SSME FMEA/CIL
REDUNDANCY SCREEN

Component Group:	Combustion Devices	Prepared:	A. El-Ahmad
CIL Item:	A330-03	Approved:	T. Nguyen
Part Number:	RS009105	Approval Date:	9/9/99
Component:	Main Combustion Chamber	Change #:	1
FMEA Item:	A330	Directive #:	CCBD ME3-01-523E
Failure Mode:	Internal rupture at the MCC nozzle interface.		
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Phase	Failure / Effect Description	Criticality Hazard Reference
SMC 4.1	Fuel leakage at the internal interface is dumped into the main exhaust gases. Loss of fuel to the LPFTP results in HPFTP cavitation, LOX-rich operation, and engine failure. Loss of vehicle. Redundancy Screens SINGLE POINT FAILURE: N/A	1 ME-B5S, ME-B5M ME-B5A,C

SSME FMEA/CIL
DESIGN

Component Group:	Combustion Devices	Prepared:	A. El-Ahmad
CIL Item:	A330-03	Approved:	T. Nguyen
Part Number:	RS009105	Approval Date:	9/9/99
Component:	Main Combustion Chamber	Change #:	1
FMEA Item:	A330	Directive #:	CCBD ME3-01-5238
Failure Mode:	Internal rupture at the MCC nozzle interface.	Page:	1 of 1

Design / Document Reference

FAILURE CAUSE: A: Delamination of the nickel plating at the aft end of the MCC.

THE LINER IS CONSTRUCTED OF NARLOY-Z, A COPPER BASE ALLOY DEVELOPED SPECIFICALLY FOR HIGH HEAT FLUX APPLICATIONS. NARLOY-Z WAS CHOSEN FOR ITS THERMAL CONDUCTIVITY AND IS COOLED BY COOLANT CHANNELS MACHINED ON THE BACK OF THE COMBUSTION WALLS (1). THE NARLOY-Z IS CLOSED OUT WITH A COPPER BARRIER AND A NICKEL OUTER JACKET. THE ELECTRODEPOSITED PROCESS IS CONTROLLED BY SPECIFICATIONS FOR PROPER ADHESION (2). ELECTRODEPOSITED NICKEL WAS CHOSEN FOR CLOSEOUT OF THE LINER BECAUSE OF ITS STRENGTH AND SUITABILITY IN PROVIDING A TRANSITION BETWEEN THE LINER AND JACKET (3). THE BONDLINE LENGTH IS DESIGNED TO PROVIDE ADEQUATE STRUCTURAL MARGIN AT THE AFT END OF THE LINER. PRIMARY STRESS FACTORS OF SAFETY MEET CEI REQUIREMENTS (4). THE NARLOY-Z IS CLOSED OUT WITH AN ELECTRODEPOSITED COPPER BARRIER WHICH PROVIDES HYDROGEN EMBRITTLEMENT PROTECTION AND A NICKEL OUTER JACKET FOR STRUCTURAL STRENGTH (1). THE BONDLINE BETWEEN THE NARLOY-Z COPPER AND NICKEL IS DESIGNED TO PREVENT DELAMINATION DUE TO STRUCTURAL LOADING. THE ENDS OF THE COOLANT CHANNELS ARE RADIUSED TO REDUCE LOADING AT THE BONDLINE (5). THE NARLOY-Z AND ELECTRODEPOSITED NICKEL THICKNESS IS INCREASED AT THE AFT END TO PROVIDE RIGIDITY AND REDUCE STRESS VALUES (6). THE ELECTRODEPOSITION PROCESS IS CONTROLLED BY SPECIFICATION FOR BONDING AND INTEGRITY (2). THE SSME BONDLINE FAILURE MARGIN HAS BEEN DEMONSTRATED BY HOT-FIRE TESTING (7). FIVE ENGINES HAVE DEMONSTRATED HOT-FIRE TIME WITH 6 DISBONDS WITH NO EFFECT TO ENGINE PERFORMANCE OR STRUCTURAL INTEGRITY. ONE OF THESE ENGINES WAS HOT-FIRED 3 ADDITIONAL TIMES AFTER A DISBOND WAS DISCOVERED WITHOUT ANY EVIDENCE OF DISBOND PROPAGATION. BASED ON THE FLAW GEOMETRY OF THREE ENGINES WHICH LEAKED DURING HOT-FIRE TESTING, A CALCULATED 1.32 LBS/SEC WORST CASE LEAKAGE WAS DETERMINED. TEST HISTORY HAS PROVEN THAT MAINSTAGE OPERATION IS ACCEPTABLE WITH BONDLINE LEAKAGE OF THIS MAGNITUDE. PERFORMANCE ANALYSIS INDICATES THAT 22.2 LBM/SEC MCC BONDLINE LEAKAGE IS REQUIRED TO EXCEED THE HPOT TURBINE DISCHARGE TEMPERATURE REDLINE. LEAKAGE OF THIS MAGNITUDE WOULD CORRESPOND TO A 25 INCH LONG FAILURE (OR 33.6% OF THE TOTAL BONDLINE LENGTH) (7). HOWEVER, ACCELERATED DEGRADATION OF THE MCC HOT GAS WALL IS EXPECTED PRIOR TO REACHING THIS AMOUNT OF FUEL LEAKAGE. BASED ON RECENT TESTING ON ED213, A COOLANT LOSS OF 7 LBM/SEC IS EXPECTED TO BE SUFFICIENT TO DAMAGE THE MCC. THIS CORRESPONDS TO A 7.96 INCH BOND LINE FAILURE (OR 10.7% OF THE TOTAL BONDLINE LENGTH). BONDLINE FAILURES OF THIS LENGTH ARE NOT EXPECTED BECAUSE OF PROOF PRESSURE TEST SCREENING FOR GROSS BOND DEFICIENCIES AND THE HOT-FIRE BONDLINE FAILURE HISTORY. HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE LINER MEET CEI REQUIREMENTS (8). THE LINER PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE IT CONTAINS NO FRACTURE CRITICAL PARTS (9). THE LINER HAS BEEN DESIGN VERIFICATION TESTED FOR LINER LIFE AND STRUCTURAL LOADING REQUIREMENTS (10). DISASSEMBLY RESULTS OF ENGINE 2010 REVEALED NO INDICATIONS OF DELAMINATION.

(1) RSS-8574-8; (2) RA1509-018 (3) MPTR-71 175 302. (4) RSS-8546 CP320R0003B; (5) RS009107; (6) RS009105; (7) CD 90 NOZ-0005/ FRR-96-011; (8) RL00532, CP320R0003B; (9) NASA TASK 117; (10) RSS-303-33 RSS-303-34

FAILURE CAUSE: B: Weld failures at the turnaround manifold of the liner.

THE TURNAROUND MANIFOLD INCORPORATES FOUR WELDS ON THE CLOSURE RING. TWO CIRCUMFERENTIAL WELDS (11,12) AND TWO SHORT CONNECTING WELDS (13,14) THAT JOIN THE BASE RING HALVES. THE WELD PREPARATIONS ARE SPECIFIED ON THE DRAWINGS (1),(2), (3). THE INLET TEMPERATURES OF THE MANIFOLD PROTECT THE SUBASSEMBLIES AND WELDS FROM HYDROGEN EMBRITTLEMENT (4). THE WELD PREPARATION AND PROCESS IS CONTROLLED PER SPECIFICATION PARAMETERS (5). NICKEL 61 FILLER IS USED FOR WELDS 11 AND 12 BECAUSE OF ITS COMPATIBILITY WITH ARMCO 21-6-9 CRES AND THE NICKEL BASE. WELD JOINTS 13 AND 14 ARE MADE FROM INCONEL 625. THE PRIMARY FACTORS OF SAFETY MEET CEI REQUIREMENTS (6). THE PARENT MATERIAL ADJACENT TO THE ROOT PREP IS RADIUSED TO REDUCE THE LOADING ON THE CLOSEOUT RING (1) (7). THE FACE SIDE OF THE WELDS AND RING IS MACHINED FLUSH TO REDUCE SURFACE STRESS RISERS (2). HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE WELDS MEET CEI REQUIREMENTS (8). THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY THE WELD ASSESSMENT (9). 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 (9). THE CHAMBER HAS BEEN DESIGN VERIFICATION TESTED FOR LINER LIFE AND STRUCTURAL REQUIREMENTS (10).

(1) RS009106; (2) RS009105 (3) RS009109; (4) RSS-8574-8; (5) RL10011; (6) RSS-8546, CP320R0003B; (7) RS009109 (8) RL00532, CP320R0003B (9) RSS-8756, (10) RSS-303-28, RSS-303-33, RSS-303-34

SSME FM[illegible]CIL
INSPECTION AND TEST

Component Group:	Combustion Devices	Prepared:	A. El-Ahmad
CIL Item:	A330-03	Approved:	T. Nguyen
Part Number:	RS009105	Approval Date:	9/9/99
Component:	Main Combustion Chamber	Change #:	1
FMEA Item:	A330	Directive #:	CCSD-ME3-01-5239
Failure Mode	Internal rupture at the MCC nozzle interface.		
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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference RS009105
A	LINER		
	MATERIAL INTEGRITY	THE NARLOY-Z MATERIAL IS VERIFIED PER SPECIFICATION REQUIREMENTS	RB0170-175
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1511-001
	ELECTRODEPOSITED PLATING BOND AND STRENGTH - EDCu AND EDNi	THE ELECTRODEPOSIT OF COPPER TO NARLOY IS INSPECTED FOR DEFECTS AND DEPOSITION PER SPECIFICATION REQUIREMENTS.	RA1505-013
		A HOT WATER IMMERSION TEST CHECKS FOR COPPER BOND	
		THE SPECIMENS PLATED AT THE SAME TIME AS THE LINER ARE INSPECTED FOR METALLURGY, MECHANICAL BOND, AND TENSILE STRENGTH	
		A PROOF PRESSURE TEST IS PERFORMED ON THE LINER.	RL00228
		THE AFT END OF MCC IS INSPECTED ULTRASONICALLY FOR BOND AFTER PROOF PRESSURE TESTING.	RL00433
		BONDLINE IS PENETRANT INSPECTED AFTER PROOF TEST PER SPECIFICATION REQUIREMENTS.	RA0115-115
B	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 RA0507-034 RA0115-115
	UNVERIFIABLE ROOT WELDS RS009105 WELDS 11, 12, 13, & 14	UNVERIFIABLE ROOT WELDS ARE INSPECTED PER DRAWING AND SPECIFICATION REQUIREMENTS AS APPLICABLE	RA0115-035 RA0115-127 RA1115-031
		WELDS 11, 12, 13, & 14 PROOF TESTED PER SPECIFICATION REQUIREMENTS	RL00501
		WELDS ARE LEAK CHECKED PER SPECIFICATION REQUIREMENTS.	RL00411
		THE SPLIT RING CLOSEOUT AT WELDS 11-14 IS ULTRASONICALLY INSPECTED FOR WALL THICKNESS AFTER FINAL MACHINING	RS009105
		MCC IS PROOF PRESSURE TESTED PER SPECIFICATION REQUIREMENTS.	RL00501
	ASSEMBLY INTEGRITY	THE HOT FIRE TESTING AND 2ND E & M INSPECTIONS VERIFY MCC INTEGRITY.	RL00050-04 RL00050-06 RL00050-07
	FLIGHT FLOW TESTING	THE MCC BOND LINE IS ULTRASONICALLY INSPECTED AFTER EACH FLIGHT.	OMRSD V41BU0.031
		A THRUST CHAMBER NOZZLE LEAK TEST INCLUDING THE MCC NICKEL/COPPER BOND LINE IS PERFORMED PRIOR TO EACH FLIGHT.	OMRSD V41BQ0.150

Component Group:	Combustion Devices		
CIL Item:	A330-03	Approved:	T. Nguyen
Part Number:	RS009105	Approval Date:	9/9/99
Component:	Main Combustion Chamber	Change #:	1
FMEA Item:	A330	Directive #:	CCBD ME3-01-5238
Failure Mode:	Internal rupture at the MCC nozzle interface.	Page:	2 of 2

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 88RC09761.		
Operational Use:	Not Applicable.		

SSME / 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 M03 01-5239

Component	Basic Part Number	Weld Number	Weld Type	Class	Root Side Not Access	Critical Initial Flaw Size Not Detectable HCF	LCF	Comments
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	II	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	EBW	Ia	X	X	X	
MAIN COMBUSTION CHAMBER	RS009105	18	EBW	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	

Component	Basic Part Number	Weld Number	Weld Type	Class	Root Side Not Access	Critical Initial Flaw Size Not Detectable HCF	LCF	Comments
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	6,13	GTAW	I	X	X	X	
MCC OUTLET ELBOW	R0016282	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	

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. El-Ahmad
Approved: T. Nguyen
Approval Date: 9/8/99
Change #: 1
Directive #: CCBD ME3-01-5228

Base Line Rationale	Variance	Change Rationale	Variant Dash Number
1. A330-01 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