

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

Component Group: Ducts and Lines  
CIL Item: K104-02  
Part Number: RS007043  
Component: Fuel Bleed Duct  
FMEA Item: K104  
Failure Mode: Fails to contain hydrogen.

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	Fuel leak into aft compartment. Overpressurization of aft compartment. Possible fire or detonation. Loss of vehicle. Redundancy Screens: SINGLE POINT FAILURE: N/A	1 ME-D3P,D, ME-D3S,A,M,C

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**SSME A/CIL  
DESIGN**

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

THE DUCT ASSEMBLY (1) IS MANUFACTURED UTILIZING INCONEL 718 MATERIAL FOR THE FLANGE AND INTERMEDIATE DUCT SUPPORT. THE REMAINDER OF THE ASSEMBLY IS ARMCO 21-6-9 TUBING, BAR, AND SHEET. ARMCO 21-6-9 WAS SELECTED FOR ITS STRENGTH AT CRYOGENIC TEMPERATURES, CORROSION RESISTANCE, AND RESISTANCE TO STRESS CORROSION CRACKING (2). HYDROGEN ENVIRONMENT DOES NOT HAVE A SIGNIFICANT EFFECT ON IT. THE FLANGE IS COPPER PLATED TO PROTECT IT FROM HYDROGEN ENVIRONMENT EFFECTS. INCONEL 718 WAS SELECTED FOR ITS STRENGTH, RESISTANCE TO STRESS CORROSION, CORROSION RESISTANCE, HIGH/LOW CYCLE FATIGUE CHARACTERISTICS, AND WELDABILITY (2). AN ACTIVE CORROSION INHIBITOR IS APPLIED TO THE EXTERNAL SURFACES OF THE UNINSULATED DUCT FOR ADDED CORROSION RESISTANCE (3). HYDROGEN ENVIRONMENT EFFECT IS NOT A PROBLEM DUE TO CRYOGENIC OPERATING TEMPERATURES AND LOW PRESSURES. FLANGES ARE HEAT TREATED TO DEVELOP FULL MATERIAL STRENGTH AND HARDNESS. FLANGE SECTIONS INCORPORATE RADIUS JOINTS TO REDUCE STRESS CONCENTRATIONS. OFFSET LIMIT REQUIREMENTS ARE ESTABLISHED TO REDUCE STRESS CONCENTRATIONS AND IMPROVE WELD GEOMETRY. TUBING STOCK IS DRAWN TO MAINTAIN SURFACE REGULARITY.

(1) RS007044; (2) RSS-8582; (3) RS007043, RA1608-008, RB0125-009

**FAILURE CAUSE: B: Flex joint assemblies structural failure of: Ball, Inlet spool, Inner cone, Sleeve, Outlet spool, Ball cone, Inner bellows.**

THE LOW OPERATING PRESSURE OF THE FUEL BLEED DUCT WAS THE PRIMARY REASON FOR USING THE BALL AND SOCKET DESIGN. THIS DESIGN INCORPORATES FEWER WELDS AND A SINGLE INTERFACING MOVING SURFACE. BALL, INLET CONE, SLEEVE, BALL CONE (1) ARE FABRICATED USING HAYNES 188. IT WAS USED WHERE ELECTRON BEAM WELDING IS A REQUIREMENT. IT EXHIBITS LOW CYCLE FATIGUE LIFE IN HIGH-PRESSURE HYDROGEN AND IS CORROSION RESISTANT (3). THE INLET AND OUTLET SPOOLS (1) ARE FABRICATED USING ARMCO 21-6-9. ARMCO 21-6-9 WAS SELECTED FOR ITS STRENGTH AT CRYOGENIC TEMPERATURES, CORROSION RESISTANCE, AND RESISTANCE TO STRESS CORROSION CRACKING (3). HYDROGEN ENVIRONMENT DOES NOT HAVE AN EFFECT ON IT (3). THE TUBING (2) IS FABRICATED USING INCONEL 718 SHEET, AND HAYNES 188 IS USED FOR THE END RINGS (2). INCONEL 718 WAS SELECTED FOR ITS STRENGTH, RESISTANCE TO STRESS CORROSION CRACKING, CORROSION RESISTANCE, WELDABILITY, AND HIGH/LOW CYCLE FATIGUE CHARACTERISTICS (3). DUE TO CRYOGENIC OPERATION AND LOW PRESSURES, HYDROGEN ENVIRONMENT DOES NOT HAVE AN EFFECT ON IT (3). HAYNES 188 WAS USED WHERE ELECTRON BEAM WELDING IS A REQUIREMENT. IT EXHIBITS LOW CYCLE FATIGUE LIFE IN HIGH-PRESSURE AND IS CORROSION RESISTANT (3). THE SLEEVE HAS INTEGRAL STOPS TO PREVENT DAMAGE TO THE BALL AND SPOOL CONTACTING SURFACES SHOULD FULL ARTICULATION OCCUR. THE SPOOL INCORPORATES A CONIC STOP TO REDUCE BACKLASH AND IMPACT LOADING. 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 BALL AND SPOOL REDUCE TURBULENCE OVER THE BELLOW ASSEMBLY AND PROVIDES LAMINAR FLOW WHICH INHIBITS FLOW INDUCED VIBRATION. VENT HOLES ARE MANUFACTURED IN THE BALL AND SPOOL 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 BELLOW 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. 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 HAS COMPLETED BENDING MOMENT, FLEXURAL ENDURANCE, ULTIMATE PRESSURE, PROOF PRESSURE, VIBRATION, AND SECTIONING DVS TESTING (4).

(1) RS008942; (2) RS008892; (3) RSS-8582; (4) RSS-511-13

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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). HIGH AND LOW CYCLE FATIGUE LIFE MEET CEI REQUIREMENTS (3). THE DUCT ASSEMBLY PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH, SINCE THEY ARE NOT FRACTURE CRITICAL PARTS (4). TABLE K104 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). THE DUCT ASSEMBLY HAS SUCCESSFULLY COMPLETED PRESSURE CYCLING AND ULTIMATE PRESSURE DVS TESTING (6). THE VISUAL BELLOWS INSPECTION, HE MASS LEAK, AND ACCESSIBLE BELLOWS WELDS DYE PENETRANT INSPECTION TESTS HAVE BEEN SUCCESSFULLY COMPLETED ON ENGINE 2010 (7) AND 2014 (8) FLEX JOINTS. NO ANOMALIES WERE FOUND. THE 2010 DUCT HAD ACCUMULATED 65 STARTS AND 19,903 SECONDS. THE 2014 DUCT HAD ACCUMULATED 55 STARTS AND 15,447 SECONDS.

(1) I.L. 0126-8066; (2) RSS-8546, CP320R0003B; (3) RL00532, CP320R0003B; (4) NASA TASK 117; (5) RSS-8756, MCR 0964; (6) RSS-511-43; (7) CD#2-0152; (8) CD#2-87-0031

**SSME FME CIL  
INSPECTION AND TEST**

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	DUCT		RS007043
	DUCT		RS007044
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS007044
	HEAT TREAT	THE FLANGE AND RING HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	THE FLANGE COPPER PLATING IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1609-023
		AN ACTIVE CORROSION INHIBITOR COATING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007043 RA1608-008
	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 ASSEMBLY IS PROOF PRESSURE TESTED PER DRAWING REQUIREMENTS.	RS007044
B	BALL		RS008942
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008942
	SURFACE FINISH	THE BALL DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008942
		INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008942
	SPOOL		RS008942
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008942
	SLEEVE		RS008942
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008942
	SURFACE FINISH	THE SLEEVE DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008942
		INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008942
	CONE		RS008942
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008942
	SURFACE FINISH	THE CONE DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008942
	ASSEMBLY INTEGRITY	INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008942
BELLOWS		RS008892	
MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008892	
	THE BELLOWS GRAIN DIRECTION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008892	

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
B	MATERIAL INTEGRITY	THE BELLOWS SEAM WELD DIRECTION AND LOCATION ARE VERIFIED PER DRAWING REQUIREMENTS.	RS008892
	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 REQUIREMENTS.	RA1611-002
	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 WELDS ARE PENETRANT INSPECTED AFTER PLANISHING PER SPECIFICATION REQUIREMENTS.	RA0115-116
	ASSEMBLY INTEGRITY	THE BELLOWS ECCENTRICITY, CONVOLUTE HEIGHTS, CROWN AND ROOT RADIUS, PLY THICKNESS, AND SURFACE IRREGULARITY ARE VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS008892 RL00078
	FLEX JOINT		RS008942
	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.	RS008942
		THE FLEX JOINT IS ACCEPTANCE TESTED PER SPECIFICATION REQUIREMENTS.	RL00220
ALL CAUSES	DUCT		RS007043
	ASSEMBLY INTEGRITY	ASSEMBLY IS PROOF PRESSURE TESTED PER DRAWING REQUIREMENTS.	RS007043
	FLIGHT FLOW TESTING	THE EXTERNAL SURFACE IS VISUALLY INSPECTED PRIOR TO EACH LAUNCH.	OMRSD V41BU.030
		A HELIUM SIGNATURE LEAK TEST IS PERFORMED PRIOR TO EACH LAUNCH. (LAST TEST)	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**

**FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE**

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Base Line Rationale	Variance	Change Rationale	Variant Dash Number
1. K104-02 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 2080.	RS007043-121

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

Component Group: Ducts and Lines  
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 FMEA Item: K104

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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	RS007044	1	GTAW	I	X			
DUCT	RS007044	3	GTAW	I	X	X		
DUCT	RS007044	4	GTAW	I	X			
DUCT	RS007044	5	GTAW	I	X	X		
DUCT	RS007044	6	GTAW	I	X			
DUCT	RS007044	7-10	GTAW	I	X			
DUCT	RS007044	11	GTAW	I	X	X		
BELLOWS	RS008892	1,2	GTAW	I		X	X	
BELLOWS	RS008892	3,4	EBW	I				
BELLOWS	RS008892	5,6	GTAW	I				
FLEX JOINT	RS008942	1	EBW	I,II	X			
FLEX JOINT	RS008942	2,3	EBW	II	X			
FLEX JOINT	RS008942	4	GTAW	I	X			
FLEX JOINT	RS008942	5	GTAW	I	X			
FLEX JOINT	RS008942	6,7	GTAW	I		X		