

SSME FMEA/CIL
REDUNDANCY SCREEN

Component Group: Block I, II, & IIA Joints
CIL Item: L601A-01
Part Number: See Table L601A
Component: Fuel System Joints
FMEA Item: L601A
Failure Mode: Leakage.

Prepared: M. Oliver
Approved: M. LaCroix
Approval Date: 4/16/01
Change #: 2
Directive #: CCBD ME3-01-6012

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Phase	Failure / Effect Description	Criticality Hazard Reference
SM 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-FD3S,A,M,C

SSME FMEA/CIL DESIGN

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FAILURE CAUSE: A: Seal failure.

ALL THE FUEL JOINTS NOTED IN THE FMEA USE PRESSURE-ASSISTED SEALS, EXCEPT FOR A MOLD-IN-PLACE ELASTOMER PLATE SEAL USED AT THE MAIN COMBUSTION CHAMBER-TO-HOT GAS MANIFOLD. THE PRESSURE-ASSISTED SEALS ARE A VARIATION OF A "U" SHAPE CROSS-SECTION SEAL RING (1). THE SEALS ARE COMPRESSED DURING THE JOINT ASSEMBLY, WHICH PROVIDES A LOAD AT THE SEAL TIPS TO PROVIDE SEALING CAPABILITY AT LOW PRESSURES. AS THE PRESSURE INCREASES, IT ACTS ON THE "U" SHAPE AND INCREASES THE LOAD TO THE SEAL TIPS AND PROVIDES SEALING CAPABILITY AT THE HIGH SYSTEM PRESSURES. THE COMBINATION OF THE INSTALLATION DEFLECTION AND THE PRESSURE INSIDE OF THE "U" SHAPE PERMITS THE SEALING TIP TO COMPENSATE FOR THE JOINT SEPARATION UNDER SYSTEM PRESSURE. THESE INTERACTIONS PROVIDE FOR LEAK FREE JOINTS. THE SEAL MATERIAL IS INCONEL 718. THIS ALLOY IS USED FOR ITS STRENGTH, HEAT TREATABILITY, AND ABILITY TO RETAIN THEIR STRENGTH AT BOTH CRYOGENIC AND ELEVATED TEMPERATURES (2). THE SEALS ARE PLATED OR TEFLON COATED TO PROVIDE A DUCTILE LOW YIELD STRENGTH MATERIAL ON THE SEAL TIP SO THE SEAL WILL CONFORM TO THE SURFACE TOPOGRAPHY ON THE MATING FLANGES. THE MOST COMMON SEALS ARE THE RD261-3014 AND RD261-3017 (VARIOUS SIZES) SEALS. THESE SEALS ARE MADE OF INCONEL 718 AND ARE USED IN JOINTS WITH SERVICE TEMPERATURE REQUIREMENTS FROM -423 DEGREES F TO 1000 DEGREES F, AND PRESSURES UP TO 8,000 PSIG. THEY ARE SILVER PLATED WITH AN INITIAL GOLD UNDERCOAT. THE GOLD UNDERCOAT PREVENTS OXIDATION OF THE SUBSTRATE AT TEMPERATURES ABOVE 600 DEGREES F, AND THUS PREVENTS BLISTERING OF THE SILVER PLATING. SILVER IS USED DUE TO ITS LOW YIELD STRENGTH AND DUCTILITY REQUIRED FOR EFFECTING A SEAL, AND ITS CORROSION RESISTANCE (2). SEAL PART NUMBER RD261-3019 IS IDENTICAL TO THE RD261-3017 EXCEPT IT HAS RHODIUM OVERPLATE ON THE SILVER PLATING TO PREVENT THE BONDING OF THE SILVER TO THE MATING FLANGE SURFACE AT TEMPERATURES ABOVE 1000 DEGREES F (2).

THE RS008854, RS008855, AND RS008856 ARE SIMILAR TO THE RD261-3014 AND RD261-3017 SEALS EXCEPT THAT GOLD PLATING IS USED IN PLACE OF SILVER PLATING WHEN ONE OR BOTH FLANGES ARE MADE OF TITANIUM (2). GOLD PROVIDES A LOW YIELD STRENGTH DUCTILE MATERIAL FOR THE SEAL TIP COMPARABLE WITH SILVER. BOTH OF THESE PLATINGS PROVIDE PROTECTION FROM HYDROGEN ENVIRONMENT EFFECTS. WELDED TUBING MAY BE USED TO FABRICATE SEALS LARGER THAN 2.5 INCHES (3) FOR TWO SEAL DESIGNS. THE WELDS ARE REQUIRED TO MEET ALL CLASS 1 REQUIREMENTS PER RL10011 (4). TWO SPECIAL SEALS, RS008858 AND RS008862, ARE USED ON CRYOGENIC JOINTS. THESE SEALS ARE OF THE "U" SHAPE CONFIGURATION. HOWEVER, THE SEALING TIP IS WIDER THAN THE PREVIOUSLY DISCUSSED SEALS AND IS COATED WITH TEFLON. THE SEAL MATERIAL IS INCONEL 718. THE TEFLON PROVIDES THE SOFT INTERFACE AT THE SEAL-FLANGE INTERFACE. THE WIDE TIP AND TEFLON COATING PROVIDE THE ADVANTAGE OF BEING MORE FORGIVING OF SMALL SURFACE IMPERFECTIONS, SUCH AS PITS IN ALUMINUM CASTINGS, AND ALSO RESULTS IN A LOWER BEARING PRESSURE WHICH PREVENTS THE SEAL TIP FROM MARKING SOFT ALUMINUM FLANGES.

THE RD261-3014 AND RD261-3017 SEALS WERE DVS TESTED IN SIMULATED ENGINE JOINTS AT CRYOGENIC TEMPERATURES. TWO RD261-3014 SEALS WITH OUTSIDE DIAMETERS OF 1.1 AND 3.8 INCHES AND TWO RD261-3017 WITH OUTSIDE DIAMETERS OF 0.8 AND 1.1 INCHES WERE CHILLED TO MINUS 250 +/- 50F AND PRESSURE CYCLED FROM AMBIENT PRESSURE TO 8,970 PSIG FOR 240 CYCLES WHILE DEMONSTRATING THEIR ABILITY TO SEAL (5). IN ADDITION TO THE ABOVE TESTS, SEALS HAVE BEEN SUBJECTED TO STRUCTURAL VERIFICATION AT PRESSURES UP TO TWICE OPERATING PRESSURE AFTER COMPLETION OF 240 PRESSURE CYCLES WHILE STILL MEETING THE LEAKAGE REQUIREMENT (6).

THE RS008864 SEAL IS A MOLDED-IN-PLACE PLATE SEAL. IN THIS DESIGN AN ELASTOMER IS MOLDED AND BONDED INTO GROOVES ON EACH SIDE OF AN INCONEL 718 SEAL PLATE. ALL OF THE JOINT BOLT LOADING IS REACTED THROUGH THE PLATE. THIS RESULTS IN GOOD CONTACT BETWEEN THE MATING FLANGES AND THE SEAL PLATE. A PORTION OF THE ELASTOMER HEIGHT IS ABOVE THE SEAL PLATE SURFACE. THE ELASTOMER CONFIGURATION IS DESIGNED TO SUBSTANTIALLY FILL THE SEAL GROOVE, BUT LESS THAN 100% WHEN THE JOINT IS COMPRESSED BY THE BOLT LOADING DURING ASSEMBLY. THIS COMPRESSION IS SUFFICIENT FOR THE ELASTOMER TO CONFORM TO THE MATING FLANGE TOPOGRAPHY AND EFFECT A SEAL AT LOW PRESSURE. WHEN THE SYSTEM PRESSURE IS APPLIED, THE ELASTOMER IS FURTHER COMPRESSED AND INCREASES THE ELASTOMER-FLANGE CONTACT PRESSURE SO THE FLUID CANNOT ESCAPE. THIS OPERATIONAL CONCEPT IS SIMILAR TO AN O-RING. ADEQUATE BOLTLOAD IS USED TO KEEP FLANGE DEFLECTION TO A LEVEL WHERE THE ELASTOMER CANNOT BE FORCED OUT BETWEEN THE SEAL PLATE AND THE FLANGES. THIS SEAL DESIGN WAS SELECTED FOR THE JOINT BETWEEN THE MAIN COMBUSTION CHAMBER AND THE HOT-GAS MANIFOLD. THE JOINT OPERATES IN THE -40 DEGREES F TO +211 DEGREES F TEMPERATURE RANGE, WHICH IS WELL WITHIN THE TEMPERATURE LIMITS OF THE ELASTOMER (2). THIS MOLD-IN-PLACE SEAL WAS DVS TESTED IN A SIMULATED ENGINE JOINT (5). THE JOINT WAS PRESSURE CYCLED FROM ZERO TO A MAXIMUM PRESSURE OF 4,000 PSIG AT BOTH AMBIENT TEMPERATURE AND 455 DEGREES F AND DEMONSTRATED THE ABILITY TO MEET THE LEAKAGE LIMITS.

SEALS REMOVED FROM BROKEN JOINTS ARE EITHER REPLACED OR ARE REINSPECTED AND REUSED. GENERAL GUIDELINES ARE TO REPLACE SEALS AT ALL STRETCH JOINTS AND OTHER HARD-TO-GET-AT JOINT SEALS. NON-STRETCH JOINT SEALS WITH EASY ACCESS ARE REINSPECTED AND REUSED IF FOUND ACCEPTABLE. SPECIAL SEALS MAY BE RETURNED FOR OVERHAUL REFURBISHING IF DISASSEMBLY INSPECTIONS FIND SCRATCHES OR OTHER DEFECTS (7). HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE FUEL SEALS MEET CEI REQUIREMENTS (10). THE MINIMUM FACTORS OF SAFETY FOR THE FUEL SEALS MEET CEI REQUIREMENTS (11). THE SEALS PARENT MATERIALS WERE CLEARED

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FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE THEY ARE NOT FRACTURE CRITICAL PARTS (12). THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY THE WELD ASSESSMENT (13). TABLE L601A LISTS ALL FMEA/CIL WELDS AND IDENTIFIES THOSE WELDS IN WHICH CRITICAL INITIAL FLAW SIZE IS NOT DETECTABLE AND THOSE WELDS IN WHICH THE ROOT SIDE IS NOT ACCESSIBLE FOR INSPECTION. THOSE WELDS IN WHICH THE CRITICAL INITIAL FLAW SIZE IS NOT DETECTABLE ARE ACCEPTABLE FOR FLIGHT BY RISK ASSESSMENT (13). SPECIAL PACKAGING REQUIREMENTS ARE SPECIFIED TO PROTECT THE SEALS DURING SHIPMENT OR STORAGE (14).

THE JOINT FLANGES ARE DESIGNED TO INTERFACE WITH THE SEAL AND HAVE THE NECESSARY FEATURES TO PROVIDE A LEAK FREE JOINT. THE FLANGE DESIGN SPECIFIES THE REQUIREMENTS FOR SURFACE FLATNESS, SURFACE FINISH, AND THE SEALING SURFACE AREA ON THE FLANGE. THIS ENSURES THAT THE SEAL MATING AREA IS CLOSELY INSPECTED TO VERIFY IT IS FREE OF DEFECTS WHICH WOULD CAUSE LEAKAGE. TYPICALLY, ONE FLANGE HAS A SEAL GROOVE FOR POSITIONING THE SEAL WHILE THE OTHER FLANGE IS FLAT. BOLT HOLE CLEARANCES ARE CONTROLLED BY THE FLANGE DESIGN TO PREVENT EXCESSIVE LATERAL MOTION WITHIN THE JOINT. THE FLANGE DESIGN ALSO CONTROLS THE DEFLECTION IN BOTH THE RADIAL AND CIRCUMFERENTIAL DIRECTIONS. RADIAL DEFLECTIONS ARE LARGELY CONTROLLED BY THE THICKNESS OF THE FLANGE WHILE CIRCUMFERENTIAL DEFLECTIONS ARE CONTROLLED BY FLANGE THICKNESS AND BOLTING REQUIREMENTS. THE JOINT DESIGNS HAVE CLOSE BOLT SPACING TO PREVENT UNACCEPTABLE FLANGE BOWING (DEFLECTION) BETWEEN BOLTS. TYPICAL FLANGES WERE USED DURING DVS STATIC SEAL TESTING WHICH CONFIRMED DESIGN REQUIREMENTS USED ON THE ENGINE FLANGES (5) (6) (15). LEAK CHECKS DURING ENGINE BUILD AND AT INTERVALS DURING ENGINE SERVICE HAVE SHOWN THAT THE FLANGES PERFORM SATISFACTORILY AND MAINTAIN JOINT INTEGRITY. THIS HAS BEEN FURTHER DEMONSTRATED BY THE FLANGES ON TWO HIGH TIME ENGINES: ENGINE 2010 WITH 65 STARTS AND 19,903 SECONDS OF HOT FIRE TIME (9), AND ENGINE 2014 WITH 70 STARTS AND 19,102 SECONDS OF HOT FIRE TIME (8).

(1) RD261-3014, RD261-3017, RD261-3019, RS008854, RS008855, RS008856, RS008858, RS008862; (2) RSS-8582; (3) RS008854, RD261-3014; (4) RF0004-301; (5) RSS-514-16; (6) RSS-514-6; (7) RD261-3014, RS008854, RS008858, RS008864; (8) SSME-86-00096; (9) 529-143-IL-85-0126; (10) RL00532, CP320R0003B; (11) RSS-8546; (12) NASA TASK 117; (13) RSS-8756; (14) RA0116-082, ST0116GA0002; (15) RSS-514-12

FAILURE CAUSE: B: Loss of bolt preload.

JOINT BOLTING IS AN INTEGRAL PART OF STATIC SEAL JOINTS. THE BOLTING IS DESIGNED TO TAKE INTO CONSIDERATION BOTH THE PRESSURE SEPARATING LOAD AND ALL EXTERNAL LOADS THAT ACT ON THE JOINT. BOLTS ARE SPACED CLOSELY TOGETHER TO MINIMIZE FLANGE DEFLECTION. HIGH STRENGTH BOLTS ARE USED TO PROVIDE THE NECESSARY CLAMPING LOAD WHILE KEEPING THE TOTAL JOINT WEIGHT TO A MINIMUM. THE BOLT MATERIALS ON FLUID SYSTEMS ARE A-286 AND INCONEL 718, WHICH ARE USED FOR THEIR STRENGTH, ELASTIC MODULUS, AND COMPATIBILITY WITH ENGINE ENVIRONMENT (1) TEMPERATURES. THE BOLTS OR NUTS ARE NORMALLY COATED WITH DRY-FILM LUBRICANTS OR PLATED TO REDUCE THE TORQUE REQUIRED FOR TIGHTENING AND TO REDUCE THE LOAD RANGE VARIATIONS DUE TO FRICTION. THE FASTENERS (BOLTS AND STUDS) MAY BE INSTALLED INTO THREADED HOLES OR IN NUTS. THE BOLTS ARE LOCKWIRED TO PREVENT BOLT BACKOFF ON THREADED HOLE INSTALLATIONS AND THE NUTS HAVE SELF-LOCKING DEFORMED THREADS, OR PRELOAD-LOCKING THREAD FORMS TO PREVENT NUT BACKOFF ON BOLT-NUT INSTALLATIONS. FASTENER INSTALLATION IS CONTROLLED AT ENGINE ASSEMBLY TO ENSURE THAT THE INSTALLATION HAS THE PROPER BOLT LOADING AND NO DAMAGE OCCURS TO EITHER THE FASTENERS OR FLANGES. ON TORQUED INSTALLATIONS THE TORQUE IS APPLIED IN THREE EQUAL STEPS WITH TORQUE AT EACH STEP APPLIED IN A CROSS TORQUEING PROCEDURE (2). ON HIGH PRESSURE JOINT INSTALLATIONS, THE FASTENERS (BOLTS AND STUDS) ARE STRETCHED TO A DRAWING SPECIFIED ELONGATION. THIS OPERATION IS CONTROLLED BY A SPECIFICATION (3) WHICH REQUIRES AN INITIAL TORQUE TO BE APPLIED IN A CROSS TORQUEING PROCEDURE. THE FASTENERS ARE THEN STRETCHED TO A FINAL ELONGATION USING A SPECIAL MACHINE (EXTENSOMETER) AND USING A CROSS TORQUEING PROCEDURE. THE STRETCHING PROCEDURES ARE PERFORMED BY TRAINED AND CERTIFIED PERSONNEL AND WITNESSED BY A CERTIFIED INSPECTOR. BOLTS ARE REQUIRED TO BE LOCKWIRED AFTER INSTALLATION (2) (3). REUSE OF NUTS OR FASTENERS REQUIRES RELUBRICATION AND REINSPECTION FOR GALLING, THREAD DAMAGE, OR WRENCHING ELEMENT DISTORTION. ALL SELF-LOCKING NUTS REQUIRE VERIFICATION OF THE LOCKING FEATURE DURING NUT INSTALLATION (2) (3). LOCKING ABILITY OF PRELOAD LOCKING NUTS IS NOT AFFECTED BY INSTALLATION CYCLES AND DOES NOT REQUIRE VERIFICATION OF LOCKING FEATURE. THE MATERIALS USED FOR THE WASHERS IN THE JOINT BOLTING ARE SELECTED FOR THEIR COMPRESSIVE YIELD STRENGTH TO PREVENT YIELDING UNDER JOINT OPERATING PRESSURES (1). THE STRETCH FASTENERS WERE USED THROUGHOUT THE STATIC SEAL DVS TESTING ON SIMULATED JOINTS WHICH DEMONSTRATED THE BOLTING DESIGN APPROACH AND THE ABILITY OF THE JOINTS TO MEET THE LEAKAGE REQUIREMENTS (4). LEAK CHECKS DURING ENGINE BUILD AND AT INTERVALS DURING ENGINE SERVICE HAVE SHOWN THAT JOINT INTEGRITY IS SATISFACTORILY MAINTAINED BY THE BOLTING DESIGNS.

(1) RSS-8582; (2) RA0101-002; (3) RL00114; (4) RSS-514-6, RSS-514-16

SSME FMEA/CIL INSPECTION AND TEST

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference	
A	SEAL-P/A		RD261-3014	
	SEAL-P/A		RD261-3017	
	SEAL-P/A		RD261-3019	
	SEAL-P/A		RS008854	
	SEAL-P/A		RS008855	
	SEAL-P/A		RS008856	
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.		RD261-3014
				RD261-3017
				RD261-3019
				RS008854
				RS008855
				RS008856
	TUBING WELDS ON MATERIALS USED TO FABRICATE SEALS ARE INSPECTED PER SPECIFICATION REQUIREMENTS INCLUDING X-RAY AND PENETRANT INSPECTIONS.		RF0004-301	
			RL10011	
	HEAT TREAT OF SEALS IS VERIFIED PER DRAWING REQUIREMENTS.		RD261-3014	
			RD261-3017	
			RD261-3019	
			RS008854	
			RS008855	
			RS008856	
	SEALS ARE PENETRANT INSPECTED PER DRAWING REQUIREMENTS.		RD261-3014	
			RD261-3017	
			RD261-3019	
			RS008854	
			RS008855	
			RS008856	
PLATING INTEGRITY	SEAL PLATING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.		RD261-3014	
			RD261-3017	
			RD261-3019	
			RS008854	
			RS008855	
			RS008856	
			RA1609-020	
			RA1609-001	
SURFACE FINISH	SEAL SURFACE FINISHES ARE VERIFIED PER DRAWING REQUIREMENTS.		RD261-3014	
			RD261-3017	
			RD261-3019	
			RS008854	
			RS008855	
			RS008856	

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A	CLEANLINESS	SEALS ARE VERIFIED TO BE CLEAN TO PROPELLANT SERVICE LEVEL PER DRAWING REQUIREMENTS.	RD261-3014 RD261-3017 RD261-3019 RS008854 RS008855 RS008856
	SEAL, MOLDED IN PLACE-PLATE		RS008864
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008864
		MATERIAL HARDNESS INSPECTION VERIFIES PROPER HEAT TREAT.	RS008864
	ELASTOMER INTEGRITY	THE ELASTOMER SEAL IS VERIFIED TO BE FREE OF FLASH, VOIDS, NICKS, DEFECTS, OR OTHER IRREGULARITIES WHICH WOULD IMPAIR SEALING.	RS008864
	SURFACE FINISH	THE METALLIC SEALING SURFACES ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008864
	SEAL, P/A, TEFLON COATED		RS008862
	SEAL, P/A, TEFLON COATED		RS008858
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS008862
		HEAT TREAT OF SEALS IS VERIFIED PER DRAWING REQUIREMENTS.	RS008862
			RS008858
		SEALS ARE PENETRANT INSPECTED PER DRAWING REQUIREMENTS.	RS008862
			RS008858
	TEFLON COATING INTEGRITY	TEFLON COATING IS VERIFIED PER DRAWING REQUIREMENTS.	RS008862
			RS008858
	SURFACE FINISH	SEAL SURFACE FINISHES ARE VERIFIED PER DRAWING REQUIREMENTS.	RS008862
			RS008858
	CLEANLINESS	SEALS ARE VERIFIED TO BE CLEAN TO PROPELLANT SERVICE LEVEL PER DRAWING REQUIREMENTS.	RS008862
			RS008858
	FLANGE SEALING SURFACE INTEGRITY	ALL FLANGE SEALING SURFACES ARE INSPECTED FOR SURFACE FINISH, WIDTH, AND LOCATION PER DRAWING REQUIREMENTS.	SEE TABLE L601A-CIL
		SEAL GROOVE DIMENSIONS ARE VERIFIED ON APPLICABLE JOINT FLANGES PER DRAWING REQUIREMENTS.	SEE TABLE L601A-CIL

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B	BOLT		RD111-1009
	BOLT		RD111-4008
	BOLT		RD111-4022
	BOLT		RD111-4100
	BOLT		RD111-4101
	BOLT		RD111-4103
	BOLT		RD111-4105
	BOLT		RS007645
	NUT		RD114-8010
	NUT		RD114-1019
	NUT		RD114-8013
	NUT		RD114-8017
	BOLT PRELOAD	BOLT AND NUT FINAL TORQUES ARE VERIFIED PER DRAWING REQUIREMENTS.	
	STRETCH BOLT AND STUD LENGTHS ARE INSPECTED PRIOR TO INSTALLATION PER DRAWING REQUIREMENTS.		SEE TABLE L601A-CIL
	FINAL STRETCH BOLT AND STUD LENGTHS ARE VERIFIED PER DRAWING REQUIREMENTS.		SEE TABLE L601A-CIL
	PROPER LOCK WIRING OF BOLTS IS VERIFIED.		SEE TABLE L601A-CIL
	NEW SELF-LOCKING NUTS ARE LOT SAMPLE ACCEPTANCE TESTED TO ASSURE BREAK AWAY TORQUES AND LOCKING FEATURES ARE MAINTAINED AFTER MULTIPLE INSTALLATION AND REMOVAL CYCLES.		RB0170-156 RD114-8010
BOLT LUBRICATION	BOLT DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.		RD111-1009 RD111-4008 RD111-4022 RD111-4100 RD111-4101 RD111-4103 RD111-4105 RS007645
NUT LUBRICATION	NUT DRY FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.		RD114-8010 RD114-8013 RD114-8017
	SILVER PLATING ON NOTED NUT IS INSPECTED PER DRAWING REQUIREMENTS.		RD114-1019
ALL CAUSES	LEAK TESTS	THE ENGINE ASSEMBLY ABOVE THE HEAT SHIELD IS BAGGED AND HELIUM LEAK TESTED TO VERIFY ADEQUATE JOINT SEALING.	RL00712
		ALL JOINTS ARE LEAK TESTED PRIOR TO GREEN RUN.	RL00050-04
		ALL INTERCONNECT JOINTS ARE LEAK TESTED AFTER GREEN RUN.	RL00056-06 RL00056-07
		COMPONENT JOINTS ARE LEAK TESTED DURING FUNCTIONAL AND PROOF PRESSURE TESTING.	SEE TABLE L601A-CIL
		JOINTS ARE LEAK TESTED WHENEVER DISTURBED.	OMRSD V41GEN.560

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ALL CAUSES	LEAK TESTS	ALL FUEL JOINTS WITHIN THE AFT COMPARTMENT (EXCEPT INSTRUMENTATION) ARE SIGNATURE LEAK TESTED PRIOR TO EACH FLIGHT. CONTINGENCY REQUIREMENTS FOR VIOLATED PROPELLANT JOINTS, AFTER SIGNATURE LEAK TEST, WITH 4 FASTENERS OR LESS ARE BUBBLE SOAP AND MASS SPECTROMETER LEAK TESTED PRIOR TO EACH FLIGHT. (LAST TEST)	OMRSD S00000.950 OMRSD V41GEN.560 MF0001-003

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 CIL SYSTEM JOINTS

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Joint	Location	Seal Part Number	Seal Part Number Description	Torque or Stretch	Locking Feature	Assembly Drawing
D2	ATD HPOTP (4750000) TO HPOTP TURBINE SECONDARY SEAL DRAIN LINE RS007111	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007006
D26	HPOTP TURBINE SECONDARY SEAL DRAIN LINE RS007111 TO OVERBOARD LINE	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007006
F1	LPFTP RS007601 TO ORBITER INTERFACE	N/A		N/A	N/A	N/A
F1.1	LPFTP RS007601 TO LPFTP SHAFT SPEED TRANSDUCER RES7005	RD261-3019	PRESSURE ACTUATED - RHODIUM PLATE OVER SILVER OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
F2	LPFTP RS007601 TO LPFTP DISCHARGE DUCT RS007018	RS008862	PRESSURE ACTUATED - TEFLON COATED INCO 718	STRETCH	LOCKWIRE	RS007003
F2.2	LPFTP DISCHARGE PRESSURE TRANSDUCER LINE R0019554 TO LPFTP DISCHARGE DUCT RS007018	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
F2.2.1	LPFTP DISCHARGE PRESSURE TRANSDUCER LINE R0019554 TO LPFTP DISCHARGE PRESSURE TRANSDUCER RES7001	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
F2.3	LPFTP DISCHARGE DUCT RS007018 TO LPFTP DISCHARGE TEMPERATURE TRANSDUCER RES7002	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
F3	LPFTP DISCHARGE DUCT RS007018 TO HPFTP RS007501 (BLOCK I AND IIA ONLY) OR HPFTP/AT 4700000 (BLOCK II ONLY)	RS008854	PRESSURE ACTUATED - GOLD PLATE OVER INCO 718	STRETCH	LOCKWIRE	RS007003
F3.1	HPFTP RS007501 TO HPFTP SHAFT SPEED TRANSDUCER RES7005 (BLOCK I AND IIA ONLY)	RS008856	PRESSURE ACTUATED - GOLD PLATE OVER INCO 718	TORQUE	LOCKWIRE	RS007007
F3.1	HPFTP/AT 4700000 TO HPFTP/AT SHAFT SPEED TRANSDUCER 4701550 (BLOCK II ONLY)	4700956	PRESSURE ACTUATED - TEFLON COATED INCO 718	TORQUE	LOCKWIRE	4700801
F3.4	HPFTP/AT 4700000 TO COVER 4701415 (BLOCK II ONLY)	4701484	PRESSURE ACTUATED - TEFLON COATED INCO 718	TORQUE	LOCKWIRE	4700801
F3.4.1	HPFTP/AT 4700000 TO PLUG 4701133 (BLOCK II ONLY)	4700954	PRESSURE ACTUATED - TEFLON COATED INCO 718	TORQUE	LOCKWIRE	4700801
F4	HPFTP RS007501 (BLOCK I AND IIA ONLY) OR HPFTP/AT 4700000 (BLOCK II ONLY) TO HIGH PRESSURE FUEL DUCT R035533	RS008854	PRESSURE ACTUATED - GOLD PLATE OVER INCO 718	STRETCH	LOCKWIRE	RS007004
F4.1	HIGH PRESSURE FUEL DUCT R035533 TO HPFTP DISCHARGE PRESSURE TRANSDUCER LINE R0019552	RS008856	PRESSURE ACTUATED - GOLD PLATE OVER INCO 718	TORQUE	LOCKWIRE	RS007007
F4.1.1	HPFTP DISCHARGE PRESSURE TRANSDUCER LINE R0019552 TO HPFTP DISCHARGE PRESSURE TRANSDUCER RES7001	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
F4.2	HIGH PRESSURE FUEL DUCT R035533 TO FUEL BLEED VALVE RS008056	RS008854	PRESSURE ACTUATED - GOLD PLATE OVER INCO 718	STRETCH	LOCKWIRE	RS007004

* Unnumbered Component Joint

Component Group: Block I, II, & IIA Joints
Item Name: Fuel System Joints
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Approved: M. LaCroix
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Joint	Location	Seal Part Number	Seal Part Number Description	Torque or Stretch	Locking Feature	Assembly Drawing
F4.2.1	FUEL BLEED DUCT RS007043 TO FUEL BLEED DUCT (WITH FBV) R0018043	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007003
F4.3	FUEL BLEED DUCT RS007043 TO ORBITER INTERFACE	N/A		N/A	N/A	N/A
F5.1	NOZZLE DIFFUSER INLET MANIFOLD RS009156 TO ASI FUEL SUPPLY FILTER R0018225	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
F5.1.1	ASI FUEL SUPPLY FILTER R0018225 TO ASI FUEL SUPPLY LINE R0010758	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
F5.2	ASI FUEL SUPPLY LINE R0010758 TO MAIN INJECTOR RS009126	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
F6.1	NOZZLE INLET MANIFOLD RS009156 TO MCC DRYING PURGE LINE R039301	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
F6.1.1	MCC DRYING PURGE LINE R039301 TO FUEL SYSTEM PURGE LINE RS007130	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
F6.1.2	ATD MCC DRYING PURGE MANIFOLD R039301 TO PORT PLATE COVER R039322	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
F6.4	MCC INLET RS009109 TO NOZZLE FUEL DIFFUSER RS009156 (BLOCK I ONLY)	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKING NUT	RS007002
F6.4	LTMCC INLET ELBOW R046294 TO NOZZLE FUEL DIFFUSER RS009156 (BLOCK II AND IIA ONLY)	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD INCO 718	STRETCH	LOCKING NUT	RS007002
F6.6	MCC INLET MANIFOLD RS009109 TO COVER PLATE RS007167 (BLOCK I ONLY)	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007002
F6.6.1	MCC LINER CAVITY PRESSURE TAP RS009112 TO FITTING R053840	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007002
F6.14	LTMCC INLET MANIFOLD R046290 TO INLET ELBOW R046294 (BLOCK II AND IIA ONLY)	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD INCO 718	STRETCH	LOCKWIRE	RS007002
F6.15	LTMCC OUTLET MANIFOLD R046281 TO OUTLET ELBOW R046284 (BLOCK II AND IIA ONLY)	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD INCO 718	STRETCH	LOCKWIRE	RS007002
F6.17	MCC RS009110 MANIFOLD TO ORIFICE PLATE R055590 (BLOCK I ONLY)	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD INCO 718	STRETCH	LOCKWIRE	RS007002
F7	LPFTP TURBINE DRIVE DUCT R0018041 TO MCC RS009110 (BLOCK I ONLY)	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007003
F7	LPFTP TURBINE DRIVE DUCT R0018041 TO LTMCC OUTLET ELBOW R046284 (BLOCK II AND IIA ONLY)	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD INCO 718	STRETCH	LOCKWIRE	RS007003
F7.1	LPFTP TURBINE DRIVE DUCT R0018041 TO MCC COOLANT OUTLET TEMPERATURE TRANSDUCER RES7004	RD261-3019	PRESSURE ACTUATED - RHODIUM PLATE OVER SILVER OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007

* Unnumbered Component Joint

Component Group: Block I, II, & IIA Joints
Item Name: Fuel System Joints
Item Number: L601A

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Joint	Location	Seal Part Number	Seal Part Number Description	Torque or Stretch	Locking Feature	Assembly Drawing
F7.1a	LPFTP TURBINE DRIVE DUCT R0018041 TO MCC COOLANT OUTLET PRESSURE TRANSDUCER RES7001	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
F7.2	LPFTP TURBINE DRIVE DUCT R0018041 TO PLUG RS009528	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007003
F8	LPFTP RS007601 TO LPFTP TURBINE DRIVE DUCT R0018041	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007003
F9	LPFTP RS007601 TO LPFTP TURBINE DISCHARGE DUCT RS007037	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007003
F9.1	LPFTP TURBINE DISCHARGE DUCT RS007037 TO PLUG RS009528	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007003
F9.2	LPFTP TURBINE DISCHARGE DUCT RS007037 TO FUEL TANK PRESSURANT LINE RS007046	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
F9.3	FUEL TANK PRESSURANT DUCT RS007046 TO ORBITER INTERFACE	N/A		N/A	N/A	N/A
F10	LPFTP TURBINE DISCHARGE DUCT RS007037 TO POWERHEAD R0018001	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007003
F11	CCV RS008259 TO NOZZLE RS008161	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007004
F16	POWERHEAD R0018001 TO MCC RS009105 (BLOCK I ONLY)	RS008864	SEAL PLATE - SYNTHETIC ELASTOMER SEAL RINGS IN INCO 718 RING	STRETCH	LOCKWIRE	RS007002
F16	POWERHEAD R0018001 TO LTMCC R046300 (BLOCK II AND IIA ONLY)	RS008864	SEAL PLATE - SYNTHETIC ELASTOMER SEAL RINGS IN INCO 718 RING	STRETCH	LOCKWIRE	RS007002
F17	NOZZLE RS009158 MIXER TO POWERHEAD R0018001	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007002
F20	HPFTP RS007501 TO BOSS RS007167 COVER (BLOCK I AND IIA ONLY)	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007002
F20	HPFTP/AT 4700000 TO PLATE 4701083 (BLOCK II ONLY)	4700959	PRESSURE ACTUATED - GOLD PLATE OVER WASPALLOY	TORQUE	LOCKWIRE	4700801
F21	FPB RS009025 TO FPB ASI FUEL SUPPLY LINE R0018052	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
F22	FPB ASI FUEL SUPPLY LINE R0018052 TO MAIN INJECTOR ASI FUEL SUPPLY LINE R0010758	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
F23	MAIN INJECTOR ASI FUEL SUPPLY LINE R0010758 TO OPB ASI FUEL SUPPLY LINE R0010751	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
F25	OPB RS009546 TO OPB ASI FUEL SUPPLY LINE R0010751	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004

* Unnumbered Component Joint

Component Group: Block I, II, & IIA Joints
Item Name: Fuel System Joints
Item Number: L601A

Prepared: M. Oliver
Approved: M. LaCroix
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Joint	Location	Seal Part Number	Seal Part Number Description	Torque or Stretch	Locking Feature	Assembly Drawing
N11	HPFTP RS007501 TO HPFTP COOLANT LINER PRESSURE TRANSDUCER LINE R0017856 (BLOCK I AND IIA ONLY)	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
N11.1	HPFTP COOLANT LINER PRESSURE TRANSDUCER LINE R0017856 TO HPFTP BEARING PURGE LINE R0019431 (BLOCK I AND IIA ONLY)	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
N11.2	HPFTP COOLANT LINER PRESS. TRANSD. LINE R0017856 TO HPFTP COOLANT LINER PRESS. TRANSD. RES7001 (BLOCK I AND IIA ONLY)	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKING NUT	RS007007
N11.3	HPFTP/AT 4700000 TO PLUG 4701080 (BLOCK II ONLY)	4701095	GOLD PLATE OVER CRES A347	TORQUE	LOCKWIRE	4700801
N11.4	HPFTP/AT 4700000 TO PLUG 4701080 (BLOCK II ONLY)	4701095	GOLD PLATE OVER CRES A347	TORQUE	LOCKWIRE	4700801
N12	HPFTP BEARING PURGE LINE R0019431 TO HEAT SHIELD PENETRATING HPFTP PURGE LINE RS009270	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
N15	MCC DRYING PURGE LINE RS009270 TO HEAT SHIELD PENETRATING LINE RS007159	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKING NUT	RS007005
N18	ATD HPOTP (475000) TO HPOTP TURBINE BEARING PURGE LINE R039138	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
*	HPFTP COVER RS007540 TO THRUST HOUSING R0019204 (BLOCK I AND IIA ONLY)	RS008858	PRESSURE ACTUATED - TEFLON COATED INCO 718	TORQUE	LOCKWIRE	RS007501
*	HPFTP THRUST BEARING HOUSING R0019204 TO INLET RS007512 (BLOCK I AND IIA ONLY)	RS008858	PRESSURE ACTUATED - TEFLON COATED INCO 718	TORQUE	LOCKWIRE	RS007501
*	HPFTP INLET RS007512 TO HOUSING RS007568 (BLOCK I AND IIA ONLY)	RS008855	PRESSURE ACTUATED - GOLD PLATE OVER INCO 718	DEF MEAS	LOCKWIRE	RS007501
*	LPFTP VOLUTE HOUSING RS007603 TO MANIFOLD HOUSING R0019865	RS008858	PRESSURE ACTUATED - TEFLON COATED INCO 718	TORQUE	LKWASHR & PINS	RS007632

* Unnumbered Component Joint

SSME FMEA/CIL
WELD JOINTS

Component Group: Block I, II, & IIA Joints
 CIL Item: L601A
 Part Number: See Table L601A
 Component: Fuel System Joints
 FMEA Item: L601A

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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	
SEAL	RD261-3014	1	GTAW	I				
SEAL	RS008854	1 PLC	GTAW	I				