

SSME FTA/CIL
REDUNDANCY SCREEN

Component Group: Fuel Turbopumps
 CIL Item: B500-C6
 Part Number: RS007601
 Component: Low Pressure Fuel Turbopump
 FMEA Item: B600
 Failure Mode: Fuel leakage past lift-off seal.

Prepared: F. Cromwell
 Approved: T. Nguyen
 Approval Date: 11/1/99
 Change #: 2
 Directive #: CCBD ME3-01-5248

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Phase	Failure / Effect Description	Criticality Hazard Reference
P 4.1	Fuel flow into turbine and through the MCC and nozzle. Possible open air fire/detonation. Loss of vehicle. Redundancy Screens: SINGLE POINT FAILURE: N/A	1 ME-A1P
C 4.1	Fuel flow into turbine and through MCC and nozzle. Open air fire/detonation if on launch pad. Loss of vehicle. Redundancy Screens: SINGLE POINT FAILURE: N/A	1 ME-A1A

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SSME FMEA/CIL DESIGN

Component Group: Fuel Turbopumps
CIL Item: B600-06
Part Number: RS007601
Component: Low Pressure Fuel Turbopump
FMEA Item: B600
Failure Mode: Fuel leakage past lift-off seal.

Prepared: F. Cromwell
Approved: T. Nguyen
Approval Date: 11/1/89
Change #: 2
Directive #: CCBD MEJ-01-5248

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Design / Document Reference

FAILURE CAUSE: A: Contamination.
B: Damaged sealing surfaces on lift-off seal or shaft.
C: Binding within lift-off seal.
E: Damage due to failure to lift-off.

THE LIFT-OFF SEAL (1) IS A SPRING-LOADED, PRESSURE-ACTUATED, FACE-RIDING CARBON NOSE SEAL. THE SEAL HOUSING AND ADAPTER ARE MANUFACTURED UTILIZING AN A-286 CRES BAR. A-286 CRES WAS SELECTED FOR ITS RESISTANCE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT AND CRYOGENIC MECHANICAL PROPERTIES (2). THE SEAL PREVENTS HYDROGEN LEAKAGE INTO THE TURBINE DURING PRESTART AND PROPELLANT DUMP. THE TURBOPUMP IS ASSEMBLED WITH A PRELOAD ON THE SEAL RING ASSEMBLY, WHICH MATES WITH A LIP ON THE SHAFT (3). THE SEAL RING IS MANUFACTURED UTILIZING P5N CARBON, WHICH WAS SELECTED FOR ITS SURFACE WEAR CHARACTERISTICS (2). THE ADAPTER IS DESIGNED TO PROVIDE AN INTERFERENCE FIT WITH THE OUTSIDE DIAMETER OF THE CARBON SEAL RING. HT424 EPOXY RESIN IS UTILIZED TO BOND THE CARBON SEAL RING IN THE ADAPTER. THE MATING LIP OF THE SHAFT IS FLAME-SPRAYED WITH TUNGSTEN CARBIDE FOR WEAR RESISTANCE AND IMPROVED SEALING CHARACTERISTICS. THE SEAL RING ASSEMBLY CARBON NOSE SURFACE IS REQUIRED TO BE FLAT TO WITHIN 3 HELIUM LIGHT-BANDS. AND THE MATING LIP ON THE SHAFT IS REQUIRED TO BE FLAT TO WITHIN 2 HELIUM LIGHT-BANDS. THE SEAL PRELOAD IS SUPPLIED BY THIRTY-TWO MAIN SPRINGS (14) MANUFACTURED UTILIZING 302 CRES WIRE (2). THIS MATERIAL WAS SELECTED FOR ITS MODULUS OF ELASTICITY, DUCTILITY AT CRYOGENIC TEMPERATURES, AND ITS INSENSITIVITY TO HYDROGEN ENVIRONMENT EMBRITTLEMENT.

DURING START, A PRESSURE UNBALANCE DEVELOPS ACROSS THE SEAL TO OFFSET THE SPRING LOAD AND RETRACT THE SEAL. MAINSTAGE PRESSURES ARE APPROXIMATELY 8 TIMES GREATER THAN THE FORCE REQUIRED TO OPEN THE SEAL. THE SEAL REMAINS OPEN UNTIL THE PRESSURE DECAYS DURING ENGINE SHUTDOWN. THE SEAL RETRACTION IS ACCOMMODATED BY AN INTERNAL CAVITY WHICH IS VENTED TO ATMOSPHERIC PRESSURE BY AN EXTERNAL DRAIN LINE. THE CAVITY DRAIN LINE IS ROUTED THROUGH THE SEAL HOUSING AND MATES WITH A PASSAGE AT THE MANIFOLD (4) INTERFACE. THE SEAL AT THIS LOCATION IS PROVIDED BY A PRESSURE-ASSISTED 'DOUGHNUT' STATIC SEAL (5), WHICH SEATS IN A GROOVE ON THE MANIFOLD FLANGE.

THE INTERNAL CAVITY IS FORMED BY STEPPED DIAMETERS ON THE ADAPTER AND MATING DIAMETERS ON THE SEAL HOUSING. TWO SPRING-LOADED INTERNAL SEALS PROVIDE SEALING BETWEEN THE HIGH PRESSURE HYDROGEN AND THE CAVITY DURING OPERATION. THE SEALS ARE MANUFACTURED UTILIZING VESPEL SP-211, WHICH WAS SELECTED FOR ITS SEALING AND LUBRICATION CHARACTERISTICS (2). THE SEALS ARE BOTTOMED AGAINST THE HOUSING UTILIZING PISTONS FABRICATED FROM 303 CRES BAR. THE PISTON PRELOAD IS SUPPLIED BY FORTY-EIGHT SPRINGS (14) FABRICATED FROM 302 CRES WIRE. THE PUMP-END SPRINGS ARE BOTTOMED AGAINST A 302 CRES WASHER, WHICH IS SECURED BY A MATING GROOVE IN THE HOUSING. THE TURBINE-END SEAL SPRINGS ARE BOTTOMED AGAINST AN A-286 CRES PLATE WHICH IS SECURED TO THE HOUSING UTILIZING TWELVE EACH 300 SERIES CRES SCREWS (15). A-286 AND THE 300 SERIES CRES ALLOYS WERE SELECTED FOR THE SAME CHARACTERISTICS DISCUSSED ABOVE. THE SCREWS ARE STAKED AT THE SEAL ASSEMBLY TO PREVENT ROTATION. ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (6). MOVEMENT OF THE SEAL PISTON IS GUIDED BY A BUSHING, WHICH PILOTS IN A GROOVE IN THE SEAL HOUSING. THE BUSHING IS MANUFACTURED UTILIZING VESPEL SP-211 WHICH WAS SELECTED FOR ITS LUBRICATING CHARACTERISTICS (2). THE ADAPTER DIAMETERS WHICH MATE WITH THE VESPEL SEALS AND THE BUSHING, ARE CHROME-PLATED TO PROVIDE A SMOOTH SURFACE ON WHICH TO SLIDE.

THE LIFT-OFF SEAL HOUSING IS SECURED TO THE MANIFOLD BY 18 BOLTS (7) AND CUP WASHERS (8), WHICH ALSO ATTACH THE NOZZLE (9) AND TURBINE SEAL (10). THE LIFT-OFF SEAL HOUSING OUTSIDE DIAMETER AND MANIFOLD INSIDE DIAMETER ARE CLOSELY TOLERANCED TO ASSURE ACCURATE PILOTING OF THE SEAL STACK AND MINIMIZE THE EFFECT OF HOUSING DEFLECTIONS ON THE SEAL INTERNAL CLEARANCES. THE PROPELLANT FILTER AT THE EXTERNAL TANK PRECLUDES CONTAMINANTS FROM ENTERING THE FLOW STREAM (11). THE SEAL IS HANDLED, PACKAGED, AND STORED TO PRECLUDE INTRODUCTION OF CONTAMINANTS PRIOR TO SERVICE (12). THE LIFT-OFF SEAL HAS BEEN DESIGN VERIFICATION TESTED (13).

(1) R0012162; (2) RSS-8577; (3) RS007628; (4) RS007602; (5) RFS1116; (6) RLCJ353; (7) RS007607; (8) RSCJ7629; (9) R0019783; (10) RC019804; (11) ICD 13M-5300; (12) RL10001
(13) RSS-404; (14) RC019230; (15) R0019865

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Component Group: Fuel Turbopumps
CIL Item: B600-08
Part Number: RS007601
Component: Low Pressure Fuel Turbopump
FMEA Item: B600
Failure Mode: Fuel leakage past lift-off seal.

Prepared: T. Nguyen
Approved: T. Nguyen
Approval Date: 11/1/99
Change #: 2
Directive #: CCBD ME3-01-5248

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Design / Document Reference

FAILURE CAUSE: D: Leakage past static seal at lift-off seal to manifold interface.

THE LIFT-OFF SEAL FLANGE SEAL (1) IS A PRESSURE-ASSISTED SEAL WHICH PREVENTS LEAKAGE AROUND THE LIFT-OFF SEAL HOUSING (2) INTO THE TURBINE DURING PRESTART AND PROPELLANT DUMP. THE SEAL IS MANUFACTURED UTILIZING A-286 CRES (3), WHICH WAS SELECTED FOR ITS MECHANICAL PROPERTIES AND RESISTANCE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT. THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE SEAL IS SILVER-PLATED TO CONFORM TO SEALING SURFACE IRREGULARITIES. THE SEAL IS PLOTTED IN A GROOVE ON THE MANIFOLD AND THE PRELOAD IS ESTABLISHED BY DRAWING REQUIREMENTS. THE SEAL IS NON-SERIALIZED AND NOT TIME HISTORY TRACKED, BUT HAS INFINITE ALLOWABLE LIFE (4)

(1) RES1200 (2) R0012162; (3) RSS-8577; (4) RL00532, CP320R0003B

FAILURE CAUSE: ALL CAUSES

THE HIGH AND LOW CYCLE FATIGUE LIFE FOR THE LIFT-OFF SEAL AND STATIC SEAL MEET CEI REQUIREMENTS (1). THE MINIMUM FACTORS OF SAFETY FOR THESE PARTS MEET CEI REQUIREMENTS (2). THE LIFT OFF SEAL ASSEMBLY PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/IDE FLAW GROWTH SINCE THEY CONTAIN NO FRACTURE CRITICAL PARTS (3). REUSE OF PARTS DURING OVERHAUL IS CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (4).

(1) RL00532, CP320R0003B; (2) RSS-8546, CP320R0003B; (3) NASA TASK 117; (4) RL00531

SSME FMEA/CIL
INSPECTION AND TEST

Component Group: Fuel Turbopumps
 CIL Item: B600-06
 Part Number: RS007601
 Component: Low Pressure Fuel Turbopump
 FMEA Item: B600
 Failure Mode: Fuel leakage past lift-off seal.

Prepared: F. Cronwell
 Approved: T. Nguyen
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Failure Causes A, B, C, E	Significant Characteristics SHAFT LIFT-OFF SEAL	Inspection(s) / Test(s)	Document Reference
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS	RS007628 RS007628 R0012162 AMS 5737 RB0130-115 ASTMA 240 RB0130-090 AMS 5640
		EPOXY INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0120-022
		THE SHAFT IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	SPRING INTEGRITY	SPRING CHARACTERISTICS ARE VERIFIED PER SPECIFICATION REQUIREMENTS.	ASTM A313
		TENSILE STRENGTH IS VERIFIED PER DRAWING REQUIREMENTS.	R0019230

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Component Group: Fuel Turbopumps
 Cl. Nam: B600-06
 Part Number: RS007601
 Component: Low Pressure Fuel Turbopump
 FMEA Item: B600
 Failure Mode: Fuel leakage past lift-off seal.

Prepared: R. Cronwell
 Approved: T. Nguyen
 Approval Date: 11/1/99
 Change #: 2
 Directive #: CCRD MF3-01-5248

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Failure Causes A B C E	Significant Characteristics	Inspector(s) / Test(s)	Document References
	SPRING INTEGRITY	SPRING CLOSED ENDS ARE GROUND SQUARE AND DEBURRED PER DRAWING REQUIREMENTS.	R001230
	SURFACE FINISH	THE SHAFT-TO-SEAL MATING SURFACE FLAME-SPRAY IS VERIFIED PER DRAWING REQUIREMENTS.	RS007628
		THE LIFT-OFF SEAL CARBON SEAL RING MATING SURFACE IS VERIFIED PER DRAWING REQUIREMENTS.	R0012152, RES1098
		SEAL CHROME PLATING IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1609-002
	SEAL RING ASSEMBLY	ASSEMBLY REQUIREMENTS OF THE CARBON SEAL RING IN THE ADAPTER IS VERIFIED PER DRAWING REQUIREMENTS.	R0012162, RES1098
	ASSEMBLY INTEGRITY	ASSEMBLY OF THE LIFT-OFF SEAL IS VERIFIED PER SPECIFICATION REQUIREMENTS.	R100813
		SCREW STAKING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	R0012152 RA1618-005

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Component Group: Fuel Turbopumps
 CIL Item: B600-06
 Part Number: RS007501
 Component: Low Pressure Fuel Turbopump
 FMEA Item: B500
 Failure Mode: Fuel leakage past lift-off seal.

Prepared: T. Nguyen
 Approved: T. Nguyen
 Approval Date: 11/1/99
 Change #: 2
 Directive #: CCBD ME3-01-5248

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Failure Causes A, B, C, E	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
	ASSEMBLY INTEGRITY	THE FOLLOWING FUNCTIONAL CHECKS ARE PERFORMED PER DRAWING AND SPECIFICATION REQUIREMENTS - AMBIENT AND CRYOGENIC LOAD DEFLECTION. - NOSE LEAK CHECK. - VESPEL SEAL LEAK CHECK - SEAL ACTUATION AND RE-SEAT CHECK	RL00939 RI 30939 RL00939 RL00939
	LOFTP		RSC07601
	ASSEMBLY INTEGRITY	TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT.	OMRSD V41B50.010
D	SEAL:		RES1200
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	
	HEAT TREAT	HEAT TREAT IS VERIFIED PER DRAWING REQUIREMENTS.	
	SURFACE FINISH	SILVER PLATING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RES1200 RA1509-014
		THE MATING SURFACES OF THE LIFT-OFF SEAL, HOUSING MANIFOLD, AND SEAL ARE INSPECTED PRIOR TO ASSEMBLY PER DRAWING AND SPECIFICATION REQUIREMENTS.	RSC07601 RL00353
ALL CAUSES	UPFTP		RS007501
	CLEANLINESS OF COMPONENTS	THE SEAL AND UPSTREAM COMPONENTS ARE VERIFIED CLEANED FOR FUEL SERVICE PER SPECIFICATION REQUIREMENTS.	RL10001
	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. SEAL LEAK CHECKS ARE PERFORMED AT ASSEMBLY. OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT-FIRE TESTING AND 2ND E & M TESTS ON INSPECTIONS.	RL00631 RA0115-16 RL00353 RL00050-04 RL00056-06 RL00056-07 RL00461

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Component Group: Fuel Turbopumps
CIL Item: B600-06
Part Number: R5007801
Component: Low Pressure Fuel Turbopump
FMEA Item: B600
Failure Mode: Fuel leakage past lift-off seal.

Prepared: F. Cromwell
Approved: T. Nguyen
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Change #: 2
Directive #: CCBD MF3-01-5248

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
ALL CAUSES	ASSEMBLY INTEGRITY	THE COMBINED SYSTEM LEAK CHECK IS PERFORMED PER SPECIFICATION REQUIREMENTS. DATA FROM PREVIOUS FLIGHT OR HOT-FIRE IS REVIEWED FOR PROPER TURBOPUMP OPERATION/PERFORMANCE. (LAST TEST)	OMRSD V41BQ0 010 OMRSD V41BQ0 020 OMRSD V41BQ0 050 M/SFC FLN 1228

Failure History: Comprehensive failure history data is maintained in the Problem Reporting database (PRAMS/PRACA).
 Reference: NASA letter SA21/98-308 and Rocketdyne letter 98RC09761.

Operational Use: Not Applicable.

WELDED JOINTS

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

Prepared: F. Cromwell
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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	

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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
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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

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