SSME FMEA/CIL
REDUNDANCY SCREEN

Component Group:	**Joints**	**Prepared:**	**D. Early**
CIL Item:	**L103B-01**	**Approved:**	**T. Nguyen**
Part Number:	**RS007002**	**Approval Date:**	**7/25/00**
Component:	**Hot Gas System Joint G3**	**Change #:**	**1**
FMEA Item:	**L103B**	**Directive #:**	**CCBD ME3-01-5638**
Failure Mode:	**Leakage.**	**Page:**	**1 of 1**

Phase	Failure / Effect Description	Criticality Hazard Reference
SM 4.1	Hot gas leakage into aft compartment. Leakage onto controller body sufficient to raise temperature above operating range results in pneumatic shutdown if both DCU's halt. Aft compartment overpressurization. Possible fire or detonation. Loss of vehicle.	1 ME-D3S,A,M,C
	Redundancy Screens: SINGLE POINT FAILURE: N/A	

SSME FMEA/CIL
DESIGN

Component Group:	**Joints**	**Prepared:**	**D. Early**
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Design / Document Reference

FAILURE CAUSE: A: Seal failure.

ALL THE HOT GAS JOINTS NOTED IN THE FMEA USE PRESSURE-ASSISTED SEALS. THE JOINT G3 PRESSURE-ASSISTED SEAL IS A VARIATION OF A "U" SHAPE CROSS-SECTION SEAL RING (1). THE SEAL IS 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. THE R053811 SEALS ARE MADE OF INCONEL 718 AND ARE USED IN JOINTS WITH SERVICE TEMPERATURE REQUIREMENTS FROM -423 DEGREES F TO +1200 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. THE SEALS HAVE 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). SILVER PLATING PROVIDES PROTECTION FROM HYDROGEN ENVIRONMENT EFFECTS (2). SEAM WELDED TUBING MAY BE USED TO FABRICATE SEALS LARGER THAN 2.5 INCHES (3) ON THE SEAL DESIGN. 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 R053811 SEAL WAS DVS TESTED IN A SIMULATED ENGINE JOINT AT A HIGH TEMPERATURE. THE SEALS MET LEAKAGE REQUIREMENTS WHILE THE PRESSURE WAS CYCLED FROM AMBIENT TO 5,000 PSIG FOR 240 CYCLES (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, THE SEALS STILL MET THE LEAKAGE REQUIREMENT (6). HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE HOT GAS SEALS MEET CEI REQUIREMENTS (9). THE MINIMUM FACTORS OF SAFETY FOR THE 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 L103B 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 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) R053811; (2) RSS-8582; (3) R053811; (4) RF0004-301; (5) RSS-514-12; (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-514-16

Compone· ıup:	Joints	Prepared:	D. Early
CIL Item:	L103B-01	Approved:	T. Nguy\
Part Number:	RS007002	Approval Date:	7/25/00
Component:	Hot Gas System Joint G3	Change #:	1
FMEA Item:	L103B	Directive #:	CCBD ME3-01-5638
Failure Mode:	Leakage.	Page:	2 of 2

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 CLOSE 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 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 A FASTENER REQUIRES RELUBRICATION AND INSPECTION 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 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-514-16, RSS-514-12, RSS-514-6

SSME FMEA/CIL
INSPECTION AND TEST

Component Group: Joints
CIL Item: L103B-01
Part Number: RS007002
Component: Hot Gas System Joint G3
FMEA Item: L103B
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		R053811
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	R053811
		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.	R053811
		SEALS ARE PENETRANT INSPECTED PER DRAWING REQUIREMENTS.	R053811
	PLATING INTEGRITY	SEAL PLATING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	R053811 RA1609-020 RA1609-001
	SURFACE FINISH	SEAL SURFACE FINISHES ARE VERIFIED PER DRAWING REQUIREMENTS.	R053811
	CLEANLINESS	SEALS ARE VERIFIED TO BE CLEAN TO PROPELLANT SERVICE LEVEL PER DRAWING REQUIREMENTS.	R053811
	FLANGE SEALING SURFACE INTEGRITY	FLANGE SEALING SURFACES ARE INSPECTED FOR SURFACE FINISH, WIDTH, AND LOCATION PER DRAWING REQUIREMENTS.	RS007070 RS007729
		SEAL GROOVE DIMENSIONS ARE VERIFIED ON APPLICABLE JOINT FLANGES PER DRAWING REQUIREMENTS.	RS007070 RS007729
B	NUT STUD		RD114-8010 RE113-3003
	BOLT PRELOAD	STRETCH BOLT AND STUD LENGTHS ARE INSPECTED PRIOR TO INSTALLATION PER DRAWING REQUIREMENTS.	RS007002 RL00114
		FINAL STRETCHED STUD LENGTHS ARE VERIFIED PER DRAWING REQUIREMENTS.	RS007002 RL00114
		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	STUD DRY-FILM LUBRICATION IS VERIFIED PER DRAWING REQUIREMENTS.	RE113-3003
	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 ADEQUATE JOINT SEALING.	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
		JOINTS ARE LEAK TESTED WHENEVER DISTURBED.	OMRSD V41GEN.565

Componer	**up:**	**Joints**	
CIL Item:		**L103B-01**	
Part Number:		**RS007002**	
Component:		**Hot Gas System Joint G3**	
FMEA Item:		**L103B**	
Failure Mode:		**Leakage.**	

Prepared:	**D. Early**
Approved:	**T. Nguye**
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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
ALL CAUSES	LEAK TESTS	SIGNATURE LEAK TESTING VERIFIES ADEQUATE JOINT SEALING 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.