ATK ALLIANT TECHSYSTEMS
THIOKOL PROPULSION

CRITICAL ITEMS LIST (CIL)

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

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Case Subsystem 10-01	PART NAME:	Propellant (1)
ASSEMBLY:	Propellant, Liner, Insulation, Inhibitor 10-01-02	PART NO.:	(See Section 6.0)
		PHASE(S):	Boost (BT)
FMEA ITEM NO.:	10-01-02-01R Rev N	QUANTITY:	(See Section 6.0)
CIL REV NO.:	N	EFFECTIVITY:	(See Table 101-6)
DATE:	27 Jul 2001	HAZARD REF.:	BC-07
SUPERSEDES PAGE:	211-1ff.		
DATED:	31 Jul 2000		
CIL ANALYST:	F. Duersch		
APPROVED BY:		DATE:	

RELIABILITY ENGINEERING: K. G. Sanofsky 27 July 2001

ENGINEERING: T. R. Hoffman 27 July 2001

1.0 FAILURE CONDITION: Failure to operate (B)

2.0 FAILURE MODE: 1.0 Failure to ignite or excessive ignition delay

3.0 FAILURE EFFECTS: Failure of RSRM to ignite will cause the remaining RSRM and Space Shuttle to nose over, due to thrust imbalance, causing loss of RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Propellant grain surface or material contamination	A
1.2	Leaching of AP from propellant surfaces	B
1.3	Improper mixing techniques of propellant materials	C
1.4	Nonconforming raw materials	D
1.5	Propellant aging effects	E

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

1. Propellant used in the RSRM is an 86 percent solid-loaded, aluminized formula using Polybutadiene Acrylonitrile (PBAN) and epoxy as the binder. This formula is designated as TP-H1148. A cylindrical, Center Perforated (CP) grain design is employed in each of four separately cast segments except that the forward segment CP transitions into an eleven-point star geometry for approximately half of its length. See Figure 1. The four cast segments are identified per Thiokol drawings as Loaded segment assemblies forward, center (2 each) and aft.

2. Each lot of propellant raw materials is standardized per engineering to meet burn rate and mechanical property requirements. Thrust balancing is achieved by matched-pair casting and segment pairs are acceptable based on calculated burn rates from 5-inch CP evaluation motor firings. Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
	Propellant	TP-H1148	STW5-3343	1,106,880 LB/Motor
		Terpolymer (PBAN)	STW4-2600	Per Mix Ratio
		Epoxy Resin	STW4-2601	Per Mix Ratio
		Ammonium Perchlorate	STW4-2602	Per Mix Ratio
		Aluminum Powder	STW4-2603	Per Mix Ratio
		Ferric Oxide	STW4-2604	Per Mix Ratio (nominal)

The above materials make up TP-H1148 propellant that is used in the following parts:

1U76674	Segment Assembly, Loaded, Forward	Various	1 ea/Motor
1U76675	Segment Assembly, Loaded, Center	Various	2 ea/Motor
1U77504	Segment Assembly, Loaded, Aft	Various	1 ea/Motor

6.1 CHARACTERISTICS:

1. Burn rate at 625 psia and 60°F — 0.368 psi
2. Maximum stress — 110 psi minimum
3. Strain at maximum stress — 30% minimum
4. Autoignition temperature (copper block test) — 489°F

7.0 FAILURE HISTORY/RELATED EXPERIENCE:

1. Current data on test failures, flight failures, unexplained failures, and other failures during RSRM ground processing activities can be found in the PRACA database.

8.0 OPERATIONAL USE: N/A

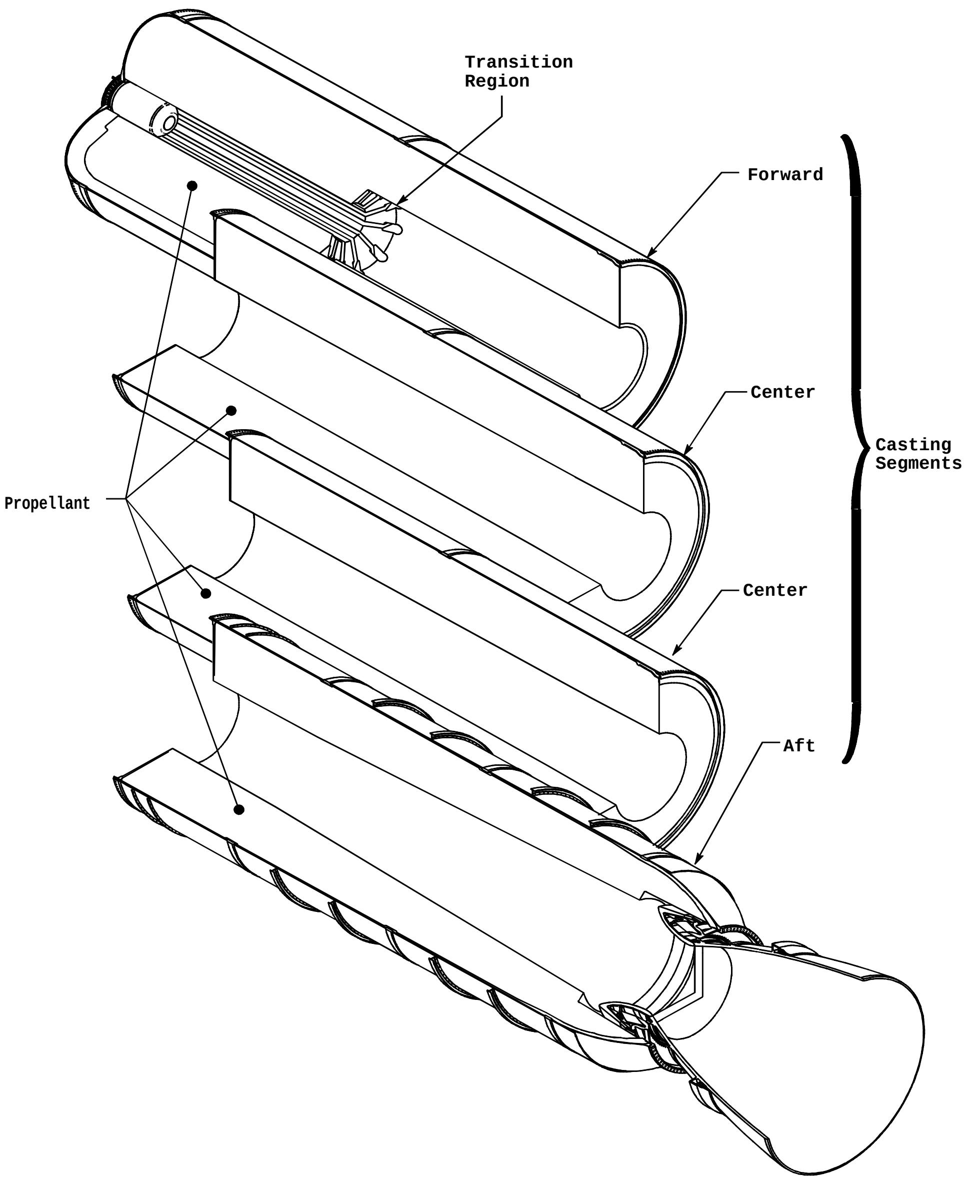

Figure 1. RSRM Propellant Configuration

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN	FAILURE CAUSES
A,D	1. Raw material conformance specifications, material properties requirements, means of verification, and appearance of materials for TP H1148 propellant are per engineering for the following materials: a. Terpolymer (PBAN) b. Epoxy resin c. Ammonium perchlorate d. Aluminum powder e. Ferric oxide
A	2. Cast segment shipping configuration includes end covers to provide protection against contamination during shipping and storage using Handling Kits defined per engineering drawings.
A	3. The nozzle plug provides protection against contamination during shipment of the aft segment and after the RSRM is assembled.
A,C,E	4. Calculation of burn rates is used to provide data for matched pairs of motor segments to minimize unbalanced thrust performance. Matched pairs are cast from the same combinations of propellant material evaluations and identified by part number and serial number to assure storage and use as matched pairs.
A	5. Qualification Motors QM-1 and QM-2 were composed of matched pair segments. Resulting performance data were well within the imbalance tolerances for ignition transient, steady state, and tailoff phases per TWR-12646.
A,C	6. Contamination control requirements and procedures are described in TWR-16564.
B	7. TP-H1148 propellant, used in the RSRMs, is similar to propellant used in Poseidon, Peacekeeper, Pershing, Minuteman, and Titan Motors which demonstrated acceptable performance after storage under uncontrolled humidity conditions for durations, in some cases, much greater than would ever be experienced by RSRM segments per TWR-13279 and TWR-13720.
B	8. Inspection of STS-1 motor segments, prior to stacking operations, revealed that some leaching of AP from the propellant surface existed but since the amount of leaching was evaluated from the depth of the leached AP, it was determined that the leach depth was small and should not effect performance and was judged to be acceptable. It was decided to fly the motors to determine propellant aging factors on motor performance parameters per TWR-14118.
B	9. Moisture, high humidity, and temperature are maintained within limits during storage, grinding, and propellant mixing operations per shop planning.
B	10. The nozzle protective plug is installed and verified prior to shipping. This plug seals the grain after assembly to preclude humidity from extended periods of storage in the stacked configuration.
C	11. Propellant mix proportions and mechanical properties requirements of TP-H1148 are per engineering and are suitable for use at a wide temperature range per TWR-11501. Adhesion requirements of propellant and liner systems are also per engineering.

C 12. An evaluation is a combination of single raw material lots and all of the propellant standardization, verification, and production batches produced by this combination of lots. Adjustments for ferric oxide, HB polymer (terpolymer) and Epoxy Curing Agent (ECA) proportions are determined per standardization processes and engineering to meet target burn rate and stress and strain values.

C 13. Material weighing is per TU-STD-12.

C 14. 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.

C 15. Burn rate analyses are performed per engineering using 5-inch CP test motors cast from at least one out of every three propellant batches for each segment.

E 16. Aging effects on TP-H1148 propellant were assessed through an accelerated aging study in which samples of propellant were stored at various temperatures and periodically tested for mechanical properties. Results of this study show that propellant stress capability increases slightly with age, and strain capability shows a slight decrease per TWR-12182.

E 17. Studies were done analyzing aging and humidity characteristics of TP-H1148 propellant compared to UTP-3001 propellant used in the Titan III program. It was determined that mechanical properties did not change significantly with age but exhibited a decline in 20-minute relaxation modulus upon storage at 80 percent relative humidity. TP-H1148 propellant was much less affected by storage at high humidity than UTP-3001 propellant, and stress capability decline was arrested by dryout per TWR-13279.

E 18. A comparison of SRM propellants with similar propellants from Minuteman, Poseidon, Peacekeeper, and Pershing (with storage in some cases much longer than 5 years) was done to determine aging effects. It was determined that there were no detrimental effects on mechanical properties over a 5-year storage period per TWR-13720.

E 19. Prior to stacking of STS-1, an inspection revealed leached AP but no cracking. STS-1 was in the Florida high humidity environment for 19 months per TWR-14118.

E 20. Structural analyses of propellant grain and bond lines were performed to verify positive margins of safety for storage per TWR-16961.

E 21. Grain surface or bond line anomaly repairs, either at Thiokol or KSC, are inspected per engineering.

E 22. Castable Inhibitor anomaly repair is inspected per engineering as recommended per TWR-63370.

E 23. Thermal analyses were performed for RSRM components during in-plant transportation and storage to determine acceptable temperatures 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.

E 24. Analyses of ballistic performance data from all TEM motors indicate propellant meets ballistic performance requirements of HPM and RSRM CEI Specifications after aging for up to 6.5 years per TWR-64166.

E

25. 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.

9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TESTS	(T)				CIL CODE
			1.	For New HB Polymer, verify:		
	A,D	(T)		a.	Acid number	ALC000,ALC001,ALC004
	A,D	(T)		b.	Acrylonitrile content	ALC005,ALC006,ALC009
	A,D	(T)		c.	Agerite stalite content	ALC010,ALC011,ALC014
	A,D	(T)		d.	Cetyldimethyl benzyl ammonium chloride content	ALC015,ALC016,ALC019
	A,D	(T)		e.	Chloride	ALC020,ALC021,ALC024
	A,D	(T)		f.	Unbound/total acid ratio	ALC025,ALC026,ALC029
	A,D	(T)		g.	Infrared spectrum	ALC030,ALC031,ALC034
	A,D	(T)		h.	Iron content	ALC035,ALC036,ALC039
	A,D	(T)		i.	Moisture content	ALC040,ALC041,ALC045
	A			j.	No shipping or handling damage	ALC046
	A,D	(T)		k.	Viscosity	ALC060,ALC061,ALC064
	A,D			l.	Workmanship shall be such that the HB polymer is a viscous liquid, light to dark amber/brown in color, which may contain small visible particulates	ALC065A
			2.	For Retest HB Polymer verify:		
	A	(T)		a.	Viscosity	ALC050
	A	(T)		b.	Acid number	ALC050A
	A	(T)		c.	Moisture content	ALC050B
	A	(T)		d.	Iron content	ALC050C
	A	(T)		e.	Infrared spectrum	ALC050D
			3.	For New Liquid Epoxy Resin verify:		
	A,D	(T)		a.	Hydrolyzable chlorine percent	ALD006,ALD009,ALD015
	A,D	(T)		b.	Infrared spectrum	ALD030
	A,D	(T)		c.	Moisture percent	ALD035,ALD038,ALD042
	A			d.	No shipping or handling damage	ALD052
	A,D	(T)		e.	Specific gravity	ALD061,ALD063,ALD068
	A,D			f.	Workmanship is uniform in appearance and free from visible contamination	ALD075
	A,D	(T)		g.	Viscosity	ALD082,ALD085,ALD091
	A,D	(T)		h.	Weight per epoxy	ALD098,ALD101,ALD107
			4.	For Retest Liquid Epoxy Resin verify:		
	A	(T)		a.	Hydrolyzable chlorine percent	ALD011
	A	(T)		b.	Viscosity	ALD083
	A	(T)		c.	Moisture	ALD989
	A	(T)		d.	Weight per epoxy	ALD103
			5.	For New Ammonium Perchlorate, verify:		
	A,D	(T)		a.	Acid insolubles	ALE001,ALE002,ALE006
	A,D	(T)		b.	Bromate	ALE007,ALE008,ALE011
	A,D	(T)		c.	Bulk density	ALE012,ALE013,ALE016
	A,D	(T)		d.	Chlorate	ALE017,ALE018,ALE020
	A,D	(T)		e.	Chloride	ALE022,ALE023,ALE026
	A,D	(T)		f.	External moisture content	ALE028,ALE029,ALE032
	A,D	(T)		g.	Internal moisture content	ALE033,ALE034,ALE037

A,D	(T)		h.	Iron	ALE038,ALE039,ALE042
A			i.	No shipping or handling damage	ALE044
A,D	(T)		j.	Particle size distribution	ALE045,ALE046,ALE050
A,D	(T)		k.	Assay, as ammonium perchlorate	ALE052,ALE055,ALE056
A,D	(T)		l.	pH	ALE058,ALE059,ALE062
A,D	(T)		m.	Phosphate	ALE063,ALE064,ALE067
A,D	(T)		n.	Photomicrographic analysis	ALE068,ALE069,ALE072
A,D	(T)		o.	Sulfated ash	ALE091,ALE092,ALE095
A,D	(T)		p.	Total moisture content	ALE097,ALE100,ALE101
A,D			q.	Workmanship is uniform in appearance and free from unacceptable contamination	ALE105
		6.	For Retest Ammonium Perchlorate, verify:		
A	(T)		a.	Total moisture	ALE078
A	(T)		b.	Internal moisture content	ALE078A
A	(T)		c.	External moisture content	ALE078B
A	(T)		d.	Particle size	ALE078C
		7.	For New Aluminum Powder, verify:		
A,D	(T)		a.	Free active aluminum content	ALF001,ALF004,ALF005
A,D	(T)		b.	Iron content	ALF006,ALF007,ALF010
A			c.	No shipping or handling damage	ALF011
A,D	(T)		d.	Particle size distribution	ALF012,ALF013,ALF016
A,D			e.	Workmanship is uniform and free from contamination	ALF024
A,D	(T)		f.	Volatile matter content	ALF025,ALF026,ALF029
		8.	For Retest Aluminum Powder verify:		
A	(T)		a.	Particle size distribution	ALF020
A	(T)		b.	Free active aluminum	ALF020A
A	(T)		c.	Volatile matter	ALF020B
		9.	For New Ferric Oxide, verify:		
A,D	(T)		a.	Calcination loss	ALG000,ALG001
A,D	(T)		b.	Iron content	ALG010,ALG012
A			c.	No shipping or handling damage	ALG019
A,D	(T)		d.	Specific surface area	ALG031,ALG032
A,D			e.	Workmanship is uniform in appearance and free from visible contamination	ALG040
A,D	(T)		f.	Volatile loss	ALG049,ALG050
		10.	For Retest Ferric Oxide, verify:		
A	(T)		a.	Iron content	ALG008
A	(T)		b.	Specific surface	ALG009A
A	(T)		c.	Volatile loss	ALG009B
		11.	For New Propellant, SRM, TP-H1148, verify:		
C	(T)		a.	Aluminum plus ferric oxide content in uncured batch samples	AOV012
A,C			b.	Aluminum powder dust hood clean and no loose objects during premix preparation (Applicable only for premix operations in Bldg M-120)	AOV013
A,C			c.	For each premix, HB polymer, aluminum powder, iron oxide, and ECA meet bill of material requirements and are within storage life	

			limits during propellant premix preparation	AOV014
A,C		d.	Aluminum powder is properly conditioned during propellant premix preparation per shop planning (Applicable only for Premix operations in Bldg M-120)	AOV015
C		e.	AP spillage weight does not exceed requirements during propellant mixing operations	AOV018
C		f.	AP spillage does not exceed requirements during oxidizer preparation	AOV019
C		g.	Adjusted Burn Rates of the 5 inch CPs for matched segments are within specifications	MKL023
A,C		h.	Cleanliness of facility during oxidizer preparation	AOV026
A		i.	Cleanliness of mix bowl during premix preparation	AOV027
A,C		j.	Cleanliness of mix bowl exterior and its cover and that the lid is installed prior to shipping premix	AOV028
A		k.	Cleanliness of mixing facility prior to mixing	AOV032
A,D		l.	AP within storage life limits	AOV037
C		m.	Desiccant requirements of AP during mixing	AOV040
C		n.	ECA properly added and ECA addition time recorded during propellant premix preparation	AOV042
A,C		o.	For each premix, HB polymer and ECA are properly conditioned during propellant premix preparations per shop planning	AOV046
C		p.	Ground oxidizer particle size distribution in production batches	AOV048
C		q.	HB polymer percent in uncured propellant	AOV052
C		r.	Weight of HB polymer, aluminum powder, ECA, and iron oxide in mix bowl during propellant premix preparation	AOV055
A,C		s.	Humidity and temperature during oxidizer preparation	AOV056
C		t.	Hygrometer reading acceptable before and during grinding operations	AOV064
A,C,D	(T)	u.	Liquid-strand burn rate of uncured propellant	AOV067
C		v.	AP lot number complies with material end item requirements	AOV068
C		w.	Mill load settings are acceptable during oxidizer preparation	AOV082
C		x.	Minimum time required for total mix cycle during mixing	AOV083
C		y.	Minimum time requirement met between end of AP addition and end of mix	AOV084
C		z.	Stock and lot number correct during oxidizer preparation	ALE086
C		aa.	Oxidizer addition time requirement met during mixing	AOV090
C		ab.	Oxidizer content in uncured propellant batch samples	AOV093
C		ac.	Premix constituent lot numbers comply with bill of materials during mixing	AOV096
C		ad.	Premix constituents weights comply with batch card during mixing	AOV098
C		ae.	Propellant samples taken after propellant mixing from different locations in the mix bowl	AOV102
C		af.	Sampling requirements met during oxidizer preparation	AOV104
C		ag.	Scalping screen for lumpy aluminum powder or foreign material during propellant premix preparation (Applicable only for Premix operations in Building M-120)	AOV105
C		ah.	Premix material production data sheet is properly completed during propellant premix operations. (Applicable only for Premix operations in Bldg M-120)	AOV107
A,C		ai.	Conditioning and acceptability of AP during oxidizer preparation	AOV110
C	(T)	aj.	Strain at maximum stress	AOV113
C	(T)	ak.	Maximum stress	AOV117
A		al.	Conditioning of AP tote bins during oxidizer preparation	AOV121
C		am.	Temperature requirement for end of mix is met	AOV125
C		an.	Total solids content in uncured propellant batch samples	AOV127
A,C		ao.	Tote bins clean and acceptable during oxidizer preparation	AOV128
A,C		ap.	Uniform appearance and no visible contamination in propellant batch samples	AOV129
C		aq.	Weight of unground and ground AP during oxidizer preparation	AOV135
C		ar.	Weight of unground and ground AP complies with the batch card	

				during propellant mixing	AOV136
	A		as.	Work area clean during premix preparation	AOV139
		12.	For New Loaded Segment Assembly (Forward, Center, Aft) verify:		
	E		a.	Component temperatures and exposure to ambient environments during in-plant transportation or storage are acceptable	BAA008,BAA009,BAA010
	A		b.	Cleanliness of propellant grain during final processing per engineering	AFJ010,AFF011,AFH016
	A		c.	Core is clean, free of defects, and has current recycle status prior to installation	AFJ009,AFF010,AFH015
	A		d.	Installation of polyethylene sheet prior to installation of vacuum bell	AFJ022,AFF030,AFH034
577	A		e.	Core was cleaned within two hours of going into the segment per shop planning	FDJ008,FDJ008A
577	A		f.	Proper lubrication of bell-to-bowl connector butterfly valve with polymer prior to installing per shop planning	FDJ006,FDJ006A,FDJ006B
577	A		g.	Mold plate is free of contamination prior to segment mating using the white glove test per shop planning	FDJ007,FDJ007A
		13.	For New Segment, Rocket Motor, Forward, verify:		
	A		a.	Cleanliness of propellant grain during final processing per engineering	AFF011A
	E		b.	Component environments during in-plant transportation or storage	BAA021
		14.	For New Handling Kit, Forward Segment, verify:		
	A		a.	End cover is in place on the segment to protect the propellant grain and insulation from ultra violet degradation prior to shipping	AID000
		15.	For New Handling Kit, Aft Segment and Center Segment, verify:		
	A		a.	End covers are in place on the segments to protect the propellant grain and insulation from ultra violet degradation prior to shipping	AID000A,AID000B
		16.	For New 5" CP motor, verify:		
	A,C,D (T)		a.	Test data for propellant standardization and burn rate	AKU000
		17.	KSC verifies:		
	B,E		a.	AP leaching is removed from each segment per OMRSD, File V, Vol I, B47GEN.030	OMD029
	A		b.	Propellant surfaces are protected against damage and environmental conditions except as required for inspection and processing per OMRSD, File V, Vol I, B47GEN.060	OMD032
	A,B,E		c.	Each segment (forward, forward center, aft center) is free of unacceptable propellant grain surface defects per OMRSD, File V, Vol I, B47SG0.012	OMD073
	A,B,E		d.	Each (aft) segment is free of unacceptable propellant grain surface defects per OMRSD, File V, Vol I, B47SG0.013	OMD074