SSME FMEA/CIL
REDUNDANCY SCREEN

Component Group:	Combustion Devices	Prepared:	A. Kay
CIL Item:	A200-07	Approved:	T. Nguyen
Part Number:	RS009122	Approval Date:	9/9/99
Component:	Main Injector	Change #:	2
FMEA Item:	A200	Directive #:	CCBD ME3-01-5238
Failure Mode:	External rupture.	Page:	1 of 1

Phase	Failure / Effect Description	Critically Hazard Reference
SVC 4.1	LOX and hot-gas leakage into the aft compartment will cause overpressurization and fire. Loss of vehicle. Redundancy Screens: SINGLE POINT FAILURE: N/A	I ME-B4S, ME-B4A,C, ME-B4M

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Design / Document Reference

FAILURE CAUSE: A: Weld or parent material failure.

THE OXIDIZER INLET HIGH PRESSURE CAVITIES AND INLET DUCT ARE CONSTRUCTED OF INCONEL 718. THE WEIGHT SAVINGS PROVIDED BY THE HIGH STRENGTH OF INCONEL 718 IS THE PRIMARY REASON FOR ITS SELECTION. INCONEL 718 IS DUCTILE AT CRYOGENIC TEMPERATURES (1). THE ENTIRE SUBASSEMBLY RECEIVES A HEAT TREAT TO GIVE IT FULL STRENGTH (2). A FATIGUE ANALYSIS WAS PERFORMED ON THE MAIN INJECTOR. THE ANALYSIS RESULTED IN CEI REQUIREMENTS BEING MET FOR HIGH CYCLE FATIGUE AND LOW CYCLE FATIGUE (3). MAIN INJECTORS WITH CAST INLET TEES ARE LIFE LIMITED BY MAJOR WAIVER (11). FACTORS OF SAFETY FOR PRIMARY STRESS SHOW ACCEPTABLE MARGINS MEETING CEI REQUIREMENTS (4). INCONEL 718 IS OXYGEN COMPATIBLE UNDER THESE CONDITIONS (5). ALL MATERIAL IS PROCURED TO SPECIFICATION REQUIREMENTS (6). THE CONFIGURATION OF THE OXIDIZER CAVITIES WAS SELECTED TO MOVE THE LOAD CONCENTRATION AWAY FROM THE WELD JOINT AND INTO PARENT MATERIAL. THE OXIDIZER INLET PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE IT CONTAINS NO FRACTURE CRITICAL PARTS (7). THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY THE WELD ASSESSMENT (8). 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 (8). THE BRAZE JOINTS ARE DONE IN A TEMPERATURE CONTROLLED FURNACE (1). THIS REDUCES THE POTENTIAL FOR LIQUID METAL EMBRITTLEMENT OR BRAZE DEFECTS. PREVIOUS PROBLEM AREAS AT THE THRUST CONE WITH LIQUID METAL EMBRITTLEMENT HAVE INSPECTIONS TO PRECLUDE THE PROBLEM DURING FABRICATION. STRAIN GAUGE AND ACCELEROMETER DATA HAVE BEEN OBTAINED DURING TESTING IN THE AREA OF THE OXIDIZER INLET SHELLS AND INLET TEE TO DETERMINE THE ENVIRONMENT AND STRAINS IN THIS AREA. CRITICAL WELDS ARE FLUSH GROUND TO MEET CEI REQUIREMENTS (10). EVALUATION OF THE OXIDIZER MANIFOLD FROM ENGINE 2010 REVEALED NO DEFECTS OR ANOMALOUS CONDITIONS (9).

(1) RSS-8572-9; (2) RS009128; (3) RL00532, CP320R0003D; (4) RSS-8546, CP320R0003B; (5) RSS-8571-9; (6) RB0170-153, RB0170-154, RB0170-155; (7) NASA TASK 117; (8) RSS-8755; (9) I.L. CD 88-1042; (10) ECP 967, RS009126; (11) DAR 2221.

FAILURE CAUSE: B: Splitter failure.

SPLITTER VANE CRACKING IS ASSOCIATED WITH FLOW INDUCED VIBRATION. HOT FIRE TESTING IS CONDUCTED TO IDENTIFY ENGINES WHICH EXHIBIT THIS PHENOMENON (1). THESE UNITS ARE SUBJECT TO SPLITTER VANE MODIFICATION AND RE-PRESSURE TEST (2). THE PRESENT DESIGN OF THE SPLITTER VANE WAS SELECTED TO ELIMINATE THE 4kHz FLUID STRUCTURAL COUPLING MECHANISM WHICH, IN SOME CASES, HAD PREVIOUSLY RESULTED IN UNACCEPTABLY HIGH LEVELS OF VIBRATION AND EVENTUAL SPLITTER VANE CRACKING. EXTENSIVE ANALYSIS HAS BEEN PERFORMED ON THE MODIFIED SPLITTER SHOWING INFINITE LIFE AND ADEQUATE FACTORS OF SAFETY (2).

(1) RL00050-04, (2) ECP 989, R0017622

FAILURE CAUSE: ALL CAUSES

THE MAIN INJECTOR HAS COMPLETED DVS TESTING (1).

(1) DVS-333

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SSME FMEA/CIL
INSPECTION AND TEST

Component Group:	Combustion Devices	Prepared:	A. Kay
CIL Item:	A200-07	Approved:	T. Nguyen
Part Number:	RS009122	Approval Date:	9/9/99
Component:	Main Injector	Change #:	2
FMEA Item:	A200	Directive #:	CCBD ME3-01-5239
Failure Mode:	External rupture.	Page:	1 of 2

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	INLET FLANGE		RS009146
	INLET ELBOW		RS009147
	INLET CAP		RS009423
	INLET CAP		RS009154
	INJECTOR ASSEMBLY		RS009122
	OXIDIZER SHELLS		RS009235
	TORUS STRUCTURE		RS009145
	BASE		RS009124
	TEE		RS009234
	ASI LINE		RS007179
	IGNITER ASSEMBLY		RS009061
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-153 RB0170-174 RB0170-154 RB0170-155 RB0170-213
		ASI TUBING IS INSPECTED ULTRASONICALLY AND THE O.D. IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS	RB0170-213
		INLET TEE, SHELLS, AND ORIFICES ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	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.	RL10011 RA0607-094 RA0115-116 RA0115-005 RA0115-127 RA1115-001
		THE OXIDIZER TORUS WELDS ARE INSPECTED PRIOR TO AND AFTER E.B. WELDING TO ASSURE CORRECT E. B. WELD TRACKING AND PENETRATION (INCLUDING BORING, ETCH, PENETRANT, AND PLUG WELDING).	RL00261
		THE WELD 55 AND 55 BRAZE JOINTS ARE INSPECTED VISUALLY, RADIOGRAPHICALLY, AND BORESCOPED PER DRAWING REQUIREMENTS. RADIOGRAPHIC INSPECTION PROVIDES 90% COVERAGE. LIKE DEFECTS ARE DETECTABLE WITH 90% COVERAGE DUE TO FLAW SIZE BEING GREATER THAN 10%.	RS009126 RA0107-009 RA0115-006
		RS009061 WELD 1 IS VISUALLY INSPECTED FOR BRAZE FLOW AND LEAK CHECKED AFTER FURNACE BRAZING.	RA1507-009
		WELD 16 GEOMETRY (RADIUS BETWEEN WELD BEAD AND INLET TEE) IS VERIFIED PER DRAWING REQUIREMENTS.	RS009126 ECP 967
		OXIDIZER INLET SHELLS AND THE TORUS AREAS ARE INSPECTED FOR CORRECT CONTOUR AFTER WELDING.	RS009126

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
ALL CAUSES	ASSEMBLY INTEGRITY	THE OXIDIZER MANIFOLD IS PROOF PRESSURE TESTED, LEAK CHECKED, AND PENETRANT INSPECTED PRIOR TO THRUST CONE INSTALLATION PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS009125 RL00127 RA0116-115
		ASI IS PROOF PRESSURE AND LEAK TESTED PER SPECIFICATION AND DRAWING REQUIREMENTS ASI WELDS ARE PENETRANT INSPECTED AFTER PROOF TEST PER SPECIFICATION REQUIREMENTS.	
		THE HOT FIRE TESTING AND 2ND E & M INSPECTIONS VERIFY INJECTOR INTEGRITY.	RL00050-04 RL00056-06 RL00056-07
		THE HELIUM SIGNATURE LEAK TESTING VERIFIES NO EXTERNAL LEAK OR RUPTURE	OMRSD S00000.950
		THE INJECTOR IS VISUALLY INSPECTED EXTERNALLY PRIOR TO EACH LAUNCH. (LAST INSPECTION)	OMRSD V41BL0.023
8	TEE		RS009234
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS	RB0170-155
		FOUR TENSILE BARS ARE FORMED WITH EACH CASTING TO ASSURE CORRECT MATERIAL TYPE AND STRENGTH.	RS009234
		TEE AND SPLITTER ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0116-116
		SPECIAL CASTING X-RAYS ARE PERFORMED PER STANDARD AND CRITICAL GRADE REQUIREMENTS AS DETAILED ON THE DRAWING	RP0091-001 RS009234
		TEE WITH SPLITTER IS HEAT TREATED WITH INJECTOR ASSEMBLY PER SPECIFICATION REQUIREMENTS.	RA0611-020
	ABSENCE OF HIGH VIBRATIONAL LOADING	SPLITTER VANE GEOMETRY IS VERIFIED PER CURRENT DRAWING REQUIREMENTS	RS009122 ECP 559R1
		GIMBAL ACCELEROMETERS AND STRAIN GAUGES DETECT HIGH VIBRATIONAL LOADING DURING HOT FIRE ACCEPTANCE TESTING AND SCREEN UNACCEPTABLE UNITS OUT.	RL00050-04 RL00461
		ENGINE GIMBAL ACCELEROMETER DATA FROM THE PRIOR FLIGHT IS REVIEWED TO DETECT HIGH VIBRATIONAL LOADS	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 88RC0976

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]