ATK ALLIANT TECHSYSTEMS
THIOKOL PROPULSION

CRITICAL ITEMS LIST (CIL)

No. 10-05-04-08R/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1R
SUBSYSTEM:	Assembly Hardware/Interface Subsystem	PART NAME:	Forward-to-Aft Exit Cone Joint, Primary O-ring, Secondary O-ring (2)
ASSEMBLY:	Fwd-to-Aft Exit Cone Interface 10-05-04		
FMEA ITEM NO.:	10-05-04-08R Rev M		
CIL REV NO.:	M (DCN-533)	PART NO.:	(See Section 6.0)
DATE:	10 Apr 2002	PHASE(S):	Boost (BT)
SUPERSEDES PAGE:	361-1ff.	QUANTITY:	(See Section 6.0)
DATED:	31 Jul 2000	EFFECTIVITY:	(See Table 101-6)
CIL ANALYST:	R. E. L. Hamilton	HAZARD REF.:	BN-02
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 Leakage of the primary O-ring and secondary O-ring

3.0 FAILURE EFFECTS: Seal failures could result in hot gas flowing through joint resulting in a burn-through causing loss of aft exit cone and thrust imbalance between SRBs and loss of RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Nonconforming O-ring splice or repair	A
1.2	Nonconforming O-ring dimensions	B
1.3	O-ring cut or damaged	C
1.4	Nonconforming O-ring voids, inclusions, or subsurface indications	D
1.5	Age degradation of O-ring	E
1.6	Moisture and/or fungus degradation of O-ring	F
1.7	O-ring gland does not meet dimensional or surface finish requirements	G
1.8	O-ring improperly installed	H
1.9	Transportation, handling, or assembly damage	I
1.10	Sealing surfaces contamination or corrosion	J
1.11	Nonconforming physical or mechanical properties	K

5.0 REDUNDANCY SCREENS:

SCREEN A: Pass--The leak test procedure verifies the primary O-ring and secondary O-ring seals.
SCREEN B: Fail--No provision is made for failure detection by the crew.
SCREEN C: Fail--The primary and secondary O-ring seal will be pressurized and seal can be lost due to a single credible cause such as a surface defect on the sealing surface.

1. The primary O-ring and secondary O-ring form part of a redundant seal system when the leak check port seals. The secondary O-ring will see no pressure unless the primary O-ring fails. If the primary O-ring fails, the secondary O-ring will be pressurized and will maintain a seal. If the primary O-ring and secondary O-ring fail, a leak path will exist and could result in loss of vehicle and crew.

6.0 ITEM DESCRIPTION:

1. There is one aft exit cone-to-nozzle joint on each RSRM, with the joint containing a primary and secondary O-ring. The assembled joint (Figure 1) is per engineering drawings. Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No	Name	Material	Specification	Quantity
1U77647	Aft Booster Build-up--KSC			1/motor
1U52837	Housing, Exit Cone, Nozzle			1/motor
1U79152	Exit Cone Assembly, Forward Section			1/motor
1U52842	Shell, Exit Cone, Aft			1/motor
1U75150	Packing, Preformed Fluorocarbon	Black Fluorocarbon Rubber	STW4-3339	1/motor
1U51916	Cartridge Assembly	Heavy-Duty Calcium Grease, Filtered and Loaded in an Application Cartridge	STW7-3657	A/R
1U75801	Packing, Lubricated	Black Fluorocarbon Rubber O-ring and Lubricant	STW7-2999	1/motor
1U79155	Exit Cone Subassembly-Nozzle, Aft			1/motor
	Corrosion-Preventive Compound and O-ring Lubricant	Heavy-Duty Calcium Grease	STW5-2942	A/R

6.1 CHARACTERISTICS:

1. The aft exit cone-to-forward exit cone joint (Figure 2) allows the aft exit cone to be mounted to the aft case segment at the launch site. The unit is sealed with O-rings and there is one leak check port to verify that there is no leakage after assembly.

2. Seals at the aft exit cone-to-forward exit cone joint are designed so that the O-ring maintains constant contact with its cavity at all times. Squeeze, fill, and tracking are taken into account relating to O-ring groove tolerances.

3. The O-ring is a one-time-use item.

4. The joint and seals are an important part of the assembled rocket motor case. The assembled RSRM is a combustion chamber made up of segments and the nozzle. It is sealed with O-rings, and must contain and direct pressure generated by burning propellant.

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

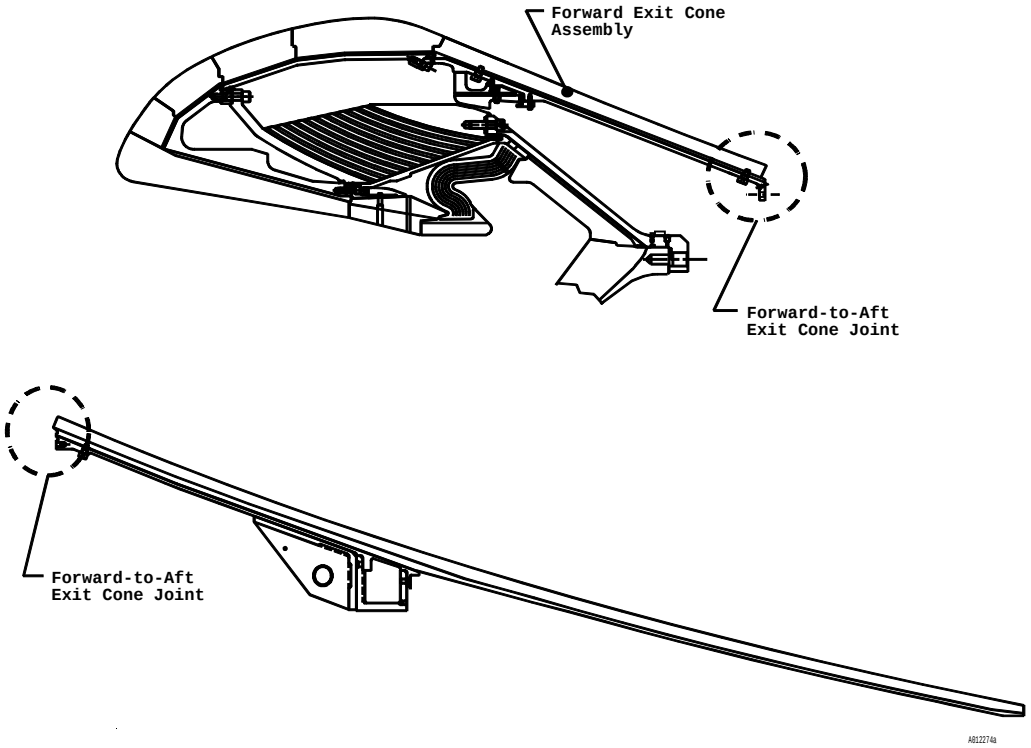

Figure 1. Forward-to-Aft Exit Cone Joint Location

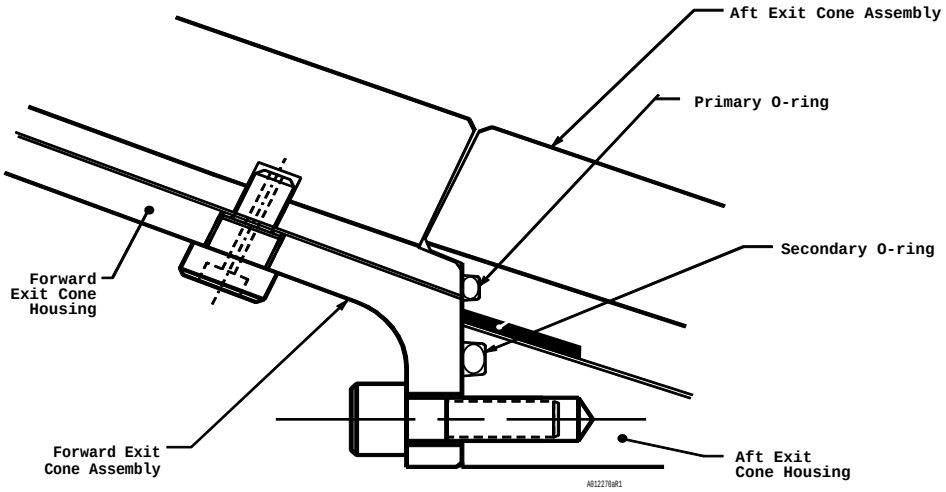

Figure 2. Forward-to-Aft Exit Cone Joint, Primary and Secondary O-Ring

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN		FAILURE CAUSES
A	1.	Large O-rings are per engineering that covers process controls for fabrication of spliced joints and repairs.
A	2.	Splice joints are cut on an angle and bonded together in a mold (using 100 percent of the scarf area) using an adhesive with the same physical and chemical properties as the parent stock.
A,D	3.	O-rings were tested to determine size and types of flaws that could cause sealing problems per TWR-17750 and TWR-17991.
B	4.	Criteria determining O-ring dimensions are per TWR-15771.
B,H	5.	O-ring design provides constant contact between the O-ring and mating nozzle sealing surfaces.
B,D	6.	Large O-rings are per engineering that establishes geometric dimensions and fabrication details.
C,H	7.	Large O-rings are individually packaged as follows: a. Per engineering drawings prior to lubrication. b. Per engineering drawings after lubrication.
C,H	8.	Large O-ring design allows for a minimum of stretching during installation without damage to the O-ring per engineering.
H	9.	To assure the correct O-ring is installed in its designated location, large O-rings are unpackaged and installed one at a time.
C	10.	Material selection for O-rings was based in part on resistance to damage per TWR-17082.
C,H	11.	Design development testing of O-ring twisting and its effect on performance is per ETP-0153 and TWR-17991.
E	12.	Fluorocarbon rubber O-rings are suitable for periods of storage up to 20 years (O-ring Handbook, ORD 5700, Copyright 1982, by Parker Seal Group, Lexington, KY). Environment and age is significant to useful seal life, both in storage and actual service as follows: a. O-rings are packaged and stored to preclude deterioration caused by ozone, grease, ultraviolet light, and excessive temperature.
E	13.	Large O-ring time duration of supplier storage and total shelf life prior to installation is per engineering.
E	14.	Aging studies of O-rings after 5 years installation life were performed. Test results are applicable to all RSRM fluorocarbon seals. Fluorocarbon maintained its tracking ability and resiliency. Fluorocarbon was certified to maintain its sealing capability over 5 years per TWR-65546.
E	15.	O-rings are one-time-use items.

E 16. Grease is stored at warehouse-ambient condition that is any condition of temperature and relative humidity experienced by the material when stored in an enclosed warehouse, in unopened containers, or containers that were resealed after each use. Storage under these conditions is per engineering.

E 17. Aging studies to demonstrate characteristics of grease after 5 years installation life were performed on TEM-9. Results showed that grease provided adequate corrosion protection for D6AC steel, and that all chemical properties of grease remained intact per TWR-61408 and TWR-64397.

E 18. For lubricated O-rings the time duration of storage after lubrication is per engineering drawings.

E 19. Large O-rings and filtered grease are included in the nozzle life verification.

F 20. Large O-rings are black fluorocarbon rubber.

F 21. O-ring swell is negligible unless the O-ring undergoes a long period of water immersion (O-ring Handbook, ORD 5700, Copyright 1982, by Parker Seal Group, Lexington, KY).

F 22. Fluorocarbon rubber is a non-nutrient to fungus growth (O-ring Handbook, ORD 5700, Copyright 1982, by Parker Seal Group, Lexington, KY).

F 23. Large O-rings are kept dry and clean prior to packaging.

G 24. Primary and secondary O-ring gland design is per engineering drawings and conforms to dimensions determined by Thiokol Design Engineering calculations for squeeze, fill, and tracking per TWR-15771.

G 25. Results of qualification tests and analysis for O-ring sealing in phenolics are per TWR-16357.

G 26. Sealing surface requirements during refurbishment are per engineering drawings and specifications.

I 27. Transportation and handling of the nozzle assembly by Thiokol is per IHM 29.

I 28. The RSRM and its component parts, when protected per TWR-10299 and TWR-11325, are capable of being handled and transported by rail or other suitable means to and from fabrication, test, operational launch, recovery and retrieval, and refurbishment sites.

I 29. 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.

I 30. Support equipment used to test, handle, transport, and assemble or disassemble the RSRM is certified and verified per TWR-15723.

I 31. Analysis is conducted by Thiokol engineering to assess vibration and shock load response of the RSRM nozzle during transportation and handling to assembly and launch sites per TWR-16975.

I 32. 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.

I 33. Repairs to damaged phenolic sealing surfaces are performed using standard shop practice at Thiokol and KSC per shop planning.

J 34. Filtered grease is applied to nozzle sealing surfaces per engineering drawings during final assembly processes.

J 35. Filtered grease filtering is per engineering to control contamination.

J 36. Removal of surface contamination or corrosion is a standard shop practice used whenever contamination or corrosion is noted on metal components.

K 37. Large O-rings are high-temperature, low-compression set, fluid-resistant, black fluorocarbon rubber.

K 38. Filtered grease is per engineering drawings and conforms to material requirements determined by Thiokol engineering.

K 39. Temperature prior to launch is monitored for the nozzle flexible bearing and case-to-nozzle joint and is maintained per TWR-15832. The aft exit cone-to-nozzle joint is within the temperature maintained area and benefits from temperature conditioning. Joint thermal analysis (O-ring resiliency testing) is per ETP-0276 and TWR-18597.

B,G,I 40. 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 B,G,I 41. 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 the forward exit cone assembly and the aft exit cone assembly 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 Large O-ring verify:	
A		a.	Diameter	AEB026,AEB027
A		b.	Splice is bonded over 100 percent of the scarf area	AEB133,AEB134
A		c.	No more than five splices	AEB167,AEB169
A		d.	Repairs	AEB265,AEB266
A		e.	Adhesive is made from fluorocarbon rubber	AEB308,AEB311
A		f.	Splice bond integrity	AEB317,AEB319
A,D	(T)	g.	Subsurface indications	AEB354
A,C,D,F		h.	Surface quality	AEB388,AEB389
A,K	(T)	i.	Tensile strength	AEB401,AEB402
A,K	(T)	j.	Ultimate elongation	AEB442,AEB443
B		k.	Correct identification	AEB100,AEB087
B		l.	Diameter	AEB018,AEB014,AEB015,AEB023
C,E,F		m.	Packaging is free of staples or other objects	LAA054
E,F		n.	Packaging for damage or violation	AEB179
E,F,K		o.	Material is fluorocarbon rubber	AEB141,AEB151
F		p.	Clean and dry when packaged	AEB031,AEB034
K	(T)	q.	Tensile strength	AEB394,AEB396
K	(T)	r.	Ultimate elongation	AGM408,AGW075
K	(T)	s.	Shore A hardness	AGM304,AGM312
K	(T)	t.	Compression set	AKW006,AKW011
		2.	For New O-ring, Lubricated verify:	
C		a.	O-ring packaging was not damaged or violated	LAA103
H		b.	O-ring is cleaned and lubricated per drawing requirements	LAA104
C,H		c.	O-ring is packaged per drawing requirements	LAA105
		3.	For New Exit Cone Assembly, Forward Section verify:	
C,G		a.	Insulation-to-housing bondline is flush with adjacent surfaces	NCC005
C,G		b.	No unacceptable defects or sharp edges of adhesive bondline, aft end	NCC007
G		c.	O-ring sealing surfaces	ADI159
G		d.	No unacceptable defects and surface finish of phenolic sealing surface of aft end	NCC006
		4.	For New Filtered Grease verify:	
E,F,J,K		a.	Grease is received from storage unopened or resealed	ACP015
E,F,J,K		b.	Shelf life of the grease, prior to filtering	AMB018L
E,F,J,K	(T)	c.	Contamination	ANO064
E,F,J,K		d.	Grease conforms to specification	LAA044
E,F,J,K		e.	Cartridge conforms to drawing	LAA046
E,F,J,K		f.	Filtered grease is capped and sealed after filling	LAA047
E,F,J,K		g.	Filtered grease is sent to storage capped and sealed (recapped and resealed)	LAA063
		5.	For New Grease verify:	
E,F,J		a.	Material received in closed containers	ANO015
E,F,K		b.	Type	ANO050
E		c.	No shipping or handling damage	ANO058

K	(T)	d.	Penetration	LAA037
K	(T)	e.	Dropping point	ANO042
K	(T)	f.	Zinc concentration	LAA038

6. For New Housing, Exit Cone, Nozzle verify:

G		a.	Surface finish	ADG140,ADG139

7. For Refurbished Housing, Exit Cone, Nozzle verify:

G		a.	Surface finish	ADG000

8. For New Aft Exit Cone, Shell, verify:

G		a.	Forward end secondary O-ring groove diametric location	ADK058
G		b.	Forward end secondary O-ring groove depth	ADK092
G		c.	Forward end secondary O-ring groove width	ADK093
G		d.	Forward end secondary O-ring groove surface finish value	ADK184,ADK186

9. For Refurbished Aft Exit Cone, Shell, verify:

G		a.	Surface finish on repaired sealing surfaces	ADK178

10. For New Exit Cone, Subassembly-Nozzle, Aft verify:

G		a.	O-ring groove depth	AGL083
G		b.	O-ring groove surface finish	AGL183
G		c.	O-ring groove width	AGL086
G		d.	O-ring groove diametric location	AGL064

12. KSC verifies:

A,B,C,D, G,H,I,J	(T)	a.	Leak test is performed prior to sealant backfill and the results are acceptable per OMRSD File V, Vol I, B47NZ0.110	OMD056
C,E,F,J		b.	No damage to shipping box, shipping bag, and O-ring prior to installation per OMRSD File V, Vol I, B47NZ0.052	OMD050
H,J		c.	Application of filtered grease on forward and aft exit cone sealing surfaces prior to installation of O-rings per OMRSD File V, Vol I, B47NZ0.120	OMD057
H		d.	Application of filtered grease to nozzle field joint O-rings per OMRSD File V, Vol I, B47NZ0.130	OMD058
C,H		e.	Correct parallel alignment of the nozzle field joint mating surfaces during the mating operation per OMRSD File V, Vol I, B47NZ0.060	OMD051
E		f.	Expiration date is not exceeded for materials installed at KSC per OMRSD File V, Vol I, B47GEN.160	OMD042
F,G,I,J		g.	Aft exit cone mating surfaces for damage or contamination prior to application of primer and again just prior to assembly (including black light inspection for contamination) per OMRSD File V, Vol I, B47NZ0.032	OMD048
G,I,J		h.	Forward exit cone mating surfaces prior to assembly to ensure absence of damage or contamination per OMRSD File V, Vol I, B47SG0.072	OMD080