

SSME FMEA/CIL
REDUNDANCY SCREEN

Component Group: Fuel Turbopumps
 C/L Item: B200-07
 Component: High Pressure Fuel Turbopump
 Part Number: RS007501
 Failure Mode: Turbine discharge flow blockage.

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
SMC 4.1	Flow blockage decreases turbine pressure ratio, reduces turbopump speed, flow and discharge pressure. Decreased flow is sensed by controller which increases fuel preburner oxidizer flow. A rapid buckling may result in extensive turbine damage from over-temperature. Possible burst of pump inlet due to pressure surge. Loss of vehicle. Redundancy Screens SINGLE POINT FAILURE: N/A.	1 ME-B4S, ME-B4M, ME-B4A,C, ME-D1S,M, ME-D1A,C

SSME FMEA/CIL DESIGN

Component Group: Fuel Turbopumps
CIL Item: B200-07
Component: High Pressure Fuel Turbopump
Part Number: RS007601
Failure Mode: Turbine discharge flow blockage.

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Design / Document Reference

FAILURE CAUSE: A: Turnaround duct distortion/buckling.
B: Sheet metal cracking resulting in loss of pieces.
C: Stiffener vane cracking resulting in loss of pieces or disengagement of slip joint.

THE MAIN HOUSING (1) TURNAROUND DUCT IS A WELDMENT OF HAYNES 188 SHEET METAL COMPONENTS (2). THIS ALLOY WAS SELECTED FOR ITS TENSILE STRENGTH AT ELEVATED TEMPERATURES, LOW CYCLE FATIGUE LIFE, AND RESISTANCE TO DEGRADATION AND OXIDATION IN A HIGH-PRESSURE HYDROGEN RICH STEAM ENVIRONMENT. THE MATERIAL IS ANNEALED TO IMPROVE MECHANICAL PROPERTIES. THE TURNAROUND DUCT PROVIDES THE AERODYNAMIC PASSAGE FOR TURBINE EXHAUST GASES TO FLOW TO THE HOT-GAS MANIFOLD. SECTIONS OF THE TURNAROUND DUCT ARE WELDED AS SUBASSEMBLIES, WHICH ARE WELDED INTO THE MAIN HOUSING. SOME WELDS IN THE FLOW AREA ARE GROUND FLUSH TO ELIMINATE FLOW DISTORTION. STRUT CANS ARE WELDED AROUND THE MAIN HOUSING DISCHARGE STRUTS TO PROTECT THE STRUTS FROM DIRECT HOT-GAS IMPINGEMENT. THE HATBAND IS WELDED TO THE INNER LINER AT THE TURBINE DISCHARGE TO RETAIN THE BELLOW'S SHIELD LIP. TWELVE STIFFENER VANES AT THE DISCHARGE OF THE SECOND-STAGE BLADES AND 12 POSTS LOCATED BETWEEN THE MAIN HOUSING'S DISCHARGE STRUTS ADD RIGIDITY TO THE TURNAROUND DUCT SHEET METAL. THE STIFFENER VANES ARE WELDED TO THE INNER AND OUTER LINER TO PRECLUDE CRACKING AT THE JOINT SLIP JOINTS WITH THE OUTER LINER AT THE SECOND-STAGE BLADE EXHAUST AND THE G-6 FLANGE ALLOW RADIAL GROWTH DURING OPERATION. A SINGLE CONVOLUTION BELLOW'S ALLOWS FOR AXIAL MOVEMENT. HOT-GAS VENT HOLES IN THE OUTER LINER AND ON THE DOWNSTREAM SIDE OF THE STRUT CANS ALLOW THE PRESSURE TO EQUALIZE ACROSS THE LINER. THE VENT HOLES ARE LOCATED ON THE 12 O'CLOCK SIDE TO CORRECT FOR THE TURBINE TRANSVERSE ΔP GENERATED BY THE HOT-GAS MANIFOLD. EXTERNAL PRESSURE ON THE TURNAROUND DUCT IS LESS THAN OR EQUAL TO THE INTERNAL PRESSURE WHICH REDUCES THE POSSIBILITY OF DISTORTION. RIBS ON THE TURBINE END SIDE OF THE COOLANT LINER ASSURE EQUAL EXTERNAL PRESSURIZATION WHEN CONTACT OCCURS AT THIS LOCATION. LOW CYCLE FATIGUE INDUCED SHEET METAL CRACKS DO OCCUR FROM THE LARGE THERMAL SHOCK EXPERIENCED DURING ENGINE START AND SHUTDOWN. THE CRACKS CAN PROPAGATE BY HIGH CYCLE FATIGUE DURING OPERATION. THE CRACKING IS CONTROLLED PER REQUIREMENTS OF THE SHEET METAL CRACKING SPECIFICATION (3). THE SPECIFICATION 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. CRACKS WHICH EXCEED THE SPECIFICATION LIMITS ARE WELD REPAIRED (4). REPAIR OF SHEET METAL CRACKS IS A MAINTENANCE ITEM. CONTINUED USE WITH ALLOWABLE DISCREPANCIES RESULTING FROM OPERATION IS EVALUATED AND CONTROLLED PER THE REQUIREMENTS OF THE MAINTENANCE CONTROL DOCUMENT (5). MINIMUM FACTORS OF SAFETY FOR THE HOUSING MEET CEI REQUIREMENTS (6). THE MAIN HOUSING TURNAROUND DUCT PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/INDE FLAW GROWTH BY CRITICAL INITIAL FLAW SIZE DETECTABILITY (7). THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/INDE FLAW GROWTH BY THE WELD ASSESSMENT (8). TABLE B200 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 (8). REUSE OF PARTS DURING OVERHAUL IS CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (9).

(1) RS007577, RS007568, RD019768; (2) RSS-8580-10; (3) RL00655; (4) RF0001-007, RF0001-015; (5) RSS-8793; (6) RSS-8546-16, CP320R0003B; (7) NASA TASK 117; (8) RSS-8756; (9) RL00528

FAILURE CAUSE: D: Failure of coolant liner.

THE COOLANT LINER (1) IS A WELDMENT OF TWO HAYNES 188 COMPONENTS (2) WITH THE MAIN HOUSING (3). THIS ALLOY WAS SELECTED FOR ITS TENSILE STRENGTH AT ELEVATED TEMPERATURES, LOW CYCLE FATIGUE LIFE, AND RESISTANCE TO DEGRADATION AND OXIDATION IN A HIGH-PRESSURE HYDROGEN ENVIRONMENT. THE MATERIAL IS ANNEALED TO IMPROVE MECHANICAL PROPERTIES. THE COOLANT LINER CONTAINS THE LIQUID HYDROGEN FLOW WHICH COOLS THE MAIN HOUSING OUTER STRUCTURE DURING OPERATION. SIXTY RIBS ON BOTH OF THE LINER DETAILS ASSURE THE EVEN DISTRIBUTION OF THE COOLANT AROUND THE LINER. THE COOLANT LINER PRESSURE REDLINE IS DESIGNED TO SAFELY SHUTDOWN THE ENGINE BEFORE SUFFICIENT PRESSURE COULD ACCUMULATE BEHIND THE LINER TO CAUSE BUCKLING. THE COOLANT LINER MEETS HIGH AND LOW CYCLE FATIGUE LIFE (4) AND MINIMUM FACTORS OF SAFETY CEI REQUIREMENTS (5). THE COOLANT LINER PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/INDE FLAW GROWTH BY CRITICAL INITIAL FLAW SIZE DETECTABILITY (6). THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/INDE FLAW GROWTH BY THE WELD ASSESSMENT (7). TABLE B200 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 (7).

(1) RS007568; (2) RSS-8580-10; (3) RS007577; (4) RL00532, CP320R0003B; (5) RSS-8546-16, CP320R0003B; (6) NASA TASK 117; (7) RSS-8756

**SSME FMEA/CIL
INSPECTION AND TEST**

Component Group: Fuel Turbopumps
 CIL Item: B200-07
 Component: High Pressure Fuel Turbopump
 Part Number: RS007501
 Failure Mode: Turbine discharge flow blockage.

Prepared: D. Early
 Approved: T. Nguyen
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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A, B, C	SHIELD THERMAL SHIELD THERMAL HOUSING HPFTP		R0012171 R0019788
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	
		FORGINGS ARE PENETRANT AND ULTRASONIC INSPECTED PER DRAWING AND SPECIFICATION REQUIREMENTS.	R0019229 RA0115-116 RA0115-012
		DETAILS ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	DETAIL PARTS HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS	RA0111-018
		ASSEMBLY 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.	RI10011 RA0607-094 RA0115-116 RA0115-006 RA1115-001 RA0115-127
D	THERMAL SHIELDS MATERIAL INTEGRITY		RS007568

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Item: HPFTP
 Part Number: RS007501
 Component: High Pressure Fuel Turbopump
 Failure Mode: Turbine discharge flow blockage.

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
D	MATERIAL INTEGRITY	FORGING IS PENETRANT AND ULTRASONIC INSPECTED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007568 RA0115-116 RA0115-012
	HEAT TREAT	DETAIL PARTS ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS. ASSEMBLY HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0115-116 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 RA0607-094 RA0115-116 RA0115-006 RA1115-001 RA0115-127
		CLOSE OUT WELD JOINT FIT-UP AND QUALITY ARE VERIFIED BY BORESCOPE INSPECTION PER DRAWING REQUIREMENTS.	RS007568
ALL CAUSES	HPFTP		RS007501
	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.	RL00528 RA0115-116
		OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT FIRE TESTING AND 2ND E&M TESTS ON INSPECTIONS.	RL00050-04 RL00050-06 RL00050-07 RL00461
		AN INTERNAL BORESCOPE INSPECTION OF THE STIFFENER VANES IS PERFORMED AFTER EACH TURBOPUMP REMOVAL.	OMRSD V41BU0.080
		AN INTERNAL BORESCOPE INSPECTION OF THE TURBINE DISCHARGE SHEET METAL IS PERFORMED PRIOR TO EACH FLIGHT.	OMRSD V41BU0.075
		DATA FROM 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 88RCC09781.
 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
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 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
 Part Number: RS007501

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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	14	GTAW	I				
HOUSING	RS007568	48	EBW	I	X	X	X	
HOUSING	RS007568	49	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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 CIL Item: B200
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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	