

**SSM/ ME/CIL**  
**REDUNDANCY SCREEN**

Component Group: Joints  
CIL Item: L102A-01  
Part Number: See Table L102A  
Component: Oxidizer System Joints  
FMEA Item: L102A  
Failure Mode: Leakage.

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

Page: 1 of 1

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Phase	Failure / Effect Description	Criticality Hazard Reference
SM 4.1	Oxidizer leakage into aft compartment. Overpressurization of aft compartment. Loss of vehicle.  Redundancy Screens: SINGLE POINT FAILURE: N/A	1 ME-C3S, ME-C3M, ME-C3A,C

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## SSME FMEA/CIL DESIGN

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Page: 1 of 2

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### Design / Document Reference

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**FAILURE CAUSE: A: Seal failure.**

ALL THE OXIDIZER JOINTS NOTED IN THE FMEA USE PRESSURE-ASSISTED SEALS. 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 MATERIALS ARE EITHER INCONEL 718, INCONEL X-750, OR A-286. THESE ALLOYS ARE USED FOR THEIR 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 RD261-3016 IS IDENTICAL TO THE RD261-3014 EXCEPT IT HAS A 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).

WELDED TUBING MAY BE USED TO FABRICATE SEALS LARGER THAN 2.5 INCHES (3). ON THESE TWO SEAL DESIGNS, THE WELDS ARE REQUIRED TO MEET ALL CLASS 1 REQUIREMENTS PER RL10011 (4). ONE SPECIAL SEAL, RS008862, IS USED ON CRYOGENIC JOINTS. THIS SEAL IS 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 SEALS MEET THE LOX COMPATIBILITY REQUIREMENTS (5). 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 (6).

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 (7). 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 (8).

FOUR SPECIAL SMALL CROSS SECTION MACHINED SEALS, RES1248, RES1256, RES1257, AND RES1277, ARE USED DUE TO SPACE RESTRICTIONS AT SOME JOINTS. THESE SEALS ARE ALSO PRESSURE-ASSISTED. THEY ARE OF THE "U" SHAPE CONFIGURATION AND ARE MADE OF A-286 OR INCONEL X-750. THE SOFT SEAL INTERFACES ARE EITHER GOLD, SILVER, OR TEFLON.

HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE OXIDIZER SEALS MEET CEI REQUIREMENTS (11). THE MINIMUM FACTORS OF SAFETY FOR THE OXIDIZER SEALS MEET CEI REQUIREMENTS (12). THE SEALS PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE THEY ARE NOT FRACTURE CRITICAL PARTS (13). THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY THE WELD ASSESSMENT (14). TABLE L102A 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 (14). SPECIAL PACKAGING REQUIREMENTS ARE SPECIFIED TO PROTECT THE SEALS DURING SHIPMENT OR STORAGE (15).

THE 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

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Page: 2 of 2

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Design / Document Reference

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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 (7) (8) (16). 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 (10).

(1) RD261-3014, RD261-3016, RD261-3017, RES1257, RES1277; (2) RSS-8582; (3) RD261-3014, RD261-3016; (4) RF0004-301; (5) RL10017; (6) RD261-3014, RD261-3016; (7) RSS-514-16; (8) RSS-514-6; (9) 529-143-IL-85-0126; (10) SSME-86-00096; (11) RL00532, CP320R0003B; (12) RSS-8546; (13) NASA TASK 117; (14) RSS-8756; (15) RA0116-082; (16) 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, LOCKING INSERTS, OR IN NUTS. THE BOLTS ARE LOCKWIRED TO PREVENT BOLT BACKOFF ON THREADED HOLE INSTALLATIONS AND THE SELF-LOCKING INSERTS AND NUTS HAVE DEFORMED THREADS 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 A FASTENER 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). THE MATERIALS USED FOR THE WASHERS AT 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-514-16, RSS-514-12, RSS-514-6

**SSME FMEA/CIL**  
**INSPECTION AND TEST**

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 Page: 1 of 4

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	SEAL-P/A		RD261-3014
	SEAL-P/A		RD261-3016
	SEAL-P/A		RD261-3017
	TRANSDUCER STATIC SEAL		RES1277
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RD261-3014 RD261-3016 RD261-3017 RES1277
		TUBING WELDS ON MATERIALS USE 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 RD261-3016 RD261-3017 RES1277
		SEALS ARE PENETRANT INSPECTED PER DRAWING REQUIREMENTS.	RD261-3014 RD261-3016 RD261-3017 RES1277
	PLATING INTEGRITY	SEAL PLATING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RD261-3014 RD261-3016 RD261-3017 RES1277 RA1609-020 RA1609-001
	SURFACE FINISH	SEAL SURFACE FINISHES ARE VERIFIED PER DRAWING REQUIREMENTS.	RD261-3014 RD261-3016 RD261-3017 RES1277
	CLEANLINESS	SEALS ARE VERIFIED TO BE CLEAN TO PROPELLANT SERVICE LEVEL PER DRAWING REQUIREMENTS.	RD261-3014 RD261-3016 RD261-3017 RES1277
	SEAL, P/A, TEFLON COATED		RS008862
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS. HEAT TREAT OF SEAL IS VERIFIED PER DRAWING REQUIREMENTS. SEAL IS PENETRANT INSPECTED PER DRAWING REQUIREMENTS.	RS008862 RS008862 RS008862
	TEFLON COATING INTEGRITY	TEFLON COATING IS VERIFIED PER DRAWING REQUIREMENTS.	RS008862

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Page: 2 of 4

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A	SURFACE FINISH	SEAL SURFACE FINISHES ARE VERIFIED PER DRAWING REQUIREMENTS.	RS008862
	CLEANLINESS	SEALS ARE VERIFIED TO BE CLEAN TO PROPELLANT SERVICE LEVEL PER DRAWING REQUIREMENTS.	RS008862
	SEAL, MINIATURE		RES1248
	SEAL, INTERNAL PRESS.		RES1256
	SEAL, INTERNAL PRESS.		RES1257
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RES1248 RES1256 RES1257
		SEAL IS PENETRANT INSPECTED PER DRAWING REQUIREMENTS.	RES1257
	TEFLON COATING INTEGRITY	TEFLON COATING IS VERIFIED PER DRAWING REQUIREMENTS.	RES1257
		LOX COMPATABILITY OF TEFLON COATING IS VERIFIED.	RES1257
	PLATING INTEGRITY	SEAL PLATING IS VERIFIED PER DRAWING REQUIREMENTS.	RES1248 RES1256 RES1257
	SEALING SURFACE INTEGRITY	THE SEALING SURFACE FINISH IS VERIFIED PER DRAWING REQUIREMENTS.	RES1248 RES1256 RES1257
	CLEANLINESS	SEALS ARE VERIFIED TO BE CLEAN TO PROPELLANT SERVICE LEVEL PER DRAWING REQUIREMENTS.	RS010161 RS010180 RES1257
	FLANGE SEALING SURFACE INTEGRITY	ALL FLANGE SEALING SURFACES ARE INSPECTED FOR SURFACE FINISH, WIDTH, AND LOCATION PER DRAWING REQUIREMENTS.	SEE TABLE L102A-CIL.
		SEAL GROOVE DIMENSIONS ARE VERIFIED ON APPLICABLE JOINT FLANGES PER DRAWING REQUIREMENTS.	SEE TABLE L102A-CIL.
B	BOLT		RD111-1009
	BOLT		RD111-1011
	BOLT		RD111-4008
	BOLT		RD111-4010
	BOLT		RD111-4022
	BOLT		RD111-4100
	BOLT		RD111-4101
	BOLT		RD111-4102
	BOLT		RD111-4103
	BOLT		RD111-4105
	SCREW		RD112-5007
	BOLT		RS007837
	NUT		RD114-8010
	NUT		RD114-8017
	NUT		RD114-1019

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**Page:** 3 of 4

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B	BOLT PRELOAD	BOLT AND NUT FINAL TORQUES ARE VERIFIED PER DRAWING REQUIREMENTS.	SEE TABLE L102A-CIL.	
		STRETCH BOLT AND STUD LENGTHS ARE INSPECTED PRIOR TO INSTALLATION PER DRAWING REQUIREMENTS.	SEE TABLE L102A-CIL.	
		FINAL STRETCH BOLT AND STUD LENGTHS ARE VERIFIED PER DRAWING REQUIREMENTS.	SEE TABLE L102A-CIL.	
		PROPER LOCK WIRING OF BOLTS IS VERIFIED.	SEE TABLE L102A-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 AND SCREW DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.		RD111-1009 RD111-1011 RD111-4008 RD111-4010 RD111-4022 RD111-4100 RD111-4101 RD111-4102 RD111-4103 RD111-4105 RD112-5007 RS007837
				RD114-8010 RD114-8017
				RD114-1019
NUT LUBRICATION	NUT DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.		RD114-8010 RD114-8017	
		SILVER PLATING ON NOTED NUT IS INSPECTED.	RD114-1019	
ALL CAUSES	LEAK TESTS	THE ENGINE ASSEMBLY ABOVE THE HEAT SHIELD IS BAGGED AND HELIUM LEAK TESTED WHICH VERIFIES NO EXCESSIVE JOINT LEAKAGE.	RL00712	
		ALL JOINTS ARE LEAK TESTED PRIOR TO HOT FIRE.	RL00050-04	
		ALL INTERCONNECT JOINTS ARE LEAK TESTED AFTER HOT FIRE.	RL00056-06 RL00056-07	
		COMPONENT JOINTS ARE LEAK TESTED DURING FUNCTIONAL AND PROOF PRESSURE TESTING.	SEE TABLE L102A-CIL.	
		THE GOX SYSTEM JOINTS ARE LEAK TESTED PRIOR TO EACH FLIGHT (LAST GOX SYSTEM TEST).	OMRSD V41BP0.010	
		JOINTS ARE LEAK TESTED WHENEVER DISTURBED.	OMRSD V41GEN.555 OMRSD V41BP0.010	
		ALL OXIDIZER JOINTS WITHIN THE AFT COMPARTMENT (EXCEPT INSTRUMENTATION JOINTS AND JOINTS DOWNSTREAM OF ANTI-FLOOD VALVE) 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.555 MF0001-003	

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Directive #: CCB D ME3-01-5638

Page: 4 of 4

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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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Directive #: CCBDB ME3-01-5638  
Page: 1 of 5

Joint	Location	Seal Part Number	Seal Part Number Description	Torque or Stretch	Locking Feature	Assembly Drawing
O1	LPOTP RS007801 TO ORBITER INTERFACE	N/A		N/A	N/A	N/A
O1.1	LPOTP RS007801 TO LPOTP SHAFT SPEED TRANSDUCER RS007802	RES1277	PRESSURE ACTUATED - SILVER PLATE OVER INCO X750.	TORQUE	LOCKWIRE	RS007007
O1.2	LPOTP TURBINE DRIVE MANIFOLD RS007802 TO COVER RS007836	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007002
O1.3	LPOTP TURBINE DRIVE MANIFOLD RS007802 TO COVER RS007836	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007002
O2	LPOTP RS007801 TO LPOTP DISCHARGE DUCT RS007015	RS008862	PRESSURE ACTUATED - TEFLON COATED INCO 718	STRETCH	LOCKWIRE	RS007003
O2.2	LPOTP DISCHARGE DUCT RS007015 TO LPOTP DISCHARGE PRESSURE TRANSDUCER LINE RS007365	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
O2.2.1	LPOTP DISCHARGE PRESSURE TRANSDUCER LINE RS007365 TO LPOTP DISCHG PRESS TRANSD RES7001/RE2233	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
O2.3	LPOTP DISCHARGE DUCT RS007015 TO BOSS RS007167	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
O2.4	LPOTP DISCHARGE DUCT RS007015 TO BOSS RS007167	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007003
O2.5	LPOTP DISCHARGE DUCT RS007015 TO ACCUMULATOR INLET FLOW BAFFLE R0012666	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
O2.6	ACCUMULATOR INLET FLOW BAFFLE R0012666 TO POGO ACCUMULATOR RS007280	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
O2.7	POGO ACCUMULATOR RS007280 TO BOSS RS007167 PLATE	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
O3	LPOTP DISCHARGE DUCT RS007015 TO HPOTP RS007701	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007003
O3.1	HPOTP RS007701 TO BOSS RS009528 PLUG	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007002
O3.2	HPOTP RS007701 TO BOSS RS009528 PLUG	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007002
O3.3	HPOTP RS007701 TO BOSS R0012132 PLUG	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007002
O4	HPOTP RS007701 TO LPOTP TURBINE DRIVE DUCT RS007035	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007003

\* Unnumbered Component Joint

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 Directive #: CCBD ME3-01-5638  
 Page: 2 of 5

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O5	LPOTP TURBINE DRIVE DUCT RS007035 TO LPOTP RS007801	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007003
O6	HPOTP RS007701 TO HIGH PRESSURE OXIDIZER DUCT RS007021	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007004
O6.1	HIGH PRESSURE OXIDIZER DUCT RS007021 TO HPOTP DISCHARGE PRESSURE TRANSDUCER LINE R0019550	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
O6.1.1	HPOTP DISCHARGE PRESSURE TRANSDUCER LINE R0019550 TO HPOTP DISCHG PRESS TRANSD RES7001/RE2233	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
O6.2	HIGH PRESSURE OXIDIZER DUCT RS007021 TO BOSS COVER RS007106	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
O7	HIGH PRESSURE OXIDIZER DUCT RS007021 TO MOV RS008255	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007004
O7.1	MOV RS008255 TO MAIN INJECTOR ASI LINE RS007152	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
O8	MOV RS008255 TO MAIN INJECTOR INLET RS009147	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007004
O8.1	MAIN INJECTOR INLET RS009147 TO BOSS RS007167 PLATE	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007002
O8.2	MAIN INJECTOR OXIDIZER MANIFOLD RS009124 TO BOSS RS007167 PLATE	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007002
O8.3	MAIN INJECTOR OXIDIZER MANIFOLD RS009124 TO MCC OXIDIZER INJECTOR TEMP TRANSD RES7002	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
O8.4	MAIN INJECTOR OXIDIZER INLET RS009147 TO MCC DOME PURGE LINE RS007103	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O8.5	OXIDIZER INLET ELBOW RS007010 TO BOSS COVER RS007167	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007002
O9	HIGH PRESSURE OXIDIZER DUCT RS007021 TO PREBURNER PUMP SUPPLY DUCT RS007029	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007004
O9.1	PREBURNER PUMP SUPPLY DUCT RS007029 TO PLATE RS007162	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
O10	PREBURNER PUMP SUPPLY DUCT RS007029 TO HPOTP RS007701	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007004
O11	HPOTP RS007701 TO OPB OXIDIZER SUPPLY DUCT RS007032	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007004
O11.1	OPB OXIDIZER SUPPLY DUCT RS007032 TO PBP DISCHARGE PRESSURE TRANSDUCER LINE RS007363	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007

\* Unnumbered Component Joint

Component Group: Joints  
Item Name: Oxidizer System Joints  
Item Number: L102A

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Approval Date: 7/25/00  
Change #: 1  
Directive #: CCBD ME3-01-5638  
Page: 3 of 5

Joint	Location	Seal Part Number	Seal Part Number Description	Torque or Stretch	Locking Feature	Assembly Drawing
O11.1.1	PBP DISCHARGE PRESSURE TRANSDUCER LINE RS007363 TO PBP DISCHG PRESS TRANSD RES7001/RE2233	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
O11.1.2	PBP DISCHARGE PRESSURE TRANSDUCER LINE RS007363 TO PBP DISCHG TEMP TRANSD RES7002	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007007
O12	OPB OXIDIZER SUPPLY DUCT RS007032 TO OPOV RS008258	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007004
O12.1	OPOV RS008258 TO OPB OXIDIZER PURGE ADAPTER RS007258	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
O12.1.2	OPB ASI OXIDIZER SUPPLY LINE RS007186 TO OPB ASI BYPASS LINE RS009529	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
O12.1.3	OPB ASI OXIDIZER SUPPLY LINE RS007186 TO OPB ASI INLET RS009086	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
O12.1.4	OPB ASI OXIDIZER SUPPLY LINE RS007186 TO OPB ASI PURGE LINE R0010828	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O12.2	OPB OXIDIZER PURGE ADAPTER RS007258 TO OPB ASI OXIDIZER SUPPLY LINE RS007186	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
O12.3	OPB PURGE LINE RS007134 TO OPB OXIDIZER PURGE ADAPTER RS007258	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O13	OPOV RS008258 TO OPB INLET RS009014	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007004
O14	FPB OXIDIZER SUPPLY DUCT RS007031 TO OXIDIZER BLEED LINE RS007041	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007004
O14.1	OXIDIZER RECIRCULATION BLEED LINE RS007297 TO OXIDIZER BLEED FLEX LINE RES1221	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007003
O15	OXIDIZER BLEED FLEX LINE RES1221 TO ORBITER INTERFACE	N/A		N/A	N/A	N/A
O16	FPOV RS008257 TO FPB OXIDIZER SUPPLY DUCT RS007031	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007004
O16.1	FPOV RS008257 TO FPB OXIDIZER PURGE ADAPTER RS007259	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
O16.1.2	FPB ASI OXIDIZER SUPPLY LINE RS007187 TO FPB RS009529	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
O16.1.3	FPB ASI OXIDIZER SUPPLY LINE RS007187 TO FPB ASI RS009086	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
O16.1.4	FPB ASI PURGE LINE R0010747 TO FPB ASI OXIDIZER SUPPLY LINE RS007187	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005

Component Group: Joints  
 Item Name: Oxidizer System Joints  
 Item Number: L102A

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

Page: 4 of 5

Joint	Location	Seal Part Number	Seal Part Number Description	Torque or Stretch	Locking Feature	Assembly Drawing
O16.2	FPB OXIDIZER PURGE ADAPTER RS007259 TO FPB ASI OXIDIZER SUPPLY LINE RS007187	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007004
O16.3	FPB OXIDIZER PURGE ADAPTER RS007259 TO FPB PURGE LINE RS007135	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O17	FPOV RS008257 TO FPB INLET RS009030	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007005
O18	PB PUMP INLET DUCT RS007029 TO HEAT EXCHANGER SUPPLY DUCT RS007083	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007005
O18.1	AFV RS007083 TO TEST PORT COVER R0019128	RES1257	PRESSURE ACTUATED - TEFLON COATED A286.	TORQUE	LOCKWIRE	RS007005
O19	HEAT EXCHANGER SUPPLY DUCT RS007083 TO HEAT EXCHANGER RS008801	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O19.1	HEAT EXCHANGER INLET RS008685 TO HEAT EXCHANGER BYPASS ORIFICE RS008681	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O19.2	HEAT EXCHANGER BYPASS ORIFICE RS008681 TO HEAT EXCHANGER OUTLET RS008685	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O20.1	HEAT EXCHANGER DUCT RS007049 TO HEAT EXCHANGER OUTLET PRESSURE TRANSDUCER LINE RS007367	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O20.1.1	HEAT EXCHANGER OUTLET PRESSURE TRANSDUCER LINE RS007367 TO OXID TANK PRESS TRANSD RES7001/RE2233	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O20.2	HEAT EXCHANGER DUCT RS007049 TO OXIDIZER TANK PRESSURANT DUCT RS007016	RD261-3016	PRESSURE ACTUATED - RHODIUM PLATE OVER SILVER OVER GOLD OVER INCO 718.	STRETCH	LOCKWIRE	RS007005
O21	OXIDIZER TANK PRESSURANT DUCT RS007016 TO ORBITER INTERFACE	N/A		N/A	N/A	RS007005
O23	HEAT EXCHANGER DUCT RS007049 TO POGO GOX SUPPLY LINE RS007285	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O24	GOX CONTROL VALVE RS007147 TO POGO GOX SUPPLY LINE RS007285	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O24.1	GOX CONTROL VALVE RS007147 TO RIV OVERRIDE LINE RS007369	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O24.2	RIV RS010161 TO RIV OVERRIDE LINE RS007369	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O25	GOX CONTROL VALVE RS010142 TO POGO PRECHARGE LINE RS007284	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005

\* Unnumbered Component Joint

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Item Number: L102A

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Change #: 1  
Directive #: CCBD ME3-01-5638  
Page: 5 of 5

Joint	Location	Seal Part Number	Seal Part Number Description	Torque or Stretch	Locking Feature	Assembly Drawing
O26	POGO PRECHARGE LINE RS007284 TO ACCUMULATOR SUPPLY LINE RS007352 AT GCV	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O26.1	HPV RS010182 TO POGO PRECHARGE LINE RS007284	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O26.2	HPV RS010181 TO POGO PRECHARGE PRESSURE TRANSDUCER RES7001/RE2233	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O27	ACCUMULATOR SUPPLY LINE RS007283 TO POGO ACCUMULATOR RS007280	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O28	POGO ACCUMULATOR RS007280 TO ADAPTER RS007298	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O29	RIV RS010161 TO ADAPTER RS007298	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O30	OXIDIZER BLEED LINE RS007041 TO OXIDIZER RECIRCULATION BLEED LINE RS007297	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
O31	OXIDIZER RECIRCULATION BLEED LINE RS007297 TO POGO RECIRCULATION LINE RS010439	RD261-3017	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	TORQUE	LOCKWIRE	RS007005
*	MOV HOUSING RS008255 TO BELLOWS RS008211	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS008255
*	MOV HOUSING RS008255 TO CAP RS008272	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS008255
*	FPOV HOUSING RS008236 TO BELLOWS RS008230	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS008257
*	FPOV HOUSING RS008236 TO CAP RS008266	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS008257
*	OPOV HOUSING RS008236 TO BELLOWS RS008230	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS008258
*	AFV HOUSING R0019121 TO CAP R0019122	RES1257	PRESSURE ACTUATED - TEFLON COATED A286.	TORQUE	LOCKWIRE	RS007083
*	HPOTP HOUSING RS007729 TO PBP VOLUTE RS007739	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007701
*	RIV HOUSING RS010162 TO SEAT RS010170	RES1248	PRESSURE ACTUATED - GOLD PLATE OVER A286.	TORQUE	LOCKWIRE & LKG INSERT	RS007005 RS010161
*	HPV BODY RS010182 TO SEAT RS010183	RES1256	PRESSURE ACTUATED - GOLD PLATE OVER A286.	TORQUE	LOCKWIRE	RS010180
*	HPV HOUSING RS010181 TO SEAT RS010183	RES1256	PRESSURE ACTUATED - GOLD PLATE OVER A286.	TORQUE	LOCKWIRE	RS010180

\* Unnumbered Component Joint

**SSME IEA/CIL**  
**WELD JOINTS**

Component Group: Joints  
 CIL Item: L102A  
 Part Number: See Table L102A  
 Component: Oxidizer System Joints  
 FMEA Item: L102A

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 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	
SEAL	RD261-3014	1	GTAW	I				
SEAL	RD261-3016	1	GTAW	I				