

**SSME FMEA/CIL
REDUNDANCY SCREEN**

Component Group: Fuel Turbopumps
 CIL Item: B200-13
 Component: High Pressure Fuel Turbopump
 Part Number: RS007501
 Failure Mode: Energy loss in diffusers and housing.

Prepared: D. Early
 Approved: T. Nguyen
 Approval Date: 4/21/99
 Change #: 1
 Directive #: CCBD ME3-01-5206
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Phase	Failure / Effect Description	Criticality Hazard Reference
S 4.1	<p>Losses result in reduced turbopump output. Decreased flow is sensed by the controller which increases the fuel preburner oxidizer flow. Excessive turbine discharge temperature will cause a redline 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>	1R ME-D1S.M
M 4.1	<p>Losses result in reduced turbopump output. Decreased flow is sensed by the controller which increases the fuel preburner oxidizer flow. Excessive turbine discharge temperature will cause a redline 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>	1R ME-D1S.M

**SSME FMEA/CIL
DESIGN**

Component Group: Fuel Turbopumps
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Design / Document Reference

FAILURE CAUSE: A: Fracture, distortion of diffuser pilot lip.
B: Fracture, distortion of diffuser vane.

THE FLOW FROM THE FIRST- AND SECOND-STAGE IMPELLERS IS PASSED THROUGH TWO DIFFUSER STAGES (1) (2) THESE COMPONENTS DIFFUSE THE FLUID FROM THE DISCHARGE OF ONE IMPELLER TO THE INLET OF THE NEXT. THE DIFFUSERS ARE MANUFACTURED UTILIZING ALUMINUM ALLOY TENS-60-T80 CASTINGS. THIS MATERIAL WAS SELECTED FOR ITS STRENGTH, RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING, CASTABILITY, AND ITS PROPERTIES ARE NOT DEGRADED IN A HYDROGEN ENVIRONMENT (3). THE MATERIAL IS SOLUTION TREATED, AGE-HARDENED, AND CHROMIC OR SULFURIC ACID ANODIZED. THE FIRST-STAGE DIFFUSER IS PINNED TO THE SECOND-STAGE DIFFUSER, WHICH IN TURN IS INDEXED TO THE HOUSING. IRREGULARLY SPACED LUGS IN THE HOUSING ENGAGE SLOTS IN THE DIFFUSER AND PROVIDE FREEDOM FOR THE DIFFUSERS TO MOVE AXIALLY RELATIVE TO THE HOUSING WHILE REACTING TO THE TORQUE LOADS. THE DIFFUSERS ARE POSITIONED AXIALLY RELATIVE TO THE INLET IMPELLERS, AND EACH OTHER BY THE USE OF SHIMS (4). THE SECOND-STAGE IS PILOTTED RADIALLY BY A LIP ON THE HOUSING. THE FIRST-STAGE DIFFUSER IS PILOTTED RADIALLY BY A LIP ON THE PUMP INLET. THE DIFFUSERS PILOT LIP CORNERS ARE RADIUSED TO REDUCE THE STRESS CONCENTRATIONS AT THIS LOCATION. A PRELOAD SPRING (5) BETWEEN THE SECOND-STAGE DIFFUSER AND THE HOUSING KEEPS THE DIFFUSER AND SHIM STACK TIGHT FOR HANDLING AND SHIPPING PURPOSES. IN OPERATION THE PRESSURE FORCES LOAD THE STACK AGAINST THE INLET. ALL DIFFUSER VANE FILLETS ARE RADIUSED TO ELIMINATE STRESS RISERS. DESIGN VERIFICATION TESTING DEMONSTRATED THE FACTOR OF SAFETY ON BURST ON A SECOND-STAGE DIFFUSER (6). THE DIFFUSER IS PROOF PRESSURE TESTED TO VERIFY ITS STRUCTURAL INTEGRITY (7). THE DIFFUSERS HAVE BEEN DESIGN VERIFICATION TESTED FOR STRESS SAFETY FACTORS, LOW CYCLE FATIGUE LIFE, AND DEFLECTIONS (8).

(1) RS007527; (2) RS007532; (3) RSS-8580-10; (4) RS007564, RS007546; (5) RS007507; (6) RSS-404-28; (7) RL00023; (8) RSS-404-22

FAILURE CAUSE: C: Fracture, distortion of housing vane.

THE 13 DIFFUSER VANES ARE MACHINED INTO THE MAIN HOUSING (1) AT THE ENTRY OF THE DISCHARGE VOLUTE. THE HOUSING IS MANUFACTURED UTILIZING AN INCONEL 718 FORGING. INCONEL 718 WAS SELECTED FOR ITS MECHANICAL PROPERTIES AT CRYOGENIC TEMPERATURES, RETENTION OF TOUGHNESS AND DUCTILITY AT CRYOGENIC TEMPERATURES, RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING (2). THE VANES DO NOT REQUIRE PROTECTION FOR HYDROGEN ENVIRONMENT EMBRITTLEMENT IN THEIR CRYOGENIC OPERATING ENVIRONMENT. THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE HOUSING VANES GUIDE AND DIFFUSE THE FLOW FROM THE THIRD-STAGE IMPELLER INTO THE VOLUTE LINER. THE VANE FILLETS ARE RADIUSED TO REDUCE STRESS RISERS. THE HOUSING IS PROOF PRESSURE TESTED TO VERIFY ITS STRUCTURAL INTEGRITY (3). THE HOUSING HAS BEEN DESIGN VERIFICATION TESTED FOR STRESS SAFETY FACTORS, LOW CYCLE FATIGUE LIFE, AND DEFLECTIONS (4).

(1) RS007577, RS007568; (2) RSS-8580-10; (3) RL00143; (4) RSS-404-25

FAILURE CAUSE: ALL CAUSES

THE HIGH AND LOW CYCLE FATIGUE LIFE FOR THE DIFFUSERS AND HOUSING VANES MEET CEI REQUIREMENTS (1). THE MINIMUM FACTORS OF SAFETY FOR THESE PARTS MEET CEI REQUIREMENTS (2). THE FIRST AND SECOND-STAGE DIFFUSER PARENT MATERIAL WAS CLARIFIED FOR FRACTURE MECHANICS INDE FLAW GROWTH SINCE THEY ARE NOT FRACTURE CRITICAL PARTS, EXCEPT FOR THE HOUSING ASSEMBLY WHICH WAS CLEARED BY CRITICAL INITIAL FLAW SIZE AND DETECTABILITY (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).

(1) RL00532, CP320RD003B; (2) RSS-8546-16, CP320RD003B; (3) NASA TASK 117; (4) GP405R0002 PT 1 3.2 3-5.3; (5) RL00528

**SSME FMEA/CIL
INSPECTION AND TEST**

Component Group: Fuel Turbopumps
 CIL Item: B200-13
 Component: High Pressure Fuel Turbopump
 Part Number: RS007501
 Failure Mode: Energy loss in diffusers and housing.

Prepared: D. Early
 Approved: T. Nguyen
 Approval Date: 4/21/99
 Change #: 1
 Directive #: CCSD ME3-01-5206
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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A B	DIFFUSER FIRST-STAGE DIFFUSER SECOND-STAGE		RS007527 RS007532
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS	RS007527 RS007532 RB0170-099
		THE DIFFUSER CASTING IS RADIOGRAPHIC INSPECTED PER SPECIFICATION REQUIREMENTS.	RL10003
		THE DIFFUSER IS PROOF PRESSURE TESTED PER SPECIFICATION REQUIREMENTS.	RL00023
		DIFFUSER ACCESSIBLE SURFACES ARE PENETRANT INSPECTED PRIOR TO AND FOLLOWING PROOF PRESSURE TEST PER SPECIFICATION REQUIREMENTS.	RA0115-116
		DIFFUSER HIDDEN SURFACES ARE PENETRANT INSPECTED PRIOR TO AND FOLLOWING PROOF PRESSURE TEST PER SPECIFICATION REQUIREMENTS	RA0115-116 RL00343
		THE DIFFUSER CHROMIC OR SULFURIC ACID ANODIZE OR HARD ANODIZED COATING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007527 RS007532 RA1609-003
	ASSEMBLY INTEGRITY	THE DIFFUSER PILOT LIP DIAMETERS ARE VERIFIED PER DRAWING REQUIREMENTS.	RS007527 RS007532
		THE HOUSING PILOT LIP DIAMETER IS VERIFIED PER DRAWING REQUIREMENTS.	RS007568
		THE INLET PILOT LIP DIAMETER IS VERIFIED PER DRAWING REQUIREMENTS.	RS007512
		THE ASSEMBLY OF THE DIFFUSER INTO THE TURBOPUMP IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007568 RL00351
		DIFFUSER VANE PROFILES AND THICKNESSES ARE VERIFIED PER DRAWING REQUIREMENTS.	RS007527

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A, B	ASSEMBLY INTEGRITY	DIFFUSER VANE PROFILES AND THICKNESSES ARE VERIFIED PER DRAWING REQUIREMENTS.	RS007527 RS007532 RS007501
	HPFTP		
C	ASSEMBLY INTEGRITY	SHAFT TRAVEL PERFORMED PRIOR TO EACH FLIGHT. TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT.	OMRSD V41B50.020
	HOUSING		RSC07568
D	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS. HOUSING FORGING IS PENETRANT AND ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116 RA0115-012
		HOUSING PROOF PRESSURE TEST IS PERFORMED PER SPECIFICATION REQUIREMENTS.	RL00143
		HOUSING IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
E	ASSEMBLY INTEGRITY	HOUSING DIFFUSER VANE PROFILES AND THICKNESSES ARE VERIFIED PER DRAWING REQUIREMENTS HOUSING DIFFUSER VANES RADII ARE INSPECTED PER DRAWING REQUIREMENTS	RS007568
	HPFTP		RS007501
ALL CAUSES	CLEANLINESS OF COMPONENTS	COMPONENTS ARE VERIFIED CLEANED PER SPECIFICATION REQUIREMENTS	RL10001
	ASSEMBLY INTEGRITY	OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT-FIRE TESTING AND 2ND E & M TESTS ON INSPECTIONS. 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 DATA FROM PREVIOUS FLIGHT OR HOT FIRE IS REVIEWED FOR PROPER TURBOPUMP OPERATION/PERFORMANCE. (LAST TEST)	RL00050-04 RL00056-06 RL00058-07 RL00461 RL00528 RA0115-116 MSFC PLN 1228

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Component Group: Fuel Turbopumps
CIL Item: B200-13
Component: High Pressure Fuel Turbopump
Part Number: RS007601
Failure Mode: Energy loss in diffusers and housing.

Prepared: D. Early
Approved: T. Nguyen
Approval Date: 4/21/89
Change #: 1
Directive #: CCBD ME1-01-5206
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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
Failure History:	Comprehensive failure history data is maintained in the Problem Reporting database (PRAMS/PACA) Reference: NASA letter SA21/BB/300 and Rockeidyne letter 88RC09761		
Operational Use:	Not Applicable.		

SSME FMEA/CIL
FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE

Component Group: Fuel Turbopumps
 Item Name: High Pressure Fuel Turbopump
 Item Number: B200
 Part Number: RS007501

Prepared: D. Early
 Approved: T. Nguyen
 Approval Date: 4/21/99
 Change #: 2
 Directive #: CCBD ME3-01-5208

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Base Line Rationale	Variance	Change Rationale	Variant Dash Number
1. B200-15 RS007502; CAUSE A, B200-24; RS007605; CAUSE A THE INNER AND OUTER BEARING RACES ARE EDDY CURRENT INSPECTED PER RL00743.	BEARING RACES RECEIVED FROM SUPPLIER SPLIT BALL BEARING INCORPORATED RECEIVED NO GENERAL EDDY CURRENT INSPECTION	GENERAL EDDY CURRENT INSPECTION OF RACES REPLACES TYPE IVC IN PENETRANT INSPECTION IN DETECTING SURFACE FLAWS USE AS IS RATIONALE: 1. RACES 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. B200-13 RS007527, RS007532, CAUSE A & B. B200-26; RS007532; CAUSE B. DIFFUSER HIDDEN SURFACES ARE PENETRANT INSPECTED PER RL00343.	SOME DIFFUSERS MAY NOT RECEIVE THE POST PROOF TEST HIDDEN SURFACE IIP PENETRANT INSPECTION	USE AS IS RATIONALE 1. IMPLEMENTATION OF HIDDEN SURFACE INSPECTION REQUIREMENT IS NOT A RESULT OF AN OBSERVED HARDWARE ANOMALY BUT AS A RESULT OF ROCKETDYNE'S STAND DOWN.	SEE DAR 2751 FOR VARIANT PART SERIAL NUMBERS
3 B200-14 CAUSE A, RS007568 B200-21 CAUSE B, RS007568 B200-26 CAUSE A, RS007568 WELD JOINTS RS007568 TABLE B200 HPFT FMEA/CIL WELD JOINTS RS007568 HOUSING CURRENT CONFIGURATION IS THE ONE (1) PIECE "113" CAP, USING FOUR (4) WELDS AND FOUR (4) WELD NUMBERS	SOME HOUSINGS (POSSIBLY TWO) MAY HAVE BEEN FABRICATED WITH THE TWO (2) PIECE "113" CAPS (THIS HAS AN EXTRA WELD: #13 AND THREE EXTRA WELD NUMBERS 13, 68 & 69)	TO REDUCE CONFUSION ON THE DRAWING AND ON THE MANUFACTURING FLOOR	SEE MCR 2524. SAME -113 DASH NUMBER.
4 B200-02; CAUSE A, RS007524 CAUSE B, RS007524; CAUSE C, RS007524	SOME TURBINE BEARING SUPPORTS (RS007524) ARE FABRICATED USING A WELDMENT OF HAYES 188 SHEET METAL INSTEAD OF THE EDM FORGING.	HIGH CYCLE FATIGUE INDUCED INLET SHEET METAL CRACKS DO OCCUR FROM THE OPERATIONAL ENVIRONMENT EXPERIENCED DURING ENGINE OPERATION. THE CRACKING IS CONTROLLED PER THE REQUIREMENTS OF THE SHEET METAL INSPECTION SPECIFICATION (RL00655) WHICH LIMITS THE CRACKING LENGTH, SPACING, AND SHAPE, TO PRECLUDE SHEET METAL PIECES FROM DISLODGING. THE CRITERIA IS BASED ON CRACK GROWTH RATES AND ENGINE TEST EXPERIENCE. ANY CRACKS, WHICH EXCEED THE SPECIFICATION LIMITS, ARE WELD REPAIRED (RF0001-007). THE TURBINE BEARING SUPPORT WITH WELDED SHEET METAL IS LIFE LIMITED BY MAJOR WAIVER DAR 2709.	RS007524-201 AND SUBS.

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Component Group: Fuel Turbopumps
 Item Name: High Pressure Fuel Turbopump
 Item Number: B200
 Part Number: RS007501

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Base Line Rationale	Variance	Change Rationale	Variant Dash Number
5 B200-18 CAUSE A, B200-17 CAUSE A, B200-18 CAUSE A, B200-19 CAUSE A, B200-22; CAUSE A,B,C,E	SOME LIFT-OFF SEAL HOUSING DRAIN LINES ARE FABRICATED USING INTERSECTING LINE DRILLED HOLES THE HOLE THAT INTERSECTS THE OUTSIDE DIAMETER OF THE HOUSING FLANGE HAS A PLUG INSTALLED. THE PLUG IS THEN WELDED AT THE HOUSING OUTSIDE DIAMETER TO FORM A TIGHT GAS SEAL	LOW CYCLE FATIGUE CRACKING HAS BEEN OBSERVED IN THE PLUG WELD. CRACK INITIATION AND PROPAGATION OCCURS AT SHUTDOWN/COOLDOWN ALL UNITS RECEIVE A STANDARD POST FLIGHT INSPECTIONS BY LEAK CHECK. LEAK CHECK POST FLIGHT WILL DETECT A CRACK PRIOR TO REFLIGHT. POST LEAKAGE AT THE DRAIN LINE IS LIMITED TO 10 SCIM. ALL FLIGHT UNITS WILL CONTINUE TO RECEIVE A LEAK CHECK POST FLIGHT FOR THE DRAIN LINE PLUG WELD UNTIL THE ENTIRE FLEET IS RETROFIT WITH THE EDM DRAIN LINE CONFIGURATION	R0019230-071 AND SUBS.

**SSME FMEA/CIL
WELD JOINTS**

Component Group: Fuel Turbopumps
 CIL Item: B200
 Component: High Pressure Fuel Turbopump
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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	
SHIELD	R0012171	1,24, 28-52	GTAW	II	X			
SHIELD	R0012171	26	GTAW	II				
LIFT-OFF SEAL	R0019230	1, 2	GTAW	II	X			
SHIELD	R0019788	25, 28	GTAW	II				
SHIELD	R0019788	27, 50	GTAW	II	X			
SHIELD	R0019788	51, 52	GTAW	I				
SHIELD	R0019788	53, 55	GTAW	II				
BELLOWS	RS007505	1-4	GTAW	I		X		
BELLOWS	RS007505	5, 6	EBW	I		X		
INLET	RS007512	4	GTAW	I		X		
INLET	RS007512	5-6	GTAW	I				
INLET	RS007512	7-10, 12, 13	GTAW	I				
INLET	RS007512	11	EBW	II				
INLET	RS007512	14, 15	GTAW	I				
INLET	RS007512	16	GTAW	I		X		
BEARING SUPPORT	RS007524	14	EBW	I				
BEARING SUPPORT	RS007524	18	EBW	I	X			
BEARING SUPPORT	RS007524	29, 30	GTAW	I	X	X		
BEARING SUPPORT	RS007524	118	GTAW	I	X			
BEARING SUPPORT	RS007524	119, 121	EBW	I				
BEARING SUPPORT	RS007524	120	GTAW	II	X			
BEARING SUPPORT	RS007524	229-241	GTAW	II	X			
HOUSING	RS007568	75, 223, 228, 230, 298	GTAW	I	X	X	X	
HOUSING	RS007568	74	GTAW	I				
HOUSING	RS007568	48	EBW	I	X	X	X	
HOUSING	RS007568	43	GTAW	I	X			
HOUSING	RS007568	51	GTAW	II	X	X		
HOUSING	RS007568	52	GTAW	II	X			
HOUSING	RS007568	53	EBW	I				

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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	
HOUSING	RS007568	56	EBW	II	X			
HOUSING	RS007568	56	GTAW	II	X			
HOUSING	RS007568	57, 324, 325	GTAW	II				
HOUSING	RS007568	58	GTAW	II	X	X	X	
HOUSING	RS007568	59	EBW	I				
HOUSING	RS007568	74, 229, 297	GTAW	I	X	X	X	
HOUSING	RS007568	76, 77	GTAW	I		X		
HOUSING	RS007568	78-89	GTAW	II	X			
HOUSING	RS007568	90-101	GTAW	II	X			
HOUSING	RS007568	102	GTAW	I	X			
HOUSING	RS007568	139	GTAW	II	X			
HOUSING	RS007568	140	GTAW	II	X			
HOUSING	RS007568	150, 154	GTAW	II	X			
HOUSING	RS007568	174-185	GTAW	II	X			
HOUSING	RS007568	191, 192, 195, 196, 245, 455, 456	GTAW	II	X	X		
HOUSING	RS007568	193, 194, 197-202, 204-207	GTAW	II		X		
HOUSING	RS007568	203, 217, 218, 234, 236	GTAW	II	X	X		
HOUSING	RS007568	212, 213	GTAW	II				
HOUSING	RS007568	214, 215	GTAW	II	X			
HOUSING	RS007568	222, 239	GTAW	I		X		
HOUSING	RS007568	224, 225	GTAW	I		X	X	
HOUSING	RS007568	226, 227	GTAW	I		X		
HOUSING	RS007568	231, 232	GTAW	II	X	X		
HOUSING	RS007568	233	GTAW	II	X			
HOUSING	RS007568	237, 238	GTAW	II				
HOUSING	RS007568	246-248	GTAW	II				
HOUSING	RS007568	326-349	GTAW	II	X			
HOUSING	RS007568	374-397	GTAW	II	X			
HOUSING	RS007568	399	GTAW	I	X	X	X	

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						HCF	LCF	
HOUSING	RS007568	401-424	GTAW	II	X			
HOUSING	RS007568	425-448	GTAW	II	X			
HOUSING	RS007568	450 (OPT)	GTAW	II				
HOUSING	RS007568	450 (OPT)	EBW	II	X			
HOUSING	RS007568	454	GTAW	II	X			
HOUSING	RS007568	537 (OPT)	GTAW	II				
ROTOR SEAL	RS007588	1	EBW	I				
SEA.	RS007592	25	EBW	II	X			