

~~SINGLE POINT FAILURE~~
REDUNDANCY SCREEN

Component Group: Combustion Devices
 CIL Item: A330-02
 Part Number: RS009105
 Component: Main Combustion Chamber
 FMEA Item: A330
 Failure Mode: Fuel leaks into the closed cavity between the liner and structural jacket.

Prepared: A. El-Ahmad
 Approved: T. Nguyen
 Approval Date: 5/9/99
 Change #: 2
 Directive #: CCBD ME3-01-5238

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Phase	Failure / Effect Description	Criticality Hazard Reference
SMC 4.1	Leakage into the closed cavity causes burst diaphragm rupture, venting the cavity into the engine fuel drain system. Excessive leakage causes deformation of the liner in the divergent section. Significant changes in the exhaust gases flow produces a strong shock at the downstream nozzle wall. Tube failures cause loss of fuel to the preburners and high turbine temperatures. Cavity overpressurization causes rapping of welds, sudden loss of fuel, engine failure, and aft compartment overpressurization and fire. Loss of vehicle.	1 MF-145S, ML B5M ME-E5A,C
Redundancy Screen: SINGLE POINT FAILURE N/A		

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Component/ p: Combustion Devices
CIL Item: A330-02
Part Number: RS009105
Component: Main Combustion Chamber
FMEA Item: A330
Failure Mode: Fuel leaks into the closed cavity between the liner and structural jacket.

Prepared: A. Li-AM
Approved: T. Nguye.
Approval Date: 9/9/99
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Design / Document Reference

FAILURE CAUSE: C. Fracture of manifold to liner welds.

THE TWO WELD JOINTS THAT MAY CAUSE INTERNAL LEAKAGE ARE WELD JOINT 10 ON THE INLET AND WELD 15 ON THE OUTLET. INCONEL 625 WAS SELECTED FOR WELD 10 DUE TO ITS WELDABILITY AND COMPATIBILITY WITH EACH BASE METAL AND ITS STRENGTH (1). THE WELD PREPARATION OF THE JOINT IS SPECIFIED PER DRAWING REQUIREMENTS (2)(3). WELD JOINT 10 IS NOT SUSCEPTABLE TO HYDROGEN EMBRITTLEMENT DUE TO LOW OPERATING TEMPERATURES (4). WELD JOINT 15 USES NICKEL 611 OR THE WELD MATERIAL BECAUSE OF ITS COMPATIBILITY WITH INCONEL 718, THE NICKEL BASE, AND INCOLOY 903. JOINT 15 IS PRE-HEATED PRIOR TO WELDING AND IS MADE IN SEVERAL SEGMENTS TO PRECLUDE POST WELD SHRINKAGE RESULTING IN RESIDUAL STRESSES. THE WELD PREPARATION IS SPECIFIED ON THE DRAWINGS (2) (5). JOINT 15 IS PROTECTED FROM HYDROGEN EMBRITTLEMENT BY COPPER PLATING (6). THE PLATING IS CONTROLLED FOR COVERAGE AND ADHESION BY SPECIFICATION (7). THE PRIMARY STRESS FACTORS OF SAFETY MEET CEI REQUIREMENTS (8). THE JACKET SIDE OF WELD 15 IS PROTECTED FROM HYDROGEN EMBRITTLEMENT BY AN INCOLOY 903 OVERLAY (8). RELIEF GROOVES ON BOTH SIDES OF WELD 15 REDUCE THE STRESS LEVELS IN THE WELD MATERIAL AND PREVENT OXIDATION OF THE ELECTRODEPOSITED NICKEL OR NICKEL 61 OVERLAY (2)(9). HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE WELDS MEET CEI REQUIREMENTS (10). THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/IDE FLAW GROWTH BY THE WELD ASSESSMENT (11). TABLE A330 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 (11). THE WELDS HAVE BEEN DESIGN VERIFICATION TESTED FOR STRUCTURAL LOADS (12)

(1) 572K-2; (2) RS009105; (3) RSC09109; (4) RSS-8574-8; (5) RS009109; (6) RS009105; (7) RA1109-002; (8) RSS-8546, CP320R0003B; (9) RS009112; (10) RL00522, CP320R0003B; (11) RSS-0755; (12) RSS-303-33

FAILURE CAUSE: ALL CAUSES

THE MCC HAS COMPLETED DVS TESTING (1). THE MCC INCORPORATES A VENT LINE TO ALLOW PASSAGE OF GASES FROM THE CLOSED LINER/JACKET AREA OUT THE REAR OF THE VEHICLE. HOT-FIRE TESTING OF ENGINE 0213 WITH A KNOWN LEAK INTO THE MCC LINER CAVITY HAS VERIFIED THE FUNCTION AND STRUCTURAL INTEGRITY OF THE BURST DIAPHRAGM AND VENT DRAIN LINE SYSTEM. THE MCC BURST DIAPHRAGM VENT SYSTEM MAINTAINED A GREATER THAN 1.4 FACTOR OF SAFETY FOR START AND MAINSTAGE AND A 1.14 FACTOR OF SAFETY IS MAINTAINED FOR CUTOFF. THE CRITICAL CUTOFF PHASE TIMING IS FROM CUTOFF COMMAND TO +1.5 SECONDS AFTER THIS TIME LACK OF OXIDIZER AND DECREASING ENGINE POWER LEVELS ELIMINATES POTENTIAL UNCONTAINED MCC FAILURES (2).

(1) DVS-303; (2) IL CD-89-NOZ-001

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**SSME FMEA/CIL
DESIGN**

Component Group: Combustion Devices
CIL Item: A330-02
Part Number: RS009106
Component: Main Combustion Chamber
FMEA Item: A330
Failure Mode: Fuel leaks into the closed cavity between the liner and structural jacket.

Prepared: A. El-Ahmad
Approved: T. Nguyen
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Design / Document Reference

FAILURE CAUSE: A: Failure in EDNi liner closeout structure caused by long liner inner wall crack(s).

THE PRE-START PURGE MINIMIZES THE POSSIBILITY OF ICE FORMATION IN COOLANT PASSAGE. THE COOLANT PASSAGES ARE DESIGNED SUCH THAT MINOR REDUCTION IN COOLANT FLOWRATE CAN BE SUSTAINED WITHOUT FAILURE OF THE HOT-GAS WALL. COOLANT HOLES IN THE INJECTOR FACEPLATE PROVIDE COOLANT TO REDUCE THE POSSIBILITIES OF OVERHEATING OF THE MCC WALLS (1). CRACKS IN THE HOT GAS WALL GROW SLOWLY DUE TO INCREASED COOLANT BEING LOCALLY DUMPED THROUGH THE CRACK. USAGE LIMITS FOR MCC HOT WALL CRACKS HAVE BEEN ESTABLISHED. USAGE LIMITS ARE DEFINED BY SPECIFICATION (2). CHANNEL CRACKS, PIN HOLES, BLISTERS, AND SURFACE CRACKING ARE ACCEPTABLE. CRACKS IN EXCESS OF TEN AFFECTED CHANNELS GREATER THAN 3 INCHES LONG EXHIBITING PARENT MATERIAL LOSS ARE NOT ACCEPTABLE. NARLOY-Z IS USED AS THE COMBUSTION CHAMBER HOT GAS WALL MATERIAL BECAUSE OF ITS ABILITY TO RESIST THERMAL STRAINS GENERATED DURING TEST. IT EXHIBITS EXCELLENT THERMAL CONDUCTIVITY, THERMAL FATIGUE, AND STRENGTH AT ELEVATED TEMPERATURES (3). CHANNEL PASSAGES ARE DESIGNED TO ALLOW PASSAGE OF PARTICLES UP TO 0.040. THE CRITICAL REGIONS OF THE HOT-GAS WALL ARE POLISHED TO A 15 MICRON INCH SURFACE FINISH TO MAINTAIN LAMINAR FLOW AND REDUCE ROUGHENING OF THE SURFACE (4). ELECTRODEPOSITED NICKEL WAS SELECTED AS THE STRUCTURAL CLOSEOUT MATERIAL BECAUSE OF ITS GOOD STRENGTH AND SUITABILITY IN PROVIDING A TRANSITION METAL FOR WELDING THE JACKET TO THE LINER (5). IT HAS A BARRIER OF ELECTRODEPOSITED COPPER WHICH PROVIDES HYDROGEN EMBRITTLEMENT PROTECTION FOR THE ELECTRODEPOSITED NICKEL (6). A PRIMARY STRESS FACTOR OF SAFETY MEET CEI REQUIREMENTS (7). HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE LINER MEET CEI REQUIREMENTS (8). THE LINER PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NOE FLAW GROWTH SINCE IT CONTAINS NO FRACTURE CRITICAL PARTS (9). THE LINER HAS BEEN DESIGN VERIFICATION TESTED FOR THERMAL FATIGUE RESISTANCE OF NARLOY (10), COOLANT PASSAGE RESTRICTION (11), LINER LIFE (12), AND COOLING REQUIREMENTS (13). NARLOY-Z CRACKS ARE AN OFF-DESIGN CONDITION AND ARE DISPOSITIONED INDIVIDUALLY BY MATERIAL REVIEW ACTION. MAIN COMBUSTION CHAMBER 9002 HAS COMPLETED 72 MAINSTAGE TESTS PRIOR TO LINER COLD WALL CRACK INITIATION AND AFTER THE FORMATION OF A 1.5-INCH LONG NARLOY-Z CRACK. MAIN COMBUSTION CHAMBER UNIT 0307 DEMONSTRATED 41 TESTS WITH A 7-INCH LONG NARLOY-Z CRACK PRIOR TO RETIREMENT. THE DESTRUCTIVE INSPECTION OF UNIT 0307 DID NOT REVEAL ANY CRACKS IN THE LINER COLD WALL SIDE. EXTENSIVE OPERATING HISTORY OF MAIN COMBUSTION CHAMBERS SHOWING EVIDENCE OF HOT-GAS INTRUSION INTO CHANNELS WITH LONG CRACKS.

(1) RS009140; (2) RL00050-04, RF0001-052, (3) RSS-8574-8; (4) RS009107, (5) MPTR-71-175-302; (6) SSME 72-1328; (7) RSS-8546 CP320R0003B; (8) RL00532, CP320R0003B; (9) NASA TASK 117; (10) RSS-303-2; (11) RSS-303-21; (12) RSS-303-28; (13) RSS-303-32

FAILURE CAUSE: B: Jacket EB closeout weld overpenetration into ED-Ni liner.

ELECTRON BEAM BACK-UP STRIPS PROVIDE PROTECTION AGAINST OVERPENETRATION OF EB CLOSEOUT WELDS INTO THE ELECTRODEPOSITED NICKEL LINER (1). THE EB WELD PROCESS GIVES EXCELLENT UNIFORM WELDING WITH CONTROLLED PENETRATION. THE WELDING PROCESS ENTAILS SAMPLE SPECIMENS AND CONTROLLED PARAMETERS PER SPECIFICATION REQUIREMENTS (2).

(1) RS009112, (2) RA0607-054

**SSMC FUEL CELL
INSPECTION AND TEST**

Component Group: Combustion Devices
 CIL Item: A330-02
 Part Number: RS009105
 Component: Main Combustion Chamber
 FMEA Item: A330
 Failure Mode: Fuel leaks into the closed cavity between the liner and structural jacket.

Prepared: A. El-Ahmad
 Approved: T. Nguyen
 Approval Date: 07/99
 Change #: 2
 Directive #: CCBD ME3-01-5238

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	LINER, SLOTTED		RS009105
	E.D. COPPER CLOSEOUT AND BOND	HOT WATER IMMERSION TEST CHECKS FOR PLATING DEFECTS. THE ELECTRODEPOSITED COPPER AND ELECTRODEPOSITED NICKEL SPECIMENS ARE EXAMINED FOR CONFORMANCE PER SPECIFICATION REQUIREMENTS. A PROOF PRESSURE TEST IS PERFORMED AFTER ELECTRODEPOSITED NICKEL PLATING. A MASS SPEC LEAK TEST IS PERFORMED AFTER CHAMBER PROOF TEST.	RA1109-018 RL00228 RL00551
B	ELECTRON BEAM WELD OVER PENETRATION	EB WELD SAMPLES MADE PRIOR TO ACTUAL WELD. VERIFY CORRECT WELD PENETRATION AND SETUP. AN ULTRASONIC INSPECTION CHECKS THE WELD QUALITY. THE PROCEDURE AND PENETRATION IS CHECKED PER WELD SPECIFICATION. RS009105 WELDS 5, 6, 7, 16, 39, 40.	RA0607-094 RL00225 RA0115-012 RL00257 RA0115-116 RL00260 RL00482
	WELD INTEGRITY	A MASS SPEC LEAK CHECK IS PERFORMED FOLLOWING PROOF PRESSURE TEST. ALL WELDS ARE INSPECTED TO DRAWING AND SPECIFICATION REQUIREMENTS PER WELD CLASS. INSPECTIONS INCLUDE: VISUAL, DIMENSIONAL, PENETRANT, RADIOGRAPHIC, ULTRASONIC, AND FILLER MATERIAL, AS APPLICABLE. SPECIAL INSPECTIONS PER SPECIFICATIONS OF JACKET EB WELDS 5, 6, 7, 16, 39, & 40 ARE PERFORMED (INCLUDING BORING, ETCH, PENETRANT, AND WELD FILL).	RL00501 RL10011 RA0607-094 RA0115-116 RA0115-000 RA0115-127 RA1115-001 RL00257 RL00260 RL00482 RL00255
C	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. UNVERIFIABLE ROOT WELDS ARE INSPECTED PER DRAWING AND SPECIFICATION REQUIREMENTS AS APPLICABLE.	RL10011 RA0607-094 RA0115-116 RA0115-000 RA0115-127 RA1115-001
	UNVERIFIABLE ROOT WELDS RS009105 WELDS CLASS II - 10, 15	WELD 15 IS CLEANED AND VISUALLY INSPECTED USING 3X MAGNIFICATION OR GREATER AFTER EACH WELD PASS. EACH WELD PASS IS PEENED FOR STRESS RELIEF. INSPECTION HOLES ARE MADE IN COMPLETED WELD TO ASSURE ADEQUATE PENETRATION, THEN FILLED. WELD 10 ROOT PASS IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS. COMPLETED WELD JOINTS ARE LEAK TESTED PER SPECIFICATION REQUIREMENTS. MCC ASSEMBLY IS PROOF PRESSURE TESTED PER SPECIFICATION REQUIREMENTS.	RS009105 RA0115-115 RL00167 RL00501

Component Group: Combustion Devices
 CIL Item: A330-02
 Part Number: RS009105
 Component: Main Combustion Chamber
 FMEA Item: A330
 Failure Mode: Fuel leaks into the closed cavity between the liner and structural jacket.

Approved: T. Nguyen
 Approval Date: 9/8/93
 Change #: 2
 Directive #: CCBD ME3-01-5238

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
C	WELD INTEGRITY	A MASS SPEC LEAK TEST IS PERFORMED POST PROOF TEST.	RL00501
	UNVERIFIABLE ROOT WELDS R009016 WELDS CLASS II - 10,15		
	COPPER PLATE OVERLAY ON WELD #5	PLATING IS INSPECTED FOR COVERAGE AND ADHESION PER SPECIFICATION REQUIREMENTS	RA1109-002
ALL CAUSES	ASSEMBLY INTEGRITY	THE HOT FIRE TESTING AND 2ND E & M INSPECTIONS VERIFY LINER AND WELD INTEGRITY.	RL00050-04 RI 00056-06 RL00056-07
		MCC HOT-GAS WALL IS INSPECTED AFTER EACH LAUNCH FOR CRACKS.	OMRSD V41BU0.029
		A BURST DIAPHRAGM INSPECTION IS PERFORMED AFTER HOT-FIRE FOR POSSIBLE PRESSURIZATION DUE TO LEAKAGE (LAST TEST)	RL00050-04 RL00056-06 RL00056-07
		A BURST DIAPHRAGM LEAK CHECK IS PERFORMED PRIOR TO EACH FLIGHT.	OMRSD V41BU0.240

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Failure History: Comprehensive failure history data is maintained in the Problem Reporting database (PRAMS/PRACA).
 Reference: NASA letter SA21/88/308 and Rockwell letter 88RCC9751.
 Operational Use: Not Applicable

**SSME I A/CIL
WELD JOINTS**

Component Group: Combustion Devices
 CIL Item: A330
 Component: RS009105
 Part Number: Main Combustion Chamber
 A330

Prepared: A. El-Ahmad
 Approved: T. Nguyen
 Approval Date: 9/9/99
 Change #: 1
 Directive #: CCBD MC3 01-5239
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Component	Basic Part Number	Weld Number	Weld Type	Class	Critical Initial		Comments
					Root Size Not Access	Flaw Size Not Detectable	
					HCF	LCF	
MAIN COMBUSTION CHAMBER	RS009105	5	EBW	Ia	X	X	
MAIN COMBUSTION CHAMBER	RS009105	6,7	EBW	Ib	X	X	
MAIN COMBUSTION CHAMBER	RS009105	58,59	EBW	Ia	X	X	
MAIN COMBUSTION CHAMBER	RS009105	10	GTAW	I	X	X	X
MAIN COMBUSTION CHAMBER	RS009105	11,12,13,14	GTAW	II	X	X	X
MAIN COMBUSTION CHAMBER	RS009105	15	GTAW	II	X	X	
MAIN COMBUSTION CHAMBER	RS009105	16	ESW	Ia	X	X	X
MAIN COMBUSTION CHAMBER	RS009105	18	ESW	I	X		
MAIN COMBUSTION CHAMBER	RS009105	22	PAW	II	X		
MAIN COMBUSTION CHAMBER	RS009105	23	PAW	II	X		
MAIN COMBUSTION CHAMBER	RS009105	24,26	EBW	I			
MAIN COMBUSTION CHAMBER	RS009105	25	EBW	I			
MAIN COMBUSTION CHAMBER	RS009105	39,40	EBW	I	X	X	
MAIN COMBUSTION CHAMBER	RS009105	41-44,69,70	GTAW	II	X		
MAIN COMBUSTION CHAMBER	RS009105	55,56	EBW	I	X		
MAIN COMBUSTION CHAMBER	RS009105	65	GTAW	II	X		
MAIN COMBUSTION CHAMBER	RS009105	68	GTAW	II	X	X	
LINER	RS009105	1	GTAW	II	X	X	X
MCC INLET MANIFOLD	RS009109	1,9,12	GTAW	I	X	X	
MCC INLET MANIFOLD	RS009109	2,3	GTAW	I	X	X	
MCC INLET MANIFOLD	RS009109	6-8	EBW	Ib	X		
MCC INLET MANIFOLD	RS009109	10	GTAW	I	X	X	
MCC INLET MANIFOLD	RS009109	11,13	GTAW	I		X	
MCC INLET MANIFOLD	RS009109	14	GTAW	I	X		
MCC INLET MANIFOLD	RS009109	15	GTAW	I	X	X	
MCC INLET MANIFOLD	RS009109	16	GTAW	I		X	
MCC INLET MANIFOLD	RS009109	17	GTAW	I			
MCC OUTLET MANIFOLD	RS009110	1	GTAW	I		X	X
MCC OUTLET MANIFOLD	RS009110	2	GTAW	I		X	X
MCC OUTLET MANIFOLD	RS009110	3,4	GTAW	I			
MCC OUTLET MANIFOLD	RS009110	5,6	GTAW	I	X	X	X

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Component Group: Combustion Devices
 CIL Item: A330
 Component: RS009105
 Part Number: Main Combustion Chamber
 A330

Approved: T. Nguyen
 Approval Date: 5/5/99
 Change #: 1
 Directive #: CCB0 ME3-01-5238
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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	
MCC OUTLET MANIFOLD	RS009110	9	GTAW	I	X	X		
MCC OUTLET MANIFOLD	RS009110	10	GTAW	I	X	X		
MCC OUTLET MANIFOLD	RS009110	22	GTAW	I				
MCC OUTLET MANIFOLD	RS009110	24-27	GTAW	I	X	X		
MCC OUTLET MANIFOLD	RS009110	30	GTAW	I				
MCC OUTLET ELBOW	RS009497	1,2	GTAW	I		X		
MCC OUTLET ELBOW	RS009497	10	GTAW	I				
MCC OUTLET ELBOW	RS009497	3	GTAW	I				
MCC OUTLET ELBOW	RS009497	11	GTAW	I				
MCC OUTLET ELBOW	RS009497	4	GTAW	I		X		
MCC OUTLET ELBOW	RS009497	5	GTAW	I				
MCC OUTLET ELBOW	RS009497	9,12	GTAW	I	X	X	X	
MCC OUTLET ELBOW	RS009497	8,13	GTAW	I	X	X	X	
MCC OUTLET ELBOW	RS018262	3	GTAW	I		X	X	COMPLETED WELD ASSESSMENT REQUIRED
MCC INLET NECK	RS009499	1,2	GTAW	I	X	X	X	
MCC INLET NECK	RS009499	3,4	GTAW	I		X	X	

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SSME FMEA/CIL
FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE

Component Group: Combustion Devices
 Item Name: Main Combustion Chamber
 Item Number: A330
 Part Number: RS009105

Prepared: A. ElAhmad
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Base Line Rationale	Variance	Change Rationale	Variant Dash Number
1. A330-04 OUTLET MANIFOLD PROOF PRESSURE TESTED TO 7 875 PSIG (ECP 830)	OUTLET MANIFOLD PROOF TESTED TO 6 600 PSIG.	HIGHER PRESSURE ENHANCED CONFIDENCE IN PROOF PRESSURE TEST EFFECTIVITY. USE AS IS RATIONALE ALL UNITS RE-PENETRANT INSPECTED AND RE-XRAYED USING SPECIAL HIGH SENSITIVITY TECHNIQUES.	-351, -371, 401, -431 -441 -451

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