

**SSME FMEA/CIL
REDUNDANCY SCREEN**

Component Group: Fuel Turbopumps
 CIL Item: B600-01
 Part Number: RS007901
 Component: Low Pressure Fuel Turbopump
 FMEA Item: B600
 Failure Mode: Energy loss at turbine Inlet.

Prepared: F. Cromwell
 Approved: T. Nguyen
 Approval Date: 11/1/99
 Change #: 4
 Directive #: CC8D ME3-01-5248

Page: 1 of 1

Phase	Failure / Effect Description	Criticality Hazard Reference
S 4.1	<p>Loss of energy available to turbine results in decreased turbine power. Loss of turbine power causes reduced LPFTP speed and reduced output flow and pressure delivered to the HPFTP. The controller senses the increased HPFTP demand and increases the fuel preburner oxidizer flow. In the event of HPFTP cavitation, excessive turbine discharge temperatures result in a premature engine shutdown. Mission scrub if detected by redline. Loss of vehicle due to HPFTP turbine failure may result if not detected.</p> <p>Redundancy Screens: TURBOPUMP SYSTEM - SENSOR SYSTEM: UNLIKE REDUNDANCY</p> <p>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</p>	<p>1R ME-D1S,M</p>
M 4.1	<p>Loss of energy available to turbine results in decreased turbine power. Loss of turbine power causes reduced LPFTP speed and reduced output flow and pressure delivered to the HPFTP. The controller senses the increased HPFTP demand and increases the fuel preburner oxidizer flow. In the event of HPFTP cavitation, excessive turbine discharge temperatures may result in a premature engine shutdown. Mission abort if detected by redline. Loss of vehicle due to HPFTP turbine failure may result if not detected.</p> <p>Redundancy Screens: TURBOPUMP SYSTEM - SENSOR SYSTEM: UNLIKE REDUNDANCY</p> <p>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.</p>	<p>1R ME-D1S,M</p>

B - 529

SSME FACIL
DESIGN

Component Group: Fuel Turbopumps
CIL Item: B600-01
Part Number: RS007601
Component: Low Pressure Fuel Turbopump
FMEA Item: B600
Failure Mode: Energy loss at turbine inlet.

Prepared: F. Cromwell
Approved: T. Nguyen
Approval Date: 11/1/99
Change #: 4
Directive #: CCBD ME3-01-5248

Page: 1 of 1

Design / Document Reference

FAILURE CAUSE: A: Excessive loss of nozzle bolt preload.

THE TURBINE NOZZLE ASSEMBLY (1) IS BOLTED TO THE HOUSING (2) BY 18 BOLTS AND CUPWASHERS (3). THE BOLTS ALSO SECURE THE TURBINE SEAL (4) AND THE LIFT-OFF SEAL (5) TO THE HOUSING. THE NOZZLE BOLTS ARE MANUFACTURED UTILIZING FORGED A-286 CRES (6), WHICH IS RESISTANT TO HYDROGEN ENVIRONMENT EMBRITTLEMENT AND HAS THE REQUIRED MECHANICAL PROPERTIES. THE MATERIAL IS SOLUTION TREATED, COLD-WORKED, AGED AND COLD-WORKED TO IMPROVE MECHANICAL PROPERTIES. THE CUPWASHERS ARE MANUFACTURED UTILIZING 321 CRES (6), WHICH WAS SELECTED FOR ITS TENSILE STRENGTH, DUCTILITY, AND ITS INSENSITIVITY TO HYDROGEN ENVIRONMENT EMBRITTLEMENT. THE MATERIAL IS ANNEALED TO IMPROVE MECHANICAL PROPERTIES. THE BOLTS ARE DRY-FILM LUBRICATED TO REDUCE FRICTION, PROVIDING A MORE CONSISTENT CLAMPING LOAD. THE CUPWASHERS ARE STAKED AT ASSEMBLY TO PREVENT BOLT ROTATION. ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (7). THE NOZZLE BLOCKAGE AND TURBINE DRIVELINE ORIFICE (F-7) ARE SIZED TO PRECLUDE EXCESSIVE TURBINE DELTA P AND BOLT LOADING. THE GREEN RUN SPECIFICATION LIMITS THE MAXIMUM ALLOWABLE TURBINE DELTA PRESSURE (8). THE BOLTS AND CUPWASHERS ARE NOT SERIALIZED OR TIME HISTORY TRACKED BUT HAVE INFINITE ALLOWABLE LIFE (9).

(1) R0019783; (2) RS007632; (3) RS007607, RS007620; (4) R0019904; (5) R0012162; (6) RSS-8577; (7) RL00353; (8) RL00461; (9) RL00532, CP320R0003B

FAILURE CAUSE: B: Fracture, distortion of nozzle vane.

THE NOZZLE (1) HAS 43 VANES AND A MINIMUM OF 12 PASSAGES ARE BLOCKED TO INCREASE TURBINE PERFORMANCE. THE VANES GUIDE AND ACCELERATE THE HYDROGEN FLOW TOWARDS THE FIRST-STAGE ROTOR. THE NOZZLE VANE FILLETS ARE RADIUSED TO REDUCE STRESS RISERS. THE CLEARANCE BETWEEN THE NOZZLE ASSEMBLY (2) AND ROTOR IS CONTROLLED BY THE NOZZLE SHIM (3) AND DRAWING REQUIREMENTS. THE NOZZLE IS MANUFACTURED UTILIZING AN A-286 CRES FORGING. A-286 CRES WAS SELECTED FOR ITS RESISTANCE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT AND ITS MECHANICAL PROPERTIES (4). THE MATERIAL IS SOLUTION-TREATED AND AGE-HARDENED.

(1) RS007522; (2) R0016763; (3) RS007616; (4) RSS-8577

FAILURE CAUSE: C: Excessive blocking plate leakage.

THE NOZZLE ASSEMBLY (1) INCLUDES 2 SYMMETRICALLY LOCATED PLATES (2) WHICH BLOCK A MINIMUM OF 12 OF THE 43 NOZZLE (3) PASSAGES TO INCREASE TURBINE PERFORMANCE. THE BLOCKING PLATE AXIAL CLEARANCE IS CONTROLLED PER DRAWING REQUIREMENTS. THE BLOCKING PLATE LEAKAGE IS CALCULATED DURING THE WATER CALIBRATION TEST OF THE NOZZLE. SPECIFICATION REQUIREMENTS LIMIT THE AMOUNT OF ACCEPTABLE LEAKAGE (4). THE BLOCKING PLATES ARE HELD IN PLACE BY THE CAPS (5) WHICH ARE SECURED BY SCREWS (6) THAT ARE STAKED IN PLACE. ASSEMBLY PROCEDURES FOR STAKING ENSURE DEFECT-FREE INSTALLATION (7). THE NOZZLE CAPS, BLOCKING PLATES AND SCREWS ARE MANUFACTURED UTILIZING A-286 CRES (8), WHICH WAS SELECTED FOR ITS RESISTANCE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT AND ITS MECHANICAL PROPERTIES. THE MATERIAL IS SOLUTION-TREATED AND AGE-HARDENED.

(1) R0019783; (2) R0019761; (3) RS007622; (4) RL00538; (5) R0019762; (6) NAS1102E08; (7) RA1618-035; (8) RSS-8577

FAILURE CAUSE: ALL CAUSES

THE HIGH AND LOW CYCLE FATIGUE LIFE FOR THE NOZZLE ASSEMBLY, BOLTS, AND CUPWASHERS MEET CEI REQUIREMENTS (1). THE MINIMUM FACTORS OF SAFETY FOR THESE PARTS MEET CEI REQUIREMENTS (2). THE HARDWARE PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/INDE FLAW GROWTH SINCE THEY CONTAIN NO FRACTURE CRITICAL PARTS (3). THE CONTROLLER SOFTWARE IS CONFIGURED TO DETECT AND RESPOND PROPERLY TO THE FAILURES IDENTIFIED AND COMMAND A SAFE ENGINE STATE (4). REUSE OF PARTS DURING OVERHAUL IS CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (5).

(*) RL00532, CP320R0003B; (2) RSS-8546, CP320R0003B; (3) NASA TASK 117; (4) CP406R0002 PT 1.3.2.3.5.3; (5) RL00531

B - 530

SSME FMEA/CIL
INSPECTION AND TEST

Component Group: Fuel Turbopumps
 CIL Item: B600-D1
 Part Number: RS007601
 Component: Low Pressure Fuel Turbopump
 FMEA Item: B600
 Failure Mode: Energy loss at turbine inlet.

Prepared: F. Cromwell
 Approved: T. Nguyen
 Approval Date: 11/1/99
 Change #: 4
 Directive #: CCBD MEJ-01-5248

Page: 1 of 2

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference	
A	BOLT CUPWASHER MANIFOLD		RS007607 RS007629 RS007603	
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS		
		BOLT IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116	
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS	RBC160-014 RAC311-020	
	SURFACE FINISH	BOLT DRY FILM LUBRICATION IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0112-003	
	ASSEMBLY INTEGRITY	BOLT TORQUE IS VERIFIED PER DRAWING REQUIREMENTS. CUPWASHER DEFORMATION IS VERIFIED PER DRAWING REQUIREMENTS. SUBASSEMBLIES ARE VERIFIED AS BOTTOMED PER SPECIFICATION REQUIREMENTS.	RS007501 RL00353	
	LPFTP		RS007501	
	ASSEMBLY INTEGRITY	TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT FLOW TO VERIFY ASSEMBLY INTEGRITY.	OMRSD V415S0-010	
	B	NOZZLE ASSEMBLY NOZZLE		R0019783 RS007622
		MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS007622
		NOZZLE FORGING IS PENETRANT AND ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS	RA0115-116 RA0115-012	
		NOZZLE IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116	
HEAT TREAT		HEAT TREAT IS VERIFIED PER DRAWING REQUIREMENTS.	RS007622	
CLEANLINESS OF COMPONENTS		THE SSME SYSTEM CLEANLINESS IS VERIFIED THROUGHOUT ASSEMBLY PER SPECIFICATION REQUIREMENTS	RL10001	
ASSEMBLY INTEGRITY		VANE RADI AND COORDINATE MEASUREMENTS ARE VERIFIED PER DRAWING REQUIREMENTS.	RS007622	
LPFTP			RS007601	
ASSEMBLY INTEGRITY		TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT, TO VERIFY ASSEMBLY INTEGRITY	OMRSD V415S0-010	
C		NOZZLE ASSEMBLY NOZZLE CAP PLATE SCREW		R0019783 RS007622 R0019782 R0019781 NAS1102EC8

B - 531

Component Group: Fuel Turbopumps
 GIL Item: B600.01
 Part Number: RS007601
 Component: Low Pressure Fuel Turbopump
 FMEA Item: B600
 Failure Mode: Energy loss at turbine inlet.

Prepared: F. Cromwell
 Approved: T. Nguyen
 Approval Date: 11/1/99
 Change #: 4
 Directive #: CCBD ME3 01-5248

Page: 2 of 2

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
C	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RSC07622 RC019782 RC019781 NAS11C2E05
	HEAT TREAT	THE CAP AND PLATE ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	ASSEMBLY INTEGRITY	THE CAP AND PLATE HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS	RA0611-020
		THE NOZZLE ASSEMBLY IS FLOW CALIBRATED PER SPECIFICATION REQUIREMENTS.	RL00530
		THE BLOCKING PLATES SIZE AND POSITION IS VERIFIED PER DRAWING REQUIREMENTS	RC019783
		THE BLOCKING PLATES ARE VERIFIED FLUSH TO NOZZLE VANES PER DRAWING REQUIREMENTS.	
		THE SCREW STAKING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RC019783 RA1618-035
ALL CAUSES	LPFTP		RSC07601
	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 CLASSIFICATION.	RL00531 RA0115-115
		OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT-FIRE TESTING AND 2ND E & M TESTS ON INSPECTIONS.	RL00050-04 RL00056-09 RL00058-07 RL00461
		DATA FROM PREVIOUS FLIGHT OR HOT-FIRE IS REVIEWED FOR PROPER TURBOPUMP OPERATION/PERFORMANCE (LAST TEST)	MSFC PLN 122B

B - 532

Failure History: Comprehensive failure history data is maintained in the Problem Reporting database (PRAMS/PRACA)
 Reference: NASA letter SA21/88/308 and Rockwell letter 88RC09761.
 Operational Use: Not Applicable

**SOME F A/CIL
D JOINTS**

Component Group: Fuel Turbopumps
 CIL Item: B600
 Part Number: RS007601
 Component: Low Pressure Fuel Turbopump
 FMEA Item: B600

Prepared: F. Cromwell
 Approved: T. Nguyen
 Approval Date: 11/1/99
 Change #: 2
 Directive #: CCBD ME3-01-5248
 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	
MANIFOLD	RS007603	1	EBW	Ia	X			
MANIFOLD	RS007603	2	GTAW	I				
MANIFOLD	RS007603	5,8,10	GTAW	II	X	X		
MANIFOLD	RS007603	9,10	GTAW	II	X			
MANIFOLD	RS007603	13	GTAW	I				
MANIFOLD	RS007603	17	EBW	II	X	X	X	
MANIFOLD	RS007603	18	GTAW	I	X	X	X	

B - 580

SSME FMEA/CIL
FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE

Component Group: Fuel Turbopumps
 Item Name: Low Pressure Fuel Turbopump
 Item Number: B600
 Part Number: RS007601

Prepared: F. Cromwell
 Approved: T. Nguyen
 Approval Date: 11/1/99
 Change #: 3
 Directive #: CCBD ME3-01-5248

Page: 1 of 1

Base Line Rationale	Variance	Change Rationale	Variant Dash Number
1. B600-06. RS007606, RS007605; CAUSE A. THE INNER AND OUTER BEARING RINGS ARE EDDY CURRENT INSPECTED PER RA1615-034.	BEARING RINGS RECEIVED FROM SUPPLIER SPLIT BALL BEARING INCORPORATED RECEIVED NO GENERAL EDDY CURRENT INSPECTION.	GENERAL EDDY CURRENT INSPECTION OF RINGS REPLACES TYPE IVC IN PENETRANT INSPECTION IN DETECTING SURFACE FLAWS. USE AS IS RATIONALE: 1 RINGS ARE SUPPLIED BY SPLIT BALL BEARING INCORPORATED RECEIVED 10X VISUAL AND TYPE IVC PENETRANT INSPECTION INSTEAD OF GENERAL EDDY CURRENT INSPECTION. FLAW DETECTABILITY RELIABILITY LEVELS BETWEEN PENETRANT AND GENERAL EDDY CURRENT INSPECTIONS ARE 0.060 AND 0.057 RESPECTIVELY	SEE DAR 2745 FOR VARIANT PART SERIAL NUMBERS
2. B600-10. THE HOUSING INSULATION IS PROTECTED BY A KEVLAR COMPOSITE SURFACE WITH L-T-80 FIRE RETARDANT ALUMINUM TAPE APPLIED TO THE KEVLAR SURFACE	CERTAIN FLIGHT HOUSINGS HAVE NICKEL PLATED INSULATION WITH COPPER PLATED TIE-IN AREAS.	THE BLOCK I AND PHASE II HAVE NICKEL PLATING TO PROTECT THE INSULATION FROM MECHANICAL DAMAGE AND PROVIDE A MOISTURE BARRIER. THE HOUSING IS COPPER PLATED AT THE INSULATION CLOSE-OUT AREAS TO IMPROVE THE NICKEL BOND. THE MINIMUM FACTORS OF SAFETY FOR THE INSULATED HOUSING MEET C.E.I. REQUIREMENTS. DAR 2068 ADDRESSES THE TIME CONSTRAINTS FOR NICKEL PLATED INSULATION WITH COPPER PLATED TIE-IN CONFIGURATIONS.	RS007632-171, -181, -201, -211
3. B600-05 THE BALLS ARE POSITIONED BY AN FEP COATED ARMALON CAGE. FEP COATING ON CAGES USED TO REDUCE POCKET AND BALL WEAR THUS INCREASING BEARING LIFE.	BLOCK I AND PHASE II PUMPS DO NOT HAVE FEP COATED CAGES.	BLOCK I AND PHASE II CAGES HAVE TEFLON CONTAINED IN THE FIBERGLASS CAGE THAT PROVIDES BEARING LUBRICATION.	RS007605-027 RS007606-007, -025
4. B600-01. BLOCK II NOZZLE ASSEMBLY ALLOWS A MINIMUM OF 12 OF THE 43 NOZZLE PASSAGES TO BE BLOCKED.	BLOCK I PHASE II NOZZLE ASSEMBLY ALLOWS A MINIMUM OF 16 OF THE 43 NOZZLE PASSAGES TO BE BLOCKED	THE BLOCK I PHASE II NOZZLE ASSEMBLY DOES NOT VIOLATE THE REQUIREMENTS OF THE BLOCK II NOZZLE ASSEMBLY. BLOCK I PHASE II NOZZLE MEETS CEI NOZZLE VANE REQUIREMENTS.	R0019793-091
6. B600-02. CAUSE B,C THE SECOND STAGE ROTOR BRAZE JOINT INTEGRITY IS ULTRASONIC INSPECTED PER DRAWING REQUIREMENTS.	CERTAIN SECOND STAGE ROTORS RECEIVED NO ULTRASONIC INSPECTION OF THE BRAZE JOINT.	THE BRAZE JOINTS OF ALL SECOND STAGE ROTORS HAVE RECEIVED A VISUAL AND PENETRANT INSPECTION. ALL PARTS SUSPECTED TO HAVE BRAZE JOINT ANOMALIES HAVE BEEN ADDRESSED.	RS007625-031
6. B600-02. CAUSE D NOZZLE COPPER PLATING ADHESION IS VERIFIED PER DRAWING REQUIREMENTS.	CERTAIN NOZZLES DID NOT RECEIVE A BAKE TEST.	ADHESION BAKE TEST IS NOT REQUIRED FOR NOZZLES WHICH HAVE BEEN PREVIOUSLY HOT FIRE TESTED. THE HOT FIRE ENVIRONMENT ADEQUATELY VERIFIES THE COPPER PLATING ADHESION INTEGRITY.	RS007622-025 R0019793-023
7. B600-02. CAUSE E. THE STATOR COPPER PLATING ADHESION IS VERIFIED PER DRAWING REQUIREMENTS	CERTAIN STATORS DID NOT RECEIVE A BAKE TEST.	ADHESION BAKE TEST IS NOT REQUIRED FOR STATORS WHICH HAVE BEEN PREVIOUSLY HOT FIRE TESTED. THE HOT FIRE ENVIRONMENT ADEQUATELY VERIFIES THE COPPER PLATING ADHESION INTEGRITY	RS007623-031

C - 591