CRITICAL ITEMS LIST (CIL)

No. 10-05-02-01R/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Assembly Hardware/Interfaces Subsystem	PART NAME:	Case-to-Nozzle Joint, Metal Components (1)
ASSEMBLY:	Case-to-Nozzle Interface 10-05-02	PART NO:	(See Section 6.0)
FMEA ITEM NO.:	10-05-02-01R Rev M	PHASE(S):	Boost (BT)
CIL REV NO.:	M (DCN-533)	QUANTITY:	(See Section 6.0)
DATE:	10 Apr 2002	EFFECTIVITY:	(See Table 101-6)
SUPERSEDES PAGE:	351-1ff.	HAZARD REF.:	BC-04
DATED:	31 Jul 2000		
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: Failures of components would result in the expulsion of the nozzle and instantaneous thrust increase followed by large thrust decrease causing loss of RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Nonconforming materials	A
1.2	Cracks, voids, or other material defects	B
1.3	Nonconforming heat treatment	C
1.4	Contamination and/or corrosion	D
1.5	Stress corrosion	E
1.6	Nonconforming dimensions	F
1.7	In-service degradation and/or fatigue	G
1.8	Improper assembly techniques	H
1.9	Transportation, handling, or assembly damage	I
1.10	Damaged threads	J

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

1. Nozzle-to-Case joint metal components consist of the nozzle fixed housing and the aft case segment (Figures 1 and 2). Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U76034	Bolt, Case/Nozzle	Inconnel 718	AMS 5662 QQ-P-416	100/motor
1U75167	Bolt, Machine	MP35N Alloy	AMS 5844 QQ-P-416	99/motor 01/motor
	Fastener, Cadmium Plated		STW3-1533	A/R
1U77640	Segment, Rocket Motor, Aft			1/motor
1U76887	Pin, Spring	CRES 420	MS16582	1/motor
1U76794	Case Segment, Aft, Forging	D6AC Steel	STW4-2606, STW7-2608	1/motor
1U50129	Dome, Aft			1/motor
	Steel, Alloy, High	D6AC Steel	STW4-2606	
1U75642	Case Assembly, Painted Aft Dome	Various		1/motor
8U50800	Shipping Kit-Segment			A/R
	Helical-Coil Inserts	302/304 Corrosion-Resistant Steel	NASM33537	A/R
	Sealing Compound	Synthetic Rubber, Polysulfide	STW5-9072	A/R

6.1 CHARACTERISTICS:

1. The entire nozzle assembly is attached to the motor case through the Fixed Housing Assembly. It is attached to the case by means of 100 bolts in the fore-aft direction and 100 bolts in the circumferential plane and the joint is sealed with O-rings and Stat-O-Seals. This joint is provided with a leak check port and vent port that are closed after test with plugs (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

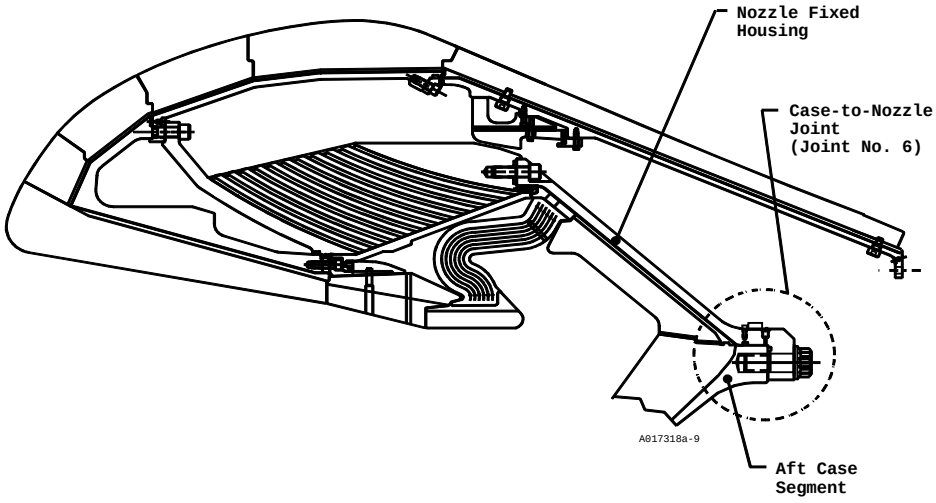

Figure 1. Case-to-Nozzle Joint, Metal Components Location

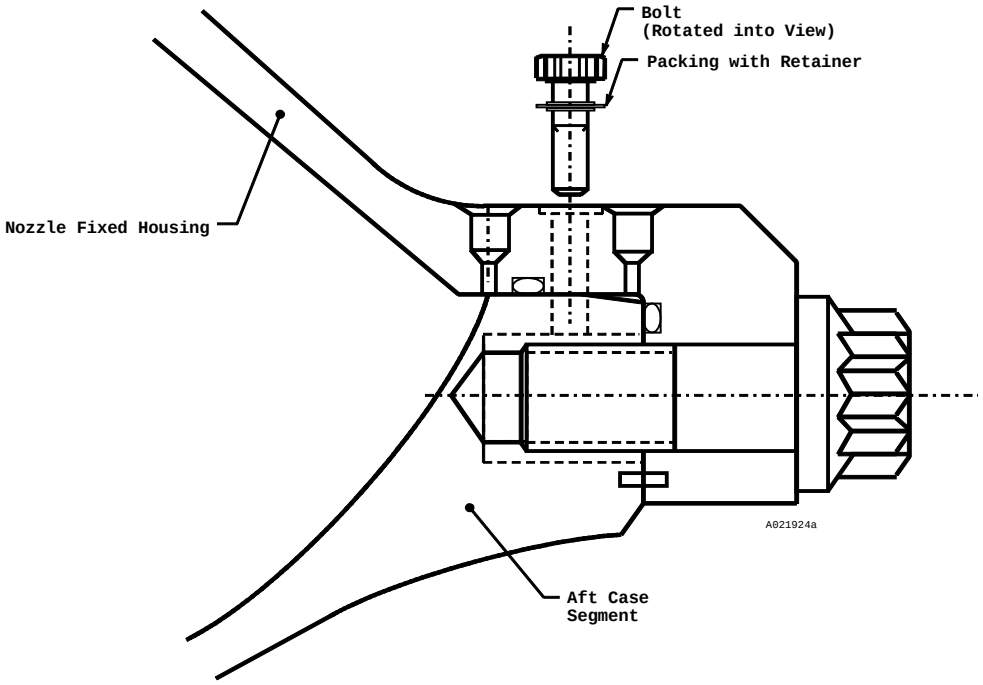

Figure 2. Case-to-Nozzle Joint, Metal Components

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN	FAILURE CAUSES	
A	1.	The nozzle fixed housing and aft case segment are made from a low-alloy, high-strength D6AC steel. Chemical composition, mechanical properties, and metallurgical characteristics for each component are per engineering.
A,D	2.	Spring pins are corrosion resistant steel (CRES) 420.
A,B,C,D,E,F,G	3.	Structural analyses per TWR-16975 show that all 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.
B	4.	The aft case segment and nozzle fixed housing are metal parts that are designed to specific loads and safety factors and are additionally designed for reuse. TWR-16875 provides justification for reuse and criteria for acceptance of RSRM components. Controls in this program are per engineering and provide justification for reuse of parts containing cracks, voids, or other material defects.
B	5.	The aft case segment and nozzle fixed housing are heat treated for high strength and high toughness with reduced internal and surface stresses per engineering.
A,C,G	6.	The nozzle to case joint axial bolt is heat treated steel. Specific requirements are for tensile and yield strength per engineering.
A,C,G	7.	Radial bolt Material is alloy steel that is heat treated per AMS specifications.
C,G	8.	The basic forging was analyzed per JSC Specification SE-R-0006 and the results reported in TWR-10719 for the Fixed Housing. This report shows the forging to be free of re-entrant or sharply folded lines and that the principal grain flow is oriented parallel with principal stresses expected.
D	9.	All metal surfaces of the nozzle fixed housing are protected from corrosion per engineering.
	10.	Aft case segment surfaces are inspected for contamination, and cleaned as necessary.
D	a.	During processing, Thiokol takes steps to protect all case segment exposed bare metal surfaces to minimize corrosion. Superficial discoloration is allowed as long as it does not interfere with inspection of the hardware. Corrosion is removed prior to hardware assembly per engineering.
D	b.	During local transportation, Thiokol uses environmentally controlled shipping containers which allow case segments to be shipped without grease per TWR-65920.
D	c.	Case segments are painted with primer and top coat.
D	d.	Filtered grease is applied to sealing surfaces prior to assembly.
D	11.	Contamination control requirements and procedures are per TWR-16564.
D,E,G	12.	Refurbishment of the nozzle fixed housing is per engineering drawings and specifications.
D	13.	The indexing pin is made from alloy steel that has excellent corrosion resistance.

D,E	14.	Refurbishment of the Aft Case Segment is acceptable per engineering.
D	15.	Radial bolts are made from alloy steel per AMS specifications, that has excellent corrosion resistance.
D	16.	Nozzle-to-Case joint axial bolts are made from alloy steel that has excellent corrosion resistance.
D	17.	Nozzle-to-case joint radial and axial bolts are refurbished per engineering.
D	18.	Protection of sealing surfaces, O-rings, and leak check port threads from damage and contamination during handling and shipment is provided by installed protective plugs per shop planning.
E	19.	Stress-corrosion resistance characteristics of D6AC steel, coupled with residual stress tests, support the conclusion that stress corrosion does not present a problem to the current design per TWR-12718.
	20.	The heat-treat process of tempering reduces surface and internal stresses:
C,E,G	a.	The nozzle fixed housing is a heat treated D6AC steel forging per engineering.
C,E,G	b.	The aft case segment is fabricated from D6AC steel and heat treated per engineering.
E	21.	A stress test report describes development test methods used to determine residual stresses in D6AC steel. From the test data, it is concluded the maximum tensile stress is less than the stress corrosion cracking threshold per TWR-12718.
E	22.	Nozzle to case joint radial and axial bolts are made of materials listed in the MSFC specification which are alloys with high resistance to stress corrosion cracking, therefore, a Material Use Agreement is not required.
E	23.	A Material Use Agreement is required for the Aft Segment and Fixed Housing per MSFC specifications.
E,F	24.	Stress analysis for maximum allowable dimensional pre-assembly mismatch is per TWR-17118. Stress analysis for the effects of plastic yielding during hydro-proof testing is per TWR-17118. Stress corrosion of mismatched components is per TWR-16873.
E	25.	Bolts are cadmium plated per Federal Specifications.
E	26.	Relief from hydrogen embrittlement is accomplished by baking.
F	27.	Aft Case Segment dimensions are per engineering.
F	28.	Nozzle fixed housing dimensions are per engineering drawings.
F,G	29.	Nozzle-to-case joint axial bolt dimensions are per engineering drawings. These bolts are reused.
F,G	30.	Radial bolt dimensions are per engineering drawings. These bolts are reused.
F	31.	Refurbished nozzle fixed housing dimensions are per engineering drawings and specifications.
F	32.	Refurbished Aft Case Segment dimensions are per engineering.

G	33.	TWR-16873 and TWR-16875 provide analysis in determining service life of the Case Segments and Nozzle Fixed Housing.
H	34.	An indexing pin on the Nozzle, Fixed Housing ensures correct component positioning as the Nozzle Fixed Housing and Aft Dome Segment are mated per TWR-10341.
H	35.	Snug torque values, installation sequence, and angle of rotation for the axial and radial bolts of the Nozzle-to-Case Joint are per engineering. The bolt loading method was qualified per TWR-66211 and TWR-66738.
H	36.	Corrosion-preventive compound is filtered to control contamination.
H	37.	Guide pins are used to aid in assembly of the Nozzle-to-Case Joint per shop planning.
I	38.	Shop procedures are developed to minimize errors during handling and assembly. Nozzle components are tagged "program critical hardware" per shop planning and the Thiokol IHM 29.
I	39.	Requirements for handling RSRM components during assembly, storage, and transportation are similar to those for previous and other current programs at Thiokol. These requirements dictate RSRM case segments must be handled by or near a joint to avoid damage. All lifting hooks and slings are fitted with safety hooks per TWR-13880.
I	40.	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	41.	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	42.	Protection of leak check vent port threads from damage and contamination during handling is provided by installed protective plugs. Protective plugs are removed when leak tests are performed and flight plugs are installed. Inspections are performed to verify no transportation or handling damage.
I	43.	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	44.	Aft Dome internal threads at the Case-to-Nozzle Joint must satisfy thread requirements for new and refurbished Aft Domes per engineering. Threads will have no damage or defects greater than that called out in engineering. Threads are inspected after proof testing.
J	45.	New and refurbished Aft Domes are proof tested per engineering. Aft Dome threads are loaded in this test.
J	46.	Thread damage repair requires Discrepancy Report and Materials Review Board action per engineering. Helical inserts may be used per engineering. Thiokol is

performing tests to assure the twenty-use requirement and structural capability of helical inserts in D6AC steel per TWR-18555.

A,B,C,D,E,F,G 47. 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 performance of the RSRM nozzle were identified due to PE.

533 A,B,C,D,E,F,G 48. 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 fixed housing 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,B,C,D,E,F,G 49. TWR-61410 was updated to include boundary conditions created by the Performance Enhancement (PE) Program. This report analyzed temperature conditions created from flight loads. PE temperatures are equal to current generic temperatures for all locations for the critical time of liftoff. For a few locations at the factory joints and case acreage during flight, temperatures rise, but only slightly, and maximum case temperatures are lower than current generic certification. For flight load events, PE temperatures are not significantly different from current generic temperatures. There is no impact on previous analyses or margins of safety for the case membranes, factory joints, and field joints per TWR-61410.

9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TEST	(T)			CIL CODE
			1.	For New Housing, Nozzle-Fixed verify:	
A,C		(T)	a.	Chemical composition	ADV018
A,C		(T)	b.	Elongation	ADV063
A,C		(T)	c.	Fracture toughness (K_{IC})	ADV073
A		(T)	d.	Grain size	ADV133
A		(T)	e.	Inclusion rating	ADV135
A		(T)	f.	Macro structure	ADV134
A,C		(T)	g.	Reduction in area	ADV171
A,C		(T)	h.	Ultimate tensile strength	ADV213
A,C		(T)	i.	Yield strength	ADV229
B,E,G		(T)	j.	Magnetic-particle	ADV113
B,E,G		(T)	k.	Ultrasonic	ADV222
B,E,G		(T)	l.	Hydroproof test	ADV097
C			m.	Material	ADV195
C			n.	Heat treat	ADV085
D			o.	Grease application	ADV090
D			p.	Corrosion protection is per specification	ADV090
F			q.	Thickness	ADV034,ADV034A,ADV035,ADV035A ADV204,ADV205,ADV207,ADV208
F			r.	Flatness	ADV039,ADV040,ADV042,ADV043
F			s.	Diameter	ADV048,ADV049,ADV053,ADV054,ADV055,ADV057
F			t.	Height	ADV069,ADV070
F		(T)	u.	Hydroproof test	ADV097
F			v.	Profile	ADV154,ADV155
F			w.	Run out	ADV178,ADV179
F			x.	True position	ADV210A,ADV211,ADV212,ADV212A
			2.	For Refurbished Housing, Nozzle-Fixed verify:	
B,E,G		(T)	a.	Hydroproof test	ADV092
D			b.	Surfaces cleaned	ADV029
E,G		(T)	c.	Magnetic-particle	ADV110
F			d.	Thickness	ADV033
F			e.	Diameter	ADV050,ADV058
F			f.	Height	ADV071
F			g.	Straightness	ADV152
F			h.	Roundness	ADV176,ADV180,ADV182
F			i.	Flatness	ADV197
G			j.	Painted surfaces for heat degradation	ADV082
			3.	For New Case Segment, Aft, Forging, verify:	
A,C		(T)	a.	Elongation after heat treatment	AAJ055,AAJ058
A,C		(T)	b.	Ultimate strength, uniaxial, after heat treatment	AAJ174,AAJ175
A,C		(T)	c.	Fracture toughness after heat treatment	AAJ065,AAJ068
A,C		(T)	d.	Reduction in area after heat treatment	AAJ006,AAJ153
A,C		(T)	e.	Yield strength after heat treatment	AAJ201,AAJ204
A,C		(T)	f.	Chemical composition (D6AC)	AAJ021
B,E		(T)	g.	Ultrasonic inspection of the forging	AAJ177
F			h.	Wall thickness near clevis	AAJ195,AAJ196
F			i.	Wall thickness near Datum -G-	AAJ198,AAJ199
F			j.	Wall thickness at point B	AAJ016,AAJ192

4. For New Bolt, Case/Nozzle verify:

A,C	(T)	a.	Mechanical properties	AGE010
A,C	(T)	b.	Chemical composition	AGE003
A,C		c.	Material	AGE020
F		d.	Diameter of bolt shank	AGE008,AGE009
F		e.	Length dimension	AGE012,AGE013
F		f.	Length of grip	AGE015,AGE016
F		g.	Threads	AGE018,AGE019
F		h.	Circular run out of bolt bearing surface	AGE026,AGE027
F		i.	Fillet role radius area	AGE032,AGE033

5. For Refurbished Bolt, Case/Nozzle verify:

B	a.	Surface defects	AGE006
D,G	b.	Part is acceptable	AGE034
F	c.	Threads	AGE017

6. For New Bolt, Machine verify:

A,C	(T)	a.	Ultimate tensile strength	AEI040
A,C	(T)	b.	Material and chemical composition	AEI018
B		c.	Part is acceptable	AEI501
F		d.	"L" dimension	AEI010,AEI011
F		e.	"B" diameter	AEI006,AEI007
F		f.	Threads	AEI016,AEI017
F		g.	Run out between Datum -A- and Datum -B-	AEI031,AEI032
F		h.	Circular run out of bolt bearing surface	AEI024,AEI025
F		i.	"R" radius	AEI027,AEI028

7. For Refurbished Bolt, Machine verify:

B	a.	Surface defects	AEI004A
D,G	b.	Part is acceptable	AEI501
F	c.	Threads	AEI015

8. For New Pin, Spring, Tubular, Slotted verify:

A	(T)	a.	Chemical properties	AJS000
A	(T)	b.	Mechanical properties	AJS002
A		c.	Correct material (CRES 420 or carbon steel as required per engineering)	AJR001

9. For New Insert, Helical Coil, verify:

A	a.	Material is corrosion resistant steel	RHB001

10. For New Case Segment, Aft, verify:

B,E,G,J	(T)	a.	Magnetic particle inspection after hydroproof test	AAJ114
B,E,F,G,J	(T)	b.	Hydroproof test	AAJ078
F		c.	Inner clevis leg wall thickness	AAJ092,AAJ092A
F		d.	Outer clevis leg wall thickness	AAJ146,AAJ146A
F		e.	Flange thickness at Datum -G-	AAJ060,AAJ061
F		f.	True position of aft boss threaded holes	AAJ169,AAJ170
F		g.	Depth of threads in aft boss threaded holes	AAJ038,AAJ039
F		h.	Tap drill depth of aft boss threaded holes	AAJ036,AAJ167

F		i.	Flatness of Datum -G-	AAJ062,AAJ063
F		j.	Diameter of Datum -A-	AAJ040,AAJ041
F		k.	Diameter of Datum -F-	AAJ043,AAJ044
F		l.	Run out of Datum -F-	RAA207
F		m.	Clevis pin hole diameter	AAJ030,AAJ026A
J	(T)	n.	Axial and radial threaded bolt holes are eddy-current inspected after hydroproof, and all non-conforming conditions are dispositioned	AAJ051
J		o.	Depth of threads in aft boss threaded holes	AAJ038,AAJ039
J		p.	Tap drill depth of aft boss threaded holes	AAJ036,AAJ167
J		q.	Axial and radial threaded holes with Go-No-Go gauge after hydroproof	AAJ010
J		r.	True position of aft boss threaded holes	AAJ169,AAJ170

11. For Refurbished Case Segment, Aft, verify:

B,E,G,J	(T)	a.	Hydroproof test	AAJ075
E,G,J	(T)	b.	Magnetic-particle inspection after hydroproof test	AAJ105
D		c.	Surfaces are cleaned to remove foreign material and corrosion	AAJ030
F		d.	Case wall thickness	FAA587
F		e.	Inner clevis leg wall thickness	AAJ093
F		f.	Outer clevis leg wall thickness	AAJ147
F		g.	Clevis sealing surface gap	AAJ028
F		h.	Axial and radial threaded holes with Go-No-Go gauge after hydroproof	AAJ011
F		i.	Clevis pin hole diameter	AAJ025
F		j.	Diameter of inner boss	AAJ042
J	(T)	k.	Axial and radial threaded bolt holes are eddy-current inspected after hydroproof, and all non-conforming conditions are dispositioned	RAA208
J		l.	Axial and radial threaded holes with Go-No-Go gauge after hydroproof	AAJ011

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

D,H		a.	Aft Segment and Fixed Housing holes are clean and free from debris and foreign material prior to assembly	AGJ007
D		b.	Fixed Housing vent ports and leak check ports are cleaned and free from foreign material	AGJ023
D		c.	Aft Segment Boss and Fixed Housing Aft end holes are free from damage including scratches, pits, galls, and burrs prior to assembly	AGJ104
D		d.	Fixed Housing aft end leak check port is free from damage prior to installation of the leak check port plug	AGJ015
D		e.	Fixed Housing aft end vent port is free from damage prior to installation of the Adjustable Vent Port Plug	AGJ015A
D		f.	Sealant is applied around bolt heads	AGJ215
D		g.	Sealant is applied around joint seam	AGJ216
D,I		h.	Leak check vent ports have protective plugs installed	AGJ148
H		i.	Axial bolts are torqued in proper sequence prior to leak test	AGJ076
H		j.	Radial Bolt, Machine is torqued to proper specification prior to leak test	AGJ211
H		k.	Radial bolts are torqued in proper sequence prior to leak test	AGJ210
H		l.	Fixed Housing surface by black light inspection for proper grease application	AGJ120
H		m.	Proper location of all bolts	AGJ205
H	(T)	n.	Axial and Radial bolts are tightened with a snug torque and angle-of-twist	AGJ238
H		o.	Axial bolts are coated with lubricant on grips and under heads	AGJ075
H		p.	Radial bolts are coated with lubricant on grips and under heads	AGJ209

H	q.	Molykote spray lubricant is applied to the threads of the axial bolts and air dried before installation per the process specification	LHA047
H	r.	Molykote spray lubricant is applied to the threads of the radial bolts and air dried before installation per the process specification	LHA048
D,H	s.	Application of lubricant to aft dome axial and radial surfaces	BAA600
	13.	For New Case Assembly, Aft Dome, Painted verify:	
D	a.	Shelf life and environmental history, paint and primer	FAA090,FAA091
D	b.	For application of paint and primer, facilities and equipment are clean	FAA092
D	c.	For application of paint and primer, humidity and case temperature	FAA098
D	d.	Surfaces to be primed are clean and free from contamination	FAA097
D	e.	Container is covered after mixing, paint and primer	FAA099,FAA100
D	f.	Full cover coat, paint and primer	FAA093,FAA094
D	g.	Runs, sags, drips, and inclusions are acceptable per specification, paint and primer	FAA095,FAA096
D	h.	Dry film thickness, paint and primer	FAA101,FAA102
	14.	For Shipping Kit-Segment, verify:	
I	a.	Transportation EDR data is acceptable	RAA232
	15.	KSC verifies:	
I	a.	Segments and nozzle components are free of damage per OMRSD File V, Vol I, B47SG0.061.	OMD079