TWR-60699

Solid Rocket Motor
Thiokol Corporation

Final Postflight Hardware Evaluation Report 360T025 (RSRM-25, STS-46)

March 1993

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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Contract No.	NAS8-38100
DR No.	4-23
WBS No.	4C601-04-01
ECS No.	SS4768

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(NASA-CR-192562) POSTFLIGHT HARDWARE EVALUATION 360T025 (RSRM-25, STS-46) Final Report (Thiokol Corp.) 32 p

N93-30617

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Release 3-26-93

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Concurrence by:

Case Design

Joints & Seals Design

Integration Design

Nozzle Design

Igniter / Instrumentation / Electrical Design

Thermal Insulation Design

Quality, Performance Evaluation

Systems Assurance

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List of Acronyms

Acronym	Definition
CCP	Carbon Cloth Phenolic
CEI	Contract End Item
CPT	Component Program Team
ET	External Tank
GCP	Glass Cloth Phenolic
ID	Inside Diameter
IFA	In-Flight Anomaly
KSC	Kennedy Space Center
LDI	Low Density Indication
LH	Left Hand
NASA	National Aeronautics and Space Administration
OD	Outside Diameter
PEEP	Postflight Engineering Evaluation Plan
PFAR	Postfire Anomaly Record
PFOR	Postfire Observation Record
RH	Right Hand
RSRM	Redesigned Solid Rocket Motor
RTV	Room Temperature Vulcanized (Rubber)
S&A	Safe and Arm Device
SII	SRM Ignition Initiator
STS	Space Transportation System
TWR	Thiokol Wasatch Report

1.0 INTRODUCTION

This document is the final report for the Clearfield disassembly evaluation and a continuation of the KSC postflight assessment for the 360T025 (STS-46) RSRM flight set. All observed hardware conditions were documented on PFORs and are included in Appendices A through C. Appendices D and E contain the measurements and safety factor data for the nozzle and insulation components. This report, along with the KSC Ten-Day Postflight Hardware Evaluation Report (TWR-60687), represents a summary of the 360T025 hardware evaluation. The as-flown hardware configuration is documented in TWR-60470. Disassembly evaluation photograph numbers are logged in TWA-1986.

The 360T025 flight set disassembly evaluations described in this document were performed at the RSRM Refurbishment Facility in Clearfield, Utah. The final factory joint demate occurred on 16 March 1993.

Detailed evaluations were performed in accordance with the Clearfield PEEP, TWR-50051, Revision A. All observations were compared against limits that are also defined in the PEEP. These limits outline the criteria for categorizing the observations as acceptable, reportable, or critical. Hardware conditions that were unexpected and/or determined to be reportable or critical were evaluated by the applicable CPT and tracked through the PFAR system.

Figure 1 shows the RSRM Case Configuration.

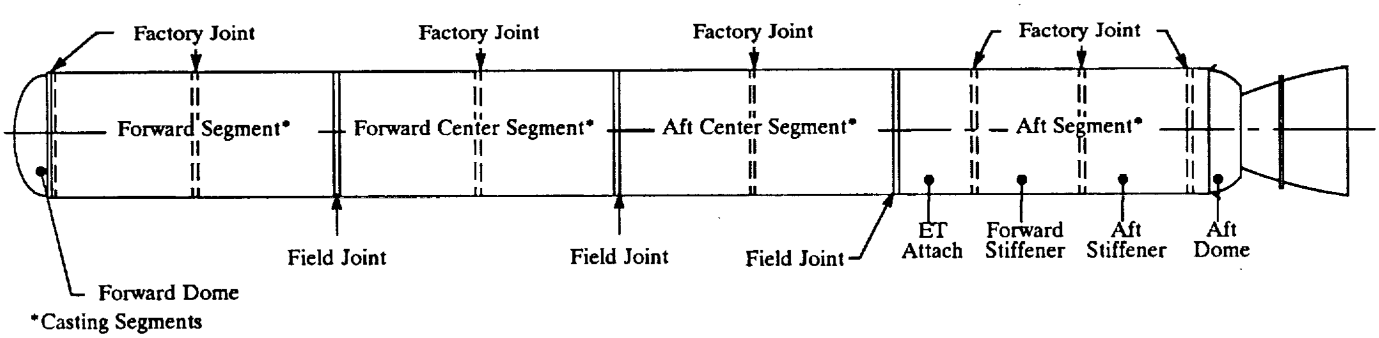

Figure 1. Case Configuration

2.0 REFERENCES

The following documents are referenced herein:

CPW1-3600A	Prime Equipment Contract End Item Detail Specification, Part I of Two Parts; Performance, Design, and Verification Requirements, Space Shuttle Redesigned Solid Rocket Motor CPW1-3600A For Space Shuttle Solid Rocket Motor Project, Operational Flight Motors (RSRM-4 and subsequent)
TWA-1986	360T025, STS-46, Clearfield Postflight Photo Log
TWR-50050	KSC Postflight Engineering Evaluation Plan (PEEP)
TWR-50051	Clearfield Postflight Engineering Evaluation Plan (PEEP)
TWR-60639	Postflight Hardware Special Issues, 360T025 (STS-46), Clearfield
TWR-60470	STS-46, RSRM-025, 360T025, KSC Processing Configuration and Data Report
TWR-60687	KSC Ten-Day Postflight Hardware Evaluation Report, 360T025 (STS-46)

3.0 EVALUATION SUMMARY

Table I provides a summary of all postflight-related Squawks/Preliminary PFARs, PFARs, IFAs, and SPRs for 360T025.

Table I. Summary of 360T025 Problems

	Squawks/Prelim. PFARs	PFARs	IFAs	SPRs
KSC	15	7	0	0
Clearfield	10	3	0	0
Total	**25**	**10**	**0**	**0**

A description of all 360T025 problems is included in Table II. This includes PFARs, Squawks (written at KSC) and Preliminary PFARs (written at Clearfield) that were written and not elevated to PFARs. All preliminary PFARs are discussed in Section 4.0 of this document. Information relating to postflight Squawks can be found in TWR-60687.

3.1 CEI Specification Compliance

Based on hardware evaluations at KSC and Clearfield, as defined in the respective PEEPs (TWR-50050, Revision C and TWR-50051, Revision A), all CEI (CPW1-3600A) motor performance requirements were met.

Table II. Problem Summary for 360T025

PFAR/SQUAWK/ PRELIM. PFAR NUMBER	TYPE	ELEVATED FROM	REFERENCE SPR NUMBER	REFERENCE IFA NUMBER	EVALUATION LOCATION	RESPONSIBLE COMPONENT TEAM	SPAT/ RPRB DATE	DESCRIPTION
46-018	SQUAWK	N/A	N/A	N/A	KSC	PORTS/PLUGS	08/07/92	DAMAGED THREADS ON THE 40 DEGREE OPT (OPERATIONAL PRESSURE TRANSDUCER)
46-021	SQUAWK	N/A	N/A	N/A	KSC	SEAL SURF.	08/10/92	FIXED HOUSING RADIAL BOLT HOLE SPOTFACE DAMAGE
46-022	SQUAWK	N/A	N/A	N/A	KSC	NOZZLE	08/10/92	DISASSEMBLY DAMAGE TO WIPER O-RING
46-023	SQUAWK	N/A	N/A	N/A	KSC	IGNITER	08/11/92	UNBONDED PAINT/PRIMER ON O.D. OF IGNITER ADAPTER
46-024	SQUAWK	N/A	N/A	N/A	KSC	PORTS/PLUGS	08/11/92	SCRATCH ON IGNITER INNER JOINT LEAK CHECK PLUG SEAL SEAL SURFACE
46-025	SQUAWK	N/A	N/A	N/A	KSC	SEALS	08/12/92	ENVIRONMENTAL SEAL SEPARATED FROM THE RETAINER
46-028	SQUAWK	N/A	N/A	N/A	KSC	SEALS	08/12/92	VOID ON AFT FACE, INNER SEAL CROWN OF THE INNER GASKET
46-029	SQUAWK	N/A	N/A	N/A	KSC	SEALS	08/12/92	VOID ON AFT FACE, PRIMARY SEAL CROWN OF THE OUTER GASKET
46C-02	PRELIM.	N/A	N/A	N/A	H-5/H-7	SEAL SURF.	08/14/92	HEAVY CORROSION ON THROAT HOUSING (JOINT 4) SEALING SURFACE
46C-04	PRELIM.	N/A	N/A	N/A	H-5/H-7	NOZZLE	08/18/92	BUBBLED PAINT ON FLEX BEARING FORWARD END RING
46C-06	PRELIM.	N/A	N/A	N/A	H-5/H-7	NOZZLE	08/18/92	HEAT AFFECT NOSE INLET ASSEMBLY CCP BELOW THE CHAR LINE
46C-07	PRELIM.	N/A	N/A	N/A	H-5/H-7	NOZZLE	08/18/92	HEAT AFFECTED THROAT ASSEMBLY CCP BELOW THE CHAR LINE
46C-08	PRELIM.	N/A	N/A	N/A	H-5/H-7	NOZZLE	08/19/92	BEARING PROTECTOR SLAG DAMAGE
46C-09	PRELIM.	N/A	N/A	N/A	H-5/H-7	NOZZLE	09/15/92	TRANSPORTATION DAMAGE TO AEC
46C-10	PRELIM.	N/A	N/A	N/A	H-5/H-7	INSULATION	11/20/92	APP. COMPLIANCE SAFETY FACTOR VIOLATIONS FOR CENTER AFT SEGMENT
360T025A-01	PFAR	46-001	N/A	N/A	KSC	CASE	09/03/92	UNBONDED PAINT ON AFT STIFFENER SEGMENT
360T025B-02	PFAR	46-016	N/A	N/A	KSC	IGNITER	09/03/92	FOREIGN MATERIAL ON S&A SEAL SURFACE AT 9 DEGREES OF IGNITER ADAPTER
360T025B-03	PFAR	46-017	N/A	N/A	KSC	PORTS/PLUGS	09/03/92	DAMAGED THREADS ON THE 270 DEGREE OPT (OPERATIONAL PRESSURE TRANSDUCER)
360T025B-04	PFAR	46-020	N/A	N/A	KSC	SEAL SURF.	09/03/92	FIXED HOUSING RADIAL BOLT HOLE SPOTFACE DAMAGE
360T025B-05	PFAR	46-030	N/A	N/A	KSC	IGNITER	09/03/92	ABNORMALITY IN OUTER GASKET LEAK TEST GROOVE AT 315 DEGREES
360T025B-06	PFAR	46-031	N/A	N/A	KSC	SEAL SURF.	09/03/92	NICK ON 180 DEGREE SPECIAL BOLT/OPT INTERFACE FROM THE PORT CHAMFER INTO THE SECONDARY SEAL ZONE
360T025B-07	PFAR	46-032	N/A	N/A	KSC	PORTS/PLUGS	09/03/92	FOREIGN MATERIAL ON IGNITER OUTER JOINT LEAK CHECK PLUG
360T025B-08	PFAR	46C-01	N/A	N/A	H-5/H-7	NOZZLE	09/03/92	TRANSPORTATION DAMAGE TO FIXED HOUSING AFT FLANGE
360T025B-09	PFAR	46C-03	N/A	N/A	H-5/H-7	SEALS	09/03/92	DISASSEMBLY DAMAGE TO JOINT 5 PACKINGS WITH RETAINERS
360T025B-10	PFAR	46C-05	N/A	N/A	H-5/H-7	NOZZLE	09/03/92	GAS PATH WITH RTV NOT BELOW THE CHAR LINE IN JOINT 3

4.0 COMPONENT EVALUATIONS

The following sections detail, by component, the hardware condition observed at Clearfield.

4.1 Insulation

Internal insulation evaluations of the igniters, case acreage, joints, and liners are summarized in the following sections. PFORs documenting the observations are found in Appendix A. Only the RH motor was evaluated as specified in the Clearfield PEEP.

4.1.1 Thermal Performance Evaluation

Summaries of the safety factors for the nozzle-to-case joint, field joint, factory joint, case acreage and igniter insulation are found in Tables III through VII, respectively. All safety factors for these areas can be found in Appendix E, Tables E-I through E-XI. All joint insulation regions, including factory joints, must meet a minimum safety factor of 2.0. A minimum safety factor of 1.5 is required in the acreage insulation regions. The igniter insulation forward of the igniter nozzle insert (Station 5), requires a minimum remaining insulation thickness of 0.010 inch.

Preliminary PFAR 46C-10 was written for apparent CSF violations on the RH aft center segment (see Table IV). The apparent violations occurred at the factory joint (161.4 inch station) which has a history of providing inaccurate prefire data. The 161.4 inch station will be replaced by the 163.0 inch station effective RSRM-31. All other safety factors were within CEI specification limits. All thermal protection requirements were met.

4.1.2 Internal Insulation Samples

Removal of internal insulation samples was not required on 360T025 per the Clearfield PEEP.

Table III. Summary of 360T025 Nozzle-to-Case Joint and Field Joint Insulation Safety Factors

Joint	Min. Compliance Safety Factor (CSF) *	Degree Location	Min. Actual Safety Factor (ASF) *	Degree Location
Nozzle-to-Case Joint RH	4.0	0.0	4.5	0.0
Aft Field Joint, RH	4.8	316.0	5.1	316.0
Center Field Joint, RH	9.9	46.0	10.6	46.0
Forward Field Joint, RH	13.9	136.0	14.8	136.0

* Minimum required joint insulation safety factor is 2.0.

Table IV. Summary of 360T025 Factory Joint Insulation Safety Factors

Joint	Station (inches)	Min. Compliance Safety Factor (CSF) *	Degree Location	Min. Actual Safety Factor (ASF) *	Degree Location
Aft Dome/ Stiffener, RH	56.0	3.55	180.0	4.37	180.0
Stiffener/ Stiffener, RH	177.7	2.44	136.8	3.76	136.8
Stiffener/ET Attach, RH	299.1	2.83	136.8	4.56	136.8
Aft Center, RH	161.4	1.21**	46.0	3.54	46.0
Forward Center, RH	161.4	4.21	316.0	10.32	316.0
Forward Cylinder/ Cylinder, RH	162.0	4.02	90.0	5.59	90.0
Forward Dome/ Cylinder, RH	321.0	3.67	286.0	3.87	286.0

* Minimum required joint insulation safety factor is 2.0.

** Preliminary PFAR 46C–10 written on apparent CSF violations.

Table V. Summary of 360T025 Case Acreage Insulation Safety Factors

Segment	Min. Compliance Safety Factor (CSF) *	Station (inches)	Degree Location	Min. Actual Safety Factor (ASF) *	Station (inches)	Degree Location
Aft Dome, RH	2.16	45.0	226.8	2.30	45.0	226.8
Aft, RH	2.15	158.5	226.8	2.19	158.5	226.8
Aft Center, RH	2.31	163.0	0.0	2.78	30.7	46.0
Forward Ctr., RH	3.78	71.5	46.0	4.29	71.5	46.0
Forward, RH	1.91	371.0	90.0	2.41	187.0	154.0

* Minimum required case acreage insulation safety factor is 1.5.

Table VI. Summary of 360T025 Igniter Insulation Safety Factors

	Min. Compliance Safety Factor (CSF) *	Station	Degree Location	Min. Actual Safety Factor (ASF) *	Station	Degree Location
LH Igniter Chamber OD	2.75	3	330.0	2.93	3	330.0
RH Igniter Chamber OD	2.65	2	330.0	3.02	2	330.0
LH Igniter Chamber ID	4.01	7	270.0	4.28	7	270.0
RH Igniter Chamber ID	8.69	9	150.0	9.93	9	150.0
LH Adapter	2.37	11	90.0	2.83	11	90.0
RH Adapter	2.79	11	240.0	3.33	11	240.0
LH Inner Joint	5.69	10	270.0	6.19	10	270.0
RH Inner Joint	5.87	10	150.0	6.48	10	150.0
LH Outer Joint	3.86	1	0.0	4.43	1	90.0
RH Outer Joint	3.47	**	286.0	3.95	**	286.0

* Minimum required safety factors are 1.5 for the chamber and adapter acreage and 2.0 for the igniter joints.

** Minimum compliance safety factor was located on forward dome side of the outer joint at the 403 inch station location.

Table VII. Summary of 360T025 Igniter Insulation at Station 5

Igniter	Station	Minimum Postflight Thickness *	Degree Location
Igniter, LH	5	0.063	240.0
Igniter, RH	5	0.069	330.0

* Minimum required thickness is 0.010 inch at Station 5.

4.1.3 Liner

Detailed liner maps are included in Appendix A. The remaining liner patterns were typical of past flight motors.

4.1.4 Igniter Nozzle Insert

LH

The postflight igniter nozzle insert throat diameter measurements were 6.362 inches at 0 degrees, 6.432 inches at 60 degrees, and 6.436 inches at 120 degrees. Using the maximum postfire measurement provides a thermal factor of safety of 7.8.

RH

The postflight igniter nozzle insert throat diameter measurements were 6.356 inches at 0 degrees, 6.359 inches at 60 degrees, and 6.399 inches at 120 degrees. Using the maximum postfire measurement provides a thermal factor of safety of 8.5.

4.1.5 Results of Special Issues and Concerns (Internal Insulation)

TWR-60639 identified areas for special evaluation of 360T025 at Clearfield.

1. **Condition:** Prior to casting of the RH aft segment, moisture was introduced into the vacuum bell and was evident on the core and casting dam. The liner in the segment was also exposed to this same environment.

   Results: The performance of the aft segment insulation was compared to the RSRM database to determine if any significant increased erosion of the insulation was experienced due to possible failure of the liner system. The aft segment insulation performance was well within the RSRM database. No significant increased insulation erosion was noted. The aft segment insulation performance tables are included in Appendix E.

2. Condition: Pattern labels (Type FSX-11) lost during insulation layup are potentially included in the rubber of RSRM-25 RH forward segment.

Results: No foreign material was noted during the postrinse internal insulation evaluation of the forward segment.

4.1.6 Results of Special Issues and Concerns (External Insulation)

TWR-60639 identified one area for special evaluation of 360T025 at Clearfield.

1. Condition: Three areas of cork were missing from the LH center forward GEI cork run on RSRM-24. The potential exists for localized unbonded areas on RSRM-25 cork runs.

Results: Over 20 feet of GEI cork runs were removed from four segments (minimum of four feet from four different runs on four different segments) for bondline evaluation. All of the cork removed was well bonded. Results are documented in Appendix A on PFOR clarification form, pg. A-13.

4.2 <u>Case, Seals, and Joints</u>

Seal and joint evaluations of the S&As, factory joints, internal nozzle joints, ports, and port plugs were performed. PFORs documenting the observations are found in Appendix B.

4.2.1 S&As

Figure 2 shows the Safe and Arm device (S&A) configuration. The S&As were disassembled on 13 August 1992 at the Clearfield H-5 facility.

No anomalous conditions were observed. Typical galling was observed on each B-B housing land between the SII primary and secondary seal surfaces. The galling was acceptable since it did not exceed 0.020 inch in depth (non-sealing surface).

Typical soot was observed up to, but not past, the forward primary rotor shaft O-ring of both S&As. No O-ring or seal surface damage was observed.

4.2.2 Factory Joints

The factory joints were inspected by Quality Assurance at Clearfield. All fourteen factory joints were in good condition with no heavy corrosion on any of the joints. No O-ring heat effects or erosion were observed.

4.2.3 Internal Nozzle Joints

Details can be found in Section 4.3.

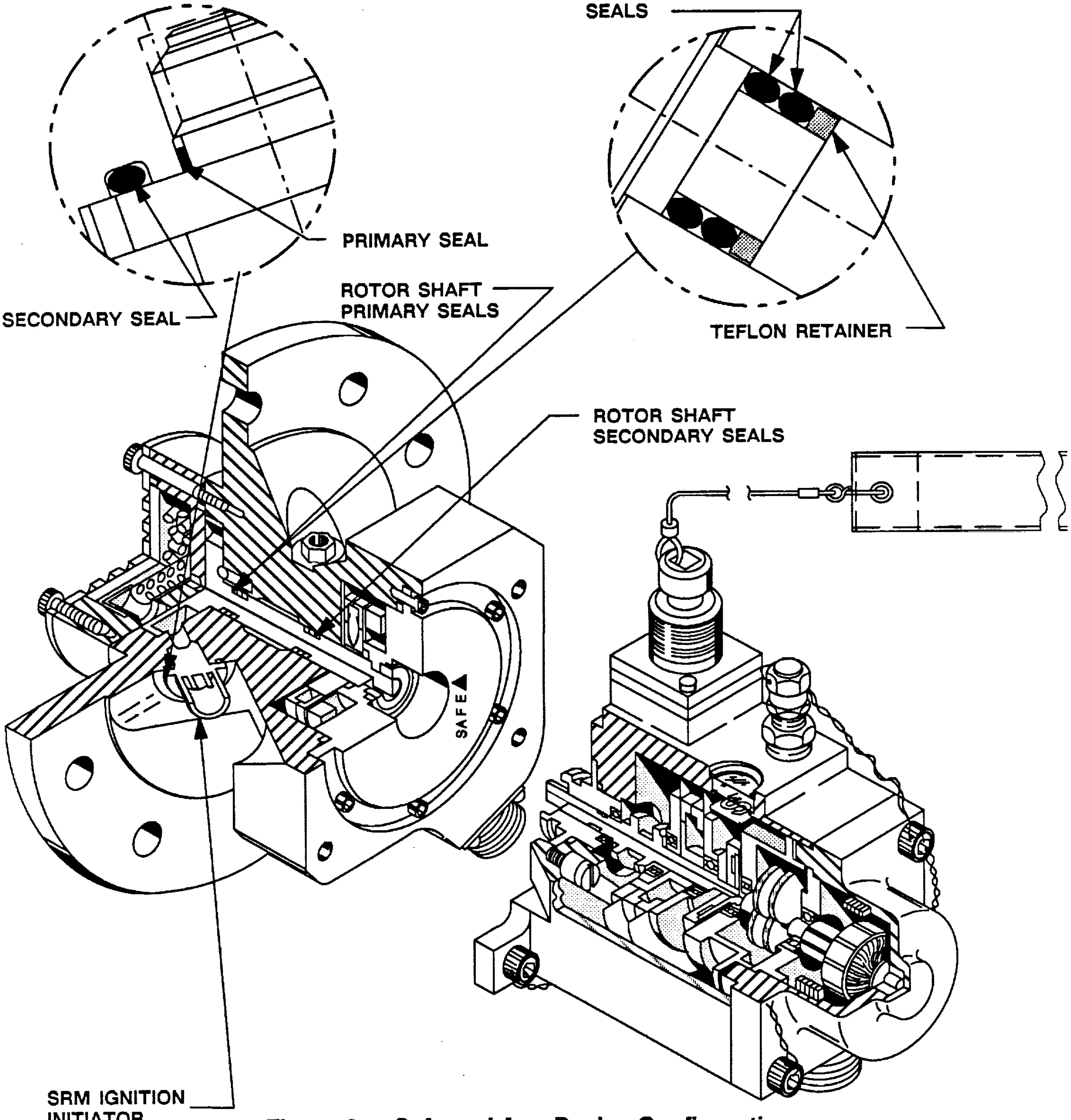

Figure 2. Safe and Arm Device Configuration

4.2.4 Ports and Port Plugs

All plug breakaway and running torques were nominal and are documented on applicable PFORs in Appendix B.

S&As
No anomalous conditions were observed on any of the S&A leak check ports, plugs, SII ports, SIIs, or O-rings.

Factory Joints
No anomalous conditions were observed on any of the factory joint leak check ports, plugs, or O-rings.

Internal Nozzle Joints
No anomalous conditions were observed on any of the internal nozzle joint leak check ports, plugs, or O-rings.

4.2.5 Results of Special Issues and Concerns (Case, Seals, and Joints)

TWR-60639 identified areas for special evaluation of 360T025 at Clearfield. The case, seals, and joint issues are listed below with their respective results.

1. Condition: Beginning with RSRM-23, the case factory joints were returned to standard 1U51899-04 shims (0.034 inch thick) configuration instead of custom shims (variable thickness). Because RSRM-23 was delayed, RSRM-25 was the second motor set to use the standard shims. This change was implemented to reduce factory joint fretting.

Results: Light fretting was noted on LH aft center factory joint. However, because a specific evaluation for fretting was not included on all individual joint PFORs, it is not known whether the evaluation was performed on all joints.

2. Condition: Current O-rings on SRM Igniter Initiator (SIII) were replaced with improved dimensionally controlled O-rings (P/N 1U50228-47).

Results: No damage was observed to the SII secondary O-rings (P/N 1U50228-47) of each S&A.

3. Condition: The nozzle fixed housing forward end bolt chamfers and spotfaces have previously been affected by the glass beading operation during refurbishment. Material was deformed or removed from the edge of the chamfer. This condition may exist on this flight set and could compromise the Packing with Retainer seal if defects also exist on the Packing with Retainer and on the fixed housing spotface at corresponding locations.

Results: No metal damage or rounded chamfers were observed on the bolt through hole spotfaces of either nozzle.

4. Condition: A recent seals audit identified discrepancies between the Refurbishment and process finalization specifications (STW7-3434 and STW7-3450, respectively) and Engineering requirement drawings. The specifications do not provide adequate criteria for the throat support housing forward and aft seal surfaces of nozzle Joints 3 and 4.

Results: Joint 3-RH - Light-to-medium corrosion was noted on the housing intermittent full circumference. No other corrosion or metal damage was noted.

Joint 4-RH - Light corrosion was noted adjacent to but not in the footprint on the forward exit cone (corrosion was heavy at 230-255 degrees). Light-to-medium corrosion with pitting was noted on the throat seal surface from 162-200 degrees (corrosion was heavy at 250-251 degrees). The deepest pit was 0.002 inch.

Joint 3-LH - Light-to-medium corrosion was noted on the housing intermittent full circumference. No other corrosion or metal damage was noted.

Joint 4-LH - Light-to-medium intermittent corrosion was noted on the aft surface of the throat support hosuing. No metal damage was noted on the throat support housing forward and aft seal surfaces with the following exceptions: Burnishing on the throat forward seal surface at 130 degrees (0.1 inch circumferential X 0.1 inch radial) and 133 degrees 10.63 circumferential X 0.1 inch radial)

4.3 Nozzle

Figure 3 defines the internal joint nomenclature and details the internal nozzle joint configuration used in this report. Also shown in Figure 3 are the materials used in the nozzle. The internal nozzle joints were disassembled on 14–18 August 1992 at the Clearfield H-6 facility.

The condition of the 360T025 nozzle internal joints was generally typical of previous flight nozzles. RTV was below the char line in all joints except Joint 3 on the RH nozzle where gas penetrated the joint RTV in one area. The primary and secondary O-rings in all joints showed no signs of blowby, erosion, heat effects, or disassembly damage.

Metal damage due to disassembly or handling was found on the LH aft exit cone and RH fixed housing. The RH nozzle assembly shifted during transportation resulting in light scratches and displaced metal on the aft end of the fixed housing flange (forward face). Preliminary PFAR 46C-01 was written against this condition. Two areas of metal damage were found on the aft exit cone assembly. The first area was located on the compliance ring OD at 198 degrees. The damage measured 0.080 inch circumferential, extending 0.090 inch aft of the top of the compliance ring, with an approximate depth of 0.120 inch. The second area consisted of a rounded corner of the forward OD edge of the exit cone shell. The area was located from 330–340 degrees measuring approximately 0.070 inch axial. Preliminary PFAR 46C-09 was written as a result of these conditions.

The following sections provide detailed assessments of nozzle internal joints, bondlines, char and erosion performance, flex boot, bearing protector, and flex bearing performance, and throat erosion data. The outcome of special issues and concerns for this nozzle flight set is also presented. PFORs documenting the observations are found in Appendix B and C.

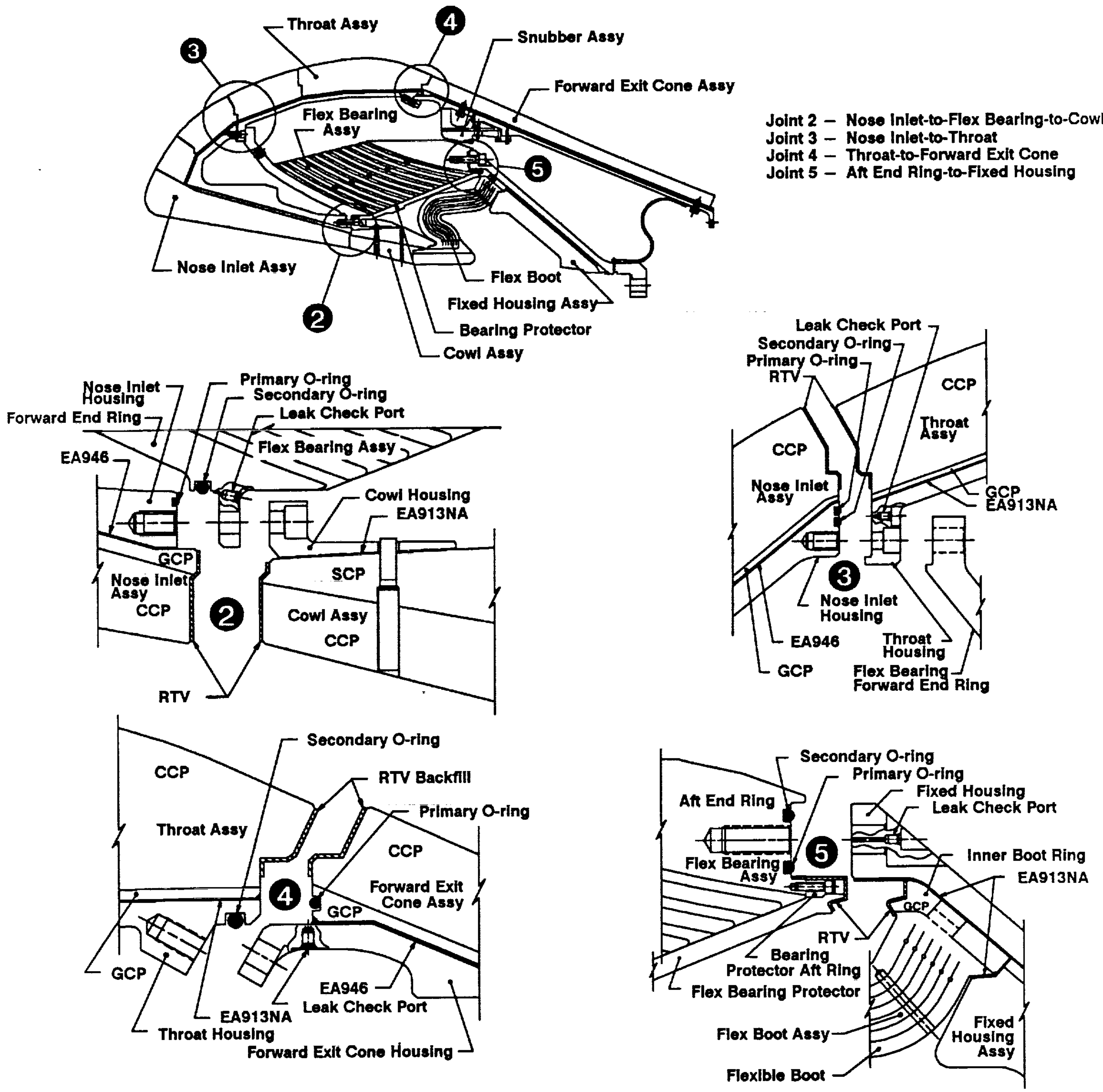

Figure 3. Internal Nozzle Joint Configuration

4.3.1 Nose Inlet/Forward End Ring/Cowl (Joint 2)

LH

No anomalous conditions were observed. Typical scalloped shaped soot was observed full circumference. Soot reached the primary O-ring at 44–46, 162–174, 198–228 and 272–274 degrees. No O-ring or seal surface damage was observed.

There was typical mixing of RTV and adhesive with the RTV below the char line over the complete circumference. Typical soot entered the joint between layers of RTV and adhesive. Soot and light corrosion reached the bolt circle intermittently around the full circumference.

Grease coverage on the joint metal surfaces was nominal. No excessive grease was found in the bolt holes. Medium-to-heavy corrosion was present on the forward end chamfer area of the cowl housing intermittent full circumference. There was also light corrosion on the OD of the forward mounting face of the cowl housing full circumference. The forward end ring flange OD had intermittent light-to-medium corrosion in areas where the paint was chipped or missing but there was no evidence of heat effects. There was also light-to-medium corrosion on the forward end ring flange mounting face and nose inlet ID surface but did not extend into the O-ring footprints.

No separations were observed on the nose inlet assembly or cowl assembly.

RH

No anomalous conditions were observed. Typical scalloped shaped soot was observed full circumference. Soot reached the bolt circle and primary O-ring at 56–60, 150–156 and 218–222 degrees, but did not go past the footprint. No O-ring or seal surface damage was observed.

There was typical mixing of RTV and adhesive with the RTV below the char line over the complete circumference. Typical soot entered the joint between layers of RTV and adhesive. A terminated gas path was found within the RTV at 320 degrees. It did not extend to the metal housing.

Grease coverage on the joint metal surfaces was nominal. No excessive grease was found in the bolt holes. Intermittent light corrosion was located on the forward end chamfer of the cowl housing. Medium corrosion was found at 255–340 degrees on the cowl ID with intermittent light corrosion existing on the remaining circumference. The forward end ring flange OD had chipped paint from 247–252 degrees with light-to-medium corrosion but no heat effects. There was light-to-medium corrosion on the forward end ring flange mounting face and nose inlet ID surface, but it did not extend into the O-ring footprints.

No separations were observed on the nose inlet assembly or cowl assembly.

4.3.2 Nose Inlet/Throat (Joint 3)

LH

No anomalous conditions were observed. No O-ring or seal surface damage was observed.

RTV was below the char line over the complete circumference with slight scalloping below the char line at 13, 24, and 63 degrees. No gas paths were observed in this joint.

Grease coverage on the joint metal surfaces was nominal. No excessive grease was found in the bolt holes. Typical light-to-heavy corrosion was observed inboard of the primary O-ring intermittently full circumference. No other metal damage was observed.

There were no separations observed on the nose inlet assembly. The forward end of the throat assembly was separated full circumference between metal-to-adhesive with a maximum radial width of 0.010 inch.

RH

Three anomalous conditions were observed. Gas penetrated into the joint at 211 degrees. Very light sooting reached the primary O-ring in this area. No O-ring or seal surface damage was observed.

RTV was below the char line except at 211 degrees. The area of RTV that did not extend below the char line measured 0.60 inch circumferentially at the char line (3.80 inches circumferentially maximum) by 0.70 inch radially from the char line. Preliminary PFAR 46C-05 was written against this condition. Associated heat affected CCP was also found at 211 degrees on both the nose inlet and throat joint surfaces with a shallow depth of approximately 0.005-0.010 inch. Preliminary PFARs 46C-06 and 46C-07 were written against these observations. Uncured RTV was also observed at 48-80 degrees, 100-114 degrees, and 141-162 degrees.

Grease coverage on the joint metal surfaces was nominal. No excessive grease was found in the bolt holes. Typical light-to-medium corrosion was observed inboard of the primary O-ring intermittently full circumference. No other metal damage was observed.

The aft end of the nose inlet assembly was separated full circumference between adhesive-to-GCP with a maximum radial width of 0.010 inch. There were no separations observed on the throat assembly.

4.3.3 Throat/Forward Exit Cone (Joint 4)

LH

No anomalous conditions were observed. No O–ring or seal surface damage was observed.

RTV was below the char line over the complete circumference of the joint. The RTV reached the primary O–ring from 0–45 degrees, 83–105 degrees, and 173–300 degrees. No gas paths were observed in this joint.

Grease coverage on the joint metal surfaces was nominal. No excess grease was found in the bolt holes. Light–to–medium corrosion was observed intermittently on the inboard 0.070 inch of the throat. The corrosion did not extend into the O–ring footprint. Light burnishing was found on the throat aft surface. No other metal damage was observed.

Two metal–to–adhesive separations with a maximum radial width of 0.015 inch and one GCP–to–CCP separation with a maximum radial width of 0.20 inch were observed on the FEC forward end. The aft end of the throat assembly exhibited a metal–to–adhesive separation full circumference with a maximum radial width of 0.010 inch.

RH

One anomalous condition was observed. Medium–to–heavy corrosion existed on the outboard edge of the throat aft surface with the deepest pit, measuring 0.002 inch, located on the sealing surface at 250–251 degrees. Preliminary PFAR 46C–02 was written against this condition. No O–ring damage was observed.

RTV was below the char line over the complete circumference of the joint. RTV did not reach the primary O–ring. No gas paths were observed in this joint.

Grease coverage on the joint metal surfaces was nominal. No excess grease was found in the bolt holes. Light–to–medium corrosion was also observed on the inboard of the throat aft surface intermittently with heavy corrosion existing from 162–200 degrees. No other metal damage was observed.

The aft end of the throat assembly was separated full circumference between metal and the adhesive with a maximum radial width of 0.010 inch. The forward end of the forward exit cone also had a metal–to–adhesive separation full circumference with a maximum radial width of 0.100 inch.

4.3.4 Flex Bearing/Fixed Housing (Joint 5)

LH

No anomalous conditions were observed. No rounded chamfers were observed on the spotfaces for the Packings with Retainers. All 72 Packings with Retainers had typical disassembly damage to the elastomer. No O-ring or seal surface damage was observed.

The RTV coverage was nominal. The RTV extended forward intermittently around the full circumference on the ID of bearing protector inner ring to the flex bearing aft end ring/ bearing protector interface. The RTV did not reach the primary O-ring. Three small voids in the RTV were found due to the assembly process. No gas paths were observed in this joint.

Grease coverage on the joint metal surfaces was nominal. Intermittently medium-to-heavy corrosion was observed on the ID aft tip of the aft end ring. No other metal damage was observed.

There was typical even sooting on the bearing protector and the flex boot ID.

No separations were observed between the inner boot ring and the fixed housing.

RH

No anomalous conditions were observed. No rounded chamfers were observed on the spotfaces for the Packing with Retainers. Seventy-one out of 72 Packings with Retainers had typical disassembly damage to the elastomer. Thirty-five out of 72 Packing with Retainers had radial scratches with raised metal on the retainer and/or gouges in the rubber element. The damage appeared to have occurred during bolt and/or Packing with Retainer removal. Preliminary PFAR 46C-03 was written against this condition. No O-ring or seal surface damage was observed.

The RTV coverage was nominal. The RTV extended to, but not past the primary O-ring from 150-220 and 330-335 degrees. Intermittent voids were observed in the RTV due to the assembly process. No gas paths were observed in this joint.

Grease coverage on the joint metal surfaces was nominal. No excess grease was found in the bolt holes. Intermittent medium-to-heavy corrosion was observed on the ID aft tip of the aft end ring. The heaviest corrosion was located from 160-0-100 degrees. Pit depth was not measured. Medium corrosion was observed on the secondary seal surface (in the footprint) of the fixed housing at 323 degrees. The corrosion occurred after splashdown. Several radial scratches, which could not be felt with a 5-mil brass shim, were observed across the primary seal surface of the fixed housing at 350 degrees.

There was typical even sooting on the bearing protector and the flex boot ID.

No separations were observed between the inner boot ring and the fixed housing.

4.3.5 Aft Exit Cone Assembly Bondlines

LH

No anomalous conditions were observed. The primary mode of separation was 61 percent adhesive-to-GCP, 31 percent within GCP, and 8 percent metal-to-adhesive. The secondary mode was not recorded. Intermittent small voids (0.10 inch diameter maximum) were observed throughout the polysulfide.

RH

No anomalous conditions were observed. The primary mode of separation was 52.5 percent within the GCP, 35 percent adhesive-to-GCP, and 12.5 percent metal-to-adhesive. The secondary mode was not recorded. Four adhesive voids were documented with a diameter greater than 0.5 inch. Intermittent small voids (0.10 inch diameter maximum) were observed throughout the polysulfide.

4.3.6 Forward Exit Cone Assembly Bondlines

LH

No anomalous conditions were observed. The mode of separation was 67.5 percent adhesive-to-GCP, 27.5 percent metal-to-adhesive, and 5 percent within adhesive. Medium-to-heavy corrosion was present in areas of the adhesive-to-metal separation. Seven adhesive voids had a diameter greater than 0.5 inch.

RH

No anomalous conditions were observed. The mode of separation was 72 percent metal-to-adhesive, 27 percent adhesive-to-GCP and 1 percent within the adhesive. Medium-to-heavy corrosion was present in areas of the adhesive-to-metal separation. Four adhesive voids were found that had a diameter greater than 0.5 inch.

4.3.7 Throat Assembly Bondlines

RH

No anomalous conditions were observed. The throat inlet ring and throat ring mode of separation was 100 percent metal-to-adhesive. Light-to-heavy corrosion was observed over the full axial length of throat support housing and full circumference with heavy corrosion existing over 65 percent of the surface. Intermittent 'wormhole' voids were found near the aft end. The largest measured 4.6 inches axially by 17.0 inches circumferentially. Intermittent voids (less than 0.50 inch diameter) were observed over the entire surface.

No anomalous conditions were observed. The throat inlet ring and throat ring mode of separation was 63 percent metal-to-adhesive, 31 percent GCP-to-CCP, and 6 percent adhesive-to-GCP. The secondary mode of separation was 65 percent adhesive-to-GCP and 35 percent metal-to-adhesive. Medium-to-heavy corrosion was present on the throat ring only at the metal-to-adhesive separation areas. There were two voids that exceeded 0.50 inch in diameter.

4.3.8 Nose Inlet Rings (-503, -504) Bondlines

LH

No anomalous conditions were observed. The mode of separation was 100 percent metal-to-adhesive. Medium-to-heavy corrosion was present in the areas of the adhesive-to-metal separation. Two adhesive voids were found that had a diameter greater than 0.50.

RH

No anomalous conditions were observed. The mode of separation was 100 percent metal-to-adhesive. Intermittent light-to-medium corrosion was present over the entire surface. No adhesive voids were found that exceeded 0.50 inch in diameter.

4.3.9 Nose Cap Bondlines

LH

No anomalous condition were observed. The primary mode of separation was 96 percent GCP-to-CCP and 4 percent metal-to-adhesive. The secondary mode of separation was 67 percent adhesive-to-GCP and 33 percent metal-to-adhesive. Light corrosion was found on the forward and aft ends. No adhesive voids were found that exceeded 0.50 inch in diameter.

LH

No anomalous conditions were observed. The primary mode of separation was 86 percent GCP-to-CCP, 8 percent within the GCP, and 6 percent metal-to-adhesive. The secondary mode of separation was 78 percent adhesive-to-GCP and 22 percent metal-to-adhesive. Light-to-heavy corrosion was found on the forward end and light-to-medium corrosion was found on the aft end. Four adhesive voids had a diameter greater than 0.50 inch.

4.3.10 Cowl Assembly Bondlines

LH

No anomalous conditions were observed. The mode of separation was 100 percent metal–to–adhesive. Medium corrosion was observed on the bonding surface around the full circumference. Five adhesive voids had a diameter greater than 0.50 inch.

RH

No anomalous conditions were observed. The mode of separation was 100 percent metal–to–adhesive. Medium corrosion was observed on the bonding surface around the full circumference. No adhesive voids were found that had a diameter greater than 0.50 inch.

4.3.11 Fixed Housing Assembly Bondlines

LH

No anomalous conditions were observed. The primary mode of separation was 65 percent GCP–to–CCP and 35 percent within GCP. The secondary mode of separation was 100 percent adhesive–to–GCP. Eight adhesive voids had a diameter greater than 0.50 inch. Intermittent adhesive voids with diameters of 0.50 inch maximum or smaller were observed around the circumference. No corrosion was observed on the housing.

RH

No anomalous conditions were observed. The primary mode of separation was 50 percent within GCP and 50 percent GCP–to–CCP. The secondary failure mode was 100 percent adhesive–to–GCP. Eight adhesive voids had a diameter greater than 0.5 inch. No corrosion was observed on the housing.

4.3.12 Ultrasonic Inspection of Fixed Housing Assemblies

Ultrasonic inspection was conducted on both of the fixed housing assemblies. The bondlines appeared nominal with no significant (greater than 1.0 inch diameter) unbonds detected. Several small (less than 1.0 inch diameter) unbond indications were found on both fixed housing bondlines.

4.3.13 Char and Erosion Performance

Char and erosion margins of safety are summarized in Table VIII. The char and erosion data tables for each component liner can be found in Tables D–I through D–XII of Appendix D. Measurement stations that contain an "N/A" means that data was not available due to missing material. The aft exit cone liners were not recovered and therefore are not included. All stations showed positive margins of safety. The measurement stations can be found in Figure D-1.

Table VIII. 360T025 Nozzle Char and Erosion Minimum Margins of Safety Summary

Hardware	Stations*												
Forward Exit Cone Assembly, LH	**1**	**4**	**4.6**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**32.9**	**34**	
	0.29	0.27	0.23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Forward Exit Cone Assembly, RH	**1**	**4**	**4.6**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**32.9**	**34**	
	0.27	0.26	0.24	0.24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Throat Assembly, LH	**1**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**23**
	0.20	0.22	0.16	0.12	0.10	0.20	0.28	0.34	0.38	0.29	0.54	0.50	0.29
Throat Assembly, RH	**1**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**23**
	0.16	0.14	0.14	0.12	0.08	0.19	0.21	0.25	0.35	0.37	0.46	0.41	0.21
Nose Inlet Rings (–503, –504), LH	**28**	**30**	**32**	**34**	**36**	**38**	**39**						
	0.22	0.39	0.23	0.45	0.39	0.20	0.14						
Nose Inlet Rings (–503, –504), RH	**28**	**30**	**32**	**34**	**36**	**38**	**39**						
	0.23	0.33	0.21	0.44	0.42	0.28	0.20						
Nose Cap, LH	**1.5**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**
	N/A	0.56	0.67	0.64	0.70	0.87	0.88	0.62	0.59	0.60	0.11	0.01	0.05
Nose Cap, RH	**1.5**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**
	N/A	0.58	0.65	0.67	0.72	0.74	0.77	0.72	0.67	0.66	0.26	0.11	0.23
Cowl/OBR, LH	**0.3**	**1**	**2**	**3**	**4**	**5**	**6**	**6.8**	**8**	**9**	**10**	**11.3**	
	0.48	0.34	0.21	0.17	0.26	0.36	0.47	0.42	0.29	0.42	0.60	0.57	
Cowl/OBR, RH	**0.3**	**1**	**2**	**3**	**4**	**5**	**6**	**6.8**	**8**	**9**	**10**	**11.3**	
	0.22	0.29	0.29	0.38	0.40	0.51	0.59	N/A	0.31	0.51	0.54	0.53	
Fixed Housing Assembly, LH	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10.75**		
	2.02	0.83	0.72	0.71	0.66	0.61	0.68	0.67	1.19	2.15	N/A		
Fixed Housing Assembly, RH	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10.75**		
	2.25	0.86	0.81	0.90	0.93	0.81	0.74	0.80	0.97	2.42	N/A		

* Station locations are shown in bold with the margin of safety shown below.

4.3.14 Flex Boot Performance

The performance of both the LH and RH flex boots was nominal. Typical even sooting on both flexible boot inside diameters was present. Both the LH and RH flex boots had a minimum of 3.1 NBR plies intact. Positive margins of safety were achieved at all measurement stations. The flex boot performance margins of safety are summarized in Table IX.

Table IX. 360T025 Flex Boot Margins of Safety

	Left Hand			Right Hand		
Degree Location	Remaining Plies	Max. Material Affected Depth (in.)	Performance Margin of Safety	Remaining Plies	Max. Material Affected Depth (in.)	Performance Margin of Safety
0	3.3	1.30	0.28	3.1	1.37	0.21
90	3.2	1.34	0.24	3.3	1.30	0.28
180	3.1	1.37	0.21	3.9	1.11	0.50
270	3.1	1.37	0.21	3.2	1.34	0.24

* Minimum flex boot overall prefire thickness is 2.5 inches.

4.3.15 Bearing Protector Performance

Close examination showed both of the bearing protectors performed as expected during flight. Both of the protectors were evenly sooted around the circumference and showed typically greater erosion in–line with the cowl vent holes. Five areas of heat effects with slight erosion were found on the RH bearing protector other than at the vent hole locations. The areas were located from 2.7 inches to 6.5 inches from the aft end of the bearing protector at 162 degrees, 165 degrees, 167 degrees, 180 degrees, and 183 degrees. The maximum erosion occurred at 165 degrees measuring 0.80 inch axial, 1.40 inch circ., by 0.12 inch in depth. A corresponding heat affected and slightly eroded area was found at 165 degrees on the flex boot. Slag fragments were found in the boot cavity. It is believed that slag entering through the vent holes caused this condition. No indications of soot or heat effects were found on the ID side of the bearing protector. Preliminary PFAR 46C–08 was written as a result of this observation. PFOR pg. C–12 shows the postflight bearing protector thickness measurements every ten degrees.

4.3.16 Flex Bearing Performance

LH

The flex bearing performance during flight was acceptable. There were no anomalies associated with flight or splashdown. Examination of the flex bearing revealed no damage, soot, heat effect, or flow indications. Intermittent areas of snubber segment scuffing were found on the aft end ring due to splashdown. Intermittent bubbled (unbonded) paint was found on the flex bearing forward end ring OD at various axial locations around the circumference. The largest bubble was located at 13 degrees and measured 0.20 inch diameter. No corrosion was found under the bubble. Preliminary PFAR 46C–04 was written as a result of this observation.

RH

No anomalous conditions were observed. The flex bearing performance during flight was acceptable, with no anomalies reported. Examination of the flex bearing revealed no damage, soot, heat effect, or flow indications. Intermittent areas of snubber segment scuffing were found on the aft end ring due to splashdown.

4.3.17 Throat Diameter

No anomalous conditions were observed. The average LH nozzle postfire throat diameter was 55.909 inches (erosion rate of 8.4 mils/sec based on an action time of 121.87 sec). The average RH nozzle postfire throat diameter was 55.992 inches (erosion rate of 8.7 mils/sec based on an action time of 122.09 sec). RSRM postfire throat diameters have ranged from 55.787 to 56.072 inches.

4.3.18 Results of Special Issues and Concerns (Nozzle)

identified areas for special evaluation of 360T025 at Clearfield. The nozzle issues are listed below with their respective results.

1. Condition: Low Density Indications (LDIs) were observed in the GCP of the LH nose cap from 220–to–260 degrees and at 7.5 to 15.6 inches from the forward end. X–ray interpretation indicated that these areas were density variations.

Results: After removal of the GCP, there was no evidence of the noted LDIs.

2. Condition: Wetline indications were observed in the aft end of the LH fixed housing GCP and were located 0.25 and 0.40 inch aft of the phenolic O–ring groove. Circumferential degree locations and length are as follows: 43 degrees, 9.4 inches; 61 degrees, 1.0 inch; 115 degrees, 23.2 inches; 150 degrees, 14.6 inches; 180 degrees, 41.5 inches; 230 degrees, 1.7 inches; 280 degrees, 12.5 inches; 330 degrees, 45.8 inches. These indications were removed at final assembly level.

Results: A visible resin rich band was observed at 0.40 inch aft of the wiper O–ring groove at 43–46 degrees and at 0.30 inch aft of the O–ring groove from 330–345 degrees. This corresponds to two of the noted wetline indications. The other areas at 61 degrees, 115 degrees, 150 degrees, 180 degrees, 230 degrees, and 280 degrees were not found.

3. Condition: Low Density Indications (LDIs) were noted at CCP/GCP interface in the RH fixed housing insulation. Indications are located 125–to–132 degrees, 1.78 inches from aft tip of the glass. The circumferential extent is 7.11 inches.

Results: No LDIs were observed on the sample.

4. Condition: Bent and broken flex bearing protector forward ring screws have been observed on flight and static test motors. Exact cause of the damage is under investigation.

Results: The portion of cowl insulation segments over the screws was removed by coring over the head of each screw. No bent or broken flex bearing protector forward ring screws were found on either the LH or RH nozzle.

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