THIOKOL
AEROSPACE & INDUSTRIAL TECHNOLOGIES

CRITICAL ITEMS LIST (CIL)

No. 10-03-04-05/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Ignition Subsystem 10-03	PART NAME:	Igniter Liner (1)
ASSEMBLY:	Igniter Assembly 10-03-04	PART NO.:	(See Table A-3)
FMEA ITEM NO.:	10-03-04-05 Rev M	PHASE(S):	Boost (BT)
CIL REV NO.:	M	QUANTITY:	(See Table A-3)
DATE:	31 Jul 2000	EFFECTIVITY:	(See Table A-3)
SUPERSEDES PAGE:	433-1ff.	HAZARD REF.:	BI-05
DATED:	30 Jul 1999		
CIL ANALYST:	F. Duersch		
APPROVED BY:		DATE:	

RELIABILITY ENGINEERING: K. G. Sanofsky 31 Jul 2000

ENGINEERING: S. R. Graves 31 Jul 2000

1.0 FAILURE CONDITION: Failure during operation (D)

2.0 FAILURE MODE: 1.0 Adhesive/cohesive failure of the liner

3.0 FAILURE EFFECTS: Increased burn surface results in increased chamber pressure and thrust imbalance between the two RSRMs, causing loss of SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Contamination	A
1.2	Incorrect liner mixing proportions and methods	B
1.3	Nonconformance to temperature control during curing of liner	C
1.4	Improper insulation surface preparation	D
1.5	Liner coverage not uniform or complete	E
1.6	Improper liner cure time	F
1.7	Storage degradation	G
1.8	Nonconforming materials	H

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION: RSRM insulated igniter chamber liner.

1. Liner is an HC polymer-based, asbestos float-filled adhesive used to line the RSRM igniter chamber (Figure 1). Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U77610	Segment, Rocket Motor, Fwd	Composite of various Components		1/motor
1U77499	Igniter Assembly	Composite of various Components		1/motor
1U77372	Chamber Assembly, Igniter, Loaded	Composite of various Components		1/motor
1U77371	Chamber Assembly, Igniter, Insulated	Composite of various Components		1/motor
	Liner, Solid Rocket Motor, Space Shuttle Project	Composite of various Materials	STW5-3224	A/R
		Liquid Polymer (HC), Polybutadiene, Carboxyl Terminated with Antioxidant	STW4-3152	Per mix ratio
		Tris [1-(2-Methyl) Aziridinyl] Phosphine Oxide (MAPO)	STW4-2647	Per mix ratio
		Epoxy Resin, Medium Viscosity, Trifunction,Distilled	STW4-2646	Per mix ratio
		Floats, Pulp, Asbestos	STW4-2636	Per Mix Ratio
		Thixotropic Powder Modified Castor Oil	STW4-2648	Per Mix Ratio
		Iron Hexoate (2-ethyl) 6 Percent	STW4-2645	Per Mix Ratio
	TP-H1178 Propellant, RSRM Igniter, Space Shuttle Project	Composite of various Materials	STW5-2833	150 lb/igniter (nominal)

6.1 CHARACTERISTICS:

1. Liner provides bonding between TP-H1178 propellant and igniter insulation. Liner is a liquid polymer-based material that promotes cross-linking and propellant is also a highly cross-linking polymer-based material. A chemical bond is formed between liner and propellant. Liner processing is per TWR-10341.

2. Liner functions as a bonding agent and was developed to ensure that liner bond strength (to insulation and propellant) is sufficient to assure cohesive failure in the propellant before any failure in the liner. Thus, propellant is the weak link in the system.

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

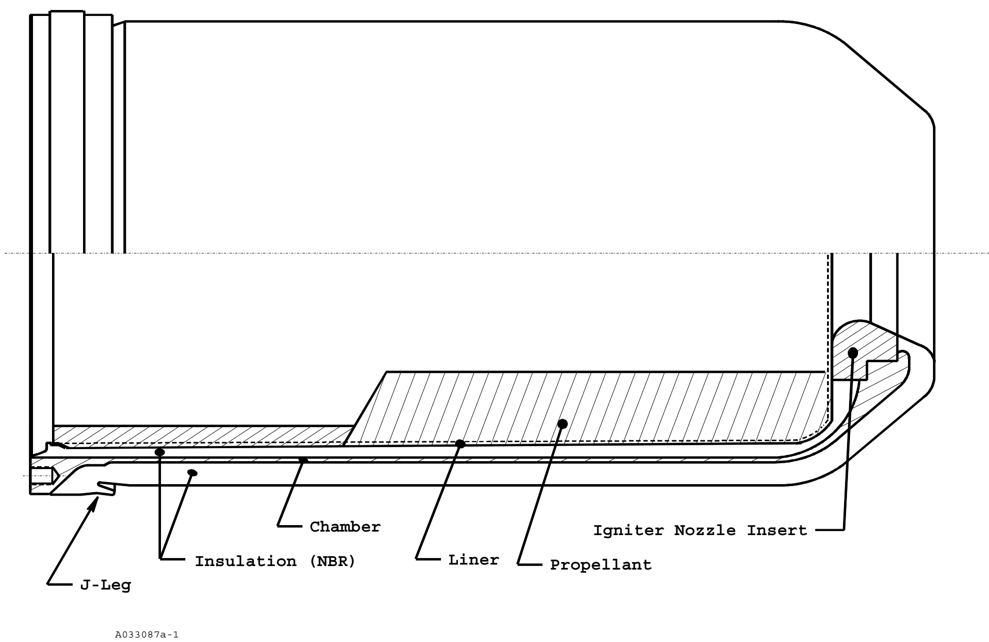

Figure 1. Liner in Loaded Igniter Chamber Assembly

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN	FAILURE CAUSES	
A,H	1.	Physical properties and contamination requirements for raw materials used in liner are per engineering.
A,H	2.	Liner constituents are required to be free from visual contamination per engineering.
A,H	3.	Contamination controls during liner mixing are per shop planning.
A,B,C,D,E,F,G,H	4.	Structural analysis of the loaded igniter was done to verify factors of safety for the insulation-to-liner bond and the liner-to-propellant bond. This analysis shows compliance with CEI requirements for these bonds as reported in TWR-17195.
A,H	5.	Preparation of bonding surfaces and their cleanliness are controlled as follows:
A,H		a. Bonding surface preparation for NBR and liner is per engineering drawings.
A,H		b. CONSCAN verification tests for determining cleanliness of bonding surfaces were developed and are controlled by engineering. Data collection and analysis was evaluated for qualification per TWR-18229.
A,H		c. Contamination control requirements and procedures are described in TWR-16564.
B	6.	Proportions of raw materials used in the liner are established per engineering.
B	7.	Standardization batches are formulated to determine the amount of thixotropic powder required for production batches per engineering.
B	8.	Proportions of asbestos floats and iron hexoate are fixed, thixotropic powder is standardized, and the remaining constituents are determined by equivalents per engineering.
B	9.	Raw material weighing is per engineering drawings and specifications.
B	10.	Raw material addition sequence, mix time, temperature of mix, and housekeeping are controlled per shop planning.
B	11.	Adequacy of raw material proportions related to liner strength was verified in a characterization analysis per TWR-15276.
C,F	12.	The maximum acceptable time period (pot life) between liner mixing and application is per shop planning.
C,F	13.	Maximum acceptable liner use life from end of cure to start of preheat for propellant casting is per engineering.
C,F	14.	Ambient temperature liner pre-cure after liner application is performed per shop planning.
C,F	15.	Liner cure temperature is per engineering.
C,F	16.	Allowable temperature excursions are defined per shop planning.

C,F	17.	Temperatures below the allowable minimum cure temperature are compensated by extending the cure time by an amount equal to total excursion time below minimum cure temperature per shop planning.
C,F	18.	Time and temperature constraints for liner cure to prevent liner bubbling during chamber preheat and casting were determined by testing as reported in TWR-14203.
C,F	19.	Liner cure time and temperature requirements were designed to provide optimum adhesion as analyzed and verified in TWR-15276.
C,F	20.	Liner cure is completed during the propellant cure process per engineering.
D	21.	Prior to liner application, the insulation surface is scrubbed with solvent per shop planning.
D	22.	The insulated igniter chamber is preheated to provide optimum liner adhesion per shop planning.
E	23.	Acrylonitrile butadiene rubber (NBR) at the nozzle end of the chamber is coated with liner by a hand-brush application. The rest of the inside of the igniter chamber is coated with liner material using sling lining methods. Thickness is controlled by applied weight and careful rationing of materials. This flow is described in TWR-10341. Liner processing and application is controlled per shop planning.
E	24.	Liner viscosity is established per engineering and controlled per shop planning.
G	25.	Liner is designed with enough strength to assure cohesive failure in the propellant making the propellant the weak link. An analysis was performed to characterize the liner formula to provide optimum strength as reported in TWR-15276.
G	26.	Mechanical properties of the liner used in the igniter are established per engineering.
G	27.	Shelf life requirements for constituents used in the liner are per engineering.
G	28.	Storage life requirements for liner were analyzed and testing was performed to study aging and humidity effects on liner performance. This analysis was a comparison of HC Polymer with two different types of antioxidants (PBNA and 12246). Polymer containing A02246 antioxidant exhibited better peel strength, less degradation in high humidity, better strain capabilities, and lower uniaxial stress per TWR-15278.
G	29.	Analysis of aged igniters was done and through aging up to 64 months, there was no apparent degradation to the igniter systems or degradation of performance verifying the 5-year storage life requirement per TWR-13003.
G	30.	Accelerated aging tests performed on the igniter PLI bond system per TWR-16106 indicated that 90 degree peel strength of the PLI bond decreases with time, high temperature, and high humidity storage during curing of the liner in the test specimen. Once the liner is cured, 90 degree peel strength stabilizes. Tensile adhesion strength of the PLI bond remains constant with time, high temperature, and high humidity storage. Accelerated aging tests indicated no degradation to the igniter PLI bond.
G	31.	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.

G 32. The Flight Igniter is included in the RSRM Forward Segment life verification.

D 33. A Spray-in-Air cleaning system is used to clean metal components as part of the bonding surface preparation processing sequence.

A,D 34. As a result of the RSRM Performance Enhancement (PE) Program, load factors for ignition system PLI (Propellant, Liner, and Insulation) components were updated. Structural responses to both the original and PE loads cases were analytically compared. For all conditions, there were insignificant changes in induced stresses and therefore none of the ignition system PLI structural safety factors were changed as a result of the RSRM PE program per TWR-73983.

9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TESTS	(T)				CIL CODE
			1.	For New Iron Hexoate, verify:		
	A,H	(T)		a.	Specific gravity	ALJ024,ALJ026,ALJ029
	A,H	(T)		b.	Viscosity	ALJ031,ALJ034,ALJ036
	A,H	(T)		c.	Iron content	ALJ011,ALJ013,ALJ016
	A,H	(T)		d.	Infrared spectrum	ALJ004,ALJ006,ALJ009
			2.	For New Floats, Asbestos verify:		
	A,H	(T)		a.	Volatile matter	ALI051
	A,H	(T)		b.	pH (aqueous extract)	ALI023
	A,H	(T)		c.	Calcination loss	ALI002
	A,H	(T)		d.	Fiber size distribution	ALI011
	A,H	(T)		e.	Wet volume	ALI053
			3.	For New Epoxy Resin, verify:		
	A,H	(T)		a.	Viscosity	ALK041
	A,H	(T)		b.	Specific gravity	ALK034
	A,H	(T)		c.	Weight per epoxy	ALK045
	A,H	(T)		d.	Hydrolyzable chlorine	ALK006
	A,H	(T)		e.	Moisture	ALK021
	A,H	(T)		f.	Infrared spectrum	ALK014
			4.	For New Mapo, verify:		
	A,H	(T)		a.	Reactive imine	ALL040
	A,H	(T)		b.	Moisture	ALL025
	A,H	(T)		c.	Specific gravity	ALL050
	A,H	(T)		d.	Viscosity	ALL079
	A,H	(T)		e.	Total chlorine	ALL072
	A,H	(T)		f.	Hydrolyzable chlorides	ALL004
	A,H	(T)		g.	Infrared spectrum	ALL018
			5.	For New Thixotropic Powder verify:		
	A,H	(T)		a.	Density	ALM002
	A,H	(T)		b.	Hydroxyl number	ALM016
	A,H	(T)		c.	Particle size	ALM037
	A,H	(T)		d.	Melting point	ALM023
	A,H	(T)		e.	Moisture	ALM030
			6.	For New Liquid Polymer (HC), verify:		
	A,H	(T)		a.	Viscosity	AMC045,AMC047,AMC051
	A,H	(T)		b.	Specific gravity	AMC038,AMC040,AMC044
	A,H	(T)		c.	Carboxyl equivalents	AMC009,AMC011,AMC015
	A,H	(T)		d.	Moisture	AMC025,AMC027,AMC031
	A,H	(T)		e.	AO2246 antioxidant content	AMC000,AMC002,AMC006
	A,H	(T)		f.	Infrared spectrum	AMC018,AMC020,AMC024
	A,H			g.	Workmanship is uniform in appearance and free from visible contamination	FDJ001

7. For New Liner, verify:

A,B,H	(T)	a.	Viscosity (uncured) standardization	AOA117
A,B,H	(T)	b.	Steel-to-steel tensile adhesion strength (cured) standardization	AOA077
A,B,H	(T)	c.	Peel strength (cured) standardization	AOA032
A,B,E,H	(T)	d.	Viscosity of production batches	AOA094
A,H,G		e.	Liquid polymer is acceptable	AMC032
A,H		f.	Liquid polymer is free of contamination	AMC034
A,H,G		g.	MAPO is acceptable	ALL036
A,H		h.	MAPO is free of contamination	ALJ020A
A,H,G		i.	Epoxy resin is acceptable	ALK025
A,H		j.	Epoxy resin is free of contamination	ALM046
A,H,G		k.	Asbestos is acceptable	ALK025A
A,H		l.	Asbestos is free of contamination	ALI035
A,H,G		m.	Thixotropic powder is acceptable	ALJ020AA
A,H		n.	Thixotropic powder is free of contamination	ALJ020
A,H,G		o.	Iron hexoate is acceptable	ALL036D
A,H		p.	Iron hexoate is free of contamination	ALL038
B		q.	Mix temperature of liner batch per shop planning	AOA081
B		r.	Raw materials are weighed per shop planning	AOA048A
B		s.	Polymer conditioned to proper temperature per shop planning	AOA038
B		t.	Proper raw materials used per shop planning	AOA048
B		u.	Required inspection buy offs of mix per shop planning	AOA054
B		v.	Mix times per shop planning	AOA010
B		w.	Sequence of material addition per shop planning	AOA057
G		x.	Shelf life of liner materials not exceeded	AOA061

8. For New Igniter Assembly verify:

A,B,C, F,G,H	(T)	a.	Initiator LAT for proper propellant burn time and pressure per the igniter specification.	AKU021
G		b.	Component temperatures and exposure to ambient environments during in-plant transportation or storage are controlled per the temperature exposure limit specification	BAA015

9. For New Chamber Assembly-Igniter Loaded, verify:

C,F	a.	Pre-cure acceptable	AEE028
C,F	b.	Elevated temperature cure	AEE015
C,F	c.	Temperature excursions and adjusted cure time are acceptable	AEE000
C,F	d.	Use life from end of liner pre-cure to start of propellant casting not exceeded per the liner specification	AAM085A
A,B,C,F,H	e.	Liner pot life between mixing and application was not exceeded	AOA012
C,F	f.	Proper cure of cast propellant	ANG000
A,H	g.	Insulation surface is clean and acceptable prior to liner application	AEE005
D	h.	Internal insulation surface scrubbed with solvent	AED012
D	i.	Chamber preheat is within required temperature range per shop planning and preheat operation completion time is recorded	AED007A
E	j.	Liner application is complete and acceptable	AEE010
E	k.	Weight of liner per drawing	AEE056
G	l.	Component temperatures and exposure to ambient environments during in-plant transportation or storage are per the transportation and handling specification	BAA014
A,B,C,F	m.	Propellant-to-liner peel tests for liner mixes are acceptable	WJB006
E,F	n.	Time delay between consecutive liner applications is per the liner	

		specification	MKL042
	10.	For New Chamber Assembly-Igniter, Insulation, verify:	
D	a.	Voids do not exceed requirements	AED005
	11.	For New Segment, Rocket Motor, Forward, verify:	
G	a.	Component environments during in-plant transportation or storage	BAA021
	12.	KSC verifies:	
G	a.	life requirements for the expected launch schedule are met per OMRSD, File II, Vol III, C00CA0.030.	OMD019