SSME FA/CIL
REDUNDANCY SCREEN

Component Group:	Oxidizer Turbopumps	Prepared:	C. Abesamis
CIL Item:	B800-03	Approved:	T. Nguyen
Component:	Low Pressure Oxidizer Turbopump	Approval Date:	6/7/99
Part Number:	RS007801	Change #:	2
Failure Mode:	Failure to transmit torque.	Directive #:	CCBD ME3-01-6214
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Phase	Failure / Effect Description	Criticality Hazard Reference
SMC 4.1	Turbine unloads and overspeeds, resulting in shaft unbalance and internal component rub. Potential LPOTP fire or explosion. Loss of vehicle.	1 ME-C2S,A,M,C
	Redundancy Screens: SINGLE POINT FAILURE: N/A	

SSME FMEA/CIL
DESIGN

Component Group:	Oxidizer Turbopumps
CIL Item:	B800-03
Component:	Low Pressure Oxidizer Turbopump
Part Number:	RS007801
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Design / Document Reference

FAILURE CAUSE: A: Spline failure between inducer and rotor.
B: Rotor failure.

SHAFT TORQUE FROM THE ROTOR (1) IS TRANSMITTED TO THE INDUCER (2) BY A SET OF INVOLUTE SPLINES. AN EXTERNAL FILLET-ROOT SIDE-FIT SPLINE IS MACHINED ONTO THE ROTOR, WHICH ENGAGES WITH AN INTERNAL FILLET-ROOT SIDE-FIT SPLINE MACHINED INTO THE INDUCER. THE SIDE FIT DESIGN AFFORDS AN INCREASE IN THE SPLINE FILLET RADII FOR GREATER LOAD CAPACITY. THE ROTOR AND INDUCER ARE MANUFACTURED UTILIZING K-MONEL FORGINGS. THE ROTOR IS FABRICATED FROM TWO MACHINED FORGINGS, A ROTOR AND AN END CAP, WHICH ARE (CLASS I) WELDED TOGETHER TO FORM A RIGID STRUCTURE. THE ROTOR FORGING GRAIN FLOW IS SPECIFIED TO MAXIMIZE MATERIAL PROPERTIES (1). K-MONEL WAS SELECTED FOR ITS TENSILE STRENGTH, CORROSION RESISTANCE, TOUGHNESS, AND DUCTILITY AT CRYOGENIC TEMPERATURES (3). THE ROTOR AND INDUCER ARE SOLUTION HEAT TREATED AND AGE-HARDENED (1) (2). CHROME PLATING AND DRY-FILM LUBRICATION ARE UTILIZED AT THE INDUCER PILOT AND BEARING JOURNALS OF THE ROTOR (1) TO MINIMIZE FRICTION AND FRETTING POTENTIALS. THE STATOR VANE (4) AND ROTOR TURBINE BLADE LANDS (1) ARE SILVER PLATED FOR ENHANCED THERMAL CONDUCTIVITY AND IGNITION RESISTANCE. THE INDUCER HAS COMPLETED DESIGN VERIFICATION TESTING FOR BLADE NATURAL FREQUENCY (5).

(1) RS007805; (2) RS007812; (3) RSS-8579-9; (4) RS007808; (5) RSS-401-1

FAILURE CAUSE: C: Loss of inducer retainer nut preload due to nut failure, lock failure, or vibration.

THE INDUCER NUT (1) ENGAGES WITH THREADS ON THE ROTOR (2) TO RETAIN THE INDUCER TO THE ROTOR. THE NUT IS PRELOADED AT ASSEMBLY AND A CUPWASHER LOCK (3) IS SECURED AGAINST THE NUT AND INDUCER TO PREVENT NUT DISENGAGEMENT FROM THE ROTOR. DRY-FILM LUBRICANT IS APPLIED TO THE ROTOR AND NUT THREADS TO REDUCE FRICTION AND ALLOW EQUAL LOAD APPLICATION TO THE THREADED SURFACES DURING ASSEMBLY (1) (2). THE NUT IS MANUFACTURED UTILIZING HEAT TREATED A-286 CRES, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH, DUCTILITY, AND TOUGHNESS AT CRYOGENIC TEMPERATURES (4). THE CUPWASHER LOCK IS MANUFACTURED UTILIZING ANNEALED 302 CRES, WHICH WAS SELECTED FOR ITS STRENGTH AND DUCTILITY IN BENDING APPLICATIONS (4). THE ALLOYS ARE RESISTANT TO CORROSION AND STRESS CORROSION CRACKING (4). ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (5). COMPONENT DYNAMIC BALANCE REQUIREMENTS FOR THE ROTOR (2) AND INDUCER (6) MINIMIZES SYNCHRONOUS LOADS AT THE LOCK INTERFACES. VEHICLE CLEANLINESS REQUIREMENTS MINIMIZES DAMAGE POTENTIAL FROM CONTAMINATION IMPACT (7). THE NUT AND LOCK HAVE BEEN ASSESSED TO HAVE INFINITE LIFE (8) AND ARE NOT TRACKED BY SERIALIZATION.

(1) RS007829; (2) RS007805; (3) RS007830; (4) RSS-8579-9; (5) RL01323; (6) RS007812; (7) ICD 13M15000; (8) RL00532, CP320R0003B

FAILURE CAUSE: ALL CAUSES

K-MONEL, A-286 CRES AND 302 CRES SATISFY LOX COMPATIBILITY REQUIREMENTS (1). THE HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE ROTOR, INDUCER, NUT, AND LOCK MEET CEI REQUIREMENTS (2). THE MINIMUM FACTORS OF SAFETY FOR THESE PARTS MEET CEI REQUIREMENTS (3). THE ROTOR, INDUCER AND INDUCER NUT PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE THEY CONTAIN NO FRACTURE CRITICAL PARTS (4). THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY THE WELD ASSESSMENT (5). 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 (5). REUSE OF PARTS DURING OVERHAUL ARE CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (6).

(1) RSS-8579-9; (2) RL00532, CP320R0003B; (3) RSS-8548-16, CP320R0003B; (4) NASA TASK 117; (5) RSS-8758; (6) RL01219

SSME FM CIL
INSPECTION AND TEST

Component Group:	Oxidizer Turbopumps	Prepared:	C. Abesamis
CIL Item:	B800-03	Approved:	T. Nguyen
Component:	Low Pressure Oxidizer Turbopump	Approval Date:	6/7/99
Part Number:	RS007801	Change #:	2
Failure Mode:	Failure to transmit torque.	Directive #:	CCBD ME3-01-5214
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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A, B	ROTOR ASSEMBLY INDUCER		RS007805 RS007812
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RB0170-051 RS007805 RS007812
		ROTOR AND INDUCER ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		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 RA1115-001 RA0115-127
	SURFACE FINISH	ROTOR CHROME AND SILVER PLATING ARE VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1609-011 RA1609-002
		ROTOR DRY-FILM LUBRICATION IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007805 RA0112-003
	ASSEMBLY INTEGRITY	ROTOR/INDUCER MATING SPLINES ARE INSPECTED DURING MANUFACTURING BY GAGE AND BY MEASUREMENT PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007805 RS007812 RA0115-143
		ROTOR AND INDUCER BALANCE ARE VERIFIED PER DRAWING REQUIREMENTS.	RS007805 RS007812

Component Group: Oxidizer Turbopumps
CIL Item: B600-03
Component: Low Pressure Oxidizer Turbopump
Part Number: RS007801
Failure Mode: Failure to transmit torque.

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

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
C	NUT NUT LOCK		RS007829 RS007830
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	
	HEAT TREAT	NUT HEAT TREAT IS VERIFIED PER DRAWING REQUIREMENTS.	RS007829
		NUT LOCK ANNEALING IS VERIFIED PER DRAWING REQUIREMENTS.	RS007830
	SURFACE FINISH	NUT DRY-FILM LUBRICATION AND BURNISH ARE VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0112-003 RA0112-007
	ASSEMBLY INTEGRITY	NUT INSTALLATION AND TORQUE ARE VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007801 RL01323
		NUT LOCK DEFORMATION IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	
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
		SHAFT TRAVEL IS PERFORMED PRIOR TO EACH FLIGHT (PHASE II AND BLOCK I).	OMRSD V41BS0.032
		SHAFT TRAVEL IS PERFORMED PRIOR TO AND AFTER ACCEPTANCE TESTING AND EVERY 10 STARTS THEREAFTER (BLOCK II AND IIA).	OMRSD V41BS0.033
		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
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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