ATK ALLIANT TECHSYSTEMS
THIOKOL PROPULSION

CRITICAL ITEMS LIST (CIL)

No. 10-04-04-01/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Lightning Protection, ESD, and Instrumentation 10-04	PART NAME:	Insulation of Ground Environmental Instrumentation Components (1)
ASSEMBLY:	Ground Environmental Instrumentation (GEI) 10-04-04	PART NO.:	(See Section 6.0)
		PHASE(S):	Boost (BT)
FMEA ITEM NO.:	10-04-04-01 Rev N	QUANTITY:	(See Section 6.0)
CIL REV NO.:	N	EFFECTIVITY:	(See Table 101-6)
DATE:	27 Jul 2001	HAZARD REF.:	BC-11
SUPERSEDES PAGE:	511-1ff.		
DATE:	31 Jul 2000		
CIL ANALYST:	D. F. Bartelt		
APPROVED BY:		DATE:	

RELIABILITY ENGINEERING: K. G. Sanofsky 27 Jul 2001

ENGINEERING: V. B. Teller 27 Jul 2001

1.0 FAILURE CONDITION: Failure during operation (D)

2.0 FAILURE MODE: 1.0 Structural failure

3.0 FAILURE EFFECTS: Break up and loss of insulation over the Ground Environmental Instrumentation (GEI). Debris damages adjacent STS systems causing loss of crew and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Bond line failure of the cork or ablation compound	A
1.2	Vibration and aeroshear	B
1.3	Nonconforming material properties	C
1.4	Cork or ablation compound not manufactured or applied to required thickness	D
1.5	Aeroheating and plume radiation	E
1.6	Transportation, handling, or assembly damage	F
1.7	Moisture, fungus, or age degradation	G

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

1. The Ground Environmental Instrumentation (GEI), which comprises a network of temperature sensors and lead wires bonded to the RSRM, is encapsulated in insulating materials. Insulating materials used on the external surface of the case are referred to collectively as the Thermal Protection System (TPS). GEI installation is completed in engineering drawings. Drawings and materials associated with the GEI insulation are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U77648	Assembly and Closeout, RSRM, KSC	Various		1/motor
1U77610	Segment, Rocket Motor, Forward	Various		1/motor
1U77620	Segment, Rocket Motor, Forward Center	Various		1/motor
1U77630	Segment, Rocket Motor, Aft Center	Various		1/motor
1U77640	Segment, Rocket Motor, Aft	Various		1/motor
1U77713	Case Assembly, Painted Forward Segment	Various		1/motor
1U77714	Case Assembly, Painted Center Segment	Various		2/motor
1U77715	Case Assembly, Painted Aft Segment	Various		1/motor
1U75642	Aft Dome, Painted	Various		1/motor
	Top Coating (paint)	Epoxy	STW5-3225	A/R
	Primer, Zinc-rich	Epoxy	STW5-3226	A/R
	Insulation	Sheet Cork	STW4-2700	A/R
	Rubber	EPDM	STW4-2736	A/R
	Paint	Moisture and Fungus Protection Paint	STW4-9084	A/R
	Ablation Compound, Cork-Filled (K5NA)	Ground Cork, Epoxy Resin, Curing Agent	STW5-3183	A/R
	Epoxy Resin Adhesive, Non-Asbestos	Epoxy Resin and Curing Agent	STW4-3218	A/R

6.1 CHARACTERISTICS:

1. GEI is used to monitor temperatures before launch only and has no function during and after launch. However, structural failure of GEI insulation during launch could cause debris damage to the orbiter. Temperature sensors and wires are embedded in K5NA insulation between strips of molded and cut sheet cork (see Figure 1). K5NA ablation compound is a mixture of granular cork and epoxy adhesive. Covering structures of K5NA and sheet cork restrain the electrical components and also serve as thermal protection. If bonds between the insulating materials and case are too weak, or if materials are too weak, then portions of GEI insulation may come loose and become flying debris.

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

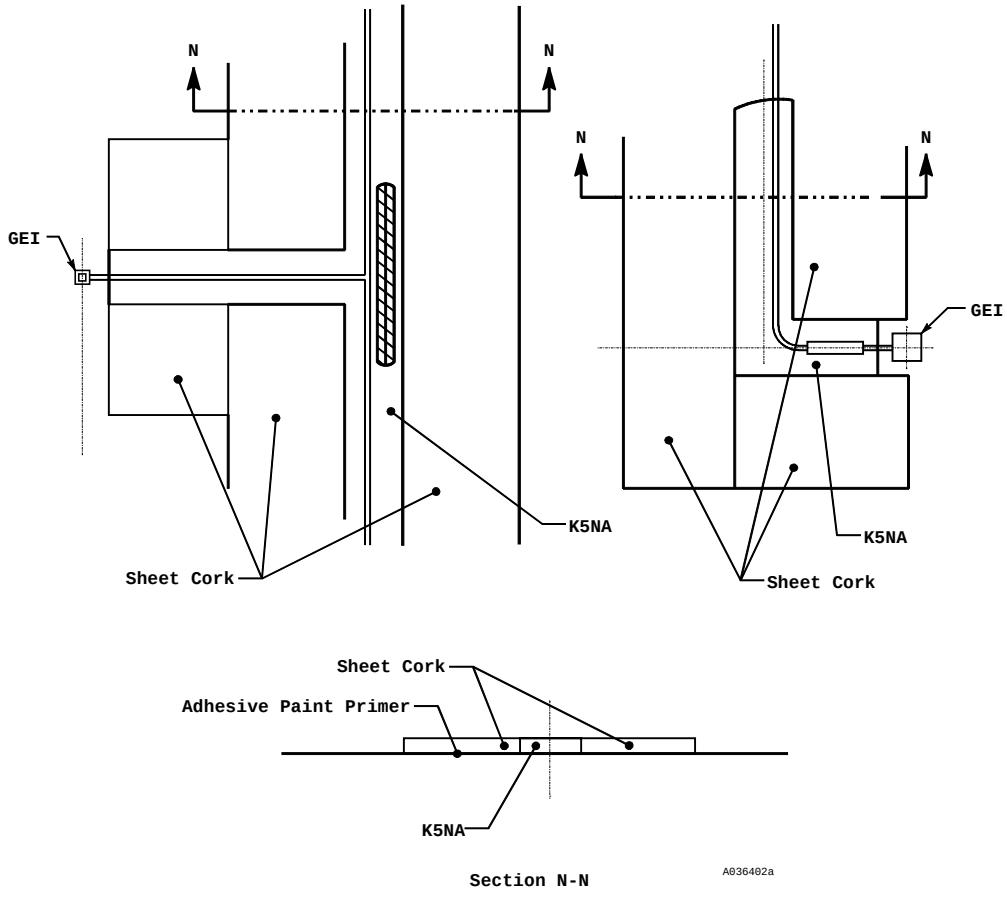

Figure 1. Ground Environmental Instrumentation (GEI)
Examples Showing Insulating Structure.

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN FAILURE CAUSES

A 1. Adhesion of GEI insulation (TPS) is assured by control of contamination and workmanship at each step of the process as follows:

a. Clean, prime and paint
b. Application of cork dams
c. Installation of GEI
d. Application of ablation compound over the GEI
e. Painting of TPS

A 2. A debris prevention analysis for GEI insulation is per TWR-18091.

A,B,D,E 3. Testing of GEI structures for resistance to aerodynamic and aerothermal loading was not performed. However, wind tunnel testing of similar FJPS and heater cable closeout structures is part of qualification testing per TWR-17243. There were no bondline failures, structural failures, nor excessive erosion. This indirectly demonstrates the structural integrity of GEI insulation bondlines, ablation compound (K5NA), and sheet cork under aeroshear environments. Thermal response of TPS structure to aeroheating was satisfactory which indirectly demonstrates thermal integrity of GEI insulation bondlines, ablation compound, and sheet cork under aeroheating environments.

A 4. Positive margins of safety, over a required factor of safety of 2.0 for structural loading, were demonstrated by analysis per TWR-16969 for cork and TWR-18871 for ablation compound, K5NA.

A,B,C,D,E 5. Thermal analysis of current GEI insulation construction was performed, showing that the presently used covering of ablation compound (K5NA) provides adequate thermal protection per TWR-18879. Validation of properties for TPS materials are as follows:

Thermal and Material	Development and Structural Analyses	Acceptance Testing
Cork	TWR-16969 TWR-18879	TWR-50020, TWR-50021 (moisture tests)
Ablation compound (K5NA)	TWR-18871 TWR-18879	TWR-50020, TWR-50021 (moisture tests)
Paint	-------	TWR-66657 (moisture tests)

B 6. Vibration and pressurization testing of similar FJPS was performed per TWR-17245. Testing included environmental conditioning to pre-launch natural environments consisting of high temperature, high humidity, salt, fog, rain, and low temperature. After conditioning, the test article was subjected to flight and re-entry random vibration, vehicle dynamics vibration, and water landing shock. Post-test visual inspections performed after each sub test emphasized examinations for obvious debonds, delaminations, and/or any other degradation. Following testing and post-test inspections, pull tests were performed on cork discs isolated from the surrounding cork. Pull test data are used for materials and adhesives evaluation only, but these data and other test results verify the structural integrity of GEI structures, including absence of insulation bond degradation during short-term exposure to worst-case natural environments.

D,E 7. Cork material thickness is per engineering drawings and specifications.

D,E 8. Application of ablation compound is per engineering drawings and specifications.

F 9. Rail car transportation shock and vibration levels for the segment are monitored per on-car instrumentation and recorders, and loads are per analysis. Monitoring records are evaluated by Thiokol to verify that shock and vibration levels per MSFC specifications were not exceeded.

F 10. Support equipment used to test, handle, transport, and assemble or disassemble the RSRM is certified and verified per TWR-15723.

G 11. To prevent moisture and fungus damage or age degradation prior to installation:

a. Packaging prevents absorption of moisture during shipment and storage. Packaging material must be capable of being resealed during use.
b. Cork material must have a minimum storage life of 2 years from date of receipt when stored at warehouse-ambient temperature. Each time a container is opened, it is resealed to maintain material properties during storage. Storage life may be extended if the material passes re-tests.

G 12. After installation, to prevent moisture and fungus damage, all exposed surfaces of cork, adhesive, and ablation compound are coated with paint. Engineering imposes the following requirements:

a. Paint must have a low permeability to moisture and must be resistant to weathering and fungus growth. Conformance to requirements on accelerated weathering, fungus resistance, and permeability are verified as part of material qualification testing.
b. Paint must have a minimum storage life of one year from date of manufacture when stored in its original container at the specified temperature.

G 13. Cork and K5NA bond testing on aged TEM motors for over five years, maintained a positive structural margin of safety per TWR-64178.

B,E,F 14. TWR-66825-2 and -6 were updated to incorporate the Performance Enhancement (PE) Program. Predicted PE temperatures and aerodynamic loads for the Systems Tunnel, Systems Tunnel Cork, and GEI TPS remain essentially unchanged. Load factors were updated to include rigid body loads, but resulting effects were insignificant. Existing stresses and structural margins of safety quoted for the Generic Aero/Heating Certification are valid for PE per TWR-66825-2 & -6.

9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TESTS (T)				CIL CODES
			1.	For New Case Assembly, Painted Segment (Forward, Center, and Aft) verify:	
	A,G		a.	Shelf life and environmental history, paint and primer	AEY035,AEY048,AEZ035 AEZ045,AFB035,AFB045
	A,G		b.	For application of paint and primer, facilities and equipment are clean	AEY037,AEZ034,AFB034
	A,G		c.	Surfaces to be primed are clean and free from contamination	AEY005,AEZ005,AFB005
	A,G		d.	For application of paint and primer, humidity and case temperature	AEY018,AEZ016,AFB016
	A,G		e.	Container is covered after mixing, paint and primer	AEY034,AEY040,AEZ031 AEZ037,AFB031,AFB037
	A,G		f.	Full cover coat, paint and primer	AEY014,AEY015,AEZ012 AEZ013,AFB012,AFB013
	A,G		g.	Runs, sags, drips, and inclusions are acceptable per specification, paint and primer	AEY033,AEY047,AEZ030 AEZ044,AFB044,FAA103
	A,G		h.	Dry film thickness, paint and primer	AEY025,AEY002,AEZ022 AEZ002,AFB022,AFB002
	A,G	(T)	i.	Adhesion strength, paint and primer	FAD005,FAD006,FAD007
			2.	For New Case Assembly, Aft Dome, Painted verify:	
	A,G		a.	Shelf life and environmental history, paint and primer	FAA090,FAA091
	A,G		b.	For application of paint and primer, facilities and equipment are clean	FAA092
	A,G		c.	Surfaces to be primed are clean and free from contamination	FAA097
	A,G		d.	For application of paint and primer, humidity and case temperature	FAA098
	A,G		e.	Container is covered after mixing, paint and primer	FAA099,FAA100
	A,G		f.	Full cover coat, paint and primer	FAA093,FAA094
	A,G		g.	Runs, sags, drips, and inclusions are acceptable per specification, paint and primer	FAA095,FAA096
	A,G		h.	Dry film thickness, paint and primer	FAA101,FAA102
	A,G	(T)	i.	Adhesion strength, paint and primer	FAD008
			3.	For New Segment, Rocket Motor (Forward, Forward Center, Aft Center, and Aft), verify:	
	A,C,G	(T)	a.	Shore A hardness of epoxy resin adhesive before removal of bonding aids for cork insulation bonding	AFR008,AFS008,AFU008,AFW040
	A,G		b.	Light abrasion and cleaning of all bonding surfaces prior to bonding cork	AFR009,AFS009,AFU009,AFW009
	A,G		c.	Epoxy resin adhesive application for cork installation	AFR010,AFS010,AFU010,AFW010
	A,G		d.	Entire cork bonding surface of the case is free of contamination per black light inspection	AFR015,AFS040,AFU040,AFW035
	A,G		e.	Repair of defects, unbonds, voids, and gaps in cork insulation	AFR025,AFS025,AFU025,AFW023
569	A,G		f.	Epoxy resin adhesive for cork insulation bonding is mixed per planning requirements	AFR031,AFS031,AFU031,AFW028
	A,C,G	(T)	g.	Shore D hardness of each mix of epoxy resin adhesive for cork insulation bonding	AFR036,AFS036,AFU036,AFW041
	A,G		h.	Vacuum bag pressure and application within pot life	FAA211,FAA212,FAA213,FAA214
	A,G		i.	Case bonding surface temperature prior to	

			bonding cork	FAB001,FAB005,FAB009,FAB013
A,G		j.	After cutting cork pieces, examine for loose or damaged areas	FAB002,FAB006,FAB010.FAB014
A,G		k.	Epoxy resin adhesive pot life for cork insulation bonding	FAB003,FAB007,FAB011,FAB015
A,G		l.	Epoxy resin adhesive curing schedule for cork insulation bonding	FAB004,FAB008,FAB012,FAB016
A,G		m.	Cork insulation is free of damage, voids, or unbond conditions	FAB510,FAB511,FAB512,FAB513
A,C,G	(T)	n.	Shore D hardness of samples for ablation compound	FAF010,FAF012,FAF014,FAF016
A,D,E,G		o.	Application of ablation compound	FAB022,FAB023,FAB024,FAB025
A,G		p.	Shelf life and environmental history of paint prior to application	FAB031,FAB034,FAB037,FAB040
A,G		q.	Full coverage of paint with no runs, sags, or bubbles	FAB032,FAB035,FAB038,FAB041
A,G		r.	No contamination of paint prior to application	FAB033,FAB036,FAB039,FAB042
A,G		s.	No visible contamination of epoxy resin adhesive for cork insulation bonding before, during and after application	FAB091,FAB092,FAB093,FAB094
A,G		t.	Dry fit of cork pieces	AFR026,AFS026,AFU026,AFW024
A	(T)	u.	Pull tests for cork insulation bonding	RAA227,RAA228,RAA229,RAA230

4. For New Cork, Sheet verify:

A,C	(T)	a.	Density	ALR003,ALR004
A,C	(T)	b.	Tensile strength	ALR044,ALR045
A,C	(T)	c.	Tensile elongation	ALR038,ALR039
A,C	(T)	d.	Recovery	ALR025
A,C	(T)	e.	Flexibility	ALR013,ALR014
A,C		f.	Workmanship	FAA005
D,E		g.	Thickness	ALR001
G		h.	No shipping or handling damage	ALR023
G		i.	Opened cork containers are resealed	ALR022

5. For Retest Cork, Sheet verify:

C,G	(T)	a.	Density	ALR009
C,G	(T)	b.	Flexibility	ALR017
C,G	(T)	c.	Specific heat	ALR035

6. For New Epoxy Resin Adhesive, Non-Asbestos verify:

C	(T)	a.	Filler content (Part A)	AMD009,AMD013
C	(T)	b.	Epoxide content (Part A)	AMD002,AMD006
C	(T)	c.	Titratable nitrogen (Part B)	AMD035,AMD039
C		d.	Certificate of Conformance	FAA014
C		e.	Workmanship	AMD015
C	(T)	f.	Working life	AMD043
C	(T)	g.	Tensile adhesion steel-to-steel	AMD031

7. For Retest Epoxy Resin Adhesive, Non-Asbestos verify:

C	(T)	a.	Tensile adhesion, steel-to-steel	AMD033

8. For New Ablation Compound verify:

A,C	(T)	a.	Tensile strength	ANX019,ANX021
A,C	(T)	b.	Shore D hardness	ANX006,ANX008

A,C	(T)	c.	Specific gravity	ANX016
A,C		d.	Solids content	ANX012
A,C		e.	Pot life	FAF011
A,C		f.	Workmanship	FAF013

9. For New Paint, Moisture and Fungus Protection verify:

C,G	(T)	a.	Color	ANU002
C,G	(T)	b.	Nonvolatile content	ANU009
C,G	(T)	c.	Viscosity	ANU018
C,G	(T)	d.	Weight per gallon	ANU025
C,G		e.	Supplier Certificate of Conformance	ANU015
C,G		f.	Workmanship	DJM012
C,G	(T)	g.	Adhesion	DJM013

10. KSC verifies:

A,F		a.	Segments and nozzle components are free of damage per OMRSD File V, Vol I, B47SG0.061	OMD079
G		b.	No fungus or contamination upon TPS surface repair per OMRSD File V, Vol I, B47GEN.070	OMD034