ATK ALLIANT TECHSYSTEMS
THIOKOL PROPULSION

CRITICAL ITEMS LIST (CIL)

No. 10-02-01-03R/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Nozzle Subsystem 10-02	PART NAME:	Nose Inlet Assembly (1)
ASSEMBLY:	Nozzle and Aft Exit Cone 10-02-01	PART NO.:	(See Section 6.0)
FMEA ITEM NO.:	10-02-01-03R Rev N	PHASE(S):	Boost (BT)
CIL REV NO.:	N	QUANTITY:	(See Section 6.0)
DATE:	17 Jun 2002	EFFECTIVITY:	(See Table 101-6)
SUPERSEDES PAGE:	310-1ff.	HAZARD REF.:	BN-04
DATED:	10 Apr 2002		
CIL ANALYST:	B. A. Frandsen		
APPROVED BY:		DATE:	

RELIABILITY ENGINEERING: K. G. Sanofsky — 17 Jun 2002

ENGINEERING: P. M. McCluskey — 17 Jun 2002

1.0 FAILURE CONDITION: Failure during operation (D)

2.0 FAILURE MODE: 1.0 Thermal failure of carbon phenolic ablative liner or glass phenolic insulator components

3.0 FAILURE EFFECTS: Burn-through of Nose Inlet Assembly could result in breakup and loss of nozzle causing loss of RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Carbon phenolic or glass phenolic material not manufactured to required thickness	A
1.2	Bond line failure of the glass phenolic-to-metal housing bond, glass phenolic-to-carbon phenolic bond, nose cap-to-forward nose ring radial joint, or forward nose ring-to-aft inlet ring radial joint	
1.2.1	Bonding surfaces not properly prepared or adequately cleaned	B
1.2.2	Bonding material not properly mixed, applied, or cured	C
1.2.3	Contamination during processing	D
1.2.4	Process environments detrimental to bond strength	E
1.2.5	Nonconforming material properties	F
1.2.6	Bond lines not to required thickness	G
1.3	Structural failure	
1.3.1	Improper ply angle orientation in phenolic components	H
1.3.2	Nonconforming raw material properties	I
1.3.3	Nonconforming manufacturing processes	J
1.3.4	Nonconforming dimensions	K

1.3.5	Improper joint angle between phenolic components	L
1.4	Improper thermal characteristics due to nonconforming raw material properties	M
1.5	Component degradation during assembly, handling, transportation, or storage	N
1.6	Temperature, humidity, vibration, and shock during boost phase	O
1.7	Porosity, voids, de-laminations, inclusions, or cracks	P

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

Nozzle Nose Inlet Assembly--insulator and liner

1. The RSRM Nozzle Nose Inlet Assembly is one of a series of interconnected modular nozzle components (Figure 1). The Nose Inlet Assembly interfaces with the throat assembly and bearing forward end ring. Figure 2 provides a sectional view of the RSRM nozzle showing the Nose Inlet Assembly. The Nose Inlet Assembly (Figure 3) consists of an aluminum superstructure that is insulated with glass-cloth phenolic and lined with carbon-cloth phenolic. Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U77640	Segment, Rocket Motor, Aft			1/motor
1U79149	Nose-Throat-Bearing Cowl			
	Housing Assembly, Nozzle			1/motor
1U77660	Nozzle Assembly, Final			1/motor
1U79145	Nose Inlet Assembly, Nozzle			1/motor
	Nose Inlet (Test)	Product Specification	STW3-9020	A/R
5U77654	Nose Inlet Assembly Phenolic			
	Rings Ablative Liner	Carbon-Cloth Phenolic	STW5-3279	A/R
	Insulator	Glass-Cloth Phenolic	STW5-2651	A/R
	Resin, Phenolic Laminating	Thermosetting Phenolic	MIL-R-9299	A/R
	Adhesive, TIGA 321	Adhesive,Two-Part	STW5-9203	A/R
	Tape	Cloth Phenolic, Pre-impregnated	STW5-3621	A/R
	Primer, Cyclohexane Silane	Silane Primer	STW5-9206	A/R

6.1 CHARACTERISTICS:

1. The Nose Inlet Assembly consists of the nose cap, forward nose ring, and aft inlet ring (Figure 3). Carbon-cloth phenolic liner forms a gas contour path around the nose. The liner is designed to char and erode away during exposure to rocket exhaust gases at temperatures that are over 5600^{o}F. Glass cloth pre-impregnated with phenolic resin is used to insulate the nose inlet aluminum shell.

2. Structural analyses for nozzle bondlines using adhesives EA946 and EA913NA do not include residual stresses. For this reason, RWW0548 has been approved to waive the requirements to include residual stress in ultimate combined load structural analyses for the current nozzle structural adhesives. New analyses techniques developed for TIGA adhesive may show a negative margin of safety if same analyses were applied to EA946 and EA913NA bondlines. Extensive testing and model validation was conducted for TIGA adhesive to address residual stresses, which have not been performed on EA946

and EA913NA adhesives. Therefore, inclusion of residual stresses in the structural analyses for EA946 and EA913NA bondlines is waived.

Flight rational includes the following: 1. Nozzles are considered fully qualified with a demonstrated reliability of 0.996. 2. The 2.0 bond safety factor is meant to cover unknown conditions such as residual stress effects. 3. Process controls have been added to include monitoring and controlling of bond loads, monitoring Coeflex-shim differentials, controls on rounding forces, controls on flange mismatch, controls on transportation temperatures, improvements in grit blast, eliminated bond surface contact with black plastic, TCA-wipe prior to grit blast rather than after, and other process changes. 4. The use of improved materials include adding silane primer (adhesion promoter), virgin grit blast media for pre-bond grit blast, and incorporate the use of fresh adhesive for nozzle structural bonds.

Future incorporation of TIGA 321 adhesive on RSRM-94 will eliminate the need for waiver RWW0548. Certification analyses will include residual stresses for TIGA 321 adhesive.

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

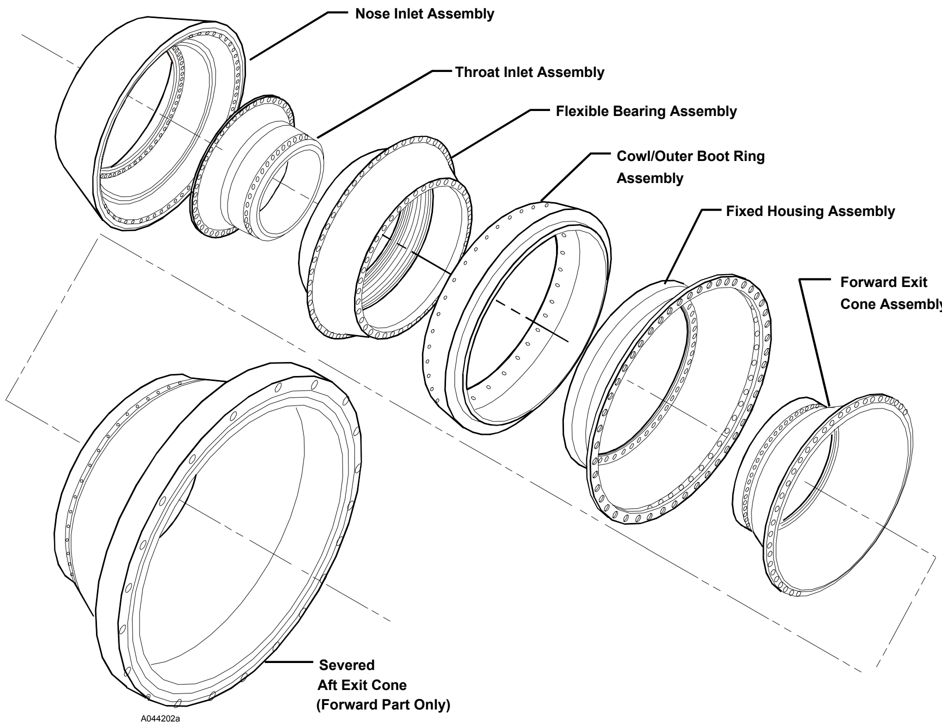

Figure 1. RSRM Nozzle Assembly Components

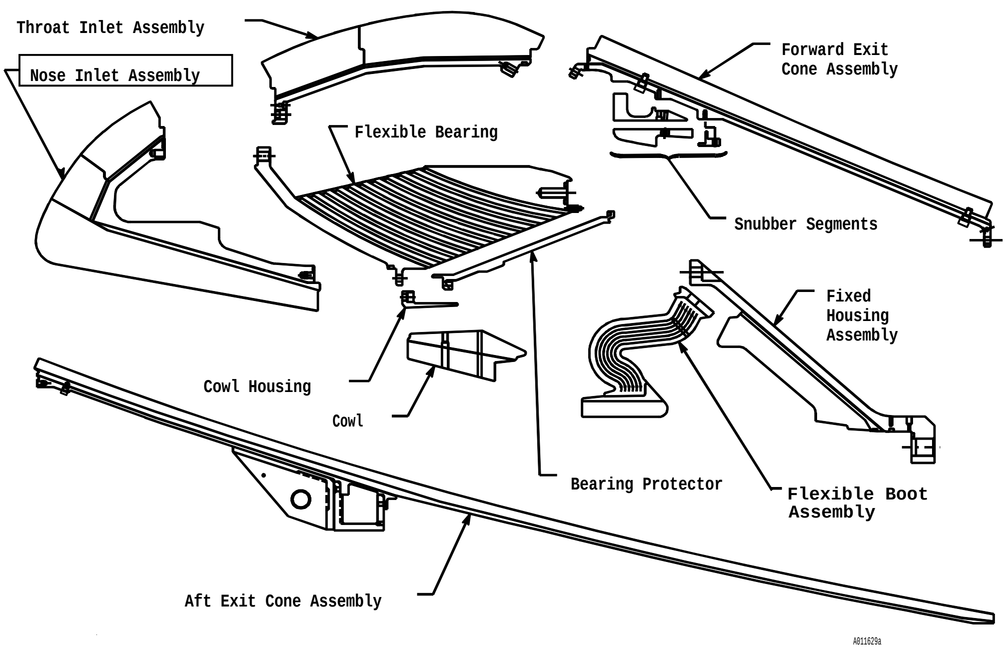

Figure 2. Exploded Section of Nozzle

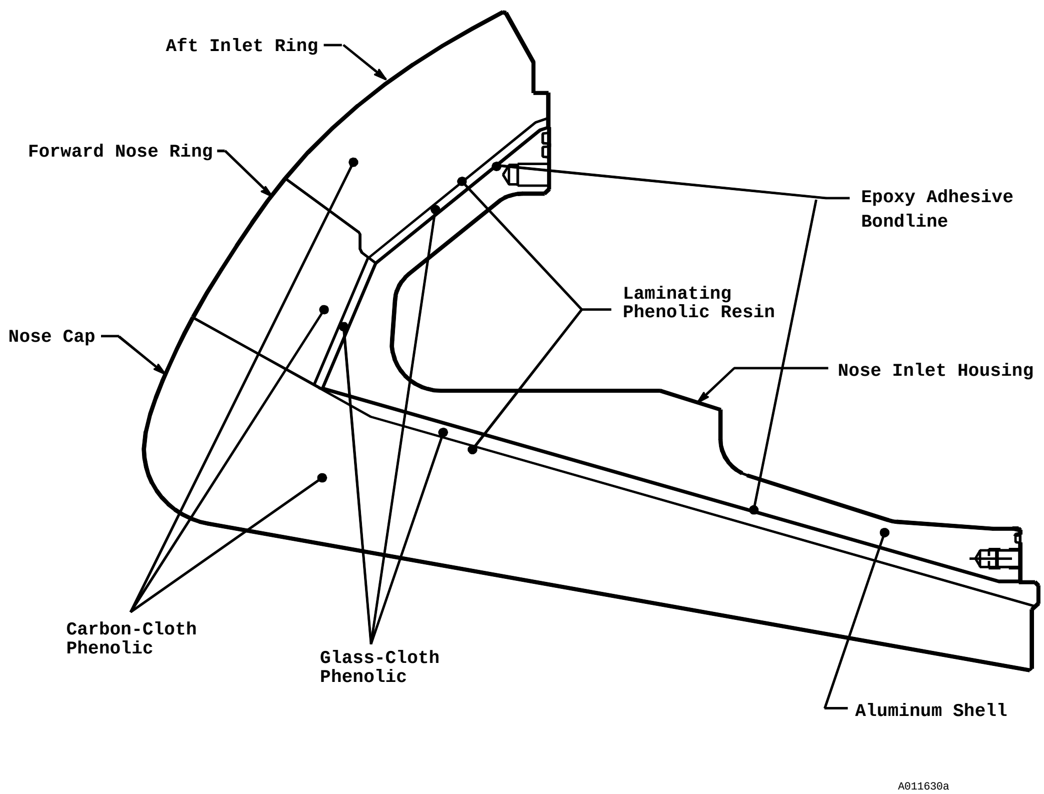

Figure 3. Nose Inlet Assembly

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN FAILURE CAUSE		
A,K	1.	The Nose Inlet Assembly design is per engineering drawings.
K,N	2.	Pre-assembly mismatch causing bond line stresses was shown to be within allowable limits per TWR-16975.
A,H,I,J, K,L,M,P	3.	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 nose inlet 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.
A,K	4.	During Nose Inlet Assembly manufacturing, control is exercised by calibrated machinery. Mandrels control the inside diameter profile and templates control the outside diameter profile. After the phenolics are built up to a specified thickness and cured, they are machined to the specified dimensions.
B,C,D,J	5.	Preparation and cleaning methods for bonding surfaces are per shop planning. Cleanliness of bonding surfaces is determined by a combination of visual inspection and visual inspection aided by black light. Surface inspection is per shop planning. Preparation, cleaning, and inspection methods for aft exit cone bond lines are per process critical planning.
B,C,D,E,F,G,O	6.	Structural analysis documented in TWR-16975 show that nozzle phenolic-to-metal bondlines have positive margins of safety based on a safety factor of 2.0. These analyses used standard conditions as allowed by the CEI specification.
B,C,D,E,G,J,P	7.	Analysis to determine allowable radial bond line void criteria for the Nose Inlet Assembly is per TWR-61340.
C	8.	Epoxy adhesive, two-part, is mixed, applied, and cured per shop planning and engineering drawings.
C	9.	Phenolic resin, laminating is applied to carbon and glass phenolic surfaces and composite structures are cured per shop planning and engineering drawings.
D,E	10.	Contamination control requirements and procedures are per TWR-16564.
E	11.	The nozzle manufacturing building is a controlled environment facility with temperature and humidity controls. There is controlled access to the facility through a separate room with a card reader.
F	12.	Material properties for epoxy adhesive are per engineering.
F	13.	Material properties for laminating phenolic resin are per government specifications for Resin, Phenolic Laminating.
G	14.	Bond line thickness between the insulator-to-housing, insulator-to-liner, and Nose

Inlet Assembly phenolic components is per shop planning.

G	15.	Insulation-to-housing bond line thickness is per engineering drawings.
G	16.	The insulation-to-liner bond line is a thin uniform layer of resin per engineering drawings.
G	17.	Nose Inlet Assembly phenolic component bond gaps are per engineering drawings.
G	18.	Dry-fit to develop bond line shim size is done using the Coe-flex method per engineering drawings and shop planning.
G	19.	Preparation methods for bond line thickness are per shop planning. The type of inspection for each surface as well as the bonding process is per process critical planning.
H	20.	Bias-cut carbon phenolic tape is wrapped on mandrels to required ply angles per engineering drawings.
H	21.	Glass-cloth phenolic tape is wrapped to the required ply angle per engineering drawings.
I,M	22.	Material properties affecting structural and thermal integrity are controlled per Thiokol or government specifications for the following materials: a. Carbon-Cloth Phenolic b. Glass-Cloth Phenolic c. Resin, Phenolic Laminating d. Adhesive, LER, Silicone Filled
I,M	23.	Intermixing of equivalent materials from different suppliers within the glass phenolic or carbon phenolic components is not permitted per engineering drawings.
J,P	24.	Nose Inlet Assembly manufacturing processes are per engineering drawings and shop planning.
J,P	25.	Nose Inlet Assembly manufacturing processes were demonstrated and qualified on development and qualification motors per TWR-18764-09.
L	26.	Carbon phenolic components of the Nose Inlet Assembly are fabricated per engineering drawings.
L	27.	Joint gaps are controlled by dry-fitting phenolic components to the housing. By means of shop handling equipment, a bonding fixture, impression compounds, and shims, the proper bond gaps are determined. Size, number, and location of shims are per shop planning.
L	28.	Results of a nose inlet bonding study test indicate redesigned machining, bonding, and tooling significantly reduced peak strain levels due to bonding and produced a more even strain distribution per TWR-16712. Additional testing was performed to evaluate the bonded system strength with results per TWR-16712.
N	29.	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.
N	30.	Handling and lifting requirements for RSRM components are similar to those for previous and current programs conducted by Thiokol per TWR-13880.

N	31.	Transportation and handling of the Nozzle Nose Inlet Assembly items by Thiokol is per IHM 29.
N	32.	The Nose Inlet Assembly is covered with a protective cover and stored in a temperature controlled building until used as a part of a larger assembly.
N	33.	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 the external environment at all times by either covers or shipping containers until assembled as part of the RSRM.
N	34.	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.
N	35.	Support equipment used to test, handle, transport, and assemble or disassemble the RSRM is certified and verified per TWR-15723.
N	36.	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.
N	37.	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.
N	38.	Thermal analyses were performed for RSRM components during in-plant transportation and storage to determine acceptable temperature and ambient environment exposure limits per TWR-50083. Component temperatures and exposure to the ambient environment during in-plant transportation or storage are per engineering.
O	39.	Analysis is conducted by Thiokol engineering to assess dynamic, acoustic, and vibration response of the RSRM nozzle operation during boost phase per TWR-16975.
O	40.	Analysis of nozzle natural frequency and vibration response throughout motor burn is per TWR-16975.
O	41.	Environmental conditions, similar to those occurring during the boost phase, were demonstrated on static firings per TWR-18764-09.
P	42.	Surface and subsurface defect criteria rationale are per TWR-16340.
B	43.	A Spray-in-Air cleaning system is used to clean metal components as part of the bonding surface preparation processing sequence.
I,J,M	44.	Two lots of carbon-cloth phenolic from the same supplier may be used to fabricate the nose cap of the Nose-Inlet Assembly, Nozzle.
E,N,O	45.	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.

9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TESTS	(T)			CIL CODES
			1.	For New Nose Inlet Assembly Phenolic Rings verify:	
	A,K		a.	VBM re-calibration date	AHO000
	P		b.	Alcohol wipe	AHO003,AHO004,AHO005
	G,J		c.	Carbon cloth tape wrapping	AHO007,AHO009,AHO011
	J		d.	Carbon-cloth tape wrapping is complete and acceptable	AHO008,AHO010,AHO012
	B,J		e.	Clean tape wrap surface prior to resin application	AHO016,AHO017,AHO018
	J		f.	Carbon-cloth material (phenolic tape)	AHO031,AHO032,AHO033
	J		g.	Glass-cloth material (phenolic tape)	AHO034,AHO035,AHO036
	C,E,J		h.	Autoclave cure of glass is complete and acceptable	AHO050,AHO063,AHO068
	C,E,J		i.	Hydroclave cure of carbon is complete and acceptable	AHO054,AHO057,AHO060
	J		j.	Glass cloth tape wrapping	AHO070,AHO072,AHO074
	J		k.	Glass cloth tape wrapping is complete and acceptable	AHO071,AHO073,AHO075
	B,D,J		l.	Grit blast--nose cap	AHO076
	J		m.	Surface finish of final part profile for carbon	AHO077,AHO078,AHO079
	J		n.	Surface finish of final part profile for glass	AHO080,AHO081,AHO082
	J		o.	Clean mandrel tape wrap surface for first wrap	AHO083,AHO084,AHO085
	A,J,K		p.	Mandrel recycle date	AHO087,AHO089,AHO091
	A,K		q.	Glass outside diameter profile--nose cap	ADT090
	I,M,J		r.	One supplier--carbon phenolic material	AHO093,AHO094,AHO095
	I,M,J		s.	One supplier--glass phenolic material	AHO096,AHO097,AHO098
	A,H,J,K		t.	Proper mandrel--first wrap	AHO099,AHO100,AHO101
	H		u.	Proper mandrel--second wrap	AHO102,AHO103,AHO104
	D,E,J,P	(T)	v.	Radiographic examination is acceptable	ADT106,ADT109,ADT115
	C,D,G,J		w.	Resin application	AHO117,AHO119,AHO121
	A,K		x.	Mandrel used at second wrap is the same as first wrap nose cap	ADT120
	C,I,M		y.	Single source for resin	AHO135,AHO136,AHO137
	I,J		z.	Shelf life--carbon	AHO138,AHO139,AHO140
	I,J		aa.	Shelf life--glass	AHO141,AHO142,AHO143
			2.	For New Nose Inlet Assembly, Nozzle verify:	
	C,D		a.	Adhesive application	ADT000,ADT001,ADT002
	C		b.	Adhesive (LER, Silicon filled) is mixed per planning requirements	ANM001
	C,E,J		c.	Adhesive cure for bond	ADT005,ADT006,ADT007
	C,F,I	(T)	d.	Adhesive for void repair, (Cure Cup Hardness Test)	ANM013
	L		e.	Aft end surface profile of nose cap after final machine	ADT015
	J		f.	Alcohol wipe phenolic surfaces	ADT019
	G		g.	Placement and bonding of shims is the same as determined at dry-fit	ADT029,ADT030,ADT031,ADT032,ADT033
	J		h.	Bond	ADT034,ADT035,ADT036
	N		i.	Component temperatures and exposure to ambient environments during in-plant transportation or storage	BAA036
	A,K		j.	Current re-calibration date of set master tooling or VBM re-calibration if set master is not used	ADT037
	I		k.	Shelf life of adhesive, LER, silicone filled	ANM037
	B,C,D,E,F, I,J,M	(T)	l.	Witness panel results for adhesive integrity	SAA038
	B,D		m.	Bonding surfaces are free of unacceptable surface contamination (black light)	ADT039

C			n.	Proper cure of silane primer	SAA041
G,J,L			o.	Bond gap at dry-fit	ADT059,ADT060,ADT061,ADT062,ADT063
B,D,J			p.	The time limit between grit blasting and primer application	ADT071,ADT073,ADT074
A,J,L			q.	Profile of carbon flame surface	ADT088
D,J			r.	Nose inlet housing after grit blast	ADT091,ADT093,ADT095
J			s.	Bonding prep	ADT092,ADT094,ADT096
J,L			t.	Profile of forward end of forward nose ring	ADT099
L			u.	Aft end profile of aft inlet ring is within tolerance	ADT100
C			v.	Phenolic part is seated within adhesive pot life	ADT122,ADT123,ADT124
G			w.	Shim size used at final dry-fit	ADT127,ADT128,ADT129, ADT130,ADT131
E			x.	Temperature of bond surfaces per planning requirements	ADT137,ADT138,ADT139
B,C			y.	Silane primer application on bond surfaces with minimum overlap	SAA042
C,E			z.	Type I tensile test specimens are prepared for nose cap bond	ANM022
C,E			aa.	Type I tensile test specimens are prepared for aft inlet ring bond	ANM023
C,E			ab.	Type I tensile test specimens are prepared for forward nose ring bond	ANM024
C,E	(T)		ac.	Adhesive for bonding (Tensile Adhesion Test)	ANM043
		3.	For New Nose Inlet (Test) verify:		
J	(T)		a.	Compressive strength (carbon & glass)	AHO024,AHO030
J	(T)		b.	Residual volatiles (carbon & glass)	AHO110,AHO116
J	(T)		c.	Resin content (carbon & glass)	AHO128,AHO134
J	(T)		d.	Specific gravity (carbon & glass)	AHO149,AHO156
		4.	For New Nose-Throat-Bearing-Cowl Assembly verify:		
B,C,D,G,J	(T)		a.	Radiographic examination of bond lines and thermal barrier is acceptable	BBB001
585		5.	For New Approved Solvent, verify:		
B,D			a.	Certificate of Conformance is complete and acceptable	AJJ007A
		6.	For New Adhesive, LER, Silicone Filled verify:		
F,I	(T)		a.	Pot life	ANM025
F,I	(T)		b.	Tensile adhesion strength	ANM045
		7.	For New Adhesive, Modified Epoxy (Grey) verify:		
F,I,M	(T)		a.	Average molecular weight (epoxy paste)	ANL002
F,I,M	(T)		b.	Epoxide equivalent, epoxy resin	ANL029,ANL027
F,I,M	(T)		c.	Ingredient percentages	ANL045,ANL060
F,I	(T)		d.	Pot life	ANL074,ANL075
F,I	(T)		e.	Steel-to-steel tensile adhesion	ANL094
F,I,M			f.	Visual examination (workmanship)	ANL117
F,I,M	(T)		g.	Titratable nitrogen, curing agent	ANL159,ANL160
F,I	(T)		h.	Viscosity, epoxy resin	ANL176,ANL178
		8.	For New Silicon Dioxide, verify:		
F,I,M	(T)		a.	Bulk density	ALP002,ALP008
F,I,M	(T)		b.	Loss on ignition	ALP040
F,I,M	(T)		c.	Moisture	ALP058,ALP064
F,I,M	(T)		d.	pH	ALP097,ALP101

9. For New Resin, Phenolic Laminating verify:

F,I,M	(T)	a.	Specific gravity	AJG006
F,I,M		b.	Data pack is complete and acceptable	AJG022
F,I,M	(T)	c.	Viscosity	AJG037

10. For New Carbon-Cloth Phenolic verify:

I,M	(T)	a.	Carbon filler content--uncured	AOF000
I,M	(T)	b.	Cloth content--uncured	AOD017
I	(T)	c.	Compressive strength--cured	AOD027
I,M	(T)	d.	Density--cured	AOD058
I,M	(T)	e.	Dry resin solids--uncured	AOD067
I	(T)	f.	Inter-laminar shear--cured	AOD075
I,M	(T)	g.	Resin content--cured	AOD112
I,M	(T)	h.	Resin flow--uncured	AOD140
I,M	(T)	i.	Sodium content--uncured	AOD164
I,M		j.	Supplier data pack is acceptable and complete	AOD206
I,M	(T)	k.	Volatile content--uncured	AOD222

11. For Retest Carbon-Cloth Phenolic verify:

I,M	(T)	a.	Resin flow	AOD131
I,M	(T)	b.	Volatile content	AOD236

12. For New Glass-Cloth Phenolic verify:

I,M	(T)	a.	Cloth content--uncured	AMN007
I	(T)	b.	Compressive strength--cured	AMN014
I,M	(T)	c.	Density--cured	AMN038
I,M	(T)	d.	Dry resin solids--uncured	AMN048
I	(T)	e.	Inter-laminar shear strength--cured	AMN057
I,M	(T)	f.	Resin content--cured	AMN088
I,M	(T)	g.	Resin flow--uncured	AMN121
I,M	(T)	h.	Volatile content--uncured	AMN195
I,M		i.	Supplier data pack is complete and acceptable	AMN172

13. For Retest Glass-Cloth Phenolic verify:

I,M	(T)	a.	Resin flow	AMN103
I,M	(T)	b.	Volatile content	AMN178

14. For Retest Phenolic Slit Tape verify:

I,M	(T)	a.	Resin flow	AMN103A,AOD131A
I,M	(T)	b.	Volatile content	AMN178A,AOD236A

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

585 N		a.	Approved solvent wipe	AGJ029
N		b.	Component environments during in-plant transportation or storage	BAA030
N		c.	Nozzle assembly for handling damage and protective cover is cleaned and in place	AGJ167

16. For New Nozzle Assembly, Final verify:

N		a.	Alcohol wipe test of nozzle insulation prior to shipment to nozzle installation operation	ADI014

N			b.	Component temperatures and exposure to ambient environments during in-plant transportation or storage	BAA028
		17.	For Nozzle Assembly, Structural Bond line Requirements For verify:		
B,C,D,E, F,I,J,M	(T)		a.	Phenolic-to-adhesive interface checks meet specification requirements	PPC001
		18.	KSC verifies:		
N			a.	Nozzle rigid phenolic components for no visible damage per OMRSD File V, Vol I, B47SG0.141	OMD086