CRITICAL ITEMS LIST (CIL)

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

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Nozzle Subsystem 10-02	PART NAME:	Nose Inlet-to-Forward End Ring Joint, Phenolic Components (1)
ASSEMBLY:	Nozzle and Aft Exit Cone 10-02-01		
FMEA ITEM NO.:	10-02-01-10R 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:	323-1ff.	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 resulting in break up and expulsion of the nozzle, causing a thrust imbalance between SRBs, resulting in 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 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
1.6	Ply lift of carbon-cloth phenolic	
1.6.1	Excessive volatile content	H

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

1. The nose inlet-to-forward end ring joint, is made up of phenolic components (nose inlet assembly, nozzle) assembled into the Nose-Throat-Bearing-Cowl & Boot, Housing Assembly, Nozzle (Figure 1). Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U79153	Nose-Throat-Bearing-Cowl-Housing Assembly, Nozzle			1/motor
1U79149	Nose-Throat-Bearing-Cowl Assembly, Nozzle			1/motor
1U76609	Cowl, Flexible Boot Nozzle			1/motor
	Cowl Insulation (Test)	Product Specification	STW3-3459	A/R
5U76609	Cowl Flexible Boot Phenolic			1/motor
		Carbon-Cloth Phenolic	STW5-3279	202 lbs.
		Silica-Cloth Phenolic	STW5-2652	236 lbs.
1U76608	Cowl, Flexible Boot, Nozzle			1/motor
1U79148	Housing Assembly, Cowl			1/motor
1U52838	Housing Assembly, Cowl, Nozzle			1/motor
1U79145	Nose Inlet Assembly			1/motor
	Nose Inlet (Test)	Product Specification	STW3-9020	A/R
5U77654	Nose Inlet Assembly			1/motor
	Phenolic Rings	Glass-Cloth Phenolic	STW5-2651	174 lbs.
		Carbon-Cloth Phenolic	STW5-3279	1391 lbs.
	Tape, Cloth Phenolic		STW5-3621	A/R

6.1 CHARACTERISTICS:

1. The Nose Inlet Assembly consists of an insulated and lined aluminum structure that interfaces with the throat inlet assembly and forward end ring. The assembly forms submerged outside chamber and inlet flow contours. Insulation liners consist of carbon-cloth phenolic on surfaces exposed to hot gases, backed by Glass-Cloth Phenolic (GCP) to protect the aluminum housing. The assembly is sealed with O-rings at each end to preclude penetration of hot, high-pressure gasses from the chamber.

2. The forward end ring is part of the flex bearing that provides omni-directional thrust vector control capability. End rings absorb applied loads while simultaneously controlling bearing motion during vectoring.

3. The nose inlet housing and forward end ring are bolted together. The phenolic joint is formed by the Nose Inlet Assembly and cowl assembly carbon-cloth ablative and silica-cloth lines. The gap between phenolic components is then back filled deeper than the expected char line with sealing compound. Design of the gap allows for thermal expansion of the nozzle and tolerances in mating nozzle component contours. Sealing compound provides a high-temperature, flexible structural support for nozzle phenolic layers that face together 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

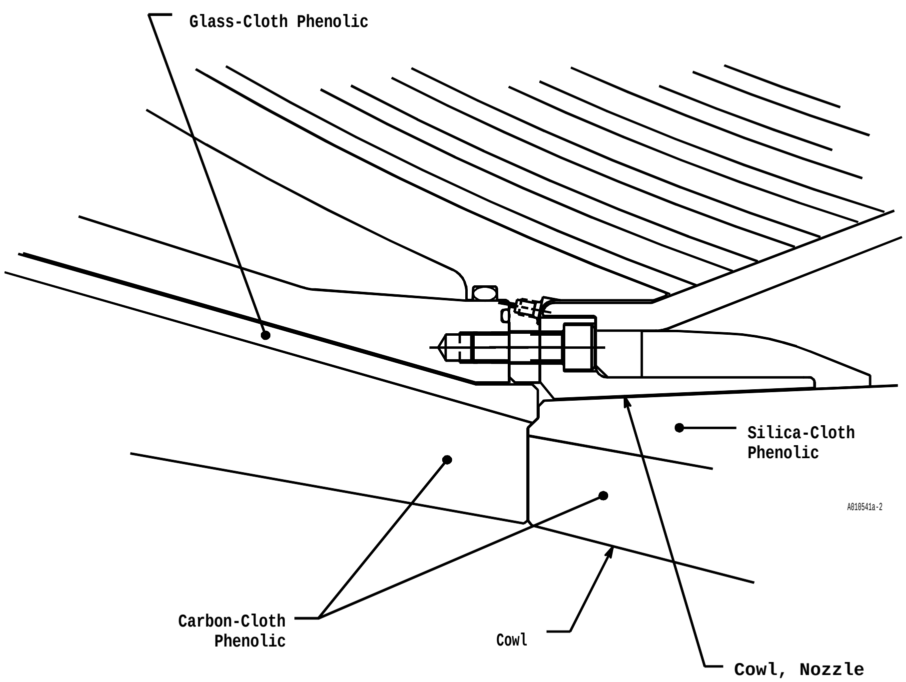

Figure 1. Nose Inlet-to-Forward End Ring Joint

9.0 RATIONALE FOR RETENTION

9.1 DESIGN:

DCN	FAILURE CAUSES		
	A,G	1.	Fabrication dimensions for the following are per engineering drawings: a. Nose Inlet Assembly b. Cowl, flexible boot assembly
	A,G	2.	Final machining and mandrel surface configuration provides the proper nozzle contour per engineering drawings and shop planning.
	A,C,D,G	3.	Bond gaps are controlled by dry-fitting the cowl housing and flexible boot. Proper bond gaps are determined by means of shop handling equipment, a bonding fixture, impression compounds, and shims. Size, number, and location of shims are controlled per engineering drawings and shop planning.
533	A,B,C,E,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 nose inlet 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.
	B	5.	Carbon-Cloth Phenolic materials function as an insulative and ablative liner in the RSRM nozzle with material characteristics per engineering.
	B	6.	Glass-Cloth Phenolic material is used as an insulator and is accepted per engineering.
	B	7.	Silica-Cloth Phenolic material is used as an insulator and is accepted per engineering.
	B,F	8.	The fabrication process for the Cowl, Flexible Boot Nozzle assembly consists of two tape wrappings and two machining operations. The mandrel is first wrapped with silica phenolic tape, autoclave cured, and contour machined. The billet is then over wrapped with carbon-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 nose cap portion of the Nose Inlet Assembly consists of two tape wrappings and two machining operations. The mandrel is first wrapped with glass-phenolic tape, autoclave cured, and contour machined. The billet is then over wrapped with carbon-phenolic tape, hydroclave 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,C,F	11.	Ply lifts per TWR-19047 occur in parts wrapped parallel to the centerline (cowl, aft exit cone). Ply lifts are caused by a build-up of pore pressure at the char/virgin interface. As char thickness increases and permeability decreases late in motor burn, pore pressures can exceed the tensile strength of the char, resulting in a ply

spread. Drop in motor pressure can exacerbate during motor tail off. The short plies at the aft end of the cowl are charred completely, such that they are not anchored in virgin material. This feature, in combination with ply lifts, results in char wedge outs. In addition, zero degree plies do not erode uniformly, resulting in a "ratty" appearance. Changing the ply angle to 50^{o} eliminates ply lifts, and a smooth uniform erosion pattern similar to the forward end of the outer boot ring is obtained.

C 12. Proper alignment of parts is per engineering drawings.

C 13. The Cowl, flexible boot, nozzle is bonded to the cowl housing with epoxy adhesive per engineering drawings and shop planning.

C 14. Additional testing to expand the database on design tolerances and residual stresses of nozzle phenolic joints is per TWR-16975.

C 15. 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.

D 16. Handling and lifting requirements for RSRM 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. 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 19. Carbon-Cloth Phenolic materials are per engineering.

533 E 20. Structural analysis documented in TWR-16975 show that nozzle phenolic-to-metal bondlines have positive margins of safety based on a safety factor of 2.0. These analyses used standard conditions as allowed by the CEI specification.

E 21. Material properties of carbon phenolics are per TWR-15995.

H 22. Manufacturing of Carbon-Cloth Phenolic is per engineering.

H 23. Uncured Carbon-Cloth Phenolic materials are tested for volatile content per engineering.

H 24. Bias-cut carbon phenolic for the nose inlet assembly, nozzle, and straight-cut carbon phenolic for the cowl, flexible boot, nozzle, are wrapped over the wrap mandrel to the ply angle per engineering drawings. Ply angle is mandrel-controlled per tooling and machine set up.

H 25. Cowl Carbon-Cloth Phenolic material is tape wrapped to establish a new 50^{o} ply angle to insure that it will have the same ply-angle-to-flow as the adjacent outer boot ring, which does not experience ply lifting per TWR-61933.

H	26.	Tape wrap and cure 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 material is tag end tested for residual volatiles per engineering.
H	29.	The amount of volatiles contained in nozzle carbon phenolics is per manufacturing processes demonstrated on development and qualification motors per TWR-18764-09.
E,F,H	30.	Two lots of carbon-cloth phenolic from the same supplier may be used to fabricate the nose cap of the Nozzle Nose-Inlet Assembly.
A,B,C,E,G,H	31.	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.
A,C,D,G	32.	Joint gap at nozzle joint 2 is established/controlled by the machining profiles of phenolic components per engineering drawings. Following joint assembly, the surface C (cowl carbon phenolic to nose cap carbon phenolic) gap is verified by feeler gauge. Surface C feeler gauge inspection and subassembly machining profiles confirm acceptability of the remaining internal joint gap dimensions.

9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TESTS	(T)			CIL CODES
			1.	For New Cowl Flexible Boot Phenolic verify:	
	A,C,G		a.	Forward end surface profile after final machine	AFL021
	A,C,G		b.	Forward carbon and silica phenolic chamfer after final machine	AFL022,AFL025
	B,F		c.	Alcohol wipe phenolic surfaces	AFL001
	B,F	(T)	d.	Radiographic examination of cowl is acceptable	AFL037
	H		e.	Autoclave cure is complete and acceptable	AFL005
	H		f.	Tape wrapping is complete and acceptable	AFL009
	H		g.	Proper mandrel is used	AFL050
			2.	For New Cowl, Flexible Boot, Nozzle verify:	
	A,C,G		a.	Forward end flatness after final machine	AFL023
			3.	For New Cowl Insulation (Test) verify:	
	B,F,H	(T)	a.	Compressive strength (silica and carbon)	AMO004,AOD038
	B,F,H	(T)	b.	Residual volatiles (silica and carbon)	AMO017,AOD093
	B,F,H	(T)	c.	Resin content (silica and carbon)	AMO019,AOD116
	B,F,H	(T)	d.	Specific gravity (silica and carbon)	AMO025,AOD173
			4.	For New Nose Inlet Assembly, Nozzle verify:	
	A,C,G		a.	Aft phenolic chamfer after final machine	ADT014,ADT016
	A,C,G		b.	Aft end surface profile of nose cap after final machine	ADT015
	B,F		c.	Alcohol wipe phenolic surfaces	ADT019
	D		d.	Component temperatures and exposure to ambient environments during in-plant transportation or storage	BAA036
			5.	For New Nose Inlet Assembly Phenolic Rings verify:	
	A,C,G		a.	Proper mandrel--first wrap	AHO100
	B,F	(T)	b.	Radiographic examination is acceptable	ADT106,ADT109,ADT115
	H		c.	Carbon-cloth tape wrapping is complete and acceptable	AHO010,AHO012,AHO008
	H		d.	Hydroclave cure of carbon is complete and acceptable	AHO054,AHO057,AHO060
	H		e.	Proper mandrel--first wrap	AHO099,AHO101
	H		f.	Proper mandrel--second wrap	AHO103
			6.	For New Nose Inlet (Test) verify:	
	B,F	(T)	a.	Compressive strength (glass)	AHO030
	B,F,H	(T)	b.	Compressive strength (carbon)	AHO024
	B,F	(T)	c.	Residual volatiles (glass)	AHO116
	B,F,H	(T)	d.	Residual volatiles (carbon)	AHO110
	B,F	(T)	e.	Resin content (glass)	AHO134
	B,F,H	(T)	f.	Resin content (carbon)	AHO128
	B,F	(T)	g.	Specific gravity (glass)	AHO156
	B,F,H	(T)	h.	Specific gravity (carbon)	AHO149
			7.	For New Housing Assembly, Cowl verify:	

A,C,D,G			a.	Proper bond gaps are attained per dry fit	ADQ180
C,D			b.	Bonding of assemblies	ADQ038
		8.	For New Nose-Throat-Bearing-Cowl Housing Assembly, Nozzle verify:		
A,C,G			a.	Fixed housing is properly aligned with index pin--aft end ring	ADQ178
D			b.	All primed interfacing surfaces are free from damage (inner boot ring)	ADQ003
D			c.	All primed interfacing surfaces are free from contamination (inner boot ring)	ADQ003A
D			d.	All primed interfacing surfaces are free from damage (bearing protector)	ADQ004
D			e.	All primed interfacing surfaces are free from contamination (bearing protector)	ADQ049
		9.	For New Nose-Throat-Bearing-Cowl Assembly verify:		
D			a.	All primed interfacing surfaces are free from damage (cowl)	ADQ002
D			b.	All primed interfacing surfaces are free from damage (nose cap)	ADQ005
D			c.	All primed interfacing surfaces are free from contamination (cowl)	ADQ048
D			d.	All primed interfacing surfaces are free from contamination (nose cap)	ADQ050
		10.	For New Boot, Flexible Bearing, Nozzle verify:		
D			a.	Component temperatures and exposure to ambient environments during in-plant transportation or storage	BAA029
		11.	For New Nozzle Assembly, Final verify:		
D			a.	Component temperatures and exposure to ambient environments during in-plant transportation or storage	BAA028
		12.	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
		13.	For Retest Carbon-Cloth Phenolic verify:		
E	(T)		a.	Resin flow	AOD131
E	(T)		b.	Volatile content	AOD236
		14.	For Retest Phenolic Slit Tape verify:		
E	(T)		a.	Resin flow	AOD131A
E	(T)		b.	Volatile content	AOD236A