

CRITICAL ITEMS LIST (CIL)

No. 10-02-01-42R/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1R
SUBSYSTEM:	Nozzle Subsystem 10-02	PART NAME:	Fixed Housing-to-Aft End Ring Joint, Primary O-ring, Packing with Retainer (2)
ASSEMBLY:	Nozzle and Aft Exit Cone 10-02-01	PART NO.:	(See Section 6.0)
FMEA ITEM NO.:	10-02-01-42R 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:	342-1ff.	HAZARD REF.:	BN-03
DATED:	31 Jul 2000	DATE:	
CIL ANALYST:	B. A. Frandsen		
APPROVED BY:			

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 any packing with retainer
- 3.0 FAILURE EFFECTS: Failure could result in hot gas flowing through the joint resulting in burn-through and loss of nozzle, causing a thrust imbalance between SRBs, and causing 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 and packing with retainer dimensions	B
1.3	O-ring and packing with retainer cut or damaged	C
1.4	Nonconforming O-ring voids, inclusions, or subsurface indications and nonconforming packing with retainer voids or inclusions	D
1.5	Age degradation of O-ring and packing with retainer	E
1.6	Moisture and/or fungus degradation of O-ring and packing with retainer	F
1.7	O-ring gland or packing with retainer mating surfaces do not meet dimensional or surface finish requirements	G
1.8	O-ring, packing with retainer, or special washer 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

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5.0 REDUNDANCY SCREENS:

- SCREEN A: Fail--The leak test procedure verifies the Packing With Retainers. The primary O-ring cannot be verified due to blockage of potential leak paths by sealant.
- SCREEN B: Fail--The O-ring and Packing With Retainer failure cannot be detected by the crew.
- SCREEN C: Pass--The O-ring and Packing With Retainer cannot be lost by a single credible cause or event.

1. The primary O-ring, and Packing with Retainer, together, form part of a redundant seal system at the Fixed Housing-to-Aft End Ring, Nozzle Joint (Joint 5). The Packing with Retainer will not be pressurized unless the primary O-ring fails. If the primary O-ring fails, the Packing with Retainer will be pressurized and still maintain a seal. If both the primary O-ring and any Packing with Retainer fail, a leak path will exist and could result in loss of crew and vehicle.

6.0 ITEM DESCRIPTION:

1. The Fixed Housing-to-Aft End Ring Joint has a primary O-ring and Packing with Retainer. The assembled joint is shown per Figures 1, 2, and 3 for the nozzle nose-throat-bearing-cowl-housing assembly. Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U79153	Nose-Throat-Bearing-Cowl Housing Assembly, Nozzle			1/motor
1U75150	Packing, Preformed Fluorocarbon	Black Fluorocarbon Rubber	STW4-3339	1/motor
1U52833	Aft End Ring			1/motor
1U52945	Housing, Nozzle Fixed			1/motor
1U51369	Washer, Special	4130 Alloy Steel	AMS-6351 QQ-P-416	72/motor
1U75374	Packing with Retainer	4130 Alloy Steel With Fluorocarbon Rubber	MIL-S-18729, QQ-P-416, MIL-R-83248 Type I, Class 1	72/motor
1U76385	Screw	Alloy Steel with Cadmium Plating	FF-S-86 NAS 1351 QQ-P-416	72/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

6.1 CHARACTERISTICS:

1. The Fixed Housing-to-Aft End Ring Joint allows the fixed housing to be mounted to the aft end ring. The unit is assembled with O-rings and bolts (with packing with retainer and washers) to assure there is no leakage.
2. The primary O-ring and packing with retainer, at the Nozzle Fixed Housing-to-Aft End Ring Joint, are designed so that seals maintain constant contact with their cavities at all times. Squeeze, fill, and tracking are taken into account relating to O-ring gland tolerance.
3. Packing with retainer, special washers, screws, and primary O-ring are one-time-use items.
4. The joint and seals are an important part of the assembled rocket motor case. The assembled RSRM is a



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combustion chamber made up of segments and the nozzle. It is sealed with O-rings and packing with retainer, 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

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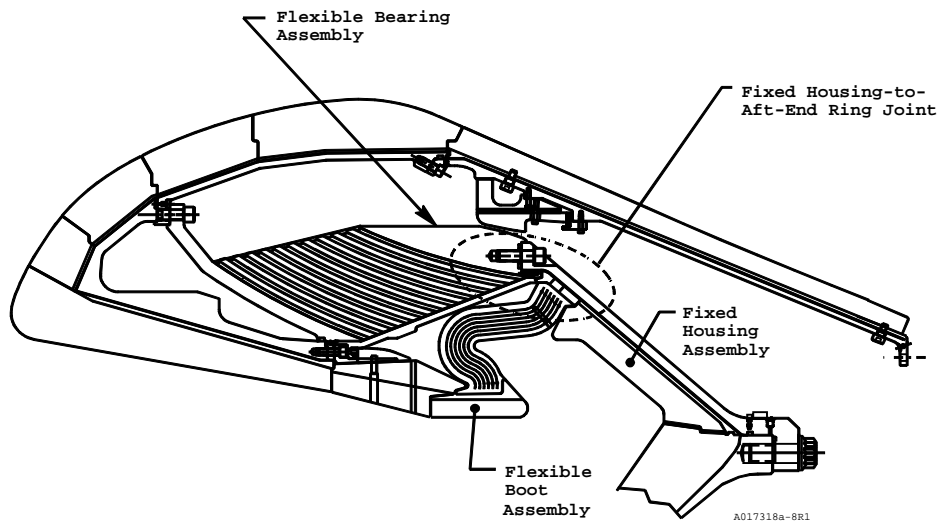


Figure 1. Fixed Housing-to-Aft End Ring Joint Location

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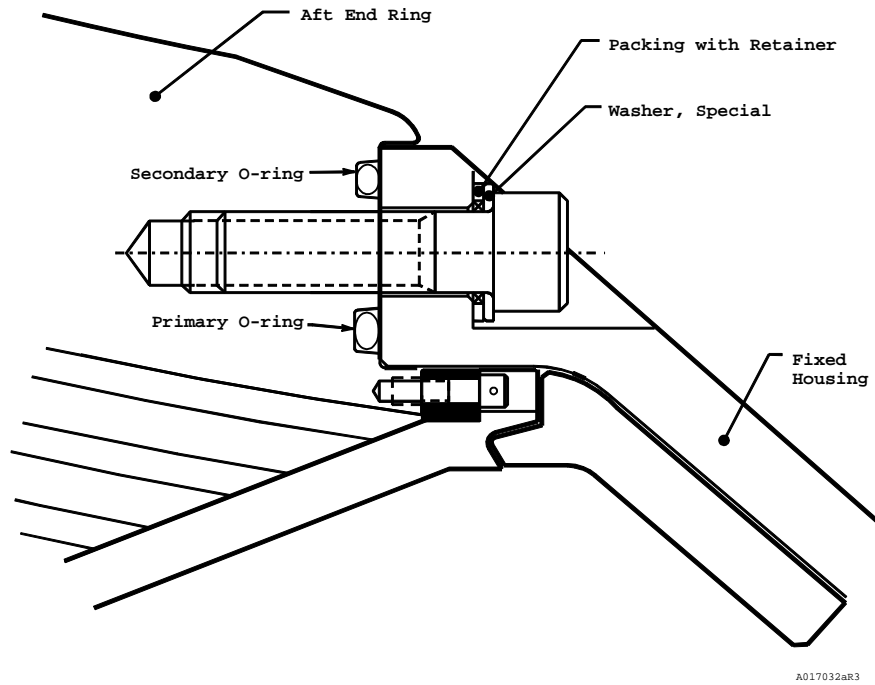


Figure 2. Fixed Housing-to-Aft End Ring Joint Packing with Retainer

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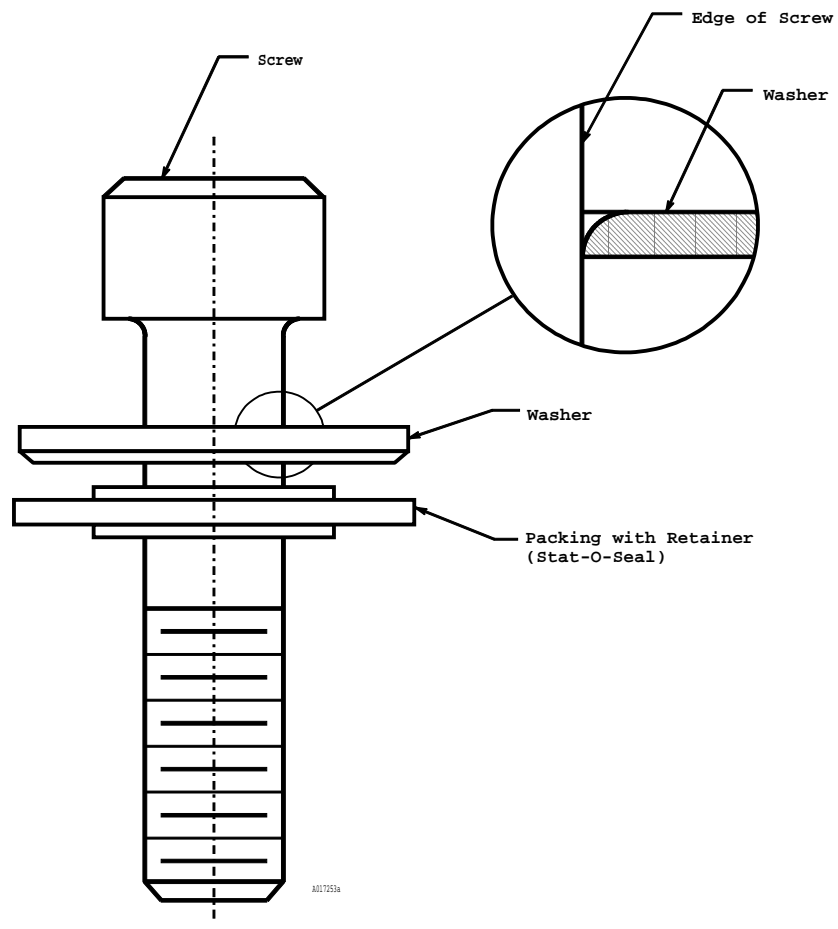


Figure 3. Packing with Retainer, Washer, and Screw Assembly

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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 | 3. | Packing with retainer is a net-molded seal with no splices. |
| A,D | 4. | O-rings were tested to determine size and types of flaws that could cause sealing problems per TWR-17750 and TWR-17991. |
| A,B,C,D,G,H,I,J | 5. | A pressure test is performed per engineering. This test verifies the packing with retainer seal but the primary O-ring, is not conclusively verified due to possible masking of potential leak paths by joint sealants. |
| B | 6. | Large O-ring dimensions are determined by Thiokol Design Engineering calculations for squeeze, tracking, and fill per TWR-15771. |
| B | 7. | Criteria determining primary O-ring dimensions are per TWR-15771. |
| B | 8. | Primary O-ring design provides constant contact between the O-ring and mating sealing surfaces. |
| B,D | 9. | Packing with retainer is per engineering that establishes geometric dimensions and fabrication details. |
| C,H | 10. | Large O-rings are individually packaged per engineering. |
| C | 11. | Packing with retainer is individually packaged per engineering. |
| C,H | 12. | Large O-ring design allows for a minimum of stretching during installation without damage to the O-ring per engineering. |
| C,H | 13. | The packing with retainer, special washer, and screw are installed per engineering. |
| C | 14. | Material selection for O-ring and packing with retainer elastomer was based in part on resistance to damage per TWR-17082 and TWR-17155. |
| H | 15. | Use of packing with retainer is qualified per TWR-17078 and TWR-17155. |
| C,H | 16. | Design development testing of O-ring twisting and its effect on performance is per ETP-0153 and TWR-17991. |
| H | 17. | Packing with retainer rubber is mechanically and adhesively bonded to the retainer. The mechanical bond is built into the design of the retainer. |
| D | 18. | Large O-rings are per engineering that establishes geometric dimensions and fabrication details. |
| D | 19. | Acceptance criteria for packing with retainer elastomer defects are per engineering. |

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- E 20. 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 21. Large O-ring time duration of supplier storage and total shelf life prior to installation is per engineering.
- E 22. Packing with retainer time duration of supplier storage and total shelf life prior to installation is per engineering.
- E 23. Aging studies of O-rings after 5 years installation life were performed. Test results are also 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 24. O-rings and packing with retainer are one-time-use items.
- E 25. 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 26. 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 27. Large O-rings, packing with retainer, and filtered grease are included in the aft segment life verification.
- F 28. Large O-rings are black fluorocarbon rubber.
- F 29. Packing with retainer sealing material is fluorocarbon rubber.
- F 30. 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 31. Fluorocarbon rubber is a non-nutrient to fungus growth (O-ring Handbook, ORD 5700, Copyright 1982, by Parker Seal Group, Lexington, KY).
- F 32. Large O-ring and packing with retainer are kept dry and clean prior to packaging.
- G 33. Primary 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 34. Surface finish on the fixed housing packing with retainer sealing surface is per engineering drawings.
- G 35. Screw dimensional and surface finish requirements are per engineering drawings.
- G 36. Washer, Special and Packing with Retainer dimensions are per engineering drawings.

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- G 37. Sealing surface requirements during refurbishment are per engineering drawings and specifications.
- G 38. The special washer and screw are one-time-use items.
- I 39. Transportation and handling of nozzle assembly items by Thiokol is per IHM 29.
- I 40. The RSRM and its component parts, when protected 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, retrieval, and refurbishment sites.
- I 41. 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 42. Support equipment used to test, handle, transport, and assemble or disassemble the RSRM is certified and verified per TWR-15723.
- I 43. 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 44. 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 45. Filtered grease is applied to sealing surfaces of the nozzle nose-throat-bearing-cowl-housing assembly during final assembly processes.
- J 46. Filtered grease filtering is per engineering to control contamination.
- J 47. Removal of surface contamination or corrosion is a standard shop practice used whenever contamination or corrosion is noted.
- J 48. Contamination control requirements and procedures are per TWR-16564.
- K 49. Packing with retainer material requirements are per engineering as follows:
 - a. The retainer is a heat treated 4130 alloy steel per MIL specifications and cadmium plating per Federal Specifications.
 - b. Sealing material is high-temperature, low-compression set, fluid-resistant, fluorocarbon rubber.
- K 50. Large O-rings are high-temperature, low-compression set, fluid-resistant, black fluorocarbon rubber.
- K 51. Washer, Special material requirements are per engineering as follows:
 - a. Heat treated alloy steel per MIL specifications
 - b. Cadmium plated per engineering
- K 52. Mechanical properties of the Screw are per engineering.



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|-----------|-----|---|
| K | 53. | Filtered grease is per engineering drawings and conforms to material requirements determined by Thiokol engineering. |
| K | 54. | Temperature prior to launch is monitored for the nozzle flexible bearing and the case-to-nozzle joint and is maintained to requirements per TWR-15832. The fixed housing-to-aft end ring 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 | 55. | 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 | 56. | 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. |

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9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TESTS (T)	CIL CODES
	1. For New Nose-Throat-Bearing-Cowl Housing Assembly, Nozzle verify:	
A,B,C,D, G,H,I,J (T)	a. Joint seals are pressure tested	ADQ114
H	b. Correct identification of primary O-ring at time of installation	ADQ052
H	c. Correct identification of packing with retainer at time of installation	ADQ054
C,H	d. Installation and fit of primary O-ring	ADQ079
C,H,J	e. Packing with retainer is properly installed and free of contamination	ADQ191
H	f. Fixed housing to aft end ring screw torquing sequence	ADQ233
C,H	g. Washer, Special, is installed with radius side toward head of fixed housing to aft end ring screw	ADQ241
H	h. Amount of torque used on each fixed housing to aft end ring screw	ADQ262
C,H	i. Condition of primary O-ring after installation into O-ring groove	ADQ001
H,J	j. Application of filtered grease to Aft End Ring O-ring grooves prior to assembly	ADQ012
H	k. Application of filtered grease to primary O-ring prior to assembly	ADQ021
H,J	l. Application of filtered grease to packing with retainer prior to installation	ADQ026
H,J	m. Filtered grease is applied to Housing, Nozzle Fixed packing with retainer sealing surfaces	ADQ027
C	n. Primary O-ring is free from damage prior to installation	ADQ159
C,I	o. Packing with retainer is free from damage prior to filtered grease application	ADQ244
E	p. Shelf life of the filtered grease was not exceeded prior to use	LAA049
E	q. Primary O-ring shelf life has not expired	ADQ176
E	r. Packing with retainer shelf life has not expired	ADQ251
E	s. Primary O-ring packaging was not damaged or violated prior to installation	ADQ175
E	t. Packing with retainer packaging is not damaged just prior to installation	ADQ252
F	u. Primary O-ring is free from fungus prior to installation	ADQ162
F	v. Primary O-ring is free from moisture prior to installation	ADQ163
F	w. O-ring grooves in the Aft End Ring are free from fungus prior to assembly	ADQ168
F	x. O-ring grooves in the Aft End Ring are free from moisture prior to assembly	ADQ170
F	y. Packing with retainer is free from fungus prior to filtered grease application	ADQ247
F	z. Packing with retainer is free from moisture prior to filtered grease application	ADQ248
I	aa. Fixed housing to aft end ring screw is free from damage prior to installation	ADQ190
I	ab. O-ring grooves in Aft End Ring are free from damage prior to assembly	ADQ206
I	ac. Sealing surfaces on Housing, Nozzle-Fixed forward end are free from damage prior to assembly	ADQ207
I	ad. Washer, Special, is free from damage prior to installation	ADQ240
I	ae. Packing with retainer sealing surface is not damaged prior to inserting fixed housing to aft end ring screw	ADQ250
J	af. Sealing surfaces on Housing, Nozzle-Fixed forward end are free from corrosion and contamination prior to assembly	ADQ202
J	ag. O-ring grooves in Aft End Ring are free from corrosion and contamination prior to assembly	ADQ208
J	ah. Fixed housing to aft end ring screw is free from contamination and corrosion, prior to installation	ADQ232
J	ai. Washer, Special, is free from contamination and corrosion prior	

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J to installation ADQ239
 aj. Packing with retainer is free from contamination and corrosion ADQ246
 prior to filtered grease application

2. 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		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
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	AEB034,AEB031
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

3. For New Packing with Retainer verify:

B		a.	Diameter "A"	AFC014
B		b.	Seal thickness dimension "D"	AFC063
B		c.	Retainer thickness dimension "E"	AFC052
B		d.	Diameter "C"	AFC015
C,H		e.	Rubber is adhesively bonded to each retainer	LAA042
C,E,F		f.	Each packing with retainer is packaged in the correct material	AFC046
C,D		g.	Surface quality	AFC068
F,K		h.	Seal material is fluorocarbon rubber	AFC028,AFC026
F		i.	Seals are clean and dry when packaged	AFC056
K		j.	Retainer is chrome moly steel	AEX001A
K		k.	Heat treat tensile strength	AEX001
K		l.	Cadmium plating	AFC003
K	(T)	m.	Shore A hardness of rubber	AJF013,LAA021,AJF012,LAA025
K	(T)	n.	Tensile strength of rubber	AJF015,LAA022,AJF014,LAA026
K	(T)	o.	Percent elongation of rubber	AJF017,LAA023,AJF016,LAA027
K	(T)	p.	Compression-set of rubber	AJF002,LAA024,AJF001,LAA028

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:

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E,F,J		a.	Material received in closed containers	ANO015
E,F,K		b.	Type	ANO050
E,F		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 Washer, Special verify:				
G		a.	Outside diameter	ACA033
G		b.	Inside diameter	ACA018
G		c.	Thickness	ACA043
G		d.	Surface finish	ACA022
K		e.	Material is 4130 steel	ACA000
K		f.	Heat treat tensile strength by hardness check	CIC009
K		g.	Cadmium plate	ACA038
7. For New Aft End Ring verify:				
G		a.	O-ring groove depth	ADE044
G		b.	O-ring groove diameter	ADE046
G		c.	O-ring groove surface finish	ADE047,ADE048
G		d.	O-ring groove width	ADE054
8. For Refurbished Aft End Ring verify:				
G		a.	O-ring groove surface finish	ADE068
9. For New Housing, Nozzle-Fixed verify:				
G		a.	Diameter	ADV030
G		b.	Surface finish	ADV186A,ADV187A,LAA139,LAA140
10. For Refurbished Housing, Nozzle Fixed verify:				
G		a.	Surface finish	ADV192
11. For New Screw verify:				
G		a.	By lot sample shank surface finish	AHA002
G		b.	By lot sample shank diameter	AHA001
G		c.	By lot sample grip length	AHA000
J,K		d.	Cadmium plating	LAA031
K		e.	Material (chemical and physical properties)	LAA029
K	(T)	f.	Breaking strength	LAA030
K		g.	Magnetic-particle inspection	LAA032
K	(T)	h.	Stress durability testing	LAA033
K		i.	Stress relieved	LAA034
K		j.	Embrittlement relieved	LAA035
K		k.	Locking element	LAA036
12. KSC verifies:				
E		a.	Life requirements for the expected launch schedule are met per OMRSD File II, Vol III, C00CA0.030	OMD019