SSME FMEA/CIL
REDUNDANCY SCREEN

Component Group:	Joints	Prepared:	D. Early
CIL Item:	L102B-01	Approved:	T. Nguyen
Part Number:	See Table L102B	Approval Date:	7/25/00
Component:	Oxidizer System Joints O22 and OPOV Housing-To-Cap Joint	Change #:	1
FMEA Item:	L102B	Directive #:	CCBD ME3-01-5638
Failure Mode:	Leakage.		
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Phase	Failure / Effect Description	Criticality Hazard Reference
SM 4.1	Oxidizer leakage into aft compartment. Leakage onto controller body sufficient to cause electronics to drop below operating range results in pneumatic shutdown if both DCU's halt. Overpressurization of aft compartment. Loss of vehicle. Redundancy Screens: SINGLE POINT FAILURE: N/A	1 ME-C3S, ME-C3M, ME-C3A,C

SSME FMEA/CIL DESIGN

Component Group:	**Joints**	**Prepared:**	**D. Early**
CIL Item:	**L102B-01**	**Approved:**	**T. Nguyen**
Part Number:	**See Table L102B**	**Approval Date:**	**7/25/00**
Component:	**Oxidizer System Joints O22 and OPOV Housing-To-Cap Joint**	**Change #:**	**1**
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Failure Mode:	**Leakage.**		
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Design / Document Reference

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 MATERIAL IS INCONEL 718. THIS ALLOY IS USED FOR ITS STRENGTH, HEAT TREATABILITY, AND ABILITY TO RETAIN ITS STRENGTH AT BOTH CRYOGENIC AND ELEVATED TEMPERATURES (2). THE SEALS ARE PLATED 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. THESE SEALS 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). WELDED TUBING MAY BE USED TO FABRICATE SEALS LARGER THAN 2.5 INCHES (3). THE WELDS ARE REQUIRED TO MEET ALL CLASS 1 REQUIREMENTS PER RL10011 (4). 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 (1).

THE RD261-3014 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 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).

HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE OXIDIZER SEALS MEET CEI REQUIREMENTS (9). THE MINIMUM FACTORS OF SAFETY FOR THE OXIDIZER SEALS MEET CEI REQUIREMENTS (10). THE SEALS PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE THEY ARE NOT FRACTURE CRITICAL PARTS (11). THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY THE WELD ASSESSMENT (12). TABLE L102B 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 (12). SPECIAL PACKAGING REQUIREMENTS ARE SPECIFIED TO PROTECT THE SEALS DURING SHIPMENT OR STORAGE (13).

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 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) (14). 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 (7), AND ENGINE 2014 WITH 70 STARTS AND 19,102 SECONDS OF HOT FIRE TIME (8).

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

Component Group:	**Joints**	**Prepared:**	**D. Early**
CIL Item:	**L102B-01**	**Approved:**	**T. Nguyen**
Part Number:	**See Table L102B**	**Approval Date:**	**7/25/00**
Component:	**Oxidizer System Joints O22 and OPOV Housing-To-Cap Joint**	**Change #:**	**1**
FMEA Item:	**L102B**	**Directive #:**	**CCBD ME3-01-5638**
Failure Mode:	**Leakage.**		
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Design / Document Reference

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 COMPATABILITY 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

Component Group: Joints
CIL Item: L102B-01
Part Number: See Table L102B
Component: Oxidizer System Joints O22 and OPOV Housing-To-Cap Joint
FMEA Item: L102B
Failure Mode: Leakage.

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	SEAL-P/A		RD261-3014
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RD261-3014
		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
		SEALS ARE PENETRANT INSPECTED PER DRAWING REQUIREMENTS.	RD261-3014
	PLATING INTEGRITY	SEAL PLATING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RD261-3014 RA1609-020 RA1609-001
	SURFACE FINISH	SEAL SURFACE FINISHES ARE VERIFIED PER DRAWING REQUIREMENTS.	RD261-3014
	CLEANLINESS	SEALS ARE VERIFIED TO BE CLEAN TO PROPELLANT SERVICE LEVEL PER DRAWING REQUIREMENTS.	RD261-3014
	FLANGE SEALING SURFACE INTEGRITY	ALL FLANGE SEALING SURFACES ARE INSPECTED FOR SURFACE FINISH, WIDTH, AND LOCATION PER DRAWING REQUIREMENTS.	SEE TABLE L102B-CIL.
		SEAL GROOVE DIMENSIONS ARE VERIFIED ON APPLICABLE JOINT FLANGES PER DRAWING REQUIREMENTS.	SEE TABLE L102B-CIL.
B	BOLT BOLT NUT		RD111-4100 RD111-4101 RD114-8010
	BOLT PRELOAD	BOLT AND NUT FINAL TORQUES ARE VERIFIED PER DRAWING REQUIREMENTS.	SEE TABLE L102B-CIL.
		STRETCH BOLT AND STUD LENGTHS ARE INSPECTED PRIOR TO INSTALLATION PER DRAWING REQUIREMENTS.	SEE TABLE L102B-CIL.
		FINAL STRETCH BOLT AND STUD LENGTHS ARE VERIFIED PER DRAWING REQUIREMENTS.	SEE TABLE L102B-CIL.
		PROPER LOCK WIRING OF BOLTS IS VERIFIED.	SEE TABLE L102B-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.	RD111-4100 RD111-4101
	NUT LUBRICATION	NUT DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RD114-8010
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

Component Group:	**Joints**	**Prepared:**	**D. Early**
CIL Item:	**L102B-01**	**Approved:**	**T. Nguyen**
Part Number:	**See Table L102B**	**Approval Date:**	**7/25/00**
Component:	**Oxidizer System Joints O22 and OPOV Housing-To-Cap Joint**	**Change #:**	**1**
FMEA Item:	**L102B**	**Directive #:**	**CCBD ME3-01-5638**
Failure Mode:	**Leakage.**	**Page:**	**2 of 2**

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
ALL CAUSES	LEAK TESTS	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 L102B-CIL.
		JOINTS ARE LEAK TESTED WHENEVER DISTURBED.	OMRSD V41GEN.555
		THESE JOINTS ARE SIGNATURE LEAK TESTED PRIOR TO EACH FLIGHT. (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 IEA/CIL
CIL SYS EM JOINTS

Component Group: Joints
Item Name: Oxidizer System Joints O22 and OPOV Housing-To-Cap Joint
Item Number: L102B

Prepared: D. Early
Approved: T. Nguyen
Approval Date: 7/25/00
Change #: 1
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Joint	Location	Seal Part Number	Seal Part Number Description	Torque or Stretch	Locking Feature	Assembly Drawing
O22	OPB OXIDIZER SUPPLY DUCT RS007032 TO FPB OXIDIZER SUPPLY DUCT RS007031	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS007005
*	OPOV HOUSING RS008236 TO CAP RS008266	RD261-3014	PRESSURE ACTUATED - SILVER PLATE OVER GOLD OVER INCO 718	STRETCH	LOCKWIRE	RS008258

* Unnumbered Component Joint

SSME FMEA/CIL
WELD JOINTS

Component Group: Joints
CIL Item: L102B
Part Number: See Table L102B
Component: Oxidizer System Joints O22 and OPOV Housing-To-Cap Joint
FMEA Item: L102B

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	Critical Initial Flaw Size Not Detectable LCF	Comments
SEAL	RD261-3014	1	GTAW	I				