

SSME FMEA/CIL  
**REDUNDANCY SCREEN**

Component Group: Combustion Devices  
 CIL Item: A335-03  
 Part Number: R046390  
 Component: Large Throat Main Combustion Chamber  
 FMEA Item: A335  
 Failure Mode: Internal rupture at the MCC nozzle interface.

Prepared: A. El-Ahmad  
 Approved: T. Nguyen  
 Approval Date: 9/9/99  
 Change #: 3  
 Directive #: CCBDMEM-01-5238

Page: 1 of 1

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	- ML-B55, ML-B5M ME-B5A,C

**SSME FMEA/CIL  
DESIGN**

Component Group: Combustion Devices  
CIL Item: A335-03  
Part Number: R046300  
Component: Large Throat Main Combustion Chamber  
FMEA Item: A335  
Failure Mode: Internal rupture at the MCC nozzle interface.

Prepared: A. El-Ahmad  
Approved: T. Nguyen  
Approval Date: 9/9/99  
Change #: 3  
Directive #: CCBD WE3-01-5238

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 STRESS 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). HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE LINER MEETS CEI REQUIREMENTS (7). THE LINER PARENT MATERIALS WERE CLARIFIED FOR FRACTURE MECHANICS/INDE FLAW GROWTH SINCE IT CONTAINS NO FRACTURE CRITICAL PARTS (8).

(1) 572K; (2) RA1609-018; (3) MPTR-71-175-302; (4) SSE-44L-03, CP320R0003B; (5) R0017707; (6) R0017705; (7) RL00532 CP320R0003B; (8) NASA TASK 117

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

THE AFT ANNULUS FORMED BY THE INLET LINER AND THE CLOSURE RING ARE FABRICATED BY TWO CIRCUMFERENTIAL WELDS 11, 12, AND TWO SHORT CONNECTING WELDS 13, 14 THAT JOIN THE SPLIT 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 COMPATABILITY WITH INCONEL 625 SPLIT RING 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 SPLIT RING (1)(7). THE FACE SIDE OF THE WELDS AND RING ARE 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/INDE FLAW GROWTH BY THE WELD ASSESSMENT (9). TABLE A336 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).

(1) R0017706; (2) R046300; (3) R046290; (4) 572K; (5) RL10011; (6) RSS 8758, CP320R0003B; (7) R046290; (8) RL00532, CP320R0003B; (9) RSS-8758

A - 164

**SSME FMEA/GIL  
INSPECTION AND TEST**

Component Group: Combustion Devices  
 CIL Item: A335-03  
 Part Number: R048300  
 Component: Large Throat Main Combustion Chamber  
 FMEA Item: A335  
 Failure Mode: Internal rupture at the MCC nozzle interface.

Prepared: A. El-Ahmad  
 Approved: T. Nguyen  
 Approval Date: 8/8/99  
 Change #: 3  
 Directive #: CCBD ME3-01-5238

Page: 1 of 2

A - 165

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	LINER		
	MATERIAL INTEGRITY	THE NARLOY-Z MATERIAL IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-175
	HEAT TREAT/ANNEAL	HEAT TREAT/ANNEAL IS VERIFIED PER DRAWING REQUIREMENTS.	R007706
	ELECTRODEPOSITED PLATING BOND AND STRENGTH - EDC <sub>0</sub> AND EDNI	THE ELECTRODEPOSIT OF COPPER TO NARLOY IS INSPECTED FOR DEFECTS AND DEPOSITION PER SPECIFICATION REQUIREMENTS	RA1609-019
		A HOT WATER IMMERSION TEST CHECKS FOR COPPER BOND AND PLATING INTEGRITY.	
		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	RL00787
		THE AFT END OF MCC IS INSPECTED ULTRASONICALLY FOR BOND AFTER PROOF PRESSURE TESTING	RL00780
		BONDLINE IS PENETRANT INSPECTED AFTER EVERY PROOF TEST PER SPECIFICATION REQUIREMENTS.	RA0115-116 RL00784
B	WELD INTEGRITY R048300 WELDS 11, 12, 13 & 14	WELDS ARE INSPECTED TO DRAWING AND SPECIFICATION REQUIREMENTS PER WELD CLASS. INSPECTIONS INCLUDE: VISUAL, DIMENSIONAL, PENETRANT AND FILLER MATERIAL AS APPLICABLE. THE ROOT WELDS 11-14 ARE BORESCOPE INSPECTED TO VERIFY WELD PENETRATION.	RL10011 RA0115-115
		WELDS ARE PROOF TESTED PER SPECIFICATION REQUIREMENTS.	RL00784
		WELDS ARE LEAK CHECKED PER SPECIFICATION REQUIREMENTS.	RL00779
		THE SPLIT RING IS ULTRASONICALLY INSPECTED FOR WALL THICKNESS AFTER FINAL MACHINING.	R048300
		MCC IS PROOF PRESSURE TESTED PER SPECIFICATION REQUIREMENTS	RL00784
	ASSEMBLY INTEGRITY	THE HOT FIRE TESTING AND 2ND E & M INSPECTIONS VERIFY MCC INTEGRITY	RL00550-04 RL00550-06 RL00550-07
	FLIGHT FLOW TESTING	THE MCC BOND LINE IS ULTRASONICALLY INSPECTED AFTER EACH FLIGHT.	OMRSD V41BL0.031
		A THRUST CHAMBER NOZZLE LEAK TEST INCLUDING THE MCC NICKEL/COPPER BONDLINE IS PERFORMED PRIOR TO EACH FLIGHT.	OMRSD V41B00.160

Component 1: Combustion Devices  
C/L Item: A335-03  
Part Number: R040300  
Component: Large Throat Main Combustion Chamber  
FMEA Item: A335  
Failure Mode: Internal rupture at the MCC nozzle Interface

Prepared: T. Nguyen  
Approved: T. Nguyen  
Approval Date: 9/8/99  
Change #: 3  
Directive #: CDBD MEJ-01-5238

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 SA21/38/308 and Rocketdyne letter 88RCC9761		
Operational Use:	Not Applicable.		

A - 166

**SSME :A/CIL  
WELD JOINTS**

Component Group: Combustion Devices  
 CIL Item: A335  
 Component: R046300  
 Part Number: Large Throat Main Combustion Chamber  
 A335

Prepared: A. El-Ahmad  
 Approved: T. Nguyen  
 Approval Date: 9/9/99  
 Change #: 3  
 Directive #: CCBD MES-01-5239  
 Page: 1 of 1

Component	Basic Part Number	Weld Number	Weld Type	Class	Access	Critical Initial		Comments
						Root Side Not	Flaw Size Not Detectable	
						HCF	LCF	
MAIN COMBUSTION CHAMBER	R046300	5	EBW	Ia	X	X	X	
MAIN COMBUSTION CHAMBER	R046300	6,7	EBW	Ib	X	X	X	
MAIN COMBUSTION CHAMBER	R046300	58,59	GTAW	II	X	X	X	
MAIN COMBUSTION CHAMBER	R046300	10	GTAW	II	X	X	X	
MAIN COMBUSTION CHAMBER	R046300	11,12	GTAW	II	X	X	X	
MAIN COMBUSTION CHAMBER	R046300	13,14	GTAW	II	X	X	X	
MAIN COMBUSTION CHAMBER	R046300	15	GTAW	II	X	X	X	
MAIN COMBUSTION CHAMBER	RC46300	16	FBW	II	X	X	X	
MAIN COMBUSTION CHAMBER	R046300	18	EBW	I	X			
MAIN COMBUSTION CHAMBER	R046300	22,23	EBW	I, Ia	X			
MAIN COMBUSTION CHAMBER	R046300	39,40	EBW	I	X			
MAIN COMBUSTION CHAMBER	R046300	63	GTAW	II	X	X	X	
MAIN COMBUSTION CHAMBER	RC46300	69,70	GTAW	II	X	X	X	

A - 175