ATK ALLIANT TECHSYSTEMS
THIOKOL PROPULSION

CRITICAL ITEMS LIST (CIL)

No. 10-02-03-01R/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Nozzle Subsystem 10-02	PART NAME:	Flex Bearing Assembly (1)
ASSEMBLY:	Flex Bearing Assembly 10-02-03	PART NO:	(See Section 6.0)
FMEA ITEM NO.:	10-02-03-01R Rev M	PHASE(S):	Boost (BT)
CIL REV NO.:	M	QUANTITY:	(See Section 6.0)
DATE:	17 Jun 2002	EFFECTIVITY:	(See Table 101-6)
SUPERSEDES PAGE:	345-1ff.	HAZARD REF.:	BN-06
DATED:	31 Jul 2000		
CIL ANALYST:	S. E. Rodgers		
APPROVED BY:		DATE:	

RELIABILITY ENGINEERING: K. G. Sanofsky 17 Jun 2002

ENGINEERING: P. M. McCluskey 17 Jun 2002

1.0 FAILURE CONDITION: Failure during operation (D)

2.0 FAILURE MODE: 1.0 Structural failure of Flex Bearing Assembly

3.0 FAILURE EFFECTS: Loss of nozzle causing loss of SRB, RSRM, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Failure of the elastomer	
1.1.1	Nonconforming physical or mechanical properties	A
1.1.2	Nonconforming dimensions	B
1.1.3	Nonconforming raw material properties	C
1.1.4	Nonconforming manufacturing processes	D
1.2	Failure of metal parts (shims and end rings)	
1.2.1	Nonconforming dimensions	E
1.2.2	Nonconforming material properties	F
1.2.3	Improper heat treatment	G
1.2.4	Corrosion	H
1.2.5	Nonconforming flaws	I
1.2.6	In-service degradation or fatigue	J
1.2.7	Stress-corrosion cracking	K
1.3	Bondline failure of elastomer-to-metal bond	
1.3.1	Bonding surfaces not properly prepared or adequately cleaned	L

1.3.2	Bonding material not properly mixed, applied, or cured	M
1.3.3	Contamination during processing	N
1.3.4	Process environments detrimental to bond strength	O
1.3.5	Nonconforming material properties	P
1.4	Components damage or degradation during assembly, storage, handling, or transportation	Q

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

1. Bearing Assembly, Nozzle Flexible (Figure 1). Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U52833	Aft End Ring (may be made from 1U50083)	D6AC Steel Alloy, High Strength	STW4-2709	1/motor
1U52834	Forward End Ring	D6AC Steel	STW4-2709	1/motor
1U50085	Ring, Bearing Assembly Forward	D6AC Steel	STW4-2709	1/motor
1U50097	Shim	D6AC Steel	STW4-2709	10 ea
1U51916	Cartridge (filled with Corrosion-Preventive Compound and O-Ring Lubricant)	Heavy-Duty Calcium Grease	STW5-2942	A/R
1U76888	Pressure Plug	Stainless Steel Type 303 or 304	ASTM A276	1/Flex Bearing Assembly
1U50228	Packing Preformed	Black Rubber	STW4-3339	1/Flex Bearing Assembly
AE99310E	Coupling, Bulkhead	Stainless Steel		1/Flex Bearing Assembly
	Rubber Compound, Natural Adhesive	Natural Rubber	STW5-2943	A/R
	Primer, Rubber-to-Metal, SRM Flex Bearing	Chlorinated Rubber	STW5-2656	A/R
	Adhesive Rubber-to-Metal, SRM Flex Bearing	Chlorinated Rubber	STW5-2657	A/R
	Cement, Natural Rubber Base	Natural Rubber	STW5-2783	A/R
	Adhesive Primer, Rubber-to-Metal	Adhesive Primer	STW5-2664	A/R
	Adhesive, Rubber-to-Metal	Chlorinated Rubber	STW5-2665	A/R
	Coatings, Epoxy-Polyamide	Epoxy and a Polyamide Resin Activator	STW5-3225	A/R
	Primer, Zinc-Rich Epoxy-Polyamide	Pigmented Epoxy Resin Base and a Polyamide Resin Activator	STW5-3226	A/R
	Sealing Compound, Temperature-Resistant, High-Adhesion	Synthetic Rubber	STW5-9072	A/R

6.1 CHARACTERISTICS:

1. The Nozzle Flexible Bearing provides capability for the nozzle to vector, that controls flight direction while maintaining internal motor chamber pressures.

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

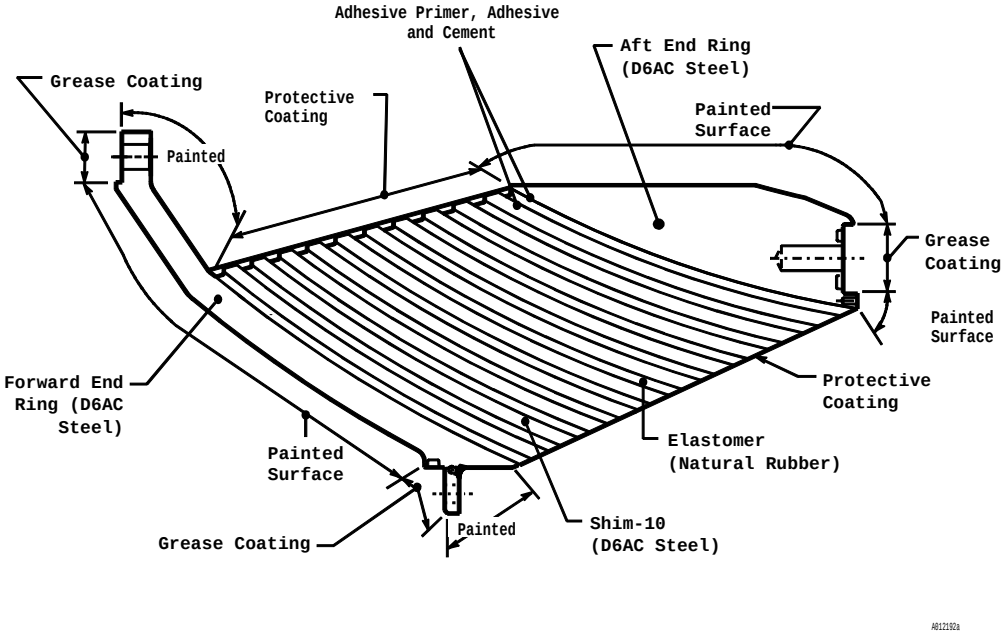

Figure 1. RSRM Flexible Bearing Assembly

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN	FAILURE CAUSES	
A	1.	Cured properties of the elastomer conform to engineering requirements.
A,B,C,D,E,F, G,H,I,J,K,L, M,N,O,P,Q	2.	Design factor of safety on the RSRM Nozzle Flex Bearing Assembly is 1.4. Analysis performed on the flex bearing showed a positive margin of safety per TWR-16975.
A	3.	Design rationale for physical and mechanical properties of Rubber Compound, Natural are per engineering.
B	4.	Raw form elastomer thickness conforms to engineering requirements.
B	5.	Vulcanized flex bearing elastomer dimensions conform to engineering.
B	6.	CIL-controlled processes during manufacturing are established by shop planning. Certified tooling controls elastomer thickness per engineering drawings.
C	7.	Uncured elastomer raw material properties and formula are established per engineering.
C	8.	Design rationale for raw material properties is per TWR-15995.
	9.	Preparation of bonding surfaces (cleanliness and process environments) is as follows:
D,L,N,O	a.	Contamination control requirements and procedures are described in TWR-16564.
D,L,N,O	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.
E	10.	Shim, aft end ring, and forward end ring dimensions conform to engineering drawings.
E	11.	Refurbished shim, aft end ring, and forward end ring dimensions meet the dimensional requirements of engineering drawings.
E	12.	Design criteria for shims and end rings are per TWR-15995.
F	13.	The flex bearing aft end ring, forward end ring, and shims are made of D6AC steel as defined by engineering.
F	14.	Chemical composition of D6AC steel is tested per mill analysis to meet engineering drawing requirements.
F,H,K	15.	D6AC steel components on the flex bearing conform to the Material Use Agreement.
F	16.	Design rationale for material properties are per TWR-15995.
G	17.	Shims are heat treated per engineering.
G	18.	The aft end ring is heat treated per engineering.
G	19.	The forward end ring is heat treated per engineering.

G	20.	Design criteria for heat treatment are per TWR-15995.
H,K	21.	Flex bearing metal parts corrosion limits are defined per engineering.
H,K	22.	Adhesive primers and bonding agents are mixed and applied to metal surfaces for corrosion protection and insulation bonding per engineering and shop planning.
H,K	23.	The Flex Bearing Assembly is provided corrosion protection per engineering.
H,K	24.	Corrosion is removed from refurbished shims, forward end rings, and aft end rings per engineering.
H,K	25.	Refurbished forward end ring flange and through holes, excluding the leak check port, are magnetic-particle inspected during each refurbishment per engineering.
I	26.	Shim acceptable flaw limits are established by engineering.
I	27.	Aft end ring acceptable flaw limits are established by engineering.
I	28.	Forward end ring acceptable flaw limits are established by engineering drawings and specifications.
I	29.	Scratches, gouges, damaged threads, corrosion pits, cracks, and surface imperfections meet engineering requirements.
I,J	30.	Flaw detection and control requirements are described in TWR-16875. Flex bearing shims are a fracture control item per TWR-16875. TWR-16875 confirms that the shims will meet safe life requirements.
J	31.	D6AC steel used in flex bearing metal parts is sample tested during the heat treat process and is traceable to forging and location within the ingot by identification markings and meet proper requirements per engineering.
J	32.	Evaluation of the RSRM bearing shim forging is per TWR-10727.
J	33.	Forward end ring acceptable flaw limits are established by engineering drawings and specifications.
L,N,O	34.	Sensitivity of natural and induced environments of the flex bearing was analyzed and the results indicated per TWR-13880.
	35.	The following documents control mixing, application, and curing of bonding materials:
M		a. Adhesive Primer is mixed and applied per engineering drawings and shop planning.
M		b. Adhesive, Rubber-to-Metal, RSRM Flex Bearing is mixed and applied per engineering drawings and shop planning.
M		c. Cement, Natural Rubber Base is mixed, bonded, and cured to shims and end rings per shop planning.
M		d. Elastomer is applied per engineering drawings and shop planning, and is bonded and cured to shims and end rings per shop planning.
M	36.	Bonding (vulcanizing) of the rubber-to-metal to form the flex bearing is controlled by process specifications containing critical process instructions.
M	37.	Results of the flex bearing aging study per TWR-63806 determined that there is no discernable degradation of the flex bearings over a fifteen year time period. Only

acceptable variations in material properties were realized. A flex bearing built with materials complying with engineering requirements will perform acceptably when stored for the required five years.

P 38. Rubber-to-metal adhesive primer bonds meet material engineering requirements.

P 39. Adhesive, Rubber-to-Metal, RSRM Flex Bearing meets material engineering requirements.

P 40. Cement, Natural Rubber Base meets material engineering requirements.

P 41. Elastomer meets material engineering requirements.

P 42. Qualification of material properties of the adhesive rubber-to-metal, adhesive primer, and cement-natural rubber base, was previously qualified under the initial qualification program for the flex bearing. Further testing of the flex bearing is part of the RSRM nozzle qualification program and is documented in TWR-18764-10.

Q 43. Transportation and handling of the Flex Bearing Assembly at Thiokol is controlled per shop planning and IHM 29.

Q 44. The Flex Bearing Assembly is stored out of the nozzle in a cool, dry place. It is protected during storage prior to installation by applicable protective coatings, and stored in a closed container to minimize corrosion, contamination, and exposure to sunlight per engineering.

Q 45. Nozzle flex bearing components are designed to be acceptable for flight after 5 years storage following acceptance testing per engineering. The design provides for nine further flights with reuse acceptance prior to each flight per engineering. Age tracking is provided per the TWR related to the applicable serial number.

E,Q 46. Bare metal surfaces are coated to provide corrosion protection during storage and useful life per engineering.

Q 47. Shipping links are used to protect and restrain the Nozzle Flex Bearing from moving during transportation as part of the aft shipping segment to the launch site per engineering drawings.

Q 48. 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.

Q 49. The nozzle assembly is shipped in the aft segment. Railcar transportation shock and vibration levels are monitored per engineering and applicable loads are derived per 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.

Q 50. Aging effect on Nozzle Flex Bearings was evaluated and the predicted aging factor on a 20-year service life determined per TWR-24344.

Q 51. 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.

Q 52. 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.

9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TESTS (T)			CIL CODE
		1.	For New Rubber Compound, Natural, verify:	
A,C,P	(T)	a.	Specific gravity	ANP051,ANP053,ANP056
A,C,P	(T)	b.	Hardness	ANP017,ANP020,ANP010
A,C,P	(T)	c.	Shear strength	ANP046
A,C,P	(T)	d.	Shear modules	ANP034
A		e.	No shipping or handling damage	AMP032A
B		f.	Thickness (average) of rubber compound at temperature	HHH019
C	(T)	g.	Mooney viscosity	ANP023,ANP021
C		h.	Cure initiation time	ANP006,ANP003,ANP000
D		i.	Texture	HHH021
L,N,O		j.	Cleanliness	ANP007
		2.	For Re-tested Rubber Compound, Natural, verify:	
A,C,P	(T)	a.	Shear modules	ANP033
A,C,P	(T)	b.	Shear strength	ANP043A
C		c.	Cure initiation time	ANP002
		3.	For New Bearing Assembly, Nozzle Flexible verify:	
D,H,I,K,J	(T)	a.	Torque test of bearing	ADJ147
D,H,I,K,J		b.	Pivot point characterization	ADJ149B
D,H,I,K,J		c.	Flat plate axial deflection test	ADJ029A
D,L,N,O		d.	Cleanliness elastomer during bearing lay up	ADJ034
D,L,M,N,O		e.	Cure conforms to planning requirements	ADJ047
D,L,M,N,O,P		f.	Separations prior to acceptance testing	ADJ052
D,M		g.	Elastomer surface imperfections	ADJ134
D,H,I,J, K,L,N,O	(T)	h.	Thrust relief piston axial deflection test	ADJ141
B		i.	Average overall height stack-up dimension after acceptance testing	HHH020
E,Q		j.	No corrosion prior to assembly	AAI027
E,L,N,O		k.	Flex bearing metal parts have been grit blasted prior to assembly	AAI012
H,K		l.	Adhesive and adhesive primer applied to designated surfaces	ADJ013,ADJ014
H,K		m.	Corrosion-preventive compound (grease) is properly applied to designated areas	ADJ035E
H,I,K		n.	Non sealing surface defects do not exceed requirements	ADJ036
H,I,K		o.	Cracks do not exceed requirements	ADJ044
H,K		p.	Epoxy-polyamide coating applied to designated surfaces	ADJ108
H,K		q.	Epoxy-polyamide primer applied to designated surfaces	ADJ110
I		r.	Damaged threads do not exceed requirements	ADJ050A
I,J,L,M,N,O	(T)	s.	Tensile leak test	ADJ064
I		t.	Sealing surface defects are acceptable	ADJ128
L,N,O		u.	Warm-up oven is cleaned	BHU100
L,N,O		v.	Overhead spray booth doors are closed during spraying operation	BHU101
L,N,O		w.	Bonding surfaces of metal parts are free of contamination prior to primer application	ADJ033
L,N,O		x.	Cutting table is clean prior to rubber lay-up	ADJ048
L,N,O		y.	Handling equipment is clean during flex bearing fabrication	ADJ073
L,N,O		z.	Hydrothermograph is maintained during entire flexible bearing fabrication	ADJ076
L,N,O		aa.	No contamination exists on the flexible bearing mold surfaces that contact the flexible bearing and no loose contamination exists on	

			the entire flexible bearing mold. Stains are acceptable on the entire mold	ADJ088
L,N,O		ab.	Overhead crane oil protection cover is in place during flex bearing fabrication	ADJ096
L,N,O		ac.	Overhead crane is clean during flex bearing fabrication	ADJ098
L,N,O		ad.	Rubber lay-up hand tools are clean prior to use	ADJ126
L,N,O		ae.	Spray booth is clean	ADJ130
L,N,O		af.	Spray booth is free from loose material	ADJ131
M		ag.	Adhesive, rubber to metal and adhesive primer mixed prior to use per shop planning	ABT009,ABT010
M		ah.	Cement, natural rubber base mixed prior to use per shop planning	ABT011
M		ai.	Adhesive materials not mixed from different lots	ABT015
M		aj.	Bonding materials (adhesive, cement, elastomer) used prior to shelf life expiration date	ABT016,ABT017,ABT018
M		ak.	Adhesive, adhesive primer, or cement is applied	ABT000,ABT001,ABT003
M	(T)	al.	Separations after acceptance testing	ADJ052B
Q		am.	Bearing is stored in a closed container when not in process	ADJ133
Q		an.	Component temperatures and exposure to ambient environments during in-plant transportation or storage	BAA033
Q		ao.	No handling damage prior to installation of bearing hardware	AAI014

4. For Refurbished Bearing Assembly, Nozzle Flexible verify:

D,H,I,K,J	(T)	a.	Pivot point characterization test	ADJ111
D,H,I,K,J	(T)	b.	Torque test of bearing	ADJ147A
D,H,I,K,J	(T)	c.	Tensile leak test	ADJ064A
L,M,N,O				
H,K		d.	Adhesive and adhesive primer applied to designated surfaces	ADJ013A,ADJ014A
H,K,Q		e.	Corrosion-preventive compound is properly applied to designated areas	ADJ035A
H,K		f.	Cracks do not exceed requirements	ADJ044A
H,K		g.	Epoxy-polyamide coating applied to designated surfaces	ADJ108A
H,K		h.	Epoxy-polyamide primer applied to designated surfaces	ADJ110A
I		i.	Non sealing surface defects do not exceed requirements	ADJ036A
I		j.	Damaged threads do not exceed requirements	ADJ050
I		k.	Sealing surface defects are acceptable	ADJ070
I,J	(T)	l.	Magnetic particle inspection of the flange forward end ring	BHU111
M	(T)	m.	Separations after acceptance testing	ADJ052C
Q		n.	Bearing is stored in a closed container when not in process	ADJ133A

5. For New Shim verify:

E		a.	Height dimension	AAI031C
E		b.	Shim thickness	AAI031
E		c.	Forward diameter dimension	AAI031D
E,Q		d.	Corrosion protection is per specification	AAI023
G		e.	Ultimate strength of shim	AAI0000
G		f.	Yield strength of shim	AAI000A
G		g.	Elongation of shim	AAI000B
G		h.	Reduction of area of shim	AAI000C
G	(T)	i.	K_{IC} (fracture toughness) of shim	AAI000D
I	(T)	j.	Ultrasonic test after final machining	AAI040
I,J	(T)	k.	Magnetic-particle inspection	AAI017

6. For Refurbished Shim verify:

E		a.	Shim thickness	AAI032A

E		b.	Forward diameter dimension	AAI031E
E,Q		c.	Corrosion protection is per specification	ADJ035F
H,K,L,N,O		d.	Corrosion removed	ADJ037B
I,J	(T)	e.	Magnetic-particle inspection	AAI018
J		f.	Deformed parts do not exceed requirements	AAI005
J		g.	Deformed holes do not exceed requirement	AAI003
L,N,O		h.	Shim has no unacceptable contamination	AAI034

7. For New Ring, Bearing Assembly, Forward verify:

E		a.	Diameter dimension	ADF009
E		b.	Thickness	ADF018
E		c.	Flatness	ADF025
E		d.	Run out	ADF060,ADF065,ADF068
E,Q		e.	Corrosion protection is per specification	ADF034
F,G	(T)	f.	Ultimate strength	ADF052
F,G	(T)	g.	Yield strength	ADF052A
F,G	(T)	h.	Elongation	ADF052B
F,G	(T)	i.	Reduction of area	ADF052C
F,G	(T)	j.	K_{IC} (fracture toughness)	ADF052D
I	(T)	k.	Ultrasonic inspection	ADF092,ADF090
I	(T)	l.	Magnetic-particle	ADF046,ADF044
Q		m.	Handling damage	AAG016

8. For New Aft End Ring verify:

E,Q		a.	Corrosion protection is per specification	ADE005
E		b.	Diameter dimension	ADE012
E		c.	Flatness	ADE023
E		d.	Run out of diameter	ADE063
F,G	(T)	e.	Ultimate strength	ADE076
F,G	(T)	f.	Yield strength	ADE076A
F,G	(T)	g.	Elongation	ADE076B
F,G	(T)	h.	Reduction of area	ADE076C
I	(T)	i.	Ultrasonic	ADE080
I	(T)	j.	Magnetic particle	ADE040

9. For Refurbished Aft End Ring verify:

E,Q		a.	Corrosion protection	ADE005A
E		b.	Diameter dimension	ADE013,ADJ017
E		c.	Diameter roundness	ADJ016,ADJ018
H,K		d.	Corrosion removed	ADJ037
I,J	(T)	e.	Magnetic particle	ADE037
J		f.	Deformed parts do not exceed requirement	AAF006
J		g.	Deformed holes do not exceed requirement	AAF004
L,N,O		h.	No unacceptable contamination	AAF032

10. For Refurbished Ring, Bearing Assembly, Forward verify:

E		a.	Diameter dimension	ADJ068,ADJ066
E		b.	Roundness	ADJ069,ADJ067
E		c.	Height	ADF022
H,K		d.	No unacceptable corrosion or corrosion products	ADJ037A
I,J	(T)	e.	Magnetic particle	ADF039
J		f.	Deformed parts do not exceed requirement	AAG005
J		g.	Bolt hole deformation, pitting	AAG003
L,N,O		h.	No unacceptable contamination	AAG032

		11.	For New Adhesive Primer, verify:	
P		a.	Material is acceptable	AMP032
P	(T)	b.	Peel adhesion	AMP010
P	(T)	c.	Solids content	AMR059,AMR067
P	(T)	d.	Density	AMR006,AMR012
P	(T)	e.	Viscosity	AMR083,AMR092
P	(T)	f.	Peel adhesion	AMR026,AMR022
P		g.	Workmanship	AMR041
		12.	For New Adhesive, Rubber-To-Metal verify:	
L,N,O		a.	Workmanship is uniform in appearance and free from visible contamination	
P	(T)	b.	Peel adhesion	AMS002
P	(T)	c.	Solids content	AMS015
P	(T)	d.	Specific gravity	AMS025
P	(T)	e.	Viscosity	AMS037
		13.	For New Cement, Natural Rubber Base verify:	
L,N,O		a.	Workmanship	ANC000
P	(T)	b.	Solids content	ANC012
P	(T)	c.	Specific gravity	ANC016
P	(T)	d.	Peel strength	ANC004
P	(T)	e.	Shear strength	ANC008
585		14.	For New Approved Solvent, verify:	
L,N,O		a.	Certificate of Conformance is complete and acceptable	AJJ007A
		15.	For New Adhesive, Rubber-to-Metal, SRM Flex Bearing verify:	
P	(T)	a.	Peel adhesion	AMQ007
P	(T)	b.	Viscosity	AMQ031
		16.	For Re-tested Adhesive, Rubber-to Metal, SRM Flex Bearing verify:	
P	(T)	a.	Peel adhesion	AMQ004
P	(T)	b.	Viscosity	AMQ029
		17.	For Retest Cement, Natural Rubber Base verify:	
P	(T)	a.	Solids content	ANC011
P	(T)	b.	Specific gravity	ANC015
P	(T)	c.	Peel strength	ANC003
P	(T)	d.	Shear strength	ANC007
		18.	KSC verifies:	
Q		a.	Flex bearing was maintained at the minimum average temperature or thermally conditioned prior to launch per OMRSD, File II, Vol I, S00FA0.776	OMD013
Q		b.	Flex bearing temperature readings meet specification limits prior to vectoring per OMRSD, File II, Vol I, S00GEN.680	OMD117
D		c.	No disengaged link (275 degree location) and no loose or disengaged link (35 and 155 degree location) when aft segment is	

		horizontal per OMRSD, File V, Vol I, B47SG0.540	OMD112
F	d.	Segments and nozzle components are free of damage per OMRSD, File V, Vol I, B47SG0.061	OMD079