

**SSME FTA/CIL  
REDUNDANCY / SCREEN**

Component Group: Combustion Devices  
CIL Item: A055-03  
Part Number: R0018001  
Component: Powerhead (Phase II+)  
FMEA Item: A055  
Failure Mode: Shell or propellant duct rupture

Prepared: A. Kay  
Approved: T. Nguyen  
Approval Date: 9/9/99  
Change #: 4  
Directive #: CCRO ME3-01-6239

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Phase  
SMC  
41

Failure / Effect Description  
External fire or hot-gas leak, Overpressurization of aft compartment, Loss of vehicle.  
Redundancy Screens: SINGLE POINT FAILURE: N/A

Criticality  
Hazard Reference  
1  
ME-FB19, A.M.C

SSME FMEACIL  
DESIGN

Component Group: Combustion Devices  
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Failure Mode: Shell or propellant duct rupture.

Prepared: A. Kay  
Approved: T. Nguyen  
Approval Date: 3/9/93  
Change #: 4  
Directive #: CCBD-MES-01-523R

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Design / Document Reference

FAILURE CAUSE: A: Weld/parent material failure.

THE PHASE II+ HOT-GAS STRUCTURAL SHELLS ARE FABRICATED FROM INCONEL 718. THIS ALLOY WAS SELECTED ON THE BASIS OF ITS STRENGTH AND SATISFACTORY PERFORMANCE AS DEMONSTRATED ON THE THREE DUCT HOT-GAS MANIFOLD CONFIGURATION. HYDROGEN EMBRITTLEMENT PROTECTION FOR THE PARENT MATERIAL IS NOT REQUIRED DUE TO LOW STRAIN LEVELS (1). INCONEL 718 WELD JOINTS EXPOSED TO HYDROGEN AND SUBJECT TO PLASTIC STRAIN ARE PROTECTED FROM HYDROGEN ENVIRONMENT EMBRITTLEMENT WITH WELD OVERLAYS OF INCOLOY 903, WHICH IS HYDROGEN ENVIRONMENT EMBRITTLEMENT RESISTANT. THE PHASE II+ HOT-GAS MANIFOLD DESIGN FEATURES TWO LARGE ELLIPTICAL FUEL SIDE TRANSFER TUBES, AN INCREASED AREA MAIN INJECTOR TORUS AND FUEL BOWL, AND INCREASED AREA OXIDIZER SIDE TRANSFER TUBES. THESE DESIGN CHARACTERISTICS WERE INCORPORATED TO IMPROVE OPERATING CONDITIONS FOR THE MAIN INJECTOR AND TURBOPUMPS BY ACHIEVING MORE UNIFORM HOT-GAS AND COOLANT VELOCITIES RESULTING IN REDUCED MAIN INJECTOR LOX POST LOADING, MINIMIZED TURBINE HOUSING SIDE LOADS AND REDUCED HPFTP DISCHARGE TEMPERATURE AND TRANSVERSE DELTA PRESSURE. VERIFICATION THAT THE PHASE II+ STRUCTURAL SHELL DESIGN COMPLIES WITH ENGINE OPERATIONAL AND STRUCTURAL REQUIREMENTS WAS BASED ON STRUCTURAL AND COMPUTATIONAL FLUID DYNAMIC (CFD) ANALYSIS, LABORATORY WATER AND AIR FLOW TESTING (2) AND ENGINE HOT-FIRE TESTING (3). THE RESULT OF FLUID DYNAMICS SHOWS REDUCED FLOWFIELD VELOCITIES, IMPROVED FLOW UNIFORMITY, REDUCED STRUCTURAL LOADING AND REDUCED SYSTEM PRESSURE LOSSES. A STRENGTH ANALYSIS WAS PERFORMED TO VERIFY THE STRUCTURAL INTEGRITY OF THE PHASE II+ HOT-GAS MANIFOLD STRUCTURAL SHELLS. THE ANALYSIS VERIFIED THE STRUCTURAL CAPABILITY OF THE DESIGN TO MEET ALL STRENGTH DESIGN REQUIREMENTS (2). THIS ANALYSIS WAS BASED ON AN ASSESSMENT OF THE MOST CRITICAL ENGINE OPERATING CONDITIONS WHICH ESTABLISHED THE LIMIT DESIGN PRESSURE AND THE MAXIMUM EXPECTED OPERATING LOADS. ANALYSIS OF THE HOT-GAS MANIFOLD STRUCTURAL SHELL SHOWS THAT CEI PRIMARY FACTORS OF SAFETY AND LOW AND HIGH CYCLE FATIGUE REQUIREMENTS ARE MET (4).

THE PHASE II+ POWERHEAD COOLANT SUPPLY DUCTS ARE FABRICATED FROM INCOLOY 903. THIS ALLOY WAS SELECTED FOR ITS RESISTANCE TO HIGH-PRESSURE HYDROGEN ENVIRONMENT EMBRITTLEMENT PROTECTION, SEMI-CORROSION RESISTANCE, RESISTANCE TO STRESS CORROSION CRACKING AND SATISFACTORY PERFORMANCE AS DEMONSTRATED ON THE THREE DUCT HOT-GAS MANIFOLD CONFIGURATION. THE PHASE II+ POWERHEAD COOLANT DUCTS DESIGN FEATURES INCREASED WALL THICKNESS AT THE TUBE TO TRANSITION RING WELDS FOR REDUCED SENSITIVITY TO WELD OFFSET. ANALYSIS OF THE PHASE II+ POWERHEAD DUCTS SHOWS THAT CEI PRIMARY FACTORS OF SAFETY ARE MET. THE ANALYSIS FOR DUCT LOW AND HIGH CYCLE FATIGUE MEETS CEI REQUIREMENTS (4). THE DUCT PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NOE FLAW GROWTH SINCE THEY ARE NOT FRACTURE CRITICAL PARTS, EXCEPT FOR THE FUEL AND OXIDIZER CHAMBER ASSEMBLIES, HEAT EXCHANGER BOWL, AND HOT GAS MANIFOLD SHELLS WHICH WERE CLEARED BY CRITICAL INITIAL FLAW SIZE DETECTABILITY (5). THE FMEACIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/NOE FLAW GROWTH BY THE WELD ASSESSMENT (6). TABLE A055 LISTS ALL FMEACIL 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 (6). THE POWERHEAD ASSEMBLY HAS COMPLETED DVR TESTING (7).

(1) RSS-5581-10 (2) RSS-9690, RSS-8714 (3) RSS-8674 (4) CEI CP32DR003. (5) NASA TASK 117; (6) RSS-8756. (7) RSS-8079-1

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**SSME FME CA  
INSPECTION AND TEST**

Component Group: Combustion Devices  
 CIL Item: A055-03  
 Part Number: R0018001  
 Component: Powerhead (Phase II+)  
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 Failure Mode: Shell or propellant duct rupture.

Prepared: A. Kay  
 Approved: T. Nguyen  
 Approval Date: 9/9/99  
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 Directive #: CCBD ME3-01 5238

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	OPB CHAMBER ASSY FFR CHAMBER ASSY SINGLE TUBE HEX SHELL SINGLE TUBE HEX ASSEMBLY HOT-GAS MANIFOLD OXIDIZER STRUCTURAL SHELL FUEL STRUCTURAL SHELL POWERHEAD ASSEMBLY MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	R0017425 R0017435 R039051 R039060 R0018020 R0018022 R0018021 R0018001 RB0170-153 RB0170-155 RB0170-196 RB0170-211 RB0170-212 RAD115-012 RAD115-116 RAD115-116 RAC611-020 R0017435 R0017425 RL10011 RA1607-071 RAD115-116 RAC115-002 RAC115-127 RA1115-001 R0018001 RL00775 R0018020 RL00768
	WELD INTEGRITY	ALL FORGING DETAILS ARE ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS INNER SURFACES OF THE MANIFOLD SHELLS ARE PENETRANT INSPECTED AFTER CHEM-MILL PER DRAWING AND SPECIFICATION REQUIREMENTS. THE EXTERIOR OF THE R039051 HEX BOWL AND THE R0018020 MANIFOLD ARE PENETRANT INSPECTED AFTER MACHINING PER SPECIFICATION REQUIREMENTS. MANIFOLD HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS. THE R0017425 AND R0017435 PREBURNER CHAMBERS ARE PROOF PRESSURE TESTED PRIOR TO WELDING INTO HOT-GAS MANIFOLD. 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 ARE PERFORMED ON R0018001 WELDS 51 AND 52 (WELD LAYER THICKNESS AND PEENING). PREBURNERS TO HOT GAS MANIFOLD WELDS 1 AND 5 ARE INSPECTED FOR JOINT INTEGRITY THROUGH INSPECTION HOLES DRILLED IN THE E.S. WELDS.	

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Approved: T. Nguyen  
 Approval Date: 9/9/99  
 Change #: 4  
 Directive #: CCBD ME3-01-5238

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	MANIFOLD DUCTS/FLANGES		
	DUCT		R0018006
	DUCT		R0018002
	DUCT		R0018011
	DUCT		R0018003
	DUCT		R0018004
	FLANGE		R0018045
	FLANGE		RS008148
	FLANGE		R0018005
	DUCTING MATERIAL INTEGRITY	THE INCOLOY 903 AND INCONEL 718 DUCTING PIECES AND FLANGES ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS	
	INCONEL 718 FORGINGS ARE ULTRASONICALLY INSPECTED FOR INTERNAL DEFECTS, PER SPECIFICATION REQUIREMENTS.		RA0115-012
	R0018011 TUBING IS 100% ULTRASONICALLY INSPECTED FOR LONGITUDINAL AND CIRCUMFERENTIAL DEFECTS PER SPECIFICATION REQUIREMENTS.		RA0115-124
	HEAT TREAT OF THE DUCTING IS VERIFIED PER SPECIFICATION REQUIREMENTS.		RAC611-020
WELD INTEGRITY	ALL WELDS ARE INSPECTED TO DRAWING AND SPECIFICATION REQUIREMENTS PER WELD CLASS. INSPECTIONS INCLUDE: VISUAL, DIMENSIONAL, PENETRANT, RADIOGRAPHIC, ULTRASONIC, AND FILLER MATERIAL, AND OFFSET, AS APPLICABLE.		RL10011 RA1607-071 RAC115-116 RA0115-006 RAC115-127
ASSEMBLY INTEGRITY	POWERHEAD ASSEMBLY AND DUCTS ARE PROOF PRESSURE TESTED PER SPECIFICATION REQUIREMENTS		R0018001 RL00845
	ALL POWERHEAD ASSEMBLY EXTERNAL WELDS ARE PENETRANT INSPECTED AFTER PROOF PRESSURE TESTING PER DRAWING AND SPECIFICATION REQUIREMENTS.		R0018001 RAC115-116 RF0001-120
	THE POWERHEAD IS CLEANED TO SPECIFICATION REQUIREMENTS.		R0018001 RL10001 RA1610-016
	HOT FIRE TESTING AND 2ND E & M INSPECTIONS VERIFY MANIFOLD INTEGRITY.		RL00050-04 RL00055-06 RL00055-07
	HELIUM SIGNATURE TEST PERFORMED PRIOR TO EACH FLIGHT VERIFIES PGM WALL INTEGRITY (LAST TEST)		OMRSD S00030.903

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Component:            ip:    **Combustion Devices**  
CIL Item:             **A055-03**  
Part Number:         **R0018001**  
Component:           **Powerhead (Phase II\*)**  
FMEA Item:           **A055**  
Failure Mode:         **Shell or propellant duct rupture**

Prepared:            A. Kay  
Approved:            T. Nguyen  
Approval Date:       9/9/99  
Change #:            4  
Directive #:          CCBD MEJ-01-523R

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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 SA21.88/309 and Rocketdyne letter BBR009781.		
Operational Use:	Not Applicable		

**SSME FA/CIL  
WELD JOINTS**

Component Group: Combustion Devices  
 CPL Item: A055  
 Component: R0018001  
 Part Number: Powerhead (Phase II\*)  
 A055

Prepared: A. Kay  
 Approved: T. Nguyen  
 Approval Date: 9/9/99  
 Change #: 3  
 Directive #: CCBD 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	
OXIDIZER PREBURNER LINER	R0011552	1(OPT)	EBW	I		X		
OXIDIZER PREBURNER LINER	R0011552	1(OPT)	GTAW	I		X		
OXIDIZER PREBURNER LINER	R0011552	2(OPT)	EBW	I		X		
OXIDIZER PREBURNER LINER	R0011552	2(OPT)	GTAW	I		X		
FUEL PREBURNER LINER	R0017428	1	GTAW OR EBW	I				
FUEL PREBURNER LINER	R0017428	2	GTAW OR EBW	I				
POWERHEAD	R0018001	1	GTAW	I	X	X	X	
POWERHEAD	R0018001	3	GTAW	I	X	X	X	
POWERHEAD	R0018001	5	GTAW	I		X		
POWERHEAD	R0018001	6	GTAW	I				
POWERHEAD	R0018001	7	GTAW	I	X			
POWERHEAD	R0018001	8	GTAW	I	X	X	X	
POWERHEAD	R0018001	9	GTAW	I	X	X	X	
POWERHEAD	R0018001	10	GTAW	I	X	X	X	
POWERHEAD	R0018001	11	GTAW	I	X	X	X	
POWERHEAD	R0018001	12	GTAW	I	X	X	X	
POWERHEAD	R0018001	13	GTAW	I	X	X		
POWERHEAD	R0018001	16	GTAW	II	X			
POWERHEAD	R0018001	17-24	GTAW	II	X	X		
POWERHEAD	R0018001	25	GTAW	II	X			
POWERHEAD	R0018001	26-29	GTAW	II	X			
POWERHEAD	R0018001	50	GTAW	II	X		X	
POWERHEAD	R0018001	51-52	EBW/GTAW	NONE/II	X	X	X	
POWERHEAD	R0018001	53	GTAW	I				
POWERHEAD	R0018001	54	GTAW	I				
FPB FUEL SUPPLY DUCT	R0018002	1	GTAW	I				
FPB FUEL SUPPLY DUCT	R0018002	2	GTAW	I	X			
FPB FUEL SUPPLY DUCT	R0018002	3	GTAW	I		X		
FPB FUEL SUPPLY DUCT	R0018002	4	GTAW	I	X	X	X	
FPB FUEL SUPPLY DUCT	R0018002	5	GTAW	I		X	X	

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Component Group: Combustion Devices  
 GIL Item: A055  
 Component: R0018001  
 Part Number: Powerhead (Phase II+)  
 A055

Prepared: 9/19/99  
 Approved: T. Nguyen  
 Approval Date: 9/9/99  
 Change #: 3  
 Directive #: CCBD WE3-01-5238  
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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	
FPS FUEL SUPPLY DUCT	R0018002	6	GTAW	I		X	X	
PREBURNER FUEL SUPPLY DUCT	R0018004	1	GTAW	I				
PREBURNER FUEL SUPPLY DUCT	R0018004	2	GTAW	I				
HGM COOLANT SUPPLY DUCT	R0018011	1	GTAW	I				
HGM COOLANT SUPPLY DUCT	R0018011	2	GTAW	I				
HOT GAS MANIFOLD	R0018020	1	EBW	NONE	X	X		
HOT GAS MANIFOLD	R0018020	2	EBW	NONE	X	X	X	
HOT GAS MANIFOLD	R0018020	3	EBW	II	X	X	X	
HOT GAS MANIFOLD	R0018020	4	EBW	II	X	X	X	
HOT GAS MANIFOLD	R0018020	5	EBW	NONE	X	X		
HOT GAS MANIFOLD	R0018020	6	EBW	NONE	X	X	X	
HOT GAS MANIFOLD	R0018020	7	EBW	II	X	X	X	
HOT GAS MANIFOLD	R0018020	8	EBW	II	X	X	X	
HOT GAS MANIFOLD	R0018020	9-10	EBW	I		X	X	
HOT GAS MANIFOLD	R0018020 R0018022 R039051	13&59,2,2	GTAW	II	X	X		
HOT GAS MANIFOLD	R0018020	16	GTAW/EBW	II	X	X	X	
HOT GAS MANIFOLD	R0018020	17	EBW	Ib			X	
HOT GAS MANIFOLD	R0018020	18&57	GTAW	I	X	X	X	
HOT GAS MANIFOLD	R0018020	53	GTAW	I	X	X		
HOT GAS MANIFOLD	R0018020	56	GTAW	I	X	X	X	
HOT GAS MANIFOLD	R0018020	58	GTAW	I	X	X	X	
HOT GAS MANIFOLD	R0018020	61	GTAW	I	X	X	X	
FUEL HALF SHELL HGM	R0018021	1&7	EBW/GTAW	I	X	X		
FUEL HALF SHELL HGM	R0018021	3	GTAW	I				
FUEL HALF SHELL HGM	R0018021	4	EBW	I				
FUEL HALF SHELL HGM	R0018021	5	EBW	I	X			
OXIDIZER HALF SHELL HGM	R0018022	6	EBW	I		X	X	
HOT GAS MANIFOLD	R0018020	62	GTAW	I	X	X	X	

**SSME FMEA/CIL**  
**FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE**

Component Group: Combustion Devices  
 Item Name: Powerhead (Phase II\*)  
 Item Number: A056  
 Part Number: R0018001

Prepared: A. Kay  
 Approved: T. Nguyen  
 Approval Date: 9/8/99  
 Change #: 7  
 Directive #: CCBDM3-01-5238

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Base Line Rationale	Variance	Change Rationale	Variant Dash Number
1. R0018011-11 INCORPORATES COMBINED DETAILS ELIMINATING 10 WELD JOINTS.	POWERHEAD CONFIGURATIONS EXIST WITH FABRICATED COOLANT DUCT SUB ASSEMBLIES REQUIRING ADDITIONAL WELD JOINTS	IMPROVED HARDWARE RELIABILITY DUE TO THE ELIMINATION OF 10 WELD JOINTS. CEI REQUIREMENTS ARE MAINTAINED.	R0018011-1 R0018012-1 R0018013-1 R0018001-681 -701, - 731 -991, -1051.
2. A056 03: NO RATIONALE EFFECTED.	POWERHEADS EXIST UTILIZING THE COMBINED FOUR ZONE PROOF PRESSURE TEST FROM THE HOT GAS MANIFOLD. CEI REQUIREMENTS ARE MAINTAINED.	HOT GAS MANIFOLD PROOF PRESSURE TEST ACCOMPLISHED SEPARATELY PRIOR TO COOLANT DUCT AND MAIN INJECTOR INSTALLATION.	R0018001-681 -701, - 731 -991, -1051.