THIOKOL
AEROSPACE & INDUSTRIAL TECHNOLOGIES

CRITICAL ITEMS LIST (CIL)

No. 10-05-01-08R/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1R
SUBSYSTEM:	Assembly Hardware/Interfaces 10-05	PART NAME:	Field Joint, Primary Clevis O-ring, Secondary Clevis O-ring (2)
ASSEMBLY:	Field Joints and Kits 10-05-01		
FMEA ITEM NO.:	10-05-01-08R Rev M		
CIL REV NO.:	M	PART NO.:	(See Section 6.0)
DATE:	31 Jul 2000	PHASE(S):	Boost (BT)
SUPERSEDES PAGE:	226-1ff.	QUANTITY:	(See Section 6.0)
DATED:	30 Jul 1999	EFFECTIVITY:	(See Table 101-6)
CIL ANALYST:	F. Duersch	HAZARD REF.:	BC-01
APPROVED BY:		DATE:	

RELIABILITY ENGINEERING: K. G. Sanofsky 31 Jul 2000

ENGINEERING: S. R. Graves 31 Jul 2000

1.0 FAILURE CONDITION: Failure during operation (D)

2.0 FAILURE MODE: 1.0 leakage due to primary clevis O-ring and secondary clevis O-ring failure

3.0 FAILURE EFFECTS: Failure in the primary O-ring and secondary O-ring leak path would allow hot gas to flow through this path resulting in burn through causing a loss of RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Nonconforming dimensions or improper O-ring splice joint	A
1.2	O-ring gland does not meet dimensional and surface finish requirements	B
1.3	Joint rotation	C
1.4	Improper mating of segments	D
1.5	Damage to sealing surface during transportation and handling	E
1.6	O-ring cut, damaged, or improperly installed	F
1.7	Sealing surface contamination	G
1.8	O-ring voids, inclusions, and subsurface indications	H
1.9	Low O-ring resiliency	I
1.10	Aging degradation of O-ring	J
1.11	Alignment slot induced O-ring groove mechanical deformation	K
1.12	Grease masking the leak check test results	L
1.13	Moisture and/or fungus degradation of O-ring	M

1.14 Nonconforming materials N

5.0 REDUNDANCY SCREENS:

SCREEN A: Pass--The primary and secondary O-rings are capable of verification.
SCREEN B: Fail--No burnthrough indication is available to the crew during boost.
SCREEN C: Fail--The redundant O-rings could be lost due to a single credible cause such as a scratch.

1. Primary and secondary O-rings together form a redundant seal system when the leak check port O-ring seals. The secondary O-ring will see no pressure unless the primary O-ring fails. If the primary O-ring fails, the secondary O-ring will be pressurized and still maintain a seal. If both O-rings fail, a leak path will exist and could result in loss of vehicle and crew.

6.0 ITEM DESCRIPTION:

1. Field joint, Primary Clevis O-ring, Secondary Clevis O-ring (Figure 1)

2. The field joint is assembled at KSC per engineering drawings. There are three case field joints on each RSRM with each joint including one primary and one secondary O-ring (Figure 2). Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U77648	Assembly and Closeout, RSRM, KSC	Various, Field Joint Interference Fit	STW9-3668	1/motor
1U50716	Case Seg, Attach, Light Weight	D6AC Steel	STW7-2744	1/motor
1U50717	Case Seg, Cylinder, Light Weight	D6AC Steel	STW7-2744	2/motor
1U50130	Case Seg, Attach, Standard Weight	D6AC Steel	STW7-2744	1/motor
1U52982	Case Seg, Capture Cylinder, Light Weight	D6AC Steel	STW7-2744	2/motor
1U52983	Case Seg, Capture Cyl, Standard Weight	D6AC Steel	STW7-2744	1/motor
1U75150	Packing, Preformed Fluorocarbon	Rubber O-rings	STW4-3339	6/motor
1U75801	Packing, Lubricated	Black Fluorocarbon Rubber O-ring and Lubricant	STW7-2999	6/motor
1U51916	Cartridge Assembly	HD Calcium Grease	STW7-3657	A/R

6.1 CHARACTERISTICS:

1. Field joints and their associated seals are designed to allow for handling smaller segments that could later be assembled into RSRMs.

2. Four subassemblies or segments are transported to KSC where final assembly is accomplished by joining the four segments at the field joints.

3. Seals at each field joint are designed so that the O-ring maintains constant contact with its sealing surface at all times. Squeeze and fill are taken into account relating to O-ring grooves, tolerance, swell, case growth, joint rotation, and resiliency. The design allows easy installation without overstretching.

4. Primary and secondary O-rings are one-time-use items.

5. The assembled RSRM is a combustion chamber made up of segments. It is sealed with O-rings and must contain 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

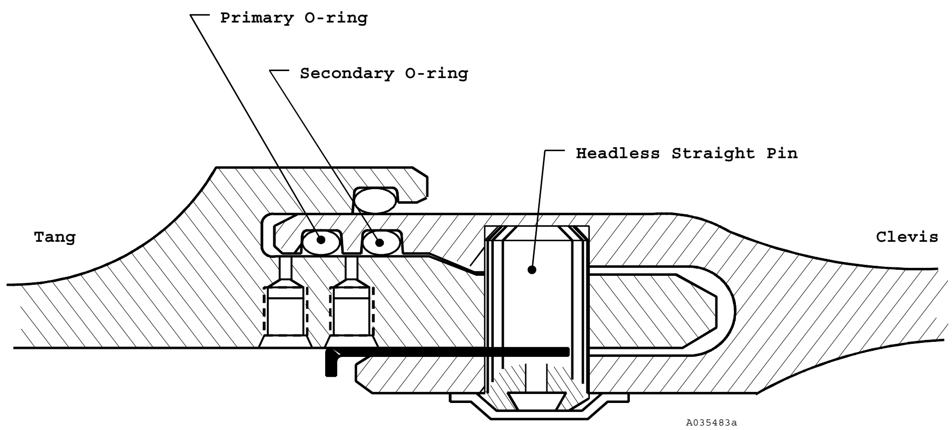

Figure 1. Primary and Secondary Clevis O-rings

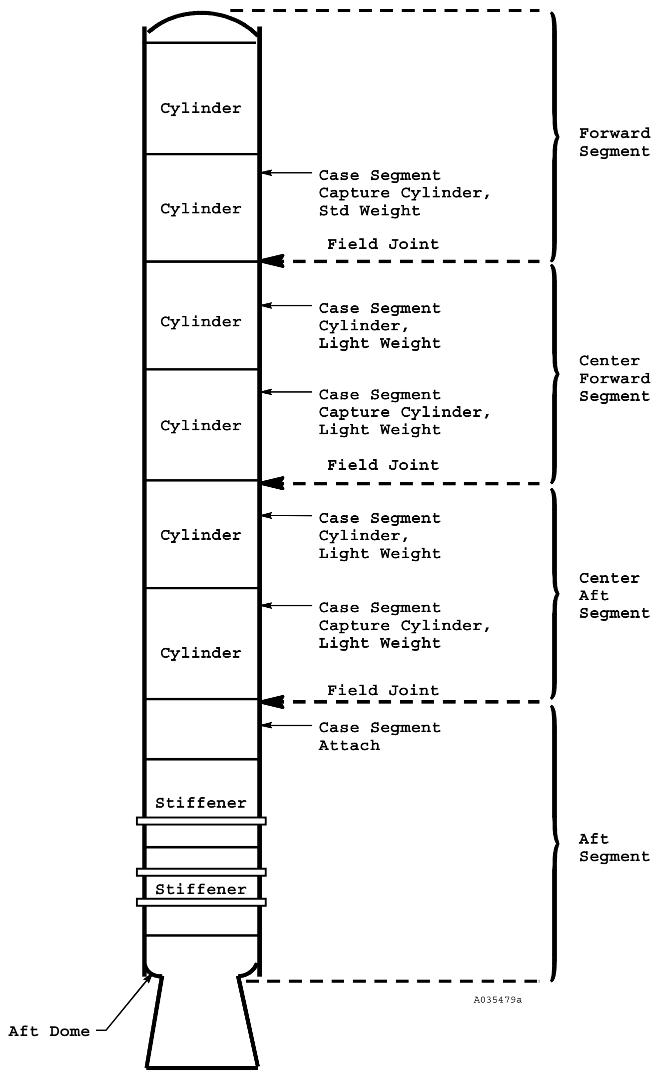

Figure 2. Field Joint Locations

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN	FAILURE CAUSES
A	1. Large O-ring dimensions are per Thiokol Design Engineering calculations for squeeze, tracking, and fill per TWR-15771.
A	2. Large O-rings are per engineering that covers process controls for fabrication of spliced joints and repairs.
A	3. Splice joints are cut on an angle and bonded together in a mold using 100 percent of the scarf area, and using an adhesive with the same physical and chemical properties as the parent stock.
A,H	4. O-rings were tested to determine sizes and types of flaws that could cause sealing problems per TWR-17991.
A	5. Both O-ring designs provide a constant contact between the O-ring and mating sealing surfaces.
B	6. Primary and secondary O-ring groove dimensions and surface finish are per Thiokol Design Engineering calculations for squeeze and fill per TWR-15771.
B	7. Clevis and tang dimensions are per engineering.
B	8. The sealing surface of the tang where the seal takes place is per engineering.
B	9. Sealing surface requirements during refurbishment are per engineering.
B	10. Qualification of sealing surface finish value is per TWR-17065.
C	11. The tang of the case segment was redesigned to provide a capture feature with custom shimming to minimize joint rotation per engineering. Selection criteria for custom shims are per engineering.
C	12. The O-ring and gland are designed to provide constant contact at all times per TWR-15771.
C	13. Squeeze and fill calculations are performed including effects of joint rotation, thermal effects, and compression set per TWR-15771 and TWR-16682.
C	14. Requirements for RSRM field joint interference fit, as determined by profile measuring device data under temperature-controlled conditions, is per engineering.
D,K	15. O-ring and sealing surface damage due to mechanical deformation is minimized by the use of the Field Joint Assembly Fixture (FJAF) which mates the RSRM field joints. Due to shipping and handling effect and propellant loads, the actual shape of the RSRMs may not be circular. Design of the FJAF minimizes the effects of mechanical deformation.
D	16. Metal segments are selected by matching dimensional fitting to obtain acceptable o-ring squeeze and interference fit per engineering. Segments that comply with drawing dimensional tolerances and criteria (within stated tolerances) provide an acceptable o-ring squeeze and interference fit.

E	17.	Transportation and handling of case segments by Thiokol while at Thiokol is per IHM 29-063.
E,G	18.	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, retrieval, and refurbishment sites.
E	19.	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.
E	20.	Support equipment used to test, handle, transport, and assemble or disassemble the RSRM is certified and verified per TWR-15723.
E	21.	Motor segments are protected during shipping by a segment shipping cover assembly per engineering.
E	22.	Railcar transportation shock and vibration levels for the segments are monitored per engineering with loads derived by analysis. Monitoring records are evaluated by Thiokol to verify that shock and vibration levels per MSFC specifications were not exceeded.
F,H,I	23.	Large O-rings are per engineering that establishes design requirements and fabrication details.
F	24.	Large O-rings are individually packaged per engineering. Storage requirements are per engineering.
F	25.	O-rings per TWR-15771 are designed for ease of installation in the groove without overstretching. The design also minimizes the risk of damage when installing mating hardware. Proper installation without overstretching is per engineering drawings.
F	26.	Material selection for the O-rings was based in part on resistance to damage per TWR-17082.
F	27.	O-ring installation is with a light coat of filtered grease per shop planning.
F	28.	Design development testing of O-ring twisting and its effect on performance was performed per ETP-0153 and TWR-17991.
G	29.	Sealing surfaces are inspected for contamination, and cleaned as necessary. 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. b. During local transportation, Thiokol uses environmentally controlled shipping containers, which allow case segments to be shipped without grease per TWR-65920.
G	30.	Removal of surface contamination or corrosion is a standard shop practice at Thiokol and KSC whenever contamination or corrosion is noted.

G	31.	Filtered grease is applied to sealing surfaces during final assembly processes per engineering drawings.
G	32.	Requirements for process environmental control are established for all critical process operations per SN-C-0005.
G	33.	Filtered grease filtering is per engineering to control contamination.
I	34.	Engineering developed an O-ring resiliency testing procedure per TWR-300186 and TWR-15774.
I	35.	Additional resiliency testing was performed on O-rings per TWR-16818 and TWR-16952.
I	36.	Temperature prior to launch is monitored for the case field joint and is maintained per TWR-15832. O-ring resiliency within required temperature boundaries is per TWR-17991.
J	37.	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.
J	38.	Large O-ring time duration of vendor storage and total shelf life prior to installation is per engineering.
J	39.	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.
J	40.	O-rings (primary and secondary) are one-time-use items.
J	41.	Grease is stored at warehouse-ambient condition which is any condition of temperature and relative humidity experienced by the material when stored in an enclosed warehouse, in unopened containers, or containers which were resealed after each use. Storage life under these conditions is per engineering.
J	42.	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 grease remained intact per TWR-61408 and TWR-64397.
L	43.	Design development tests show that the presence of excess grease requires an increase in the amount of pressure to detect a flaw. The test also shows 200 psig overcomes grease blockage per TWR-16505.
M	44.	Large O-rings are black fluorocarbon rubber.
M	45.	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).

M 46. Fluorocarbon rubber is a non-nutrient to fungus growth (O-ring Handbook, ORD 5700, Copyright 1982 by Parker Seal Group, Lexington, KY).

M 47. Large O-rings are kept clean and dry prior to packaging.

N 48. Large O-rings are high-temperature, low-compression set, fluid-resistant, black fluorocarbon rubber.

N 49. Filtered grease conforms to materials per engineering drawings and specifications.

N 50. Joint temperature for the primary and secondary O-rings prior to launch meets RSRM launch constraints for fluorocarbon O-rings per TWR-15832.

G 51. Filtered grease is included in the life verification.

I 52. Large O-rings are included in the life verification.

C 53. 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 case membranes, factory joints, and field joints per TWR-61410.

9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TESTS	(T)				CIL CODE
			1.	For New Large O-ring verify:		
	A			a.	Diameter	AEB014,AEB015,AEB018,AEB023,AEB026,AEB027
	A			b.	Correct identification	AEB100
	A			c.	Splice is bonded over 100 percent of the scarf area	AEB133,AEB134
	A			d.	No more than five splices	AEB167,AEB169
	A			e.	Repairs	AEB265,AEB266
	A			f.	Adhesive is made from fluorocarbon rubber	AEB308,AEB311
	A			g.	Splice bond integrity	AEB317,AEB319
	A,H	(T)		h.	Subsurface indications	AEB354
	A,F,H,M			i.	Surface quality	AEB388,AEB389
	A,N	(T)		j.	Tensile strength	AEB401,AEB402,AEB394,AEB396
	A,N	(T)		k.	Ultimate elongation	AEB442,AEB443,AGM408,AGW075
	C,N	(T)		l.	Compression set	AKW006,AKW011
	F			m.	Packaging is free of staples or other objects	LAA054
	M			n.	Clean and dry when packaged	AEB031,AEB034
	M,N			o.	Material is fluorocarbon rubber	AEB141,AEB151
	N	(T)		p.	Shore A hardness	AGM304,AGM312
			2.	For New Case Segment, Capture Cylinder, Standard Weight, verify:		
	B			a.	Surface finish of tang sealing surfaces	ADX125,ADX125A
	B,C			b.	Sealing surface diameter at tang	ADX015,ADX052
	C			c.	Tang thickness	ADX157,ADX157A
	C			d.	Tang sealing surface thickness	ADX156,ADX156A
	C			e.	Capture feature gap	ADX011,ADX094
	C			f.	Tang outer diameter	FAC010
	C			g.	Capture feature outer diameter	FAC012
	C			h.	Distance from Datum -A- to capture feature inner diameter	MKL013
			3.	For Refurbished Case Segment, Capture Cylinder, Standard Weight, verify:		
	B			a.	Surface finish of tang sealing surfaces	AOJ002C
	B,C			b.	Sealing surface diameter at tang	FAC014
	B,E			c.	Field joint sealing surfaces for defects	AOJ003C
	B			d.	Random surface finish measurements of tang sealing surface repairs	AOJ002X
	C			e.	Tang thickness	ADX157,ADX157A
	C			f.	Tang sealing surface thickness	ADX156,ADX156A
	C			g.	Capture feature gap	ADX011,ADX094
	C			h.	Tang outer diameter	FAC010
	C			i.	Capture feature outer diameter	FAC015
			4.	For New Case Segment, Capture Cylinder, Light Weight, verify:		
	B			a.	Surface finish of tang sealing surfaces	ADW129,ADW129A
	B,C			b.	Sealing surface diameter at tang	ADW149,ADW053
	C			c.	Tang thickness	ADW161,ADW161A
	C			d.	Tang sealing surface thickness	ADW160,ADW160A
	C			e.	Capture feature gap	ADW012,ADW098
	C			f.	Tang outer diameter	FAC201
	C			g.	Capture feature outer diameter	FAC203

C		h.	Distance from Datum -A- to capture feature inner diameter	MKL012
	5.		For Refurbished Case Segment, Capture Cylinder, Light Weight, verify:	
B		a.	Surface finish of tang sealing surfaces	AOJ002B
B,C		b.	Sealing surface diameter at tang	FAC205
B,E		c.	Field joint sealing surfaces for defects	AOJ003B
B		d.	Random surface finish measurements of tang sealing surface repairs	AOJ002Y
C		e.	Tang thickness	ADW155
C		f.	Tang sealing surface thickness	FAB231
C		g.	Capture feature gap	ADW145
C		h.	Tang outer diameter	FAC204
C		i.	Capture feature outer diameter	ADW051
	6.		For Refurbished Case Segment, Cylinder, Light Weight, verify:	
B		a.	Depth of clevis O-ring grooves	ABM028
B		b.	Width of clevis O-ring grooves	ABM174
B		c.	Surface finish of clevis O-ring grooves	AOJ003
B,E		d.	Field joint sealing surfaces for defects	AOJ003A
B		e.	Random surface finish measurements of O-ring groove repairs	AOJ003Z
C		f.	Outer clevis leg wall thickness	FAB221
C		g.	Inner clevis leg wall thickness	ABM083
C		h.	Outer clevis leg inner diameter (two places)	FAC601
C		i.	Inner clevis leg inner diameter	FAC602
	7.		For Refurbished Case Segment, Attach, Standard Weight, verify:	
B		a.	Surface finish of clevis O-ring grooves	MAA100
B		b.	Depth of clevis O-ring grooves	MAA101
B		c.	Width of clevis O-ring grooves	MAA102
B,E		d.	Field joint sealing surfaces for defects	RAA231
B		e.	Random surface finish measurements of O-ring groove repairs	MAA100Z
C		f.	Outer clevis leg wall thickness	FAB703
C		g.	Inner clevis leg wall thickness	MAA104
C		h.	Outer clevis leg inner diameter (two places)	FAC701
C		i.	Inner clevis leg inner diameter	FAC702
	8.		For New Case Segment, Attach, Light Weight, verify:	
B		a.	Surface finish of clevis O-ring grooves	ABL140,ABL141
B		b.	Clevis O-ring grooves corner radius (4 places)	ABL129,ABL129A
B		c.	Depth of clevis O-ring grooves	ABL031,ABL031A
B		d.	Width of clevis O-ring grooves	ABL181,ABL181A
C		e.	Outer clevis leg wall thickness	ABL127,ABL127A
C		f.	Inner clevis leg wall thickness	ABL078,ABL081
C		g.	Outer clevis leg inner diameter (two places)	FAC301
C		h.	Inner clevis leg inner diameter	FAC302
C		i.	Inner clevis leg outer diameter (Datum -C-)	ABL075
	9.		For Refurbished Case Segment, Attach, Light Weight, verify:	
B		a.	Surface finish of clevis O-ring grooves	AOJ002
B		b.	Depth of clevis O-ring grooves	ABL028
B		c.	Width of clevis O-ring grooves	ABL179
B,E		d.	Field joint sealing surfaces for defects	AOJ002A

B		e.	Random surface finish measurements of O-ring groove repairs	AOJ002Z
C		f.	Outer clevis leg wall thickness	FAB212
C		g.	Inner clevis leg wall thickness	ABL077
C		h.	Outer clevis leg inner diameter (two places)	FAC305
C		i.	Inner clevis leg inner diameter	FAC306

10. For RSRM Acceptance Criteria for Interference Fit, verify:

C		a.	Interference fit of the RSRM field joints for each flight set	FAE001

11. For New O-ring, Lubricated verify:

F,J,M		a.	O-ring packaging has not been damaged or violated	LAA103
F,G,L,M		b.	O-ring is cleaned and lubricated per drawing requirements	LAA104
F,G,J,M		c.	O-ring is packaged per drawing requirements	LAA105
J		d.	O-ring shelf life has not expired prior to lubrication	LAA097
J,N		e.	There is at least the minimum required shelf life of the filtered grease remaining prior to use	LAA255

12. For New Filtered Grease verify:

G,N	(T)	a.	Contamination	ANO064

13. For New Grease verify:

N	(T)	a.	Penetration	LAA037
N	(T)	b.	Dropping point	ANO042
N	(T)	c.	Zinc concentration	LAA038

14. KSC verifies:

A,B,D,E F,G,H,K	(T)	a.	Clevis Joint Leak Test results are acceptable for each segment per OMRSD File V, Vol I, B47CJ0.011	OMD026
G,I,J		b.	Expiration date is not exceeded for materials installed at KSC per OMRSD File V, Vol I, B47GEN.160	OMD042
B,E,G,M		c.	Tang and Clevis Field Joint unpainted surfaces are free from surface defects or contamination per OMRSD File V, Vol I, B47SG0.122	OMD085
F,M		d.	No damage to shipping box, shipping bag, or O-rings prior to installation per OMRSD File V, Vol I, B47SG0.152	OMD087
D,K		e.	RSRM field joint (segments) radial alignment prior to mating per OMRSD File V, Vol I, B47SG0.170	OMD089
D,K		f.	RSRM field joint parallel alignment per OMRSD File V, Vol I, B47SG0.180	OMD090
D,K		g.	Tang/clevis joint clocking, matching pins and slots are vertically aligned per OMRSD File V, Vol I, B47SG0.191	OMD091
D,K		h.	Segment joint pin protrusion is acceptable per OMRSD File V, Vol I, B47SG0.214	OMD093
D,K		i.	Acceptable field joint engagement rate during segment mating per OMRSD File V, Vol I, B47SG0.290	OMD095
D,K		j.	Field joint leak check and vent ports are open and unobstructed per OMRSD File V, Vol I, B47SG0.300	OMD096
D,K		k.	RSRM field joint geometry (tang and outer clevis leg) prior to mating per OMRSD File V, Vol I, B47SG0.330	OMD100
D,K		l.	Field joint assembly fixture shim selection and joint gaps per	

			OMRSD File V, Vol I, B47SG0.360	OMD102
F,G,L	(T)	m.	Application of filtered grease to the field joints (O-ring grooves, sealing surfaces, pin holes) per OMRSD File V, Vol I, B47SG0.370	OMD103
F,G,L	(T)	n.	Application of filtered grease to Field Joint O-rings and Thermal Barrier per OMRSD File V, Vol I, B47SG0.380	OMD104
D,K		o.	Acceptable contact between FJAF and segment outer clevis leg during mating operations per OMRSD File V, Vol I, B47SG0.390	OMD105
C		p.	Correct field joint pin retainer clips (custom shims) are installed per OMRSD File V, Vol I, B47SG0.510	OMD110
I		q.	Field joint heaters are activated and that temperatures are in compliance with NASA Launch Commit Criteria (NSTS-16007) per OMRSD File II, Vol I, S00FA0.610	OMD011