TWR- 17591 VOL. VII
ECS #: SS 1004

SPACE SHUTTLE
Solid Rocket Motors
Morton Thiokol Inc.

QM-8 Field Joint Protection System Final Report Volume 7

June 1989

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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FORM TC 4677 (REV 8-86)

(NASA-CR-183748) QM-8 FIELD JOINT PROTECTION SYSTEM, VOLUME 7 Final Report (Morton Thiokol) 23 p CSCL 21H

N90-13586

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MORTON THIOKOL, INC.

Space Operations

TWR-17591 VOL. VII
QM-8 FIELD JOINT PROTECTION SYSTEM FINAL REPORT
VOLUME 7
FINAL REPORT

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RELEASE

ACRONYMS

JPS	Joint Protection System
RSRM	Redesigned Solid Rocket Motor
RTD	Resistance Temperature Device

ABSTRACT

This report contains the pre-launch functioning data of the Field Joint Protection System (JPS) used on QM-8. Also included is the post fire condition of the JPS components following the test firing of the motor. The JPS components are:

1. Field Joint Heaters
2. Field Joint Sensors
3. Field Joint Moisture Seal
4. Moisture Seal Kevlar Retaining Straps
5. Field Joint External Extruded Cork Insulation
6. Vent valve
7. Power Cables
8. Igniter Heater

1.0 INTRODUCTION

Qualification Motor (QM) 8 was test fired on 20 January 1989. The three field joints of the motor were protected by the Joint Protection Systems (JPS). See Figure 1. The JPS heaters were turned on prior to the test firing to assure the joint O-ring temperature was between 85 and 122 degrees F at the time of ignition. The purpose of the moisture seal is to prevent entry of rain into the joint. The cork insulation provides thermal protection for the JPS during flight.

2.0 OBJECTIVES

The objective of this report is to document the performance of the JPS heaters and the post fire condition of the JPS components.

The following objectives of CTP-0038 are addressed in this report: (Numbers in parentheses identify CEI specification paragraphs)

BE. Certify the igniter heater maintains the igniter gasket rubber seal at the required temperature (3.2.1.5.3)

BL. Certify the ability of the field joint heater assembly to maintain the temperature of the field joints (3.2.1.11.a)

BR. Certify the reliability of the RSRM design (3.2.3)

BU. Certify that the shedding of external debris is precluded (3.2.6.5)

3.0 CONCLUSIONS AND RECOMMENDATIONS

Maintain Field Joint Temperature

The JPS heaters performed per specification and maintained the field joint temperatures within the required temperature range at the time of motor ignition (3.2.1.11.a).

Reliability of the RSRM Design

The JPS system performed its intended function without failure (3.2.3)

Shedding of External Debris is Precluded

All components of the JPS system remained bonded in place during the test. No debris was generated (3.2.6.5)

Maintain Ignitor Gasket Seals Temperature

The igniter heater performance was nominal (3.2.1.5.3)

4.0 RESULTS/DISCUSSIONS

4.1 Pre-Fire Performance

4.1.1 Field Joint Heater System

The heater temperature control system operated as predicted and maintained the temperature at the controlling

RTD at 86° with a maximum deviation of -0.6° to +0.5°. The four temperature sensors at each field joint were continuously monitored and the coldest sensor was manually selected for temperature control. Figure 2 is a plot of the temperature of the controlling RTD of the three field joints. The drop in temperature at 0600 and 1000 hours was due to heater power shut off.

4.1.2 Igniter Heater System

The Igniter Heater was turned on at T-12 hours. Temperatures at the sensors was maintained at 78 plus or minus 1 degree F. Igniter heater was shut down at T-2 minutes.

4.2 POST-TEST INSPECTION

4.2.1 FJPS External Insulation

Post-test inspection was conducted prior to FJPS removal from the motor no evidence of damage was observed. See Table 1 for pre-dissasembly evaluation worksheet. All the cork appeared to be intact and bonded to the case. After the cork was stripped from the case, the bondlines were inspected for voids.

Voids were found in the leading edge cork insulation to case bondlines of all joints. These were attribrited to improperly positioning of the cork during installation and from insufficient adhesive. The improper positioning of the cork occurred with one piece of cork on the center joint. This cork was installed 1/2 inch forward of it's intended position on the moisture seal, resulting in a long narrow void between the leading edge of the moisture seal and the cork. Some of the voids resulting from insufficient adhesive extended to the leading edge of the cork. See Table 2 through 4 evaluation worksheet.

4.2.2 EPDM Moisture Seal-to-Cork Bondlines

To inspect this bondline, the moisture seal had to be peeled off the cork with considerable force. The peeled surfaces showed that the EA 934NA remained on the cork with small black EPDM particles embedded in the adhesive surface, indicating the EPDM to EA 934NA interface is the weaker of the bond surfaces.

4.2.3 Kevlar Strap-to-Cork Bondline

This bondline was difficult to peel back. In some areas, the EA 934NA was embedded in both the inside and outside straps, especially where the pin retainer band trunnions lift the Kevlar strap and allow adhesive to flow underneath the band.

4.2.4 Moisture Seal Condition

The moisture seals showed no evidence of rips or tears in the areas where the pin retainer trunnions contact the moisture seal. However, because of the excellent bond between the EA934NA and the moisture seal, an occasional piece of the moisture seal was ripped up during disassembly. See Table 5 for the evaluation worksheets.

4.2.5 Kevlar Strap Condition

The straps were fully intact. There was no evidence of fiber damage or adhesive cracking at the buckle interfaces. The areas where the pin retainer trunnions raise the strap showed no fiber distortion or breakage and had adhesive underneath forming a smooth surface for the Kevlar strap to ride on.

4.2.6 JPS Heater

The heaters showed no evidence of delamination, cracking, or overheating. See Table 6 for evaluation worksheet.

4.2.7 JPS Sensor

The sensor could not be observed until after the cork insulation was removed. There were no anomalies such as cracking, except that which was caused by the removal of the cork insulation. See Table 6 for the evaluation worksheet.

4.2.8 Heater Cables

The heater cables were in excellent condition following the test. No voids are missing material, debonds, or charred material were found. Table 7 is the pre disassembly and Table 8 is the post disassembly worksheets for the heater cables.

4.2.9 Vent Valves

One vent valve was installed on each of the three field joints at the 135° location. All three vent valves were open to back pressure following the test. See Table 9 for the evaluation worksheet.

4.2.10 Igniter Heater

During post fire inspection the igniter heater installation and components were inspected. Igniter heater, cork insulation, T-bolt latch band clamp, and heater power cables were intact and properly secured on the igniter adapter and forward dome with no anomalies noted. There was a .030 inch air gap approximately .50 inch long between the heater and case at the location of the clamp buckle, however, no buckling or warpping of the heater was noted. After removal of the igniter heater components the heater was carefully inspected. No discoloration, charring, warpping, or buckling of the heater was noted. See Tables 10 and 11 for the evaluation worksheet.

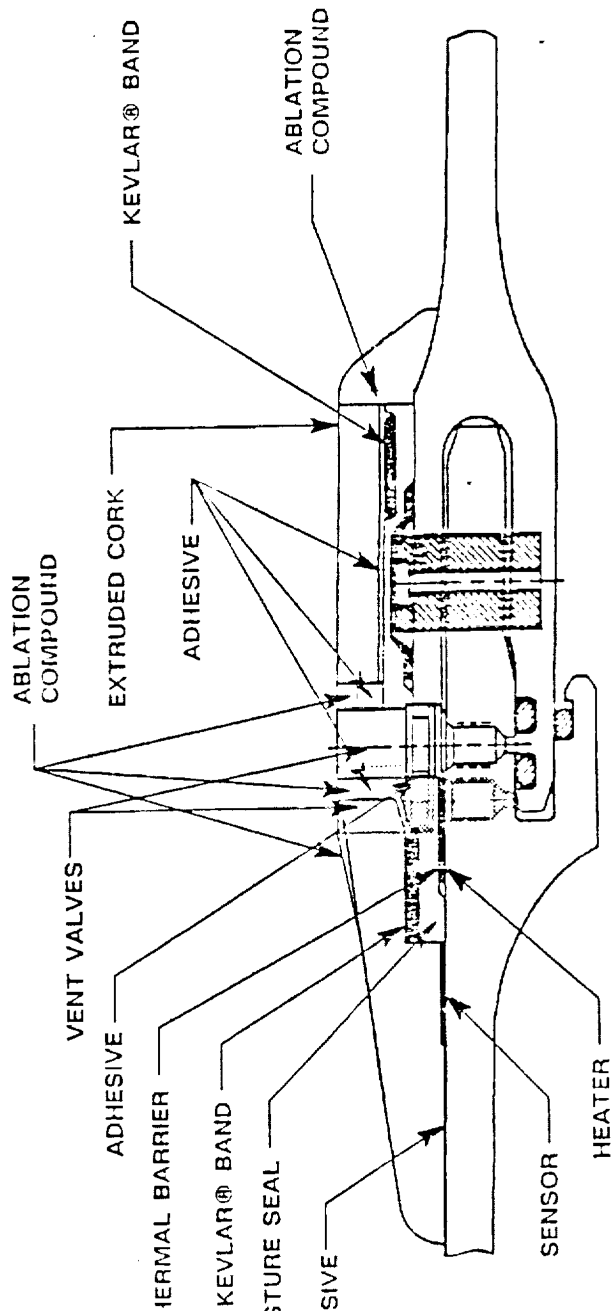
KEVLAR® BAND
ABLATION COMPOUND
ABLATION COMPOUND
EXTRUDED CORK
ADHESIVE
VENT VALVES
ADHESIVE
THERMAL BARRIER
KEVLAR® BAND
MOISTURE SEAL
ADHESIVE
SENSOR
HEATER

FIGURE 1

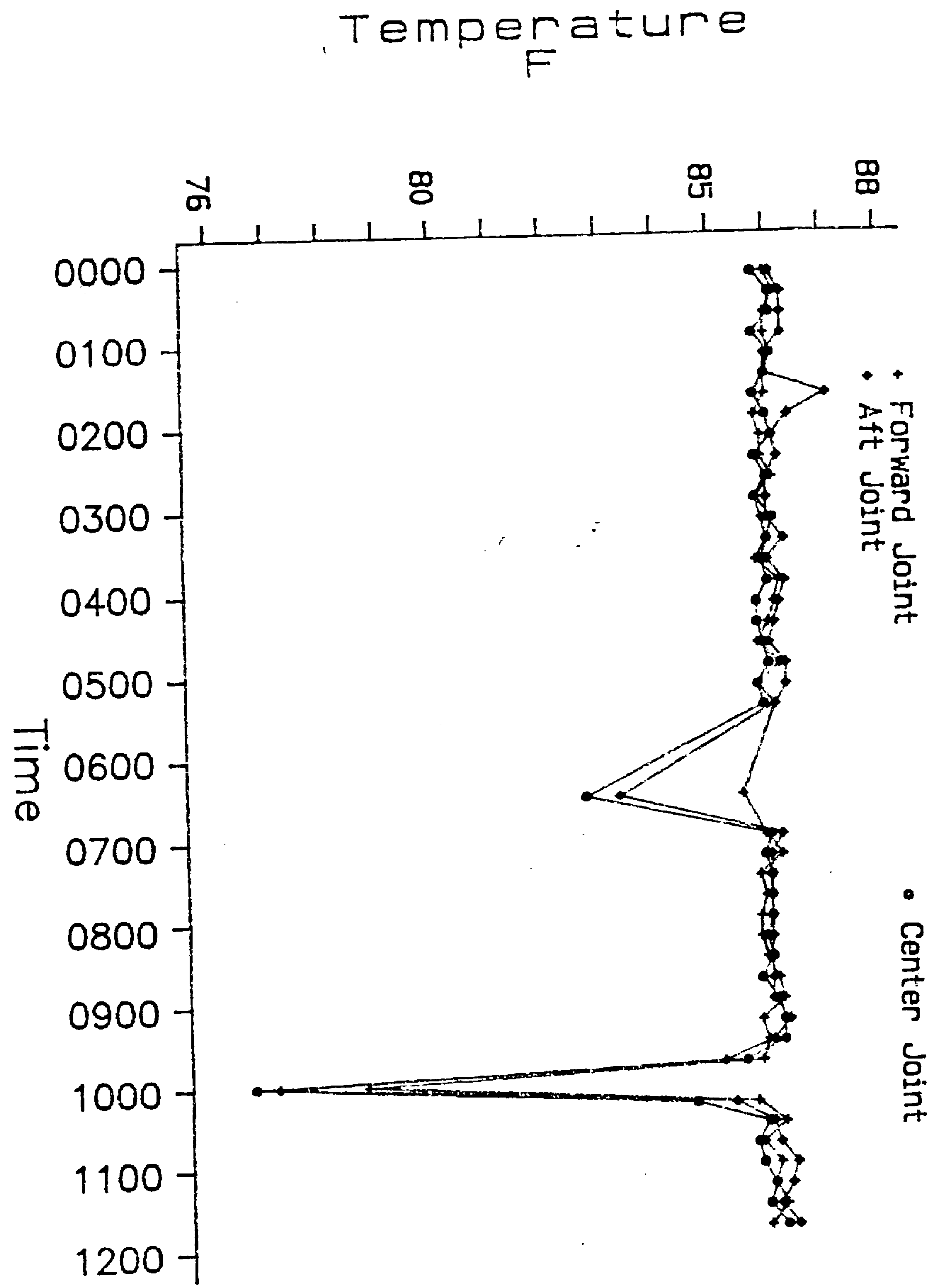
Temperature
F
76
80
85
88
Time
0000
0100
0200
0300
0400
0500
0600
0700
0800
0900
1000
1100
1200
+ Forward Joint
◆ Aft Joint
• Center Joint

Figure 2

Table I

Field Joint External Insulation Condition - Evaluation Checkoff Worksheet Pre-disassembly

Inspector(s): Elgie Hale

Motor No.: QM-8 Date: 1/23/89

Field Joint: [X] Forward (FWD) [X] Center (CTR) [X] Aft (AFT)

Component: JPS

I. External Cork Insulation

A. Voids or Missing Material (TPSVD)? ____ yes x no

B. Debonds (DEBND)? ____ yes x no

C. Charred Material (HTAFF)? ____ yes x no

If any of the above conditions exist, note:

Condition (Observation Code)	Axial Location (Station) (In.)	Starting Degree Location (Deg.)	Ending Degree Location (Deg.)	Circumferential Width (In.)	Axial Length (In.)	Radial Depth (In.)

Notes / Comments

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Table 2

Field Joint External Insulation Condition - Evaluation Checkoff Worksheet

Inspector(s): Elgie Hale

Motor No.: QM-8 Date: 1/23/89

Field Joint: [x] Forward (FWD) [ ] Center (CTR) [ ] Aft (AFT)

Component: JPS

I. External Cork Insulation

A. Voids or Missing Material (TPSVD)? ___ yes _x_ no

B. Debonds (DEBND)? _x_ yes ___ no

C. Charred Material (HTAFF)? ___ yes _x_ no

If any of the above conditions exist, note:

Condition (Observation Code)	Axial Location (Station) (In.)	Starting Degree Location (Deg.)	Ending Degree Location (Deg.)	Circumferential Width (In.)	Axial Length (In.)	Radial Depth (In.)
DEBONDS	851	118	122	.5 case next	to M.S.	
DEBONDS	851	258	282	.5 case next	to M.S.	
DEBONDS	851	298	302	4" leading	edge	
DEBONDS	851	308	311	1" case next	to M.S.	

Notes / Comments

INtermittant smaller voids (less than 1 in. D) wre observed around the joint.

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Table 3

Field Joint External Insulation Condition - Evaluation Checkoff Worksheet

Inspector(s): ELGIE HALE

Motor No.: QM-8 | Date: 2/3/89

Field Joint: ☐ Forward (FWD) ☒ Center (CTR) ☐ Aft (AFT)

Component: JPS

I. External Cork Insulation

A. Voids or Missing Material (TPSVD)? ___ yes _x_ no

B. Debonds (DEBND)? _x_ yes ___ no

C. Charred Material (HTAFF)? ___ yes _x_ no

If any of the above conditions exist, note:

Condition (Observation Code)	Axial Location (Station) (In.)	Starting Degree Location (Deg.)	Ending Degree Location (Deg.)	Circumferential Width (In.)	Axial Length (In.)	Radial Depth (In.)
DEBND	1171	0°	6°	3	5	NA
DEBND	1171	270°	274°	3	3	NA
DEBND	1171	25°	28°	1/4	3	NA
DEBND	1171	54°	69°	3	12	NA
DEBND	1171	90°	105°	3	12	NA
DEBND	1171	180°	184°	3	4	NA

Notes / Comments

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Table 4

Field Joint External Insulation Condition - Evaluation Checkoff Worksheet

Inspector(s): ELGIE HALE

Motor No.: QM-8

Date: 2/3/89

Field Joint: ☐ Forward (FWD) ☐ Center (CTR) ☒ Aft (AFT)

Component: JPS

I. External Cork Insulation

	yes	no
A. Voids or Missing Material (TPSVD)?		x
B. Debonds (DEBND)?	x	
C. Charred Material (HTAFF)?		x

If any of the above conditions exist, note:

Condition (Observation Code)	Axial Location (Station) (In.)	Starting Degree Location (Deg.)	Ending Degree Location (Deg.)	Circumferential Width (In.)	Axial Length (In.)	Radial Depth (In.)
DEBND	1491	48	56	3	6	N/A
DEBND	1491	259	281	1/2	20	N/A
DEBND	1491	214	220	1	16	N/A

Notes / Comments

Table 5

Field Joint External Insulation Condition - Evaluation Checkoff Worksheet

Inspector(s): Elgie Hale/Mike Walsh

Motor No.: QM-8 | Component: JPS | Date: 1/23/89

Field Joint: [x] Forward (FWD) [x] Center (CTR) [x] Aft (AFT)

I. Moisture Seal

A. Discolored (DSCLR)?	___ yes	x no
B. Charred Material (HTAFF)?	___ yes	x no
C. Moisture Under Seal (WATER)?	___ yes	x no
D. Loose Retainer Band (LOOSE)?	___ yes	x no

If any of the above conditions exist, note:

Affected Part (I, or II)	Condition (Code)	Starting Degree Location (Deg.)	Ending Degree Location (Deg.)	Circumferential Width (In.)	Degree Arc

Notes / Comments

Table 6

Joint Heater Condition – Evaluation Checkoff Worksheet

Inspector(s): Elgie Hale

Motor No.: QM-8	Component: JPS	Date: 2/3/89

Field Joint: [x] Forward (FWD) [x] Center (CTR) [x] Aft (AFT)

I. Heater Element

A. Delamination (DLHTR)?	___	yes	x	no
B. Adhesive to Case Separation (DEBND)?	___	yes	x	no
C. Discoloration (DSCLR)?	___	yes	x	no

II. Heater Sensor Assembly

A. Evidence of Separation (DEBND)?	___	yes	x	no
B. Delaminations (DLHTR)?	___	yes	x	no

If any of the above conditions exist, note:

Affected Part (I, II or III)	Condition (Code)	Starting Degree Location (Deg.)	Ending Degree Location (Deg.)	Circumferential Width (In.)	Degree Arc

Notes / Comments

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Table 7 Post Test

Field Joint Heater Cable Condition - Evaluation Checkoff Worksheet

Inspector(s): Duane Hanson

Motor No.: QM-8 | Date: 1/1/89

Component: TPS

I. External Cork Insulation

A. Voids or Missing Material (TPSVD)? ____ yes x no

B. Debonds (DEBND)? ____ yes x no

C. Charred (HTAFF)? ____ yes x no

II. Cables Debonded (DEBND)? ____ yes x no

If any of the above conditions exist, note:

Segment (FWD, FCS, ACS or AFT)	Condition (Observation Code)	Axial Location (Station) (In.)	Starting Degree Location (Deg.)	Ending Degree Location (Deg.)	Circumferential Width (In.)	Axial Length (In.)

Notes / Comments

Table 8 Pre-Disassembly

Field Joint Heater Cable Condition - Evaluation Checkoff Worksheet

Inspector(s): Elgie Hale

Motor No.: QM-8 | Date: 1/23/89

Component: TPS

I. External Cork Insulation

A. Voids or Missing Material (TPSVD)? ____ yes x no

B. Debonds (DEBND)? ____ yes x no

C. Charred (HTAFF)? ____ yes x no

II. Cables Debonded (DEBND)? ____ yes x no

If any of the above conditions exist, note:

Segment (FWD, FCS, ACS or AFT)	Condition (Observation Code)	Axial Location (Station) (In.)	Starting Degree Location (Deg.)	Ending Degree Location (Deg.)	Circumferential Width (In.)	Axial Length (In.)

Notes / Comments

Table 9

Field Joint Vent Valve – Evaluation Checkoff Worksheet

Inspector(s): E. HALE		
Motor No.: QM-8		Date: 2/2/89
Field Joint: [x] Forward (FWD) [X] Center (CTR) [X] Aft (AFT)		Case End: Targ
Component: JPS		

I. Vent Valves Open to Back Pressure (VVOBP)?

A. 45° Degrees	N/A yes	N/A no
B. 135° Degrees	X yes	___ no

Notes / Comments

The vent on each of the three field joints was open to back pressure.

Table 10

Igniter Heater Installation Condition - Evaluation Checkoff Worksheet

Inspector(s): Charles Greatwood		
Motor No.: QM-8		Date: 1/27/89
Joint: Igniter (IGN)	Case End: Igniter Adapter (FWD)	Component: JPS

I. Igniter Heater
   A. Securely held in place (LOOSE)? ____ yes x no
   B. Proper position (DISCP)? ____ yes x no

II. Cork Insulation
   A. Securely held in place (LOOSE)? ____ yes x no
   B. Proper position (DISCP)? ____ yes x no

III. T-Bolt Latch Band Clamp
   A. Securely held in place (LOOSE)? ____ yes x no
   B. Proper position (DISCP)? ____ yes x no

IV. Igniter Heater Power Cables
   A. Securely held in place (LOOSE)? ____ yes x no
   B. Proper position (DISCP)? ____ yes x no

If any of the above conditions exist, note:

Affected Part (I, II, III or IV)	Condition (Observation Code)	Starting Degree Location (Deg.)	Ending Degree Location (Deg.)	Circumferential Width (In.)	Axial Length (In.)

Notes / Comments
Overall condition of igniter heater installation is excellent with no anomalies noted.

Table 11

Igniter Heater Component - Evaluation Checkoff Worksheet

Inspector(s): Charles Greatwood		
Motor No.: QM-8		Date: 1/27/89
Joint: Igniter (IGN)	Case End: Igniter Adapter (FWD)	Component: JPS

		yes	no
I.	T-Bolt Latch Band Clamp Assembly Intact (BAND)?		x
II.	Igniter Heater		
	A. Delaminations (DLHTR)?		x
	B. Discolorations (DSCLR)?		x
	C. Charred (HTAFF)?		x
	D. Warped (HTAFF)?		x
III.	Heater Power Cables		
	A. Intact (LOOSE)?		x
	B. Charred (HTAFF)?		x

If any of the above conditions exist, note:

Affected Part (I, II or III)	Condition (Observation Code)	Axial Location (Station) (In.)	Starting Degree Location (Deg.)	Ending Degree Location (Deg.)	Circumferential Width (In.)	Axial Length (In.)

Notes Comments

Overall condition of igniter heater components is excellent.