ATK ALLIANT TECHSYSTEMS
THIOKOL PROPULSION

CRITICAL ITEMS LIST (CIL)

No. 10-02-01-04R/02

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM	Nozzle Subsystem 10-02	PART NAME:	Forward Exit Cone
ASSEMBLY:	Nozzle and Aft Exit Cone 10-02-01		Assembly (1)
FMEA ITEM NO.:	10-02-01-04R 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:	313-1ff.	EFFECTIVITY:	(See Table 101-6)
DATED:	27 Jul 2001	HAZARD REF.:	BN-04
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: 2.0 Structural failure of the metal housing

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

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
2.1	Nonconforming dimensions	
2.1.1	Initial manufacturing dimensions	A
2.1.2	Metal dimensions reduced by corrosion and/or refurbishment	B
2.2	Nonconforming material	
2.2.1	Improper heat treatment	C
2.2.2	Nonconforming voids, inclusions, or other material defects	D
2.3	Fatigue	E
2.4	Stress-corrosion cracking	F
2.5	Transportation, handling, and assembly damage	G

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

1. Forward Exit Cone Housing is a part of the Nozzle Assembly, Final (Figure 1 and 2). Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U79152	Exit Cone Assembly, Forward Section			1/motor
	Paint	Epoxy and a Polyamide Resin Activator	STW5-3225	A/R
	Primer	Pigmented Epoxy Resin Base and a Polyamide Resin Activator	STW5-3226	A/R
	Sealant, Polysulfide	Synthetic Rubber, Polysulfide	STW5-9072	A/R
1U77640	Segment, Rocket Motor, Aft			1/motor
1U52837	Housing, Exit Cone, Nozzle	D6AC Steel (may be made from 1U50082)	STW4-2709	1/motor

6.1 CHARACTERISTICS:

1. The forward exit cone housing is the first component of the exit cone assembly. It is attached at its forward end to the throat housing assembly and provides the attachment for the aft exit cone assembly. Additionally, the bearing snubber is attached to it. The forward exit cone assembly is forged from D6AC steel.

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

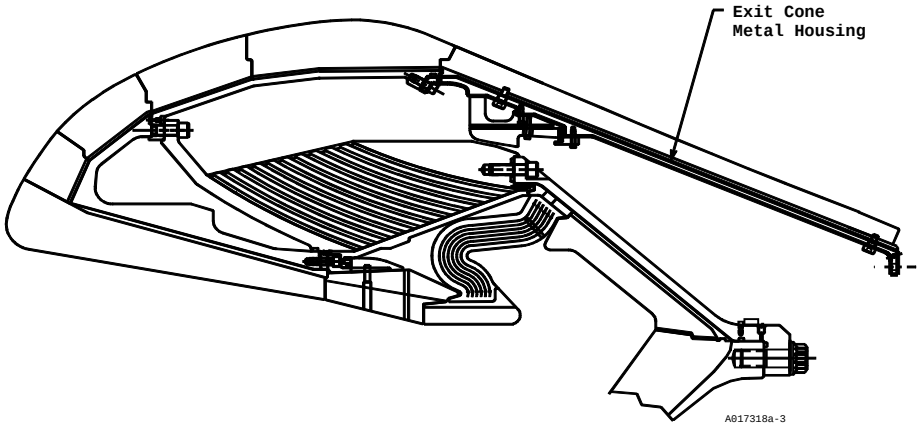

Figure 1. Nozzle Exit Cone Metal Housing Location

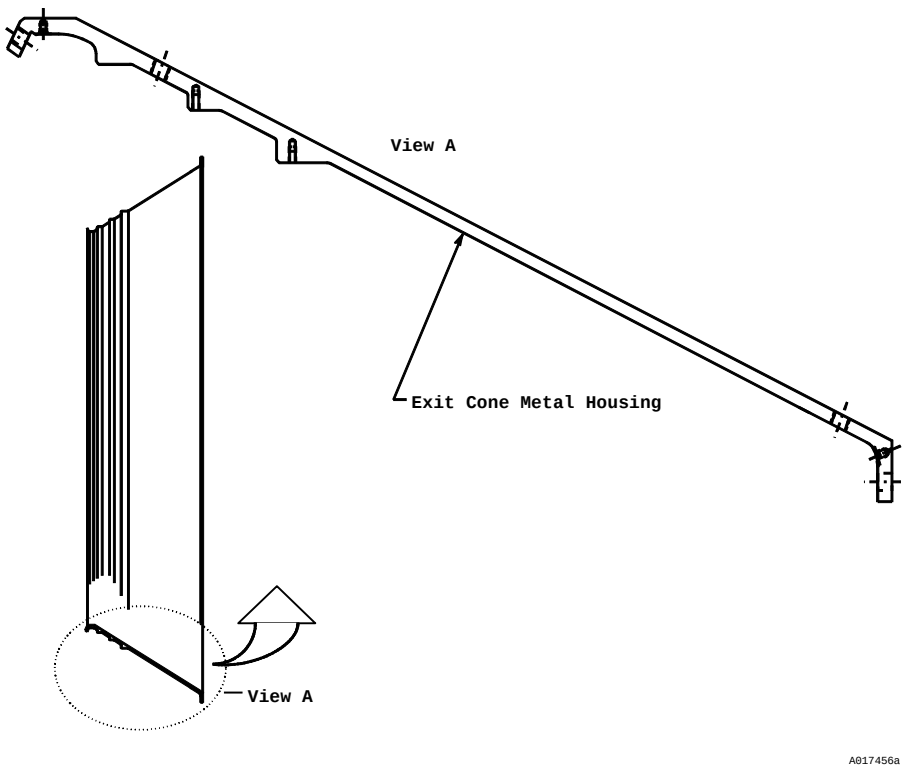

Figure 2. Nozzle Exit Cone Metal Housing

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN	FAILURE CAUSES	
A	1.	New forward exit cone dimensions are per engineering drawings.
B	2.	Refurbished forward exit cone dimensions are per engineering.
A,B,C,D,E,F	3.	Structural analyses per TWR-16975 verify that the forward exit cone housing has a positive margin of safety based on factors of safety of 1.4 on ultimate and 1.1 on yield.
B,F	4.	The supplier provides corrosion protection for new housings per engineering drawings. Thiokol provides corrosion protection for refurbished housings per engineering.
B	5.	Contamination control requirements and procedures are per TWR-16564.
B	6.	To prevent corrosion, the outer surface of the forward exit cone is coated with primer and paint.
A,B	7.	Assembly stresses are minimized as follows:
		a. Mating surface flatness is controlled by 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
C,D,E	8.	The first production forging of the forward exit cone housing was analyzed per JSC specifications and TWR-10707. The report concluded that the forging met all micro cleanliness and microstructure requirements of D6AC steel specifications, mechanical properties met or exceeded all requirements of the heat treatment specification, and the forging process produced a part free from re-entrant or sharply folded flow lines that could effect the integrity of the forged component.
D	9.	Unacceptable cracks, voids, inclusions, and other material defects for new forward exit cone housings are controlled per engineering drawings and specifications.
D	10.	Unacceptable cracks and other material surface defects for refurbished forward exit cone housings are controlled per engineering.
C,D	11.	Design verification analysis shows that the materials and geometry of the forward exit cone housing are acceptable for flight per TWR-18764-09.
	12.	The forward exit cone housing is a D6AC steel forging with requirements for:
C,E,F		a. Ultimate strength
C,E,F		b. Yield strength at 0.2 percent offset
E	13.	Material type and composition of steel are carefully controlled by the supplier per engineering. Heat treatment, controlled by heat treatment specifications, includes frequent logging of critical points and conditions.
F	14.	The forward exit cone housing has low-to-moderate resistance-to-stress corrosion as rated in MSFC specifications and, therefore, requires a Material Use Agreement.
E,F	15.	A fracture mechanics analysis of the forward exit cone housing per TWR-16875

addresses the effects of sustained and cyclic stresses in the housing. The analysis verified that there is no potential crack propagation problem in the housing and that the housing complies with the requirement of ensuring a potential service life greater than four times the basic 20 use service life.

E,F 16. Basic forging principal grain flow is oriented parallel with the principal stresses expected per engineering.

G 17. 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.

G 18. Handling and lifting requirements for RSRM components are similar to those for previous and current programs conducted by Thiokol per TWR-13880.

G 19. Transportation and handling of nozzle forward exit cone assembly items by Thiokol is per Thiokol IHM 29.

G 20. The forward exit cone assembly is covered with a protective cover and stored in a temperature controlled building until used as a part of a larger assembly.

G 21. 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 or retrieval, and refurbishment sites.

G 22. 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 23. Support equipment used to test, handle, transport, and assemble or disassemble the RSRM is certified and verified per TWR-15723.

G 24. 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 25. A protective plug is installed per shop planning in the leak check port of the throat support housing to protect the port from damage during handling and installation.

E,F,G 26. 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,F,G 27. 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 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.

E,F

28. 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.

9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TESTS (T)			CIL CODE
		1.	For New Housing, Exit Cone, Nozzle verify:	
A,B		a.	Corrosion protection is per specification	ADG009
A,B		b.	Flatness	ADG030
A,B		c.	Threads	ADG039A,ADG039E
A,B		d.	Diameter	ADG039B,ADG039C,ADG039D,ADG043
A,B		e.	Flange thickness	ADG048,ADG048A
A,B		f.	Profile	ADG104,ADG107
A,B		g.	Run out	ADG132,ADG134
A,B		h.	True position	ADG152,ADG152A,ADG152B,ADG152C
A,B		i.	VIP complete and acceptable	ADG161
A,B		j.	Wall thickness	ADG166
C,D,F	(T)	k.	Carburization	ADG014
C,D,F	(T)	l.	Decarburization	ADG031
C,D,F		m.	Heat treat	ADG066
C,D,F	(T)	n.	Magnetic particle	ADG078
C,D,F	(T)	o.	Elongation	ADG145B
C,D,F	(T)	p.	Reduction in area	ADG145C
C,D,F	(T)	q.	Ultimate strength	ADG145D
C,D,F	(T)	r.	Yield strength	ADG145E
		2.	For Refurbished Housing, Exit Cone, Nozzle verify:	
A,B		a.	Bolt holes deformation and defects	ADG012
A,B		b.	Surface defects	ADG026
A,B		c.	Diameter	ADG035,ADG040
A,B		d.	Flange-to-flange height	ADG049
A,B		e.	Deformed parts	ADG052
A,B		f.	Straightness	ADG053
A,B		g.	Roundness	ADG108,ADG113,ADG127,ADG128
C,D,F	(T)	h.	Magnetic particle	ADG076
C,D,F		i.	Painted surfaces for indications of heat degradation	ADG100
		3.	For New Exit Cone Assembly, Forward Section verify:	
A,B		a.	Complete primer coverage of required surfaces	ADI042
A,B		b.	Complete topcoat paint coverage of required surfaces	ADI043
A,B		c.	Absence of corrosion	ADI059
A,B		d.	Sealing compound application at base of fastener heads	ADI158
A,B		e.	Free of contamination	ADI022
		4.	For New Nozzle Assembly, Final verify:	
A,B		a.	All metal and plastic interfacing surfaces of the forward exit cone are cleaned prior to installation	ADG007
A,B		b.	Housing, Exit Cone, Nozzle forward end mating surface is free from corrosion and contamination prior to assembly	ADR077
A,B		c.	Nozzle assembly bare metal through-holes including the forward exit cone are protected against corrosion per drawing	ADR084
A,B		d.	Sealing compound (polysulfide sealant) is applied to interfaces of forward exit cone housing and nose throat housing	ADR208

5. For New Segment Assembly, Rocket Motor, verify:

G		a. Nozzle assembly for handling damage and protective cover is cleaned and in place	AGJ167

6. For New Forging, Forward Exit Cone, Nozzle QA verifies

C,D,F	(T)	a. Chemical composition	ADG021
C,D,F	(T)	b. Inclusion rating	ADG070
C,D,F	(T)	c. Grain size	ADG095
C,D,F	(T)	d. Macro structure	ADG095B
C,D,F	(T)	e. Ultrasonic	ADG158, ADG159

7. KSC verifies:

A,B		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. Forward exit cone mating surfaces prior to assembly to ensure absence of damage or contamination per OMRSD File V, Vol I, B47SG0.072	OMD080