ATK ALLIANT TECHSYSTEMS
THIOKOL PROPULSION

CRITICAL ITEMS LIST (CIL)

No. 10-02-06-01/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Nozzle Subsystem 10-02	PART NAME:	Nozzle Aft Exit Cone External Insulation (TPS)
ASSEMBLY:	Thermal Protection System 10-02-06		
FMEA ITEM NO.:	10-02-06-01 Rev N	PART NO:	(See Section 6.0)
CIL REV NO.:	N	PHASE(S):	Boost (BT)
DATE:	27 Jul 2001	QUANTITY:	(See Section 6.0)
SUPERSEDES PAGE:	350-1ff.	EFFECTIVITY:	(See Table 101-6)
DATED:	31 Jul 2000	HAZARD REF.:	BN-04
CIL ANALYST:	R. E. L. Hamilton		
APPROVED BY:		DATE:	

RELIABILITY ENGINEERING: K. G. Sanofsky 27 July 2001

ENGINEERING: V. B. Teller 27 July 2001

1.0 FAILURE CONDITION: Failure during operation (D)

2.0 FAILURE MODE: 1.0 Thermal failure of cork or ablation compound

3.0 FAILURE EFFECTS: Burn-through and loss of aft portion of Aft Exit Cone causing thrust reduction and loss of RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Cork or ablation compound not manufactured or applied to required thickness	A
1.2	Bond line failure of the cork and ablation compound	
1.2.1	Bonding surfaces not properly prepared or adequately cleaned	B
1.2.2	Bonding material not properly mixed, applied, or cured	C
1.2.3	Contamination during processing	D
1.2.4	Process environments detrimental to bond strength	E
1.2.5	Nonconforming material properties	F
1.2.6	Aeroheating and plume radiation	G
1.3	Moisture and/or fungus degradation of cork	H
1.4	Nonconforming material properties	I
1.5	Structural failure of cork or ablation compound due to acoustic vibration and aeroshear	J
1.6	Component degradation during assembly, handling, transportation, or storage	K

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

1. The insulated exit cone sub assembly, aft has a cork sheet layer bonded to the exterior exposed portion of the aft exit cone and paint applied over the top of the cork. The aft exit cone interfaces with the forward exit cone assembly and consists of a partial aluminum shell, glass phenolic insulator, and carbon cloth liner (Figure 1). Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U77697	Exit Cone Sub Assembly, Aft Insulated			1/motor
	Cork Sheet	Sheet Cork	STW4-2700	38 sht/motor (0.25” thick)
	Ablation Compound, Cork Filled	Epoxy Resin, Polyamide resin hardener, and Ground Cork Filler	STW5-3183	2 lb/motor
	Paint	Moisture and Fungus Protection	STW4-9084	3 gal/motor
	Adhesive, Epoxy, Two-Part	Epoxy Adhesive, Two-Part, Room-Temperature Cure	STW5-2811	36 lb/motor
1U77652	Exit Cone Sub-Assembly Nozzle, aft			1/motor

6.1 CHARACTERISTICS:

1. The insulated Aft Exit Cone for the RSRM has a layer of sheet cork bonded to its glass phenolic surface and a protective paint coating applied to the surface of the sheet cork. The cork provides a thermal protection barrier for the Aft Exit Cone with the following thermal sources being considered:

   a. Plume radiation heating from RSRM exhaust
   b. The base re-circulation heating from the aft end of the motor from its exhaust
   c. Back wash from the plume of the space shuttle main engine

2. The paint coating provides an environmental protection layer for sheet cork.

3. Engineering determined that there is no practical test available to determine cork-to-phenolic bond strength since the cork will fail before the adhesive. Testing performed to determine bond strength of the cork-to-Aft Exit Cone shows the cork will fail before the adhesive at all temperatures the Aft Exit Cone will experience from launch through separation.

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

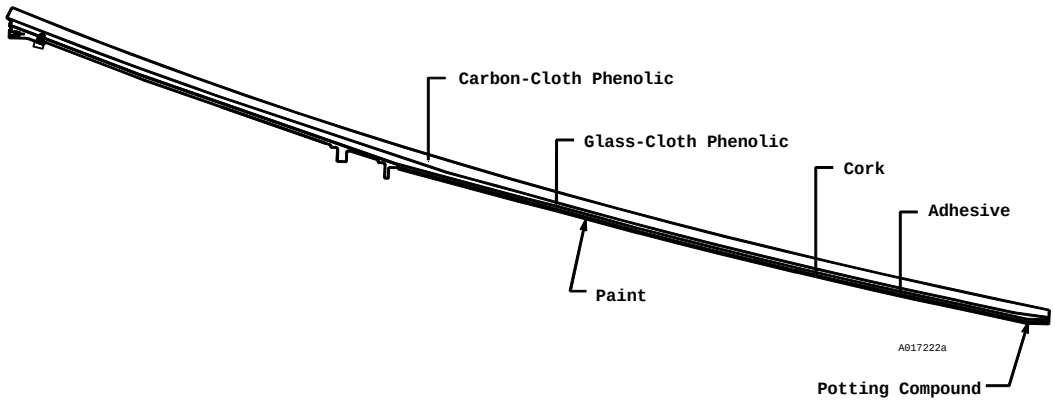

Figure 1. Insulated Aft Exit Cone Assembly

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN	FAILURE CAUSES	
A	1.	Cork material thickness is controlled per engineering drawings and specifications.
A,C	2.	Application of ablation compound is controlled per engineering drawings, specifications, and shop planning.
A,B,C,D,E,F,I	3.	Material properties and processes for nozzle Aft Exit Cone thermal protection were demonstrated on development and qualification motors and documented in TWR-18764-11.
B	4.	Preparation and cleaning of bonding cork and applying ablation compound to the aft exit cone liner are per engineering drawings, specifications, and shop planning.
B	5.	Preparation and cleaning of bonding surfaces are per shop planning. Cleanliness of bonding surfaces is determined by a combination of visual inspection and visual inspection aided by black light. Surface inspection type is per shop planning.
C	6.	Cork adhesive is mixed per engineering.
C	7.	Application and cure of cork adhesive is per engineering drawings and shop planning.
C	8.	Ablation compound is mixed per engineering.
C	9.	Process environments for mixing, application, and cure are per engineering drawings and shop planning.
D,E	10.	Cleanliness of bonding processes to prevent contamination and process environments are controlled per shop planning, engineering drawings, and TWR-16564.
D,E	11.	Additional testing to expand the database on the effects of contamination on bond strength was performed per TWR-16858.
F,I	12.	Material properties of cork are per engineering.
F,I	13.	Material properties of cork adhesive are controlled per engineering.
F,I	14.	Ablation compound is a three-part trowelable, cork-filled mastic containing: a. Ground cork, filler b. Polyamide resin, hardener c. Epoxy resin
G	15.	Thermal analysis per TWR-17221 concludes that cork sheet adequately protects the exit cone during operation.
G	16.	By design, the Aft Exit Cone on each flight motor is severed shortly before splashdown to minimize impact when the motor reaches the water. The Aft Exit Cone is not available for post-flight investigation.
G	17.	Post investigation of static fired motors showed no damage to the nozzle due to plume radiation.

H 18. Moisture and fungus degradation of cork is controlled by application of polyethylene paint per engineering drawings and shop planning. Paint provides a moisture barrier that is resistant to weathering and fungus growth.

H 19. Properties of paint are per engineering.

J 20. Structural load allocations for the Aft Exit Cone cork under acoustic vibration and aeroshear are per TWR-16801. TWR-16801 was updated to incorporate load changes associated with the Space Shuttle Vehicle (SSV) Performance Enhancement (PE) Program that was implemented to increase SSV payload capacity.

K 21. Transportation and handling of nozzle assembly items by Thiokol is per IHM 29.

K 22. Positive cradling or support devices and tie downs that conform to shape, size, weight, and contour of the component to be transported are provided to support RSRM segments and other components. Shock mounting and other protective devices are used on trucks and dollies to move sensitive loads per TWR-13880.

K 23. Support equipment used to test, handle, transport, and assemble or disassemble the RSRM is certified and verified per TWR-15723.

K 24. The nozzle assembly is shipped in the aft segment. Railcar transportation shock and vibration levels are monitored per engineering and applicable loads are derived by analysis. Monitoring records are evaluated by Thiokol to verify shock and vibration levels per MSFC Specification SE-019-049-2H were not exceeded. TWR-16975 documents compliance of the nozzle with environments per MSFC specifications.

K 25. Analysis is conducted by Thiokol engineering to assess vibration and shock load response of the RSRM nozzle during transportation and handling to assembly and launch sites per TWR-16975.

K 26. 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 IHM 29.

K 27. Two-Part Epoxy Adhesive meets 5-year aging requirements as documented in TWR-64503.

9.2 TEST AND INSPECTION:

DCN	TEST	(T)	FAILURE CAUSES and	CIL CODE
			1. For New Cork Sheet verify:	
A			a. Thickness	ALR001
F,I		(T)	b. Density	ALR003,ALR004
F,I		(T)	c. Tensile strength	ALR044,ALR045
F,I		(T)	d. Tensile elongation	ALR038,ALR039
F,I		(T)	e. Recovery	ALR025
F,I		(T)	f. Specific heat	ALR030
F,I		(T)	g. Thermal conductivity	ALR050
F,I		(T)	h. Flexibility	ALR013,ALR014
			2. For Retest Cork Sheet verify:	
F,I		(T)	a. Density	ALR009
F,I		(T)	b. Flexibility	ALR017
F,I		(T)	c. Specific heat	ALR035
			3. For New Adhesive, Epoxy, Two-Part verify:	
F,I		(T)	a. Pot life	ANE003
F,I		(T)	b. Viscosity	ANE010
F,I		(T)	c. Lap shear bond	ANE000
F,I		(T)	d. Tensile adhesion strength	ANE008
			4. For New Ablation Compound, Cork-Filled verify:	
F,I		(T)	a. Shore D hardness	ANX008,ANX006
F,I		(T)	b. Solids content	ANX012
F,I		(T)	c. Specific gravity	ANX016
F,I		(T)	d. Tensile strength	ANX021,ANX019
F,I		(T)	e. Pot life	FAF011
F,I			f. Workmanship	FAF013
			5. For New Paint, Moisture and Fungus Protection verify:	
H			a. Color	ANU002
H		(T)	b. Nonvolatile content	ANU009
H		(T)	c. Viscosity	ANU018
H			d. Weight per gallon	ANU025
H			e. Supplier Certificate of Conformance	ANU015
H			f. Workmanship	DJM012
H		(T)	g. Adhesion	DJM013
			6. For New Exit Cone, Sub-assembly-Nozzle, Aft verify:	
K			a. Component temperatures and exposure to ambient environments	BAA026
			7. For New Exit Cone Sub Assembly, Aft Insulated verify:	
A,C			a. Proper application of the ablation compound per planning requirements	HHH009
A,C			b. Proper mixing of the ablation compound	HHH001
A,C			c. Application of ablation compound was completed before pot life expiration	HHH010
B,D,E			d. Cork is wiped per the planning requirements	HHH002

	B,D,E		e.	Aft exit cone is wiped per planning requirements	HHH004
	B,D,E		f.	Dry time of the aft exit cone after solvent wipe per planning requirements	HHH005
	B,D,E		g.	With black light the cleanliness of the cork bonding surface	HHH006
	B,D,E		h.	With black light the cleanliness of the aft exit cone cork bonding surface	HHH011
	B		i.	Visual acceptance criteria does not exceed blemish conditions as described in the specification	HHH015
	B,C,D, E,F,I	(T)	j.	Witness panel results for aft exit cone cork to glass phenolic bonds	NCC019
569	C		k.	Cork adhesive (Two-part Epoxy) is mixed per planning requirements	HHH014
	C		l.	Application of cork adhesive per planning requirements	HHH012
	C	(T)	m.	Shore D hardness of cork adhesive cure cups per specifications	HHH013
	K		n.	Component temperatures and exposure to ambient environments during in-plant transportation or storage are per specifications	BAA027
	D,E		o.	Dry time of the cork after solvent wipe per planning requirements	HHH003

8. KSC verifies:

	H,K		a.	Nozzle aft exit cone for damage or contamination to metal components, cork insulation, and painted surfaces prior to assembly per OMRSD File V, Vol I, B47NZ0.020	OMD046