ATK
ALLIANT TECHSYSTEMS
THIOKOL PROPULSION

CRITICAL ITEMS LIST (CIL)

No. 10-02-01-26R/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Nozzle Subsystem 10-02	PART NAME:	Throat Inlet-to-Forward Exit Cone Joint, Phenolic Components (1)
ASSEMBLY:	Nozzle and Aft Exit Cone 10-02-01		
FMEA ITEM NO.:	10-02-01-26R Rev M	PART NO.:	(See Section 6.0)
CIL REV NO.:	M (DCN-533)	PHASE(S):	Boost (BT)
DATE:	10 Apr 2002	QUANTITY:	(See Section 6.0)
SUPERSEDES PAGE:	333-1ff.	EFFECTIVITY:	(See Table 101-6)
DATED:	6 Feb 2002	HAZARD REF.:	BN-03
CIL ANALYST:	B. A. Frandsen		
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. Break up and expulsion of the nozzle causing loss of RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Wedge-out or pocketing	
1.1.1	Nonconforming fabrication of joint angle or dimensions at interfaces between phenolic components	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 processes	F
1.5	Step discontinuities between surfaces	G

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

1. Throat Inlet-to-Forward Exit Cone Joint, Phenolic Components (Figure 1).

2. The Throat Inlet-to-Forward Exit Cone Joint features a gap between the two phenolic surfaces that is pressure back-filled after the assembly is bolted together and leak tested. Sealant prevents hot gas flow and impingement between phenolic joint components. The gap provides for thermal expansion of nozzle components and the ability to mate up surfaces for nozzle component contours. Engineering drawings assemble the throat inlet to the nose inlet to form the joint. Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U77660	Nozzle Assembly, Nozzle			1/motor
5U77804	Forward Exit Cone			1/motor
1U79152	Exit Cone Assembly, Forward Section			1/motor
		Carbon-Cloth Phenolic	STW5-3279	616 lbs.
		Glass-Cloth Phenolic	STW5-2651	153 lbs.
	Forward Exit Cone	Product Specification	STW3-3462	1/motor
1U79144	Throat Inlet Assembly, Nozzle	D6AC Steel		1/motor
5U77685	Throat-Inlet Phenolic Rings			1/motor
		Carbon-Cloth Phenolic	STW5-3279	637 lbs.
		Glass-Cloth Phenolic	STW5-2651	163 lbs.
	Throat-Inlet Assembly	Product Specification	STW3-3461	1/motor
	Tape	Cloth Phenolic, Pre-impregnated	STW5-3621	A/R

6.1 CHARACTERISTICS:

1. The Throat Inlet Assembly consists of a D6AC steel housing covered by ablative and insulative liners. It interfaces with the nose inlet, flexible bearing, and forward exit cone assemblies. The shell is convergent to contain and support the throat and throat inlet rings, preclude downstream movement, and prevent ejection loads from being transmitted into the exit cone.

2. The throat ring has a redesigned ply angle to eliminate pocketing erosion observed at the aft end. Surface contour of the throat inlet ring was modified to improve uniformity of the contour between the throat inlet and throat rings. This design thickens the part slightly, thus assuring compliance with erosion and char safety factor requirements.

3. The submerged Fixed Housing Assembly consists of a conical D6AC steel structural housing providing an integral flange on the aft end for attachment of the Aft Exit Cone at the SRB assembly site. There is carbon-cloth phenolic ablative liner with glass-cloth phenolic insulation backing that is in turn bonded and pinned to the steel shell.

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

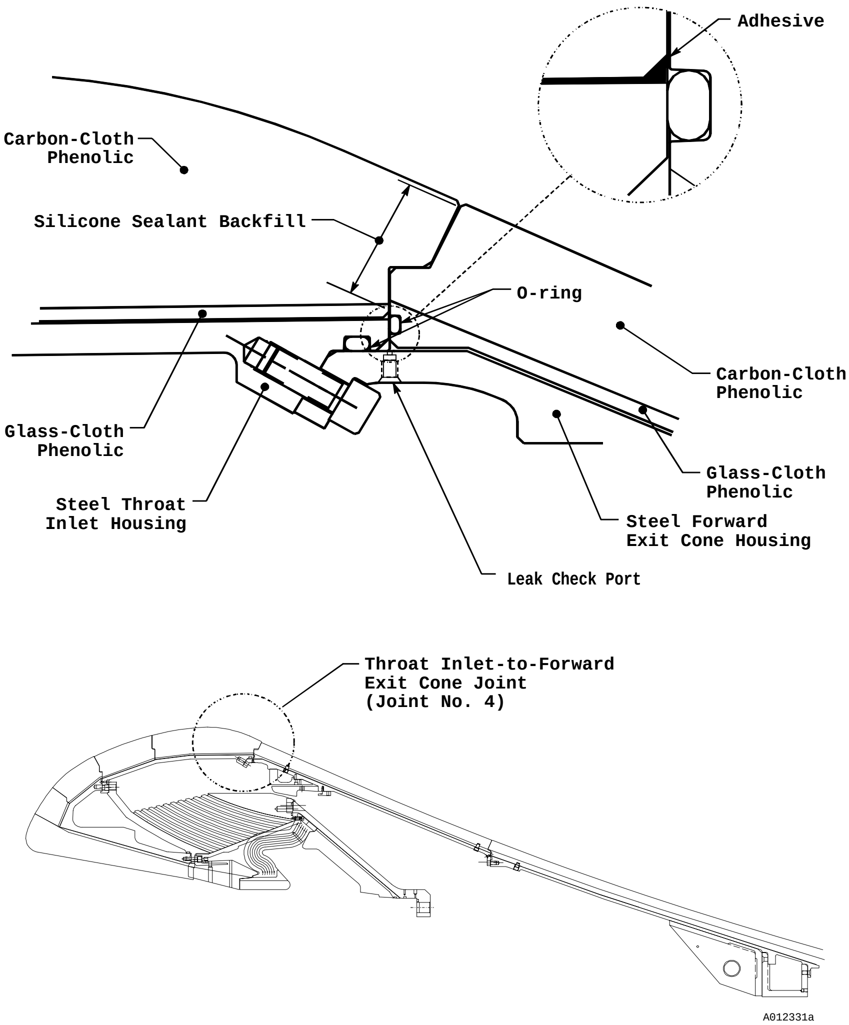

Figure 1. Throat Inlet-to-Forward Exit Cone Joint

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN	FAILURE CAUSES		
	A,G	1.	Phenolic components of the Throat Inlet Assembly and Forward Exit Cone Assembly are fabricated per engineering drawings.
	A,G	2.	Final machining and mandrel surface configuration provides the nozzle contour per engineering drawings and shop planning.
	A,C,D,G	3.	Joint gaps are controlled by dry-fitting the Exit Cone Assembly, Forward and Throat Inlet Assembly, Nozzle. By means of shop handling equipment, a bonding fixture, impression compounds, and shims, proper bond gaps are determined. Size, number, and locations of shims are per engineering drawings and shop planning.
	A,C,D,G	4.	Bolt torque and tightening sequence of the Throat Inlet Assembly, and Nozzle-to-Exit Cone Assembly, Forward is per engineering drawings and shop planning.
533	A,B,C,E,F,G	5.	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 throat rings and the forward exit cone 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	6.	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 pre-arranged sequence to preload values.
	B,E	7.	Carbon-Cloth Phenolic materials are per engineering.
	B	8.	Glass-Cloth Phenolic material is used as an insulator and is accepted per engineering.
	B,F	9.	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	10.	The fabrication process for the throat inlet assembly consists of two tape wrappings and two machinings for the throat and inlet rings. The rings are first wrapped with carbon phenolic tape, hydroclave cured, and contour machined. The billets are then over wrapped with glass phenolic tape, autoclave cured, and final machined. These processes and dimensions are per engineering drawings and shop planning.
	B	11.	Surface and subsurface defect criteria rationale are per TWR-16340.
	C	12.	Proper alignment of parts is controlled by tolerances established per engineering

Drawings and shop planning.

C 13. Additional testing to expand the database on design tolerances and residual stresses of nozzle phenolic joints is per TWR-16975.

D 14. Handling and lifting requirements for RSRM components are per TWR-13880. Handling operations at Thiokol are per shop planning and IHM 29.

D 15. Assembly procedures for the Throat Inlet Assembly, Nozzle to the Forward Exit Cone are per engineering drawings and shop planning to preclude damage to seals and sealing surfaces.

D 16. Thermal analyses were performed for RSRM components during in-plant transportation and storage to determine acceptable temperature and ambient environment exposure limits per TWR-50083. Component temperatures and exposure to ambient environments during in-plant transportation or storage are per engineering.

E 17. Material properties of carbon phenolics are analyzed per TWR-15995.

E,F 18. Two lots of carbon-cloth phenolic from the same supplier may be used to fabricate the Forward Exit Cone.

C,D 19. 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 CODES
			1.		For New Throat Inlet Assembly, Nozzle verify:	
	A,C,G			a.	Profile of throat inlet assembly is within tolerance	AAW074B
	A,G			b.	Aft end of throat inlet assembly bond line is flush with adjacent surfaces	SAA026
	A,B,F,G			c.	No unacceptable defects or sharp edges of adhesive bond line, aft end - throat inlet	SAA027
	B			d.	Alcohol wipe phenolic surfaces after final machining	AAW010
	B,F			e.	No unacceptable defects and surface finish of phenolic sealing surfaces of aft end - throat inlet	SAA025
	D			f.	component temperatures and exposure to ambient environments during in-plant transportation or storage	BAA034
			2.		For New Throat Inlet Assembly (Test) verify:	
	B,F	(T)		a.	Compressive strength (glass and carbon)	AAW044,AAW046
	B,F	(T)		b.	Residual volatiles (glass and carbon)	AAW090,AAW089
	B,F	(T)		c.	Resin content (glass and carbon)	AAW095,AAW093
	B,F	(T)		d.	Specific gravity (glass and carbon)	AAW104,AAW102
			3.		For New Exit Cone Assembly, Forward Section verify:	
	A,C,G			a.	Profile	ADI009
	B			b.	Alcohol wipe test--forward end	ADI012
	D			c.	Component temperatures and exposure to ambient environments during in-plant transportation or storage	BAA037
			4.		For New Nozzle Assembly, Final verify:	
	A,C,G			a.	Gap between the mating assemblies is acceptable per planning requirements	ADR038
	A,C,G			b.	Proper alignment per dry-fit	ADR191
	A,C,D,G			c.	Tightening sequence of socket head cap screws (throat inlet-to-forward exit cone joint) per planning requirements	ADR264
	A,C,D,G			d.	Torque value of socket head cap screws in throat inlet-to-forward exit cone joint per planning requirements	ADR268
	D			e.	Dry-fit of Forward Exit Cone-to-Throat Inlet Assembly to determine primary o-ring squeeze measurements	ADR067
	D			f.	Dry-fit of Forward Exit Cone-to-Throat Inlet Assembly to determine secondary o-ring squeeze measurements	ADR067A
	D			g.	Component temperatures and exposure to ambient environments during in-plant transportation or storage	BAA028
			5.		For New Forward Exit Cone verify:	
	B	(T)		a.	Radiographic examination is acceptable	ADI136
			6.		For New Forward Exit Cone (Test) verify:	
	B,F	(T)		a.	Compressive strength (glass and carbon)	AMN025,AOD040
	B,F	(T)		b.	Residual volatiles (glass and carbon)	AMN079,AOD095
	B,F	(T)		c.	Resin content (glass and carbon)	AMN097,AOD117
	B,F	(T)		d.	Specific gravity (glass and carbon)	AMN148,AOD175

7. For New Throat/Inlet Phenolic Rings verify:

B	(T)	a.	Radiographic examination is acceptable	AAW080,AAW083
A,B,E,F	(T)	b.	Phenolic performance test results (plasma torch or LHMEL) are acceptable	BAF100

8. 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	(T)	g.	Resin flow--uncured	AOD140
E	(T)	h.	Sodium content--uncured	AOD164
E	(T)	i.	Volatile content--uncured	AOD222
E	(T)	j.	Carbon filler content--uncured	AOF000

9. For Retest Carbon-Cloth Phenolic verify:

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

10. For Retest Phenolic Slit Tape verify:

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