

SSME FMEA/CIL
REDUNDANCY SCREEN

Component Group: Ducts and Lines
CIL Item: K201-02
Part Number: RS007015
Component: LPOTP Discharge Duct
FMEA Item: K201
Failure Mode: Internal structural failure.

Prepared: D. Early
Approved: T. Nguyen
Approval Date: 7/25/00
Change #: 1
Directive #: CCBD ME3-01-5638

Page: 1 of 1

Phase	Failure / Effect Description	Criticality Hazard Reference
SMC 4.1	Fire from LOX impact or rubbing. Loss of vehicle. Redundancy Screens: SINGLE POINT FAILURE: N/A	1 ME-C3S, ME-C3M, ME-C3A,C

SSME EA/CIL
DESIGN

Component Group: Ducts and Lines
CIL Item: K201-02
Part Number: RS007015
Component: LPOTP Discharge Duct
FMEA Item: K201
Failure Mode: Internal structural failure.

Prepared: D. Early
Approved: T. Nguyen
Approval Date: 7/25/00
Change #: 1
Directive #: CCBD ME3-01-5638

Page: 1 of 1

Design / Document Reference

FAILURE CAUSE: A: Structural failure of: Liners, Hubs, Retainer assembly, Supports, Legs, Nose, Cap, Filter.

THE LINERS, HUBS, RETAINER ASSEMBLY, EXIT SUPPORT, LEGS, NOSE, AND CAP (1) 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 (3). THE INLET SUPPORT IS MANUFACTURED UTILIZING ARMCO 21-6-9. ARMCO 21-6-9 WAS SELECTED FOR ITS STRENGTH IN THE AS WELDED CONDITION. IT IS CORROSION RESISTANT AND EXHIBITS RESISTANCE TO STRESS CORROSION CRACKING (3). THE FILTER ASSEMBLY (2) IS MANUFACTURED UTILIZING 316L CRES SCREEN AND ARMCO 21-6-9. THESE MATERIALS WERE SELECTED FOR THEIR STRENGTH AND WELDABILITY (3). MATERIALS ARE HEAT TREATED TO DEVELOP FULL MATERIAL STRENGTH AND HARDNESS (1). ALL MATERIALS USED IN THE DUCT FABRICATION ARE LOX COMPATIBLE (3). FLANGE AND DUCT SECTIONS INCORPORATE RADIUS JOINTS TO REDUCE STRESS CONCENTRATIONS. OFFSET LIMIT REQUIREMENTS ARE ESTABLISHED TO REDUCE STRESS CONCENTRATIONS AND IMPROVE WELD GEOMETRY. TUBING STOCK IS PLANISHED WHEN WELDED, OR DRAWN TO MAINTAIN SURFACE REGULARITY. INSTALLATION IS CONTROLLED FOR ANGULARITY AND OFFSET (4).

LEGS AND CONES ARE SHAPED AERODYNAMICALLY TO REDUCE FLOW FRICTION, FLOW TURBULENCE, AND LOADS ON INTERNAL PARTS (1). DURING OPERATION, PRESSURE SEPARATING LOADS CAUSE THE BELLOWS TO EXPAND RELIEVING TENSION LOADS ON THE TIE AND RETAINER ASSEMBLY. CAPS ARE WELDED IN PLACE TO PREVENT INTERNAL PIECES FROM ENTERING THE FLOW, SHOULD FAILURE OF THE TIE OCCUR. DRY-FILM LUBRICANT IS USED TO REDUCE FRICTION, GALLING, AND PARTICLE GENERATION (1). 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. ASSEMBLY TOLERANCE DIMENSIONS ARE VERIFIED BY INSERTING A PIN DURING ASSEMBLY TO PROVIDE TOLERANCE AND PREVENT EXCESSIVE TORQUE, CAUSING BINDING. RETAINER IS LOCKED TO THE TIE BY A KEYED LOCK THAT IS WELDED TO MAINTAIN ASSEMBLY TOLERANCE. RETAINER TOLERANCE REDUCES IMPACT LOAD OF HUB ASSEMBLIES AND PROVIDES DRY FLEX RETENTION. VENT HOLES ARE INCORPORATED IN THE HUB ASSEMBLIES TO PREVENT LIQUID ACCUMULATION. INTERNAL LINERS REDUCE TURBULENCE OVER THE BELLOWS ASSEMBLY AND PROVIDES LAMINAR FLOW WHICH INHIBITS FLOW INDUCED VIBRATION (1). THE INNER LINER IS POSITIONED UPSTREAM OF THE FLOW TO KEEP FROM FOLDING THE LIP INWARD. VENT HOLES ARE MANUFACTURED IN THE LINERS TO EQUALIZE PRESSURE ACROSS THE SURFACE. EDGES ARE MACHINED TO A RADIUS TO REDUCE WEIGHT, GALLING, AND BINDING ON ADJACENT CONTACT SURFACES. THE FLEX JOINT HAS COMPLETED BENDING MOMENT, FLEXURAL ENDURANCE, ULTIMATE PRESSURE, PROOF PRESSURE, VIBRATION, AND SECTIONING DVS TESTING (5). THE MINIMUM FACTORS OF SAFETY FOR THE DUCT ASSEMBLY AND FLEX JOINT MEET CEI REQUIREMENTS (6). HIGH AND LOW CYCLE FATIGUE MEET CEI REQUIREMENTS WITH THE EXCEPTION OF THE FLEX JOINT WHICH IS LIFE LIMITED BY WAIVER (7). THE DUCT ASSEMBLY PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH, SINCE THEY ARE NOT FRACTURE CRITICAL PARTS (8). TABLE K201 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 (9). THE VISUAL BELLOWS INSPECTION, HE MASS LEAK, AND ACCESSIBLE BELLOWS WELDS DYE PENETRANT INSPECTION TESTS HAVE BEEN COMPLETED ON ENGINE 2010 (10) AND (11) FLEX JOINTS. NO ANOMALIES WERE FOUND. THE 2010 DUCT HAD ACCUMULATED 18,150 STARTS AND 58 SECONDS. THE 2014 DUCT HAD ACCUMULATED 60 STARTS AND 17,099 SECONDS.

(1) RS008601; (2) RS008751; (3) RSS-8582, RSS-8575; (4) I.L. 0126-8066; (5) RSS-511-13; (6) RSS-8546, CP320R0003B; (7) RL00532, CP320R0003B, DAR 1436; (8) NASA TASK 117; (9) RSS-8756; (10) CD#2-0152; (11) CD#2-87-0031

SSME FMEA/CIL
INSPECTION AND TEST

Component Group: Ducts and Lines
 CIL Item: K201-02
 Part Number: RS007015
 Component: LPOTP Discharge Duct
 FMEA Item: K201
 Failure Mode: internal structural failure.

Prepared: D. Early
 Approved: T. Nguyen
 Approval Date: 7/25/00
 Change #: 1
 Directive #: CCBP ME3-01-5638

Page: 1 of 2

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	LINERS		RS008601
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008601
	HEAT TREAT	LINERS HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	THE LINER DRY FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008601
	ASSEMBLY INTEGRITY	INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008601
	HUBS		RS008601
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008601
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	THE HUB DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008601
	ASSEMBLY INTEGRITY	INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008601
		THE BALL AND SOCKET JOINT LAPPING, ALIGNMENT, AND SURROUNDING RADII ARE VERIFIED PER DRAWING REQUIREMENTS.	RS008601
	RETAINER ASSEMBLY		RS008601
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008601
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	THE TIE AND RETAINER DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008601
	ASSEMBLY INTEGRITY	INNER RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008601
		THE RETAINER LOAD TEST PRIOR TO CAP AND NOSE CLOSEOUT WELD IS VERIFIED PER DRAWING REQUIREMENTS.	RS008601
	SUPPORT		RS008601
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008601
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	LEGS		RS008601
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008601
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	NOSE		RS008601
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008601
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	CAP		RS008601

Component p: Ducts and Lines
 CIL Item: K201-02
 Part Number: RS007015
 Component: LPOTP Discharge Duct
 FMEA Item: K201
 Failure Mode: Internal structural failure.

Prepared: D. Early
 Approved: T. Nguyen
 Approval Date: 7/25/00
 Change #: 1
 Directive #: CCBd ME3-01-5638

Page: 2 of 2

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008601
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	FILTER		RS008751
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008757
	FLEX JOINT		RS008601
	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.	RS008601
		THE FLEX JOINT IS ACCEPTANCE TESTED PER SPECIFICATION REQUIREMENTS.	RL00208
	DUCT		RS007015
	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. (LAST TEST)	OMRSD V41BU0.030	

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

Component Group: Ducts and Lines
 CIL Item: K201
 Part Number: RS007015
 Component: LPOTP Discharge Duct
 FMEA Item: K201

Prepared: D. Early
 Approved: T. Nguyen
 Approval Date: 7/25/00
 Change #: 1
 Directive #: CCBD ME3-01-5638
 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	RS007015	1	GTAW	I				
DUCT	RS007015	2	GTAW	I	X			
DUCT	RS007015	3	GTAW	I	X			
DUCT	RS007015	4	GTAW	I	X	X		
DUCT	RS007015	5	GTAW	I	X			
DUCT	RS007015	6	GTAW	I	X			
DUCT	RS007015	7	GTAW	I	X	X		
DUCT	RS007015	8	GTAW	I	X	X	X	
DUCT	RS007015	9	GTAW	I		X		
DUCT	RS007015	10	GTAW	I				
DUCT	RS007015	11	GTAW	I	X			
DUCT	RS007015	12	GTAW	I				
DUCT	RS007015	13	GTAW	I	X			
FLEX JOINT	RS008601	1	GTAW	III	X	X		
FLEX JOINT	RS008601	2	GTAW	II	X			
FLEX JOINT	RS008601	3	GTAW	III	X			
FLEX JOINT	RS008601	4-9	GTAW	I				
FLEX JOINT	RS008601	10-15	GTAW	I				
FLEX JOINT	RS008601	16	GTAW	I				
FLEX JOINT	RS008601	17	GTAW	II	X			
FLEX JOINT	RS008601	18	GTAW	I		X		
FLEX JOINT	RS008601	25-28	GTAW	II				
FLEX JOINT	RS008601	33	GTAW	I		X		
FLEX JOINT	RS008601	34	GTAW	I				
FLEX JOINT	RS008601	35	GTAW	I				
FLEX JOINT	RS008601	36	GTAW	I				
FLEX JOINT	RS008601	52	GTAW	II		X		
FLEX JOINT	RS008601	18 PLCS	GTAW	III	X			
BELLOWS	RS008893	1-3	GTAW	I				
BELLOWS	RS008893	4,5	EBW	I				
BELLOWS	RS008893	6,7	GTAW	I				