CRITICAL ITEMS LIST (CIL)

No. 10-01-02-02/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Case Subsystem 10-01	PART NAME:	Liner (1)
ASSEMBLY:	Propellant, Liner, Insulation, Inhibitor 10-01-02	PART NO.:	(See Section 6.0)
		PHASE(S):	Boost (BT)
FMEA ITEM NO.:	10-01-02-02 Rev M	QUANTITY:	(See Section 6.0)
CIL REV NO.:	M	EFFECTIVITY:	(See Table 101-6)
DATE:	31 Jul 2000	HAZARD REF.:	BC-10
SUPERSEDES PAGE:	213-1ff.		
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 resulting in increased chamber pressure and loss of RSRM causing loss of SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Bondline failure of liner-to-propellant or insulation	
1.1.1	Contamination of raw materials/mixture or contamination of the liner interfacing surfaces to the propellant or insulation	A
1.1.2	Incorrect liner mixing proportions and methods	B
1.1.3	Interruption of the liner application process	C
1.1.4	Nonconformance to temperature control during curing of liner	D
1.1.5	Improper insulation surface preparation	E
1.1.6	Liner coverage not uniform or complete	F
1.1.7	Liner curing time less than minimum	G
1.1.8	High thermal/structural stresses of bondlines	H
1.1.9	Storage degradation (aging) of liner	I
1.1.10	Structural degradation due to transportation and handling loads	J
1.1.11	Nonconforming material properties	K

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION: RSRM insulated case liner.

1. Liner is an HC polymer-based, asbestos floats-filled adhesive used to line individual RSRM case segments (Figure 1). Approximately 374 lbs. is required for each segment. Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U76666	Segment, Insulated Forward			1/motor
1U76667	Segment, Insulated Center			2/motor
1U77503	Case Assembly, Aft Segment			1/motor
	Insulation Liner, RSRM, Space Shuttle Project	Composite of various materials	STW5-3224	1,496 lb/motor (nominal)
		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 Caster Oil	STW4-2648	Per mix ratio
		Iron Hexoate (2-ethyl) 6 Percent	STW4-2645	Per mix ratio
	Propellant, Solid Rocket Motor, TP-H1148	Composite of various materials	STW5-3343	1,106,880 lb/motor (nominal)

6.1 CHARACTERISTICS:

1. Liner provides bonding between TP-H1148N propellant and case segment insulation. Liner is a liquid polymer-based material that affords 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

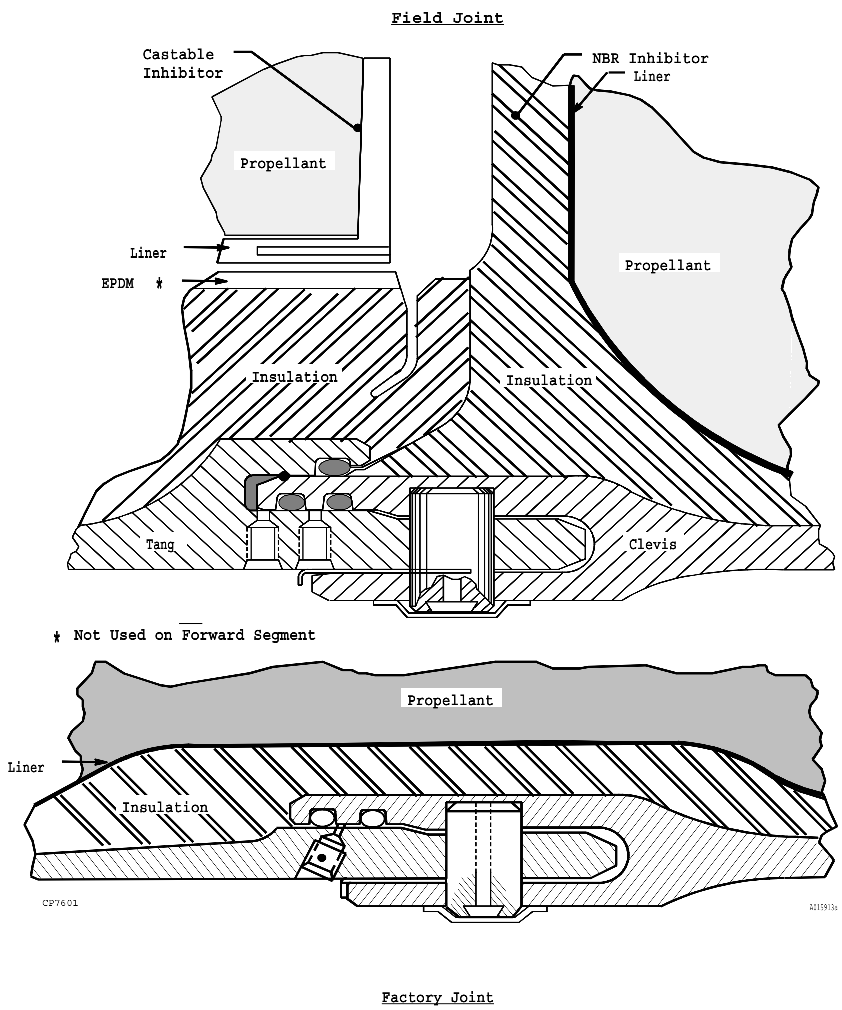

Figure 1. Liner in Field and Factory Joints

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN FAILURE CAUSES		
A,K	1.	Physical properties and contamination requirements for raw materials used in liner are established per engineering.
A	2.	Liner constituents are required to be free from visual contamination per engineering.
A	3.	Contamination controls during liner mixing are per shop planning.
A	4.	Prior to moving a lined case to the casting pits, end covers are installed on the segment to protect the liner surface from contamination per shop planning.
A,B,D,E,F,G,I,J	5.	Structural analysis on propellant grain and bondlines was done to verify factors of safety for the insulation-to-liner bond and the liner-to-propellant bond. This analysis shows positive margins of safety for these bonds as reported in TWR-16961.
A,B,C,D,E,F,G,H,K	6.	Witness panels are cured in the autoclave with the insulated segments during the cure cycle. These panels are tested to assure bondline integrity for primer, adhesive, insulation, liner, and propellant properties was achieved at the end of the cure cycle per engineering as reported in TWR-17123, TWR-64433, and TWR-64923.
A	7.	To control contamination during segment lining operations, the doors to the area are closed and the number of transients allowed are restricted. The segment insulation surface is scrubbed with appropriate solvent and dried prior to lining. The area is cleaned and inspected prior to lining and continually cleaned during the lining operation. These controls are per shop planning.
B	8.	Proportions of raw materials used in liner are established per engineering.
B	9.	Standardization batches are formulated to determine the amount of thixotropic powder required for production batches per engineering.
B	10.	Proportions of asbestos floats and iron hexoate are fixed, thixotropic powder is standardized, and the remaining constituents are determined by equivalents per engineering.
B	11.	Weighing of raw materials is specified per engineering.
B	12.	Raw material addition sequence, mix time, temperature of mix, and housekeeping are controlled per shop planning.
B,F	13.	Liner viscosity is established by engineering and controlled by shop planning.
C	14.	Total time between liner mixing operation completion and liner application is controlled per shop planning.
C	15.	Application of liner to the segment must begin within 90 minutes of end of the mixing cycle per TWR-13523.

C	16.	Application of liner mix must be completed within 150 minutes from end of the mix per TWR-13523.
C	17.	Time delay between consecutive liner applications is per engineering.
D,G	18.	The maximum acceptable time period (pot life) between liner mixing and application is specified per shop planning.
D,G	19.	Maximum acceptable liner use life from end of cure to start of preheat for propellant casting is specified per engineering.
D,G	20.	Ambient temperature liner pre-cure after liner application is performed per shop planning.
D,G	21.	Liner cure temperature is per engineering.
D,G	22.	Allowable temperature excursions are defined per shop planning.
D,G	23.	Temperatures below the allowable minimum cure temperature are compensated by extending the cure time by an amount equal to the total excursion time below minimum cure temperature per shop planning.
D,G	24.	Time and temperature constraints for liner cure to prevent liner bubbling during chamber preheat and casting were determined by testing and reported in TWR-14203.
D,G	25.	Liner cure time and temperature requirements were designed to provide optimum adhesion. These processes and requirements were analyzed and verified in TWR-15276.
D,G	26.	Propellant processing, mixing, and cure requirements are per engineering, shop planning, and described in TWR-10341. Liner cure is also completed during propellant cure per engineering.
B	27.	Adequacy of raw material proportions related to strength in the liner was verified in a characterization analysis per TWR-15276.
A,D,E,G	28.	Contamination control requirements and procedures are described in TWR-16564.
E	29.	The complete surface of the insulation is covered with patterning cloth. During vulcanization, this material forms a crosshatched pattern on the insulation surface that greatly increases the liner-to-insulation bond strength. This operation is controlled by shop planning and engineering drawings.
A,E	30.	Prior to liner application, the insulation surface is scrubbed with solvent per shop planning.
E	31.	The insulated case segment is preheated to provide optimum liner adhesion per shop planning.
F	32.	Inhibitor NBR at the forward end of the center and aft segments, and the forward segment dome are coated with liner material using a hand brush application. Thickness is controlled by applied weight and careful rationing of materials per shop planning.
F	33.	The cylindrical portion of the segment is mechanically lined using the sling-lining

technique per shop planning.

F	34.	The sling liner boom and disk are programmed to traverse the case length automatically in several passes. This multiple-pass application assures uniform liner distribution per shop planning.
F	35.	The required amount of liner material is applied with the multiple-pass sling liner. Sling lining also deaerates the liner producing a continuous, void-free material per shop planning.
B,H,I,J,K	36.	Liner is designed with sufficient strength to assure cohesive failure in the propellant making the propellant the weak link. An analysis was performed to characterize the liner formulation to provide optimum strength as reported in TWR-15276.
H	37.	Evidence of compliance with tensile adhesion, peel strength, and acceptance requirements for mechanical properties is given by tests and inspections on each liner standardization batch per engineering.
H	38.	Insulation, liner, and propellant bonding materials were designed to exceed SRM temperature requirements. Thermal analyses were completed and test data evaluated and recorded in TWR-11271.
H	39.	An overall thermal analysis was performed to show the temperature gradient through the propellant and liner, and a structural analysis on the propellant grain and bondlines was done to verify factors of safety for the insulation-to-liner bond and liner-to-propellant bond. This analysis shows positive margins of safety for these bonds as reported in TWR-16961.
H,I,J	40.	Rail-car transportation shock and vibration levels for the segments are monitored per engineering with bondline loads derived per analysis. Monitoring records are evaluated by Thiokol to verify that shock and vibration levels defined per MSFC Specifications were not exceeded.
I,J	41.	Aging studies performed, when liner formulation was changed, indicated conformance to aging stability requirements per TWR-14203.
I,J	42.	Loads induced as a result of transportation and handling were studied with respect to the structural integrity of the SRM loaded segment components. It was determined that all components within the loaded segments were structurally sound through transportation and handling prior to flight per TWR-12079.
I,J	43.	During transportation, RSRM segments are not to be subjected to shock loads more severe than allowable. No predicted loads during transportation and handling will produce stresses, internal loads, or deflections in excess of the structural capability of the RSRM or its components per TWR-12079 and TWR-13040.
I,J,K	44.	Mechanical properties requirements of liner are established per engineering.
I,J,K	45.	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 A02246). Polymer containing A02246 antioxidant exhibited better peel strength, less degradation in high humidity, better strain capabilities, and lower uniaxial stress per TWR-15278.
I,J	46.	Railway coupling and transportation tests were conducted on an inert forward

segment per TWR-11712 to verify the adequacy of tie-down provisions and to record actual g-loads during transit. Accelerations of 1.01 g longitudinal and 0.86 g vertical were the maximum loads achieved during the test although they were less than the target loads.

I,J	47.	Additional tests were performed per TWR-12079 to analyze transportation loads on the RSRM forward segment grain. These tests provide additional data for verification of vibration and shock transportation environment.
I,J	48.	Requirements for handling RSRM components during assembly, storage, and transportation are similar to those for previous and other current programs at Thiokol. These requirements dictate that case segments must be handled by or near a joint to avoid damage. All lifting hooks and slings are fitted with safety hooks per TWR-13880.
I,J	49.	Positive cradling or support devices and tie-downs that conform to shape, size, weight, and contour of components to be transported are provided to support segments and other components. Shock mounting and other protective devices are used on trucks and dollies to move sensitive loads per TWR-13880.
I,J	50.	Specially designed 200-ton railroad flatcars are used to assure that no damage occurs to flight hardware during transportation to the launch site per TWR-13880.
I,J	51.	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 controlled per engineering.
I,J	52.	Testing of real time aged propellant/liner/insulation (PLI) samples indicated that TP-H1148 Propellant and PLI bond properties were not affected by aging for up to five years per TWR-63837.
I,J	53.	Visual inspection during post-test evaluation of TEM-09 indicated that liner was not affected by aging per TWR-63479.
K	54.	Composition of liner is established per engineering.
K	55.	Mechanical properties of liner, propellant, insulation, and inhibitor as used in structural analysis as well as the physical properties of liner materials are listed in TWR-17039.
B,D,F,G,K	56.	Liner repair requirements for RSRM segments are per engineering (Liner repairs are not authorized for initiators or igniters).
H,J	57.	The grain (propellant, liner, castable inhibitor and internal insulation) of the RSRM was evaluated for the Performance Enhancement (PE) Program. The grain evaluation (PLI) shows that all areas still meet required safety factors. The PLI was conservatively re-evaluated using an increased liftoff acceleration load (not part of the Performance Enhancement Program). It was concluded that structural certification was not affected per TWR-17057.

9.2 TEST AND INSPECTION:

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

				contamination	FDJ001
		7.		For New Liner, verify:	
A,B,K	(T)		a.	Viscosity (uncured) standardization	AOA117
A,B,K	(T)		b.	Steel-to-steel tensile adhesion strength (cured) standardization	AOA077
A,B,K	(T)		c.	Peel strength (cured) standardization	AOA032
A,F	(T)		d.	Viscosity of production batches	AOA094
A,I,J			e.	Liquid polymer is acceptable	AMC032
A			f.	Liquid polymer is free of contamination	AMC034
A,I,J			g.	Asbestos is acceptable	ALK025A
A			h.	Asbestos is free of contamination	ALI035
A,I,J			i.	Iron hexoate is acceptable	ALL036D
A			j.	Iron hexoate is free of contamination	ALL038
A,I,J			k.	Epoxy resin is acceptable	ALK025
A			l.	Epoxy resin is free of contamination	ALM046
A,I,J			m.	MAPO is acceptable	ALL036
A			n.	MAPO is free of contamination	ALJ020A
A,I,J			o.	Thixotropic powder is acceptable	ALJ020AA
A			p.	Thixotropic powder is free of contamination	ALJ020
A			q.	Mix bowls are free of contamination	AMC034B
B			r.	Mix temperature of liner batch per shop planning	AOA081
B,C			s.	Mix times per shop planning	AOA010
B	(T)		t.	Total weight of asbestos floats	AOA089C
B	(T)		u.	Total weight of epoxy resin	AOA089B
B	(T)		v.	Total weight of iron hexoate	AOA089E
B	(T)		w.	Total weight of liquid polymer	AOA089
B	(T)		x.	Total weight of MAPO	AOA089A
B	(T)		y.	Total weight of thixotropic powder	AOA089D
B			z.	Sequence of material addition per shop planning	AOA057
B			aa.	Temperature for each constituent mixed per shop planning	AOA078
B			ab.	Proper raw materials used per shop planning	AOA048
B			ac.	Raw materials are weighed per shop planning	AOA048A
B			ad.	Required inspection buy offs of mix per shop planning	AOA054
B			ae.	Polymer conditioned to proper temperature per shop planning	AOA038
I,J			af.	Shelf life of liner materials not exceeded	AOA061
K	(T)		ag.	Viscosity (uncured) verification batches	AOA110
K	(T)		ah.	Steel-to-steel tensile adhesion strength (cured) verification	AOA073
K	(T)		ai.	Peel strength (cured) verification	AOA029
K	(T)		aj.	Vacuum test verification batch	AOA093
		8.		For New Loaded Segment Assembly (Forward, Center, Aft) verify:	
A,E			a.	Internal insulation and inboard side of inhibitors is clean and clean time is properly recorded	AFF043,AFH040,AFJ028
A,B,C,D,G			b.	Liner application is completed within time limit for end of mix	AFF038,AFH042,AFJ031
A			c.	End covers installed prior to shipping lined case	AFG070,AFK081,AFK081A
A			d.	Casting pit free of contamination prior to placing segment in pit	AFF007,AFH012,AFJ006
A			e.	Segment properly lined and acceptable per shop planning just prior to installation of covers and shipment to the casting pit	AFF061,AFH067,AFJ052
A			f.	End covers are intact and free of visible damage upon arrival at the casting pit	AFF061A,AFH067A,AFJ052A
A,B,C,D,E,					

F,G,H,K (T)	g.	Results of insulation-to-liner-to-propellant bondline integrity tests with witness panel per engineering	AOX018,AOX019,AOX020
A,B,C,D,E, F,G,H,K (T)	h.	Results of insulation-to-liner (hand lining) bondline integrity tests with witness panel per engineering	AOX021,AOX022,AOX023
A,B,C,D,E F,G,H,K (T)	i.	Results of insulation-to-liner (first sling line mix) bondline integrity tests with witness panels per engineering	AOX024,AOX025,AOX026
A,B,C,D,E F,G,H,K (T)	j.	Results of insulation-to-liner (second sling line mix) bondline integrity tests with witness panels	FDJ003,FDJ004,FDJ005
C	k.	Liner application started within time limit from end of mix	AFF038A,AFH072,AFJ055
D,E,G	l.	Surface temperature of the case prior to liner application is acceptable	AFF047,AFH054,AFJ043
D,G	m.	Proper cure of liner	AFF063,AFH069,AFJ054
D,G	n.	Use-life from end of liner pre-cure to start of propellant casting not exceeded per the liner specification	AFF076,AFH079,AFJ059
D,G	o.	Cure of cast propellant	AFF019,AFH021,AFJ015
E	p.	Internal insulation cleaning repeated if liner application did not start within specified time	AFF035,AFH038,AFJ027
E	q.	Cloth threads on insulation surface do not exceed limits prior to lining	AFF045,AFH051,AFJ040
F	r.	Correct liner feed rate	AFF040,AFH046,AFJ033
F	s.	Correct RPM of sling liner	AFF060,AFH066,AFJ050
F	t.	Complete coverage of liner	AFF013,AFH018,AFJ011
F	u.	Complete coverage of liner in hand-applied areas	AFF012,AFH017,AFJ012
I,J	v.	Component temperatures and exposure to ambient environments during in-plant transportation or storage are acceptable	BAA008,BAA009,BAA010
K	w.	Liner repair material is acceptable	WJB010,WJB011,WJB012
F	x.	Liner repair coverage is complete and even	WJB015,WJB016,WJB017
B,D,G,K (T)	y.	Shore A hardness of liner repair mix	AOA066,WJB013,WJB014
A,B,D,G,H (T)	z.	Propellant-to-liner peel tests for liner mixes are acceptable	AOA035,WJB003,WJB004
C	aa.	Time delay between consecutive liner applications is per the liner specification	MKL038,MKL039,MKL040

9. For New Insulated Segment Assembly (Forward, Center, Aft) verify:

I,J	a.	Component temperatures and exposure to ambient environments during in-plant transportation or storage are acceptable	BAA018,BAA019,BAA020