ATK ALLIANT TECHSYSTEMS
THIOKOL PROPULSION

CRITICAL ITEMS LIST (CIL)

No. 10-05-04-02R/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Nozzle Subsystem 10-02	PART NAME:	Forward-to-Aft Exit Cone Joint, Phenolic Components (1)
ASSEMBLY:	Fwd-to-Aft Exit Cone Interface 10-05-04		
FMEA ITEM NO.:	10-05-04-02R Rev M		
CIL REV NO.:	M (DCN-533)	PART NO.:	(See Section 6.0)
DATE:	10 Apr 2002	PHASE(S):	Boost (BT)
SUPERSEDES PAGE:	358-1ff.	QUANTITY:	(See Section 6.0)
DATED:	6 Feb 2002	EFFECTIVITY:	(See Table 101-6)
CIL ANALYST:	R. E. L. Hamilton	HAZARD REF.:	BN-02
APPROVED BY:		DATE:	

RELIABILITY ENGINEERING: K. G. Sanofsky 10 Apr 2002

ENGINEERING: B. H. Prescott 10 Apr 2002

1.0 FAILURE CONDITION: Failure during operation (D)

2.0 FAILURE MODE: 1.0 Thermal failure

3.0 FAILURE EFFECTS: Loss of thermal barrier and break up and expulsion of the Aft Exit Cone causing loss of RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Wedge out	
1.1.1	Nonconforming fabrication of joint angle or dimensions at interfaces	A
1.1.2	Porosity, voids, de-laminations, inclusions, or cracks	B
1.1.3	Assembly residual stresses	C
1.2	Assembly or handling damage of joint phenolics	D
1.3	Nonconforming raw material properties of carbon phenolics	E
1.4	Nonconforming manufacturing process	F
1.5	Step discontinuities between surfaces	G
1.6	Ply lift of carbon-cloth phenolic	
1.6.1	Excessive volatile content	H

5.0 REDUNDANCY SCREEN:

SCREEN A: N/A
SCREEN B: N/A
SCREEN C: N/A

6.0 ITEM DESCRIPTION:

1. Forward-to-Aft Exit Cone Joint, Phenolic Components (Figure 1). Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U79152	Exit Cone Assembly, Forward Section			1/motor
5U77804	Forward Exit Cone			1/motor
		Glass-Cloth Phenolic	STW5-2651	153 lbs.
		Carbon-Cloth Phenolic	STW5-3279	616 lbs.
	Forward Exit Cone (Test)		STW3-3462	1/motor
1U79155	Exit Cone, Subassembly-Nozzle, Aft			
5U77652	Exit Cone, Aft			
		Glass-Cloth Phenolic	STW5-2651	2813 lbs.
		Carbon-Cloth Phenolic	STW5-3279	4175 lbs.
	Aft Exit Cone (Test)		STW3-3463	1/motor
	Phenolic Slit Tape		STW5-3621	A/R

6.1 CHARACTERISTICS:

1. The Forward Exit Cone Assembly consists of a carbon-cloth phenolic ablative liner over wrapped with glass-cloth phenolic insulation. Composite liner is bonded and pinned into the D6AC steel forward cone housing. An O-ring at the forward end plastic structure interface precludes gas penetration along the bonded surface.

2. Aft Exit Cone liner is carbon-cloth phenolic that is over wrapped with glass-cloth phenolic. The composite assembly is pinned to the aluminum shell to provide additional strength and retention redundancy. O-ring seals prevent any gasses from penetrating along bonded or interfacing surfaces.

3. The Aft Exit Cone and Forward Exit Cone are bolted together at KSC. The gap between phenolic components is then back filled deeper than the maximum expected char line with sealing compound. Design of the gaps allows for thermal expansion of the nozzle and tolerance in mating nozzle component contours. Sealing compound provides a high-temperature, flexible structural support for nozzle phenolic layers at the joint.

4. Structural analyses for nozzle bondlines using adhesives EA946 and EA913NA do not include residual stresses. For this reason, RWW0548 has been approved to waive the requirements to include residual stress in ultimate combined load structural analyses for the current nozzle structural adhesives. New analyses techniques developed for TIGA adhesive may show a negative margin of safety if same analyses were applied to EA946 and EA913NA bondlines. Extensive testing and model validation was conducted for TIGA adhesive to address residual stresses, which have not been performed on EA946 and EA913NA adhesives. Therefore, inclusion of residual stresses in the structural analyses for EA946 and EA913NA bondlines is waived.

   Flight rational includes the following: 1. Nozzles are considered fully qualified with a demonstrated reliability of 0.996. 2. The 2.0 bond safety factor is meant to cover unknown conditions such as residual stress effects. 3. Process controls have been added to include monitoring and controlling of bond loads, monitoring Coeflex-shim differentials, controls on rounding forces, controls on flange mismatch, controls on transportation temperatures, improvements in grit blast, eliminated bond surface contact with black

plastic, TCA-wipe prior to grit blast rather than after, and other process changes. 4. The use of improved materials include adding silane primer (adhesion promoter), virgin grit blast media for pre-bond grit blast, and incorporate the use of fresh adhesive for nozzle structural bonds.

Future incorporation of TIGA 321 adhesive on RSRM-94 will eliminate the need for waiver RWW0548. Certification analyses will include residual stresses for TIGA 321 adhesive.

7.0 FAILURE HISTORY/RELATED EXPERIENCE:

1. Current data on test failures, flight failures, unexplained failures, and other failures during RSRM ground processing activity can be found in the PRACA database.

8.0 OPERATIONAL USE: N/A

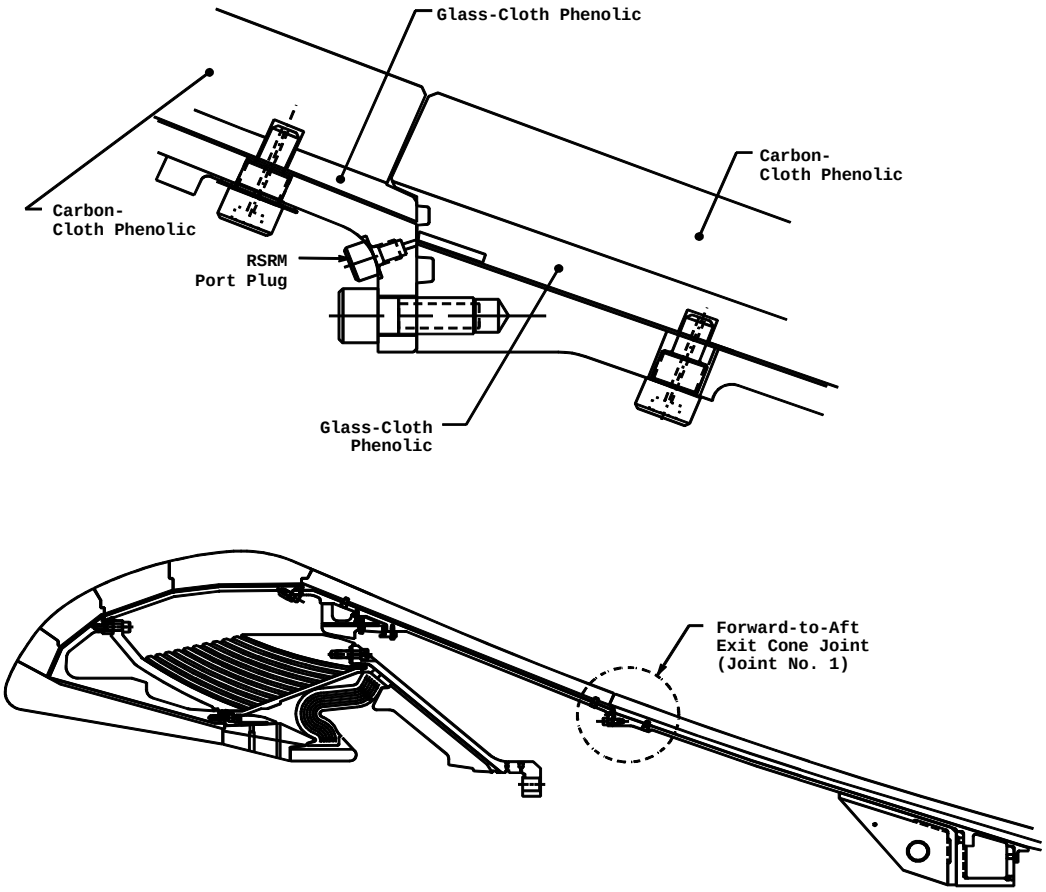

Figure 1. Forward-to-Aft Exit Cone Joint

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN	FAILURE CAUSES		
	A,G	1.	Dimensional tolerances affect fit and are per the following fabrication processes: a. Forward Exit Cone Assembly b. Aft Exit Cone Subassembly
	A,G	2.	Final machining and mandrel surface configuration provides the proper nozzle contour for the forward exit cone assembly and aft exit cone subassembly.
	A,G	3.	Torque of bolts for the aft exit cone to forward exit cone joint is per engineering drawings.
533	A,B,C,E,F,G,H	4.	Thermal analysis per TWR-17219 shows the nozzle phenolic meets the new performance factor equation based on the remaining virgin material after boost phase is complete. This performance factor will be equal to or greater than a safety factor of 1.4 for the forward exit cone assembly and the aft exit cone assembly per TWR-74238 and TWR-75135. (Carbon phenolic-to-glass interface, bondline temperature and metal housing temperatures were all taken into consideration). The new performance factor will insure that the CEI requirements will be met which requires that the bond between carbon and glass will not exceed 600 degree F, bondline of glass-to-metal remains at ambient temperature during boost phase, and the metal will not be heat affected at splashdown.
	A,C,G	5.	Assembly stresses are minimized as follows: a. Mating surface flatness is controlled by inspection of machining operations. b. Threads are cleaned and lubricated prior to assembly. c. Assembly bolts are torqued in a prearranged sequence to preload values.
	B,E	6.	Carbon-Cloth Phenolic materials function as an insulative and ablative liner in the RSRM nozzle with material characteristics per engineering.
	B	7.	Glass-Cloth Phenolic material is used as an insulator and is accepted per engineering.
	B,F	8.	The fabrication process for the forward exit cone assembly consists of two tape wrappings and two machining operations. The mandrel is first wrapped with carbon phenolic tape, hydroclave cured, and contour machined. The billet is then over wrapped with glass phenolic tape, autoclave cured, and final machined. These processes and dimensions are per engineering drawings and shop planning.
	B.F	9.	The fabrication process for the aft exit cone subassembly consists of two tape wrappings and two machining operations. The mandrel is first wrapped with carbon phenolic tape, autoclaved, and contour machined. The billet is then over wrapped with glass phenolic tape, autoclave cured, and final machined. These processes and dimensions are per engineering drawings and shop planning.
	B	10.	Surface and subsurface defect criteria rationale are per TWR-16340.
	B,F	11.	Manufacturing processes were demonstrated on development and qualification motors and are documented per TWR-18764-11.
	C	12.	Proper alignment of parts is controlled by tolerances established per engineering

drawings and shop planning.

C	13.	Assembly bondlines for phenolic interfaces are per engineering drawings.
C	14.	Assembly procedures for the aft exit cone-to-forward exit cone joint are per engineering drawings.
C	15.	Additional testing to expand the database on design tolerances and residual stresses of nozzle phenolic joints is per TWR-16975.
D	16.	Handling and lifting requirements for SRM components are per TWR-13880. Handling operations at Thiokol are per shop planning and IHM 29.
D	17.	The exit cone and exit cone fragment shipping kit is designed for transportation of the Exit Cone to the launch facility and return of the recovered exit cone fragment to Thiokol per TWA-1123.
D	18.	Assembly procedures for the aft exit cone-to-forward exit cone joint are per engineering drawings to preclude damage to seals and sealing surfaces.
D	19.	Assembly and handling processes were demonstrated on development and qualification motors per TWR-18764-11.
E	20.	Material properties of carbon phenolics are per TWR-15995.
H	21.	Manufacturing of Carbon-Cloth Phenolic is per engineering.
H	22.	Uncured Carbon-Cloth Phenolic materials are tested for volatile content per engineering.
H	23.	Packaging, storage, handling, and shipping requirements for Carbon-Cloth Phenolic are per engineering and MH&SI.
H	24.	Storage and handling of Carbon-Cloth Phenolic material is per engineering and MH&SI.
H	25.	Bias-cut carbon is wrapped over the wrap mandrel to the ply angle per engineering drawings. The ply angle is mandrel controlled per tooling.
H	26.	Tape wrap and curing of carbon-cloth phenolic is per engineering drawings and shop planning.
H	27.	After phenolic materials are wrapped and, prior to cure, components are maintained under maximum available vacuum per shop planning.
H	28.	Cured carbon-cloth materials in the forward and aft exit cones are tag end tested for residual volatiles per engineering.
H	29.	The amount of volatiles contained in nozzle carbon phenolics is controlled by manufacturing processes demonstrated on development and qualification motors per TWR-18764-11.
E,F,H	30.	Two lots of carbon-cloth phenolic from the same supplier may be used to fabricate the Forward Exit Cone.
E,F,H	31.	Two lots of carbon-cloth phenolic from the same supplier may be used to fabricate the Exit Cone, Aft.

A,B,C,D,H

32. Analysis of carbon-cloth phenolic ply angle changes for the nozzle was performed. Results show that redesigned nozzle phenolic components have a reduced in-plane fiber strain and wedge-out potential per TWR-16975. New loads that were driven by the Performance Enhancement (PE) Program were addressed in TWR-73984. No significant effects on the performance of the RSRM nozzle were identified due to PE.

9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TESTS (T)			CIL CODE
		1.	For New Exit Cone Assembly, Forward Section verify:	
A,C,G		a.	Profile	ADI085
B,F		b.	Alcohol wipe test	ADI120,SAA103
		2.	For New Exit Cone, Subassembly-Nozzle, Aft verify:	
A,C,G		a.	Profile	AGL006
B,F		b.	Alcohol wipe test	AGL010
B	(T)	c.	Radiographic examination is acceptable	AGL118
		3.	For New Forward Exit Cone (Test) verify:	
B,F	(T)	a.	Compressive strength (glass)	AMN025
B,F,H	(T)	b.	Compressive strength (carbon)	AOD040
B,F	(T)	c.	Residual volatiles (glass)	AMN079
B,F,H	(T)	d.	Residual volatiles (carbon)	AOD095
B,F	(T)	e.	Resin content (glass)	AMN097
B,F,H	(T)	f.	Resin content (carbon)	AOD117
B,F	(T)	g.	Specific gravity (glass)	AMN148
B,F,H	(T)	h.	Specific gravity (carbon)	AOD175
		4.	For New Aft Exit Cone (Test) verify:	
B,F,H	(T)	a.	Compressive strength (carbon)	AGL034
B,F	(T)	b.	Compressive strength (glass)	AGL043
B,F,H	(T)	c.	Residual volatiles (carbon)	AGL138
B,F	(T)	d.	Residual volatiles (glass)	AGL140
B,F,H	(T)	e.	Resin content (carbon)	AGL148
B,F	(T)	f.	Resin content (glass)	AGL150
B,F,H	(T)	g.	Specific gravity (carbon)	AGL173
B,F	(T)	h.	Specific gravity (glass)	AGL174
		5.	For New Forward Exit Cone verify:	
B	(T)	a.	Radiographic examination is acceptable	ADI136
H		b.	Hydroclave cure of carbon phenolic is acceptable	AHM006
H		c.	Acceptable completion of tape wrap per shop planning	AHM037A
H		d.	Proper mandrel is used	AHM020A
H		e.	Environmental history of cloth phenolic material	AOD072
H		f.	Cloth phenolic shelf life has not exceeded expiration date	AOD188
		6.	For New Exit Cone, Aft verify:	
B	(T)	a.	Radiographic examination is acceptable	AGL118A
H		b.	Proper mandrel is used	AGL001
H		c.	Autoclave cure of phenolic is acceptable	AGL019
H		d.	Acceptable completion of tape wrap per shop planning	AGL184
H		e.	Environmental history of phenolic materials	AGL104
H		f.	Carbon-cloth phenolic shelf life has not exceeded expiration date	AOD159A
		7.	For New Carbon-Cloth Phenolic verify:	

E	(T)	a.	Cloth content--uncured	AOD017
E	(T)	b.	Compressive strength--cured	AOD027
E	(T)	c.	Density--cured	AOD058
E	(T)	d.	Dry resin solids--uncured	AOD067
E	(T)	e.	Inter-laminar shear--cured	AOD075
E	(T)	f.	Resin content--cured	AOD112
E,H	(T)	g.	Resin flow--uncured	AOD140
E	(T)	h.	Sodium content--uncured	AOD164
E,H	(T)	i.	Volatile content--uncured	AOD222
E	(T)	j.	Carbon filler content--uncured	AOF000

8. For Retest Carbon-Cloth Phenolic verify:

E,H	(T)	a.	Resin flow	AOD131
E,H	(T)	b.	Volatile content	AOD236

9. For Retest Phenolic Slit Tape verify:

E,H	(T)	a.	Resin flow	AOD131A
E,H	(T)	b.	Volatile content	AOD236A

10. KSC verifies:

A,C,G		a.	Correct parallel alignment of the nozzle field joint mating surfaces during the mating operation per OMRSD File V, Vol I, B47NZ0.060	OMD051
A,C,G		b.	Nozzle bolt torque requirements per OMRSD File V, Vol I, B47GEN.130	OMD038
B,D		c.	Aft exit cone for damage (absence or penetration of ablative carbon material) prior to assembly per OMRSD File V, Vol I, B47NZ0.041	OMD049