CRITICAL ITEMS LIST (CIL)

No. 10-02-01-32R/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1R
SUBSYSTEM:	Nozzle Subsystem 10-02	PART NAME:	Throat Inlet-to-Forward Exit Cone Joint, Primary O-ring, Secondary O-ring (2)
ASSEMBLY:	Nozzle and Aft Exit Cone 10-02-01		
FMEA ITEM NO.:	10-02-01-32R Rev M		
CIL REV NO.:	M (DCN-533)	PART NO.:	(See Section 6.0)
DATE:	10 Apr 2002	PHASE(S):	Boost (BT)
SUPERSEDES PAGE:	336-1ff.	QUANTITY:	(See Section 6.0)
DATED:	31 Jul 2000	EFFECTIVITY:	(See Table 101-6)
CIL ANALYST:	B. A. Frandsen	HAZARD REF.:	BN-03
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 primary O-ring and secondary O-ring

3.0 FAILURE EFFECTS: Failure could result in hot gas flowing through joint resulting in a burn-through, and loss of nozzle causing 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 can be lost due to a single credible cause such as a surface defect on the sealing surface.

1. The primary and secondary O-ring, together, form part of a redundant seal system at the Throat Inlet-to-Forward Exit Cone Joint 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 still maintain a seal. If both the primary and secondary O-ring fail, a leak path will exist and could result in loss of vehicle and crew.

6.0 ITEM DESCRIPTION:

1. The Throat Inlet-to-Forward Exit Cone Joint has a primary O-ring and secondary O-ring (Figures 1 and 2). The assembled joint is shown per engineering drawings. Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U77660	Nozzle Assembly, Final			1/motor
1U79144	Throat Inlet Assembly, Nozzle			1/motor
1U75150	Packing, Preformed Fluorocarbon	Black Fluorocarbon Rubber	STW4-3339	1/motor
1U75547	Housing-Throat Support, Nozzle			1/motor
1U79152	Exit Cone Assembly, Forward Section			1/motor
	Corrosion-Preventive Compound and O-ring Lubricant	Heavy-Duty Calcium Grease	STW5-2942	A/R
1U51916	Cartridge Assembly	Heavy-Duty Calcium Grease, Filtered and Loaded in an Application Cartridge	STW7-3657	A/R
1U52837	Housing, Exit Cone, Nozzle			1/motor

6.1 CHARACTERISTICS:

1. The Throat Inlet-to-Forward Exit Cone Joint allows the throat inlet housing to be mounted to the Forward Exit Cone. The unit is assembled with O-rings and bolts to assure there is no leakage after assembly.

2. The primary and secondary O-ring at the Throat Inlet-to-Forward Exit Cone Joint are designed so that O-ring packing maintains constant contact with its cavity at all times. Squeeze, fill and tracking are taken into account relating to O-ring groove tolerance.

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

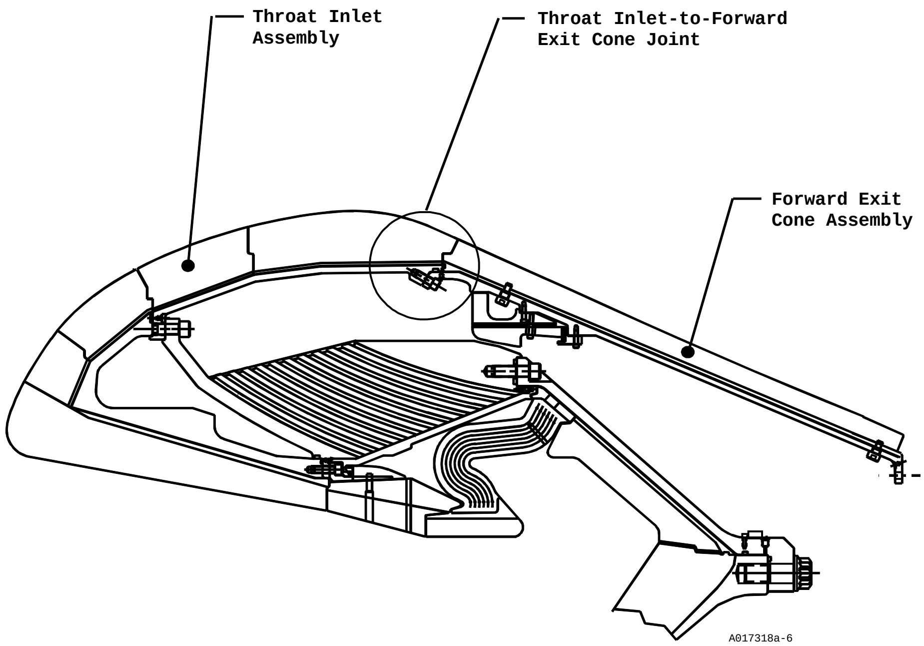

Figure 1. Throat Inlet-to-Forward Exit Cone Joint Location

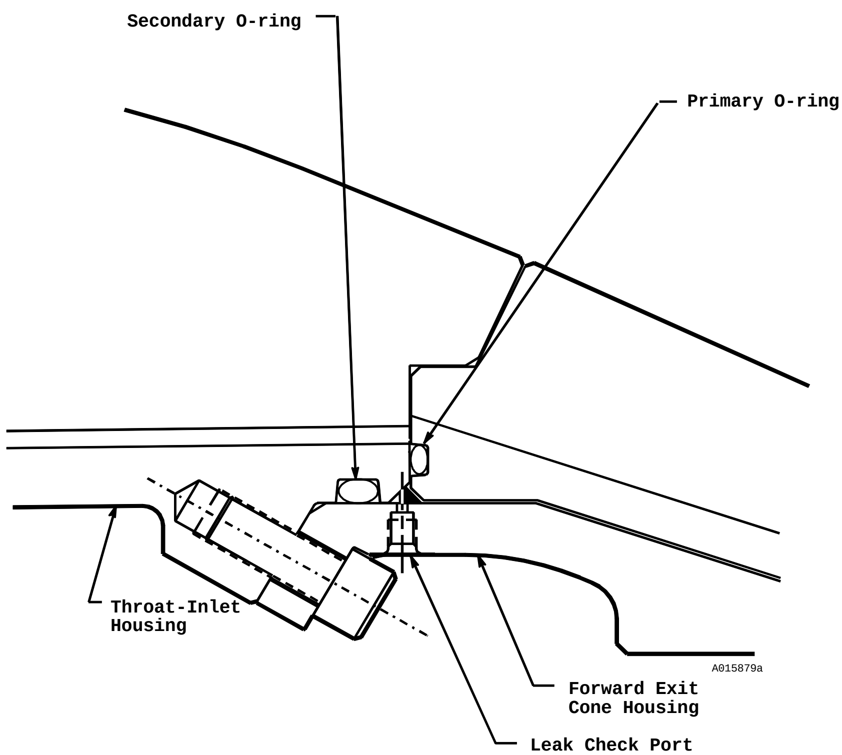

Figure 2. Throat Inlet-to-Forward Exit Cone Joint

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 primary O-ring dimensions are per TWR-15771.
B,C,H	5.	Both O-ring designs provide constant contact between the O-ring and mating nozzle sealing surfaces.
B,D	6.	Large O-rings are per engineering that establishes geometric dimensions, design requirements, and fabrication details.
C,H	7.	Large O-rings are individually packaged per engineering.
C,H	8.	Large O-ring design allows for a minimum of stretching without damage to the O-ring per engineering.
C	9.	Material selection for O-rings was based in part on resistance to damage per TWR-17082.
C,H	10.	Design development testing of O-ring twisting and its effect on performance is per ETP-0153 and TWR-17991.
H	11.	To assure the correct O-ring is installed in its designated location, large O-rings are unpackaged and installed one at a time.
E	12.	Fluorocarbon rubber O-rings are suitable for periods of storage of up to 20 years (O-ring Handbook, ORD 5700, Copyright 1982, by Parker Seal Group, Lexington, KY). Environment and age are 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 life 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 the grease remained intact per TWR-61408 and TWR-64397.

E 18. Large O-rings and filtered grease are included in the aft segment life verification.

F 19. Large O-rings are black fluorocarbon rubber.

F 20. 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 21. Fluorocarbon rubber is a non-nutrient to fungus growth (O-ring Handbook, ORD 5700, Copyright 1982, by Parker Seal Group, Lexington, KY).

F 22. Large O-rings are kept dry and clean prior to packaging.

G 23. 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 24. Design verification analysis of data from live firing tests per TWR-16534 and TWR-17563 shows that O-ring sealing surfaces are acceptable for flight per TWR-18764-09.

G 25. Sealing surface requirements during refurbishment are per engineering drawings and specifications.

I 26. Transportation and handling of the nozzle assembly items by Thiokol is per IHM 29.

I 27. 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.

I 28. 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 29. Support equipment used to test, handle, transport, and assemble or disassemble the RSRM is certified and verified per TWR-15723.

I 30. Repairs to damaged phenolic sealing surfaces are performed using standard shop practice at Thiokol per shop planning.

I 31. 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 32. 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.

J	33.	Filtered grease is applied to nozzle sealing surfaces per engineering drawings during final assembly processes.
J	34.	Filtered grease filtering is per engineering to control contamination.
J	35.	Removal of surface contamination or corrosion is a standard shop practice used whenever contamination or corrosion is noted on metal components.
J	36.	Contamination control requirements and procedures are per TWR-16564.
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 the case-to-nozzle joint and is maintained per TWR-15832. The Throat Inlet-to-Forward Exit Cone 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 throat assembly and 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.

9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TESTS	(T)				CIL CODE
			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.	Diameter	AEB014,AEB015,AEB018,AEB023
	B			l.	Correct identification	AEB087,AEB100
	C,E,F			m.	Packaging for damage or violation	AEB179
	E,F,K			n.	Material is fluorocarbon rubber	AEB141,AEB151
	E,F			o.	Packaging is free of staples or other objects	LAA054
	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 Nozzle Assembly, Final verify:		
	A,B,C,D, G,H,I,J	(T)		a.	Joint seals are pressure tested	ADR129
	H			b.	Correct identification of primary and secondary O-ring at time of installation	ADR061
	C,H			c.	Installation and fit of primary O-ring	ADR196
	C,H			d.	Installation and fit of secondary O-ring	ADR197
	C,H			e.	Condition of primary O-ring after installation into O-ring groove	ADR000
	C,H			f.	Condition of secondary O-ring after installation into O-ring groove	ADR000A
	H,J			g.	Application of filtered grease to Housing-Throat Support, Nozzle aft end O-ring groove prior to assembly	ADR020
	H,J			h.	Application of filtered grease to Exit Cone Assembly, Forward Section forward end O-ring groove prior to assembly	ADR023
	H,J			i.	Application of filtered grease to secondary O-ring prior to assembly	ADR026
	H,J			j.	Application of filtered grease to primary O-ring prior to assembly	ADR154
	C,H			k.	Primary and secondary O-ring are unpackaged, processed, and installed one at a time	ADR155
	C			l.	Primary O-ring is free from damage prior to installation	ADR156
	C			m.	Secondary O-ring is free from damage prior to installation	ADR156A
	C			n.	Secondary O-ring is free of contamination prior to lubrication	ADR185A
	E			o.	Shelf life compliance of secondary O-ring	ADR224A
	E			p.	Shelf life compliance of primary O-ring	ADR225
	E			q.	Shelf life of the filtered grease has not been exceeded prior to use	LAA133
	E			r.	Primary O-ring packaging for damage or violation at time of installation	ADR152
	E			s.	Secondary O-ring packaging for damage or violation at time of installation	ADR152A
	F			t.	Primary O-ring is free from fungus prior to installation	ADR157
	F			u.	Secondary O-ring is free from fungus prior to installation	ADR157A
	F			v.	Secondary O-ring is free from moisture prior to installation	ADR159A

F			w.	Primary O-ring is free from moisture prior to installation	ADR179
I			x.	Exit Cone Assembly, Fwd Section forward end O-ring groove is free from damage prior to installation of primary O-ring	ADR063
I			y.	Exit Cone Assembly, Fwd Section forward end O-ring sealing surface is free from damage prior to installation of secondary O-ring	ADR064
I			z.	Housing-Throat Support, Nozzle aft end O-ring sealing surfaces are free from damage prior to assembly	ADR066
I			aa.	Housing-Throat Support, Nozzle aft end O-ring groove is free from damage prior to assembly	ADR149
J			ab.	Housing, Exit Cone, Nozzle forward end mating surface is free from corrosion and contamination prior to assembly	ADR077
J			ac.	Exit Cone Assembly, Fwd Section forward end O-ring groove is free from contamination prior to assembly	ADR135
J			ad.	Housing-Throat Support, Nozzle aft end O-ring groove is free from corrosion and contamination prior to assembly	ADR180
J			ae.	Housing-Throat Support, Nozzle aft end mating surface is free from corrosion and contamination prior to assembly	ADR261
		3.	For New Throat Inlet Assembly, Nozzle verify:		
C,G			a.	Aft end of throat inlet assembly bondline is flush with adjacent surfaces	SAA026
C,G			b.	No unacceptable defects or sharp edges of adhesive bondline, aft end - throat inlet	SAA027
G			c.	No unacceptable defects and surface finish of phenolic sealing surfaces of aft end - throat inlet	SAA025
		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	ADG003,ADG002
		7.	For Refurbished Housing, Exit Cone, Nozzle verify:		
G			a.	Surface finish	ADG000
		8.	For New Exit Cone Assembly, Forward Section verify:		
G			a.	O-ring groove depth	ADI113

G		b.	O-ring groove surface finish	ADI125
G		c.	O-ring groove width	ADI126
G		d.	O-ring groove diametric location	ADI114
	9.	For New Housing, Throat Support, Nozzle verify:		
G		a.	Surface finish	AFN145A,AFN146A,AFN149,AFN150
G		b.	O-ring groove depth	AFN147,AFN148
G		c.	O-ring groove width	AFN151,AFN152
G		d.	O-ring groove location	AFN153,AFN154
	10.	For Refurbished Housing, Throat Support, Nozzle verify:		
G		a.	Surface finish	AFN004
	11.	KSC verifies:		
E		a.	Life requirements for the expected launch schedule are met per OMRSD File II, Vol III, C00CA0.030	OMD019