SSME [illegible]A/CIL
REDUNDANCY SCREEN

Component Group:	Combustion Devices	**Prepared:**	A. El-Ahmad
CIL Item:	A340-01	**Approved:**	T. Nguyen
Part Number:	RS009168	**Approval Date:**	9/9/99
Component:	Nozzle Assembly	**Change #:**	2
FMEA Item:	A340	**Directive #:**	CCBD ME3-01 5238
Failure Mode:	Multiple internal tube fuel leakage (hot wall).	**Page:**	1 of 1

Phase	Failure / Effect Description	Criticality Hazard Reference
SM 4.1	Loss of fuel insufficient to cause a limit shutdown results in off-nominal mixture ratio and propellant consumption. Mission abort may result if off-nominal propellant consumption leads to a SLE engine shutdown or premature propellant depletion.. Redundancy Screens: NOZZLE SYSTEM LIKE REDUNDANCY A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround. B: Fail - Loss of a redundant hardware items is not detectable during flight C: Pass – Loss of redundant hardware items could not result from a single credible event.	1R ME-G4M
M 4.1	Loss of fuel to the preburner increases turbine temperature and results in exceeding turbine discharge temperature limit. Loss of mission Redundancy Screens: NOZZLE SYSTEM: LIKE REDUNDANCY A Pass - Redundant hardware items are capable of checkout during normal ground turnaround. B Pass - Loss of a redundant hardware items is detectable during flight C: Pass - Loss of redundant hardware items could not result from a single credible event.	1R ME-R6S, ME-R6M

SSME FMEA/CIL
DESIGN

Component Group:	Combustion Devices	Prepared:	A. El-Ahmad
CIL Item:	A340-01	Approved:	T. Nguyen
Part Number:	RS009168	Approval Date:	9/9/99
Component:	Nozzle Assembly	Change #:	2
FMEA Item:	A340	Directive #:	CCBD ME3-01-5238
Failure Mode:	Multiple internal tube fuel leakage (hot wall).	Page:	1 of 1

Design / Document Reference

FAILURE CAUSE: A: Contamination causing tube overheating and rupture.

USE OF ROCKETDYNE CLOSURE COVERS AND SEALS AFTER CLEANING PREVENT INDUCTANCE OF CONTAMINATION INTO THE SYSTEM. RUPTURE RESULTING FROM OBSTRUCTION DUE TO CONTAMINATION WOULD OCCUR ON HOT-GAS WALL SIDE. MULTIPLE TUBE FAILURES (1) ARE REQUIRED TO RESULT IN TURBINE DISCHARGE TEMPERATURE REDLINE CUTOFF (2). THE PRE-START PURGE MINIMIZES THE POSSIBILITIES OF ICE FORMATION. THE FUEL IS FILTERED TO 400-MICRONS AT THE EXTERNAL TANK (3).

(1) LL 80-CD-3352; (2) CP406R0009 3.2.3 5.3; (3) ICD 12M15000

FAILURE CAUSE: B: Tube failure, braze joint failure at tube-to-tube, tube-to- manifold, and tube-to-jacket.

NOZZLE COOLANT TUBES ARE MADE FROM A-286 WHICH EXHIBITS STRENGTH AND RESISTANCE TO HYDROGEN EMBRITTLEMENT. HEAT TREATMENT OF A-286 IS COMPATIBLE WITH THE HIGH-TEMPERATURE BRAZE CYCLE REQUIRED BY THE NOZZLE FABRICATION PROCESS AND THE MATERIAL DEVELOPS IT FULL PROPERTIES DURING PERCIPITATION AGE-HARDENING (1). ARTIFICALLY DENTED TUBES WERE BURST TESTED AND THE RESULTS EXCEEDED CEI REQUIREMENTS (2). THE NOZZLE TUBES AND MANIFOLD ASSEMBLIES ARE NICKEL PLATED TO ASSURE GOOD BRAZE BONDING BETWEEN THE PARTS. THE PLATING IS CONTROLLED PER SPECIFICATIONS (3). THE BRAZE COMPOUNDS HAVE GOOD FLOW AND GAP FILLING CHARACTERISTICS ON NICKEL PLATED MATERIALS. THE BRAZE OPERATIONS ARE CONTROLLED PER SPECIFICATIONS (4). THE JACKET IS CONSTRUCTED OF PANELS REINFORCED BY HAT SECTIONS. THIS FORMS A REINFORCED OUTER SHELL WHICH IS BRAZED TO THE O.D. OF THE COOLANT TUBE STACK TO FORM AN INTEGRAL PRESSURE VESSEL (5). THIS CONTAINS AND EXPANDS THE EXHAUST GAS OF THE ENGINE. THE TUBES AND MANIFOLDS HAVE TIGHT TOLERANCES TO ENSURE A CORRECT TUBE STACK, AND PROPER BRAZE GAPS (6). HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE TUBES MEET CEI REQUIREMENTS (7). MINIMUM FACTORS OF SAFETY FOR THE TUBES MEET CEI LIFE REQUIREMENTS (8). THE NOZZLE ASSEMBLY PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE IT CONTAINS NO FRACTURE CRITICAL PARTS (9). THE NOZZLE HAS BEEN STRUCTURALLY DESIGN VERIFICATION TESTED (10).

(1) RSS-8573-10. (2) LL 6127 4001, SSME 85-0043; (3) RA1609-027, RA1109-005, RA1609-035; (4) RA1507-014. (5) RS009169; (6) RS009175, RS009150, RS009286, RS009172. (7) RL00532, CP320R0003B; (8) RSS-8546, CP320R0003B. (9) NASA TASK 117. (10) RSS-303-33, TCA-28

FAILURE CAUSE: C: Corrosion.

HISTORY HAS SHOWN NOZZLE COOLANT TUBE FAILURE RESULTING FROM CORROSION PITTING MANIFESTS AS LOCAL LEAKAGE (COLD AND/OR HOT WALL), WITHOUT EXTENSIVE FAILURE OF TUBES. PRIMARY CAUSE OF TUBE CORROSION IS CHLORIDE CONTAMINATION (1). MANUFACTURING CONTROLS HAVE BEEN IMPLEMENTED TO PREVENT CHLORIDE CONTAMINATION. ETCHANTS USED IN CRITICAL AREAS/PROCESSES HAVE BEEN CHANGED TO NON-CORROSION MEDIA (2). ENGINE PURGING AND DRYING PROCEDURES PRECLUDE ACCUMULATION OF MOISTURE INTERNALLY (3). ROCKETDYNE CLOSURES AND MOISTURE INDICATORS ARE EMPLOYED DURING SHIPPING/STORAGE (4). A-286 WAS CHOSEN FOR THE NOZZLE REGENERATIVE COOLANT TUBE MATERIAL BECAUSE OF ITS RESISTANCE TO HYDROGEN EMBRITTLEMENT, DUCTILITY, AND RESISTANCE TO CORROSION. THE COOLANT TUBES ARE SOLUTION TREATED AND PRECIPITATION-HARDENED DURING THE NOZZLE FABRICATION PROCESS TO DEVELOP MATERIAL PROPERTIES (5). THE TUBES ARE NICKEL PLATED (FOR BRAZING PURPOSES) WHICH AIDS IN RESISTING CORROSION (6).

(1) MPR 83-0712; (2) RA1103-003; (3) DMRSD V41CB0 060; (4) STO116RA0103, RK395-00168. (5) RSS-8573-10; (6) RS009172, RA1109-006

FAILURE CAUSE: ALL CAUSES

NO TUBE FAILURES RESULTING IN TURBINE TEMPERATURE REDLINE CUTOFF, HAVE BEEN EXPERIENCED SINCE IMPLEMENTATION OF "HEAVY WALL" TUBES. A TURBINE TEMPERTURE CUTOFF LIMITS THE DEGREES OF FAILURE. THE TURBINE TEMPERATURE REDLINE CUTOFF SYSTEM IS COMPRISED OF REDUNDANT SENSORS, REDUNDANT HARNESSES AND REDUNDANT CONTROLLER CHANNELS (1). CONTINUED USE WITH ALLOWABLE DISCREPANCIES RESULTING FROM OPERATION IS EVALUATED AND CONTROLLED PER THE REQUIREMENTS OF THE MAINTENANCE CONTROL DOCUMENT (2).

(1) CP406R0009 3.2.3.5.3 (2) RSS-8793

A - 178

SSME FMEA/CIL
INSPECTION AND TEST

Component Group:	Combustion Devices	**Prepared:**	A. El-Ahmad
CIL Item:	A340-01	**Approved:**	T. Nguyen
Part Number:	RS009168	**Approval Date:**	9/9/99
Component:	Nozzle Assembly	**Change #:**	2
FMEA Item:	A340	**Directive #:**	CCBD ME3-01-5238
Failure Mode:	Multiple internal tube fuel leakage (hot wall).	**Page:**	1 of 2

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	NOZZLE		RS009168
	TUBE		RS009172
	ICING BLOCKAGE OF TUBES	SSME PROPELLANT SYSTEM IS DRIED AND VERIFIED DRY PRIOR TO EACH FLIGHT	OMRSD V41CB0.080 (PHASE II) OMRSD V41CB0.081 (PHASE II) OMRSD V41CB0.082 (BLOCK IIIA) OMRSD V41CB0.083 (BLOCK IIIA)
		DURING PROPELLANT CONDITIONING THE FUEL SYSTEM IS PURGED TO MAINTAIN IT FREE OF MOISTURE AND ICE.	OMRSD S00FB0.310 OMRSD S00FB0.320
	UPSTREAM COMPONENT CLEANLINESS	THE UPSTREAM COMPONENTS ARE VERIFIED CLEAN TO FUEL SERVICE OR BETTER PER SPECIFICATION REQUIREMENTS.	RL10001
		TUBES ARE FLOW TESTED AFTER EACH BRAZING CYCLE DURING THE MANUFACTURING PROCESS.	RS009160
B	TUBE		RS009172
	TUBE MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0160-047
		AT LEAST ONE OF EVERY 150 TUBES IN A LOT IS SECTIONED AND EXAMINED FOR MATERIAL INTEGRITY, WALL THICKNESS, PLATING ADHESION AND THICKNESS, AND ABSENCE OF FORMING DEFECTS.	RA1102-002
		EVERY TUBE IS LEAK TESTED AFTER FORMING PER DRAWING REQUIREMENTS.	RS009177
		EACH TUBE IS PENETRANT INSPECTED FOR DEFECTS PER SPECIFICATION REQUIREMENTS.	RA0115-116
		EACH FORMED TUBE IS EXAMINED FOR CRACKS, PITS, SCRATCHES TOOL MARKS, OR OTHER DETRIMENTAL DEFECTS	RS009172
	HEAT TREAT	HEAT TREAT IS VERIFIED BY SPECIFICATION REQUIREMENTS.	RB0160-047
	TUBE TO MANIFOLD BRAZE	TUBE-TO-MANIFOLD BRAZE JOINTS ARE VISUALLY INSPECTED FOR PROPER BRAZE FLOW AT BOTH THE INTERIOR AND OUTSIDE AREAS OF THE MANIFOLDS.	RA1607-014
	TUBE-TO-TUBE/TUBE-TO-JACKET BRAZE	THE BRAZING OPERATIONS ARE PERFORMED IN A CONTROLLED ENVIRONMENT AND INSPECTED PER SPECIFICATION.	RA1607-014 RA1607-015
		FOLLOWING BRAZING OPERATIONS, THE SHELL ASSEMBLY IS VISUALLY AND RADIOGRAPHICALLY INSPECTED FOR BRAZING DEFECTS.	RS009169
		ENVELOPE CLEARANCE BETWEEN THE MCC AND THE NOZZLE TUBES IS CHECKED PER DRAWING AND SPECIFICATION REQUIREMENTS	RS009168 RS007002 OMRSD V41BU0.029
C	STRUCTUAL INTEGRITY	NOZZLE IS PROOF PRESSURE TESTED PER SPECIFICATION REQUIREMENTS.	RL00209

Component Group:	Combustion Devices	Approved:	T. NgUyen
CIL Item:	A340-01	Approval Date:	9/9/99
Part Number:	RS009168	Change #:	2
Component:	Nozzle Assembly	Directive #:	CCBD ME3-01-5238
FMEA Item:	A340		
Failure Mode:	Multiple internal tube fuel leakage (hot wall).	Page:	2 of 2

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
C	STRUCTUAL INTEGRITY	NOZZLE IS LEAK TESTED AFTER BRAZE AND PROOF PRESSURE TESTING	RS009168
ALL CAUSES	ASSEMBLY INTEGRITY	THE HOT FIRE TESTING AND 2ND E & M INSPECTIONS VERIFY NOZZLE TUBE INTEGRITY	RL00050-04 RL00055-06 RL00055-07
		THE NOZZLE IS INSPECTED FOR DAMAGE BEFORE EACH LAUNCH.	OMRSD V41BU0.353 OMRSD V41BU0.029
		NOZZLE ENCAPSULATION LEAK TEST IS PERFORMED ON NOZZLE 10th BAY FOR NOZZLES WITH POSITION UNIQUE TPS PER TIME/CYCLE REQUIREMENTS.	OMRSD V41BQ0.167 OMRSD C00BAC.015
		THE NOZZLE INTERIOR IS LEAK TESTED PRIOR TO EACH FLIGHT AT THE MANIFOLDS AND TUBE REPAIRS. (LAST TEST)	OMRSD V41BQ0.160
		NOZZLE TUBES ARE LEAK TESTED PRIOR TO EACH FLIGHT.	

Failure History: Comprehensive failure history data is maintained in the Problem Reporting database (PRAMS/PRACA)
Reference: NASA letter SA21/68/308 and Rocketdyne letter BBRC09761.

Operational Use: Not Applicable

SSME FMEA/CIL
WELD JOINTS

Component Group: Combustion Devices
CIL Item: A340
Component: RS009168
Part Number: Nozzle Assembly A340

Prepared: A. El-Ahmad
Approved: T. Nguyen
Approval Date: 9/9/99
Change #: 1
Directive #: CCRD MF3-01-5238

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
NOZZLE STEERHORN	R0012279	1(OPT), 2(OPT)	GTAW	I		X	X	
NOZZLE STEERHORN	R0012279	3	GTAW	I	X	X	X	
NOZZLE STEERHORN	R0012279	4	GTAW	I		X		
NOZZLE STEERHORN	R0012279	5,6	GTAW	I	X	X		
NOZZLE STEERHORN	R0012279	9	GTAW	I		X	X	
NOZZLE STEERHORN	R0012279	10	GTAW	I	X	X	X	
CCV DUCT	RS008161	1	EBW	I	X	X		
CCV DUCT	RS008161	2	EBW	I		X		
CCV DUCT	RS008161	3	GTAW	I		X	X	
CCV DUCT	RS008161	5	EBW	I				
NOZZLE JACKET	RS009150	1,4,5,16	GTAW	I		X		
NOZZLE JACKET	RS009150	2,3,6,7,10 11 ,14,15,18,19 22,23,26,27, 30,31,34,35	GTAW	II	X			
NOZZLE JACKET	RS009150	8,9,12,13,17, 20	GTAW	I				
NOZZLE JACKET	RS009150	21	GTAW	I				
NOZZLE JACKET	RS009150	24,25,28,29, 32,33,36	GTAW	II				
INLET DIFFUSER	RS009156	1 PLG(OPT)	EBW	I	X			
MIXER	RS009158	4	GTAW	I		X		
MIXER	RS009158	5	GTAW	I		X	X	
MIXER	RS009158	7	GTAW	I				
MIXER	RS009158	8	GTAW	I		X		
MIXER	RS009158	10	GTAW	I		X	X	
FWD MANIFOLD	RS009165	44,45	GTAW	I				
FWD MANIFOLD	RS009165	46	GTAW	I	X			
FWD MANIFOLD	RS009165	47	GTAW	I	X			
NOZZLE	RS009168	1,2	GTAW	I	X	X	X	
NOZZLE	RS009168	3	GTAW	I	X	X	X	
NOZZLE	RS009168	13,14	GTAW	I	X	X		

Component	Basic Part Number	Weld Number	Weld Type	Class	Root Side Not Access	Critical Initial Flaw Size Not Detectable HCF	LCF	Comments
NOZZLE	RSC09168	15,16	GTAW	I	X	X		
NOZZLE	RSC09168	17	GTAW	I	X	X		
NOZZLE	RSC09168	18	GTAW	I	X	X		
NOZZLE	RSC09168	19	GTAW	I		X		
NOZZLE	RSC09168	20	GTAW	I		X		
NOZZLE	RSC09168	21	GTAW	I	X	X		
NOZZLE	RSC09168	23	GTAW	I	X	X		
NOZZLE	RSC09168	24	GTAW	I	X	X	X	
NOZZLE	RSC09168	26	GTAW	I		X		
NOZZLE	RSC09168	27	GTAW	I,II		X		
NOZZLE	RSC09168	152	GTAW	I	X			
NOZZLE	RSC09168	172	GTAW	I		X		
NOZZLE	RSC09168	306A	GTAW	I	X	X	X	
NOZZLE	RSC09168	1503-1508	GTAW	I	X	X	X	
NOZZLE	RSC09168	1723,1724	GTAW	I	X	X	X	
NOZZLE	RSC09168	1725,1726	GTAW	I	X	X	X	
NOZZLE TUBE STACK	RSC09169	1	GTAW	I	X			
NOZZLE TUBE STACK	RSC09169	2 3	GTAW	I	X	X	X	
NOZZLE TUBE STACK	RSC09169	49 50	GTAW	I	X	X		
NOZZLE TUBE STACK	RSC09169	51-56	GTAW	I	X	X		
NOZZLE TUBE STACK	RSC09169	168-170	GTAW	II,I				
AFT MANIFOLD	RSC09286	1 2	GTAW	I				
AFT MANIFOLD	RSC09286	30-35	GTAW	I		X	X	
NOZZLE FUEL FEEDLINE	R056820	1	GTAW	I		X		

SSME F A/CIL
FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE

Component Group: Combustion Devices
Item Name: Nozzle Assembly
Item Number: A340
Part Number: RS009168

Prepared: A. El-Ahmad
Approved: T. Nguyen
Approval Date: 9/9/99
Change #: 2
Directive #: CCBD ME3-01-5239

Base Line Rationale	Variance	Change Rationale	Variant Dash Number
A340 02. Elimination of 9 welds from nozzle fuel coolant and distribution circuit. This change will utilize a one piece seam welded tube with a welded transition ring which is within the experience of flight history. Design eliminates 9 welds during the fabrication of each nozzle (3 welds each feedline, 3 feedlines per nozzle)	Use of nine weld design RO01227d - Weld No. 1(x3) Weld No. 2 (x3) RS009168 - Weld No. 1456, 1457 1512, 1509-1511	The nozzle high pressure fuel feed system parent materials were cleared for fracture mechanics/NDE flaw growth since they contain no fracture critical parts (NASA TASK 117). The FMEA/CIL welds are cleared for fracture mechanic/NDE flaw growth by the weld assessment (RSS-8755).	162,132,1031,1041,10 21,1031 1041,1051,10 61,1081 1091,1101,11 11,1131,1141,1151,11 61,1171,1181,1191,12 01,1211,1221 231,124 1,1251,1261,271,1281, 1291,1301