SSME FEA/CIL
REDUNDANCY SCREEN

Component Group:	Block 1 Ducts and Lines	Prepared:	D. Early
CIL Item:	K602-01	Approved:	T. Nguyen
Part Number:	R0018041	Approval Date:	7/25/00
Component:	LPFTP Turbine Drive Duct (Phase II+)	Change #:	1
FMEA Item:	K602	Directive #:	CCBD ME3-01-5638
Failure Mode:	Fails to contain hydrogen.	Page:	1 of 1

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.	1
	Redundancy Screens: SINGLE POINT FAILURE: N/A	ME-D3S,A,M,C

SSME FMEA/CIL
DESIGN

Component Group:	**Block 1 Ducts and Lines**	**Prepared:**	**D. Early**
CIL Item:	**K602-01**	**Approved:**	**T. Nguyen**
Part Number:	**R0018041**	**Approval Date:**	**7/25/00**
Component:	**LPFTP Turbine Drive Duct (Phase II+)**	**Change #:**	**1**
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Design / Document Reference

FAILURE CAUSE: A: Parent material 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) R0018041; (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 SEGMENTED 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 AND TUBES (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 RADII 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 WHICH INCREASES 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 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 (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

FAILURE CAUSE: ALL CAUSES

MINIMUM FACTORS OF SAFETY FOR THE DUCT MEET CEI REQUIREMENTS (1). HIGH AND LOW CYCLE FATIGUE LIFE FOR THE DUCT MEETS CEI REQUIREMENTS (2). THE FLEX JOINTS ARE HIGH CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (8). THE FLEX JOINT ASSEMBLIES HAVE SUCCESSFULLY COMPLETED PRESSURE CYCLING, ULTIMATE PRESSURE DVS TESTING (3). THE DUCT ASSEMBLY HAS COMPLETED CERTIFICATION TESTING BY ANALYSIS, SIMILARITY AND HOT FIRING (9). THE DUCT ASSEMBLY PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY RISK ASSESSMENT (4). TABLE K602 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 VISUAL BELLOWS INSPECTION, HE MASS LEAK, AND ACCESSIBLE BELLOWS WELDS DYE PENETRANT INSPECTION TEST HAS BEEN COMPLETED ON ENGINES 2010 (6) AND 2014 (7) FLEX JOINTS (6). 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) RSS-8546, CP320R0003B; (2) RL00532, CP320R0003B; (3) RSS-511-43; (4) NASA TASK 117; (5) RSS-8756; (6) CD#2-0152; (7) CD#2-87-0031; (8) DAR 2122; (9) VRS-0487

SSME FI /CIL
INSPECTION AND TEST

Component Group: Block 1 Ducts and Lines
CIL Item: K602-01
Part Number: R0018041
Component: LPFTP Turbine Drive Duct (Phase II+)
FMEA Item: K602
Failure Mode: Fails to contain hydrogen.

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

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	DUCT, TURBINE DRIVE LPFTP		R0018041
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	R0018041
		THE DUCT DETAILS ARE PENETRANT INSPECTED AND ULTRASONIC INSPECTED AS REQUIRED PER SPECIFICATION REQUIREMENTS.	RA0115-012 RA0115-116 MIL-I-8950
	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.	R0018041 RA0115-116
	ASSEMBLY INTEGRITY	THE DUCT IS PROOF PRESSURE TESTED PER DRAWING REQUIREMENTS.	R0018041
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.	RA0611-020
	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.	RA0611-020
	SURFACE FINISH	CAP IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		THE CAP DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS008905 RS008925
	RING RING		RS008904 RS008924

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
B	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		
	YOKE		RS008901 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		
	STABILIZER		RS008901 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		
	BELLOWS		RS008888 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 PLIES SEAM WELD LOCATIONS ARE STAGGERED PER DRAWING REQUIREMENTS.	RS008888 RS008889
	CLEANLINESS OF COMPONENTS	THE BELLOWS PLIES ARE VERIFIED CLEAN PER SPECIFICATION REQUIREMENTS PRIOR TO ASSEMBLY AND CONVOLUTING.	RA1610-044

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
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
		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/TUBES SLEEVE/TUBES		RS008901 RS008921
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008901 RS008921
		THE SLEEVE AND END FLANGE 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	SLEEVE 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
		THE FLEX JOINT IS ACCEPTANCE TESTED PER SPECIFICATION REQUIREMENTS.	RL00376 RL00377
C	PLATE		RS009528

Component Group:	**Block 1 Ducts and Lines**	**Prepared:**	**D. Early**
CIL Item:	**K602-01**	**Approved:**	**T. Nguyen**
Part Number:	**R0018041**	**Approval Date:**	**7/25/00**
Component:	**LPFTP Turbine Drive Duct (Phase II+)**	**Change #:**	**1**
FMEA Item:	**K602**	**Directive #:**	**CCBD ME3-01-5638**
Failure Mode:	**Fails to contain hydrogen.**	**Page:**	**4 of 4**

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
C	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS009528
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
ALL CAUSES	DUCT		R0018041
	ASSEMBLY INTEGRITY	THE DUCT IS PROOF PRESSURE TESTED PER DRAWING REQUIREMENTS.	R0018041
	COMPONENT CLEANLINESS	COMPONENT CLEANLINESS IS VERIFIED PER SPECIFICATION REQUIREMENTS.	R0018041
	FLIGHT FLOW TESTING	THE EXTERNAL SURFACE IS VISUALLY INSPECTED PRIOR TO EACH LAUNCH.	OMRSD V41BU0.030
		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 FMEA/CIL
WELD JOINTS

Component Group: Block 1 Ducts and Lines
CIL Item: K602
Part Number: R0018041
Component: LPFTP Turbine Drive Duct (Phase II+)
FMEA Item: K602

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

Component	Basic Part Number	Weld Number	Weld Type	Class	Root Side Not Access	Critical Initial Flaw Size Not Detectable HCF	LCF	Comments
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			
DUCT	R0018041	1	GTAW	I	X			
DUCT	R0018041	2	GTAW	I				
DUCT	R0018041	3	GTAW	I				
DUCT	R0018041	4	GTAW	I	X	X		
DUCT	R0018041	5	GTAW	I				
DUCT	R0018041	6	GTAW	I	X	X		
DUCT	R0018041	7	GTAW	I	X	X		
DUCT	R0018041	8	GTAW	I				
DUCT	R0018041	9	GTAW	I	X			
DUCT	R0018041	10	GTAW	I	X			
DUCT	R0018041	11	GTAW	I	X	X		