SSME THEA/OIL

REDUNDANCY SCREEN

Component Group:	Combustion Devices	Prepared:	A. Kay
CIL Item:	A200-09	Approved:	T. Nguyen
Part Number:	RS009122	Approval Date:	9/9/99
Component:	Main Injector	Change #:	1
FMEA Item:	A200	Directive #:	CCRD ME3-01-5238
Failure Mode:	Interpropellant plate cracks.	Page:	1 of 1

Phase	Failure / Effect Description	Criticality Hazard Reference
SMC 4.1	Ignition would occur in main injector resulting in injector powerhead burnout, and aft compartment overpressurization and fire. Loss of vehicle.	1 ME-B4S, ME-B4A.C, ME-B4M
	Redundancy Screens: SINGLE POINT FAILURE. N/A	

SSME FMEA/CIL DESIGN

Component Group:	Combustion Devices	Prepared:	A. Ray
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Design / Document Reference

FAILURE CAUSE: A: Weld or parent material failure.

THE MAIN INJECTOR BODY FORGING MATERIAL IS AN INCONEL 718 NICKEL BASED ALLOY. INCONEL 718 WAS SELECTED FOR STRENGTH, DUCTILITY, RESISTANCE TO CORROSION/STRESS CORROSION CRACKING, OXYGEN COMPATIBILITY, AND WELDABILITY (1). THE INTERPROPELLANT PLATE INCORPORATES A HEAT SHIELD ACROSS THE FACE TO PROTECT IT FROM THERMAL DAMAGE DUE TO HOT-GAS (2). HYDROGEN TRANSPIRATION COOLING OF INJECTOR FACEPLATE RESTRICTS THERMAL GROWTH WHICH GREATLY REDUCES THE POSSIBILITY OF CRACKING. THE BENDING FLEXIBILITY OF THE LIQUID OXYGEN POSTS IS SUFFICIENT TO COMPLY WITH THE RADIAL THERMAL EXPANSION AND CONTRACTION OF THE INJECTOR FACE. WELD AREAS SUBJECT TO HYDROGEN EMBRITTLEMENT ARE OVERAYED FOR PROTECTION. HIGH CYCLE FATIGUE AND LOW CYCLE FATIGUE MEET CEI REQUIREMENTS (3). THE PRIMARY STRESS FACTOR OF SAFETY MEET CEI REQUIREMENTS (4). THE INTERPROPELLANT PLATE PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE IT CONTAINS NO FRACTURE CRITICAL PARTS (5). THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY THE WELD ASSESSMENT (6). TABLE A200 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 (6). BY ANALYSIS, ALL CRACKS ARE SELF-LIMITING. DESTRUCTIVE EVALUATION OF THE MAIN INJECTOR FROM ENGINE 2010 REVEALED CRACKS ORIENTED CIRCUMFERENTIALLY AROUND THE LOX POST AND BETWEEN THE POST STUBS. THE FRACTURE MECHANISM WAS IDENTIFIED AS HYDROGEN ASSISTED LOW CYCLE FATIGUE, WHICH WAS THERMALLY INDUCED DURING SHUTDOWN TRANSIENTS. THE CRACKS SHOWED NO EVIDENCE OF HIGH CYCLE FATIGUE AND WERE SELF-LIMITING IN DEPTH EVEN WITH PORTIONS OF HEAT SHIELD MISSING. HYDROGEN ENVIRONMENT EMBRITTLEMENT IS NOT THE CONTROLLING FACTOR. THREE INJECTORS OF THE OLD HEAT SHIELD CONFIGURATION HAVE BEEN DESTRUCTIVELY EVALUATED. ALL THREE HAD SUFFERED HEAT SHIELD DAMAGE. IN ALL CASES THE THERMAL CRACKS WERE SELF-LIMITING. THE MAIN INJECTOR HAS COMPLETED DVS TESTING (7). NO (8).

(1) RSS-8572-9 (2) RS009122 (3) RL00532, CP320R0003B; (4) RSS-8546, CP320R0003B, (5) NASA TASK 1-7; (6) RSS-8756; (7) DVS-101 (8) SSME-84-1322

FAILURE CAUSE: B: Heat shield failure.

HEAT SHIELD IS MADE FROM 304L CRES WIRE CLOTH, 316L FOIL, AND 304L CRES SHEET. BOTH MATERIALS ARE RESISTANT TO DEGRADATION IN THE HOT-GAS ENVIRONMENT (1). THE HEAT SHIELD IS REINFORCED AROUND THE O.D. AND IS SECURED IN A SLOT BETWEEN THE INJECTOR AND THE POWERHEAD, BY A RETAINER RING, AND BY PROTECTOR SHIELDS (2). NO HEAT SHIELD FAILURES OCCURRED WITH THE PRESENT DESIGN. BY BEING HELD IN A SLOT OF THE POWERHEAD ASSEMBLY, TEARING BY HIGH VELOCITY GASES IS PRECLUDED. THE LOSS OF SEVERAL OUTER ROW HEAT SHIELD RETAINERS IS NOT THREATENING, DUE TO SOILD PLATES OVERLAY THE OUTER PERIPHERY OF THE HEAT SHIELD SCREEN. THE HEAT SHIELD LAYERS ARE FUSED BY E.B. CUTTING THE POST HOLES (3). THE HEAT SHIELD IS HELD IN PLACE BY HEAT SHIELD RETAINERS ON EACH POST. PREVIOUS RETAINERS THAT FAILED DUE TO GAS TURBULANCE WERE RE-DESIGNED TO INCORPORATE A NEW CONFIGURATION (4).

(1) RSS-8572-9; (2) RS009122; (3) RS009142, (4) RS009144

SSME FMEA/CIL
INSPECTION AND TEST

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CIL Item:	A200-09	Approved:	T. Nguyen
Part Number:	RS009122	Approval Date:	9/9/99
Component:	Main Injector	Change #:	1
FMEA Item:	A200	Directive #:	CCBD ME3-01-5238
Failure Mode:	Interpropellant plate cracks.	Page:	1 of 2

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	BODY, MAIN INJECTOR		RS009138
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-153
		ALL TEST SAMPLES FROM EACH FORGING ARE SUBMITTED FOR MECHANICAL PROPERTIES AND GRAIN SIZE INSPECTION.	RB0170-153
		ROUGH MACHINED FORGING ARE ULTRASONICALLY INSPECTED FOR DEFECTS PER DRAWING REQUIREMENTS.	RS009136 RS009138
		FINISH MACHINED INJECTOR BODY IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		THE INJECTOR POST OUTER ROW IS PENETRANT INSPECTED ON O.D. AFTER THE INJECTOR ELEMENTS ARE INERTIA WELDED TO INSURE NO CRACKS.	RA0115-116
	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 RA0115-005 RA0115-127 RA1115-001
	HEAT TREAT	HEAT TREAT IS PERFORMED AND VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
		INTERPROPELLANT PLATE AND INJECTOR POSTS ARE PROOF PRESSURE TESTED	RS009120
	ASSEMBLY INTEGRITY	THE HOT FIRE TESTING AND 2ND E & M INSPECTIONS VERIFY PLATE INTEGRITY.	RLD0050-04 RLD0056-06 RLD0056-07
B	HEAT SHIELD HEAT SHIELD PROTECTOR RETAINERS		RS009142 RD075954 RS009144
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RB0170-136 RS009144 RS009142
	PROPER HEAT SHIELD INSTALLATION	THE HEAT SHIELD AND RETAINER INSTALLATION AROUND LOX POST ARE VERIFIED PER SPECIFICATION AND BLUEPRINT REQUIREMENTS	RS009122 RL00191
	PROPER O.D. RETAINER INSTALLATION	THE HEAT SHIELD O.D. RETAINER INSTALLATION IS VERIFIED AT THE POWERHEAD LEVEL. THE RETAINER TACK WELDS ARE INSPECTED VISUALLY WITH 3X MINIMUM MAGNIFICATION TO CLASS II WELD REQUIREMENTS EXCEPT PENETRANT IS NOT APPLICABLE.	RS009010 RL10011
		THE HEAT SHIELD IS INSPECTED AT THE FLOW SHIELD AREA FOR EVIDENCE OF DAMAGE PRIOR TO LAUNCH. (LAST TEST)	OMRSD V41BJD.040

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
Failure History	Comprehensive failure history data is maintained in the Problem Reporting database (PRAMS/PRACA) Reference: NASA letter SA21/88/308 and Rocketdyne letter 89RC09761.		
Operational Use	Not Applicable.		

SSME / ATDL
WELD JOINTS

Component Group: Combustion Devices
CIL Item: A200
Component: RS009122
Part Number: Main Injector
A200

Prepared: A. Kay
Approved: T. Nguyen
Approval Date: 9/9/99
Change #: 1
Directive #: CCBD ME3-01-5238

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
MAIN INJECTOR ASI	RSC0906*	3	GTAW	I		X	X	
MAIN INJECTOR ASI	RSC09061	5	GTAW	I		X	X	
MAIN INJECTOR	RS009126	1	EBW	I				
MAIN INJECTOR	RS009126	6,7,52,53	GTAW	I	X	X	X	
MAIN INJECTOR	RS009126	8	EBW	I		X		
MAIN INJECTOR	RS009126	9	EBW	I	X			
MAIN INJECTOR	RS009126	10	EBW	II	X	X	X	
MAIN INJECTOR	RS009126	12,13	GTAW	I	X			
MAIN INJECTOR	RS009126	14,15	GTAW	I	X	X	X	
MAIN INJECTOR	RS009126	16,17	GTAW	I		X	X	
MAIN INJECTOR	RS009126	20	GTAW	I	X			
MAIN INJECTOR	RS009126	21	GTAW	II	X			
MAIN INJECTOR	RS009126	22	GTAW	I	X			
MAIN INJECTOR	RS009126	23-29,54	GTAW	I	X			
MAIN INJECTOR	RS009126	44,45	GTAW	I		X	X	
MAIN INJECTOR	RS009126	50,51	EBW	Ia	X	X	X	
MAIN INJECTOR	RS009126	59	EBW	Ib	X			
MAIN INJECTOR	RS009126	60,61	GTAW	II	X	X		
INLET SHELL	RSC09235	1 LFT	EBW	I				
INLET SHELL	RSC09235	1 RHT	EBW	I		X	X	
INLET SHELL	RSC09237	600 PLCS	FRW	I	X			

SSME FMEA/CIL
FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE

Component Group: Combustion Devices
Item Name: Main Injector
Item Number: A200
Part Number: RS009122

Prepared: A. Kay
Approved: I. Nguyen
Approval Date: 9/9/99
Change #: 1
Directive #: CCBD ME3-01-5238

Base Line Rationale	Variance	Change Rationale	Variant Dash Number
1. A200-07 LOX ASI SLEEVE BRAZE IS X-RAYED AND BORESCOPED. (ECP 697)	NO BORESCOPE INSPECTION.	VISUAL VERIFICATION GAVE ADDITIONAL CONFIDENCE THAT BRAZING HAS NOT CREATED LIQUID METAL EMBRITTLEMENT. USE AS IS RATIONALE: 1. ALL SLEEVES ARE X-RAYED, WHICH SPECIFICALLY INSPECTS FOR LIQUID METAL EMBRITTLEMENT CRACKING; 2. JOINT SUSCEPTIBILITY IS LOW (NO STRAIN ON TUBE DURING WELDING, BRAZE MUST FLOW ONLY TO WITNESS HOLE).	-741, -751, -771, -761, -791, -801.
2. A200-06 WALL THICKNESS OF SECONDARY FACEPLATE RETAINERS INCREASED ON OUTER THREE ROWS. (ECP 634)	PREVIOUS CONFIGURATION HAD A THINNER WALL.	THICKER WALLS GAVE ADDITIONAL LOX POST SUPPORT IN THE HIGH FLOW AREAS. USE AS IS RATIONALE: 1. HIGH FLOW AREA POSTS WERE PLUGGED AND RODDED FOR ADDITIONAL SUPPORT; 2. LIFE LIMIT ON THE MAIN INJECTOR LOX POSTS PREVENTS DAMAGE LEVELS FROM EXCEEDING ALLOWABLE LIMITS. (DAR 1373)	-771
3. A200-06 EDDY CURRENT INSPECTION ON ALL LOX POST INERTIA WELDS. (ECP 842)	NO EDDY CURRENT INSPECTION OF INERTIA WELDS.	EDDY CURRENT INSPECTION PROVIDE ADDITIONAL CONFIDENCE IN INTERNAL WELD INTEGRITY. USE AS IS RATIONALE: 1. INERTIA WELDS ARE CONTROLLED BY SPECIFICATION; 2. NO FAILURE HISTORY WITH HAYNES 188 POSTS; 3. SURFACE FINISH IS CONTROLLED TO REDUCE STRESS CONCENTRATIONS; 4. ROW 13 POSTS ARE DYE PENETRANT INSPECTED ON O.D	-791, -751, -771, -781, -791, -801, -81[illegible] 861.
4. A200-07 ELIMINATION OF BRAZE JOINTS OF ASI INLET TUBE TO BLEED TUBES	BRAZED PREVIOUS CONFIGURATION	ELIMINATION OF BRAZE JOINT ELIMINATES THE POSSIBILITY OF LIQUID METAL EMBRITTLEMENT. USE AS IS RATIONALE: 1. BRAZE JOINTS ARE DONE WITHOUT INDUCED LOADS 2. NO RESIDUAL STRESSES IN TUBES. 3. SECTIONED HARDWARE SHOWS NO PROBLEMS	-741, -771, -781.
5. A200-07 SPLITTER VANE GEOMETRY IS VERIFIED PER CURRENT DRAWING REQUIREMENTS. (ECP 988R1)	SPLITTER VANE GEOMETRY DOES NOT MEET CURRENT DRAWING REQUIREMENTS.	RE-DESIGN OF THE SPLITTER VANE ALTERED THE STRUCTURAL RESPONSE OF THE VANES TO FLOW, ELIMINATING FLOW INDUCED CRACKING. USE AS IS RATIONALE: 1. ENGINES NOT MEETING CURRENT SPLITTER VANE DRAWING REQUIREMENTS ARE SCREENED AT GREEN RUN TO IDENTIFY THOSE EXHIBITING THE 4 KHz RESPONSE. THESE ENGINES ARE REWORKED TO CURRENT DRAWING REQUIREMENTS, RE-PRESSURE TESTED AND RE-IDENTIFIED.	-1021, -1141, -116[illegible], -1171, -120[illegible], -1301, -1311, -1321, -1361 -144[illegible]