CRITICAL ITEMS LIST (CIL)

No. 10-02-01-27R/02

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Nozzle Subsystem 10-02	PART NAME:	Throat Inlet-to-Fwd Exit Cone Joint, Sealing Compound (1)
ASSEMBLY:	Nozzle and Aft Exit Cone 10-02-01		
FMEA ITEM NO.:	10-02-01-27R 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:	334-1ff.	EFFECTIVITY:	(See Table 101-6)
DATED:	27 Jul 2001	HAZARD REF.:	BN-03
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 Thermal failure

3.0 FAILURE EFFECTS: Burn-through of the primary and secondary O-rings, the metal housing, and loss of the nozzle, resulting in thrust imbalance between SRBs, causing loss of RSRM, SRB, crew, and vehicle.

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Failure of sealant (bond line, voids, tears, cracks)	
1.1.1	Sealing compound surfaces not properly prepared or adequately cleaned	A
1.1.2	Primer and sealing compound not properly mixed, applied, or cured	B
1.1.3	Contamination	C
1.1.4	Process environments detrimental to bond strength	D
1.1.5	Nonconforming material properties	E
1.1.6	Sealing compound degradation during storage or transportation	F

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

1. Sealing compound provides thermal protection between two nozzle assembly items at their phenolic surface interface (Figures 1 and 2). A gap is provided between the two phenolic surfaces for the following reasons:

   a. Allow for thermal expansion of the nozzle assembly parts during boost
   b. Allow for positive and full surface mate-up while providing for surface contour tolerances

2. Sealing compound is pressure-back-filled into the gap between the two nozzle assembly items after the two items are bolted together and the leak test was successfully performed. The assembled joint is shown in Figures 1 and 2. Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U77640	Segment Assembly, Rocket Motor			1/motor
1U77660	Nozzle Assembly, Final			1/motor
1U79153	Nose-Throat-Bearing-Cowl-Housing Assembly, Nozzle			1/motor
1U79146	Nose-Throat Assembly, Nozzle			1/motor
1U79152	Exit Cone Assembly, Forward Section			1/motor
	Primer (Adhesive-Sealant Silicone, RTV)	A One-Part Dilute Solution of Reactive Materials in Solvent	STW4-3875	A/R
	Sealing Compound (Sealant, Silicone, RTV)	A Two-Part, Room Temp Vulcanizing Silicone Rubber, High-Temp Pressurization Sealing Compound and Ablative Thermal Barrier	STW5-2813	A/R

6.1 CHARACTERISTICS:

1. The unit is bolted together with silicone rubber material pressure back-filled into the gap between the two nozzle assembly items. Sealing compound is back-filled into the gap deeper than the maximum expected char line. Sealing compound provides an ablative high-temperature flexible thermal barrier between nozzle phenolic layers that face together at the joint. The function of the sealant is to protect joint metal components from heat affect and the O-rings from erosion.

2. Suspect Discrepancy Reports were written against joint 4 sealing compound for suspected blowholes introduced during the back-filling process. This action is the result of finding heat affected joint 3 primary O-rings during post flight inspection of flight sets 360X044 and 360X045. These blowholes occur at closeout areas where two wave fronts of RTV converge. Blow holes are caused by entrapping air next to the O-ring and then compressing it as more sealant is added to the joint. As trapped air is compressed it follows the path of least resistance that is at the closeout interface and typically through the least viscous material.

   All dispositions/rework/repairs for the affected flight sets will be handled per MRB paperwork. When NDT is used to detect voids in the joint, the repair process consists of removing sealant down to the inflection point of the joint at each location where a void is identified and replacing it with new sealant using vacuum assist to reduce the chance of new voids. If NDT is not used to detect voids, the repair process consists of removing sealant down to the inflection point of the joint for the full 360 degrees, visually inspecting the residual sealant surface at the inflection point for voids, and re-back filling the joint with new sealant (except for the areas where voids are identified in the old material). After the new back-filled sealant is cured, edges of the RTV backfill opening, where voids were identified in the old sealant, will be excavated to accommodate backfill repair closeout. Repair closeout incorporates a vacuum assisted backfill. If no pigtail void is found, the vacuum assisted backfill will be at the closeout location. This process was developed and tested on sub-scale plexiglass test blocks and on full-up HPM and RSRM hardware joints that were then disassembled and inspected until the process was optimized. Certification will be achieved using tensile adhesion tests and full-up RSRM hardware repairs. Processes used for the repair work were analyzed with a process FMEA. The process FMEA systematically identified repair concerns and controls to mitigate risk. Process FMEA work is documented in TWR-73177. Flight sets affected by these Discrepancy Reports are 360X046 through 360X048 and 360X050 through 360X055.

3. Post flight inspection of STS-71 and STS-70 (RSRM flight sets 360X045 and 360X044) found heat affected nozzle joint 3 primary O-rings resulting from blow paths introduced during the backfill process. These blow holes occur at the closeout areas where two wave fronts of RTV converge. Blow holes are caused by entrapping air next to the O-ring and then compressing it as more sealant is added to the joint. As the trapped air is compressed, it follows the path of least resistance that is at the closeout interface and typically through the least viscous material thus creating a tail void.

   Until a more acceptable solution can be found to eliminate the tail void problem, the production hardware throat inlet-to-forward exit cone joint will be back-filled normally (without vacuum assist) then 360-degree repaired. The repair process consists of removing the sealant down to the inflection point of the joint for the full 360 degrees, visually inspecting the residual sealant surface at the inflection point for voids, and re-back filling the joint with new sealant (except for the areas where voids are identified in the old material). After new back-filled sealant is cured, the edges of the RTV backfill opening, where voids were identified in the old sealant, will be excavated to accommodate the backfill repair closeout. The repair closeout will incorporate a vacuum-assisted backfill. If no pigtail void is found, the vacuum-assisted backfill will be at the closeout location. This process was developed and tested on sub-scale plexiglass test blocks and on full-up HPM and RSRM hardware joints that were then disassembled and inspected until the process was optimized. The repair process was successfully demonstrated when STS-69 (RSRM flight set 360X048) was flown. CIL CODES BFR009, BFR010, BFR011, BFR012, BFR013, BFR014, BFR015, and BFR016 are added to specifically cover this repair process.

   The flight sets affected by this repair process are 360X056 and subs.

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

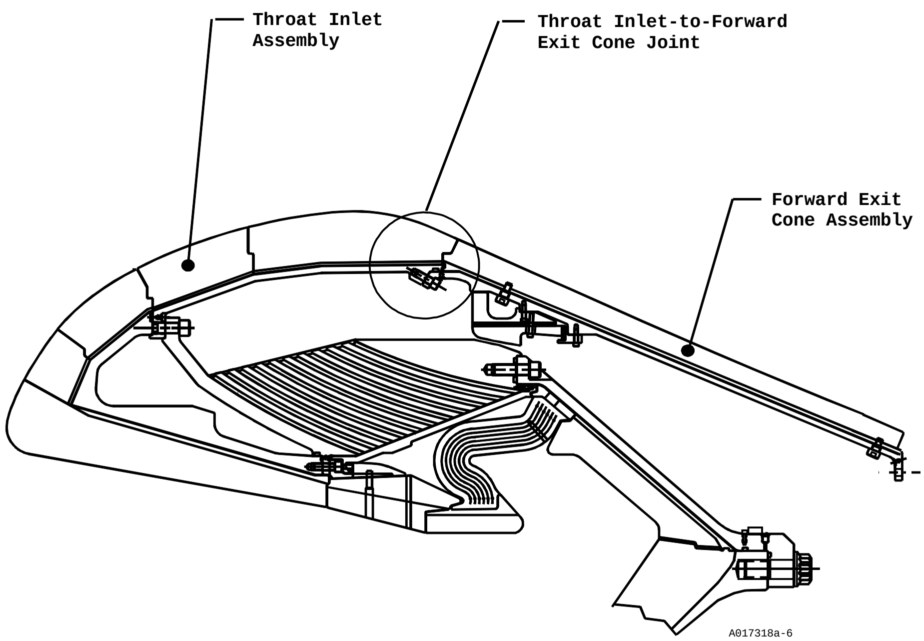

Figure 1. Throat Inlet-to-Forward Exit Cone Joint Location

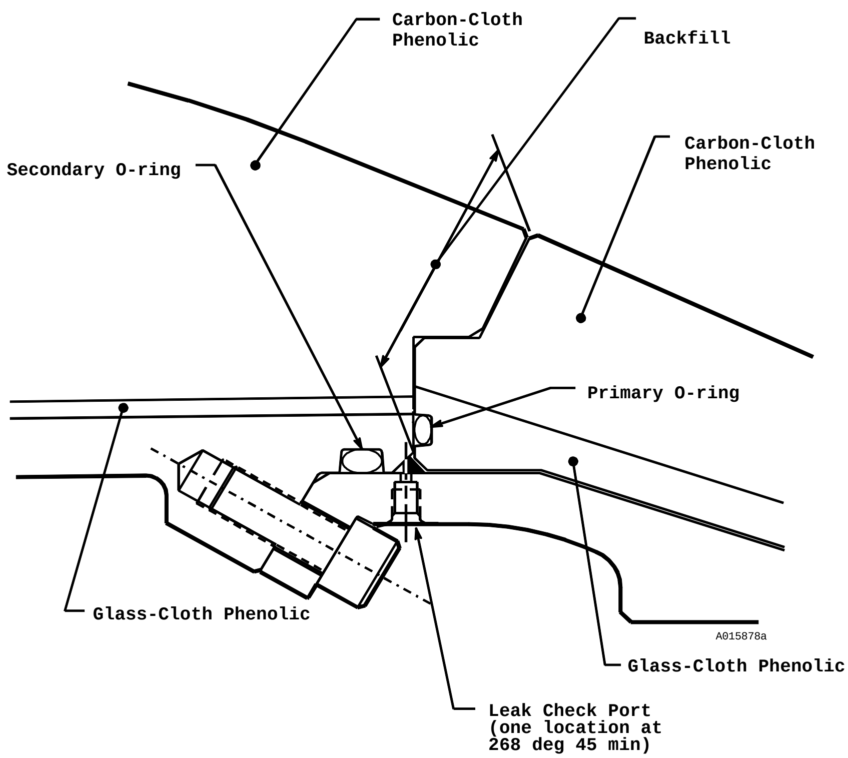

Figure 2. Throat Inlet-to-Forward Exit Cone Joint, Sealing Compound

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN FAILURE CAUSES		
A,B,C,D	1.	Preparation and cleaning of bonding surfaces is per shop planning. Cleanliness of bonding surfaces is determined by a combination of visual inspection and visual inspection aided by black light. Surface inspection type is per shop planning. Preparation, cleaning, and inspection methods for forward exit cone bond lines are identified as process critical planning.
A,B,C,D,E,F	2.	Sealing compound and method of application were qualified through testing per TWR-18764-09.
B	3.	Two-part sealing compound mix ratio is controlled per engineering and mixing instructions are per shop planning.
B	4.	Primer is prepared by the supplier per engineering.
B	5.	Primer and sealing compound application and cure are controlled per engineering drawings and shop planning. a. Sealing compound-to-carbon cloth phenolic was identified as a critical process planning step.
C,D	6.	Contamination control requirements and procedures are per TWR-16564.
C,D	7.	Primer is a one-component Room Temperature Vulcanization (RTV) silicone per engineering.
C,D	8.	Sealing compound is a two-part RTV silicone elastomer, supplied in separate sealed containers per engineering.
C,D	9.	The nozzle manufacturing building is a controlled environment facility with temperature and humidity controls. There is controlled access to the building through a separate room with a card reader.
E	10.	Material properties for primer and sealing compound are per engineering.
E	11.	Sealing compound consists of a silicone rubber base and a catalyst. The supplier supplies the correct amount of each component material to achieve the proper mix ratio per engineering.
F	12.	Requirements for handling RSRM components during assembly and transportation are similar to those for previous and other current programs at Thiokol. Proof testing is required for all lifting and handling equipment per TWR-13880.
F	13.	Support equipment used to test, handle, transport, and assemble, or disassemble the RSRM is certified and verified per TWR-15723.
F	14.	All components are inspected for handling damage after completion. Assembly and handling operations are per shop planning and IHM 29.
F	15.	The nozzle assembly, of which the throat inlet and forward exit cone assemblies are part, is shipped attached to the aft segment. Railcar transportation shock and vibration levels and container temperature are monitored for the aft segment per engineering and loads are by analysis. Monitoring records are evaluated by

Thiokol to verify that shock and vibration levels per MSFC specifications were not exceeded.

F 16. The RSRM and its component parts are protected per TWR-10299 and TWR-11325. The nozzle, which is shipped as part of the aft segment, is protected from external environments at all times by either covers or shipping containers until assembled as part of the RSRM.

F 17. 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.

F 18. 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.

F 19. 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.

D,E,F 20. 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 D,E,F 21. 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 Nozzle Assembly, Final verify:	
	A		a.	Phenolic surfaces are free of contamination prior to primer application to forward exit cone assembly	ADR042
	A		b.	Phenolic surfaces are free of contamination prior to primer application to throat inlet assembly	ADR043
	A		c.	Phenolic surfaces are free of damage prior to primer application to forward exit cone assembly	ADR044
	A		d.	Phenolic surfaces are free of damage prior to primer application to throat inlet assembly	ADR045
	A		e.	Dry time is complete prior to primer application to forward exit cone	ADR068
	A		f.	Dry time is complete prior to primer application to throat inlet assembly	ADR069
	A		g.	Primed phenolic surfaces of forward exit cone assembly are free of contamination	ADR186
	A		h.	Primed phenolic surfaces of throat inlet assembly are free of contamination	ADR187
	A		i.	Primed bonding surfaces of forward exit cone assembly are free of damage	ADR188
	A		j.	Primed bonding surfaces of throat inlet assembly are free of damage	ADR189
	A,B,C,D		k.	Solvent wipe is complete prior to primer application to forward exit cone	ADR253
	A,B,C,D		l.	Solvent wipe is complete prior to primer application to throat inlet assembly	ADR254
	B		m.	Lot number of silicone sealing compound at time of application	ADR130
	B		n.	Sealing compound (Sealant, Silicone, Two-part, RTV) is mixed per planning requirements	ADR235
	B		o.	Stock and lot number of RTV sealant primer at time of application	ADR255
	B		p.	Stock number of silicone sealing compound at time of application	ADR256
	B		q.	Plastic-to-plastic interface surfaces are primed with RTV primer prior to application of silicone sealing compound (RTV)	ADR170
	B		r.	Plastic-to-plastic interfaces are filled with sealing compound after assembly and blended to adjacent contour	ADR029
	B		s.	Application of tape layers prior to back fill	ADR032
	B		t.	Primed plastic interface surfaces are dried prior to sealing compound application	ADR168
	B		u.	Pot life of silicone sealing compound is not exceeded at time of application	ADR174
	B	(T)	v.	Sealing compound (polysulfide sealant) is cured at ambient temperature until tack-free	ADR212
	B		w.	Shelf life of primer is not exceeded at time of application	ADR226
	B		x.	Shelf life of silicone sealing compound is not exceeded at time of assembly	ADR227
	B	(T)	y.	Each mix batch cure cup samples of silicone sealing compound is tested	ADR233
	B		z.	Silicone sealing compound is properly loaded into cartridges	ADR236
	B		aa.	Joint backfill sealing compound on inside diameter of flame surface is free of inclusions, cracks, separations, surface voids and uncured material	ADR011
	C,D		ab.	Component temperatures and exposure to ambient environments during in-plant transportation or storage	BAA028
	B,D		ac.	Proper vacuum is maintained during all vacuum-assisted repairs/closeouts	BFR009
	B		ad.	Application of sealing compound to joint per shop planning	BFR017
	A,C		ae.	No loose RTV in joint gap after excavation	BFR010

B,D		af.	Vacuum-assisted repair is done at all locations where voids were showing at the inflection point in the remaining parent RTV	BFR011
B,D		ag.	Temperature of phenolics is within limits prior to repair backfill	BFR012
A,C		ah.	No obvious contamination in joint gap prior to repair backfill	BFR013
A		ai.	No obvious damage to the joint phenolics prior to repair backfill	BFR014
B,D		aj.	Vacuum assist is used to close out the repair	BFR015
B,E		ak.	Viscosity of repair material at time of backfill is acceptable	BFR016
C		al.	Phenolic surfaces are cleaned per planning requirements prior to taping backfill dam	BFR018

2. For New Adhesive-Sealant Silicone RTV verify:

C,D		a.	Containers for shipping and handling damage	ADQ220
C,D		b.	Contains no foreign matter	AIY002
C,D		c.	Material is homogeneous	AIY004
E		d.	Primer color	AIY001
E	(T)	e.	Specific gravity	AIY007
E	(T)	f.	Total solids content	AIY015

3. For New Sealant, Silicone, RTV verify:

C,D		a.	Shipping and handling damage	ADQ223
C,D		b.	Workmanship is uniform in appearance, quality and color	ANF045
E	(T)	c.	Elongation	ANF000,ANF002,ANF004
E	(T)	d.	Flow	ANF011,ANF013
E	(T)	e.	Shore A hardness	ANF021,ANF023,SAA042
E	(T)	f.	Specific gravity	ANF029,ANF031,SAA043
E	(T)	g.	Tensile strength	ANF037,ANF039,ANF040

4. For New Nose-Throat Assembly, Nozzle verify:

E	(T)	a.	Shore A hardness (cure cup samples) for each mix batch of silicone sealing compound	ADN112

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

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