ATK ALLIANT TECHSYSTEMS
THIOKOL PROPULSION

CRITICAL ITEMS LIST (CIL)

No. 10-02-01-07/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Nozzle Subsystem 10-02	PART NAME:	Flex Bearing Protector (1)
ASSEMBLY:	Nozzle and Aft Exit Cone 10-02-01	PART NO.:	(See Section 6.0)
FMEA ITEM NO.:	10-02-01-07 Rev M	PHASE(S):	Boost (BT)
CIL REV NO.:	M (DCN-533)	QUANTITY:	(See Section 6.0)
DATE:	10 Apr 2002	EFFECTIVITY:	(See Table 101-6)
SUPERSEDES PAGE:	320-1ff.	HAZARD REF.:	BN-06
DATED:	31 Jul 2000		
CIL ANALYST:	B. A. Frandsen		
APPROVED BY:		DATE:	

RELIABILITY ENGINEERING: K. G. Sanofsky 10 Apr 2002

ENGINEERING: B. H. Prescott 10 Apr 2002

1.0 FAILURE CONDITION: Failure during operation (D)

2.0 FAILURE MODE: 1.0 Thermal failure of silicone rubber or phenolic end rings

3.0 FAILURE EFFECTS: Damage to flex bearing causing loss of end ring seals, causing loss of RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Insufficient rubber or phenolic thickness	A
1.2	Bondline failure of the silicone rubber-to-phenolic protector rings	
1.2.1	Bonding surfaces not properly prepared or adequately cleaned	B
1.2.2	Bonding material not properly mixed, applied, or cured	C
1.2.3	Contamination during processing	D
1.2.4	Process environments detrimental to bond strength	E
1.2.5	Nonconforming material properties	F
1.3	Structural failure	
1.3.1	Nonconforming raw material properties	G
1.3.2	Nonconforming manufacturing processes	H
1.3.3	Nonconforming dimensions	I
1.3.4	Improperly-installed bolts	J
1.3.5	Nonconforming hardware dimensions	K
1.4	Component degradation during assembly, handling, transportation, or storage	L
1.5	Temperature, vibration, and shock	M

1.6	Porosity, voids, de-laminations, inclusions, or cracks	N
1.7	Improper thermal characteristics due to nonconforming raw materials	O

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

1. The Bearing Protector, Flexible, protects the flex bearing and end rings during motor operation. (Figure 1)

Table 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U77777	Bolt, Aluminum Coated, Nozzle	Alloy steel	NAS1341 FF-S-86 MIL-C-83488	120/motor
1U51130	Bearing Protector, Flexible			1/motor
5U51130	Bearing Protector Rings	Glass-Cloth Phenolic	STW5-2651	A/R
	Tape	Cloth Phenolic, Pre-impregnated	STW5-3621	A/R
	Rubber	Rubber Compound, Silicone	STW5-2738	95 lbs.
	Chemlok 608	Bonding Agent, Silicone Rubber	STW5-2849	A/R

6.1 CHARACTERISTICS:

1. The flexible bearing protector protects the flex bearing and end ring seals from the thermal environment of the flex boot chamber. It consists of cured and machined glass-cloth phenolic inner and outer rings bonded with a bonding agent and vulcanized with silicone rubber laid up in a mold.

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

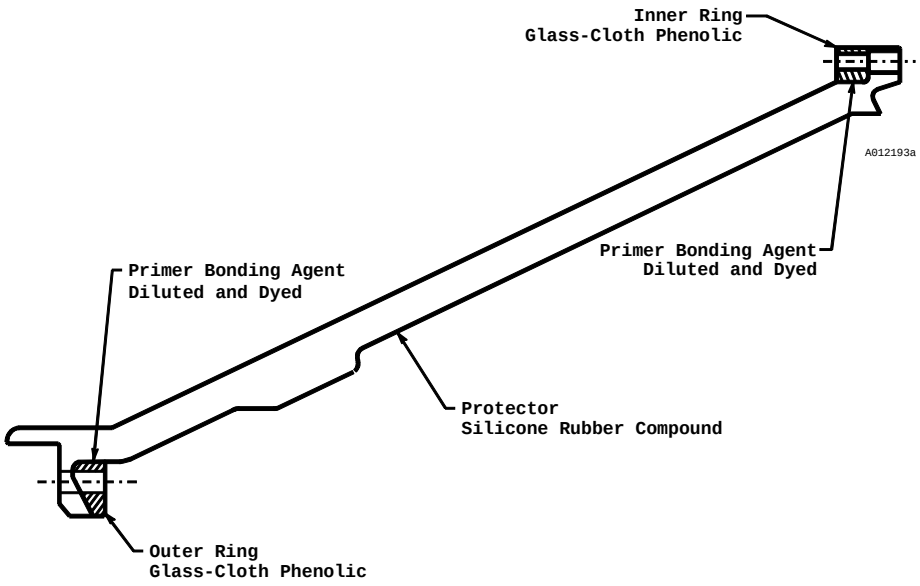

Figure 1. Flexible Bearing Protector

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN	FAILURE CAUSES	
A,I	1.	Silicone rubber thickness prior to application is per engineering.
A,I	2.	Flex bearing protector thickness and dimensions are per engineering drawings.
A,I	3.	Glass-cloth phenolic thickness and dimensions are per engineering drawings.
A,B,C,D,E,F, G,H,I,K,O	4.	Design development of the flex bearing protector is qualified by a series of tests per TWR-18764-09.
B,C,D,E,H	5.	Preparation of bonding surfaces (cleanliness and process environments) is per the following: a. Contamination control requirements and procedures are per TWR-16564. b. Preparation and cleaning of bonding surfaces are per shop planning. Surface inspection type is per shop planning. Preparation, cleaning, and inspection methods for the flex bearing protector are identified as process critical planning.
C	6.	Bonding Agent Chemlok 608 is thoroughly mixed before using.
C	7.	Bonding agent is applied to glass-cloth phenolic end ring bonding surfaces with a clean applicator ensuring there is one coat complete coverage per engineering drawings and shop planning.
C	8.	Inner and outer rings are vulcanized to the rubber protector per engineering drawings and shop planning.
C	9.	Bonding Agent Chemlock 608 called out for the Bearing Protector, Flexible is prepared, tested, and meets acceptance requirements to verify the bonding integrity of silicone rubber-to-glass-cloth phenolic per engineering.
F,G,O	10.	Silicone-rubber compound has cured material physical properties which conform to material specifications for Compound, Silicone per engineering.
F,G,O	11.	Glass-Cloth Phenolic pre-impregnated material has uncured and cured material properties per engineering.
F,G,O	12.	Bonding Agent Chemlok 608 has physical properties per engineering.
F,G,O	13.	Technical Evaluation Motor (TEM-9) showed normal char and soot patterns as seen on RSRM motors. There appeared to be no detrimental effects to the bearing protector due to long term storage. Five-year aging and humidity studies for the bearing protector are per TWR-63944.
H	14.	Inner and outer bearing protector rings are fabricated with glass-cloth phenolic by tape wrapping over a mandrel. After wrapping, the billets are vacuum-bagged and autoclave-cured. The parts are final machined and dimensionally inspected. These processes are per engineering drawings and shop planning.
H	15.	Primer is applied to the glass phenolic inner and outer rings per engineering drawings and shop planning.

H	16.	Silicone bearing protector rubber is fabricated of uncured silicone rubber by hand lay up of rubber into a mold containing the phenolic end rings. The lay up is then cured in a heated press and net molded to the configuration of the mold tool. These processes are per engineering drawings and shop planning. Tooling is per engineering drawings.
J	17.	The assembly procedure using attachment screws for the installation of the bearing protector into the nozzle assembly is per shop planning and engineering drawings.
J,L	18.	Manufacturing and assembly procedures were developed, demonstrated, and qualified per TWR-18764-09.
K	19.	Flex bearing protector dimensions are per engineering drawings. Overall dimensions are mold controlled per engineering drawings.
L	20.	The nozzle assembly is shipped in the aft segment. Railcar transportation shock and vibration levels are monitored per engineering and applicable loads are derived by analysis. Monitoring records are evaluated by Thiokol to verify shock and vibration levels per MSFC specification SE-019-049-2H were not exceeded. TWR-16975 documents compliance of the nozzle with environments per MSFC specifications.
L	21.	RSRM components will not be adversely affected for a maximum of 5-years storage.
L	22.	Installation of the bearing protector into the nozzle assembly is per shop planning and engineering drawings.
L	23.	Components are inspected for damage during handling after completion. Assembly and handling operations are per shop planning.
L	24.	To assure that no damage occurs to flight hardware during transportation to the launch site, specially designed and instrumented 200-ton railroad flatcars are used per TWR-13880.
L	25.	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 RSRM segments and other components. Shock mounting and other protective devices are used on trucks and dollies to move sensitive loads per TWR-13880.
L	26.	Age degradation of nozzle materials was shown to not be a concern. Full-scale testing of a six-year old nozzle showed that there was no performance degradation due to aging per TWR-63944. Tests on a fifteen-year old flex bearing also showed no degradation of flex bearing material properties per TWR-63806.
L,M	27.	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.
M	28.	Flight motors and static test motors were proven to be flight worthy per TWR-18764-09.
M	29.	Structural verification analysis includes safety factors, pressure, vibration and shock that proved the integrity of the flex bearing protector per TWR-11247 and TWR-17219.

	M	30. Analysis of nozzle natural frequency and vibration response throughout motor burn is per TWR-16975.
	M	31. Design development for the flex bearing protector is per TWR-11247 and TWR-17219.
	N	32. Presence of defects in the flexible bearing protector is unacceptable except as noted per engineering drawings and shop planning.
	B	33. A Spray-in-Air cleaning system is used to clean metal components as part of the bonding surface preparation processing sequence.
	E,L,M	34. Analysis of carbon-cloth phenolic ply angle changes for the nozzle was performed. Results show that redesigned nozzle phenolic components have a reduced in-plane fiber strain and wedge-out potential per TWR-16975. New loads that were driven by the Performance Enhancement (PE) Program were addressed in TWR-73984. No significant effects on the performance of the RSRM nozzle were identified due to PE.
533	E,I,M	35. Thermal analysis per TWR-17219 shows the nozzle phenolic meets the new performance factor equation based on the remaining virgin material after boost phase is complete. This performance factor will be equal to or greater than a safety factor of 1.4 for nozzle phenolics per TWR-74238 and TWR-75135. (Carbon phenolic-to-glass interface, bondline temperature and metal housing temperatures were all taken into consideration). The new performance factor will insure that the CEI requirements will be met which requires that the bond between carbon and glass will not exceed 600 degree F, bondline of glass-to-metal remains at ambient temperature during boost phase, and the metal will not be heat affected at splashdown.

9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TESTS (T)			CIL CODES
		1.	For New Bearing Protector, Flexible verify:	
A,I		a.	Acceptability of mold tooling per recycle inspection tag	ABX000
A,H,I,N		b.	Both sides of molded silicone rubber are free of defects after stretch test	ABU042
A,I		c.	Inside diameter of end rings	ABU051,ABU052
A,C,F,G,H,I,N,O		d.	Unacceptable unbonds and separations after stretch test	ABU097
B,D,E		e.	Mold release has been applied properly	ABU055
B,C,E,H		f.	Complete coverage of bonding agent to bonding surfaces of the end rings	ABU018
C,E,F,G, H,N,O	(T)	g.	Elongation stretch test results are acceptable	ABU034
B,D,E		h.	Phenolic components are free from surface contamination, grease, oil, foreign materials and other defects after solvent wipe	ABU037
D,E		i.	Removal of silicone rubber from molding surfaces prior to flexible bearing protector fabrication	ABU053
B,D		j.	Glaze is removed from bonding surfaces of phenolic components	ABU068
D,E		k.	Molding surfaces are degreased and all surface corrosion is removed	ABU078
D		l.	Bonding agent is uniform in appearance and free from visible contamination	ANN001
C		m.	Bonding agent (Chemlok 608) is mixed before using per planning instructions	ABU012
C,H		n.	Cure is complete and acceptable for the flexible bearing protector assembly per planning requirements	ABU025
C,F,G,H,N,O		o.	Unacceptable bubbles	ABU088
C,F,G,H,N,O		p.	Unacceptable tears, cuts, wrinkles, and uncured rubber	ABU094
C,F,G,H,N,O		q.	Unacceptable voids	ABU096
F,G,O		r.	Storage life of silicone-rubber compound is acceptable	ANA050
F,G,O		s.	Shelf life and environmental history of bonding agent (Chemlok 608) is acceptable	ANN006
H		t.	Proper repair of voids is complete and acceptable	ABU069
K		u.	Phenolic end ring hole diameter	ABX001,ABX003
K		v.	Acceptable tooling for phenolic end ring drilling of holes	ABX004,ABX004A
L,M		w.	Component temperatures and exposure to ambient environments during in-plant transportation or storage	BAA032
N		x.	Unacceptable holes	ABU043
		2.	For New Bearing Protector Rings verify:	
A,I		a.	Outside diameter of ring	ABU065,ABU066
A,I		b.	Thickness of glass-cloth phenolic	ABU085,ABU086
A,B,D,E,H,I,N		c.	For Contamination and damage on ring after drilling	ABU039,ABU039A
B,D,E,H,N		d.	Alcohol wipe	ABU062,ABU062A
F,G,O		e.	Only one supplier of glass-cloth phenolic is used within a ring	AHL000
F,G,O		f.	Storage life and environmental history of glass-cloth phenolic	AMN158
H		g.	Autoclave cure process is complete and acceptable for the glass phenolic end rings	ABU007,ABU007A
H		h.	Tape wrap process is complete and acceptable for glass phenolic end ring	ABU080,ABU081
		3.	For New Rubber Compound, Silicone verify:	
A,I		a.	Thickness	ANA040C

A,I		b.	Workmanship	ANA040
A,I		c.	Length	ANA040A
A,I		d.	Width	ANA040B
F,G,O	(T)	e.	Elongation	ANA007,ANA003
F,G,O	(T)	f.	Hardness	ANA017,ANA012
F,G,O	(T)	g.	Materials and composition conform to specification	ANA026
F,G,O	(T)	h.	Specific gravity	ANA037,ANA033
F,G,O	(T)	i.	Tear strength	ANA048,ANA044
F,G,O	(T)	j.	Tensile strength	ANA058,ANA054
F,G,O	(T)	k.	Vulcanized bond strength	ANA053A

4. For New Bonding Agent--Chemlok 608 verify:

C,E,F, G,O	(T)	a.	Vulcanized bond strength	ANH002
D,E		b.	Workmanship for uniform appearance and free from visible contamination	ANN001A
F,G,O	(T)	c.	Solids content	ANH001

5. For New Glass-Cloth Phenolic verify:

F,G,O	(T)	a.	Cloth content--uncured	AMN006,AMN007
F,G,O	(T)	b.	Compressive strength--cured	AMN013,AMN014
F,G,O	(T)	c.	Density--cured	AMN037,AMN038
F,G,O	(T)	d.	Dry resin solids--uncured	AMN049,AMN048
F,G,O	(T)	e.	Inter-laminar shear strength--cured	AMN055,AMN057
F,G,O	(T)	f.	Resin content--cured	AMN086,AMN088
F,G,O	(T)	g.	Resin flow--uncured	AMN120,AMN121
F,G,O	(T)	h.	Volatile content--uncured	AMN196,AMN195

6. For Retest Glass-Cloth Phenolic verify:

F,G,O	(T)	a.	Resin flow	AMN103
F,G,O	(T)	b.	Volatile content	AMN178

7. For Retest Phenolic Slit Tape verify:

F,G,O	(T)	a.	Resin flow	AMN103A
F,G,O	(T)	b.	Volatile content	AMN178A

8. For New Nose-Throat-Bearing-Cowl Assembly verify:

J	a.	Flexible bearing protector is properly installed and free from defects	ADP009
J	b.	Socket head cap screws are torqued in sequence per planning requirements, bearing protector	ADP084