTED PRIOR TO EACH LAUNCH. (LAST TEST)	OMRSD V41BU0.030 OMRSD V41BU0.380 OMRSD V41BU0.070

Componer up: Ducts and Lines
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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
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:	FAILURE MODE CAN BE DETECTED IN REALTIME BY THE FLIGHT CONTROL TEAM WHO WILL EVALUATE EFFECTS UPON VEHICLE PERFORMANCE AND ABORT CAPABILITY. BASED ON THIS EVALUATION THE APPROPRIATE ABORT MODE OR SYSTEM CONFIGURATION WILL BE SELECTED. FAILURE DETECTION CUES AND ASSOCIATED SSME PERFORMANCE DATA HAVE BEEN COORDINATED BETWEEN THE ENGINEERING AND FLIGHT OPERATIONS ORGANIZATIONS WITH THE RESPONSES DOCUMENTED IN MISSION FLIGHT RULES.		

SSME FMEA/CIL
FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE

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Base Line Rationale	Variance	Change Rationale	Variant Dash Number
1. K101-02 APPLICATION OF CORROSION INHIBITOR.	ACTIVE CORROSION INHIBITOR IS NOT APPLIED.	USE AS IS RATIONALE: (1) DUCTS ARE LOW-SHELF TIME CONFIGURATION REDUCING THE POSSIBILITIES OF CORROSION. (2) DUCTS ARE LIFE LIMITED BY MAJOR WAIVER, DAR 2074.	RS007018-471

**SSME I A/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	RS007019	1	GTAW	I				
DUCT	RS007019	3	GTAW	I	X	X	X	
DUCT	RS007019	4	GTAW	I	X	X		
DUCT	RS007019	5	GTAW	I	X	X		
DUCT	RS007019	6	GTAW	I	X			
DUCT	RS007019	7	GTAW	I	X	X		
DUCT	RS007019	8	GTAW	I	X	X		
DUCT	RS007019	9	GTAW	I	X			
DUCT	RS007019	10	GTAW	I	X	X		
DUCT	RS007019	11-15	GTAW	I	X	X	X	
DUCT	RS007019	18	GTAW	I	X	X		
DUCT	RS007019	19	GTAW	I	X			
DUCT	RS007019	20	GTAW	I	X	X	X	
DUCT	RS007019	21	GTAW	I	X	X		
DUCT	RS007019	22	GTAW	I	X	X		
DUCT	RS007019	23	GTAW	I	X	X		
DUCT	RS007019	24	GTAW	I	X	X	X	
BELLOWS	RS008886	1,2	GTAW	I				
BELLOWS	RS008886	3,4	EBW	I				
BELLOWS	RS008886	5,6	GTAW	I				
BELLOWS	RS008887	1,2	GTAW	I				
BELLOWS	RS008887	3,4	EBW	I				
BELLOWS	RS008887	5,6	GTAW	I				
FLEX JOINT	RS008961	25-30	GTAW	I		X		
FLEX JOINT	RS008961	32	GTAW	I	X			
FLEX JOINT	RS008961	33	GTAW	I	X			
FLEX JOINT	RS008961	34	GTAW	I	X			
FLEX JOINT	RS008961	35	GTAW	I	X			
FLEX JOINT	RS008961	36,37	GTAW	II				
FLEX JOINT	RS008961	38	GTAW	I				
FLEX JOINT	RS008961	39	GTAW	I	X			

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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	
FLEX JOINT	RS008961	40	GTAW	I,II	X			
FLEX JOINT	RS008961	41	GTAW	I	X			
FLEX JOINT	RS008961	43	GTAW	I				
FLEX JOINT	RS008961	44	GTAW	I				
FLEX JOINT	RS008961	51-56	GTAW	I		X		
FLEX JOINT	RS008961	59	GTAW	I				
FLEX JOINT	RS008961	72	GTAW	I	X			
BELLOWS	RS008971	1,2	GTAW	I				
BELLOWS	RS008971	3,4	EBW	I				
BELLOWS	RS008971	5,6	GTAW	I				
BELLOWS	RS008971	9,10	EBW	I				
FLEX JOINT	RS008981	25-30	GTAW	I		X		
FLEX JOINT	RS008981	32,33,41	GTAW	I	X			
FLEX JOINT	RS008981	34	GTAW	I				
FLEX JOINT	RS008981	35,38	GTAW	I	X			
FLEX JOINT	RS008981	39	GTAW	I				
FLEX JOINT	RS008981	40	GTAW	I,II	X			
FLEX JOINT	RS008981	43	GTAW	I				
FLEX JOINT	RS008981	44	GTAW	I		X		
FLEX JOINT	RS008981	45,46	GTAW	II	X	X		
FLEX JOINT	RS008981	47,48	GTAW	II	X			
FLEX JOINT	RS008981	49,50	GTAW	II				
FLEX JOINT	RS008981	51-56	GTAW	I		X		
FLEX JOINT	RS008981	59	GTAW	I				
FLEX JOINT	RS008981	60	GTAW	II				
BELLOWS	RS008991	1,2	GTAW	I				
BELLOWS	RS008991	3,4	EBW	I				
BELLOWS	RS008991	5,6	GTAW	I				
BELLOWS	RS008991	9,10	GTAW	I				