ATK ALLIANT TECHSYSTEMS
THIOKOL PROPULSION

CRITICAL ITEMS LIST (CIL)

No. 10-02-01-17R/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Nozzle Subsystem 10-02	PART NAME:	Nose Inlet-to-Throat-to-Fwd End Ring Joint, Metal Components (1)
ASSEMBLY:	Nozzle and Aft Exit Cone 10-02-01		
FMEA ITEM NO.:	10-02-01-17R 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:	327-1ff.	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 Structural failure of the metal components

3.0 FAILURE EFFECTS: Seal leakage and joint deformation, causing loss of nozzle, TVC, RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Nonconforming dimensions	
1.1.1	Initial manufacturing dimensions	A
1.1.2	Metal dimensions reduced by corrosion and/or refurbishment	B
1.2	Nonconforming material	
1.2.1	Improper heat treatment	C
1.2.2	Hydrogen embrittlement of bolts	D
1.2.3	Nonconforming voids, inclusions, or other material defects	E
1.3	Stress-corrosion cracking	F
1.4	Improperly-installed bolts	G
1.5	Transportation, handling, or assembly damage	H
1.6	Fatigue	I
1.7	Improper assembly techniques	J

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

1. Nose Inlet-to-Throat-to-Forward End Ring Joint (Figure 1,2,3) is a part of the Nozzle Assembly, Final and consists of metal components. The nose inlet assembly consists of an aluminum superstructure that interfaces with the throat assembly and forward end ring. Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U79144	Throat-Inlet Assembly Nozzle			1/motor
1U79324	Bearing Assembly, Nozzle Flexible			1/motor
1U79146	Nose-Throat Assembly, Nozzle			1/motor
1U79147	Nose-Throat-Bearing Assembly, Nozzle			1/motor
1U79149	Nose-Throat-Bearing Cowl Assy, Nozzle			1/motor
1U75398	Housing Assembly-Nose Inlet, Nozzle	7075-T73 Aluminum	STW3-3155 TT-P-1757	1/motor
1U75547	Housing, Throat-Support, Nozzle	D6AC Steel	STW4-2709	1/motor
1U78785	Forging, Throat Housing, Nozzle	D6AC Steel	STW4-2709	1/motor
1U75756	Screw	Alloy Steel Cadmium Plating	STW3-1553 NAS1351 QQ-P-416	60/motor
1U52834	Ring, Bearing Assembly, Forward	D6AC Steel	STW4-2709	1/motor
8U50800	Shipping Kit-Segment			A/R
	Corrosion Preventive Compound and O-Ring Lubricant	Heavy-Duty Calcium Grease	STW5-2942	A/R
	Primer Coating, Corrosion-Resistant, Epoxy Resin	Epoxy Resin, Corrosion-Resistant	STW5-2914	A/R
	Enamel Protective Coating, Epoxy Resin	Epoxy Resin, Enamel	STW5-2922	A/R
	Coatings, Epoxy-Polyamide	Epoxy and a Polyamide Resin Activator	STW5-3225	A/R
	Primer, Zinc-Rich Epoxy-Polymide	Pigmented Epoxy Resin Base & a Polyamide Resin Activator	STW5-3226	A/R
	Helical Insert	CRES (AMS 7245)	MS124700 NASM124700	A/R
	Chemical Coating	Alodine 1200 Chemical Coating	MIL-C-5541, Class 1A	A/R
	Sealant, Polysulfide	Synthetic Rubber, Polysulfide	STW5-9072	A/R

6.1 CHARACTERISTICS:

1. There are five main joints in the nozzle support structure. This CIL describes the nose inlet-to-throat inlet joint that consists of the nose inlet housing and the throat support housing, joined by the same bolt circle that also connects the flex bearing forward end ring. The throat inlet housing supports the nozzle throat assembly and connects ultimately to the forward exit cone assembly (Figures 1, 2, and 3). This joint is assembled per engineering drawings.

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

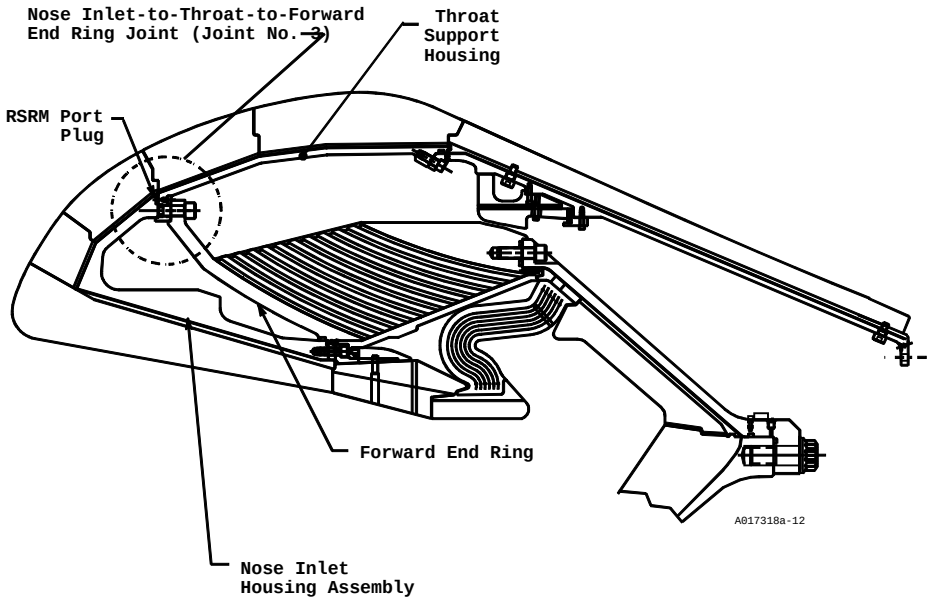
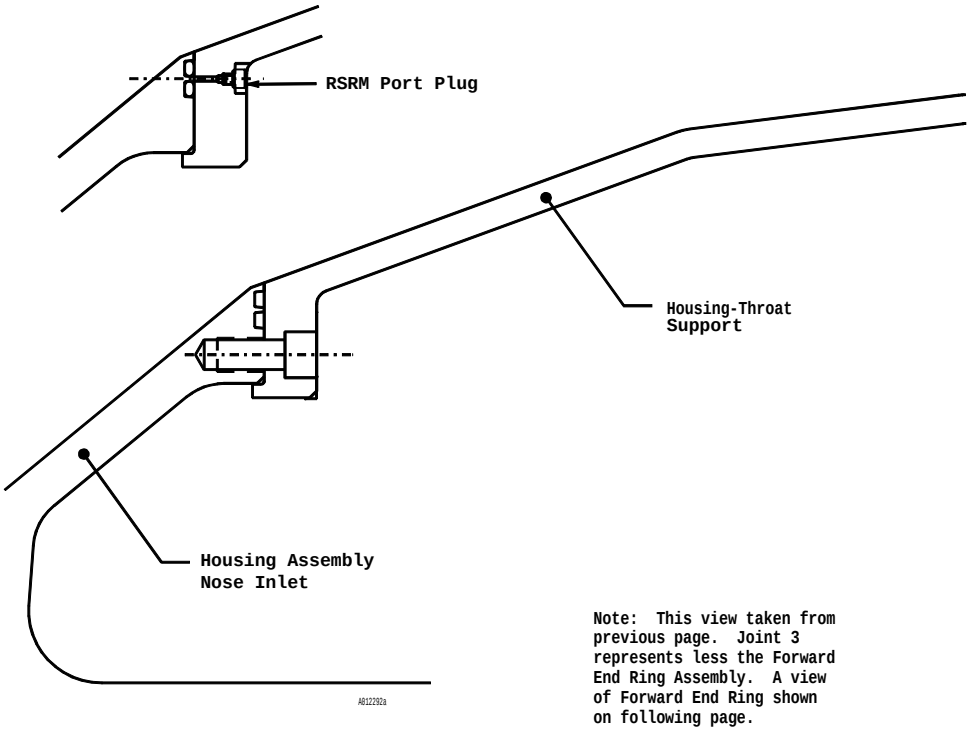


Figure 1. Nose Inlet-to-Throat-to-Forward Eng Ring Joint, Metal Components Location



Note: This view taken from previous page. Joint 3 represents less the Forward End Ring Assembly. A view of Forward End Ring shown on following page.

Figure 2. Nose Inlet-to-Throat-to-Forward End Ring Joint, Metal Components

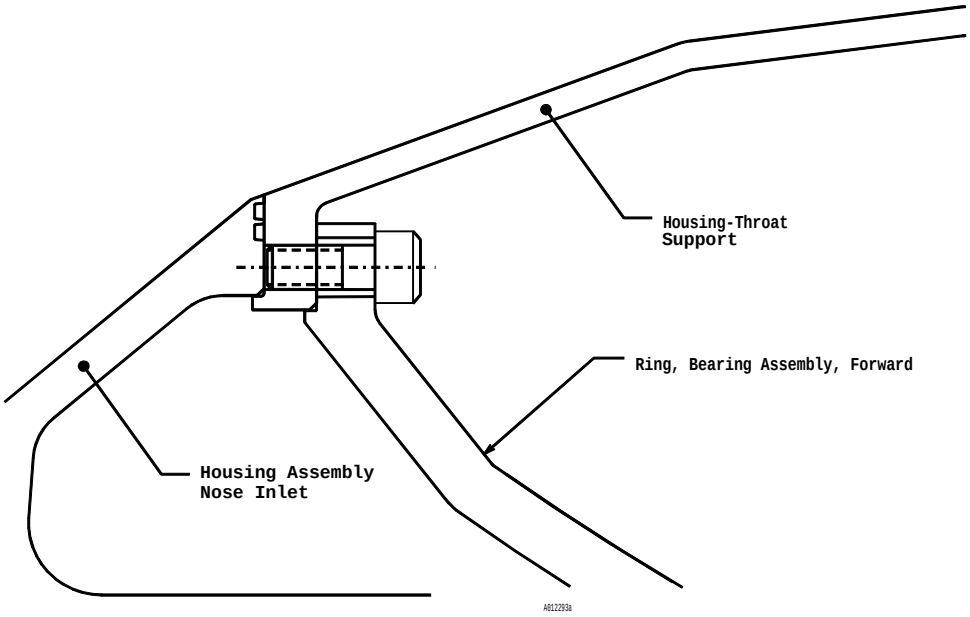


Figure 3. Nose Inlet-to-Throat-to-Forward End Ring Joint, Metal Components, Joint 3

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN FAILURE CAUSES

1. Forward End Ring-to-Throat Joint:

A	a.	Forward end ring dimensions are per engineering drawings.
B	b.	Refurbished forward end ring dimensions are per engineering drawings and specifications.
A,B	c.	Bare surfaces of the forward end ring are protected from corrosion per engineering.
A,B	d.	Corrosion protection is provided for the forward end ring per engineering.
A,B	e.	Primer and top coating are applied to the inner and outer surfaces of the forward end ring for corrosion prevention.
A	f.	Attach hardware screw dimensions are per the National Aerospace Industry Specification and engineering drawings. These are a one-time-use item.
A,B	g.	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.

2. Nose Inlet-to-Throat:

A	a.	Nose inlet housing dimensions are per engineering drawings.
B	b.	Refurbished nose inlet housing dimensions are per engineering.
A	c.	Throat support housing dimensions are per engineering drawings.
B	d.	Refurbished throat support housing dimensions are per the engineering.
A,B	e.	Corrosion protection for the throat support housing is applied per engineering.
A,B	f.	Zinc-rich, epoxy-polyamide primer and epoxy-polyamide coatings are applied to the outside diameter surface of the throat support housing for corrosion prevention for the throat inlet assembly.
A	g.	Attach hardware screw dimensions are per National Aeronautics Specifications for the nose throat assembly. These are a one-time-use item.
A,B	h.	Filtered grease is applied to interface surfaces at assembly of mating parts for the nose throat assembly.
A,B	i.	The nose inlet housing is coated with alodine per engineering.
A,B	j.	Nose inlet housing threads and helical inserts are coated with primer prior to insert installation for the housing assembly, nose/inlet, nozzle.
A,B	k.	Helical insert dimensions are specified for each NASM part. These are one-time-use items.
A,B	l.	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.

A,B,G,J 3. Effects of galvanic corrosion due to dissimilar metal interaction are described per Material Use Agreement.

C 4. The nose inlet housing is made from a heat treated 7075-T73 aluminum forging.

C 5. The throat support housing and forward end ring are made of forged and heat treated D6AC steel.

C,D 6. Bolts are cadmium plated alloy steel, baked to prevent hydrogen embrittlement. Bolts are not reused.

C,D 7. Bolts and bolt holes are coated with filtered grease for the nose throat assembly and the nose throat bearing assembly.

C,D 8. Bolts manufactured after 01 Jan 1987 are per National Aeronautics Specification (NAS) standards, that includes a bake-out treatment to reduce hydrogen content. Bolts are identified per engineering drawings.

C,D,E 9. The design verification analysis shows that materials and geometry of the nose inlet housing, fwd end ring and throat support housing are acceptable for flight per TWR-18764-09.

D,E 10. As part of the post-flight inspection plan, char and erosion of the nozzle insulation is inspected and analyzed. If char and erosion of the insulation is determined to be such that the supporting aluminum housing was exposed to high temperature, the suspect housing is analyzed. For Qualification and Production Verification motors char and eroding data were recorded per TWR-16473. For flight motors these data are recorded per TWR-50051.

11. The nose inlet-to-throat joint consists of the following parts:

F,I a. The nose inlet housing is an aluminum forging.
F,I b. The forward end ring is a D6AC steel heat treated forging.
F,I c. The throat inlet housing is a D6AC steel heat treated forging.

F,I 12. Forgings were evaluated per JSC specifications for grain pattern and anomalies that might induce residual strain and were found to meet requirements per TWR-10713, TWR-10711, and TWR-10717.

F,I 13. Analysis for useful life of the nose inlet housing, forward end ring and throat support housing is per TWR-16875.

14. The possibility of stress corrosion or fatigue damage to these parts during their service life is as follows:

a. Nose inlet housing:

A,F,I 1) TWR-16975 shows the nose inlet housing to have a positive margin of safety based on a factor of safety of 1.4 ultimate and 1.1 on yield.

A,F,I 2) The basic forging was analyzed per JSC specification SE-R-0006 and reported in TWR-10711. This report shows the forging to be free of re-entrant or sharply folded lines and the principal grain flow is oriented parallel with the principal stresses expected.

b. Throat support housing:

A,F,I 1) The throat support housing is a fracture control item per TWR-16875. TWR-16875 documents that after passing surface inspection, any undetectable flaw will not propagate to a critical size in four additional missions before the next inspection. Structural verification analysis per TWR-16975 shows the maximum stress obtained during operation will have a positive margin of safety using the factor of safety of 1.4 ultimate and 1.1 on yield.

A,F,I 2) The basic forging was evaluated per JSC specification SE-R-0006 and reported in TWR-10717. Analysis showed the forging to be free from re-entrant or sharply folded lines. Mechanical properties meet or exceed design requirements.

c. Forward end ring:

A,F,I 1) TWR-16875 includes this part since it's design was per cyclic or repeated load conditions. Fatigue analysis was performed for low-cycle fatigue, high-cycle fatigue, and fracture mechanics. Results indicate that the forward end ring design substantially exceeds the service life requirement.

A,F,I 2) The forging was evaluated per JSC specifications and TWR-10713. The report stated: The micro-cleanliness examination revealed the material meets all requirements. Macro-structure examination showed that the forging process produced a part free from re-entrant or sharply-folded flow lines and that all mechanical properties met or exceeded design requirements.

G,J 15. A thin coating of filtered grease is applied to the helical-coil inserts prior to installation of socket head cap screws for the nose throat assembly.

G,J 16. Bolt torque and tightening sequence of the nose inlet-to-throat-to-forward end ring joint is per engineering drawings and shop planning.

G,J 17. The screws used in assembling the forward end ring, nose inlet housing, and throat support housing are self-locking per engineering.

G,J 18. Prior to installation, all socket head cap screws must meet cleanliness requirements per shop planning.

G,H,J 19. During assembly, care is taken to assure that threaded inserts are not damaged. Damaged inserts are replaced per the refurbishment specification.

F,I 20. Assembly stresses are minimized as follows:

a. Mating surface flatness is per inspection of machining operations
b. Threads are cleaned and lubricated prior to assembly
c. Assembly bolts are torqued in a prearranged sequence to preload values

H 21. Transportation and handling of the nozzle assembly and case segments by Thiokol is per IHM 29.

H 22. Requirements for handling SRM components during assembly, storage, and transportation are similar to those for previous and other current programs at Thiokol. Those requirements dictate RSRM case segments are handled by or near a joint to avoid damage. All lifting hooks and slings are fitted with safety hooks per TWR-13880.

H 23. 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.

H 24. Shop procedures are developed to minimize errors during handling and assembly. Nozzle components are tagged, "program critical hardware," per shop planning.

H 25. Support equipment used to test, handle, transport, and assemble or disassemble the RSRM is certified and verified per TWR-15723.

H 26. 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.

H 27. The throat assembly is covered with a protective cover and stored in a temperature-controlled building until used as a part of a larger assembly.

H 28. 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.

F,H,I 29. 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 F,H,I 30. 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 nose inlet assembly and the throat 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 TEST (T)			CIL CODE
		1.	For New Housing Assembly-Nose/Inlet, Nozzle verify:	
A		a.	Alodine coating applied to designated surfaces	AFE001
A		b.	Flatness	AFE008,AFE009,AFE012,AFE013
A		c.	Diameter	AFE016,AFE017,AFE021,AFE022,AFE025,AFE026
A		d.	Height	AFE049,AFE050
A		e.	Primer applied to surface	AFE120
A		f.	Profile	AFE123,AFE126
A		g.	Run out	AFE135,AFE136,AFE139,AFE140
A		h.	Top coating applied to surface	AFE159
A		i.	True position	AFE160,AFE160A,AFE161,AFE161A
C,D,E		j.	Heat treat	AFE065
C,D,E,F,I		k.	Material composition	AFE080
D,E		l.	Dye penetrant	AFE030
D,E	(T)	m.	Ultrasonic	AFE165
D,E,F,I	(T)	n.	Electrical conductivity	AFE039
C,D,E,F,I	(T)	o.	Elongation	AFE083B
C,D,E,F,I	(T)	p.	Ultimate strength	AFE083
C,D,E,F,I	(T)	q.	Yield strength	AFE083A
		2.	For Refurbished Housing Assembly-Nose/Inlet Nozzle verify:	
B		a.	Diameter	AFE015
B		b.	Height	AFE048
B		c.	Straightness	AFE101,AFE103,AFE105,AFE107,AFE152
B		d.	Roundness	AFE130,AFE132
B,C		e.	Flatness	AFE154,AFE156
B		f.	Wall thickness	AFE168
D,E		g.	Dye penetrant	AFE033
C,D,E,F,I		h.	Painted surfaces for indications of heat degradation	AFE097
		3.	For New Housing, Throat Support, Nozzle verify:	
A		a.	Corrosion protection is per specification	AFN007
A		b.	Flatness	AFN030,AFN031
A		c.	Diameter	AFN043,AFN044,AFN047,AFN048
A		d.	Profile	AFN130,AFN129,AFN160,AFN161
A		e.	Minimum full thread	AFN164,AFN165
A		f.	Minor diameter max depth	AFN171,AFN172
A		g.	True position	AFN175,AFN175A,AFN175B,AFN176,AFN176A,AFN176B
A		h.	Thickness	AFN197,AFN198,AFN200,AFN201
A		i.	Run out	CIC011,CIC012,CIC013,CIC014
D,E,F,I	(T)	j.	Carburization	AFN019
D,E,F,I	(T)	k.	Decarburization	AFN033
C,D,E,F,I	(T)	l.	Ultimate strength	AFN121
C,D,E,F,I	(T)	m.	Reduction in area	AFN121C
C,D,E,F,I	(T)	n.	Yield strength	AFN162A
C,D,E,F,I	(T)	o.	Elongation	AFN162B
D,E,F	(T)	p.	Magnetic particle	AFN107
		4.	For Refurbished Housing, Throat Support, Nozzle verify:	
B		a.	Diameter	AFN042,AFN046

B		b.	Height	AFN058
B		c.	Straightness	AFN126,AFN127,AFN128
B		d.	Roundness	AFN132,AFN135
B		e.	Thickness	AFN196,AFN199
C,D,E,F,I	(T)	f.	Magnetic particle	AFN096

5. For New Ring, Bearing Assembly, Forward verify:

A		a.	Diameter dimension	ADF006,ADF007,ADF009,ADF010
A		b.	Thickness	ADF018,ADF019
A		c.	Height	ADF023,ADF024
A		d.	Flatness	ADF025,ADF026
A		e.	Corrosion protection is per specification	ADF034
A		f.	Run out	ADF060,ADF061,ADF065,ADF066,ADF068,ADF069
A		g.	True position	ADF086,ADF086A,ADF087,ADF087A
F,I		h.	Chemical composition	ADF001
C,D,E,F,I		i.	Heat treat	ADF033
D,E,F,I	(T)	j.	Magnetic particle	ADF046,ADF044
C,D,E,F,I		k.	Material	ADF050
F,I	(T)	l.	Ultimate strength	ADF052
F,I	(T)	m.	Yield strength	ADF052A
F,I	(T)	n.	Elongation	ADF052B
F,I	(T)	o.	Reduction of area	ADF052C
F,I	(T)	p.	K_{IC} (fracture toughness)	ADF052D
F,I	(T)	q.	Ultrasonic inspection	ADF092,ADF090

6. For Refurbished Ring, Bearing Assembly, Forward verify:

B		a.	Diameter dimension	ADJ068,ADJ066
B		b.	Roundness	ADJ069,ADJ067
B		c.	Height	ADF022
D,E,F,I	(T)	d.	Magnetic particle	ADF039

7. For New Nose-Throat-Bearing Assembly, Nozzle verify:

G,J		a.	Tightening sequence of cap screws	ADO057
G,J		b.	Torque of cap screws	ADO058
G,J		c.	Cap screws locking device and part number acceptable	ADO055
G,J		d.	Filtered grease dispensed from preloaded cartridges	ADO018
G,J		e.	Cap screws installed properly	ADO054
G,J		f.	Cap screws are free of visible and obvious contamination	ADO056
A		g.	Application of filtered grease	ADF029,ADO027,HHH060,HHH065
A		h.	Sealant applied to and around fastener heads	ADO050

8. For New Screw, verify:

A		a.	Lot number	AFZ062
A		b.	Length from bottom of screw head to end of screw	AFZ024
A		c.	Thread form diameter (major diameter, pitch)	AFZ041
A		d.	Certificate of Conformance accompanies each screw shipment	AFZ075
C,D,E		e.	Baking	AFZ004
C,D,E,F,I	(T)	f.	Parts are manufactured from specified material	AFZ069
D,E		g.	Parts are cadmium plated	AFZ013
C,D,E,F,I	(T)	h.	Stress durability	AFZ070
C,D,E,F,I	(T)	i.	Tensile properties	AFZ058

9. For New Bearing Assembly, Nozzle Flexible verify:

A,B	a.	Epoxy-polyamide coating applied to designated surfaces	ADJ108
A,B	b.	Epoxy-polyamide primer applied to designated surfaces	ADJ110
H	c.	No handling damage prior to installation of bearing hardware	AAI014
	10.	For New Throat Inlet Assembly, Nozzle verify:	
A	a.	Primer applied to outside diameter surface of throat support housing	AAW071
A	b.	Top coating applied to outside diameter surface of throat support housing	AAW113
	11.	For New Nose-Throat Assembly, Nozzle verify:	
G,J	a.	Filtered grease is dispensed from preloaded cartridges during assembly	ADN030
G,J	b.	Socket head capscrews locking device is acceptable at installation	ADN031
G,J	c.	Socket head capscrews part number is acceptable at installation	ADN031A
G,J	d.	Socket head capscrews are free of visible and obvious contamination prior to installation	ADN116
G,J	e.	Tightening sequence of socket head capscrews (throat inlet-to-nose inlet) per planning requirements	ADN125
G,J	f.	Torque value of socket head capscrews in throat inlet-to-nose inlet per planning requirements	ADN127
	12.	For New Insert, Helical Coil, verify:	
A	a.	Material is corrosion-resistant steel	RHB001
	13.	For Refurbished Bearing Assembly, Nozzle Flexible verify:	
C,D,E,F,I (T)	a.	Tensile leak test.	ADJ064A
	14.	For New Nozzle Assembly, Final verify:	
H	a.	Parts tagged "program critical hardware" per shop planning	AFZ055
	15.	For Shipping Kit-Segment, verify:	
H	a.	Transportation EDR data is acceptable	RAA232
	16.	For New Forging, Throat Housing, Nozzle QA verify:	
C,D,E,F,I (T)	a.	Chemical composition	AFN024
F,I	b.	Grain size	AFN065
F,I	c.	Inclusion rating	AFN090
F,I	d.	Macro structure	AFN091
C,D,E,F,I (T)	e.	Ultrasonic	AFN177,AFN184