CRITICAL ITEMS LIST (CIL)

No. 10-01-01-10R/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Case Subsystem 10-01	PART NAME:	Factory Joint, Moisture Seal and Thermal Protection System (TPS) (1)
ASSEMBLY:	Case 10-01-01		
FMEA ITEM NO.:	10-01-01-10R Rev M	PART NO.:	(See Section 6.0)
CIL REV NO.:	M	PHASE(S):	Boost (BT)
DATE:	31 Jul 2000	QUANTITY:	(See Section 6.0)
SUPERSEDES PAGE:	209-1ff.	EFFECTIVITY:	(See Table 101-6)
DATED:	30 Jul 1999	HAZARD REF.:	BC-11
CIL ANALYST:	D. J. McGough		
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 Moisture seal/TPS fails to protect factory joint from aerodynamic heating

3.0 FAILURE EFFECTS: Debris would damage the ET and orbiter. Loss of tension in pin retention strap due to overheating may let the pins work loose. This could cause a joint failure causing loss of the RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Nonconforming raw material properties	A
1.2	Voids or inclusions	B
1.3	Bondline failure	
1.3.1	Contamination of bonding enhancement material	C
1.3.2	Bonding surface not adequately cleaned	D
1.3.3	Bonding enhancement material not properly applied	E
1.3.4	Vacuum bag leaks	F
1.4	Nonconforming cure	G
1.5	Nonconforming physical and mechanical properties	H
1.6	Transportation and handling damage	I
1.7	Age degradation	J
1.8	Moisture or fungus degradation	K
1.9	Ablative failure under aerodynamic loads	L

1.10 Acoustic vibration and aeroshear M

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

1. This CIL addresses aerodynamic heat failure of the external factory joint moisture seal during boost phase of flight. The factory joint seal is applied in casting segment assemblies:

   1U76666 Case Assembly, Forward Segment Insulated
   1U76667 Case Assembly, Center Segment Insulated
   1U77503 Case Assembly, Aft Segment Insulated

2. External factory-joint weather seals consist of a specially formulated, silica-filled, ethylene propylene hexadiene monomer (EPDM-neoprene) rubber mixture, extruded or calendared to specific dimensional requirements per engineering.

3. Extruded stocks used on the external factory joint seal are produced in three specific sizes or "types" as follows:

   EPDM, Extrusion or EPDM, Silica-Filled, Uncured Type I Figure 1
   EPDM, Extrusion or EPDM, Silica-Filled, Uncured Type II Figure 2
   EPDM, Extrusion or EPDM, Silica-Filled, Uncured Type III Figure 3

   Type I is used everywhere circumferentially around the factory joint except under the systems tunnel. The Type I seal is approximately 6-inches wide, roughly one-third of an inch thick, and 6 3/4-ft long.

4. Calendared stock is produced in four nominal thickness ranges with laminated thickness and/or number limits per engineering. Only the 0.060-inch thick size is used on the external factory joint seals to overlap Type I and II butt joints.

5. Figure 4 provides radial placement information at each joint to show where each type of seal is used. Figure 5 provides cross-sectional view information on how each type of seal overlaps and fits the segment clevis and tang joint. Figure 6 depicts calendared stock use at extruded butt joints.

6. Primer and an adhesive are necessary to apply an external factory joint seal. Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
	Hatband Joint Extrusion, EPDM Rubber	Silica-Filled EPDM	STW4-3775 Type I STW4-3775 Type VIII STW4-3775 Type IX STW4-3775 Type X	46 lb 13 ea 2 ea 6 ea
	Thermal Insulation, EPDM Rubber	Silica-Filled EPDM	STW4-2536 or STW4-3775	14 A/R
	Adhesive Primer, Rubber-To-Metal	Chlorinated Rubber	STW5-2664	A/R
	Adhesive, Rubber-to-Metal, Elevated Temp	Chlorinated Rubber	STW5-2798	A/R

6.1 CHARACTERISTICS:

1. EPDM terpolymers are known for their extreme weather-resistant properties and ability to be extended (capacity for absorbing filling agents). The EPDM capacity for absorbing silicone additives gives the seal greater strength at high temperatures needed for external seal application to combat effects of aerodynamic heating. It also exhibits excellent low temperature flexibility.

2. Approximately 20 percent of the seal formula contains neoprene rubber (chlorobutadiene) that exhibits excellent moisture rejection, shape-holding ability, flexibility at high temperatures, and ozone resistance.

3. External factory joint seals are not cork covered as are the field joints. Therefore, the EPDM-neoprene rubber seal must also act as the thermal protection system (TPS) for the factory joint. The external EPDM-neoprene rubber factory joint seal must act as a total environmental protection system of the factory clevis and tang mechanical joint.

4. Extruded EPDM seals are shaped to fit across the external factory joint lip. Enough overlap is designed into the seal to assure the bondline is maintained through all phases of launch and recovery, and that during vulcanization, enough surface area exists on each side of the joint to achieve good rubber-to-metal bonding.

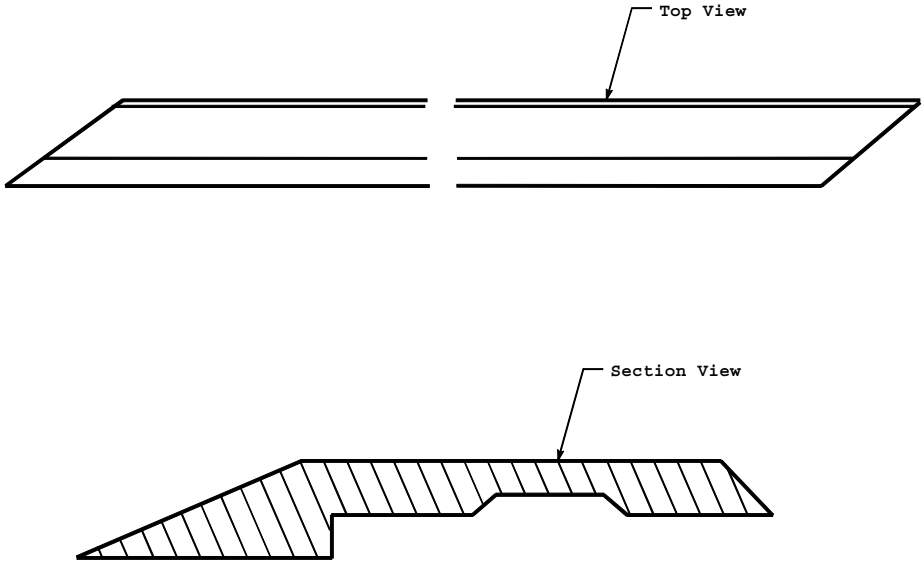
5. Seals should:

   a. Provide moisture protection of joint components
   b. Prevent entry of any liquids such as rain
   c. Provide thermal protection of joint components during the boost phase
   d. Maintain sealing integrity through mechanical shock, vibration, and expansion loads occurring during the boost phase
   e. Survive aerodynamic heating effects and ablative wear associated with the boost phase

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.

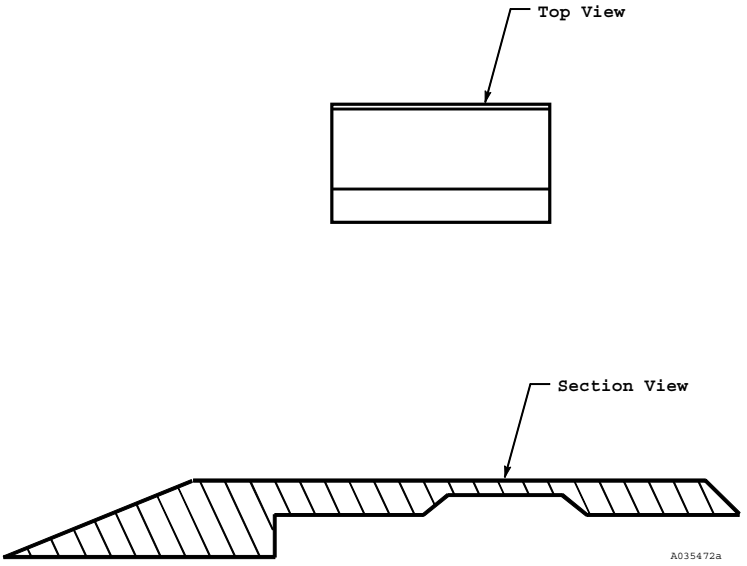
8.0 OPERATIONAL USE: N/A



Type I

Figure 1. Factory Joint EPDM Weather Seal

A035471a



Type II

Figure 2. Systems Tunnel Transition Weather Seal

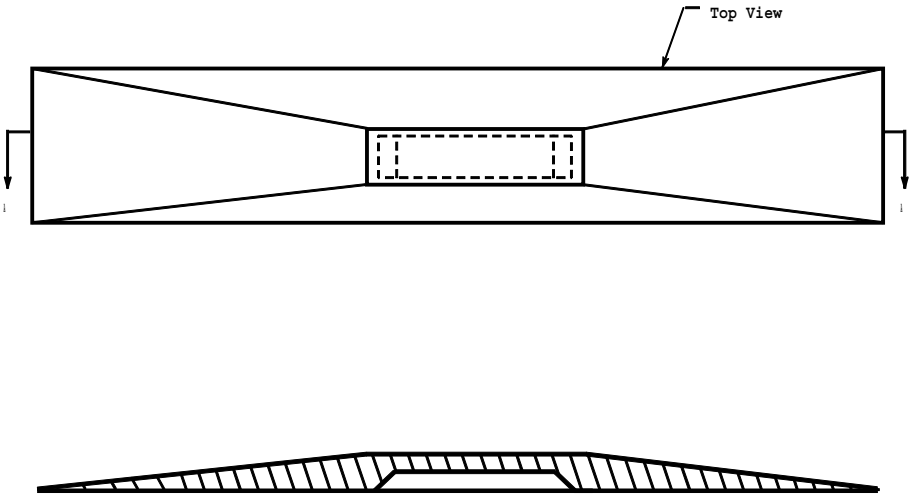


Figure 3. Connector Cover EPDM Weather Seal

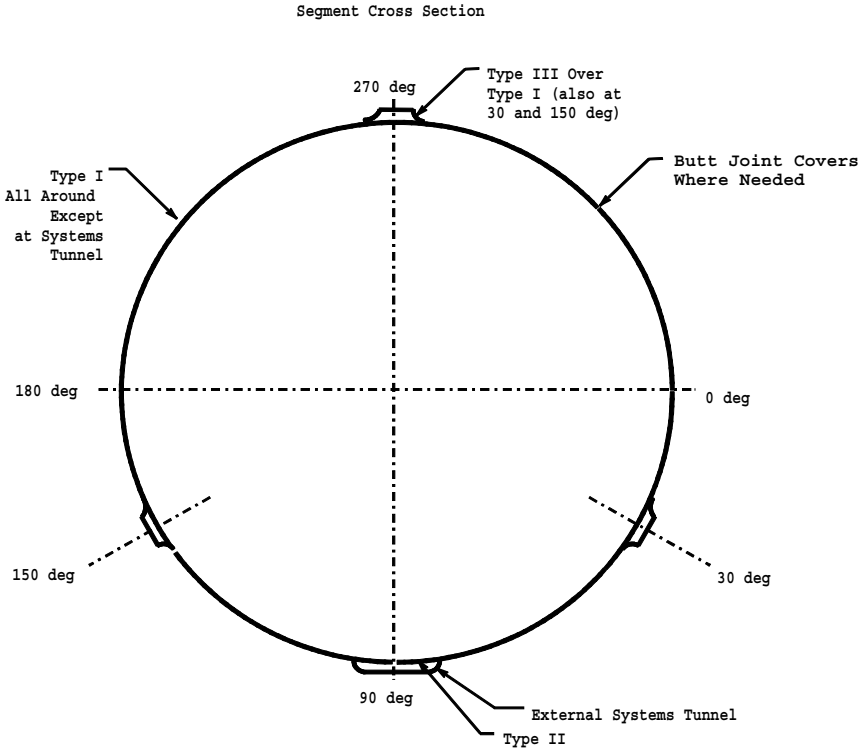
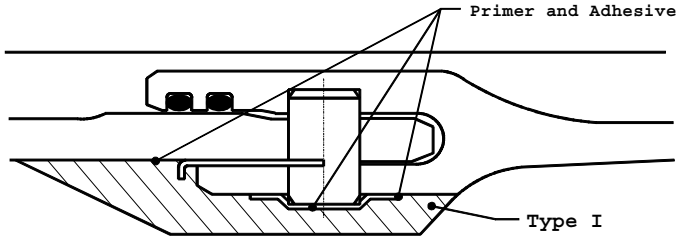
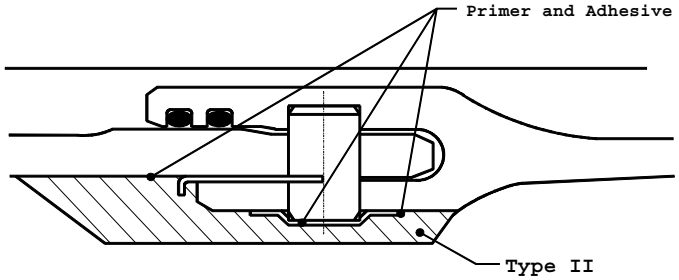


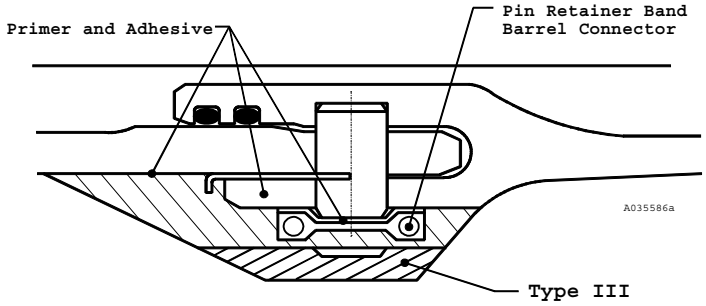
Figure 4. EPDM External Factory Joint Weather Seal Type I, II, III Locations



Normal Factory Joint Weather Seal

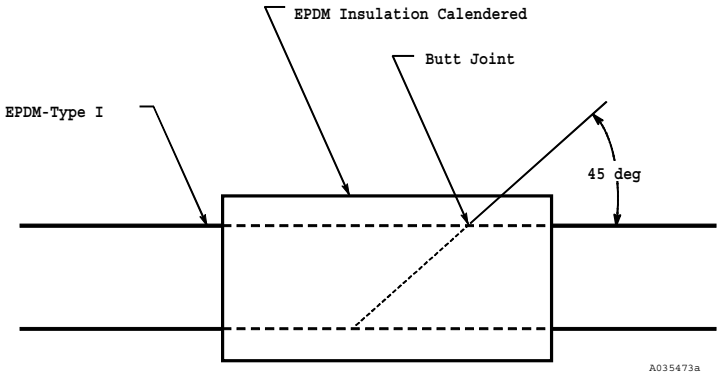


Systems Tunnel Transition Seal



Pin Retainer Band Connector EPDM Weather Seals

Figure 5. External Factory Joint EPDM Weather Seals



Typical EPDM Joint
Circumferential
View

Figure 6. Weather Seal Butt Joint EPDM Cover

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN	FAILURE CAUSES	
A	1.	Formulation from raw materials (base chemicals) of uncured EPDM-neoprene rubber thermal insulation extrusions and calendared stock must meet engineering requirements.
A	2.	Raw ingredient properties used in the uncured formula comply with requirements in EPDM, Extrusion, and EPDM Rubber specifications for extruded and calendared stock, respectively, or in EPDM, Silica-Filled, Uncured specifications for both extruded and calendared stock.
B	3.	EPDM-neoprene rubber extrusions and calendared stock meet the requirements of EPDM, Extrusion or EPDM, Silica-Filled, Uncured specifications regarding configuration and dimensions of extruded stock (Figures 1, 2, 3), and EPDM Rubber or EPDM, Silica-Filled, Uncured specification as to thickness of roll stored sheet and allowable laminae for calendared stock.
B	4.	Extruded stock and calendared stock must be free from defects that would render them unsuitable for their intended purpose (i.e., voids and inclusions of foreign matter) and be free from contamination per engineering.
C,D,E,F	5.	Careful engineering review of the manufacturing process is undertaken to avoid contaminating sealant material or surfaces to be sealed and to assure application procedures produce an adequate seal and bond per TWR-16858, TWR-16564, and shop planning.
C,D,E,F	6.	Engineering specifies contamination control during transportation and handling on raw materials through vendor specification requirements for packaging and handling. Contamination control on vendor-furnished calendared and extruded EPDM stocks is accomplished with appropriate polyethylene film coverings, and on primer and adhesive through best standard commercially available packaging.
C,D,E,F,G	7.	Contamination control requirements and procedures are described in TWR-16564.
C,D,E,F	8.	Vacuum bagging is per shop planning.
C,D,E,F	9.	Allowable vacuum leaks are a controlled process per shop planning.
G	10.	EPDM optimum cure time and temperature cycles were determined experimentally as documented in TWR-16863.
A,C,D,E, F,G,H	11.	Witness panels are cured in the autoclave with the insulated segments during the cure cycle. These panels are then tested to assure bondline integrity for primer, adhesive, insulation, liner, and propellant properties were achieved at the end of the cure cycle per engineering, TWR-17123, TWR-64433, and TWR-64923.
G	12.	Time and temperature cure cycle procedures are per shop planning.
H	13.	Physical and mechanical properties of cured EPDM stocks are specified in EPDM, Extrusion specifications (extruded stock) and EPDM Rubber specifications (calendared stock), or EPDM, Silica-Filled, Uncured specifications (both extruded and calendared stock).

H	14.	Insulation adhesive primer and bonding agent material properties conform to and are qualified to engineering requirements.
H	15.	A structural safety factor in excess of 2.0 exists with the EPDM factory joint moisture seal at 33°F in both the horizontal and vertical stacking modes per TWR-17036.
H	16.	Thermal analysis of the EPDM factory joint moisture seal is covered per TWR-16496.
I	17.	Railway coupling and transportation tests were conducted on an inert forward segment per TWR-11712 to verify the adequacy of the tie down provisions and to record actual g-loads during transit. Accelerations of 1.01-g longitudinal and 0.86-g vertical were measured and were less than vibration and shock transportation design loads.
I	18.	Additional tests were accomplished per TWR-12079 to analyze transportation loads on the RSRM forward segment grain. This testing provided additional data for verification of vibration and shock transportation environment.
I	19.	Requirements for handling RSRM components during assembly, storage, and transportation are similar to those for previous and other current programs at Thiokol. Those requirements dictate that RSRM and 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	20.	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	21.	To assure that no damage occurs to flight hardware during transportation to and in the launch site, specially designed 200-ton railroad flatcars are used per TWR-13880.
I	22.	Railcar transportation shock and vibration levels for the segments are monitored per engineering and loads are derived by analysis. Monitoring records are evaluated by Thiokol to verify that shock and vibration levels defined per MSFC Specifications were not exceeded.
J,K	23.	Uncured rubber has a storage life and temperature environment per engineering. Storage life may be extended if, after retest, the rubber conforms to engineering requirements.
J	24.	Uncured rubber is shipped within the specified time from date of manufacture per engineering.
J,K	25.	Uncured rubber is packaged and shipped in containers to prevent exposure to direct sunlight, ultraviolet radiation, ozone, and other natural contamination per engineering.
J,K	26.	During transportation, the temperature environment of uncured rubber is kept within a specified temperature range. A temperature recorder is placed with the material and is capable of producing a continuous record during transportation per engineering.

J 27. Selection of material was based upon the rationale that cured laid up vulcanized rubber on case segments in storage is designed to withstand 5 years, under contractual environments, without degradation. Age degradation is per TWR-15126, TWR-14669, and TWR-13835.

J 28. No significant degradation of EPDM external insulation/case bondline strength was identified. Test conclusions were based on tensile and peel samples taken from aged witness panels as documented in TWR-65281.

K 29. Maximum cumulative exposure time out of controlled storage is established per engineering.

K 30. To prevent moisture or fungus degradation during transportation and handling, the three types of moisture seals are placed in thin polyethylene bags. The bags are placed in containers which are constructed so that the extrusions will be adequately protected against moisture or fungus damage per engineering.

K 31. EPDM material was shown to be non-nutrient to fungus growth after testing per MIL-STD-810 and TWR-16851.

L 32. The external factory joint weather seal is composed of a specially formulated high-temperature EPDM-neoprene rubber compound that was chosen to withstand the aerodynamic environment in which it is placed. Formulation, physical, mechanical, and thermal properties are covered in EPDM, Extrusion (extruded) and EPDM Rubber (calendared) or in EPDM, Silica-Filled, Uncured (extruded and calendared) specifications.

L 33. A two-dimensional axisymmetric transient heating and material ablation computer program's (ASCHAR) results per TWR-16496 indicate EPDM temperatures approaching 219^{o}F during ascent aerodynamic heating are well below even the normal seal curing temperature, and pose no serious chemical bond-weakening problems that might lead to accelerated ablative wear.

L,M 34. Wind tunnel tests were performed to verify adequacy of the design to withstand predicted aeroshear loads per TWR-17243.

D 35. A Spray-in-Air cleaning system is used to clean metal components as part of the bonding surface preparation processing sequence.

A,B,C,D,E,F
G,H,I,L,M 36. An updated analysis was performed on the factory joint weather seal using Performance Enhancement (PE) environments. This structural analysis, using the PE environment, resulted in stresses essentially identical to those from the Generic Aero/Plume Heating Certification. All quoted stresses and positive margins of safety remain unchanged per TWR-66825-3.

A,B,C,D,E,F
G,H,I,L,M 37. 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 TESTS (T)			CIL CODE
		1.	For New EPDM Rubber, verify:	
A,G		a.	Ingredient properties	ALA026
B,C,D,E,F		b.	Workmanship	ALA039,ALA077
C,D,E,F,K		c.	No shipping or handling damage	ALA044
G		d.	Cured mechanical and physical properties	FAA829
G		e.	Coupon sample is included with shipment for each lot of extrusions	ALA007
G,H,L	(T)	f.	Ash content	ALA002,ALA003
G,H,L	(T)	g.	Hardness	ALA012,ALA013
G,H,L	(T)	h.	Initial scorch characteristics	ALA016,ALA017
G,H,L	(T)	i.	Mooney viscosity	ALA020,ALA021
G,H,L	(T)	j.	Rheology	ALA031,ALA032
G,H,L	(T)	k.	Specific gravity	ALA047,ALA048
G,H,L	(T)	l.	Tensile strength	ALA060,ALA061
G,H,L	(T)	m.	Thermal conductivity	ALA068,ALA069
G,H,L	(T)	n.	Ultimate elongation	ALA072,ALA073
		2.	For Retest EPDM Rubber, verify:	
G,H,J		a.	Chemical and physical properties of EPDM for storage life extension per Table III	FAA831
		3.	For New EPDM, Silica-Filled, Uncured, verify:	
A,G		a.	Ingredient properties	AMG024R
B,C,D,E,F		b.	Workmanship	AMG038R,AMG074R
C,D,E,F,K		c.	No shipping or handling damage	AMG043R
G,H,L		d.	Vendor records are complete and acceptable	FAA828R
G,H,L	(T)	e.	Ash content	AMG002R
G,H,L	(T)	f.	Hardness	AMG011R
G,H,L	(T)	g.	Initial scorch characteristics	AMG015R
G,H,L	(T)	h.	Mooney viscosity	AMG019R
G,H,L	(T)	i.	Rheology	AMG030R
G,H,L	(T)	j.	Specific gravity	AMG046R
G,H,L	(T)	k.	Tensile strength	AMG058R
G,H,L	(T)	l.	Ultimate elongation	AMG069R
G,H,L	(T)	m.	Tensile adhesion strength	FAA836
		4.	For Retest EPDM, Silica-Filled, Uncured, verify:	
G,H,J	(T)	a.	Tensile strength	FAA832
G,H,J	(T)	b.	Tensile adhesion strength	FAA833
G,H,J	(T)	c.	Ultimate elongation	FAA834
		5.	For New Adhesive Primer, verify:	
A	(T)	a.	Solids content	AMR059,AMR067
A	(T)	b.	Density	AMR006,AMR012
A	(T)	c.	Viscosity	AMR083,AMR092
A	(T)	d.	Peel adhesion	AMR026,AMR022
A		e.	Workmanship	AMR041

6. For New Adhesive, Rubber-to-Metal verify:

A	(T)	a.	Solids content	AND028,AND026
A	(T)	b.	Specific gravity	AND033,AND036
A	(T)	c.	Viscosity	AND046, AND044
A	(T)	d.	Peel strength, rubber-to-steel	AND014,AND009
A		e.	Workmanship	FAA842

7. For New Insulated Segment Assembly (Forward, Center, Aft) verify:

B,G,J,K		a.	Storage life and environmental history of EPDM	AFI009A,AMG010R,AFI168R, ALA010A,ALA037Q,ALA037QR
B		b.	External insulation defects and repairs are acceptable	FAA823A,FAA824A,FAA825A
C,D,E,F,J		c.	Adhesive primer is used	AMR045,AMR045D,AMR045E
C,D,E,F,J		d.	Rubber-to-metal adhesive is used	AKZ024A,FAA838,FAA841
C,D,E,F,J		e.	Storage life is acceptable for adhesive primer	AFK185B,AMR048D,AMX019
C,D,E,F,J		f.	Storage life of rubber-to-metal adhesive	FAA011,AFE082U,FAA013
C,D,E,F		g.	Blacklight inspection of joint bonding areas for grease or oil contamination prior to EPDM insulation lay up	FAA851,FAA853,FAA854
C,D,E,F		h.	Full coverage of adhesive primer	AFK022,FAA822,FAA852
C,D,E,F		i.	Full coverage of adhesive	AFG024,AFI024B,AFK076
C,D,E,F		j.	Vacuum bags evacuated and checked for leaks	AFI160,AFG177,AFK181
C,D,E,F		k.	Case surface meets requirements prior to lay up of EPDM	FAA823,FAA824,FAA825
L		l.	Factory joint weather seal thickness	AFG128,AFI156,AFK177
A,C,D,E F,G,H	(T)	m.	Results of Chemlok-to-EPDM (weather seal) bondline integrity tests with witness panel per engineering specification	AOX030,AOX031,AOX032
G		n.	Air drying of adhesive primer	AFG057,AFI063,AFI063A
G		o.	Air drying of rubber-to-metal adhesive	AFG058A,AFK239,AFI067A
G		p.	Insulation cure cycle is complete	AFG086,AFI099,AFK110

8. For New Case Assembly, Painted Forward Segment, verify:

C,D,E,F,J	a.	Storage life is acceptable for adhesive primer	RAA214
C,D,E,F,J	b.	Adhesive primer is used	RAA218
C,D,E,F	c.	Full coverage of adhesive primer	RAA225
G	d.	Air dry of adhesive primer	RAA220

9. KSC verifies:

I	a.	Segments and nozzle components are free of damage per OMRSD, File V, Vol I, B47SG0.061	OMD079