ATK ALLIANT TECHSYSTEMS
THIOKOL PROPULSION

CRITICAL ITEMS LIST (CIL)

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

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Assembly Hardware/Interfaces 10-05	PART NAME:	Forward-to-Aft Exit Cone Joint, Metal Components (1)
ASSEMBLY:	Fwd-to-Aft Exit Cone Interface 10-05-04		
FMEA ITEM NO.:	10-05-04-01R Rev N	PART NO.:	(See Section 6.0)
CIL REV NO.:	N (DCN-533)	PHASE(S):	Boost (BT)
DATE:	10 Apr 2002	QUANTITY:	(See Section 6.0)
SUPERSEDES PAGE:	357-1ff.	EFFECTIVITY:	(See Table 101-6)
DATED:	27 Jul 2001	HAZARD REF.:	BN-02
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 Structural failure of metal components

3.0 FAILURE EFFECTS: Seal leakage, joint deformation, and loss of Aft Exit Cone causing thrust imbalance between SRBs. Loss of RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Nonconforming dimensions	
1.1.1	Initial manufacturing dimensions	A
1.1.2	Metal dimensions reduced by corrosion and/or refurbishment	B
1.2	Nonconforming materials	
1.2.1	Improper heat treatment	C
1.2.2	Hydrogen embrittlement of bolts	D
1.2.3	Nonconforming voids, inclusions, or other material defects	E
1.3	Improperly-installed bolts	F
1.4	Transportation, handling, or assembly damage	G
1.5	Fatigue	H
1.6	Improper assembly techniques	I
1.7	Stress-corrosion cracking	J

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

1. Aft Exit Cone-to-Forward Exit Cone Joint, Metal Components are part of the Aft Booster Build-up (Figures 1 and 2). Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U77647	Aft Booster Build-up--KSC			1/motor
1U52842	Shell, Exit Cone, Aft	7075-T73 or 7075-T7351		1/motor
1U52837	Housing, Exit Cone	D6AC Steel	STW4-2709 MS33649	1/motor
1U78784	Forging, Forward Exit Cone	D6AC Steel	STW4-2709 MS33649	1/motor
1U75756	Screw	Alloy Steel	FF-S-86 STW3-1553 NAS1351 NAS1352 QQ-P-416	A/R
1U79149	Nose-Throat-Bearing Cowl Housing Assembly, Nozzle			A/R
1U79157	Exit Cone Assembly- Nozzle, Aft			1/motor
1U52834	Ring, Bearing	D6AC Steel	STW4-2709	1/motor
	Helical Insert	CRES	MS124700 NASM124700 TT-P-1757 AS-7245	A/R
	Helical Insert	CRES	MS124696 NASM124696 TT-P-1757 AS-7245	A/R
	Helical Insert	CRES	MS21209 NASM21209 MIL-I-8846 TT-P-1757	A/R
	Helical Insert	CRES	MS124702 NASM124702 TT-P-1757 AS-7245	A/R
	Helical Insert	CRES	MS122087 NASM122087 TT-P-1757 AS-7245	A/R
	Corrosion-Preventive Compound and O-Ring Lubricant	Heavy Duty Calcium Grease	STW5-2942	A/R
	Primer	Zinc Chromate, Low Moisture Sensitivity	TT-P-1757	A/R
1U79152	Exit Cone Assembly, Forward Section			1/motor

6.1 CHARACTERISTICS:

1. The exit cone assembly consists of two parts--the Forward Exit Cone Assembly and Aft Exit Cone Assembly. These two parts are connected together with screws and threaded helical inserts. Threaded helical inserts are installed with a coat of primer to prevent corrosion. The joint is sealed with two O-ring seals. The sealed joint is provided with a leak check port that is closed after test with a plug (Figures 1 and 2).

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

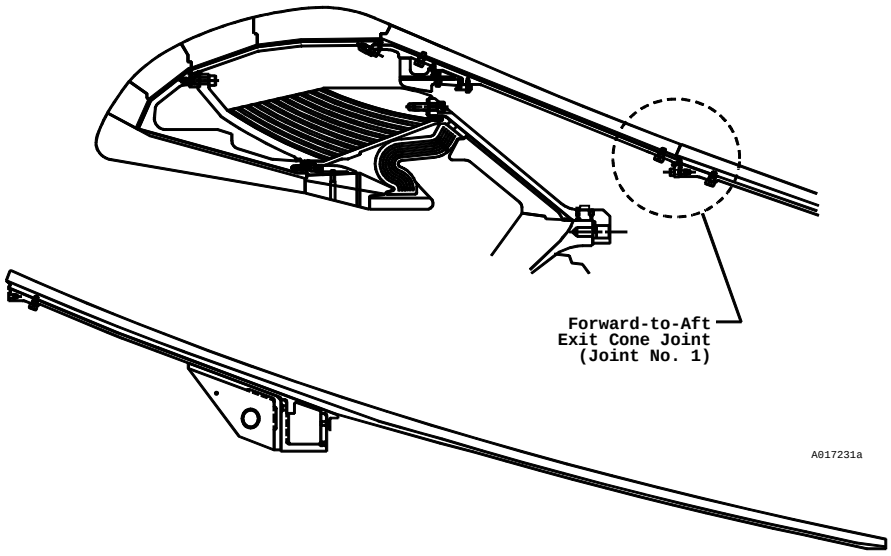

Figure 1. Forward-to-Aft Exit Cone Joint, Metal Components Location

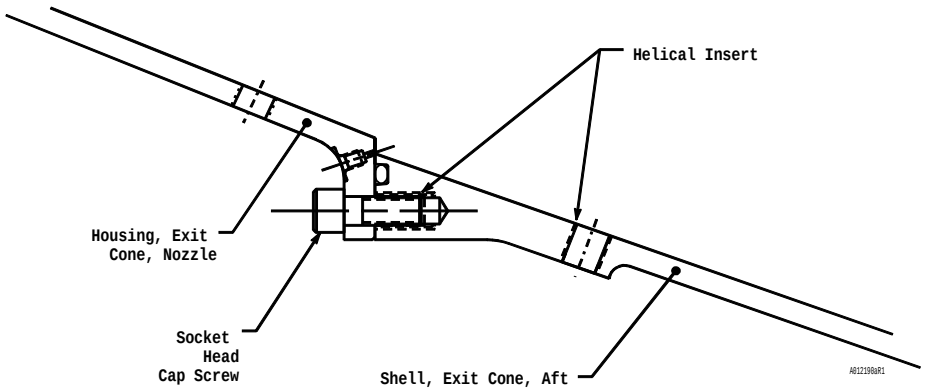

Figure 2. Forward-to-Aft Exit Cone Joint, Metal Components

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN	FAILURE CAUSES	
A	1.	Aft Exit Cone housing dimensions are per engineering drawings.
B	2.	Refurbished Aft Exit Cone housing dimensions are per engineering drawings and specifications.
A	3.	Forward Exit Cone housing dimensions are per engineering drawings.
B	4.	Refurbished Forward Exit Cone housing dimensions are per engineering drawings and specifications.
A,B	5.	Filtered grease is applied to all joint and bare metal surfaces of the Forward Exit Cone housing and Aft Exit Cone at assembly to prevent corrosion.
A	6.	Hardware attachment Screw dimensions are per engineering. Attachment Screws are not reused.
A,B	7.	Threaded inserts are installed with a coat of primer per Federal Specifications to prevent corrosion.
A	8.	Helical insert dimensions are per engineering drawings. Helical inserts are not reused.
A,B,F,J	9.	A light coating of filtered grease is applied to bare metal components prior to installation per engineering.
A,B,C,D,E	10.	Structural analyses per TWR-16975 show that metal components of the joint have a positive margin of safety based on factors of safety of 1.4 on ultimate and 1.1 on yield.
A	11.	Assembly stresses are minimized as follows: a. Mating surface flatness is per inspection of machining operations b Threads are cleaned and lubricated prior to assembly c. Assembly bolts are torqued in a prearranged sequence to preload values
A,B,F,J	12.	Effects of galvanic corrosion due to dissimilar metal interaction are controlled per engineering. A Material Use Agreement is provided per SRM-MUA-005.
D,E,H	13.	Screws are cadmium plated alloy steel, baked to prevent hydrogen embrittlement. Screws are not reused.
D,E,H	14.	Helical inserts are per material specifications. The material is Corrosion Resistant Steel per Aerospace Material Specifications for helical coil insets.
C,D,E,H	15.	Reuse criteria for the aft and forward exit cone is per engineering.
C,D,E,H	16.	As part of the post-flight inspection plan, char and erosion of the nozzle insulation is inspected and analyzed. If char and erosion of the insulation is determined to be such that the supporting aluminum housing was exposed to high temperature, the suspect housing is tested using an electrical conductivity test method. For Qualification and Production Verification Motors, char and eroding data are recorded per TWR-16473. For flight motors, data is recorded per TWR-16899,

TWR-50051, and the Clearfield Post-flight Engineering Evaluation Plan.

F,J 17. Assembly procedures for the aft exit cone to forward exit cone joint are per engineering drawings.

F,J 18. Socket head capscrews joining the aft exit cone to the forward exit cone are tightened and torqued per engineering.

F,J 19. Bolt preload and sequencing is per TWR-15995.

F,J 20. Screws are self-locking per engineering.

G 21. Transportation and handling of the nozzle assembly aft case segment, and Aft Exit Cone by Thiokol are per Thiokol IHM 29.

G 22. Requirements for handling RSRM components during assembly, storage, and transportation are similar to those for previous and other current programs at Thiokol. Those requirements dictate RSRM case segments must be handled by or near a joint to avoid damage per TWR-13880. All lifting hooks and slings are fitted with safety hooks and certified and verified per TWR-15723.

G 23. Instrumentation for monitoring temperature is provided by a multi-day recording clock for recording in-transit environments. Humidity control is per NASA Report TMX-64757.

G 24. 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.

G 25. Transportation and handling of the Nozzle Assembly, Aft Case Segment, and Aft Exit Cone at KSC is per TWR-13880.

G 26. 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.

G 27. The exit cone and exit cone fragment shipping kit is designed for transportation of the exit cone to the launch facility and return of the recovered exit cone fragment to Thiokol per TWA-1123. The shipping kit provides an enclosed container to protect the Aft Exit Cone from external environments.

J 28. The possibility of stress corrosion to the following parts during their service life was considered as follows:

C,D,E,H,J a. Basic Forward and Aft Exit Cone forgings were analyzed per JSC Specification SE-R-0006 and reported in TWR-10713. This report shows the forging to be free of re-entrant or sharply folded lines and that the principal grain flow is oriented parallel to principal stresses.

J b. The heat treat specification prescribes a testing procedure to assure resistance to stress corrosion cracking for heat treated aluminum alloy.

J c. The screw is National Aerospace Standard (NAS) alloy steel which has high resistance to stress corrosion per MSFC Specifications.

C,H,J d. Material is aluminum alloy and composition and heat treatment are determined. This material is resistant to stress-corrosion cracking per MSFC-

Standards.

C,H,J e. D6AC steel has low-to-moderate resistance to stress corrosion per MSFC-Standards and Material Use Agreement.

A,B,G,H,I 29. 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 A,B,G,H,I 30. 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.

H,J 31. The forward exit cone housing is a fracture control item per TWR-16875. TWR-16875 documents that the forward exit cone housing passes the safe life requirements. Structural verification analysis per TWR-16975 shows the maximum stress obtained during operation will have a positive margin of safety using the factor of safety of 1.4 ultimate and 1.1 on yield.

H,J 32. The aft exit cone housing is a fracture control item per TWR-16875. TWR-16875 documents that the aft exit cone housing passes the safe life requirements. Structural verification analysis per TWR-16975 shows the maximum stress obtained during operation will have a positive margin of safety using the factor of safety of 1.4 ultimate and 1.1 on yield.

9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TEST (T)			CIL CODE
	1.		For New Aft Exit Cone, Shell verify:	
A		a.	.70 cross-sectional dimension (forward end)	ADK000,ADK001
A		b.	Thickness of aft compliance ring flange	ADK007,ADK008
A		c.	Countersink .957 diameter X 81 degrees (20 holes marked A)	ADK012A,ADK013A
A		d.	Countersink .957 diameter X 81 degrees (72 holes)	ADK012D,ADK013D
A		e.	Countersink .957 diameter X 81 degrees (12 holes, 2 places)	ADK012H,ADK013H
A		f.	Chemical conversion coating on designated surfaces	ADK028
A		g.	Depth of alignment hole (forward end)	ADK037,ADK038
A		h.	Depth of alignment hole (aft end)	ADK037A,ADK038A
A		i.	Diameter of alignment hole (forward end)	ADK039,ADK040
A		j.	Diameter of alignment hole (aft end)	ADK039A,ADK040A
A		k.	Diameter 116.530	ADK042,ADK043
A		l.	.530-.539 diameter mounting holes (20 holes marked A)	ADK044,ADK045
A		m.	.530-.539 diameter mounting holes (72 places)	ADK044A,ADK045A
A		n.	.530-.539 diameter mounting holes (12 holes, 2 places)	ADK044B,ADK045B
A		o.	Diameter of datum G	ADK048,ADK049
A		p.	Diameter of datum B	ADK053,ADK054
A		q.	Diameter of datum H	ADK056,ADK057
A		r.	Thickness of forward compliance ring flange	ADK089,ADK090
A		s.	Overall length	ADK121,ADK122
A		t.	Correct paint application	ADK124
A		u.	Length between datum A and C	ADK133,ADK134
A		v.	Length between datum C and F	ADK136,ADK137
A		w.	Point C to D profile	ADK141,ADK142
A		x.	Correct primer application	ADK145
A		y.	Run out diameter B to datum C and H	ADK157,ADK158
A		z.	Run out of datum A to datum C and B	ADK171,ADK172
A		aa.	Run out of datum F to datum C and B	ADK176,ADK177
A		ab.	Forward end secondary O-ring groove surface finish value	ADK184,ADK186
A		ac.	Flatness of datum C	ADK191,ADK192
A		ad.	Threads per MS33537 (192 holes)	ADK207,ADK208
A		ae.	Threads per MS33537 (72 holes)	ADK207A,ADK208A
A		af.	Threads per MS33537 (96 holes)	ADK207B,ADK208B
A		ag.	Threads per MS33537 (16 holes marked B)	ADK207C,ADK208C
A		ah.	Threads per MS33537 (4 holes, 2 places)	ADK207D,ADK208D
A		ai.	Threads per MS33537 (60 holes)	ADK207E,ADK208E
A		aj.	True position to Datums C, H and D is within .010 diameter (4 holes, 2 places)	ADK210,ADK211
A		ak.	True position to datums C, H and D is within .010 diameter (4 holes, 4 places)	ADK210A,ADK211A
A		al.	True position to datums A and B is within .010 diameter (96 holes)	ADK210B,ADK211B
A		am.	True position to datums C, H and D is within .010 diameter (72 holes)	ADK210C,ADK211C
A		an.	True position to datums E, G and D is within .030 diameter	ADK210D,ADK211D
A		ao.	True position is within .060 diameter (60 holes)	ADK210E,ADK211E
A		ap.	True position to datums E, H and D is within .010 (72 holes)	ADK212A,ADK213A
A		aq.	True position to datums J, C and D is within .010 diameter	ADK212B,ADK213B
A		ar.	True position to datums F, H and D is within .010 diameter (10 holes, 2 places)	ADK213,ADK212

A		as.	Point E to A profile	BHU109,BHU107
A		at.	Point A to B profile	BHU110,BHU108
C,D,E,H	(T)	au.	Chemical composition of aluminum forging material	ADK023
D,E,H,J		av.	Dye penetrant (after machining)	ADK063
C,D,E,H,J		aw.	Heat treat condition of aluminum forging material	ADK101
C,D, E,H,J	(T)	ax.	Test results for stress-corrosion resistance of aluminum forging material	ADK182
C,D,E,H	(T)	ay.	Tensile strength	ADK202
C,D,E,H	(T)	az.	Yield strength	ADK202A
C,D,E,H	(T)	ba.	Elongation	ADK202B
D,E,H	(T)	bb.	Ultrasonic test prior to machining	ADK214

2. For Refurbished Aft Exit Cone, Shell verify:

B	a.	116.530 dimension B diameter	ADK002
B	b.	0.290 wall thickness	ADK006
B	c.	Threaded holes	ADK017
B	d.	Non-threaded hole diameter	ADK020
B	e.	Surface defects	ADK031
B	f.	0.70 wall thickness	ADK035
B	g.	0.385 wall thickness	ADK036
B	h.	119.820 dimension diameter	ADK055
B	i.	43.315 dimension overall height	ADK120
B	j.	36.565 dimension flange-to-flange height	ADK126
B	k.	5.275 dimension flange-to-flange height	ADK129
B	l.	A-to-B dimension straightness	ADK139
B	m.	B-to-C dimension straightness	ADK140
B	n.	93.00 dimension roundness	ADK151
B	o.	119.820 dimension roundness	ADK154
B	p.	Surface finish on repaired sealing surfaces	ADK178
B	q.	0.405 wall thickness	ADK179
B,J	r.	Surface A dimension flatness	ADK187
B,J	s.	Surface C dimension flatness	ADK188
B,J	t.	Surface F dimension flatness	ADK194
B	u.	Tapped threads are cleaned	ADK198
B	v.	Proper installation of helicoil coils	ADK209
C,D,E,H	w.	Painted surfaces for indications of heat degradation	ADK117
D,E,H	x.	Dye penetrant	ADK215

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

A	a.	Conformance of leak check port to specification	ADG024,ADG025
A	b.	Flatness	ADG029,ADG030
A	c.	Diameter	ADG036,ADG037,ADG038,ADG038B,ADG038C, ADG038D,ADG039,ADG039B,ADG039C, ADG039D,ADG118,ADG119,ADG121,ADG122
A	d.	Threads	ADG038A,ADG038E,ADG039A,ADG039E
A	e.	Corrosion protection is per specification	ADG058
A	f.	Run out	ADG115,ADG116,ADG131,ADG132,ADG133,ADG134
A	g.	True position	ADG151,ADG151B,ADG152,ADG152B
A	h.	Wall thickness	ADG165,ADG166
C,D,E,H	(T)	i.	Carburization	ADG014
C,D,E,H	(T)	j.	Decarburization	ADG031
C,D,E,H		k.	Heat treat	ADG066
C,D,E,H	(T)	l.	Elongation	ADG145B
C,D,E,H	(T)	m.	Reduction in area	ADG145C
C,D,E,H	(T)	n.	Ultimate strength	ADG145D

C,D,E,H	(T)	o.	Yield strength	ADG145E
		4.	For Refurbished Housing, Exit Cone, Nozzle verify:	
B		a.	Surface defects	ADG026
B		b.	Threaded holes	ADG144
B,J		c.	Flatness	ADG142
B		d.	Roundness	ADG128,ADG108,ADG113,ADG117
B		e.	Wall thickness	ADG005
B		f.	Flange-to-flange height	ADG049
B		g.	Diameter	ADG112
C,D,E,H		h.	Painted surfaces for indications of heat degradation	ADG100
D,E,H,J	(T)	i.	Magnetic particle	ADG076
		5.	For New Screw, verify:	
A		a.	Length from bottom of screw head to end of screw	AFZ024
A		b.	Thread form diameter (major diameter, pitch)	AFZ041
C,D,E,H		c.	Baking	AFZ004
D,E,H		d.	Parts are cadmium plated	AFZ013
C,D,E,H	(T)	e.	Stress durability	AFZ070
		6.	For New Insert, Helical Coil, verify:	
A,B,C,D,E,H		a.	Material is corrosion-resistant steel	RHB001
		7.	For New Exit Cone Assembly--Nozzle, Aft verify:	
G		a.	Handling of aft exit cone	AGK011
G		b.	Parts with defects from shipping/handling damage are finalized	BHL012
		8.	For New Exit Cone Assembly, Forward Section verify:	
G		a.	Shipping/handling damage	NCC002
		9.	For New Forging, Forward Exit Cone, Nozzle QA verifies:	
C,D,E,H	(T)	a.	Chemical composition	ADG021
C,D,E,H	(T)	b.	Inclusion rating	ADG070
C,D,E,H		c.	Grain size	ADG095
C,D,E,H		d.	Macro structure	ADG095B
D,E,H	(T)	e.	Ultrasonic	ADG158,ADG159
		10.	KSC verifies:	
A,B,F,J		a.	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
A,B,G		b.	Aft exit cone mating surfaces for damage or contamination prior to application of primer and again just prior to assembly (including blacklight inspection for contamination) per OMRSD File V, Vol I, B47NZ0.032	OMD048
F,J		c.	Nozzle bolt torque requirements per OMRSD File V, Vol I, B47GEN.130	OMD038
G		d.	Forward exit cone mating surfaces prior to assembly to ensure absence of damage or contamination per OMRSD File V, Vol I, B47SG0.072	OMD080