CRITICAL ITEMS LIST (CIL)

No. 10-01-02-04/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Case Subsystem 10-01	PART NAME:	Inhibitor (1)
ASSEMBLY:	Propellant, Liner, Insulation, Inhibitor 10-01-02	PART NO.:	(See Section 6.0)
		PHASE(S):	Boost (BT)
FMEA ITEM NO.:	10-01-02-04 Rev N	QUANTITY:	(See Section 6.0)
CIL REV NO.:	N	EFFECTIVITY:	(See Table 101-6)
DATE:	27 Jul 2001	HAZARD REF.:	BC-10
SUPERSEDES PAGE:	216-1ff.		
DATED:	31 Jul 2000		
CIL ANALYST:	F. Duersch		
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 Structural failure of the castable inhibitor

3.0 FAILURE EFFECTS: Increased burn surface resulting in increased chamber pressure and loss of RSRMs. Thrust imbalance between RSRMs could result in loss of SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Bond line failure of inhibitor-to-propellant	
1.1.1	Contamination of raw materials/inhibitor	A
1.1.2	Incorrect castable inhibitor mixing proportions	B
1.1.3	Nonconformance to temperature controls during application of inhibitor	C
1.1.4	Improper application of inhibitor	D
1.1.5	Nonconformance to curing time and temperature of inhibitor	E
1.1.6	Transportation and handling damage	F
1.1.7	Inhibitor storage degradation (aging)	G

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION: Castable Inhibitor

1. RSRM castable inhibitor is an HC polymer-based material filled with asbestos pulp floats that is cast and cured on the aft propellant surface of the forward and center segments (Figures 1 and 2). Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U76674	Segment, RSRM Loaded Forward		1/motor	
1U76675	Segment, RSRM Loaded Center		2/motor	
	Inhibitor (Castable), RSRM, Space Shuttle Project	Composite of various materials	STW5-3223	300 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 (Curing Agent)	STW4-2646	Per Mix Ratio
		Floats, Pulp, Asbestos	STW4-2636	Per Mix Ratio
		Iron Hexoate (2-Ethyl), 6%	STW4-2645	Per Mix Ratio
	Inhibitor Repair Material	Sealant, Liquid Epoxy Resin, Asbestos Float Filled	STW5-2678	A/R

6.1 CHARACTERISTICS:

1. After propellant casting, an inhibitor depression mold plate is placed on the propellant grain surface until the grain is partially cured. Upon removal of the mold plate, castable inhibitor is applied to the grain surface and cure is continued. After cure is complete, inhibitor is inspected and repaired as necessary per engineering.

2. Castable inhibitor is a liquid polymer-based material that becomes highly cross-linked upon cure. Since propellant is also highly cross-linked upon cure, a chemical bond is formed between inhibitor and propellant per TWR-15276.

3. Castable inhibitor is of similar composition to liner material. Due to the composition, inhibitor exhibits much the same properties as liner in that bond strength between inhibitor and propellant is sufficient to assure cohesive failure in the propellant before any adhesive or cohesive failure in the inhibitor.

4. A function of castable inhibitor is to control propellant burn surface area. Proper processing and material properties preclude events associated with structural failure, thus controlling propellant burn surface area. Figure 1 shows the three RSRM area locations of inhibitor. Figure 2 is an expanded view showing locations of both castable and NBR inhibitors.

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

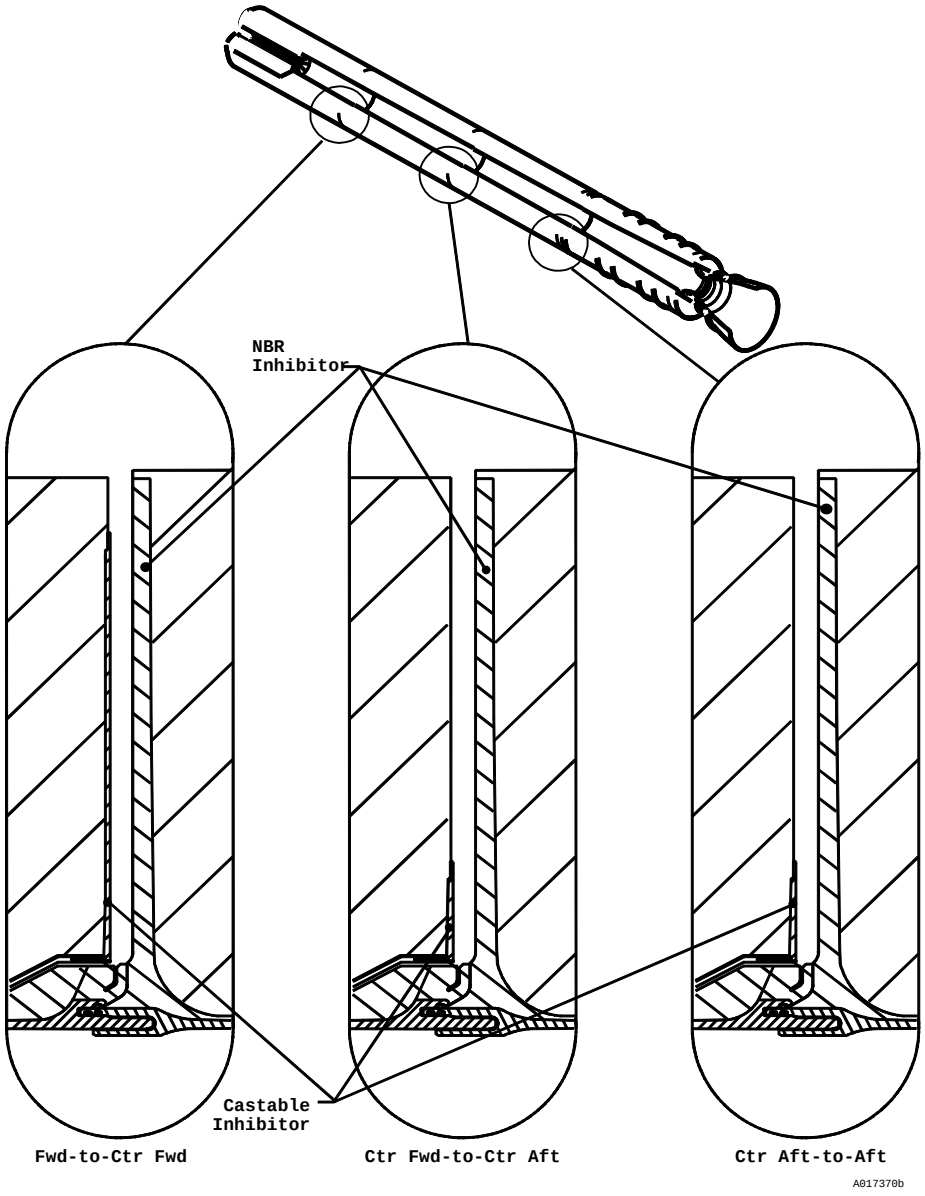

Figure 1. RSRM Castable and NBR Inhibitors

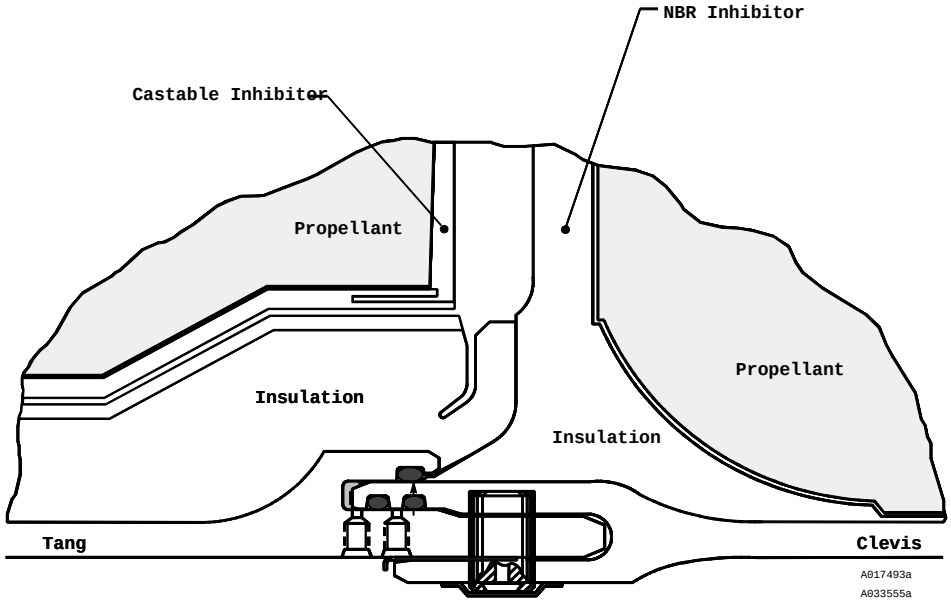

Figure 2. Castable and NBR Inhibitor

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN	FAILURE CAUSES	
A,B,C,F,G	1.	Ingredients, proportions, and mechanical properties of raw materials used in RSRM castable inhibitor are per engineering and are required to be free from visual contamination.
A	2.	Prior to segment casting, the casting pit is cleaned and verified per shop planning. Cleaning and housekeeping during processing are also controlled per shop planning.
A	3.	Contamination during processing is prevented by adherence to controls per shop planning.
A	4.	All tooling and equipment cleaning is controlled per shop planning.
A	5.	Raw materials listed below and used in the castable inhibitor are controlled per engineering: a. Asbestos floats b. Iron hexoate c. Epoxy resin d. MAPO e. Liquid Polymer
A,B	6.	Structural analyses on propellant grain and bond lines were done to verify factors of safety for the inhibitor-to-propellant bond. These analyses show positive margins of safety as reported in TWR-16961.
B	7.	Weighing tolerances of raw materials are controlled per engineering.
B	8.	The present formula for castable inhibitor was qualified on DM-6, DM-7, DM-8, DM-9, QM-6, and QM-7 as reported in TWR-18764-04.
B	9.	Raw material addition sequence, mix time, temperature of mix, and housekeeping are controlled per shop planning.
B	10.	Adequacy of raw material proportions related to strength in the castable inhibitor was determined by similarity to the characterization done for the liner since identical materials are used per TWR-15276.
C,D	11.	Liner, Propellant, and Castable Inhibitor cure processes are per engineering and shop planning. Propellant processing flow is described in TWR-10341.
C	12.	The forward 90 percent of the loaded assembly is maintained within temperature range per engineering requirements during cure interruption for inhibitor application.
C	13.	Temperature controls during application of inhibitor are per engineering drawings.
C,D,E	14.	Contamination control requirements and procedures are described in TWR-16564.
D	15.	Prior to application of castable inhibitor, the propellant aft face is determined to be acceptable per engineering.

D 16. Castable inhibitor application is per engineering drawings and shop planning.

D 17. Thickness dimensions of castable inhibitor for the case segment are per engineering drawings.

D 18. Castable inhibitor thickness requirements are verified acceptable per Development Motors DM-8 and DM-9, and Qualification Motors QM-6 and QM-7 as reported in TWR-18764-04.

D 19. Thicknesses are specified and qualified by design criteria per engineering drawings.

D 20. Tooling used for castable inhibitor application is per engineering drawings. Tool accountability is per shop planning.

E 21. Castable inhibitor is cured for a specified number of hours and temperature per engineering drawings.

E 22. Castable inhibitor cure and temperature are verified acceptable per Development Motors DM-8 and DM-9, and Qualification Motors QM-6 and QM-7 as reported in TWR-18764-04.

F 23. Castable inhibitor is formulated from the same materials as liner as well as being nearly identical in composition to liner. By similarity to liner, the characterizations of liner formulation to provide optimum strength can be considered applicable to inhibitor per TWR-15276.

F 24. Loads induced as a result of transportation and handling were studied with respect to the structural integrity of 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.

F 25. During transportation by rail, 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, TWR-12343, and TWR-13040.

F 26. 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 environments.

F 27. 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.

F 28. 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.

F 29. 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.

F 30. Railcar transportation shock and vibration levels for the segments are monitored per engineering with castable inhibitor loads derived per analysis. Monitoring

records are evaluated by Thiokol to verify that shock and vibration levels defined per MSFC specifications were not exceeded.

G 31. Aging and environmental (temperature and humidity) studies were performed to qualify the castable inhibitor and are summarized in TWR-12915.

G 32. 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.

G 33. Castable inhibitor meets "useful life" requirements by similarity to liner in that the composition of liner and castable inhibitor differs by only 0.2 percent asbestos floats per TWR-15278. Structural integrity of liner and castable inhibitor is greater than that of propellant and it was demonstrated that propellant meets "useful life" per TWR-17057. Post-test inspection of TEM-09 indicated no anomalous condition created by aging of hardware per TWR-63479. Premature loss of castable inhibitor would be evidenced by excessive erosion of the insulation.

F 34. 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	(T)	a.	Infrared spectrum	ALJ004,ALJ006,ALJ009
	A	(T)	b.	Iron content	ALJ011,ALJ013,ALJ016
	A	(T)	c.	Specific gravity	ALJ024,ALJ026,ALJ029
	A	(T)	d.	Viscosity	ALJ031,ALJ034,ALJ036
			2.	For New Floats, Asbestos verify:	
	A	(T)	a.	Calcination loss	ALI002
	A	(T)	b.	Fiber size distribution	ALI011
	A	(T)	c.	pH (Aqueous extract)	ALI023
	A	(T)	d.	Volatile matter	ALI051
	A	(T)	e.	Wet volume	ALI053
			3.	For New Epoxy Resin verify:	
	A	(T)	a.	Hydrolyzable chlorine	ALK006
	A	(T)	b.	Infrared spectrum	ALK014
	A	(T)	c.	Moisture	ALK021
	A	(T)	d.	Specific gravity	ALK034
	A	(T)	e.	Viscosity	ALK041
	A	(T)	f.	Weight per epoxy	ALK045
			4.	For New MAPO, verify:	
	A	(T)	a.	Hydrolyzable chlorides	ALL004
	A	(T)	b.	Infrared spectrum	ALL018
	A	(T)	c.	Moisture	ALL025
	A	(T)	d.	Reactive imine	ALL040
	A	(T)	e.	Specific gravity	ALL050
	A	(T)	f.	Total chlorine	ALL072
	A	(T)	g.	Viscosity	ALL079
			5.	For New Liquid Polymer (HC), verify:	
	A	(T)	a.	AO2246 antioxidant content	AMC000,AMC002,AMC006
	A	(T)	b.	Carboxyl equivalents	AMC009,AMC011,AMC015
	A	(T)	c.	Infrared spectrum	AMC018,AMC020,AMC024
	A	(T)	d.	Moisture	AMC025,AMC027,AMC031
	A	(T)	e.	Specific gravity	AMC038,AMC040,AMC044
	A	(T)	f.	Viscosity	AMC045,AMC047,AMC051
	A		g.	Workmanship is uniform in appearance and free from visible contamination	FDJ001
			6.	For New Inhibitor, RSRM Space Shuttle Project, verify:	
	A		a.	All mixer heads and equipment are cleaned prior to mixing	ANZ001
569	A		b.	Inhibitor raw materials are weighed per planning requirements	ANZ005
	A		c.	Raw materials free of visible contamination prior to use	ANZ007
	A		d.	Raw materials are acceptable just prior to use per the accept tag and shop planning	ANZ008
	A,B		e.	Tensile adhesion of propellant-to-inhibitor for production batches	ANZ027

A,B	f.	Uncured inhibiter viscosity for production and/or repair batches	ANZ038
	7.	For New Loaded Segment Assembly (Forward and Center) verify:	
A	a.	Absence of contamination on all exposed surfaces prior to casting inhibitor	AFF000,AFH002
A	b.	Aft end of segment is covered with a sheet of polyethylene during core popping	AFF002,AFH004
D	c.	Propellant/Igniter Boot terminations, after propellant trimming to a smooth contour, are acceptable per engineering	AFF003
A	d.	Aft face of propellant is free of foreign material per engineering	AFF004,AFH006
G	e.	Component temperatures and exposure to ambient environments during in-plant transportation or storage are acceptable	BAA008,BAA009
D	f.	Aft face of propellant is free of unacceptable anomalies after trimming to a smooth contour per engineering	AFH007,MKL033
D	g.	Cured aft face inhibitor surface is free from unacceptable anomalies per engineering	AFF016,AFH019
A	h.	Cured castable inhibitor for cleanliness following core pop	AFF018,AFH020
E	i.	Cure time and temperature of inhibitor	AFF020,AFH022
D	j.	Proper application of inhibitor following use of sweep template	AFF025,AFH027
D	k.	Acceptable repair of Aft Face Inhibitor anomalies per engineering	MKL027,MKL028
C	l.	Mixed inhibitor stored in temperature controlled environment is acceptable prior to application	AFF041,AFH047
A	m.	Mold plates are clean	AFF042,AFH048
A	n.	No foreign objects on or in the inhibitor surface after casting inhibitor per engineering	AFF044,AFH050
C	o.	Proper propellant cure prior to aft inhibitor application	AFF052,AFH058
C	p.	Temperature is maintained on 90 percent of loaded assembly during inhibitor application	AFF064,AFH070
A,D	q.	Sweep template is clean and assembled correctly prior to inhibitor application	AFF071,AFH074
D	r.	Ultrasonic testing to verify thickness of castable inhibitor	AFF075,AFH076
	8.	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
	9.	For New Handling Kit, 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
	10.	KSC verifies:	
D,F,G	a.	Forward and aft face propellant inhibitors and acrylonitrile butadiene rubber (NBR) inhibitor, liner, and propellant are free of defects per OMRSD, File V, Vol I, B47SG0.041	OMD077