THIOKOL
AEROSPACE & INDUSTRIAL TECHNOLOGIES

CRITICAL ITEMS LIST (CIL)

No. 10-05-01-11R/02

| | | | |
|---|---|---|---|
| SYSTEM: | Space Shuttle RSRM 10 | CRITICALITY CATEGORY: | 1 |
| SUBSYSTEM: | Assembly Hardware/Interfaces 10-05 | PART NAME: | Field Joint, Thermal Protection System (1) |
| ASSEMBLY: | Field Joints and Kits 10-05-01 | PART NO: | (See Section 6.0) |
| FMEA ITEM NO.: | 10-05-01-11R Rev M | PHASE(S): | Boost (BT) |
| CIL REV NO.: | M | QUANTITY: | (See Section 6.0) |
| DATE: | 31 Jul 2000 | EFFECTIVITY: | (See Table 101-6) |
| SUPERSEDES PAGE: | 227-1ff. | HAZARD REF.: | BC-11 |
| DATE: | 30 Jul 1999 | | |
| CIL ANALYST: | F. Duersch | | |
| APPROVED BY: | | DATE: | |

RELIABILITY ENGINEERING: K. G. Sanofsky 31 Jul 2000

ENGINEERING: H. D. Huppi 31 Jul 2000

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1.0 FAILURE CONDITION: Failure during operation (D)

2.0 FAILURE MODE: 1.0 Structural failure

3.0 FAILURE EFFECTS: Breakup and loss of thermal protection system. Debris damages adjacent STS systems causing loss of RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

| FC NO. | | DESCRIPTION | FAILURE CAUSE KEY |
|---|---|---|---|
| 1.1 | | Bondline failure of the cork or ablation compound | |
| | 1.1.1 | Bonding surfaces not properly prepared or adequately cleaned | A |
| | 1.1.2 | Bonding material not properly mixed, applied, or cured | B |
| | 1.1.3 | Contamination during processing | C |
| | 1.1.4 | Process environments detrimental to bond strength | D |
| | 1.1.5 | Nonconforming material properties | E |
| | 1.1.6 | Bond strength degradation during assembly, handling, storage, or transportation | F |
| | 1.1.7 | Bondlines not to required thickness | G |
| 1.2 | | Vibration and aeroshear | H |
| 1.3 | | Nonconforming material properties | I |
| 1.4 | | Cork or ablation compound not manufactured or applied to required thickness | J |
| 1.5 | | Aeroheating and plume radiation | K |
| 1.6 | | Transportation, handling, or assembly damage | L |

1.7 Moisture, fungus, or age degradation M

5.0 REDUNDANCY SCREENS:

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

6.0 ITEM DESCRIPTION:

1. A thermal shield for the field joint and heater is installed at KSC per engineering drawings. It comprises two rows of machined cork either side of the joint heater, with one band covering the joint pin retainer band, and K5NA ablation compound filling the space between the rows of cork and covering the heater structure.

2. Heater closeout material, composed of small amounts of machined cork and ablation compound used to cover heater cable connections. Materials are listed in Table 1.

TABLE 1. MATERIALS

| Drawing No. | Name | Material | Specification | Quantity |
|---|---|---|---|---|
| 1U77648 | Assembly and Close out, RSRM, KSC | Composite of Various Components | | 1/motor |
| 1U77160 | Cork, Fwd and Aft Strip, FJPS | Sheet Cork | STW4-2700 | Fwd 60/motor<br>Aft 60/motor |
| 1U77157 | Thermal Barrier, Cork Paint | Sheet Cork<br>Moisture and Fungus Protection | STW4-2700<br>STW4-9084 | A/R<br>10 gal |
| | Ablation Compound, Cork-Filled (K5NA) | Ground Cork, Epoxy Resin, Curing Agent | STW5-3183 or MSFC-SPEC-1918 | A/R |
| | Epoxy Adhesive, Silica-filled with Cab-O-Sil | Adhesive | STW4-3218<br>STW5-3837 | 75 lb |
| | Epoxy Resin Adhesive, Non-Asbestos | Epoxy resin and Curing Agent | STW4-3218 | A/R |

6.1 CHARACTERISTICS:

1. The Field Joint Thermal Protection System (FJPS) provides protection for field joint components from aerothermal environments during boost phase. Shielding, heat retention during prelaunch, or minimization of damage to components at water impact are not relevant to the failure mode analyzed.

2. Thermal protection for the joint heater, Kevlar heater retaining band, and other field joint components is provided by sections of thermally ablative cork bonded circumferentially around the case. Cork is supplied in cut sections of sheet cork that are machined to surface contours adjacent to the clevis and tang joint. Joint components are depicted in Figure 1. Formable ablation compound made of ground cork and epoxy resin is applied over the joint area between rings of sheet cork as depicted in Figure 1.

3. Heater closeout material, comprising ablation compound and small sections of machined cork, is used to provide thermal protection for heater cables and connectors in the area immediately forward and aft of each field joint. This area is the transition area between the forward and aft terminations of the systems tunnel FJPS in the vicinity of each field joint. Typical installations of heater closeout material are depicted in Figures 2 through 6.

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5. The circumferential FJPS structure and lesser parts referred to as heater close out material have identical materials and functions. All failure causes are relevant to the heater closeout material as well as components of the field joint FJPS that are installed circumferentially.

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

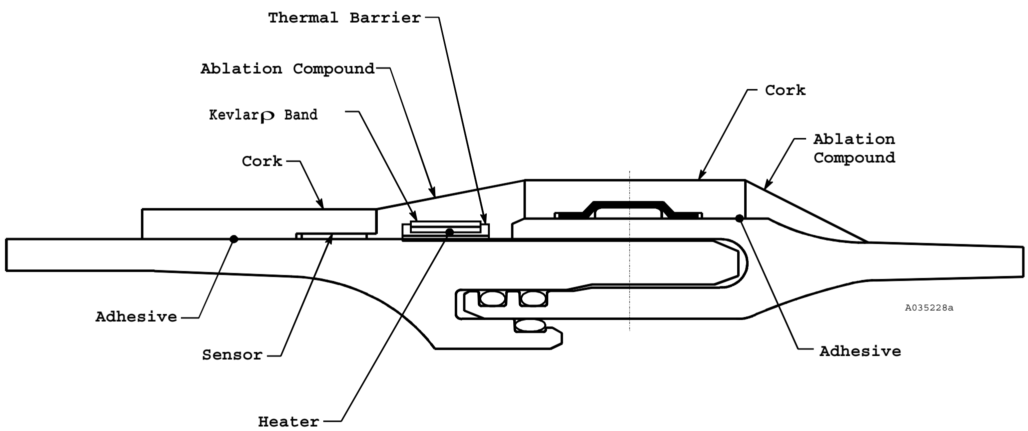



Figure 1. Cork Insulation Cross Section

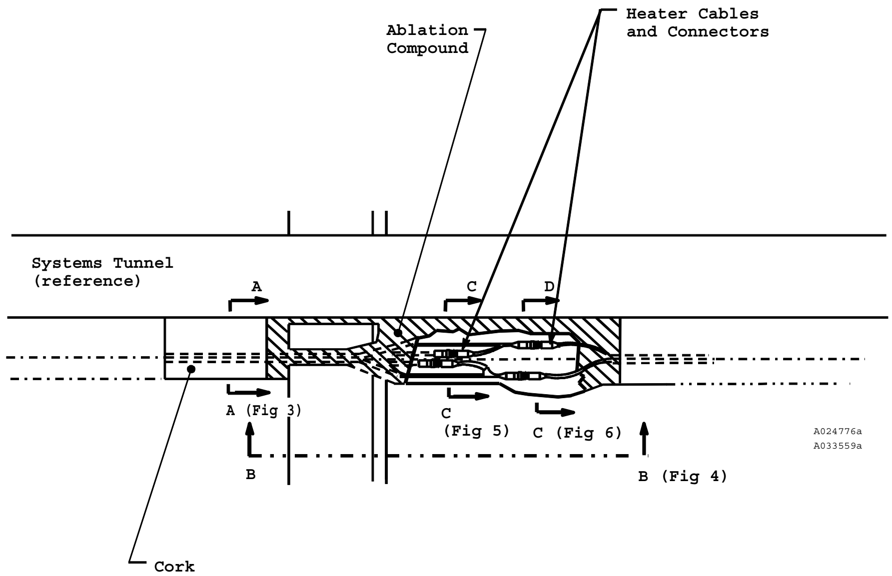
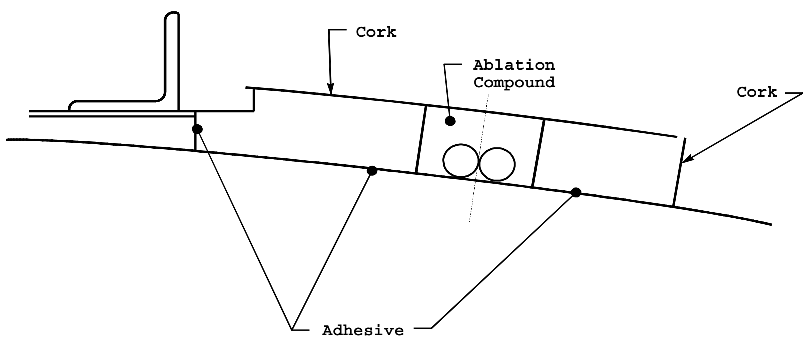
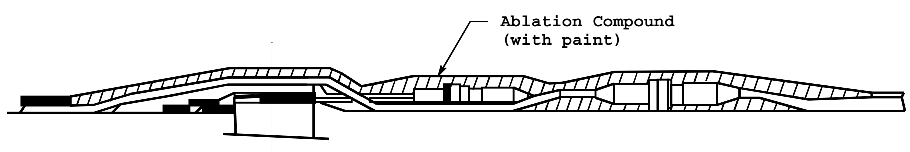



Figure 2. Heater Cables and Connectors Closeout




Section A-A

Figure 3. Heater Cables Closeout (Section A-A)




Section B-B

Figure 4. Heater Cables and Connectors Closeout (Section B-B)

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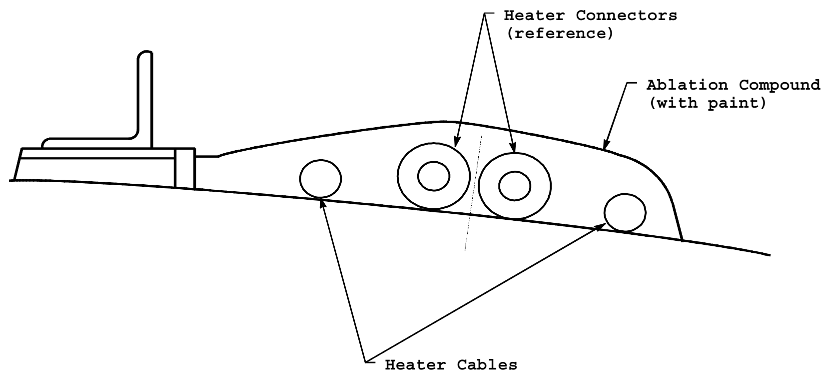
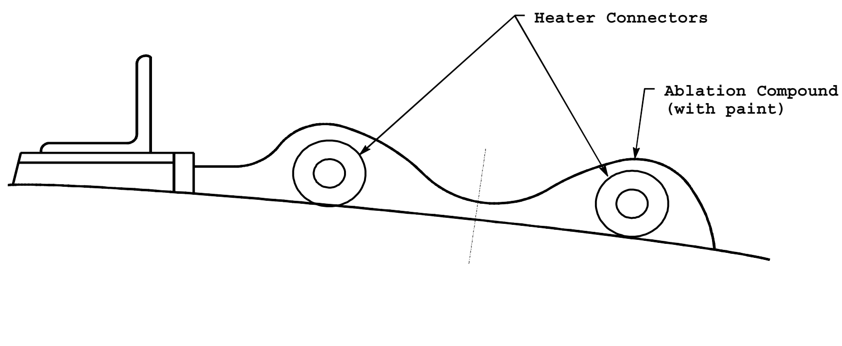



Section C-C

Figure 5. Heater Cables and Connectors Closeout Section C-C)




Section D-D

Figure 6. Heater Cables and Connectors Closeout (Section D-D)

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN FAILURE CAUSES

A,B,C,D 1. Fabrication process requirements for the field joint protection system at KSC are documented per engineering.

A,B,C,D,F,G,L 2. Bond integrity is verified by performing pull tests on cork insulation discs at KSC. A test disc is a portion of a larger bonded-in-place sheet, which was isolated from the adjacent cork by use of a cutter. Bond integrity includes: 1) Verification of processes for surface preparation and cork bonding, 2) Verification of absence of bond degradation during assembly, and 3) Verification of bonding material application.

~~576 E,I 3. Required material properties and methods of validation are documented per engineering and the following reports:~~

| ~~Thermal and Material~~ | ~~Development and Structural Analyses~~ | ~~Acceptance Testing~~ |
|---|---|---|
| ~~Cork~~ | ~~TWR-50017, TWR-50019~~ | ~~TWR-50021 (moisture test)~~ |
| ~~Adhesive (Silica-filled Epoxy)~~ | ~~TWR-50019~~ | ~~TWR-50212, TWR-60855~~ |
| ~~Ablation compound (K5NA)~~ | ~~TWR-50017, TWR-50019~~ | ~~TWR-50020 (moisture test)~~ |
| ~~Paint~~ | ~~-------~~ | ~~TWR-50021~~ |

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| Adhesive (Silica-filled Epoxy) | TWR-50019 | TWR-50212, TWR-60855 |
| Ablation compound (K5NA) | TWR-50017, TWR-50019 | TWR-50020 (moisture test) |
| Paint | ------- | TWR-66657 |

E,I 4. Silica-filled epoxy is made by mixing the curing agent (Part B) of the epoxy adhesive with microfine silicon dioxide. Properties of silica-filled epoxy are controlled by testing the separate ingredients.

F,L 5. Application and assembly of redesigned JPS and heater closeout material are per engineering. Thiokol engineering requires that cork be undisturbed during initial hours of cure.

F,L 6. For shipment to KSC, cork segments and other FJPS components are packed and packaged to provide protection against deterioration and damage during normal commercial transportation and handling and known storage conditions for a period normally not exceeding one year per engineering drawings.

F,L 7. All FJPS surfaces where the paint is damaged are repainted after verifying absence of fungus and exposed cork. If the FJPS is damaged, the damage is repaired per accepted procedures prior to repainting.

G 8. Thiokol engineering requires application of adhesive to cork and corresponding bonding surfaces on the case and Kevlar bands. The cork is then pressed into position and mechanically restrained for a time. The process results in squeezing out excess adhesive, with the remainder constituting the "required bondline thickness."

H,J,K 9. Wind-tunnel testing of the FJPS was performed as part of qualification testing of the FJPS. Three simulated field joints were tested. The test configuration consisted of FJPS components assembled to a tang-clevis joint as reported in TWR-17243. Results indicated that there were no bondline or structural failures and that temperatures of field joint components protected by cork correlated well with temperatures predicted by the thermal analysis. This directly demonstrates structural integrity of the bondlines, ablation compound, and sheet cork under aeroshear environments.

H 10. As reported in TWR-17243, qualification wind-tunnel testing of the FJPS included testing of heater cables, heater connectors, and closeout material. Three sets of heater cables and three sets of heater connectors were tested. Results indicated that the closeout material performed as designed, successfully withstanding the aeroshear environment with no evidence of structural failure or excessive erosion.

H 11. Vibration and pressurization testing of the FJPS was performed per CTP-0054 and results were reported in TWR-17245. Testing included environmental conditioning to prelaunch natural environments consisting of high temperature, high humidity, salt, fog, rain, and low temperature. After conditioning, the test article was subjected to flight and reentry random vibration, vehicle dynamics vibration, and water landing shock. Post-test visual inspections performed after each sub-test emphasized examinations for obvious de-bonds, delaminations, and any other degradation. Following testing and post-test inspections, pull tests were performed on cork discs isolated from the surrounding cork. Pull test data are used for materials and adhesives evaluation only, but these data and other test results verify the structural integrity of the FJPS, including absence of bond degradation during short-term exposure to worst-case natural environments.

J,K 12. Cork material thickness is controlled per engineering drawings and specifications.

J,K 13. Application of ablation compound is controlled per engineering drawings and specifications.

J,K 14. Results of a thermal analysis of the redesigned FJPS are reported in TWR-50017. The analysis used material thermal properties per TWR-40058. The analysis shows that the thermal protection provided by the cork and ablation compound in the new FJPS configuration results in temperatures of field joint components that are well within design constraints.

J,K 15. Material properties and processes for the FJPS were demonstrated on development and qualification motors and reported in TWR-18764-14.

M 16. The following sheet cork requirements are imposed to prevent moisture or fungus damage:

a. Packaging shall prevent absorption of moisture of the cork during shipment and storage. Packaging material shall be capable of being resealed during use.
b. Cork material shall have a minimum storage life of 2 years from date of receipt when stored at warehouse-ambient temperature. Each time a

container is opened, it is resealed to maintain material properties during storage. Storage life may be extended if the material passes retests.

M — 17. After installation, all exposed surfaces of the cork, adhesive, and ablative compound are coated with paint and conform to engineering drawings for the following:

a. Paint must have a low permeability to moisture and must be resistant to weathering and fungus growth. Test methods and acceptability requirements levied against these characteristics are per engineering.
b. Conformance to requirements on accelerated weathering, fungus resistance, and permeability are verified per the material qualification testing.
c. Paint has a minimum storage life per engineering.

F,L,M — 18. Cork and K5NA bond testing on aged TEM motors for over five years, maintained a positive structural margin of safety per TWR-64178.

A,B,C,D,H,L — 19. An updated analysis was performed on the field joint protection system 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-66825-4.

9.2 TEST AND INSPECTION:

| DCN | FAILURE CAUSES and TESTS | (T) | | | | CIL CODES |
|---|---|---|---|---|---|---|
| | | | 1. | For New Cork, Sheet verify: | | |
| | E,I | (T) | | a. | Density | ALR004 |
| | E,I | (T) | | b. | Tensile strength | ALR044,ALR045 |
| | E,I | (T) | | c. | Tensile elongation | ALR038,ALR039 |
| | E,I | (T) | | d. | Recovery | ALR025 |
| | E,I | (T) | | e. | Flexibility | ALR013,ALR014 |
| | E,I | (T) | | f. | Specific heat | ALR030 |
| | E,I | (T) | | g. | Thermal conductivity | ALR050 |
| | E,I | | | h. | Workmanship | FAA005 |
| | J,K | | | i. | Thickness | ALR001 |
| | M | | | j. | No shipping or handling damage | ALR023 |
| | M | | | k. | Opened cork containers are resealed | ALR022 |
| | | | 2. | For Retest Cork, Sheet verify: | | |
| | E,I | (T) | | a. | Density | ALR009 |
| | E,I | (T) | | b. | Flexibility | ALR017 |
| | E,I | (T) | | c. | Specific heat | ALR035 |
| | | | 3. | For New Cork, Forward and Aft Strip, Field Joint Protection System verify: | | |
| | F,L | | | a. | No damage prior to kitting | FAA001 |
| | | | 4. | For New Thermal Barrier, Cork, verify: | | |
| | F,L | | | a. | No damage prior to kitting | FAA003 |
| | | | 5. | For New Paint, Moisture and Fungus Protection verify: | | |
| | E,I | (T) | | a. | Color | ANU002 |
| | E,I | (T) | | b. | Nonvolatile content | ANU009 |
| | E,I | (T) | | c. | Viscosity | ANU018 |
| | E,I | (T) | | d. | Weight per gallon | ANU025 |
| | E,I | | | e. | Certificate of Conformance | ANU015 |
| | E,I | | | f. | Workmanship | DJM012 |
| | E,I | (T) | | g. | Adhesion | DJM013 |
| | | | 6. | For New Epoxy Resin Adhesive, Non-Asbestos verify: | | |
| | E,I | (T) | | a. | Filler content (Part A) | AMD009,AMD013 |
| | E,I | (T) | | b. | Epoxide content (Part A) | AMD002,AMD006 |
| | E,I | (T) | | c. | Titratable nitrogen (Part B) | AMD035,AMD039 |
| | E,I | | | d. | Certificate of Conformance | FAA014 |
| | E,I | | | e. | Workmanship | AMD015 |
| | E,I | (T) | | f. | Working life | AMD043 |
| | E,I | (T) | | g. | Tensile adhesion steel-to-steel | AMD031 |
| | | | 7. | For Retest Epoxy Resin Adhesive, Non-Asbestos, verify: | | |
| | E,I | (T) | | a. | Tensile adhesion steel-to-steel | AMD033 |

| | | | | |
|---|---|---|---|---|
| | | 8. | For New Epoxy Adhesive, Silica-Filled, verify: | |
| E,I | (T) | a. | Working life | FAA015 |
| E,I | (T) | b. | Tensile adhesion steel-to-steel | FAA016 |
| | | 9. | For Retest Epoxy Adhesive, Silica Filled, verify: | |
| E,I | (T) | a. | Working life | FAC054 |
| E,I | (T) | b. | Tensile adhesion steel-to-steel for storage life extension | FAC055 |
| | | 10. | KSC verifies: | |
| A,B,C,D,E,F, G,I,J,K,L | (T) | a. | Life requirements, formulation, mixing, surface preparation, application, cure and physical properties for materials applied at KSC per OMRSD File V, Vol I, B09GEN.010 | OMD023 |
| F,L,M | | b. | No fungus or contamination upon TPS surface repair per OMRSD File V, Vol I, B47GEN.070 | OMD034 |
| M | | c. | Expiration date is not exceeded for materials installed at KSC per OMRSD File V, Vol I, B47GEN.160 | OMD042 |
| A,B,C,D, F,G,L | (T) | d. | Field joint cork bond pull test results comply with the requirements per OMRSD File V, Vol I, B09TP0.060 | OMD024 |
| A,B,C,D,M | | e. | No visible contamination of TPS bonding surface area just prior to cork installation per OMRSD File V, Vol I, B63FJ0.011 | OMD116 |