SSME FMEA/CIL
REDUNDANCY SCREEN

Component Group: Oxidizer Turbopumps
CIL Item: B800-02
Component: Low Pressure Oxidizer Turbopump
Part Number: RS007801
Failure Mode: Loss of turbine power.

Prepared: C. Abesamis
Approved: T. Nguyen
Approval Date: 6/7/99
Change #: 2
Directive #: CCBD ME3-01-5214
Page: 1 of 1

Phase	Failure / Effect Description	Criticality Hazard Reference
S 4.1	Reduced pump output pressure. HPOTP discharge pressure is reduced due to the lower inlet pressure and head loss from cavitation of the main pump. The MCC pressure decreases and is sensed by the controller, which corrects by increasing the oxidizer system power by opening the OPOV. Correction required to maintain MCC pressure may cause a violation of the HPOTP turbine exhaust temperature redline and initiate premature engine shutdown. Mission scrub if detected by redline. Loss of vehicle due to HPOTP turbine or heat exchanger failure may result if not detected. Redundancy Screens: TURBOPUMP SYSTEM - SENSOR SYSTEM: UNLIKE REDUNDANCY A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround. B: Pass - Loss of a redundant hardware items is detectable during flight. C: Pass - Loss of redundant hardware items could not result from a single credible event.	1R ME-C1S,M
M 4.1	Reduced pump output pressure. HPOTP discharge pressure is reduced due to the lower inlet pressure and head loss from cavitation of the main pump. The MCC pressure decreases and is sensed by the controller, which corrects by increasing the oxidizer system power by opening the OPOV. Correction required to maintain MCC pressure may cause a violation of the HPOTP turbine exhaust temperature redline and initiate premature engine shutdown. Mission abort if detected by redline. Loss of vehicle due to HPOTP turbine or heat exchanger failure may result if not detected. Redundancy Screens: TURBOPUMP SYSTEM - SENSOR SYSTEM: UNLIKE REDUNDANCY A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround. B: Pass - Loss of a redundant hardware items is detectable during flight. C: Pass - Loss of redundant hardware items could not result from a single credible event	1R ME-C1S,M

SSME EA/CIL
DESIGN

Component Group:	Oxidizer Turbopumps	**Prepared:**	C. Abasamis
CIL Item:	B800-02	**Approved:**	T. Nguyen
Component:	Low Pressure Oxidizer Turbopump	**Approval Date:**	6/7/99
Part Number:	RS007801	**Change #:**	2
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Design / Document Reference

FAILURE CAUSE: **A: Rotor tip leakage.**
B: Stator tip leakage.
C: Turbine blade damage.
D: Stator vane damage.

POWER TO THE INDUCER IS SUPPLIED BY A SIX-STAGE, FULL-ADMISSION, UNSHROUDED HYDRAULIC TURBINE. THE TURBINE BLADES ARE MACHINED FROM AND INTEGRAL WITH THE ROTOR ASSEMBLY (1). THE STATOR VANES (2) ARE MADE IN THREE 120-DEGREE SEGMENTS OF A CYLINDRICAL SHELL AND ARE JOINED TO FORM A COMPLETE CYLINDER AROUND THE ROTOR PRIOR TO INSTALLATION. THE NOZZLE ASSEMBLY (3) FITS OVER THE SEGMENTS TO PREVENT LEAKAGE FROM THE HIGH PRESSURE SOURCE AND MAINTAINS CORRECT STATOR ALIGNMENT. THE ROTOR AND STATORS ARE MANUFACTURED UTILIZING K-MONEL FORGINGS, WHICH WAS SELECTED FOR ITS RESISTANCE TO CORROSION, WHILE MAINTAINING DUCTILITY AND TOUGHNESS AT CRYOGENIC TEMPERATURES (4). THE TIP LANDS FOR THE TURBINE BLADES AND STATOR VANES ARE SILVER PLATED (1) (2) TO FURTHER ENHANCE THERMAL CONDUCTIVITY AND RESISTANCE TO IGNITION. THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (1) (2). K-MONEL AND SILVER SATISFY LOX COMPATIBILITY REQUIREMENTS (4). A TIP CLEARANCE VERSUS TURBINE BLADING PERFORMANCE STUDY WAS CONDUCTED ON A FULL SCALE TWO-STAGE TESTER TO OPTIMIZE CLEARANCE WHILE MAINTAINING A MARGIN FROM RUBBING (5). THERE ARE NO IDENTIFIED TURBINE BLADE RESONANT CONDITIONS IN THE OPERATING RANGE. THE TURBOPUMP OPERATES BELOW THE FIRST ROTOR CRITICAL SPEED, IMPROVING STABILITY, WHILE REDUCING RADIAL DEFLECTIONS. DYNAMIC COMPONENT BALANCE REQUIREMENTS MINIMIZE ROTOR SYNCHRONOUS UNBALANCE POTENTIALS (1). CLEANLINESS REQUIREMENTS AT THE HANDLING, ASSEMBLY (6), AND VEHICLE OPERATIONAL LEVEL (7) MINIMIZE CONTAMINATION INDUCED RUBBING AND IMPACT DAMAGE POTENTIALS. THE STATOR VANES HAVE COMPLETED DESIGN VERIFICATION TESTING FOR VANE NATURAL FREQUENCY (8). THE HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE ROTOR MEETS CEI REQUIREMENTS (9). THE MINIMUM FACTORS OF SAFETY FOR THIS PART MEETS CEI REQUIREMENTS (10). THE STATOR VANES ARE HIGH CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (15). THE STATOR AND ROTOR ASSEMBLIES PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE THEY CONTAIN NO FRACTURE CRITICAL PARTS (11). THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY THE WELD ASSESSMENT (12). TABLE B800 LISTS ALL 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. THOSE WELDS IN WHICH THE CRITICAL INITIAL FLAW SIZE IS NOT DETECTABLE ARE ACCEPTABLE FOR FLIGHT BY RISK ASSESSMENT (12). THE CONTROLLER SOFTWARE IS CONFIGURED TO DETECT AND RESPOND TO THE FAILURES IDENTIFIED AND COMMAND A SAFE ENGINE STATE (13). REUSE OF PARTS DURING OVERHAUL ARE CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (14). LPOTP NOZZLES ARE LIFE LIMITED PER DEVIATION (16). ROTOR ASSEMBLIES MANUFACTURED BY CONTURA WHICH MAY CONTAIN WORSE CASE (ZERO RADIUS) DISCREPANCIES ARE LIFE LIMITED PER MAJOR WAIVER (17).

(1) RS007805; (2) RS007808; (3) RS007810; (4) RSS-8579-9; (5) DVS-SSME-401A; (6) RL10001; (7) ICD 13M15000; (8) RSS-401-6; (9) RL00532, CP320R0003B; (10) RSS-8546-15, CP320R0003B; (11) NASA TASK 117; (12) RSS-8756; (13) CP406R0008, 3.2.3.5.2, (14) RL01219; (15) DAR 2545; (16) DAR 2956; (17) DAR 2160

SSME FMEA/CIL
INSPECTION AND TEST

Component Group: Oxidizer Turbopumps
CIL Item: B800-02
Component: Low Pressure Oxidizer Turbopump
Part Number: RS007601
Failure Mode: Loss of turbine power.

Prepared: C. Abesamis
Approved: T. Nguyen
Approval Date: 6/7/99
Change #: 2
Directive #: CCBD ME3-01-6214

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A, B, C, D	ROTOR/TURBINE BLADE STATOR/STATOR VANE		RS007605 RS007608
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-051
		ROTOR IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		STATOR IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	
		ROTOR IS ULTRASONIC INSPECTED AFTER WELDING PER SPECIFICATION REQUIREMENTS.	RA0115-012
	HEAT TREAT	HEAT TREAT IS 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 RA1607-071 RA0115-116 RA0115-006

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A, B, C, D	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 RA1607-071 RA0115-116 RA0115-006 RA1115-001 RA0115-127
	SURFACE FINISH	SILVER PLATING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007808 RS007805 RA1609-011
	ASSEMBLY INTEGRITY	ROTOR/STATOR DIAMETRICAL CLEARANCES AND SEALING SURFACES ARE INSPECTED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007801 RS007805 RS007808 RL01323
		ROTOR TURBINE TO STATOR AXIAL GAP IS INSPECTED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007801 RL01323
		BLADE AIRFOIL CONTOUR AND RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	RS007805
	CLEANLINESS OF COMPONENTS	UPSTREAM COMPONENTS AND THE ROTOR AND STATOR ASSEMBLY ARE VERIFIED CLEANED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RL10001 RS007801

Component Group:	Oxidizer Turbopumps	**Prepared:**	C. Abesamis
CIL Item:	B600-02	**Approved:**	T. Nguyen
Component:	Low Pressure Oxidizer Turbopump	**Approval Date:**	6/7/99
Part Number:	RS007801	**Change #:**	2
Failure Mode:	Loss of turbine power.	**Directive #:**	CCBD ME3-01-5214
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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
ALL CAUSES	LPOTP		RS007801
	ASSEMBLY INTEGRITY	THE PUMP SUBASSEMBLIES ARE INSPECTED DURING OVERHAUL PER SPECIFICATION REQUIREMENTS. INSPECTIONS INCLUDE: VISUAL, DIMENSIONAL, PENETRANT, AND REPLACEMENT OF USAGE ITEMS AS APPLICABLE, PER OVERHAUL SPECIFICATION.	RL01219 RA0115-116
		OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT FIRE TESTING AND 2ND E & M TESTS ON INSPECTIONS.	RL00050-04 RL00056-06 RL00056-07 RL00461
		TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT.	OMRSD V41BS0.030
		DATA FROM THE PREVIOUS FLIGHT OR HOT FIRE IS REVIEWED FOR PROPER TURBOPUMP OPERATION/PERFORMANCE. (LAST TEST)	MSFC PLN 1228

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 FA/CIL WELD JOINTS

Component Group: Oxidizer Turbopumps
CIL Item: B8D0
Component: Low Pressure Oxidizer Turbopump
Part Number: RS007801

Prepared: C. Abesamis
Approved: T. Nguyen
Approval Date: 6/7/99
Change #: 2
Directive #: CCBD ME3-01-5214
Page: 1 of 1

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
ROTOR	RS007805	1PLC(OPT)	GTAW	I				
ROTOR	RS007805	1PLC(OPT)	EBW	I				
NOZZLE	RS007810	1PLC	EBW	I				

SSME FMEA/CIL
FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE

Component Group: Oxidizer Turbopumps
Item Name: Low Pressure Oxidizer Turbopump
Item Number: B800
Part Number: RS007801

Prepared: C. Abesamis
Approved: T. Nguyen
Approval Date: 6/7/99
Change #: 1
Directive #: CCBD ME3-01-5214

Base Line Rationale	Variance	Change Rationale	Variant Dash Number
1. B800-05, B800-08 BEARINGS ARE PROCESSED AND INSPECTED PER SPECIFICATION REQUIREMENTS (RL00918). (ECP 909)	BEARINGS ARE PROCESSED AND INSPECTED PER SPECIFICATION REQUIREMENTS (RL00558).	LONG TERM FATIGUE LIFE OF BEARINGS IS EXTENDED BY REDUCING THE ALLOWABLE SIZE AND QUANTITY OF ALLOWABLE DEFECTS. USE AS IS RATIONALE: 1. THE HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF BEARINGS PROCESSED PER RL00558 MEET CEI REQUIREMENTS. 2. THE MINIMUM FACTORS OF SAFETY FOR BEARINGS PROCESSED PER RL00558 MEET CEI REQUIREMENTS (RSS-8546-16).	-011, -121, -051, -071, -081, -091, -101, -111, -141, -151, -161, -181
2. B800-01 - CAUSE C / B800-09 CAUSE E THE SUPPORT IS PILOTED BY THE DEFLECTOR, WHICH IN TURN IS PILOTED BY THE NOZZLE.	THE SEAL IS PILOTED BY THE SUPPORT THE SUPPORT IS PILOTED BY THE NOZZLE.	THE PHASE II SILVER SEAL IS DESIGNED TO BE PILOTED BY THE ONE PIECE BEARING SUPPORT. THE PHASE II DESIGN ADEQUATELY CONTROLS THE STACK-UP OF THE STATIONARY HARDWARE TO PREVENT MOTION BETWEEN MATING PARTS.	RS007810-021 RS007801-191, -201
3. B800-04 CAUSE A THE INDUCER IS REDESIGNED FOR USE WITH THE LARGE THROAT MCC. THE NEW DESIGN DEMONSTRATED INCREASED PUMP CAPABILITIES AT HIGHER FLOW/SPEED WITH ACCEPTABLE INCREASE IN HEAD OUTPUT.	THE INDUCER IS DESIGNED FOR PHASE II/ BLOCK I OPERATING CONDITIONS	THE PHASE II INDUCER WAS DESIGNED FOR OPERATION WITH THE STANDARD THROAT ENGINE.	RS007812-005 RS007801-201 -191
4. B800-06 - CAUSE D, H THE BEARING OUTER RACE IS SECURED BY A TWO PIECE BEARING SUPPORT. THE SUPPORT FEATURES A STIFF INTEGRAL THRUST SHOULDER DESIGNED TO REACT TO BEARING THRUST LOADS.	THE OUTER RACE NUT SECURES THE PUMP END BEARING OUTER RACE TO THE SUPPORT. PRELOAD SUPPLIED BY THE OUTER RACE NUT REDUCES POTENTIAL FOR FRETTING OR GALLING	THE PHASE II DESIGN USING A NUT TO RETAIN THE OUTER RACE PROVIDES ADEQUATE CLAMPING AND ALIGNMENT	RS007814-015 RS007825-007 RS007826-003 RS007801-201 191
5. B800-05 - CAUSE B / B800-08 - CAUSE I BALLS ARE MADE FROM SILICON NITRIDE, WHICH WILL ELIMINATE WEAR.	THE BALLS AND RACES OF THE BEARINGS ARE MANUFACTURED UTILIZING 440C CRES	THE 440C BALLS IN THE PHASE II DESIGN ARE CONTROLLED FOR WEAR AND SPALLING BY OMRSD AND DAR Z880	RS007831-091, -181 RS007801-201 -191

Base Line Rationale	Variance	Change Rationale	Variant Dash Number
6. B800-01 - CAUSE A&B, B800-02, CAUSE A-D, B800-08 CAUSE D LPOTP NOZZLES ARE LIFE LIMITED PER DEVIATION DAR 2956	LPOTP NOZZLES ARE LIFE LIMITED PER DEVIATION DAR 2742	PHASE II LPOTP NOZZLES ARE LIFE LIMITED PER DEVIATION DAR 2742	RS007810-021
7. B800-08 - CAUSE M THE SHIM AND SPRING ARE MANUFACTURED UTILIZING INCOLOY 903, WHICH WAS SELECTED FOR CRYOGENIC MECHANICAL PROPERTIES.	B800-08 - CAUSE K THE SHIMS WERE MANUFACTURED UTILIZING NICKEL 200.	THE PHASE II DESIGN SHIM MATERIAL, NICKEL 200, PROVIDES ADEQUATE PROPERTIES FOR ITS FUNCTION.	RS007817 RS007801-201 -191
THE PUMP END BEARING OUTER RACE IS PILOTED BY THE SUPPORT AND IS RETAINED, TIGHT AGAINST THE SUPPORT SHOULDER ALONG WITH SHIMS AND SPRING, AND IS SECURED IN PLACE BY THE DEFLECTOR.	B800-09 - CAUSE D THE PUMP END BEARING OUTER RACE IS PILOTED BY THE SUPPORT AND IS RETAINED, ALONG WITH A SHIM, BY THE OUTER RACE NUT.	THE PHASE II DESIGN USING A NUT TO RETAIN THE OUTER RACE PROVIDES ADEQUATE CLAMPING AND ALIGNMENT.	
8. B800-01 THROUGH B800-09 THE PUMP SUBASSEMBLIES ARE INSPECTED DURING OVERHAUL PER SPECIFICATION REQUIREMENTS RL01219	THE PUMP SUBASSEMBLIES ARE INSPECTED DURING OVERHAUL PER SPECIFICATION REQUIREMENTS RL00473	THE RL00473 WAS SPECIFICALLY WRITTEN FOR THE PHASE II DESIGN	RS007801-191,-201
9. B800-02 THROUGH B800-04 AND B800-06 THROUGH B800-09 ASSEMBLY INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS RL01323	ASSEMBLY INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS RL00006.	THE RL00006 WAS SPECIFICALLY WRITTEN FOR THE PHASE II DESIGN	RS007801-191,-201
10. B800-04 FAILURE CAUSE A AND B NET POSITIVE SUCTION PRESSURE REQUIREMENTS WERE SATISFIED OVER THE ENTIRE OPERATING RANGE BY DESIGN VERIFICATION TESTING VRS 0553	NET POSITIVE SUCTION PRESSURE REQUIREMENTS WERE SATISFIED OVER THE ENTIRE OPERATING RANGE BY DESIGN VERIFICATION TESTING DVS-SSME-401B	THE DVS SSME 401B WAS SPECIFICALLY WRITTEN FOR THE PHASE II DESIGN	RS007801-191,-201

Base Line Rationale	Variance	Change Rationale	Variant Dash Number
11. B800-01 - CAUSE C VENT HOLES DESIGNED INTO THE SEAL RING STRUCTURE PREVENT PRESSURE BUILDUP AND DISTORTION OF THE SEAL RING ONTO THE LABYRINTH SEAL.	VENT HOLES DESIGNED INTO THE SUPPORT STRUCTURE PREVENT PRESSURE BUILDUP AND DISTORTION OF THE SEAL RING ONTO THE LABYRINTH SEAL.	PHASE II DESIGN ADEQUATELY PREVENTS PRESSURE BUILD UP	RS007816-009 RS007801-201 -191