The Orbiter subsystem hardware/software interaction analysis examines software interaction with hardware failure modes. Each failure mode identified in subsystem FMEA (failure mode and effects analysis) is examined for interaction with software. The analysis is based upon key questions which identify potential issues. These potential issues are to be resolved by providing rationale for retention or identifying and implementing changes to eliminate the issue.

The figure on the following page illustrates the relationship of the hardware/software interaction analysis to the verification process which leads to the statement of flight readiness. As shown, the analysis is a supporting item which is a portion of the data base utilized by the FRAT's (flight readiness assessment teams) and the associated SEAM (Systems Engineering Assessment Meeting) teams in planning and controlling the verification process. The overall issue of hardware/software interface compatibility is addressed by the verification process itself. The analysis scope is limited to examination of single failure modes, as identified in the FMEA, and the interaction of these failure modes with the software as reflected by the software requirements.

The hardware/software interaction analysis is performed on a preliminary basis by the JSC Reliability Division. Results are then coordinated with JSC engineering and Rockwell/Space Systems Group engineering and reliability to obtain inputs and approval signatures. The approval sheet for the AFT Reaction Control System are presented below. The Rockwell signatures represent their review of the open issues and risks, if any, performed against the summarization of the analysis. Section 5.0 presents the analysis summary which groups the failure modes by similar retention rationale and is a convenience in identifying groups of failure modes in which the analysis is similar. The reviews with Rockwell did not cover each checklist. The minutes presented in the appendix document the nature and depth of the Rockwell analysis review.

This analysis verified that no open issues remain.

Approved: 

Joseph H. Levine 11/9/86
Chief, Reliability Division
THE HARDWARE/SOFTWARE INTERACTION ANALYSIS IS PREPARED BY RELIABILITY. IT IS ONE OF MANY ANALYSES AND DOCUMENTS USED BY THE SEAM TEAMS AND FRAT'S IN THE PLANNING AND MANAGEMENT OF THE VERIFICATION PROCESS. THE OVERALL VERIFICATION PROCESS LEADS UP TO THE FINAL FLIGHT READINESS STATEMENT FOR EACH SUBSYSTEM AND THE VEHICLE AS A WHOLE.
HARDWARE/SOFTWARE INTERACTION ANALYSIS

AFT - RCS

SUBSYSTEM

FMEA # SD72-SH-0103-2

ANALYSIS DATE November 5, 1979

HARDWARE/SOFTWARE ANALYST

APPROVED:

JSC Reliability

JSC Engineering - FRAT Sponsor

Rockwell Reliability

Rockwell Engineering - FRAT Sponsor
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2.0 SCOPE</td>
<td>1</td>
</tr>
<tr>
<td>3.0 APPLICABLE DOCUMENTS</td>
<td>1</td>
</tr>
<tr>
<td>4.0 DESCRIPTION</td>
<td>2</td>
</tr>
<tr>
<td>5.0 ANALYSIS SUMMARY SHEETS</td>
<td>9</td>
</tr>
<tr>
<td>6.0 ANALYSIS CHECKLIST SHEETS</td>
<td>13</td>
</tr>
</tbody>
</table>

## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-1</td>
<td>HARDWARE/SOFTWARE ANALYSIS CHECKLIST</td>
<td>3</td>
</tr>
<tr>
<td>4-2</td>
<td>CHANGE/RETENTION RATIONALE</td>
<td>6</td>
</tr>
<tr>
<td>4-3</td>
<td>HARDWARE/SOFTWARE ANALYSIS SUMMARY</td>
<td>7</td>
</tr>
</tbody>
</table>

Appendix ............................................................................. 129
1.0 INTRODUCTION. This report documents the results of the analysis of the hardware/software interaction analysis for the AFT Reaction Control System. This analysis examines the interaction between hardware failure modes and software in order to identify associated issues/risks. These issues/risks are resolved through changes to software requirements to remove them, or surfaced to project/program management with appropriate retention rationale.

2.0 SCOPE. All Orbiter subsystems and interfacing program elements which interact with the Orbiter computer flight software are analyzed. The analysis for each subsystem or interfacing element is presented in a separate volume of this report (see section 3.1).

The analysis examines failure modes identified in the subsystem/element FMEA (failure mode and effects analysis). Potential interaction with software is examined through evaluation of the software requirements, not detailed implementation. The analysis is restricted to flight software requirements only, and excludes utility/checkout software. The BFS (backup flight system) software is considered only as necessary, and only as it differs from the primary; the basic thrust of the analysis is keyed to the primary system.

The analysis is based upon the hardware design and software requirements as they existed as of the date of the analysis. Future updates will be published as necessary to incorporate changes to either the hardware or software.

3.0 APPLICABLE DOCUMENTS.

3.1 HARDWARE/SOFTWARE INTERACTION ANALYSIS REPORT VOLUMES. The hardware/software interaction analysis results are reported on a subsystem basis, each in a separate volume. The separate volumes which make up this report are as follows:

<table>
<thead>
<tr>
<th>Volume</th>
<th>Subsystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Purge, Vent, and Drain</td>
</tr>
<tr>
<td>II</td>
<td>Payload Deployment and Retention</td>
</tr>
<tr>
<td>III</td>
<td>Payload Bay Doors</td>
</tr>
<tr>
<td>IV</td>
<td>Main Propulsion</td>
</tr>
<tr>
<td>V</td>
<td>Data Processing Subsystem</td>
</tr>
<tr>
<td>VI</td>
<td>Hydraulics</td>
</tr>
<tr>
<td>VII</td>
<td>Auxiliary Power Unit</td>
</tr>
<tr>
<td>VIII</td>
<td>Reaction Control</td>
</tr>
<tr>
<td>IX</td>
<td>Electrical Power Generation</td>
</tr>
<tr>
<td>X</td>
<td>Orbital Maneuvering</td>
</tr>
<tr>
<td>XI</td>
<td>Environmental Control and Life Support</td>
</tr>
<tr>
<td>XII</td>
<td>Integrated Avionics</td>
</tr>
<tr>
<td>XIII</td>
<td>Electrical Power Distribution &amp; Control</td>
</tr>
<tr>
<td>XIV</td>
<td>GNC (Guidance, Navigation &amp; Control) Support</td>
</tr>
<tr>
<td>XV</td>
<td>Displays &amp; Controls</td>
</tr>
<tr>
<td>XVI</td>
<td>Communications &amp; Tracking</td>
</tr>
<tr>
<td>XVII</td>
<td>Instrumentation</td>
</tr>
</tbody>
</table>
3.2 REFERENCE DOCUMENTS. The primary documents used in performing the analysis included the following:


g. SD76-SH-0010E "Functional Subsystem Software Requirements, Redundancy Management," June 1, 1979.

4.0 DESCRIPTION.

4.1 GROUND RULES. The hardware software analysis is performed according to the following ground rules:

a. The hardware/software analysis will be limited to investigating the software interaction with the failure modes of the hardware as delineated in the subsystem FMEA's.

b. Software interaction will be limited to involvement of software of the onboard computers.

c. Only failure modes of hardware with software interfaces (software monitoring and/or software control) are analyzed.

d. The software detection must be considered with respect to each phase of the mission [prelaunch (OPS 1 only), ascent, onorbit, and entry].

4.2 ANALYSIS CHECKLIST. The basic tool for the analysis is the checklist (figure 4-1). A separate checklist is used for each failure mode analyzed. Note that the "FMEA Number" in the heading refers to the FMEA document number, not the page number on which the failure mode is treated.

The checklist consists of three sections: Body, change/retention rationale summary, and explanation/comments. Each of these sections is discussed below.

4.2.1 CHECKLIST BODY. The checklist body contains the questions which drive the analysis. Blocks representing the possible answers for each question are provided. Those answers identified by asterisks entail potential issues and require explanation.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST

<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>FMEA NUMBER</th>
<th>FAILURE MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITEM</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**
   - YES ☐ NO ☐

1a. IF NOT, **DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?**
   - *YES ☐ NO ☐

2. **ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?**
   - YES ☐ *NO ☐

3. **DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?**
   - YES ☐ NO ☐

3a. IF NOT, **DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?**
   - *YES ☐ NO ☐

4. **AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?**
   - YES ☐ NO ☐

5. **CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?**
   - YES ☐ NO ☐

6. **HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)?**
   - 0 ☐ *1 ☐ 2 ☐

7. **IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?**
   - N/A ☐ YES ☐ NO ☐

8. **IF THE ANSWER TO EITHER 1 OR 3 IS YES:**
   - A. **CAN THE BFS BE ENGAGED AFTER OCCURRENCE?**
     - YES ☐ *NO ☐
   - B. **WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?**
     - YES ☐ *NO ☐

*EXPLANATION REQUIRED (SEE BELOW)*

---

**CHANGE/RETENTION RATIONALE SUMMARY:**

<table>
<thead>
<tr>
<th>1. NO H/S ISSUES</th>
<th>3. NO SOFTWARE DETECTION</th>
<th>5. ACCEPTANCE RATIONALE BELOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. HARDWARE ACCEPTS RISK</td>
<td>4. DETECTION DURING CHECKOUT</td>
<td>6. RECOMMENDED CHANGES BELOW</td>
</tr>
</tbody>
</table>

---

☐ FMEA CHANGE RECOMMENDED

**EXPLANATION/COMMENTS:**

---

Figure 4-1. Hardware/Software Analysis Checklist
The questions in the checklist body are answered using the following guidelines:

a. Question 1. Will the information provided to the onboard software and the processing of that information cause annunciation of the failure and/or initiation of a corrective action in response to this failure mode?

b. Question 1a. Answer question 1a if the answer to question 1 is "no." Information available to the software could be in the form of (1) sensor data used by onboard software but not for automatic fault detection (data used in software routines or fault detection available through callup or dedicated displays); (2) system and/or subsystem performance parameters; or (3) measurements which are downlisted. Answer "yes" if such information could be used to annunciate the failure condition or initiate responsive action. In explanation comments, specifically identify the information available for software detection.

c. Question 2. If all of the following questions are answered "no," check the "no" block and explain the difference in the explanation/comments section:

   (1) Are the master measurements listed under "Failure Detectability In-flight" on the FMEA (1) used by the onboard software in detecting time critical failures (if routed to GPC), or (2) used by the onboard software in announcing non-time critical failures via callup displays, or (3) downlisted for non-time critical failures?

   (2) Are other measurements, dedicated displays, crew detection, and system/subsystem parameters available or able to detect this failure mode?

   (3) If "failure detectability in-flight" specifies only software action, does the software actually initiate the corrective action as called out in the "corrective action" portion of the FMEA?

d. Question 3. The question considers only the cases wherein the software determines a failure.

e. Question 3a. Answer question 3a if the answer to 3 is "no." If the answer to 3a is "yes," call out the possible corrective action in the explanation/comments section.

f. Question 4. The question is considered for both the detected and the undetected failure. The overstress or inducement of another failure may be acceptable action. Overstress by software is improper commands, sequencing, or timing resulting in action exceeding hardware design requirements or exposing hardware to excessive environments.

g. Question 5. The question is considered for both the detected and the undetected failure. Limit adverse effects to effects directly resulting from software commands or subsequent actions resulting from erroneous inputs as a result of the failure.

h. Question 6. The hardware/software may change the method of detection and/or correction after the first or the second failure; consider this in answering the question. Determine if the software will be able to use the
redundancy of the hardware. If the hardware/software interaction following the particular failure mode changes the criticality, in comparison to the FMEA, check the box provided in the summary section of the checklist.

i. Question 7. If crew action is not required to respond to the failure, check the "N/A" block. Cues which provide inputs to the crew include but are not limited to cathode-ray tube annunciation, caution and warning, visual cues, audible cues, callup and dedicated displays, subsystem status data, panel meters, etc.

j. Question 8.A and 8.B. Answer these questions only if either question 1 or 3 is "yes."

(1) Question 8.A. Consider that the failure occurs while the vehicle is being flown using the primary system. What will happen if the BFS must be engaged subsequent to the failure? Will the fact that the failure has occurred prevent the BFS from operating properly, under any conditions? A "no" answer is a potential issue (requiring explanation) only if the BFS can normally tolerate the failure (when it occurs during BFS operation).

(2) Question 8.B. Consider that the failure occurs while the vehicle is under BFS control. A "no" answer is an issue (requiring explanation) only if the BFS response differs from that for the primary system.

4.2.2 Change/Retention Rationale Summary. Each failure is assigned to one of six possible groups, based upon the answers obtained in the checklist body. Boxes are provided to indicate the category assigned. Figure 4-2 presents the criteria for group assignment.

A box is also provided to indicate that changes are required to the FMEA. The FMEA evaluation of in-flight detectability is sometimes inaccurate and requires change. In addition, other errors (e.g., incorrect criticality assignment or incorrect evaluation of redundancy screens) are occasionally noted during the analysis and are documented here.

A space is provided to detail acceptance rationale, change recommendations, or suggested FMEA changes. This space may also be used to provide a short general comment to expand the retention rationale grouping.

4.2.3 Explanation/Comments. Each question answered by checking a box identified with an asterisk is discussed in this section. The circumstances for checking a box not identified with an asterisk are discussed, and the rationale for not making such a change is presented, if applicable. This section may also be used to explain, expand, or qualify answers. Each discussion is identified with the corresponding question number.

4.3 ANALYSIS SUMMARY. The analysis results are summarized on the basis of retention rationale grouping and recommended changes/retention rationale. Figure 4-3 depicts the form utilized for this purpose. A particular retention rationale definition, acceptance rationale statement, or recommended change is listed in the left column, with the applicable failure modes listed on the right. The issue/risk is briefly described with acceptance rationale or software requirements change recommendation. The summary provides a basic overview of the total analysis results.
CHANGE/RETENTION RATIONALE

1. NO * CHECKED - NO HARDWARE/SOFTWARE ISSUES ARE APPARENT FROM THE ANALYSIS. SYSTEM IS FAIL OPERATIONAL/FAIL SAFE WITH RESPECT TO THIS FAILURE MODE UNDER CURRENT DESIGN.

2. ONLY * CHECKED ON QUESTION 6 - NO HARDWARE/SOFTWARE ISSUES ARE APPARENT FROM THE ANALYSIS. RISK HAS BEEN ACCEPTED VIA HARDWARE CIL.

3. ONLY *(YES) CHECKED ON QUESTION 1a - NO SOFTWARE DETECTION IS PROVIDED. FAILURE EFFECT IS NOT TIME CRITICAL. FAILURE MAY BE DETECTED BY OTHER MEANS OR FUNCTION IS NOT MISSION/SAFETY CRITICAL.

4. * CHECKED ON QUESTION 3a - * ON 1a MAY OR MAY NOT BE CHECKED - SOFTWARE DOES NOT TAKE CORRECTIVE ACTION FOR FAILURE. FAILURE EFFECT IS NOT TIME CRITICAL. CORRECTIVE ACTION MAY BE INITIATED BY CREW. PLANNED CHECKOUT ACTIVITIES WILL DETECT FAILURE. SYSTEM IS FAIL OPERATIONAL/FAIL SAFE WITHOUT SOFTWARE DETECTION AND CORRECTION.

5. STANDARD RETENTION RATIONALE DOES NOT APPLY. SPECIFIC RETENTION RATIONALE IS SUMMARIZED FOR THIS FAILURE.

6. ISSUES IDENTIFIED AND CHANGES ARE DESIRABLE. SPECIFIC CHANGES ARE SUMMARIZED.

NOTE: DO NOT CONSIDER ANSWER TO QUESTION 2 IN DETERMINATION OF CHANGE/RETENTION RATIONALE SUMMARY CODE. CONSIDER RESPONSES TO BOTH QUESTION 2 AND 6 IN DETERMINING WHETHER AN FMEA CHANGE IS REQUIRED.

6.0 ANALYSIS CHECKLIST SHEETS

Following are the analysis checklist sheets for each failure mode evaluated.

Figure 4-2. Change/Retention Rationale
<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>ANALYSIS RESULT</th>
<th>ITEM/FAILURE MODE</th>
</tr>
</thead>
</table>

Figure 4-3.
Hardware/Software Analysis Summary
The subsystem failure modes not analyzed are also identified. These failure modes were evaluated as having hardware/software interfaces. Figure 4-4 depicts the form utilized for this purpose.

5.0 ANALYSIS SUMMARY SHEETS. The analysis results are summarized on the following sheets. The failure modes have been grouped by issue/retention rationale (or change), affording an overview of the results for the entire subsystem.
Failure modes not included in hardware/software analysis evaluated as involving no hardware/software interface.

<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>FMEA</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>ITEM</th>
<th>FAILURE MODE</th>
</tr>
</thead>
</table>

Failure modes analyzed included only those items currently on the critical items list. All other failure modes will be analyzed at a future date.
<table>
<thead>
<tr>
<th>HARDWARE ACCEPTS RISK</th>
<th>ITEM/FAILURE MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium Tank - External Leak (03-2A-201010-1)</td>
<td></td>
</tr>
<tr>
<td>Helium Feed Line - External Leakage (03-2A-201013-1)</td>
<td></td>
</tr>
<tr>
<td>D. C. Solenoid Valve, Helium - Fails Closed (03-2A-201020-1)</td>
<td></td>
</tr>
<tr>
<td>Line, Low Pressure Helium - External Leak (03-2A-201035-1)</td>
<td></td>
</tr>
<tr>
<td>Helium Fill Quick Disconnect - Fails Open (03-2A-201070-1)</td>
<td></td>
</tr>
<tr>
<td>Purge Quick Disconnect, Propellant - External Leakage (03-2A-201080-1)</td>
<td></td>
</tr>
<tr>
<td>Test Quick Disconnect - External Leakage (03-2A-201090-1)</td>
<td></td>
</tr>
<tr>
<td>Feedline and Fittings, Fuel - External Leakage (03-2A-202108-1)</td>
<td></td>
</tr>
<tr>
<td>Propellant Fill and Bleed Disconnect - Fails Open (03-2A-202150-1)</td>
<td></td>
</tr>
<tr>
<td>Propellant Tank Assembly - External Leak (03-2A-211110-1)</td>
<td></td>
</tr>
<tr>
<td>Propellant Tank Assembly - Bubbles in Propellant (03-2A-211110-2)</td>
<td></td>
</tr>
<tr>
<td>Injection Plate - Restricted Flow (03-2A-221311-1)</td>
<td></td>
</tr>
<tr>
<td>Thrust Chamber - Burn-Thru (03-2A-221312-1)</td>
<td></td>
</tr>
<tr>
<td>Nozzle Extension - Burn-Thru (03-2A-221313-1)</td>
<td></td>
</tr>
<tr>
<td>Vernier Thruster - Loss of Output (03-2A-231310-1)</td>
<td></td>
</tr>
<tr>
<td>Vernier Thruster - Fails to Stop Firing (03-2A-231310-2)</td>
<td></td>
</tr>
<tr>
<td>Vernier Thruster - Burn-Thru (03-2A-231310-3)</td>
<td></td>
</tr>
</tbody>
</table>
## HARDWARE/SOFTWARE ANALYSIS SUMMARY

### SUBSYSTEM: AFT - RCS

#### ANALYSIS RESULT

**DETECTION DURING CHECKOUT**

<table>
<thead>
<tr>
<th>ITEM/FAILURE MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium Pressure Regulator - Restricted Flow - Fails Closed (03-2A-201030-2)</td>
</tr>
<tr>
<td>Helium Quad Check Valve - Fails Closed (03-2A-201095-2)</td>
</tr>
<tr>
<td>Feedline and Fittings, OX - External Leakage (03-2A-202109-1)</td>
</tr>
<tr>
<td>Tank Isolation Valve, A. C. - Fails Closed (03-2A-202110-1)</td>
</tr>
<tr>
<td>Tank Isolation Valve, A. C. - Fails Closed (03-2A-202110-3)</td>
</tr>
<tr>
<td>Interconnect Valve, A. C. - Fails Closed (03-2A-202111-2)</td>
</tr>
<tr>
<td>Manifold Isolation Valve, A. C. - Fails Closed (03-2A-202120-3)</td>
</tr>
<tr>
<td>Manifold Isolation Valve, D. C. - Fails Closed (03-2A-202140-1)</td>
</tr>
<tr>
<td>Gimbal Joint - External Leakage (03-2A-211120-1)</td>
</tr>
<tr>
<td>Bellows Assembly - External Leakage (03-2A-221308-1)</td>
</tr>
<tr>
<td>Engine Inlet Valve - Fails Closed (03-2A-221310-4)</td>
</tr>
<tr>
<td>Analysis Result</td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td>No Software Detection</td>
</tr>
</tbody>
</table>
SUBSYSTEM: AFT - RCS
ITEM: He Tank
FAILURE MODE: External Leak

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNOUNCE OR TAKE ACTION IN RESPONSE)?
   - YES [X] NO

1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?
   - *YES [X] NO

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?
   - YES [X] *NO

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   - YES [X] NO

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   - *YES [X] NO

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?
   - *YES [X] NO

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?
   - *YES [X] NO

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.
   - 0 [X] 1 [ ] 2 [ ]

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   - N/A [X] YES [X] NO

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
   - YES [X] *NO

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY
1. NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. NO SOFTWARE DETECTION
4. DETECTION DURING CHECKOUT
5. ACCEPTANCE RATIONALE BELOW
6. RECOMMENDED CHANGES BELOW

EXPLANATION/COMMENTS:

1. V42P3110, 3113 (Right AFT) or V42P2110, 2113 (left AFT) He tank transducers will issue a class 3 alarm, RM GAX blue light on the crew-cockpit glare shield, upon sensing low pressure < 500 psi. Gross leak detection C&W is first indication.

5. A He tank leak will adversely affect the RCS quantity monitor principal function by causing meter M4 (panel 03) "RMS/OMS propellant quantity" to indicate an erroneously low percent quantity remaining. This is because He tank pressure is used in the software calculation. See FSSR 26 "sequencing", principal function 4.102.

6. No redundant tanks - loss of RCS function. Crossfeed is available.

8B. Same as primary.
SHUTTLE CRITICAL ITEMS LIST - CRIT. 102

SUBSYSTEM: AFT - REACTION CONTROl
ASSEMBLY: PRESSU RIZATION
P/N: 40282-0022-0031-0032
P/N VEND: PLO-99904-3-1-0
QUANTITY: 1

ITEM: TANK
FUNCTION:
TO STORE HELIUM AT A MAX WORKING PRESSURE OF 4000 PSI FOR PRESSURIZATION OF THE AFT RCS MODULE'S PROPULSANT SUPPLY SYSTEM. TANK CONSISTS OF DOUBLE HELT TI LINER WITH SUPERF KEVLAP 49 FIBER AND EPOXY RESIN BONDING OVER-.wrap. 30 VOL. IS 18.71 IN. VOLUME IS 3008 CU. IN.

FAILURE MODE: STRUCTURAL FAILURE

EXTERNAL LEAK

CAUSE(S):
MAT'L DEF, LINER DEF, FAULTY FAB, EPOXY CURE INADEQ, TST/HANCL DAY, SHOCK, VIS. INADEQ. OVERPRESS (GMO), INADEQ MOUNTING

EFFECT(S):
(A) LOSS OF FUNCTION/SUBSYSTEM (B) LOSS OF INTERFACE FUNCTION - INABILITY TO DEPLOY/UTILIZE PROP, POSSIBLE DAMAGE TO POD STRUCTURE & TPS. (C) MISSION MODIFICATION - X-Feed FROM OMS OR RCS. (D) POSSIBLE LOSS OF CREW VEHICLE EXCESS RATE OF LEAK MAY EXCEED POD VENT CAPAB CAUSING DAMAGE TO POD STRUCT & DEGRAD OF THERAL POUT SYS. EXCESS RETENTION OF PROP MAY ADVERSELY AFFECT VEH DY. DURING ENTRY & LNDG.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) FILAMENT WOUND TANKS ARE DESIGNED TO LEAK BEFORE RUPTURE WHICH LIMITS FAILURE PROPAGATION DUE TO SHRAPNEL. KEVLAP 49 FIBER HAS A TENSILE STRENGTH OF 500 KSI ALLOWING LIGHT WEIGHT WITH GREAT STRENGTH. INCREASED STRAIN CAPABILITY IS PROVIDED BY THE COMPRRESSIVE LOAD ON A UNPRESSURIZED LINER. VENT DOORS ARE OPEN ON ORBIT AND WILL RELIEVE ANY PRESSURE BUILDUP DUE TO LEAKAGE. THE F.S. (ASSY) IS 1.5 X WORKING PRESS. (B) 1000 PRESSURE CYCLES ARE PERFORMED DURING QUAL WHICH IS MORE THAN 4 X ANTICIPATED OPERATING LIFE. A 90-DAY CREEP TEST UNDER PRESSURE IS ALSO PERFORMED AFTER WHICH THE TANK IS EXAMINED TO VERIFY NO PERMANENT DEFORMATION OR FLAX GROWTH. PRESSURE (1.1) X WORKING PRESSURE AND LEAKAGE TESTS ARE PERFORMED DURING ATP. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. RAW MAT'L & PURCHASED COMPONENTS ARE VERIFIED BY RECEIVING INSPECTION STANDARDS AND TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQUIREMENTS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS - PARTS PROTECTION, P&P. PROCESSES, FINISHES, ASZ AND INSTALLATION. THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77 - CORROSION PROTECTION PROVISIONS, TEST HANDLING, AND STORAGE

PREPARED BY: APPROVED BY: REVIEWED:

J. TAGGART J. TAGGART J. TAGGART
C. AKERS C. AKERS C. AKERS

PREPARED WITH CHANGES
See Section 13.0

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SUBSYSTEM : AFT - REACTION CONTROL

ENVIRONMENTS: TENSILE, HEAT TREAT AND WELD SAMPLES ARE TESTED DURING IN-PROCESS FABRICATION IN ADDITION TO X-RAY & DYE PENETRANT FOR THE LINES. WIND PATTERN & WINDING CONTROL ARE USED FOR THE KEVLAR FIBER DURING IN-PROCESS MANUFACTURE. WEIGHT CONTROL IS USED FOR THE EPOXY RESIN. TURNAROUND - MONITOR LEAKAGE TESTS PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND AS PART OF THE CHECKOUT PROCEDURE PRIOR TO FLIGHT. PRESSURE CYCLES ACCUMULATED ARE ALSO RECORDED. (D) NONE AVAILABLE NEW DESIGN.
**HARDWARE/SOFTWARE ANALYSIS CHECKLIST**

**SUBSYSTEM**  |  **AFT - RCS**  
**ITEM**       |  **He Feed Line**  
**FAILURE MODE** |  **External Leakage**  

| 1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNOUNCE OR TAKE ACTION IN RESPONSE)? | YES ☑ NO □  
| --- | ---  
| 1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE? | *YES ☑ NO □  
| 2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY? | YES ☑ *NO ☐  
| 3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)? | YES ☑ NO ☐  
| 3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)? | *YES ☑ NO ☐  
| 4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE? | *YES ☑ NO ☐  
| 5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS? | *YES ☑ NO ☐  
| 6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY. | *0 ☑ *1 ☐ 2 ☑  
| 7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION? | N/A ☑ YES ☑ NO ☐  
| 8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:  
| A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE? | YES ☑ *NO ☐  
| B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE? | YES ☑ *NO ☐  

**EXPLANATION REQUIRED (SEE BELOW)**

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**CHANGE/RETENTION RATIONALE SUMMARY**

| 1. ☑ NO H/S ISSUES | 3. ☑ NO SOFTWARE DETECTION | 5. ☑ ACCEPTANCE RATIONALE BELOW  
| 2. ✗ HARDWARE ACCEPTS RISK | 4. ☑ DETECTION DURING CHECKOUT | 6. ☑ RECOMMENDED CHANGES BELOW  

**EXPLANATION/COMMENTS:**

1. V42P3110, 3113 (Right AFT) or V42P2110, 2113 (Left AFT) He Tank transducers will issue a class 3 alarm, RM GAX blue light on the crew-cockpit glare shield, upon sensing low pressure < 500 psi. Gross leak detection C&W is first indication.

2. FMEA Change - For "failure detectable in flight" V42P2110C through 2114C and 3110C through 3114C should be V42P2110C, 2112C, 2112C, 2113C, 2114C and 3110C, 3112C, 3113C, 3114C dropping out 2111C and 3111C which do not exist.

6. Feedlines are criticality 1 with no remaining success paths. Crossfeed is available.

8b. Same as primary.
SHEL. FAIL LEAK ANALYSIS - 06-11-77

PREPARED BY: K. C. GlaVinho

APPROVED BY: P.S. NEL

FILE: H-10 LEAKAGE

REPLACE CONDUIT PANEL TO PROVIDE RELIABLE FUEL FRESH FUEL IN
RELAY CYCLES/MISPERCLIZATION SYSTEM PANEL

FAILURE WIDE STRUCTURAL FAILURES \( \geq 5 \)

CATHODE:

(1) INJECTION SYSTEM (2) INTERFACES (3) MISPERCLIZATION (4) ACT IV (5) LEB/VERSITY (6) RELA T/UT/LEAKAGE (7) RQ/SYSTEM (8) DISCONTINUITY (9) LEAKAGE (10) A/C MEASURES (11) SYSTEM

VAL LEAKAGE - IF LEAK EXCESS OR EXCESS DAMAGE OCCURS

CAUTIONS:

1. VAL LEAK AN. UTILIZE fresh TANK VOLUME. FRESH FUEL OR AIR FROM A-POLE
2. VAL LEAK AN.

18

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OF POOR QUALITY.
SHUTTLE CRITICAL ITEMS LIST - CROITER 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION HELIUM
P/N: MC621-0059
P/N VENDOR: 73A630000
QUANTITY: 4

MISSIONS: HF, VF, FF, CF, SM
PHASE(S): PL, LO, DO, X, LS, X

REDUNDANCY SCREEN: A-N/A, S-N/A, C-N/A

AREA: PFESSURIZATION

PREPARED BY: N. C. GLAVINICH
APPROVED BY: S. S. MAKERS
PREPARED BY: S. S. MAKERS
APPROVED BY: NASA

ITEM: HELIUM FEED LINE

FUNCTION:
1/2 X .042 304L S.S LINES TO PROVIDE HELIUM FEED FROM HELIUM TANKS TO HELIUM REGULATION/PRESSURIZATION SYSTEM PANEL

FAILURE MODE: STRUCTURAL FAILURE (2)
Rupture, External Leakage

CAUSE(S):
- Mat'1 Def (Sulphide Stringer), VIB, SHCK, STRUCT FAIL, FATIQUE, WELD DEF, STRESS CORROS, IMP INSTALL

EFFECT(S):
- CN (A) SUBSYSTEM (B) INTERFACE (C) MISSION (D) CREW/VEHICLE:
  (A) Loss of Subsystem Pressure Regeneration Capability IFF Not Ispl Fail (upstream of Isol VLV-1 inability to Depl/Utilize PCCP)
  (B) Loss of Interface Function (Inabl to Regress PCCP Tank - Lt POD Struct & TPS Dam.
  (C) Abort Decision (Loss of Press)
  (D) Possible Loss of Crew/Vehicle - If Leak Excess Or POD/TPS Dam Deturs

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) F.S. IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF), THE WELDED CONSTRUCTION ELIMINATES JOINTS AND POSSIBLE LEAK PATHS. THE ANNEALED AREA (DUE TO WELDING) IS BACKED UP BY A SLEEVE. FASTENING CLAMPS ALLOW FREEOM OF MOVEMENT. TUBING BENDS ARE CONTROLLED BETWEEN FIXED POINTS TO FACILITATE INSTALLATION AND ACCOMMODATE VEHICLE GROWTH AND MOVEMENT. (B) PCKWELL PERFORMED TUBING CERTIFICATION TESTS PER "CRIBER TUBING VERIFICATION PLAN" (SD 75-SH-0205). THIS TESTING INCLUDED PRESSURE CYCLING AND FOR TYPICAL SHUTTLE LINES & JOINTS. SYSTEM EVALUATION TESTS AT WSTF WILL ALSO ALLOW EVALUATION IN THE INSTALLED SYSTEM CONDITION. LEAKAGE TESTS ARE PERFORMED IN-PROCES FOR TUBING SECTIONS. OPTICAL INSPECTIONS ARE ALSO PERFORMED AT THIS TIME IN ADDITION TO X-RAY AND DYE PENETRANT. LEAKAGE TESTS ARE ALSO PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND ADDITIONAL WELDS ARE ALSO SUBJECTED TO NDE. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAM. CONTROL PROCESSES, CORROS. PROTECTION PROVISIONS, NDE EXAM OF WELDS AND INSPECTION OF SURFACE AND SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELEER MANDATORY INSPECTION REQUIREMENTS. RAW MATE'1 LOT CERTIFICATION, PARTS PROTECTION, MANUF., COATING, PLATING, INSTALLATION AND ASSEMBLY OPERATIONS. HARDWARE IS INSPE. IN ACCORDANCE WITH QUALITY PLANNING REQUIREMENTS DOCUMENT (QPD) WHICH HAS BEEN APPROVED BY NASA.
SHUTTLE CRITICAL ITEMS LIST - CRITERIA 102

SUBSYSTEM : AFT - REACTION CONTROL
FMEA NO 03-21-201013-1 REV: 12/13/70

TURNAROUND - LINES IN ACCESSIBLE AREAS ARE VISUALLY INSPECTED FOR EVIDENCE OF DAMAGE AND FITCH AND PRESSURE FUNCTIONAL TESTS ARE MONITORED FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE. (G) HISTORY - CORROSION/FAB PROBLEMS DETECTED DURING Apollo CHECKOUT AND CORRECTED.

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SUBSYSTEM AFT-RCS

ITEM D.C. Solenoid Valve, He

FAILURE MODE Fails Closed

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY, ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   NO [x] YES [ ]

1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?
   *YES [x] NO [ ]

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?
   NO [x] YES [ ]

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEUTRALIZE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   NO [x] YES [ ]

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   *YES [x] NO [ ]

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?
   *YES [x] NO [ ]

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?
   *YES [x] NO [ ]

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.
   0 [x] 1 [ ]

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   N/A [x] YES [ ]

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      YES [x] NO [ ]
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      YES [x] NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
   3. [ ] NO SOFTWARE DETECTION
   5. [ ] ACCEPTANCE RATIONALE BELOW
2. [x] HARDWARE ACCEPTS RISK
   4. [ ] DETECTION DURING CHECKOUT
   6. [ ] RECOMMENDED CHANGES BELOW

See Note 2.

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Ullage transducer will give C&W alert < 200 psi.

2. Measurement numbers V42X2124X, 2126X, 3124X, and 3126X (Fu He isolation valves) needs to be added for detectability since only the measurement stimulus identification numbers for the oxidizer valves are listed now.
FACILITY NAME: KENNEDY SPACE CENTER

FLY STATES:

- PAYLOAD
- SPACECRAFT
- ULTRA VACUUM
- MAUI

FLIGHT INSTRUMENTATION:

- REFERENCE DOCUMENTS:
  - NC-51-15
  - VTO-053-01
  - SD12-070-123-2
  - XNL-14-1-01

PREPARED BY:

- LEL KURKHART
- KEL BYERS

APPROVES SYS:

- LEL KURKHART
- KEL BYERS

VALVE (L.E. SOLVENT)
- RETURN, PUMP PRESSURE: HELIUM (1/2") SI-TABLE
- LATCHING LATCH EVER: L-17247-0.5-2B-30/40/50/52/55/57

FUNCTION:
- VALVE TO CONTROL FLOW PRESSURIZATION SYSTEM IN THE K.E. VALVE IN THE OPEN POSITION A Flow Path IS PROVIDED FROM THE FLOW SUPPLY SOURCE TO THE REGULATORS. THE PARALLEL PATHS ARE PROVIDED FOR EACH FUEL TANK, ONE PATH IS NORMAL OPEN PER TANK. THE OPEN VALVE MAY BE USED AND THE PARALLEL VALVE USED SUBSEQUENT TO A PHYSICAL FAILURE.

FAILURE MODE: FAILS CLOSED (F)

CAUSATION:
- VALVE CONT Rolls PARTICULARLY DUE TO SHORT CIRCUIT, SHORT, CONNECTOR PIN OR CABLE DAMAGE, DAMPING OR POOR FLOW CONDITIONS CRITICAL.

REACTIVITY:
- AT (A) SUBSYSTEM (B) SYSTEMS (C) INTERFACES (D) mission 1 (E) general vehicle
- (A) LOSS OF RECOVERY - PARALLEL PATH AVAILABLE
- (B) VALVE OPEN
- (C) VALVE DEPLACEMENT DUE TO VALVE FAILURE IN CRITICAL PATH WHICH EXPOSES SYSTEM TO FUEL VAPOR, WHICH HAS THE POTENTIAL TO IGNITE IN CASE OF PROPELLENT SUFFICIENTLY EXPLODING PROPELLENT CONTENT
- SYSTEM INABILITY TO CONTINUE IN ITS PREVIOUS MODES OF OPERATION SUCH AS ETC.
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SHUTTLE CRITICAL ITEMS LIST - CRITERION 102

**SUBSYSTEM**: AFT - REACTION CONTROL  
**ASSEMBLY**: PRESSURIZATION  
**P/N RI**: MC234-0419-0011-0012  
**P/N VENDOR**: 73835  
**MISSIONS**: HF VF X FF CF SM  
**QUANTITY**: 8  
**RE: ASSEMBLY**: PRESSURIZATION ABORT: CRIT.  
**FUNCTION**: 

- UTILIZED TO CONTROL HELIUM PRESSURIZATION SYSTEM IN THE LFT MODULES. IN THE OPEN POSITION A FLOW PATH IS PROVIDED FROM THE HELIUM SUPPLY TANK(S) TO THE REGULATORS. TWO PARALLEL PATHS ARE PROVIDED FOR EACH PROPELLANT TANK. ONE PATH IS NORMALLY OPEN PER TANK. THE OPEN VALVE MAY BE CLOSED AND THE PARALLEL VALVE OPENED SUBSEQUENT TO A DOWNSTREAM FAILURE. 
- **FAILURE MODE**: FAILS CLOSED  
- **CAUSE(S)**:  
  - VIB CONTINUOUS INADVER CLOSING SIGNAL DUE TO SHORT CIRCUIT, SHOCK.  
  - CONNECTOR PIN OR DIODE DAMAGE, JAMMING OF POPPET, PLUGGED CRITICE.  
- **EFFECT(S)**: ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:  
  - (A) LOSS OF REDUNDANCY - PARALLEL PATH AVAILABLE.  
  - (B) NO EFFECT.  
  - (C) ASHORT DECISION - DUE TO ONLY ONE PATH REMAINING PRIOR TO CRITICAL EFFECT.  
  - (D) NO EFFECT.  
- **DISPOSITION & RATIONALE**: (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:  
  - (A) PARALLEL VALVES AND REDUNDANT POWER SOURCES ARE PROVIDED. VILLAGE PRESS IS ADEQ FOR PROP FEED WITH LESS THAN 35 PERCENT PROP REMAINING. ONE VALVE IS MAINTAINED IN THE LATCHED OPEN POSITION WITH NO POWER APPLIED & THE OTHER IS LATCHED CLOSED. AN INDUCTIVE VOLTAGE SUPPRESSION CIRCUIT IS PROV IN THE ELECTRICAL SYSTEM TO PREVENT DAMAGE TO OTHER ON-LINE COMP. REDUN DIODES LIMIT THE POSS OF DIODE FAILURE ALLOWING CURRENT SHUNT FROM THE COIL. A 100-MICRON FILTER IS PROV TO LIMIT THE POSS OF CONTAM CAUSING LEAKAGE, JAMMING MOVING PARTS - OR PLUGGING PILOT CONTROL ORIFICES. TO LIMIT THE ELECT SHORT POTENTIAL, THE LEAD AND MAGNET WIRES ARE ENCAB BY POTTING AND A FIXTURE IS USED DURING ASSEMBLY TO ENSURE THAT INSUL IS NOT DAMAGED BY THE EXIT NOTCH WHEN THE COIL SLEEVE IS PRESSED ONTO THE COIL.  
  - (B) 4000 OPER CYCLES (ON-OFF-FLOW) AND RANDOM VIB AT ANTIC MISSION LEVELS ARE PERF DURING QUAL.  

**PREPARED BY**:  
- (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:  
  - (A) PARALLEL VALVES AND REDUNDANT POWER SOURCES ARE PROVIDED. VILLAGE PRESS IS ADEQ FOR PROP FEED WITH LESS THAN 35 PERCENT PROP REMAINING. ONE VALVE IS MAINTAINED IN THE LATCHED OPEN POSITION WITH NO POWER APPLIED & THE OTHER IS LATCHED CLOSED. AN INDUCTIVE VOLTAGE SUPPRESSION CIRCUIT IS PROV IN THE ELECTRICAL SYSTEM TO PREVENT DAMAGE TO OTHER ON-LINE COMP. REDUN DIODES LIMIT THE POSS OF DIODE FAILURE ALLOWING CURRENT SHUNT FROM THE COIL. A 100-MICRON FILTER IS PROV TO LIMIT THE POSS OF CONTAM CAUSING LEAKAGE, JAMMING MOVING PARTS - OR PLUGGING PILOT CONTROL ORIFICES. TO LIMIT THE ELECT SHORT POTENTIAL, THE LEAD AND MAGNET WIRES ARE ENCAB BY POTTING AND A FIXTURE IS USED DURING ASSEMBLY TO ENSURE THAT INSUL IS NOT DAMAGED BY THE EXIT NOTCH WHEN THE COIL SLEEVE IS PRESSED ONTO THE COIL.  
  - (B) 4000 OPER CYCLES (ON-OFF-FLOW) AND RANDOM VIB AT ANTIC MISSION LEVELS ARE PERF DURING QUAL.  

**APPROVED WITH CHANGES**  
See Section 13.0
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-24-201020-1  REV: 12/12/73

DURING SYS EVAL TESTS AT STF ALLOWING EVAL UNDER SIMUL MISSION USAGE
COND. PROOF PRESSURE, LEAKAGE, OPER AND INSUL TESTS ARE PERF DURING
ATP. APROP LOCATED TEST POINTS ALLOW PRE/POST FLIGHT LEAKAGE TESTS AND
OPER TESTS ARE ALSO CONDUCTED AT THIS TIME. (C) AN IDENT IS PERF AND
THE UNIT TAGGED. CONTAM CONT PROCESS, CORROS. PROT PROV, NDE EXAM. OF
WELDS AND BRAZES, INSPE FOR SURFACE AND SUBSURFACE DEFECTS AND PROPER
ELECT TERMINATIONS ARE VERIF BY INSPE. THE FOLLOW ITEMS ARE VERIF BY
SHOP TRAVELER MANDATORY INSPE. POINTS - RAW MAT'L (LOT CERT), PARTS PROT,
MANUF., COATING, PLATING INSTALL AND ASSEMBLY OPER. THE ABOVE ITEMS AND
THE FOLL ITEMS WERE VERIF BY AUDIT Cond 8-31-77. CONTAM CONT
PROCESSES, CORROS. PROT PROV. TURNAROUND - FUNT FLOW TESTS ARE
MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON COND.
(D) APOLLO FAILURES WERE MAINLY ASSOC WITH REVERSE POLARITY AND
DEGAUSSING OF MAGNETS. THE SHUTTLE VALVE UTILIZES A CONNECTOR (RATHER
THAN LEAD WIRES) AND BLOCKING DIODE WHICH PREVENTS THIS TYPE OF ERROR
DURING CONN. A PCTENT ELECT SHORTING PROP ON A SIMILAR VALVE DUE TO
INSUL DAMAGE WAS DISCOV DURING QUAL AND COND AS DESCRIBED IN ITEM (A)
ABOVE.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

SUBSYSTEM AFT - RCS

ITEM He Pressure Regulator

FAILURE MODE Restricted Flow - Fails Closed

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?

   - YES X NO

   1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?

   - *YES □ NO □

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?

   - YES X *NO □

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?

   - YES □ NO □

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?

   - *YES X NO □

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?

   - *YES □ NO X

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?

   - *YES □ NO □

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.

   - *0 □ *1 X 2 □

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?

   - N/A □ YES X *NO □

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:

   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?

      - YES X *NO □

   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?

      - YES X *NO □

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. □ NO H/S ISSUES 3. □ NO SOFTWARE DETECTION

2. □ HARDWARE ACCEPTS RISK 4. □ DETECTION DURING CHECKOUT

5. □ ACCEPTANCE RATIONALE BELOW 6. □ RECOMMENDED CHANGES BELOW

EXPLANATION/COMMENTS:

1. Ullage transducer will give C&W alert < 200 psi.

3A. Software could provide automatic switch over to parallel leg.

6. 1 success path remaining after first failure.

7. Cathode-ray-tube and downlist is available.
SHUTTLE CRITICAL ITEMS LIST - CIBER 102

SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PRESSURIZATION

P/N: MC284-0418-0001/-0002

P/N VENDOR: 74339Q01

QUANTITY: 28

SUBSYSTEM: AFT - REACTION CONTROL FMEA NO 03-2A -201030-2 REV: 11/33/2

ASSEMBLY: PRESSURIZATION

P/N: MC284-0418-0001/-0002

P/N VENDOR: 74339Q01

QUANTITY: 28

PREPARED BY: J. TAGGART

APPROVED BY:

PREPARED BY: G. AKERS

APPROVED BY:

MC284-0418-0001/-0002

P/N VENDOR: 74339Q01

QUANTITY: 28

PREPARED BY: J. TAGGART

APPROVED BY:

PREPARED BY: G. AKERS

APPROVED BY:

ITEM: REGULATOR PRESS, HE

SERIES REDUNDANT. SET AT UNEQUAL OUTLET PRESSURES (PP 201/302/303/304).

FUNCTION:

TO REGULATE STORED HELIUM PRESSURE FROM 4000 PSIG MIX TO ULLAGE PRESSURE OF 245 (+ OR - 3) PSIG FOR PURPOSE OF PROPellant FEED TO THRUSTERS. TWO PARALLEL PATHS WITH TWO SERIES REGS ARE PROVIDED FOR EACH PROPellant TANK. PRIMARY ELEMENT SET 11 PSI LOWER THAN SECONDARY.

FAILURE MODE: FAILS CLOSED (F)

RESTRICTED FLOW.

CAUSE(S):

- CONTAM (PILOT SCREEN), FRAZED NOIST, SPRING/STEM FRACURE, PISTON BINDS, EXCESS DOME PRESS, COCKED SPRINGS, M - TAL DET.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (U) CREW/VEHICLE:

(A, B) LOSS OF REDUNDANCY (ONE OF 2 FLOW PATHS). (C) AVOID DECISION.

(1) NO EFFECT UNLESS SECOND PATH FAILS CLOSED, REENTRY CAPABILITIES ARE LOST IF FAILURE OCCURS EARLY IN ENTRY SUCH THAT ULLAGE PRESS IS NOT SUFFICIENTLY PRESSURIZED.

(6) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CREW/VEHICLE LOSS. FAILURE OF REDUNDANT PARALLEL FLOW PATH WOULD RESULT IN INABILITY TO SURVIVE OR DEPLETE RCS PROPELLANT. THIS WOULD RESULT IN POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO USE PRESERVED ENTRY PROPellant OR C G. PROBLEMS RESULTING FROM PROPELLANT WEIGHT.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:

(4) PARALLEL REGULATORS ARE PROVIDED. ULLAGE PRESS IS ACES FOR PROP TEST WITH LESS THAN 35 PERCENT PROP ERATION. 4 25-MICRON ABS GBR PLUS 10-MICRON ABS GBR PILOT FILTER IS USED TO LIMIT THE POSSIBILITY OF CONTAM INJURING JAMMING OF MOVING PARTS OR PLUGGING PILOT CONTROL ORIFICES. (8) 50,000 OPER FLOW CYCLES AND X00 GBR AT ANTIC MISSION LEVELS ARE PERFORMED DURING GUAL. ITEM IS USED DURING SYS EVAL TESTS AT WSTF ALLOWING EVAL UNDER SIMU MISSION USAGE COND. PROOF PRESS, LEAKAGE AND FLOW TESTING IS PERFORMED DURING ATP. FUCT AND LEAKAGE TESTS ARE PERFORMED DURING PRE/POST FLIGHT CHECKOUT. (C) AN ID IS PERF AND THE UNIT TAGGED. MATL & EQUIP CONFORMANCE TO CONTRACT REGMTS IS VERIF BY INSPECTION. THE FULL ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPECTION POINTS - RAW MATL, PARTS PROTECTION, MANUF, COATING, PLATING, INSTALL AND ASSY OPERATIONS. THE ABOVE ITEMS AND THE FULL ITEMS WERE VERIF BY AUDIT CONDUCTED 4-5-77 - CONTAM CONT PROCESSES AND CORROS PPOT PROV, CONTAM CONT PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIR. THE FOLLOWING

1002

S175-SH-0003
SUBSYSTEM: AFT - REACTION CONTROL FMEA NO 03-2A -231030-2 REV: 11/08/73

ITEMS WERE VERIFIED BY AUDIT OF MARCH 6, 1978. INSPECTION VERIFIES
ASSEMBLY PER INSPECTION PLANTS IN MASTER RECORD. LOG OF CLEAN ROOM AND
CALIBRATION OF TOOLS VERIFIED. CRITICAL DIMENSION 100% VERIFIED BY
INSPECTION. PARTS CLEANLINESS AND PASSIVATION BY INSPECTION. NOE
INSPECTION PERFORMED AFTER ASSEMBLY. TURNAROUND - FINCT FLOW TESTS ARE
MONITORED TO VERIFY THAT THERE IS NO RESTRICTED FLOW. (C) NO FAILURE
HISTORY OF THIS MODE FOR THIS REGULATOR.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   YES X NO 
1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?
   *YES NO 
2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?
   YES X *NO 
3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   *YES X NO 
3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   *YES X NO 
4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?
   *YES NO X 
5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?
   *YES NO X 
6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.
   0 1 X 2 
7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   N/A YES X NO 
8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      YES X NO 
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      YES X NO 
*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY
1. ☐ NO H/S ISSUES 3. ☐ NO SOFTWARE DETECTION 5. ☐ ACCEPTANCE RATIONALE BELOW
2. ☐ HARDWARE ACCEPTS RISK 4. ☐ DETECTION DURING CHECKOUT 6. ☐ RECOMMENDED CHANGES BELOW

EXPLANATION/COMMENTS:
1. Ullage transducer will give C&W alert < 200 psi. Gross leak detection will give first indication.
3A. The helium insolation valves could be automatically closed by software upon sensing a caution and warning low pressure of 200 psi.
6. Initiate cross-feed function.
7. Caution and warning low pressure light - "Right RCS" - cathode-ray tube and down-link available.
8B. Same as primary.
ORIGINAL PAGE IS OF POOR QUALITY
SHUTTLE CRITICAL ITEMS LIST - CRITER 102

SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PRESSURIZATION
P/N: MC621-0059
P/N VENDOR: 73A630030
QUANTITY: 4

Missions: HF VF X FF OF SM
PHASE(S): PL X LD X CC X DC X LS X

REDUNDANCY SCREEN: A-N/A B-N/A C-N/A

PREPARED BY: N C GLAVINICH
APPROVED BY: SSM

DES C M AKERS
REL

ITEM: LINE, LOW PRESSURE HE.
FEED LINE (3/4")

FUNCTION:
3/4" X .020 334L S.S LINES TO PROVIDE HELIUM FEED FROM REGULATORS TO PROP TANK.

FAILURE MODE: STRUCTURAL FAILURE (S)
RUPTURE, EXTERNAL LEAKAGE.

CAUSE(S):
MECHANICAL SHOCK, VIBRATION/FATIGUE, IMPROPER INSTALLATION (WELD), STRESS CORROSION, MATERIAL DEFICIENCY (SULPHIDE STRINGER).

EFFECT(S): ON (A) SUBSYSTEM (I) INTERFACES (C) MISSION (2) CREW/VEHICLE:
(A) LOSS OF SUBSYSTEM HELIUM SUPPLY, INABILITY TO DEPLETE/UTILIZE PROPELLANT, (B) LOSS OF INTERFACE FUNCTION, INABILITY TO REPRESSURE PROP TANK, POTENT POO STRUCTURE & TPS DAMAGE, (C) POTENTIAL LOSS OF MISSION OR EARLY MISSION TERMINATION, (D) POTENTIAL LOSS OF CREW/VEHICLE IF GROSS LEAK OCCURS OR TPS DAMAGE OCCURS PRECLUDING SAFE ENTRY.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) F.S. IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF). THE WELDED CONSTRUCTION ELIMINATES JOINTS AND POSSIBLE LEAK PATHS. THE ANNEALED AREA (DUE TO WELDING) IS BACKED UP BY A SLEEVE. FASTENING CLAMPS ALLOW FREEDOM OF MOVEMENT. TUBING BENDS ARE CONTROLLED BETWEEN FIXED POINTS TO FACILITATE INSTALLATION AND ACCOMMODATE VEHICLE GROWTH AND MOVEMENT. (B) ROCKWELL PERFORMED TUBING CERTIFICATION TESTS PER "ORBITER TUBING VERIFICATION PLAN" (SD75-SH-0205). THIS TESTING INCLUDED PRESSURE CYCLING AND FATIGUE FOR TYPICAL SHUTTLE LINES & JOINTS. SYSTEM EVALUATION TESTS AT WSTF WILL ALSO ALLOW EVALUATION IN THE INSTALLED SYSTEM CONDITION. LEAKAGE TESTS ARE PERFORMED IN-PROCESS FOR TUBING SECTIONS. OPTICAL INSPECTIONS ARE ALSO PERFORMED AT THIS TIME IN ADDITION TO X-RAY AND DYE PENETRANT. LEAKAGE TESTS ARE ALSO PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND ADDITIONAL WELDS ARE ALSO SUBJECTED TO NDE. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAM. CONTROL PROCESSES, CORROS. PROTECTION PROVISIONS, NDE EXAM OF WELDS AND INSPE. FOR SURFACE AND SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPE. POINTS, RAW MAT'L (LOT CERTIFICATION), PARTS PROTECTION, MANUF., COATING, PLATING, INSTALLATION AND ASSEMBLY OPERATIONS. HARDWARE IS INSPE. IN ACCORDANCE WITH QUALITY.
SUBSYSTEM: AFT - REACTION CONTROL

FMEA NG 03-2A - 201035-1
REV: 11/05/73

PLANNING REGNITS DOCUMENT (CPRD) WHICH HAS BEEN APPROVED BY NASA.

TURNAROUND. LINES IN ACCESSIBLE AREAS ARE VISUALLY INSPECTED FOR
EVIDENCE OF DAMAGE AND FLOW AND PRESSURE FUNCTIONAL TESTS ARE MONITORED
FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE. C) MINOR HISTORY -
CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.
HISTORY - CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND
CORRECTED.
SUBSYSTEM  AFT - RCS  
ITEM  Relief Valve  

FAILURE MODE  External Leak -- Fails Open

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNOUNCE OR TAKE ACTION IN RESPONSE)?  
   YES [X]  NO [ ]

1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?  
   *YES [X]  NO [ ]

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?  
   YES [X]  NO [ ]

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?  
   YES [X]  NO [ ]

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?  
   *YES [X]  NO [ ]

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?  
   YES [X]  NO [ ]

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?  
   YES [X]  NO [ ]

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.  
   *0 [ ]  *1 [X]  2 [ ]

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?  
   N/A [ ]  YES [X]  NO [ ]

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:  
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?  
      YES [X]  NO [ ]

   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?  
      YES [X]  NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES  
2. [X] HARDWARE ACCEPTS RISK  
3. [ ] NO SOFTWARE DETECTION  
4. [ ] DETECTION DURING CHECKOUT  
5. [ ] ACCEPTANCE RATIONALE BELOW  
6. [ ] RECOMMENDED CHANGES BELOW

EXPLANATION/COMMENTS:

1. Gross leak detection will give first indication.

1a. Measurements: V42P2115, 2116, 3115, and 3116 provide propellant tank ullage pressure signals from transducers.

6. Left and right AFT RCS pods provide redundancy.
ITEM: VALVE

RELIEF, PRESSURE, BURST DISC & POPPET.

FUNCTION:
- Provides pressure relief in event regulator fails open or propellant pressure rises due to thermal increase. The S.S. burst disc relief pressure is 324-340 psig. The main poppet crack and relief pressure is 315 psig and the minimum reseat pressure is 310 psi. Ambient pressure sensing internal is provided since the valve outlet is subjected to back-pressure.
- Failure mode: External leak
- Fails open, main poppet or diaphragm leaks or main poppet does not reseat as req'd after burst disc rupture.
- Cause(s):
  - Corrosion, contamination, poppet binds in guide, spring breaks or cock, seat cracks, moisture freezes, vibration, shock.
- Effect(s): on (A) Subsystem (B) Interfaces (C) Mission (D) Crew/Vehicle:
  - (A) Loss of subsystem pressurization, (B) Loss of interface function, (C) No loss of interface function, (D) Crew/vehicle is not affected.
- Disposition & Rationale (A) Design (B) Test (C) Inspection (D) Failure History:
  - (A) The burst disc is redundant to the main poppet for the external leakage mode. (Main poppet leakage would not be sensed until after burst disc actuation or failure). A 25-micron filter downstream of the burst disc will reduce the potential for contamination caused leakage failure. The helium isolation valve could be closed during static periods. This would prevent continuing loss of source pressure. The main poppet stem is a separate piece from the main sensing spring actuation mechanism, this provides close tolerance control of opening pressure and allows the poppet to seat independently of the large sensor spring force. (B) 36,000 pressure excursion cycles at system operating
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-24-201060-4  REV: 12/14/73

PRESSURE AND 400 PRESSURE RELIEF CYCLES ARE CONDUCTED DURING QUAL.
(C) AN IDENTIFICATION IS PERFORMED CONTAMINATION CONTROL PROCESS,
CONTAMINATION CONTROL PLAN, CORROS, PROTECTION PROVISION, NOE EXAM OF
WELDS, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS, PROPERLY MONITORED
HANDLING AND STORAGE ENVIRONMENT, AND MAIN AND EQUIP, CONFORMANCE TO
CONTRACT REQUIREMENTS ARE VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED
BY SHOP TRAVELER MANDATORY INSPECTION POINTS - RAW MATERIAL, (LOT CERTIFICATION),
PARTS PROTECTION, MANUFACTURING, COATING, PLATING, INSTALLATION AND ASSEMBLY
OPERATIONS. TURNAROUND - LEAKAGE TESTS ARE MONITORED TO VERIFY THAT THE
BURST DISC IS STILL INTACT AND THAT THE MAIN POPPET LEAK RATE IS WITHIN
SPECIFICATION REQUIREMENTS. VISUAL INSPECTION FOR EVIDENCE OF DETERIORATION IS ALSO
PERFORMED. (D) APOLLO FAILURES WERE DUE LARGELY TO GALVANIC CORROSION AND
CONTAMINATION CORRECTED BY DESIGN AND TEST PROCESSING CHANGES. (THE
SHUTTLE RELIEF VALVE IS A NEW DESIGN WHICH CONTAINS A FILTER AND DOES NOT
USE DISSIMILAR METALS).
<table>
<thead>
<tr>
<th>EFFECTS</th>
<th>POSSIBLE CAUSATION</th>
<th>PROBABILTY</th>
<th>VELOCITY</th>
<th>OTHER EFFECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure</td>
<td>System failure</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Failure</td>
<td>Propulsion system failure</td>
<td>High</td>
<td>High</td>
<td>Very high</td>
</tr>
</tbody>
</table>

PREPARED BY: C. Gonzalez

APPROVED BY: C.S. Akers
HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

SUBSYSTEM AFT - RCS

ITEM He Fill Quick Disconnect

FAILURE MODE Fails Open

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)? YES ☒ NO ☐

1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE? *YES ☒ NO ☐

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY? YES ☒ *NO ☐

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)? YES ☒ *NO ☐

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)? *YES ☒ NO ☐

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE? *YES ☒ NO ☐

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS? *YES ☒ NO ☐

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY. *0 ☐ *1 ☐ 2 ☒

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION? N/A ☐ YES ☒ NO ☐

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE? YES ☒ *NO ☐
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE? YES ☒ *NO ☐

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. ☐ NO H/S ISSUES 3. ☐ NO SOFTWARE DETECTION 5. ☐ ACCEPTANCE RATIONALE BELOW
2. ☒ HARDWARE ACCEPTS RISK 4. ☐ DETECTION DURING CHECKOUT 6. ☐ RECOMMENDED CHANGES BELOW

In-Flight detectability ☒

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Gross leak detection will give first indication.

6. Capped quick disconnect provides one redundant success path.
   Pod Redundancy
SYSTEM: ALT - ADJUSTMENT CONTROL, MISSILES, BALLAST, KNOCKOUT PLUGS, LINES & SEALS, LINES & SEALS DAMAGED.
- BALLAST LINE ALREADY FILLenic VES LINE FEW FOR COUNTER SERVICE & OPERATIONS AND LANDING. COUPLING IS ACCESSIBLE AT THE PELICAN SERVICING POINT.
- EJECTING MUST FAIL PRIOR TO LAUNCH.

PREPARED BY: C. SCARLETT L.E.S.
APPROVED BY: C. LARDS REL

- DISCONNECT PISTON INLET.
- LAY WITH SPRING LOADED LINE AND STRUCTURAL LINING.
- REMOVE:
- MISSILES & BALLAST LINE FITTINGS FOR COUNTER SERVICE & OPERATIONS
- COUPLING IS ACCESSIBLE AT THE PELICAN SERVICING POINT.
- EJECTING MUST FAIL PRIOR TO LAUNCH.
- LINES OF ACCEPTABLE SEAL, SEALS DAMAGED.

COULIS:
- EJECTION, Vibration, Mechanical Shock, Pipe-Pipe Structural Failure, Excessive Impaired Use, Damage Safety Of The Line, Or Excessive - Ear Of Low Test. Retaining Line Leads To Valve Carrying Unreliability.
- EFFECTS:
  1. (a) Loss of System Pressure.
  2. (b) Loss of Inter-Stage Pressure.
  3. (c) Potential Loss Of Propellant Tanks Due To Failure Lining. (d) Potential Loss Of Propellant Cannot Be Utilized Or Repletes.

CAUTION:
- VIOLATION OF QUALITY IN NON-ALIGNED, UNSTABLE PROPellant PROOFING THE FIRST IF PRESSURE CAN BE MAINTAINED.

RISKS/HAZARDS:
- Because A Structural Cap Is Spring Loaded Over The Discharge, This Failure Will Be Very Severe (In Terms). Possible Advantages Of The Vehicle Dynamics If Prop Can Be Sealed Prior To Landing. All LINES Must Be Suppressed. PER MAL NO 1932-33.

ORIGINAL PAGE IS OF POOR QUALITY
SHUTTLE CRITICAL ITEMS LIST - CRITERION 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N NO: 03-2A -221070-1
REV: 12/12/78

P/N VENDOR: 7537200C-0401/0403
MISSIONS: HF/VF/X/FF OF SM

QUANTITY: 4
PHASE(S): PL X LO X CC X DJ X LS X
ONE PER HELIUM TANK PER POD

REDUNDANCY SCREEN: A-N/A B-N/A C-N/A

PREPARED BY: DES C. SCARLETT APPROVED BY: APPROVED BY NASA
REL C. MAKERS REL C. SCARLETT

ITEM: DISCONNECT, QUICK FILL, HE
(1/4") WITH SPRING LOADED POPPET AND STRUCTURAL END CAP. 40 219/220

FUNCTION:
PROVIDE HELIUM TANK FILL AND VENT POINT FOR GROUND SERVICING OPERATIONS
AND LOADING. COUPLING IS ACCESSIBLE AT THE HELIUM SERVICING PANEL.

FAILURE MODE: FAILS OPEN (S)
EXCESS OF ACCEPTABLE RATE, SEALS DAMAGED.

CAUSE(S):
CONTAMINATION, VIBRATION, MECHANICAL SHOCK, PIECE-PART STRUCTURAL
FAILURE, EXCESS OR IMPROVE: USE, INADEQUATE SEAL DESIGN, N.C LINE
SUPPORT - SHAFT OR AND BENT. RETAINING CAP LOCSENS NEGATING GAP SEAL
RECONCENCY.

EFFECT(S): ON (A) SUBSYSTEM (-) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF SUB-SYSTEM PRESSURIZATION, (B) LOSS OF INTERFACE FUNCTION
(INABILITY TO REPRESSURIZE PROPELLANT TANKS DUE TO HELOM LOSS), (C)
LAUNCH DELAY OR ABORT, (D) POTENTIAL CREW LOSS DURING MISSION IF
PROPELLANT CANNOT BE UTILIZED OR DEPLETED.

DISPOSITION & RATIONAL (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) F.S. IS 2.0 X WORKING PRESS. ULLAGE PRESS IS ADEQ TO EXPLO TKG
WHICH PERCENT OF LESS PERMANENT. GROUND HALF COUPLINGS AND LINES ARE
SUPPORTED TO LIMIT ANY UNDEFLI STRESS ON THE COUPLING DURING SERVICE AND
PREV DAMAGE TO SEALS. A SAFETY FEATURE DURING SERVICING AND PRIOR TO
REMOVAL OF THE END CAP IS A PROV WHEREBY ANY LEAKAGE PAST THE AIRBORNE
POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING A BLEED SCREW. COMPLETE
STRESS ANALY HAS BEEN CONDUCTED. UTIL OF STRUCT BAP MINIMIZES LEAKAGE
POTENTIAL AND PROVIDES A REDUND SEAL EXCEPT FOR STRUCT FAILURE. (B) THE
COUPLING IS SUB 600 OPERATIONAL CYCLES (COUPLING AND UNCOUPLING)
DURING QUAL. RANDOM VIB TESTING IS ALSO CONDUCTED AT ANTIC VEH LEVELS
FOR 48 MINUTES IN TWO AXES. USAGE DURING YY00 TESTS AT WSTF ALLOWS
EVAL UNDER ACTUAL USAGE CON. PROOF PRESSURE TESTS ARE CONDUCTED DURING ATP
AND LEAKAGE TESTS ARE PERF BEFORE AND AFTER OPER CYCLES. (C) AN ICENT
IS PERF. RAW MATT EXAM, VISUAL INSP FOR CRITICAL SURFACE DEFECTS,
AND EQUIP CONFORMANCE TO CONTRACT REGS ARE VERIF BY RECEIVING INSP.
MEASUREMENT STANDARDS AND TEST EQUIP STANDARDS ARE IMPLEMENTED PER
REGS OF MIL SPEC. THE FOLLOWING ITEMS ARE VERIF BY SHOP TRAVER
MANDATORY INSP POINTS. PART MFG PROCESSES, COATING, ASSY AND
INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY
AUDIT Conducted 5-23-77. CORROS PROT PROF, CONTAM CONT PROFESSE, TEST...
SUBSYSTEM : AFT - REACTION CONTROL FMEA NO 03-2A-201070-1 REV: 12/12/78
HANDLING, AND STORAGE ENVIR. THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT
OF MARCH 6, 1978. INSPECTION VERIFIES ASSEMBLY PER INSPECTION POINTS IN
MASTER RECORD. LOG OF CLEAN ROOM AND CALIBRATION OF TOOLS VERIFIED.
CRITICAL DIMENSION 100% VERIFIED BY INSPECTION. PARTS CLEANLINESS AND
PASSIVATION VERIFIED BY INSPECTION. NOE INSPECTION PERFORMED AFTER
ASSEMBLY. TURNAROUND. COUPLINGS ARE VISUALLY INSIP FOR EVID OF DAMAGED
SEALS AND LEAK TESTS ARE PERFORMED. (C) APOLLO FAILURE HISTORY WAS IN
THE MAIN ASSOC WITH GROUND USAGE, IMPROPER HANDLING.
**SUBSYSTEM** AFT - RCS

**ITEM** Purge Quick Disconnect, Propellant

**FAILUR MODE** External Leakage

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>*Yes</th>
<th>*No</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does the flight software detect this failure mode (i.e., automatically announce or take action in response)?</td>
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<tr>
<td>1a. If not, does the hardware provide information that the flight software could use to detect the failure?</td>
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<tr>
<td>2. Are the answers to questions 1 and 1a consistent with the FMEA evaluation of in-flight detectability?</td>
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<tr>
<td>3. Does the flight software take action to negate the effects of the failure (either by commanding hardware action or implementing alternate program logic)?</td>
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</tr>
<tr>
<td>3a. If not, does the capability exist for the software to compensate for this failure mode (either by commanding hardware action or implementing alternate program logic)?</td>
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<tr>
<td>4. As a result of this failure mode, can the software overstress the hardware or induce another failure?</td>
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<tr>
<td>5. Can this failure mode, in combination with software logic, adversely affect other functions?</td>
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<tr>
<td>6. How many of these hardware failures can the shuttle tolerate (consider crew action and hardware/software operation)? Note change to FMEA criticality.</td>
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<tr>
<td>7. If crew action is required to respond to this failure mode, are cues provided to signal the need for intervention and the required corrective action?</td>
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<tr>
<td>8. If the answer to either 1 or 3 is YES:</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>A. Can the BFS be engaged after occurrence?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Will BFS tolerate failure without loss of crew/vehicle?</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*Explanation required (see below)*

**CHANGE/RETENTION RATIONALE SUMMARY**

1. No H/S issues.
2. Hardware accepts risk.
3. No software detection.
4. Detection during checkout.
5. Acceptance rationale below.
6. Recommended changes below.

**EXPLANATION/COMMENTS:**

1. Gross leak detection will give first indication.
2. The above statement indicates in-flight detection.
3. Need minimum of 2 yaw thrusters. Cross-feed is available. Pods are redundant.
<table>
<thead>
<tr>
<th>FIELD</th>
<th>CONTENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>UNLOAD, LOAD, AND WEIGH VEHICLES</td>
</tr>
<tr>
<td>2.</td>
<td>MATERIALS, VARIOUS</td>
</tr>
<tr>
<td>3.</td>
<td>UNLOAD, LOAD, AND WEIGH VEHICLES</td>
</tr>
<tr>
<td>4.</td>
<td>FUEL/TURBOCHARGER</td>
</tr>
<tr>
<td>5.</td>
<td>VISUAL INSPECTION</td>
</tr>
<tr>
<td>6.</td>
<td>PREPARATION</td>
</tr>
<tr>
<td>7.</td>
<td>APPROVED BY</td>
</tr>
</tbody>
</table>

- **YES**
- **NO**

**ORIGINAL PAGE IS OF POOR QUALITY**
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: MC276-0013
P/N VENDOR: 76361000
MISSIONS: HF VF X FF CF S1
QUANTITY: 28

FUNCTION: IR
P/N: MCA7-0001
CRIT. H/D: 2

MISSIONS: HF VF X FF CF S1

PHASE(S): PL LO X CG X DO X LS

REDUNDANCY SCREEN: A-PASS B-FAIL C-PASS

PREPARED BY: DES C SCARLETT
APPROVED BY: DES C SCARLETT

REL: C MAKERS REL 12/5/01
APPROVED BY: NASA:

APPROVED WITH CHANGES
See Section 13.0

ITEM: DISCONNECT QUICK, PURGE
VENT PROPELLANT WITH STRUCTURAL END CAP AND SPRING LOADED POPPET 
(1/2" & 1/4"

FUNCTION:
TO ALLOW GROUND PURGE OF PROPELLANT MANIFOLDS DURING TURNAROUND OPERATIONS.

FAILURE MODE: EXTERNAL LEAKAGE (S)
CAP LEAKS, SEALS DAMAGED RETAINING NUT LOOSENS NEGATING CAP SEAL REDUNDANCY.

CAUSE(S):
VIBRATION, PIECE PART STRUCTURAL FAILURE, CONTAMINATION, MECHANICAL SHOCK, SEAL DAMAGE, INADEQUATE MAINT OF GSE HALF, NKL LINE SUPPORT - SHAFT OR ONE BENT

EFFECT(S): ON (A) SUBSYSTEM (3) INTERFACES (2) MISSON (D) CREW/VEHICLE:
(A, B) LOSS OF REDUNDANCY
(PROPELLANT MANIFOLD ISOLATION VALVE COULD ISOLATE LEAKAGE).
(C) MISSON MODIFICATION OR ABORT DECISION.
(G) NO EFFECT UNLESS MULTIPLE FAILURES OCCUR OR EXCESS LOSS OF PROP ELANT OCCURS.
(E) FUNCTIONAL CRITICALITY EFFECT POSSIBLE CREW/VEHICLE LOSS - LOSS OF RCS ENTRY PROPELLANT.
POSSIBLE LOSS OF VEHICLE CONTROL DURING ENTRY.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) P.S. IS 2.0 X WORKING PRESSURE. REDUNDANCY PROVIDED BY INTERNAL SEAL, 
CAP & MANIFOLD ISOLATION VALVE. GROUND HALF COUPLINGS AND LINES ARE 
ADAPTED SUPPORTED TO LIMIT ANY UNDUE STRESS ON THE COUPLING DURING SERVICE 
AND PREV DAMAGE TO SEALS. A SAFETY FEATURE DURING SERVICING AND PRIOR 
TO REMOVAL OF THE END CAP IS A PROV WHEREBY ANY LEAKAGE PAST THE 
AIRBORNE POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING A BLEED SCREW.
COMPLETE STRESS ANALYSIS HAS BEEN CONDUCTED. UTIL OF STRUCT CAP MINIMIZES 
LEAKAGE POTENTIAL AND PROVIDES A REDUNDANT SEAL EXCEPT FOR STRUCTURE FAILURE.
FAILURE CAN BE ISOLATED AT MANIFOLD VALVE. (B) THE COUPLING IS SUBJ 
TO 600 OPER CYCLES (COUPLING AND UNCOUPLING) DURING QAL IN ADDITION TO 
PRESSURE CYCLING AND PROP EXPOSURE TESTS. RANDOM VIB TESTING IS 
ALSO CONDUCTED AT ANG VEH LEVELS FOR 34 MINUTES IN EACH AXIS. USAGE 
DURING SYS EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE COND. 
PROOF PRESS TESTS ARE CONDUCTED DURING ATP AND LEAKAGE TESTS ARE PERF 
BEFORE AND AFTER OPER CYCLES. (C) AN IDENT IS PERF. RAW MAT'. NO 
EXAM, VISUAL INSPECTION FOR CRITICAL SURFACE DEFECTS, AND EQUIP CONFORMANCE TO 
CONTRACT REQMTS ARE VERIFY BY RECEIVING INSPECTION. MEASUREMENT STANDARDS AND
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A -201080-1  REV:11/09/78

TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQUIREMENTS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS—PARTS PROT, MFG. PROCESSES, COATING, ASSY AND INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77. CORROS PROT, PROV CONTAM CONT PROCESSES, TEST HANDLING, AND STORAGE ENVIR. THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT OF MARCH 6, 1979. INSTRUCTION VERIFIES ASSEMBLY PER INSPECTION POINTS IN MASTER RECORD. LOG OF CLEAN ROOM AND CALIBRATION OF TOOLS VERIFIED. CRITICAL DIMENSION 100% VERIFIED BY INSPECTION. PARTS CLEANLINESS AND PASSIVATION VERIFIED BY INSPECTION. NOE INSPECTION PERFORMED AFTER ASSEMBLY. TURNAROUND—COUPLINGS WILL BE VISUALLY INSPECTED FOR EVIDENCE OF CAP SEAL DAMAGE AND CAP LEAKAGE. (O) APOLLO FAILURE HISTORY WAS IN THE MAIN ASSOCIATED WITH GROUND USAGE, IMPROPER HANDLING.
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY) ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**
   - **YES** [x] **NO** [ ]

1a. **IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?**
   - **YES** [ ] **NO** [ ]

2. **ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?**
   - **YES** [ ] **NO** [ ]

3. **DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?**
   - **YES** [ ] **NO** [ ]

3a. **IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?**
   - **YES** [x] **NO** [ ]

4. **AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?**
   - **YES** [ ] **NO** [ ]

5. **CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?**
   - **YES** [ ] **NO** [ ]

6. **HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.**
   - **YES** [ ] **NO** [ ]

7. **IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?**
   - **YES** [x] **NO** [ ]

8. **IF THE ANSWER TO EITHER 1 OR 3 IS YES:**
   - A. **CAN THE BFS BE ENGAGED AFTER OCCURRENCE?**
     - **YES** [x] **NO** [ ]
   - B. **WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?**
     - **YES** [x] **NO** [ ]

   *EXPLANATION REQUIRED (SEE BELOW)*

---

**CHANGE/RETENTION RATIONALE SUMMARY**

1. [ ] **NO H/S ISSUES**
2. [x] **HARDWARE ACCEPTS RISK**
3. [ ] **NO SOFTWARE DETECTION**
4. [ ] **DETECTION DURING CHECKOUT**
5. [ ] **ACCEPTANCE RATIONALE BELOW**
6. [ ] **RECOMMENDED CHANGES BELOW**

---

**EXPLANATION/COMMENTS:**

2. FMEA change - in flight detectability should include above measurement numbers.
3. Pod redundancy.
FUEL AND LIQUID OXYGEN SYSTEM ANALYSIS

- \textit{System-No.: 1 - Electric Control Unit:} 
- \textit{Component:} 
- \textit{Location:} 
- \textit{Function:} 
- \textit{Description:} 
- \textit{Remarks/Analysis:}

1. \textit{FailureMode: External Leaking (S)\footnote{Possible: \textit{Seal failure, excess fuel, seal damage, etc.}}}
2. \textit{Removal: \textit{Seal, O-ring failure.}}
3. \textit{Analysis: \textit{Possible: \textit{Seal failure, etc.}}}
4. \textit{Remarks/Analysis: \textit{Possible: \textit{Seal failure, etc.}}}

\textbf{Check List:}
- \textbf{DES:} 
- \textbf{EL:} 

\textit{Approve By:} 

\textit{DES: C. Scarlett} 
\textit{EL: C. Marks}

\textit{Note: This page contains a diagram and text that are not fully legible due to the quality of the image.}

\textbf{Original Page is of Poor Quality}
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N/RI: MEZ70-005-0009, 7, 19, 21
P/N VENDOR: RR42670-5, -FER42590-15-3
MISSIONS: HF, VP, XP, CF, SM
QUANTITY: 36

PREPARED BY: SCARLETT
APPROVED BY: C DE MILLS
APPROVED WITH CHANGES

ITEM: DISCONNECT, QUICK TEST
PT: (1/4") WITH SPRING LOADED POPPET AND STRUCTURAL END CAP.
201-204/207-216/331-304/307-316

FUNCTION:
TO PROVIDE ACCESS TO THE HELIUM SUPPLY SYSTEM AT VARIOUS POINTS IN THE SYSTEM (RELIEF VALVES/BURST DISCS REGULATORS, CHECK VALVES). PROVIDES FOR C/O OF PRESS SYS COMPONENTS. COMPONENT INPUTS & OUTPUTS ARE ACCESSIBLE AT THE SEV PANEL. THE END CAP PROVIDES REDUNDANCY FOR EXTERNAL LEAK.

FAILURE MODE: EXTERNAL LEAKAGE
CAP LEAKS, SEALS DAMAGED

CAUSE(S):
VIBRATION, PIECE PART STRUCTURAL FAILURE (POPPET, SEAL), MECHANICAL SHOCK, EXCESS TORQUE, SEAL DAMAGE, INADEQUATE MAINT OF THE HALF, YO LINE SUPPORT - SHAFT OR BORE GENT.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF SUBSYSTEM PRESSURIZATION OR REDUNDANCY DEPENDING ON LOCATION (B) LOSS OF INTERFACE FUNCTION (LOSS OF PROPELLANT FEED CAPABILITY). (C,D) NO EFFECT DUE TO REDUNDANT POPPET SEALS & END CAP.

FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CREW/VEHICLE LOSS. LOSS OF PRESSURANT RESULTS IN INABILITY TO BURN OR DEPLETE RCS PROPELLANT. THIS WOULD RESULT IN POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO USE RESERVED ENTRY PROPELLANT OR C.G. PROBLEMS RESULTING FROM PROPELLANT WEIGHT.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) F.S. = 2.0 X WORKING PRESS. ULLAGE PRESS IS ADEQ TO EXPEL PROP WITH 35 PERCENT OR LESS REMAINING. GROUNDED COUPLINGS AND LINES ARE ADEQ SUPPORTED TO LIMIT ANY UNDUE STRESS ON THE COUPLING DURING SERVICE AND PREV DAMAGE TO SEALS AND WELD JOINTS. A SAFETY FEATURE DURING SERVICING AND PRIOR TO REMOVAL OF THE END CAP IS A PROV WHEREBY ANY LEAKAGE PAST THE AIRBORNE POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING CAP. UTILIZATION OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUNDANT SEAL EXCEPT FOR STRUCT OR WELD FAILURES. (B) THE COUPLING IS DESIGNED FOR 400 OPER CYCLES (COUPLING AND UNCOUPLING). USAGE DURING SYS EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE COND. PRESS TESTS ARE CONDUCTED DURING ATP AND LEAKAGE TESTS ARE PERF BEFORE AND AFTER OPER CYCLES. (C) AN IDENT IS PERF AND THE UNIT TAGGED. RAW Mat'l. NO EXAM OF WELDS, VISUAL INSPE. OF WELD JOINTS FOR
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: AFT - REACTION CONTROL
FMEA NC 03-2A -201090-L  REV:12/12/76

Conformance to standard weld practice, surface defects, and equip
Conformance to contract rights are verified by receiving inspection. Measurement
Standards and test equipment standards are implemented per formats of MIL
specs. The following items are verified by shop traveler mandatory inspection
points—parts prot., WPS, processes, coating, plating, Assy and
installation. The above items and the following items were verified by
audit conducted 11-3-76. C) PROJ's PROV, contam cont processes, test
handling, and storage envir. turnaround. Couplings will be visually
inspected for evidence of seal damage and cap leakage. (couplings
between the helium isol valve & regulator & those associated with prop
tank C/O are not accessible at servicing panels) (D) Apollo failure
history was in the main assoc with ground usage, improper handling.
**ITEM**: He Quad Check Valve

**FAILURE MODE**: Fails Closed

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   - YES [X] NO

1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?
   - YES [ ] NO [ ]

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?
   - YES [ ] NO [X]

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   - YES [X] NO [ ]

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   - YES [X] NO [ ]

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?
   - YES [ ] NO [X]

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?
   - YES [ ] NO [X]

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.
   - 0 [ ] 1 [X] 2 [X]

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   - N/A [ ] YES [ ] NO [ ]

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   a. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      - YES [X] NO [ ]
   b. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      - YES [X] NO [ ]

EXPLANATION/COMMENTS:
1 & 2. Upon using the thrusters, propellant tank ullage pressure will decay until <200 psi which will give a class 2 alarm, caution and warning. (Red Light)
<table>
<thead>
<tr>
<th>TEST 01</th>
<th>TEST 02</th>
<th>TEST 03</th>
</tr>
</thead>
<tbody>
<tr>
<td>VALVE 1</td>
<td>VALVE 2</td>
<td>VALVE 3</td>
</tr>
<tr>
<td>FAILS CLOSED</td>
<td>FAILS CLOSED</td>
<td>FAILS CLOSED</td>
</tr>
</tbody>
</table>

**Effect:**

- VALVE 1, 2, 3 all fail closed.
- VALVE 1, 2, 3 all fail open.
- VALVE 1, 2, 3 all fail.
- VALVE 1, 2, 3 all fail simultaneously.
- VALVE 1, 2, 3 all fail in parallel.
- VALVE 1, 2, 3 all fail in series.
- VALVE 1, 2, 3 all fail in parallel and series.

**Possible Cause:**

- Loss of control due to valve failure.
- Loss of control due to pressure drop.
- Loss of control due to temperature drop.
- Loss of control due to electrical failure.
- Loss of control due to mechanical failure.
- Loss of control due to hydraulic failure.
- Loss of control due to pneumatic failure.
- Loss of control due to chemical failure.
- Loss of control due to biological failure.
- Loss of control due to environmental failure.

**Corrective Action:**

- Close all valves.
- Utilize backup system.
- Utilize manual override.
- Utilize emergency control system.
- Utilize alternative control system.
- Utilize remote control system.
- Utilize automatic control system.
- Utilize human intervention.
- Utilize external control system.
- Utilize internal control system.
- Utilize distributed control system.

**Possible Failure Mode:**

- Loss of control due to valve failure.
- Loss of control due to pressure drop.
- Loss of control due to temperature drop.
- Loss of control due to electrical failure.
- Loss of control due to mechanical failure.
- Loss of control due to hydraulic failure.
- Loss of control due to pneumatic failure.
- Loss of control due to chemical failure.
- Loss of control due to biological failure.
- Loss of control due to environmental failure.

**Possible Effect:**

- Loss of control due to valve failure.
- Loss of control due to pressure drop.
- Loss of control due to temperature drop.
- Loss of control due to electrical failure.
- Loss of control due to mechanical failure.
- Loss of control due to hydraulic failure.
- Loss of control due to pneumatic failure.
- Loss of control due to chemical failure.
- Loss of control due to biological failure.
- Loss of control due to environmental failure.

**Possible Cause:**

- Loss of control due to valve failure.
- Loss of control due to pressure drop.
- Loss of control due to temperature drop.
- Loss of control due to electrical failure.
- Loss of control due to mechanical failure.
- Loss of control due to hydraulic failure.
- Loss of control due to pneumatic failure.
- Loss of control due to chemical failure.
- Loss of control due to biological failure.
- Loss of control due to environmental failure.

**Corrective Action:**

- Close all valves.
- Utilize backup system.
- Utilize manual override.
- Utilize emergency control system.
- Utilize alternative control system.
- Utilize remote control system.
- Utilize automatic control system.
- Utilize human intervention.
- Utilize external control system.
- Utilize internal control system.
- Utilize distributed control system.

**Possible Failure Mode:**

- Loss of control due to valve failure.
- Loss of control due to pressure drop.
- Loss of control due to temperature drop.
- Loss of control due to electrical failure.
- Loss of control due to mechanical failure.
- Loss of control due to hydraulic failure.
- Loss of control due to pneumatic failure.
- Loss of control due to chemical failure.
- Loss of control due to biological failure.
- Loss of control due to environmental failure.

**Possible Effect:**

- Loss of control due to valve failure.
- Loss of control due to pressure drop.
- Loss of control due to temperature drop.
- Loss of control due to electrical failure.
- Loss of control due to mechanical failure.
- Loss of control due to hydraulic failure.
- Loss of control due to pneumatic failure.
- Loss of control due to chemical failure.
- Loss of control due to biological failure.
- Loss of control due to environmental failure.

**Corrective Action:**

- Close all valves.
- Utilize backup system.
- Utilize manual override.
- Utilize emergency control system.
- Utilize alternative control system.
- Utilize remote control system.
- Utilize automatic control system.
- Utilize human intervention.
- Utilize external control system.
- Utilize internal control system.
- Utilize distributed control system.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: MG224-3981-0001/-0002
P/N VENDOR: RS010500-001-011
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: MG224-3981-0001/-0002
P/N VENDOR: RS010500-001-011
FUNCTION: 17
MISSION: HF VF X FF CF SM
PHASE(S): PL L3 X CC X D0 X LS
QUANTITY: 4
QUANT.LITY: 4
PHASE(S): PL L3 X CC X D0 X LS
ITEM: VALVE, QUAD, CHECK HE
FUNCTION: EACH CHECK VALVE QUAD WITH 4 POPPETS IN SERIES - PARALLEL ARRANGEMENT PROVIDES PARALLEL REDUNDANCY FOR HUMIL PRESSURIZATION AND SERIES REDUNDANCY TO LIMIT BACK FLOW OF PROPELLANT VAPORS FROM THE PROPELLANT TANKS TO THE REGULATOR. A 304L 25 MICRON FILTER IS UTILIZED AT THE INLET. VALVE UTILIZES CUTTER SEAL DESIGN CONCEPT (TWO SEALING SURFACES PER POPPET)
FAILURE MODE: FAILS CLOSED (F)
RESTRICTED FLOW: STRUCTURE, SHOCK, VIB, POPPET BINGS IN GUIDE, CONTAMINATIONS FREEzes IN COLD VALVE, COMPRESSORS
CAUSE(S): STRUCTURE, SHOCK, VIB, POPPET BINGS IN GUIDE, CONTAMINATIONS FREEzes IN COLD VALVE, COMPRESSORS
EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF REDUNDANCY - PARAL FLOW PATH... (B,C,D) NO EFFECT UNLESS PARAL POPPETS FAIL CLOSED. FAILURE OF PARAL POPPETS WOULD CAUSE MIX RATIO SHIFT AND POSSIBLY PREVENT UTILIZATION OF ALL RCS PROPPELLANT IN ADDITION TO MIXTURE PROPELLANT PROBLEMS WITH RESULTANT THRUSTER FIRING PROBLEMS. POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO UTILIZE RESERVOIR PROPELLANT AND C.G. PROBLEMS DUE TO PROPELLANT WEIGHT
DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) SERIES-PARALLEL REDUNDANT POPPETS PROVIDE REDUNDANCY FOR THE CLOSED FAILURE MODE. TO LIMIT THE POTENTIAL FOR POPPET SHAFT BINDING OR GENERATION OF CONTAMINATION THE GUIDE PINS UTILIZE SAPPHIRE AS A WEAR RESISTANT SURFACE. A 25-MICRON INLET FILTER WILL ALSO REDUCE THE POTENTIAL FOR A CLOSED FAILURE BY LIMITING THE POTENTIAL FOR CONTAMINATION TO CAUSE BINDING OF MOVING PARTS. (B) 100,000 OPERATION CYCLES (FLOW) AND RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYSTEM EVALUATION TESTS AT WSTF ALLING EVALUATION UNDER SIMULATED MISSION USAGE CONDITIONS. PROOF PRESSURE, LEAKAGE, & OPERATION (CRACKING PRESSURE AND FLOW) TESTS ARE PERFORMED DURING ATP. APPROPRIATELY LOCATED TEST POINTS ALLOW PRE/POST FLIGHT LEAKAGE TESTS AND OPERATION TESTS WHICH ARE CONDUCTED AT THIS TIME. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED.
SHUTTLE CRITICAL ITEMS LIST - CREITER 102

SUBSYSTEM : AFT - REACTION CONTROL  PHEA NO 03-2A - 231095-2  REV: 12/12/76
CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, "DE EXAM.
OF WELDS AND BRAZES, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS ARE
VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP
TRAVELER MANDATORY INSPECTION POINTS - RAW MATERIAL (LOT CERTIFICATION), PARTS
PROTECTION, MANUFACTURING, COATING, PLATING INSTALLATION AND ASSEMBLY
OPERATIONS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY
AUDIT CONDUCTED 12-2-77. CONTAMINATION CONTROL PROCESSES, CORROS.
PROTECTION PROVISIONS, TURNOVER - FUNCTIONAL FLOW AND LEAKAGE
(BACK-FLOW) TESTS ARE PERFORMED. (Q) NO PRIOR HISTORY FOR CLOSE FAILURE
MODE FOR THIS TYPE OF DESIGN.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNOUNCE OR TAKE ACTION IN RESPONSE)?
   YES [x] NO [ ]

1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?
   *YES [x] NO [ ]

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?
   YES [ ] *NO [x]

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   YES [ ] *NO [x]

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   *YES [x] NO [ ]

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?
   *YES [x] NO [ ]

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?
   *YES [x] NO [ ]

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.
   0 [ ] 1 [ ] 2 [x]

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   N/A [ ] YES [x] NO [ ]

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      YES [x] *NO [ ]
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      YES [x] *NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY
1. NO H/S ISSUES
2. HARDWARE ACCEPTS RISK
3. NO SOFTWARE DETECTION
4. DETECTION DURING CHECKOUT
5. ACCEPTANCE RATIONALE BELOW
6. RECOMMENDED CHANGES BELOW

In-flight detectability
FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:
2. V42P2115 and 311S should be deleted from this FMEA page as they are in the oxidizer system and not the fuel system.
### Structural Analysis - F117-A

<table>
<thead>
<tr>
<th>Condition</th>
<th>Approaches</th>
<th>Use</th>
<th>Cuts Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airplane failures</td>
<td>1) Install valves, 2) Tank ISOL valves, 3) Isolate</td>
<td>Use</td>
<td>Cuts areas</td>
</tr>
<tr>
<td>Failure Type</td>
<td>(1) INITIAL STALL - LOSS OF PROG. (2) CLIMBING OF</td>
<td>Use</td>
<td>Cuts areas</td>
</tr>
<tr>
<td>Safety Precautions</td>
<td>(5) SUBSYS, (6) FLYBLADE (7) RESTORE (8) ISOLATE (9) VALVE</td>
<td>Use</td>
<td>Cuts areas</td>
</tr>
<tr>
<td>Operating Procedures</td>
<td>(1) INITIAL STALL - LOSS OF PROG. (2) CLIMBING OF</td>
<td>Use</td>
<td>Cuts areas</td>
</tr>
<tr>
<td>General Notes</td>
<td>(5) SUBSYS, (6) FLYBLADE (7) RESTORE (8) ISOLATE (9) VALVE</td>
<td>Use</td>
<td>Cuts areas</td>
</tr>
</tbody>
</table>

**Notes:**
- All valves shall be removed from the system. No areas shall be cut.
- Use care when removing valves to avoid damage.
- Ensure all safety precautions are followed.

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SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED, FUEL
P/N REV: MSC21-0059
P/N VENDOR: 73A-560001
QUANTITY: 12
CRITICAL: 1
MISSIONS: HF VFX FF GF SM
PHASE(S): PL LQ CG XD XS

AMOUNT: ONE SET PER PROPELLANT FUEL PER MODULE.
REPLACEABILITY: A-N/A S-N/A C-N/A
PREPARED BY: N.G. GLAVINICH
APPROVED BY: N.C. MAKERS

ITEM: FEEDLINE AND FITTINGS
FROM TANK TO 1) TANK VALVES, TO 2) MANIFOLD VALVES, TO 3) THRUSTERS.
FUNCTION:
(1) 1 1/2 \times 0.023 304 L.S.S. FROM TANK TO DISTRIBUTION PANEL, (2) 1 1/4 \times 0.023 FROM MANIFOLD ISOLATION VALVE TO THRUSTER MANIFOLD, (3) 1 1/4 \times 0.028 THRUSTER MANIFOLD TO PROVIDE FEED TO APPROPRIATE PROPELLANT COMPONENTS FOR THRUSTER OPERATION-3 AXIS ACCELERATION CONTROL AND ROTATIONAL CONTROL.

FAILURE MODE: STRUCTURAL FAILURE
CAUSE(S):
VIB, FATIGUE, SHOCK, WELD DEF, INSTALL/DAM, DRY/NATUE SEAL FAILURE, "AT" DEF (SULPHIDE STRINGER).

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) SUBSYSTEM DEGRADATION - LOSS OF PROP. (B) DEGRADATION OF INTERFACE FUNCTION - POSS CORROS DAMAGE IN PO. (C) LAUNCH DELAY OR ABORT DECISION. (D) POSSIBLE LOSS OF CREW/VEHICLE-IF LINE FROM TANK OUTLET Ruptures resulting in inability to utilize/deplete prop or prop reacts with fuel or ox causing fire or explosion.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) FDS IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF). DYNA NATURES HAVE DUAL SEALING SURFACES. THE WELDED CONSTRUCTION ELIMINATES JOINTS AND POSSIBLE LEAK PATHS. THE ANNEALED AREA (DUE TO WELDING) IS BACKED UP BY A SLEEVE. FASTENING CLAMPS ALLOW FREEDOM OF MOVEMENT. TUBING BENDS ARE CONTROLLED BETWEEN FIXED POINTS TO FACILITATE INSTALLATION AND ACCOMMODATE VEHICLE GROWTH AND MOVEMENT.
(B) ROCKWELL PERFORMED TUBING CERTIFICATION TESTS PER "ORBITER TUBING VERIFICATION PLAN" (SD 75-SH-0205). THIS TESTING INCLUDED PRESSURE CYCLING AND FATIGUE FOR TYPICAL SHUTTLE LINES & JOINTS.

EVALUATION TESTS AT WSTP WILL ALSO ALLOW EVALUATION IN THE INSTALLED SYSTEM CONDITION. LEAKAGE TESTS ARE PERFORMED IN-PROCESS FOR TUBING SECTIONS. OPTICAL INSPECTIONS ARE ALSO PERFORMED AT THIS TIME IN ADDITION TO X-RAY AND DYE PENETRANT. LEAKAGE TESTS ARE ALSO PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND ADDITIONAL WELDS ARE ALSO SUBJECT TO NDE. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAM CONTROL PROCESSES, CORROS. PROTECTION PROVISIONS, NDE EXAM OF WELDS AND INSPECTION FOR SURFACE AND SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER.
SUBSYSTEM: AFT - REACTION CONTROL
FMEA NO 03-2A - 202108-1 PEV: 11/03/78
MANDATORY INSPECTION POINTS: RAW MATERIAL (LOT CERTIFICATION), PARTS PROTECTION, MANUFACTURING, COATING, PLATING, INSTALLATION AND ASSEMBLY OPERATIONS.
HARDWARE IS INSPECTED IN ACCORDANCE WITH QUALITY PLANNING REQUIREMENTS (QPRD) WHICH HAS BEEN APPROVED BY NASA. TURNAROUND LINES IN ACCESSIBLE AREAS ARE VISUALLY INSPECTED FOR EVIDENCE OF DAMAGE AND FLOW AND PRESSURE FUNCTIONAL TESTS ARE MONITORED FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE.

MINOR HISTORY - CORROSION/PHAS PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.

CORRECTED.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   YES [ ] NO [ ]

1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?
   *YES [ ] NO [ ]

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?
   YES [ ] NO [ ]

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   YES [ ] NO [ ]

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   YES [ ] NO [ ]

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?
   *YES [ ] NO [ ]

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?
   *YES [ ] NO [ ]

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.
   *0 [ ] 1 [ ] 2 [ ]

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   R/A [ ] YES [ ] NO [ ]

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      YES [ ] NO [ ]

   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      YES [ ] NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY
1. [ ] NO H/S ISSUES
2. [ ] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PROPELLANT FEED, OXIDIZER
P/N MANUFACTURER: 73A560002
P/N MANUFACTURER: 73A560002
QUANTITY : 2

**ITEM:** FEEDLINE AND FITTINGS
**FUNCTION:**
- (1) 1 1/4 x 0.32 304L S.S. FROM TANK TO DISTRIBUTION PANEL,
- (2) 1 1/2 x 0.25 FROM MANIFOLD ISOLATION VALVE TO THRUSTER MANIFOLD
- (3) 3/4 x 0.023 THRUSTERS MANIFOLD TO PROVIDE FEED TO APPROPRIATE PROPELLANT
- (4) SUB-SYSTEM DEGREDATION - LOSS OF PROPELLANT

**FAILURE MODE:** STRUCTURAL FAILURE
**CAUSE(S):**
- MECHANICAL SHOCK, VIBRATION/FATIGUE, IMPROPER INSTALLATION (WELD)
- DYNAMITE SEAL FAILURE (MATERIAL DEFICIENCY)

**EFFECT(S):**
- (A) SUB-SYSTEM DEGREDATION - LOSS OF PROPELLANT
- (B) POSSIBLE LOSS OF PROPELLANT IF LINE FROM TANK OUTLET RUPTURES RESULTING IN INABILITY TO UTILIZE/DEPLETE PROPELLANT
- (C) ABORT DECISION
- (D) POSSIBLE LOSS OF PROPELLANT IF LINE FROM TANK OUTLET RUPTURES RESULTING IN INABILITY TO UTILIZE/DEPLETE PROPELLANT

**DISPOSITION & RATIONALE:**
- (A) DESIGN
- (B) TEST
- (C) INSPECTION
- (D) FAILURE HISTORY
- (A) F.S.: IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF)
- DYNAMOBASES HAVE DUAL SEALING SURFACES. THE WELDING CONSTRUCTION ELIMINATES JOINTS AND POSSIBLE LEAK PATHS. THE ANNEALED AREA (DUE TO WELDING) IS BACKED UP BY A SLEEVE. FASTENING CLAMPS ALLOW FREEDOM OF MOVEMENT.
- TUBING BENDS ARE CONTROLLED BETWEEN FIXED POINTS TO FACILITATE INSTALLATION AND ACCOMMODATE VEHICLE GROWTH AND MOVEMENT.
- (B) ROCKWELL PERFORMED TUBING CERTIFICATION TESTS PER "ORBITER" TUBING VERIFICATION PLAN (SD75-SH-0003). THIS TESTING INCLUDED PRESSURE CYCLING AND FATIGUE FOR TYPICAL SHUTTLE LINES & JOINTS.
- SYSTEM EVALUATION IN THE Installed SYSTEM CONDITION. LEAKAGE TESTS ARE PERFORMED AT THIS TIME IN ADDITION TO X-RAY AND DYE PENETRANT. LEAKAGE TESTS ARE ALSO PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND ADDITIONAL WELDS ARE ALSO SUBJECTED TO NDE. (C) IN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAM. CONTROL PROCESSES, CORROS., PROTECTION PROVISIONS, NDE EXAM OF WELDS AND INSPE. FOR SURFACE AND SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPE. POINTS: RAW MATERIAL (LOT...
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-24 -202109-1  REV:11/08/75
CERTIFICATION, PARTS PROTECTION, MANUF., CLEANING, PLATING, INSTALLATION
AND ASSEMBLY OPERATIONS. HARDWARE IS INSPECTED IN ACCORDANCE WITH QUALITY
PLANNING REQUIREMENTS DOCUMENT (QPRO) WHICH HAS BEEN APPROVED BY NASA.

TURNAROUND LINES IN ACCESSIBLE AREAS ARE VISUALLY INSPECTED FOR
EVIDENCE OF DAMAGE AND FLOWS AND PRESSURE FUNCTIONAL TESTS ARE MONITORED
FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE. (D) MINOR HISTORY -
CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.
ARE MONITORED FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE. (D) MINOR
HISTORY - CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND
CORRECTED.
1. **Does the flight software detect this failure mode (i.e., automatically announce or take action in response)?**
   - Does the flight software detect this failure mode? **[Yes X, No]**

1a. **If not, does the hardware provide information that the flight software could use to detect the failure?**
   - Is the hardware providing information? **[Yes X, No]**

2. **Are the answers to Questions 1 and 1a consistent with the FMEA evaluation of in-flight detectability?**
   - Are the answers consistent with the FMEA? **[Yes X, No]**

3. **Does the flight software take action to negate the effects of the failure (either by commanding hardware action or implementing alternate program logic)?**
   - Does the flight software take action? **[Yes X, No]**

3a. **If not, does the capability exist for the software to compensate for this failure mode (either by commanding hardware action or implementing alternate program logic)?**
   - Is there a capability to compensate? **[Yes X, No]**

4. **As a result of this failure mode, can the software overstress the hardware or induce another failure?**
   - Will the software cause overstress? **[Yes X, No]**

5. **Can this failure mode, in combination with software logic, adversely affect other functions?**
   - Will the failure affect other functions? **[Yes X, No]**

6. **How many of these hardware failures can the shuttle tolerate (consider crew action and hardware/software operation)? Note change to FMEA criticality.**
   - How many failures can be tolerated? **[0, 1 X, 2]**

7. **If crew action is required to respond to this failure mode, are cues provided to signal the need for intervention and the required corrective action?**
   - Are cues provided? **[N/A, Yes X, No]**

8. **If the answer to either 1 or 3 is Yes:**
   - **A.** Can the BFS be engaged after occurrence? **[Yes X, No]**
   - **B.** Will BFS tolerate failure without loss of crew/vehicle? **[Yes X, No]**

*Explanation required (see below)*

---

**Change/Retention Rationale Summary**

1. **No H/S issues**
2. **Hardware accepts risk**
3. **No software detection**
4. **Detection during checkout**
5. **Acceptance rationale below**
6. **Recommended changes below**

---

**Explanation/Comments:**

1. First indication "failed off" thruster C&W for 1/2 leg. Redundant paths on 3, 4, 5 leg.
2A. Software could be designed to automatically position the appropriate tank isolation valve.

6. One success path remains after first failure.
8B. Same as primary.
THE SLOW, E.
AND EFFECTS ANALYSIS - ERRORS.

1. VALVE.
2. PREPARED VS.
3. PREPARED EYE.
4. PREPARED K.
5. PREPARED E.

PREPARED:

YES
NO
YES

PREPARED VS.

YES
NO
YES

PREPARED K.

YES
NO
YES

PREPARED E.

YES
NO
YES

VICE versa: VEL.

FAILS VEL.

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SHUTTLE CRITICAL ITEMS LIST - CSITRITER 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPellant Feed
P/N PI: MC284-0430-0007-0038
P/N VENDOR: 5750023/5750026
QUANTITY: 12

THREE VALVES PER PROP TANK

REdundancy Screen: A-PASS B-PASS C-PASS

PREPARED BY: APPROVED BY: R. Gonzalez M. Des. C. M. Akeps REL SS M. E. Kiplinger
APPROVED WITH CHANGES

ITEM: VALVE
TANK ISOlation 3 PHASE 400 Hz AC Motor actuated (115-230V) LV361-366. (1-1/2 in.)

FUNCTION
THREE REdundant ISOLation VALVES are used per tank to isolate groups of manifolds (one tank isol valve controls 2 manifolds) and two parallel isol valves control the remaining 2 primary manifolds and the vernier manifold) that may exhibit opn or leakage failures and can isolate the tank during interconnect & rcs or oms crossfeed operations. Also used to prevent helium ingestion to engine at prop turn-out (manual switch). Fuel & oxygen valves can be operated independently for c/o. Line pressure relief to tank is provided.

FAILURE MODE: Fails Closed
Fails to open. fails to remain opn.

CAUSE(S):
LIMIT switch malfunction, premature power to motor, electrical short, rpc open, jamming of ball shaft or cams.

EFFECT(S): (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE;
(A-B) LOSS OF REDUNDancy propellant flow to two manifolds (on one side) and subsequent loss of thruster function, potential thruster damage from induced surge. (C) ABORT decision (dependent on which tank isol valve fails, one tank isol valve closed may lose two manifolds). (D) NO effect for single failure for all missions (loss of thruster may be critical for rts in subsequent missions for oms depletion burn). CRIT 1 FOR RTLS - LOSS of two manifolds (per pod aft) is critical for et separation & mated coast during rts. (E) FUNCTIONAL CRITICALITY effeCT - POSSIBLE CREW/VEHICAL LOSS DUE TO UTILIZE/DEplete RCS propellant.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) AC motor valve is 3-PHASE - 2 OF 3 windings are adequate for valve function. Series (Hybrid) relays provide redundancy for the premature close mode. Parallel (Hybrid) relays provide redundancy for electrical power signal. Additionally, redundant valves are provided. (One tank isol valve controls 2 of 4 manifolds and two parallel tank isol valves control the remaining 2 primary manifolds and the vernier manifold). A .400-micron filter is utilized on the inlet and outlet to limit the potential for contamination caused failure or jamming of moving parts.

ORIGINAL PAGE IS OF POOR QUALITY.
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A-222110-1  REV: 12/12/78
(R) 2500 OPERATION CYCLES (OPEN-CLOSE-OPEN) AND RANDOM VIBRATION AT
ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED
DURING SYSTEM EVALUATION TESTS AT WSTF ALLOWING EVALUATION UNDER SIM-
ULATED MISSION USAGE CONDITION. PROOF PRESSURE, LEAKAGE, OPERATION,
CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT. (C) A VISUAL INSPECTION
AND IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL PROCESS, COORD.
PROTECTION PROVISIONS, NO EXAM OF WELDS, INSPECTION FOR SURFACE AND
SUBSURFACE DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MATERIAL (LOT)
CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE
VERIFIED BY INSPECTION. MANUFACTURING, INSTALLATION, AND ASSY. OPERATIONS ARE
VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND
THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED JULY 1976/
CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE
ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIPMENT AND MATERIAL AND EQUIP-
MENT CONFORMANCE TO CONTRACT REQUIREMENTS. TURBINE/ FUNCTIONAL FLOW & LEAKAGE
TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON
COMMAND. (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
SUBSYSTEM  AFT- RCS  
ITEM  Tank Isolation Valve, A. C.  
FAILURE MODE  Fails Open  

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY) 
   ANNUNCIATE OR TAKE ACTION IN RESPONSE?  YES  NO  

1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD 
   USE TO DETECT THE FAILURE?  *YES  NO  

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA-EVALUATION OF 
   IN-FLIGHT DETECTABILITY?  YES  NO  

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE 
   (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?  YES  NO  

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS 
   FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE 
   PROGRAM LOGIC)?  *YES  NO  

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR 
   INDUCE ANOTHER FAILURE?  *YES  NO  

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT 
   OTHER FUNCTIONS?  *YES  NO  

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW, 
   ACTION AND HARDWARE/SOFTWARE OPERATION)?  NOT CHANGE TO FMEA CRITICALITY.  *0  *1  2  

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED 
   TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?  N/A  YES  NO  

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES: 
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?  YES  NO  
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?  YES  NO  

*EXPLANATION REQUIRED (SEE BELOW)  

CHANGE/RETENTION RATIONALE SUMMARY  
1. ☐ NO H/S ISSUES  3. ☐ NO SOFTWARE DETECTION  5. ☐ ACCEPTANCE RATIONALE BELOW  
2. ☐ HARDWARE ACCEPTS RISK  4. ☑ DETECTION DURING CHECKOUT  6. ☐ RECOMMENDED CHANGES BELOW  

EXPLANATION/COMMENTS:  
1A. Tank isolation valve discreets are available.
STILL TO RELOCATE EXIT

AS PLANNED

PREPARED BY:

APPROVED BY:

FILE SHEET FLOOD AT WATER ACTUATOR 115-2007

FAIL TO CLOSE FAIL TO maintain CLUTCH

WEAK CABLE LIMIT SWITCH MALFUNCTION, STRUCTURAL FAILURE, SEAL BREAK

CONE LEAKS, CORROSIVE, LOSS OF SIGNAL (COIL, RELAX, BMG)

FAILURE SYSTEM ERROR INTERPOLATION INCORRECT (CLOCK) VERS.

COIN leakage PROBLEMS DURING CROSSFIRE (CLUTCH) 4-C

APERTURE - CLUTCH FOR RCL. IF RCS TANK ISOLATION VALVE IS NOT CLOSED LEAKAGE FROM RCS PROPELLANT MAY BE DETECTED. IF ALCHEMICAL ISOLATION VALVES ARE NOT CLOSED.

COLLECTED ACTIVITY:

ANY NEED TO INITIATE CROSSFIRE OPERATIONS TO PREVENT TRANSFER OF PROPELLANTS BEETWEEN RCS OR OPS PUMP INTO RCS PUMP TANK.

PAY ATTENTION:

TWO UNITS FOR UNIT 5 TO EXIT 1 PER NASA PROJECT.
SHUTTLE CRITICAL ITEMS LIST - CREITER 102

SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PROPELLANT FEED

P/N: MC224-0430-0007-0008

P/N VENDOR: 575COZ575-0026 MISSIONS: HF VF X FF CF SM

QUANTITY: 12

THREE VALVES PER PROP TANK

PREPARED BY:

APPROVED BY:

PREPARED 3A (NAA)

TANK ISOLATION 3 PHASE 400 HZ AC MOTOR ACTUATED (115-230V) LV261-266.

FUNCTION:

THREE REDUNDANT ISOLATION VALVES ARE USED PER TANK TO ISOLATE GROUPS OF MANIFOLDS (ONE TANK ISOL VALVE CONTROLS 2 MANIFOLDS AND THE OTHER MANIFOLDS THAT MAY EXHIBIT OPEN OR LEAKAGE FAILURES AND TO ISOLATE THE TANK DURING INTERCONNECT & PBS OR GMS CROSSFEED OPERATIONS. ALSO USED TO PREVENT HElIUM INGESTION TO ENGINE AT PROP. Lined-out (MANUAL SWITCH). FUEL & OXID VALVES CAN BE OPERATED INDEPENDENTLY FOR C/O. LINE PRESS RELIEF TO TANK IS PROVIDED.

FAILURE MODE: INTERNAL LEAKAGE

FAILS OPEN, FAILS TO CLOSE, FAIL TO REMAIN CLOSED.

CAUSE(S):

VIBRATION, LIMIT SWITCH MALFUNCTION, STRUCTURAL FAILURE, SEAT CRACKS, CONTAMINATION, CORROS, LOSS OF SIGNAL (RFC SHORTS OR OPEN).

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:

(A) LOSS OF REDUNDANCY - MANIFOLD ISOLATION. (B) CRIT DECISION - Propellant Management Problems during Crossfeed Operations. (C) NO EFFECT - CRIT 1 FOR RTLS. IF RCS TANK ISOLATION VALVE WILL NOT CLOSE DURING OMS DEPLETION BURN THE RCS PROPELLANT MAY BE DEPLETED IF ASSOCIATED MANIFOLD ISOLATION VALVES ARE NOT CLOSED.

DISPOSITION & RATIONALE:

(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:

(A) AC MOTOR VALVE IS 3-PHASE - 2 OF 3 WINDINGS ARE ADEQUATE FOR VALVE FUNCTION. PARALLEL (HYBRID) RELAYS PROVIDE REDUNDANCY FOR ELECTRICAL POWER SIGNAL. A 400-MICRON FILTER IS UTILIZED ON THE INLET AND OUTLET TO LIMIT THE POTENTIAL FOR CONTAMINATION CAUSED FAILURE OR JAMMING OF MOVING PARTS. (B) 2500 OPERATION CYCLES (OPEN-CLOSE-OPEN) AND RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYSTEM EVALUATION TESTS AT WSTF ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. PROOF PRESSURE, LEAKAGE, OPERATION, CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT. (C) A VISUAL INSPECTION IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL PROCESS, COORDINATION, CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A -202110-3  REV:12/12/78

VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND
THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED JULY 1976/
CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE
ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIPMENT AND MATERIALS AND EQUIPMENT
CONFORMANCE TO CONTRACT REQUIREMENTS. TURNAROUND - FUNCTIONAL FLOW & LEAKAGE
tests are monitored to verify that valves open and close properly upon
command. (O) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST
SD72-SH-0103-2

SUBSYSTEM   APT - RCS
FMEA NUMBER   03-2A-202111-2

ITEM   Interconnect Valve, A.C.
FAILURE MODE   Fails Closed

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY)
   ANNOUNCE OR TAKE ACTION IN RESPONSE)?  
   YES [X]  NO [ ]

   1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD
       USE TO DETECT THE FAILURE?
       *YES [ ]  NO [X]

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF
   IN-FLIGHT DETECTABILITY?
   YES [ ]  NO [X]

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE
   (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   YES [ ]  NO [X]

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS
    FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE
    PROGRAM LOGIC)?
    *YES [X]  NO [ ]

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR
   INDUCE ANOTHER FAILURE?
   *YES [X]  NO [ ]

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT
   OTHER FUNCTIONS?
   *YES [X]  NO [ ]

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW
   ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.
   0 [ ]  *1 [X]  2 [ ]

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED
   TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   N/A [ ]  YES [X]  NO [ ]

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      YES [X]  NO [ ]
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      YES [X]  NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES  3. [ ] NO SOFTWARE DETECTION  5. [ ] ACCEPTANCE RATIONALE BELOW
2. [ ] HARDWARE ACCEPTS RISK  4. [X] DETECTION DURING CHECKOUT  6. [ ] RECOMMENDED CHANGES BELOW

In Flight Detectability
[X] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. "Failed off" thruster gives first indication.

6. One success path remains after first failure.

88. Same as primary.
SHUTTLE CRITICAL ITEMS LIST - CRITERIA L02

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N: MC284-0439-J037-0003
P/N: VENDCR 5750025/5750026
QUANTITY: 8

SUBSYSTEM: AFT - REACTRION CONTROL
SUBSYSTEM: NO:
MISSIONS: HF X FF X FF X SF
PHASE(S): PL LO Y TO X JO X LS

FUNCTION:
TO PROVIDE CONTROL OF INTERCONNECT LINE FOR VARIOUS MODES OF PROPELLANT FEED: 1) OPEN FOR CMCS TO RCS 2) OPEN FOR RCS TO CMCS 3) CLOSED FOR RCS TO SAME SIDE RCS AND CMCS TO CMCS. TWO INTERCONNECT VALVES PER PROP TANK ARE USED. EACH GOES INDEPENDENTLY TO SEPARATE MANIFOLD BANKS. LINE PRESSURE RELIEF TOWARDS PROP TANK IS PROVIDED.

FAILURE MODE: FAILS OPEN
CAUSE(S):
VIB, LIMITS, FAILURE, PREMATURE POWER TO MOTOR, ELECTRICAL SHORT, RC:
OPEN, JAMMING OF CW.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) C/SH/VEHICLE:
(A) LOSS OF REDUNDANCY. (B) DEGRADATION OF INTERFACE FUNCTION CROSSED PROP FEED CAN BE UTILIZED BY ONLY 2 CF & "F" MANIFOLD BANKS. (C) MISSION MODIFICATION: OPERATION CHANGES Prop ITEM A ABOVE. (D) NO EFFECT IF CMCS Missions (Loss of Thruster May Be Critical For RTLS in Subsequent Missions For CMCS Depletion Burn). CRITICAL PROP RCS - LOSS OF 1 MANIFOLD FORWARD & 1 MANIFOLD AFT IS CRITICAL FOR SE PARATION & MATED COAST DURING RTLS. SINGLE COMPUTER FAILURE COULD RESULT FROM THIS TYPE CONDITION. (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE EARLY MISSION TERMINATION - INABILITY TO DEMONSTRATE CMCS PROP FEED TO RCS.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) AC MOTOR VALVE IS 3-PHASE - 2 OF 3 WINDINGS ARE ADEQUATE FOR VALVE FUNCTION.
SERIES (HYBRID) RELAYS PROVIDE REDUNDANCY FOR THE PREMATURE CLOSE MODE. PARALLEL (HYBRID) RELAYS PROVIDE REDUNDANCY FOR ELECTRICAL POWER SIGNAL. ADDITIONALLY, REDUNDANT VALVES ARE PROVIDED. A 400-MICRON FILTER IS UTILIZED ON THE INLET AND OUTLET TO LIMIT THE POTENTIAL FOR CONTAMINATION CAUSED FAILURE OR JAMMING OF MOVING PARTS. (B) 2500 OPERATION CYCLES (OPEN-CLOSE-OPEN) AND RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYSTEM EVALUATION TESTS AT WSTF ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. PROOF PRESSURE, LEAKAGE, OPERATION, CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT. (C) A VISUAL INSPEL AND IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL PROCESS, CODES, PROTECTION PROVISIONS, NDE EXAM OF WELDS, INSPEL FOR SURFACE AND SUBSURFACE DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPEL. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPEL POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED.
SUBSYSTEM: AFT - REACTION CONTROL  FMEA NO. 03-2A-202111-2  REV: 12/12/78

JULY 1976/CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND
STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP. AND MAT'L
AND EQUIP CONFORMANCE TO CONTRACT REQS.  TURNAROUND/FUNCTIONAL FLOW &
LEAKAGE TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY
UPON COMMAND. (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
<table>
<thead>
<tr>
<th>Item</th>
<th>Manifold Isolation Valve, A.C.</th>
<th>Failure Mode</th>
<th>Fails Closed</th>
</tr>
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</table>

1. **Does the flight software detect this failure mode (i.e., automatically, annunciating or taking action in response)?**
   - YES [ ] NO [X] [ ]

1a. If not, does the hardware provide information that the flight software could use to detect the failure?
   - YES [ ] NO [ ] [ ]

2. Are the answers to questions 1 and 1a consistent with the FMEA evaluation of in-flight detectability?
   - YES [X] NO [ ] [ ]

3. **Does the flight software take action to negate the effects of the failure (either by commanding, hardware action or implementing alternate program logic)?**
   - YES [X] NO [ ] [ ]

3a. If not, does the capability exist for the software to compensate for this failure mode (either by commanding hardware action or implementing alternate program logic)?
   - YES [X] NO [ ] [ ]

4. As a result of this failure mode, can the software overstress the hardware or induce another failure?
   - YES [ ] NO [X] [ ]

5. Can this failure mode, in combination with software logic, adversely affect other functions?
   - YES [ ] NO [X] [ ]

6. How many of these hardware failures can the shuttle tolerate (consider crew action and hardware/software operation)? Note change to FMEA criticality.
   - *0 [ ] 1 [ ] 2[X] [ ]

7. If crew action is required to respond to this failure mode, are cues provided to signal the need for intervention and the required corrective action?
   - N/A [ ] YES [X] NO [ ] [ ]

8. If the answer to either 1 or 3 is YES:
   - A. Can the BFS be engaged after occurrence?
     - YES [X] NO [ ] [ ]
   - B. Will BFS tolerate failure without loss of crew/vehicle?
     - YES [X] NO [ ] [ ]

*Explanation required (see below)*

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**Change/retention rationale summary**

1. [ ] NO H/S issues
2. [ ] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [X] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

---

**FMEA change recommended**

**Explanation/comments:**

3. RCS RM automatically detects and prevents thrusting.
MPN-15B-13-0053

1. TRIMMING SYSTEM

2. ELECTRICAL SYSTEM

3. FUEL SYSTEM

4. HYDRAULICS SYSTEM

5. STRUCTURAL INTEGRITY

6. PERFORMANCE

7. OPERATIONAL LIMITS

8. AXIAL TRAVEL

9. SYSTEM DETECTIONS

10. FLIGHT CRITICAL

11. FLIGHT CRITICAL

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ANALYSIS

OF POOR QUALITY
SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PROPELLANT FEED

P/N: MC 234-0430-0001/-0002

P/N VENDOR: 5730023/5730024

MISSIONS: HF VF X FF CF SM

QUANTITY: 16

PREPARED BY: R. Gonzalez

APPROVED BY: C. Makars

ITEM: VALVE

MANIFOLD ISOLATION. 3 PHASE, 400 Hz AC MOTOR OPERATED (115-200V) (1 1/2" INLET, 1 1/4" OUTLET).

FUNCTION:
1) TO ISOLATE THRUSTERS FROM PROPELLANTS PRIOR TO SYSTEM ACTIVATION.
2) TO ISOLATE A FAILED OPEN THROTTLE OR STREAM LEAK.

FAILURE MODE: FAILS CLOSED-PREMATURE (F)

CAUSE(S):
VIBRATION, LIMIT SWITCH MALFUNCTION, PREMATURE POWER TO MOTOR, PREMATURE MOTOR SIGNAL, OFF SHORT.

EFFECT(S):
ON 1) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF REDUNDANCY-LOSS OF PROP FLOW E USE OF 3 PRIMARY THRUSTERS (1 OF 4 MANIFOLDS). (C) NO EFFECT FOR SINGLE FAILURE FOR BOTH MISSIONS (LOSS OF THRUSTER MAY BE CRITICAL FOR RTLS IN SUBSEQUENT MISSIONS FOR OMS DEPLETION BURN). (D) FOR RTLS - LOSS OF 1 MANIFOLD, FORWARD & 1 MANIFOLD IS CRITICAL FOR ET SEPARATION & MATED COAST DURING RTLS. SINGLE COMPUTER FAILURE COULD RESULT IN THIS TYPE CONDITION. (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CREW/VEHICLE LOSS DUE TO INABILITY TO USE RCS IF ALL MANIFOLD VALVES FAIL CLOSED.

DISPOSITION & RATIONALE:
(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:

(A) AC MOTOR VALVE IS 3-PHASE - 2 OF 3 WINDINGS ARE ADEQUATE FOR VALVE FUNCTION. SERIES (HYBRID) RELAYS PROVIDE REDUNDANCY FOR THE PREMATURE CLOSE MODE. PARALLEL (HYBRID) RELAYS PROVIDE REDUNDANCY FOR ELECTRICAL POWER SIGNAL. ADDITIONALLY, REDUNDANT RELAYS ARE PROVIDED. A 400-MICRON FILTER IS UTILIZED ON THE INLET AND OUTLET TO LIMIT THE POTENTIAL FOR CONTAMINATION CAUSED FAILURE OR JAMMING OF MOVING PARTS. (B) 2500 OPERATION CYCLES (OPEN-CLOSE-OPEN) AND RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYSTEM EVALUATION TESTS AT WST ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. PROOF PRESSURE, LEAKAGE, OPERATION, CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT. (C) A VISUAL INSPECTION FOR DAMAGE IS PERFORMED. CONTAMINATION CONTROL PROCESS, CORROSION PROTECTION PROVISIONS, NDE EXAM OF WELDS, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MATERIAL (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUFACTURING, INSTALLATION, AND ASSEMBLY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED JULY 1976/CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP CONFORMANCE.
TO CONTRACT REQMTS. TURNAROUND/FUNCTIONAL FLOW & LEAKAGE TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON COMMAND. (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   YES [X] NO [ ]

1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?
   *YES [ ] NO [ ]

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?
   YES [X] *NO [ ]

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   YES [X] NO [ ]

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   *YES [ ] NO [ ]

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?
   *YES [ ] NO [ ]

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?
   *YES [X] NO [ ]

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.
   *0 [X] *1 [ ] *2 [ ]

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   N/A [ ] YES [X] NO [ ]

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      YES [X] *NO [ ]
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      YES [X] *NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. NO H/S ISSUES
2. HARDWARE ACCEPTS RISK
3. NO SOFTWARE DETECTION
4. DETECTION DURING CHECKOUT
5. ACCEPTANCE RATIONALE BELOW
6. RECOMMENDED CHANGES BELOW

EXPLANATION/COMMENTS:
3. The RCS Redundancy Management software will inhibit the firing of those jets associated with the failed valve.

6. There are no success paths remaining after first failure.

8B. Same as primary.
**TABLE 1. FLIGHT, YES**

<table>
<thead>
<tr>
<th>PREPARED BY:</th>
<th>APPROVED BY:</th>
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<tbody>
<tr>
<td>JES</td>
<td>X. SCHRAB T</td>
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<tr>
<td>SEL</td>
<td>C. WALKER</td>
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**IN C: VALVE.**

- **INCREASE ILLUMINATION, VISITOR INSTRUMENT, SCL2R2D (REV 3) UM: TILL4**

**FUNCTION:**

1. **ALL VISITOR INSTRUMENT IS HAVING 1) PRIOR TO SATELLITE ACTIVITY AND 2) IN THE EVENT OF A SATELLITE INSTRUMENT OR MALFUNCTION OF SATELLITE INSTRUMENT:** (H)

**CRIT (3):**

- INCREASE ELECTRICAL SIGNAL (CONTINUOUS SIGNAL) IS LOSS ELECTRICAL SIGNAL (CONTINUOUS SIGNAL). INCREASE ELECTRICAL SIGNAL (CONTINUOUS SIGNAL) (A) SUB-SYSTEM/LINKAGES (B) MISSION (C) GLOVES/VEHICLES (D) LOSS OF FUNCTION (E) SATELLITE INSTRUMENT. 1) MEASUREMENT OR INCREASE ELECTRICAL SIGNAL-DAYLIGHT MANIPULATION. 2) MISSION MODIFICATION OR MEASUREMENT. (H) AN EFFECT ON LESS ADDITIONAL FAILURE SIGNAL.

**CORRECTIVE ACTION:**

- **UTILIZE COMBINED RCS VEHICLES.** ATTEMPT TO REPAIR VEHICLES FOR USE OF COMED VEHICLES.

**EXPLANATION:**

- **EXPLANATION FOR COLLISION WITH LOSS OF PAYLOAD/SATELLITE.** SUCH SITUATION WILL REQUIRE INALIENT ACTUATION. SEE CONSULTATION CHART. FORM 7060 1. REF MAL NU YYYY-XXXX-1: 00:00. 1. REF. 1 IN USE OF COMBINED RCS VEHICLES. 1 FREE UPLIFT AS BACK-UP VEHICLES UTILIZED AT USER REQUEST.

**ORIGINAL PAGE IS OF POOR QUALITY**
ITEM: VALVE
MANIFOLD ISOLATION, VERNIER THRUSTER, SCIENCE (28VDC) 31-STAIBLE (LATCHING) LV 256/257/357/358.

FUNCTION:
TO PROVIDE VERNIER THRUSTER ISOLATION PRIOR TO SYSTEM ACTIVATION AND 21 IN THE EVENT OF A RUNAWAY THRUSTER OR MANIFOLD LEAK.

FAILURE MODE: FAULS CLOSED. (F)

CAUSE(S):
[IMPROPER ELECTRICAL SIGNAL (CONTINUOUS SHORT), OR LEAKAGE FORCE FROM LATCHING MAGNET, MECH SLEEV, VIB.] CONTAM (AIR GAP).

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) SPACE/VEHICLE:
(A) LOSS OF FUNCTION (VERNIER THRUSTER). (B) LOSS OF INTERFACE SUBSYSTEM PAYLOAD MANIPULATION. (C) MISSION MODIFICATION OF ABD DECISION. (D) NO EFFECT UNLESS ADDITIONAL FAILURES OCCUR.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) SERIES SWITCHES (RSC'S) MINIMIZE POTENTIAL FOR UNINTENDED ACTUATION. PARAL SWITCHES (RSC'S) PROVIDE ELECTRICAL REDUNDANCY FOR THE OPENING S13. AN INDUCT VOLTAGE SUPPRESS CIRCUIT IS PROV IN THE ELECTRICAL SYSTEM TO PREVENT DAMAGE TO OTHER ON-LINE COMPONENTS. REDUNDANT DIODES LIMIT THE POSS OF DIODE FAILURE ALLOWING CURRENT SHUNT FROM THE COIL.

100 MICRON FILTER IS PROV TO LIMIT THE POSS OF CONTAM CAUSING JAMMING MOVING PARTS.

100 MICRON FILTER IS PROV TO LIMIT THE POSS OF CONTAM CAUSING JAMMING MOVING PARTS.

100 MICRON FILTER IS PROV TO LIMIT THE POSS OF CONTAM CAUSING JAMMING MOVING PARTS.

THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: AFT - REACTION CONTROl NO 03-24-202140-1 REV: 12/12/73 3-31-77. CONTAM CONT PROC, CORROS. PROT PROV TURNAROUND- FUNCT FLOW. TESTS ARE CONCITED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON COMMAND. (O) APOLLO FAILURES WERE MAINLY ASSOCIATED WITH REVERSE POLARITY AND DEGUASSING OF MAGNETS. THE SHUTTLE VALVE UTILIZES A CONNECTOR (RATHER THAN LEAD WIRES) AND A BLOCKING DIODE WHICH PREVENTS THIS TYPE OF ERROR DURING CONN. DEVEL TEST, AND ANAL SHOWED PRESS SURGE FATIGUE PROBLEM. THIS IS BEING RESOLVED BY REDUCING THE LIFE OF THE VALVE TO 50 MISSIONS.
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**
   - YES ☒ NO ☐

1a. **IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?**
   - YES ☒ NO ☐

2. **ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?**
   - YES ☒ NO ☐

3. **DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?**
   - YES ☒ NO ☐

3a. **IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?**
   - YES ☒ NO ☐

4. **AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?**
   - YES ☒ NO ☐

5. **CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?**
   - YES ☒ NO ☐

6. **HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)?**
   - 0 ☒ 1 ☐ 2 ☒

7. **IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?**
   - N/A ☒ YES ☒ NO ☒

8. **IF THE ANSWER TO EITHER 1 OR 3 IS YES:**
   - A. **CAN THE BFS BE ENGAGED AFTER OCCURRENCE?**
     - YES ☒ NO ☐
   - B. **WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?**
     - YES ☒ NO ☐

*EXPLANATION REQUIRED (SEE BELOW)*

---

**In Flight Detectability**

X FMEA CHANGE RECOMMENDED

**EXPLANATION/COMMENTS:**

1. Gross leak detection will give first indication.

6. There is one success path remaining after the first failure.

8B. Same as primary.

2. Measurements V42P2313C, 2315C, 2313C and 3315C are not listed in the MML.
SHUTTLE CRITICAL ITEMS LIST - CRITERION 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT
P/N RI: M276-0016
P/N VENDOR: 76306000 & 76306000
QUANTITY: 12

VEHICLE: 6/POD

MISSIONS: HF X FF OF SM

FUNCTION:
TO PROVIDE POP VENTING AND BLEEDING PROPELLANT TANKS DURING SERVICING IN VERTICAL VEHICLE ORIENTATION. ONE-INCH COUPLING (FUEL-LEFT POD AND OX-RIGHT PCO) SERVICES APCS AND CMS. ITEM INTEGRATES SECONDARY INTERNAL SEALS AND HAS A PRESSURE CAP WHICH IS REDUNDANT SEAL. CAP INSTALLED PRIOR TO FLIGHT.

FAILURE MODE: FAILURE OPEN. (S)

CAUSE(S): VIBRATION, PIECE PART STRUCTURAL FAILURE, MECHANICAL SHOCK CONTAMINATION, EXCESS TORQUE, SEAL DAMAGE, NO LINE SUPPORT-SHAFT OR CORE SENT, INADEQUATE MAINT OF GSE HALF.

EFFECT(S): ON (A) SUBSYSTEM (I) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF SUBSYSTEM PROPELLANT. (B) DEGRADATION OF INTERFACE SUBSYSTEM (PROPELLANT EFFECTS). (C) LAUNCH DELAY OR ABORT DECISION. (D) POTENTIAL CREW LOSS DURING MISSION IF PROPELLANT CANNOT BE UTILIZED OR DEPLETED.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) F.S. IS 2.0 X WORKING PRESS. GROUND HALF COUPLINGS AND LINES ARE ADEQUATELY SUPPORTED TO LIMIT ANY UNDEMAND STRESS ON THE COUPLING DURING SERVICE AND PREV DAMAGE TO SEALS. A SAFETY FEATURE PRIOR TO REMOVAL OF THE END CAP IS A PROVISION WHEREBY ANY LEAKAGE PAST THE AIRBORNE POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING A BLEED SCREW. COMPLETE STRESS ANALYSIS HAS BEEN CONDUCTED. USE OF STRUCTURAL CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUNDANT SEAL EXCEPT FOR STRUCTURAL failure.
(B) THE COUPLING IS SUBJECT TO 600 OPER CYCLES (COUPLING AND UNCOUPLING) DURING QUALIFICATION AND ADDITIONAL PRESSURIZATION CYCLING AND PROP EXPOSURE TESTS. RANDOM VIB TESTING IS ALSO CONDUCTED AT ATOMIC VEHICLE LEVELS FOR 34 MINUTES IN EACH AXISS. USAGE DURING SYST EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE CONDITIONS. PROOF PRESS TESTS ARE CONDUCTED DURING ATP & LEAKAGE TESTS ARE PERFORMED BEFORE & AFTER OPER CYCLES. (C) AN IDENT IS PERFORMED. RAW MATERIALS EXAM, VISUAL INSPECTION FOR SURFACE DEFECTS, & EQUIPMENT CONFORMANCE TO CONTRACT REQUIREMENTS ARE VERIFIED BY RECEIVING INSPECTION. MEASUREMENT STANDARDS & TEST EQUIPMENT STANDARDS ARE IMPLEMENTED PER REQUIREMENTS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS-PARTS.

PREPARED BY: C. SCARLETT
APPROVED BY: J. KAMLECH

RANDOM VIB TESTING IS ALSO CONDUCTED AT ATOMIC VEHICLE LEVELS FOR 34 MINUTES IN EACH AXISS. USAGE DURING SYST EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE CONDITIONS. PROOF PRESS TESTS ARE CONDUCTED DURING ATP & LEAKAGE TESTS ARE PERFORMED BEFORE & AFTER OPER CYCLES. (C) AN IDENT IS PERFORMED. RAW MATERIALS EXAM, VISUAL INSPECTION FOR SURFACE DEFECTS, & EQUIPMENT CONFORMANCE TO CONTRACT REQUIREMENTS ARE VERIFIED BY RECEIVING INSPECTION. MEASUREMENT STANDARDS & TEST EQUIPMENT STANDARDS ARE IMPLEMENTED PER REQUIREMENTS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS-PARTS.
SUBSYSTEM: AFT - REACTION CONTROL  FMEA NO 03-24-202150-1  REV: 11/08/75
PROT, MFG. PROCESSES, COATING, ASSY AND INSTALLATION. THE ABOVE ITEMS
& THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77. CORROS
PROV, CONTAM CONT PROCESSES, TEST HANDLING, & STORAGE ENVIR.
THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT OF MARCH 6, 1978. INSPECTION
VERIFIES ASSEMBLY PER INSPECTION POINTS IN MASTER RECORD. LOG OF CLEAN
ROOM AND CALIBRATION OF TOOLS VERIFIED. CRITICAL DIMENSION 100%
VERIFIED BY INSPECTION. PARTS CLEANLINESS AND PASSIVATION BY
INSPECTION. NOE INSPECTION PERFORMED AFTER ASSEMBLY.
TURNAROUND-COUPINGS ARE VISUALLY INSPECTED FOR EVIDENCE OF DAMAGE SEALS & LEAK
TESTS ARE PERFORMED. (D) APOLLO FAILURE HISTORY WAS IN THE MAIN ASSOCIATED
WITH GROUND USAGE, IMPROPER HANDLING.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?

   a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?

   a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:

   a. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?

   b. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?

*EXPLANATION REQUIRED (SEE BELOW)

CHANCE/RETENTION RATIONAL SUMMARY

1. □ NO H/S ISSUES

2. □ HARDWARE ACCEPTS RISK

3. □ NO SOFTWARE DETECTION

4. □ DETECTION DURING CHECKOUT

5. □ ACCEPTANCE RATIONAL BE Below

6. □ RECOMMENDED CHANGES BELOW

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:


6. Pod redundancy.

88. Backup flight system same as primary.
ORIGINAL PAGE IS OF POOR QUALITY

C.2
### SUBSYSTEM: AFT - REACTION CONTROL ASSEMBLY: PROPELLANT FEED

- **PMRI:** MC282-0061-0001-0002
- **PN VENDOR:** 355C3310000-0101-020
- **MISSIONS:** HF VV FF JP SM
- **QUANTITY:** 4
- **PHASE(S):** PL LD X DG X DO X LS

#### CRITICAL ITEMS LIST - CRBITER

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>TANK ASSY, PROPELLANT INCLUDING ACQUISITION DEVICE AND RETENTION SCREENS (1.5 FACTOR OF SAFETY) TK 203/204/303/304.</td>
<td></td>
</tr>
</tbody>
</table>

**FUNCTION:**

To store/supply propellant for reaction control thrusters. Tank shell contains propellant and acquisition device retains propellants for adequate feed during 1"C, 0"G and high "G" conditions. Regulated helium is supplied to the ullage to force propellant to the thrusters as req'd. 245 PSIA (+ OR -15) (17.95 CUBIC FEET).

**FAILURE MODE:**

Structural Failure (F) External Leak, Tank Wall Crack or Seal Failure.

**CAUSE(S):**

Mechanical shock, fatigue/vibration, overpressure, stress corrosion, improper propellant purity or test fluid, over temp, plume or registry gases, stress riser, weld or mate'l defect, incorrect or damaged seal.

**EFFECT(S):**

(A) Loss or degradation of sub-system dependent on extent of failure. (B) Loss or degradation of interface sub-system AFT RCS, POD, TPS or VEH damage. (C) Abort decision. (D) Possible loss of crew/vehicle (explosion, lack of propellant or inability to deplete oppositely propellant).

**DISPOSITION & RATIONALE:**

(A) Rejected (B) Rejected (C) Rejected (D) Rejected

**FAILUERE HISTORY:**

(A) The F.S. (BURST) is 1.5 X WORKING PRESSURE. COMPLETE STRESS ANALYSIS FOR EACH TANK SEGMENT WAS PERFORMED. TANK IS CLASSIFIED AS FRACTURE CRITICAL FOR HANDLING AND IS SUBJECT TO FRACTURE CONTROL REGMTS. ALL FITTINGS AND FLANGES USED ON THE TANK HAVE DUAL ELASTOMER SPRING LOADED SEALS. (B) QUAL REQUIRES 500 PRESSURE WITH (INCLUDING 200 EXPULSION CYCLES AND A 90 DAY CREEP AND PROPPELLANT EXPOSURE TEST). PROOF PRESSURE (1.3X WORKING PRESSURE) AND LEAKAGE TESTS ARE PERFORMED DURING ATP- RADIOGRAPHIC AND DYE PENETRANT TESTS ARE PERFORMED TO VERIFY NO PERMANENT DEFORMATION OR FLAW GROWTH. WELDS ARE VISUALLY INSPECTED FOR EVIDENCE OF STRESS RISER OR OTHER FLAWS. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. RAW MATE'L AND PURCHASED COMPONENTS ARE VERIFIED BY RECEIVING INSPECTION. MEASUREMENT STANDARDS AND TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REGMTS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS- PARTS PROTECTION, MFG. PROCESSES, FINISHES, ASSEMBLY INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY

---

**PREPARED BY:**

DES: R. BEMIS
REL: C. MAKERS

**APPROVED BY:**

DES: SSM
REL: SS

**APPVRED WITH CHANGES***

See Section 13.0
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A-211110-1  REV:11/03/75

AUDIT CONDUCTED 11-1-76. CORROSION PROTECTION PROVISIONS, TEST
HANDLING, AND STORAGE ENVIRONMENTS. TENSILE, HEAT TREAT AND WELD
SAMPLES ARE TESTED DURING IN-PROCESS FABRICATION IN ADDITION TO X-RAY
AND DYE PENTRANT INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS. BOTH
CERTIFIED WELDERS AND CERTIFIED INSPECTORS ARE USED FOR ALL WELDS.

TURNAROUND - INSPECTION TO MONITOR FUNCTIONAL TEST DURING PRESSURIZATION
CYCLE FOR EVIDENCE OF LEAKS. LEAKAGE TESTS ARE PERFORMED AFTER
INSTALLATION INTO THE SYSTEM AND PERIODICALLY AS PART OF CHECK-OUT
PROCEDURE PRIOR TO FLIGHT. PRESSURE CYCLES ACCUMULATED ARE ALSO
RECORDED. (0) APOLLO FAILURES WERE ASSOCIATED WITH INCORRECT TEST FLUID
(METHYL ALCOHOL), IMPROPER PROPELLANT NO CONTENT, STRESS FISSURE OR TEST
ERROR RESULTING IN CREATION OF VACUUM. CORRECTIVE ACTION WAS TAKEN FOR
ALL OF ABOVE FAILURES AND ALSO IMPLEMENTED ON SHUTTLE.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?

   *YES ☑ NO ☒

1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?

   *YES ☑ NO ☒

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?

   YES ☑ *NO ☒

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?

   YES ☑ *NO ☒

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?

   *YES ☑ NO ☒

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?

   YES ☑ *NO ☒

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?

   YES ☑ *NO ☒

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.

   *0 ☐ *1 ☒ 2 ☐

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?

   N/A ☐ YES ☒ NO ☒

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:

   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?

      YES ☒ *NO ☒

   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?

      YES ☒ *NO ☒

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. ☐ NO H/S ISSUES 3. ☐ NO SOFTWARE DETECTION 5. ☐ ACCEPTANCE RATIONALE BELOW

2. ☒ HARDWARE ACCEPTS RISK 4. ☐ DETECTION DURING CHECKOUT 6. ☐ RECOMMENDED CHANGES BELOW

EXPLANATION/COMMENTS:

1. "Failed off" thruster may illuminate if < 40 psi is sensed 3 times 80 milliseconds apart.

5. Crossfeed.

8b. Same as primary.
PAGE 97

MISSION VEHICLE DECELERATION/NO-THRUST TEST TRAJECTORY

PREPARED BY:

APPROVED BY:

1. THE PROPELLANT IS THE ONLY PROPULSIVE AGENT IN THE MISSION VEHICLE
2. DECELERATION IS THE PRODUCT OF THE PROPELLANT WITH NO-THRUST TEST TRAJECTORY
3. PROPELLANT FAILURE IS THE PRIMARY CAUSE OF THE DECELERATION PHASE
4. PROPELLANT IS THE PRIMARY SOURCE OF THE DECELERATION PHASE

5. POTENTIAL HAZARD IF FAILURE OCCURS DURING PROPELLANT DECELERATION
6. EXCESSIVE DECELERATION DUE TO EXCESSIVE PROPELLANT DECELERATION
7. POTENTIAL HAZARD IF EXCESSIVE DECELERATION OCCURS DURING PROPELLANT DECELERATION
8. EXCESSIVE DECELERATION DUE TO PROPELLANT DECELERATION
9. POTENTIAL HAZARD IF DECELERATION EXCEEDS THE SAFE LIMIT
10. EXCESSIVE DECELERATION DUE TO PROPELLANT DECELERATION
ITEM: TANK ASSY, PROPELLANT

INCLUDING ACQUISITION DEVICE AND RETENTION SCREENS (1.5 FACTOR OF SAFETY) TK 203/204/303/304.

FUNCTION:
To store/supply propellant for reaction control thrusters. Acquisition device retains propellants for adequate feed during 1"G", 0"G" and high "G" conditions. Regulated helium is supplied to the ullage to force propellant to the thrusters as reqd. 245 psia (+ or -15) (17.95 cubic feet).

FAILURE MODE: STRUCTURAL FAILURE (S) FAILS TO FEED PROPellant DUE TO RETENTION DEVICE FAILURE, GAS BUBBLES IN PROPELLANT.

CAUSE(S):
Fatigue, stress corrosion, contam, vib, mech shock, screen collapse, frozen prop, prop slosh loads, fastening hardware fails

EFFECT(S): ON (A) SYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A, B) SUBSYSTEM AND INTERFACE DEGRADATION — GAS BUBBLES IN PROP CAUSING REDUCED THRUST OR COMB INSTAB. (C) ABORT DECISION. (D) POSSIBLE LOSS OF CREW VEHICLE - NASA STATES FAILURE OF ACQUISITION DEVICE SCREENS COULD CAUSE PREMATURE GAS INJECTION INTO THE THRUSTER MANIFOLDS DURING ENTRY MANEUVERING.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) SAFETY FACTORS OF 1.5 (MINIMUM) IN SCREEN WILL MINIMIZE FAILURE POTENTIAL. (B) QUAL REQUIRES 200 EXPULSION CYCLES A 90 DAY PROPELLANT EXPOSURE TEST. DEVELOPMENT CERTIFICATION TESTS DEMONSTRATE 100 MISSION FLOW TRANSIENTS (188,800 CYCLES) AND TWO YEAR PROPellant COMPATIBILITY. PROPELLANT ACQUISITION DEVICE AND WELD INTEGRITY VERIFIED VIA BUBBLE POINT TESTS AT THE COMPONENT, SUBASSEMBLY & TANK ASSY LEVEL. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. RAW MAT'EL AND PURCHASED COMPONENT-REQmts ARE VERIFIED BY RECEIVING INSPE. MEASUREMENT STANDARDS & TEST-EQUIP STANDARDS ARE IMPLEMENTED PER REQmts OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS-PARTS PROTECTION, MFG. PROCESSES, FINISHES, ASSY AND THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 11-1-76. CORROSION PROTECTION PROVISIONS, TEST HANDLING, AND STORAGE ENVIRONMENTS. BOTH CERTIFIED WELDERS AND CERTIFIED INSPECTORS ARE USED FOR ALL WELDS. TURNAROUND - BUBBLE POINT TESTS ARE PERIODICALLY PERFORMED IN THE SYSTEM AS PART OF CHECKOUT PROCEDURE PRIOR TO FLIGHT. PRESSURE CYCLES ACCUMULATED ARE ALSO RECORDED. (D) NO IN-FLIGHT FAILURE EXPERIENCE FOR THIS DESIGN.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNOUNCE OR TAKE ACTION IN RESPONSE)?
   YES ☑ NO ☐
1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?
   YES ☑ NO ☐

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?
   YES ☑ NO ☐

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   YES ☑ NO ☐
3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   YES ☑ NO ☐

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?
   YES ☑ NO ☐

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, AVERSELY AFFECT OTHER FUNCTIONS?
   YES ☑ NO ☐

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.
   0 ☐ 1 ☑ 2 ☐

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   N/A ☐ YES ☑ NO ☐

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      YES ☑ NO ☐
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      YES ☑ NO ☐

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY
1. ☐ NO H/S ISSUES
2. ☐ HARDWARE ACCEPTS RISK
3. ☐ NO SOFTWARE DETECTION
4. ☑ DETECTION DURING CHECKOUT
5. ☐ ACCEPTANCE RATIONALE BELOW
6. ☐ RECOMMENDED CHANGES BELOW

In-flight detectability
X FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:
2. Fuel tank outlet pressure measurements V42P2310, 3310 were omitted from the FMEA and need to be added.
3A. Low pressure transducer signals could be used by software to isolate the system automatically if desired.
6. There is one success path remaining after first failure. Cross-feed.
8B. Same as primary.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N: 73P599015-1016102 (MDAC)
P/N VENDOR: ICOS-32 (ISP)
QUANTITY: 12

SUBSYSTEM: AFT - REACTION CONTROL
FMEA: 03-ZA - 21120 1
MISSIONS: HF YF X FF CP SM
PHASES: PL X L3 X CD X DO X LS Y

PREPARED BY: GLAVINICH
APPROVED BY: SSM

ITEM: CONNECTOR
FLEXIBLE, GIMBAL JOINT.

FUNCTION:
AN EXTERNALLY CONSTRAINED BELLows (UNIVERSAL SOCKET JOINT ASS'Y) IS PROVIDED FOR THE PROPELLANT TANK OUTLET LINES TO ALLOW MOVEMENT DURING PRESSURE SURGES. CONNECTING TUBES ARE WELDED TO THE BELLows AND TO THE PROP LINES.

FAILURE MODE: STRUCTURAL FAILURE (5)
EXTERNAL LEAKAGE.

CAUSE(S):
FATIGUE, SHOCK, HANDLING IMPEDQ WELD PENET., INCMP FUSION, POPCITY, CORROS RESULTING IN PIN HOLE LEAK THRU GIMBAL, PROP & SI-PGP EXPOSURE PRESS SURGE, FLow INDUCED VIB-PGC EFFECT, FLT VIB.

EFFECT(S): (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) SUBSYSTEM DEGRADATION - LOSS OF PROPELLANT. (B) DEGRADATION OF INTERFACE FUNCTION - POSS CORROS DAMAGE WITHIN POD AND ADVERSE EFFECT ON TPS (MOLECULAR VENTING). (C) LAUNCH DELAY CP ABORT DECISION. (D) POSSIBLE LOSS OF CREW/VEHICLE - IF BELLows joint ruptures resulting in INABILITY TO UTILIZE/DEPLETE PROP OR PROP REACTS W/ FUEL OR OX CAUSING FIRE OR EXPLOSION.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) MULTIPLE BELLOWS ARE UTILIZED. FLow INDUCED VIBRATION ANALYSIS AND STRESS ANALYSIS ARE CONDUCTED TO VERIFY ACCEPTABLE DESIGN. THE EXTERNAL CONSTRAINT (UNIVERSAL SOCKET JOINT ASS'Y) WOULD TEND TO LIMIT ANY GROSS PROPELLANT LEAK IN EVENT OF BELLows FAILURE. ITEM IS USED DURING SYSTEM EVALUATION TESTS AT WETF ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. (C) A VISUAL INSP AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NDE EXAM OF WELDS, INSP FOR SURFACE AND SUBSURFACE DEFECTS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSP. MANUF, INSTALLATION, AND ASY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSP POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 8-29-77. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L CONFORMANCE TO CONTRACT REGMTS. TURNAROUND - MONITOR LEAKAGE TESTS PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND AS PART OF CHECKOUT.
SUBSYSTEM :AFT - REACTION CONTROL - FMEA NO 03-2A -211120-1 REV:11/08/78

- PROCEDURE PRIOR TO FLIGHT. (D) NO FAILURE HISTORY AVAILABLE ALTHOUGH THE
APOLLO PROGRAM DID SHOW SOME PROBLEMS ON FLEX HOSE ASSY DUE TO PIN HOLE
CORROSION ASSOC. WITH RESIDUAL SOLVENTS AND PROPELLANT.
<table>
<thead>
<tr>
<th>QUESTION</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does the flight software detect this failure mode (i.e., automatically</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>- announce or take action in response)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1a. If not, does the hardware provide information that the flight software could</td>
<td>*YES</td>
<td>NO</td>
</tr>
<tr>
<td>use to detect the failure?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Are the answers to questions 1 and 1a consistent with the FMEA evaluation of</td>
<td>YES</td>
<td>*NO</td>
</tr>
<tr>
<td>in-flight detectability?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Does the flight software take action to negate the effects of the failure</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>(either by commanding hardware action or implementing alternate program logic)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3a. If not, does the capability exist for the software to compensate for this</td>
<td>*YES</td>
<td>NO</td>
</tr>
<tr>
<td>failure mode (either by commanding hardware action or implementing alternate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>program logic)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. As a result of this failure mode, can the software overstress the hardware or</td>
<td>*YES</td>
<td>NO</td>
</tr>
<tr>
<td>induce another failure?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Can this failure mode, in combination with software logic, adversely affect</td>
<td>*YES</td>
<td>NO</td>
</tr>
<tr>
<td>other functions?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. How many of these hardware failures can the shuttle tolerate (consider crew</td>
<td>*0</td>
<td>*1</td>
</tr>
<tr>
<td>action and hardware/software operation)? Note change to FMEA criticality.</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>7. If crew action is required to respond to this failure mode, are cues provided</td>
<td>N/A</td>
<td>YES</td>
</tr>
<tr>
<td>to signal the need for intervention and the required corrective action?</td>
<td></td>
<td>*NO</td>
</tr>
<tr>
<td>8. If the answer to either 1 or 3 is YES:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Can the BFS be engaged after occurrence?</td>
<td>YES</td>
<td>*NO</td>
</tr>
<tr>
<td>B. Will BFS tolerate failure without loss of crew/vehicle?</td>
<td>YES</td>
<td>*NO</td>
</tr>
</tbody>
</table>

*Explanation Required (See Below)*

**In-flight detectability**

[X] FMEA change recommended

**Explanation/Comments:**

ORIGINAL PAGE IS OF POOR QUALITY
<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>AFT — REACTION CONTROL</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASSEMBLY</td>
<td>THRUSTER/PROPELLANT FEED</td>
</tr>
<tr>
<td>P/N</td>
<td>MC621-0059</td>
</tr>
<tr>
<td>P/N VENDOR</td>
<td>73P5500C3-1001THRU1005</td>
</tr>
<tr>
<td>QUANTITY</td>
<td>56</td>
</tr>
<tr>
<td>MISSIONS</td>
<td>HF VF X FF OF SM</td>
</tr>
<tr>
<td>Phase(s)</td>
<td>PL X LO X CO X DD X LS X</td>
</tr>
</tbody>
</table>

**SHUTTLE CRITICAL ITEMS LIST — CRBITER 102**

**SUBSYSTEM:** AFT — REACTION CONTROL  
**ASSEMBLY:** THRUSTER/PROPELLANT FEED  
**P/N:** MC621-0059  
**P/N VENDOR:** 73P5500C3-1001THRU1005  
**QUANTITY:** 56  
**MISSIONS:** HF VF X FF OF SM  
**Phase(s):** PL X LO X CO X DD X LS X

**PREPARED BY:** [Signature]  
**APPROVED BY:** [Signature]  
**APPROVED BY NASA:** [Signature]  
**APPROVED WITH CHANGES:** [Signature]

**ITEM:** BELLOWS ASSY.  
**ENGINE ALIGNMENT:**

**FUNCTION:**

A STAINLESS STEEL EXTERNALLY (CYLINDER) CONSTRAINED BELLOWS WITH RIGID TUBE END CONNECTIONS IS PROVIDED AS A MEANS OF CONNECTING AND ALIGNING THE THRUSTER VALVES TO THE PROPELLANT SYSTEM.

**FAILURE MODE:** STRUCTURAL FAILURE (S)  
**EXTERNAL LEAKAGE:**

**CAUSE(S):**

FATIGUE, SHOCK, HANDLING, (N)EQ WELD, PENET, INCORP FUSION, PROPOSITY, CORROS-PROP & BI-PROP EXPOSURE, PRESSUR SURGE, FLOW INDUCED VIB-POOQ EFFECT, FLT VIB.

**EFFECT(S):** ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:

(A) SUBSYSTEM DEGRADATION — LOSS OF PROPELLANT. (B) DEGRADATION OF INTERFACE FUNCTION — PSS CORROS DAMAGE WITHIN POG AND ADVERSE EFFECT ON TPS (MOLECULAR VENTING). (C) LAUNCH DELAY OR ABOPT DECISION. (D) POSSIBLE LOSS OF CREW/VEHICLE — FAILURE NOT DETECTABLE SINCE PYT MEASUREMENTS HAVE BEEN DELETED FROM SOFTWARE FOR ASCENT AND RTLS. (ISOLATION IS POSSIBLE DURING OTHER MISSION PHASES).

**DISPOSITION & RATIONALE:**

(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:

(A) MULTIPLE BELLOWS ARE UTILIZED. FLOW INDUCED VIBRATION ANALYSIS AND STRESS ANALYSIS WERE CONDUCTED TO VERIFY ACCEPTABLE DESIGN. THE EXTERNAL CONSTRAINT WOULD TEND TO LIMIT ANY GROSS PROPELLANT LEAK IN EVENT OF BELLOWS FAILURE. PROPELLANT LEAK FROM LINE TO THRUSTER COULD BE ISOLATED BY MANIFOLD VALVE. (B) ITEM IS USED DURING SYSTEM EVALUATION TESTS AT WSTF ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. (C) A VISUAL INSPE AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS PROTECTION PROVISIONS, NDE EXAM OF WELDS, INSPE FOR SURFACE AND SUBSURFACE DEFECTS, RAW MATERIAL (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPEC POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 8-29-77. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L CONFORMANCE TO CONTRACT REQS. TURNAROUND — MONITOR LEAKAGE TESTS PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND AS PART OF CHECKOUT PROCEDURE PRIOR TO FLIGHT. (D) NO FAILURE HISTORY AVAILABLE ALTHOUGH THE APOLLO PROGRAM DID SHOW SOME PROBLEMS ON FLEX HOSE ASSY DUE TO PIN HOLE CORROSION ASSOCIATED WITH RESIDUAL SOLVENTS AND PROPELLANT.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST  SD72-SH-0103-2

SUBSYSTEM  AFT - RCS  FMEA NUMBER  03-2A-221310-4

ITEM  Engine Inlet Valve  FAILURE MODE  Fails Closed

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   YES X NO

1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?
   YES X NO

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?
   YES X NO

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   YES X NO

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   YES X NO

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?
   YES X NO

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?
   YES X NO

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.
   0 X X

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   N/A X YES

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      YES X NO
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      YES X NO

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. NO H/S ISSUES  3. NO SOFTWARE DETECTION  5. ACCEPTANCE RATIONALE BELOW
2. HARDWARE ACCEPTS RISK  4. DETECTION DURING CHECKOUT  6. RECOMMENDED CHANGES BELOW

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. "Failed off" thruster C&W.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

**SUBSYSTEM** AFT - RCS  
**FMEA NUMBER** 03-2A-221311-1  
**ITEM** Injection Plate  
**FAILURE MODE** Restricted Flow

1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**
   - Yes [x]  
   - No

1a. **IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?**
   - Yes [x]  
   - No

2. **ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?**
   - Yes [x]  
   - No

3. **DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?**
   - Yes [x]  
   - No

3a. **IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?**
   - Yes [x]  
   - No

4. **AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?**
   - Yes [x]  
   - No

5. **CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?**
   - Yes [x]  
   - No

6. **HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.**
   - 0  
   - 1  
   - 2 [x]

7. **IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?**
   - No  
   - Yes [x]  
   - Not Applicable (N/A)

8. **IF THE ANSWER TO EITHER 1 OR 3 IS YES:**
   - **A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?**
     - Yes [x]  
     - No
   - **B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?**
     - Yes [x]  
     - No

*EXPLANATION REQUIRED (SEE BELOW)*

### CHANGE/RETENTION RATIONALE SUMMARY

1. ☐ NO H/S ISSUES  
2. ☒ HARDWARE ACCEPTS RISK  
3. ☐ NO SOFTWARE DETECTION  
4. ☐ DETECTION DURING CHECKOUT  
5. ☐ ACCEPTANCE RATIONALE BELOW  
6. ☐ RECOMMENDED CHANGES BELOW

**In-Flight Detectability**

☑ FMEA CHANGE RECOMMENDED

**EXPLANATION/COMMENTS:**

1. "Failed off" thruster C&W.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: THRUSTER, PRIMARY
P/N: MC467-0028
P/N VENDOR: X30398
QUANTITY: 24
MISSIONS: HF, VP, X, FF, UF, SM

FUNCTION: PROVIDES INJECTION & VAPORIZATION OF FUEL AND OXIDIZER FOR THRUSTER INLET VALVES AND PROVIDES DOUBLE MIXING AT 1.50 OX TO FUEL RATIO FOR HYPERGOLIC REACTION WHICH PRODUCES 825 POUNDS OF THRUST AT 70,000 FEET. ALSO CONTROL CHAMBER WALL COOLING. THE INJECTOR IS CONSTRUCTED OF C-103 COLUMBIUM & WELDED TO THE CCB CHAMBER. ACOUSTIC CAVITIES ARE LOCATED AT THE OUTER PERIPHERY OF THE INJ FACE TO PREVENT HIGH FREQ CCMB INSTAB.

FAILURE MODE: FAILS OUT OF TOLERANCE (F)
AT RESTRICTED FLOW

CAUSE(S): CONTAMINATION, PRODUCTS OF COMBUSTION BLOCKING ORIFICES, FREEZING OF PROPELLANTS

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) VEHICLE:
(A) LOSS OF REDUNDANCY OR FUNCTIONAL DEGRADATION - REDUCED PROP FLOW - CHAM PRESS & THRUST, IMPAIRED CHAM INJ FILM COOLING.
(B) DEGRADATION OF INTERFACE FUNCTION - INCREDIBLE VACUUM & USE OF ALT THRUSTERS (C) NO EFFECT.
(D) NO EFFECT.
(E) FUNCTIONAL CRITICALITY EFFECT - ABORT DECISION - DEGRADED PERFORMANCE OF REDUNDANT THRUSTERS WOULD REQUIRE MISSION ABORT.

DISPOSITION & RATIONALE:
(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
74 MICRON NOMINAL FILTERS ARE PROVIDED TO CONTROL CONTAMINATION FROM SYS AND SUBSEQUENT HAZARD. AUTOMATIC SWITCH OVER (AND ISOLATION) BY C&GIC FAILURE DETECTION SYS. COMPLETE THERMAL AND STRESS ANALYSIS HAVE BEEN COMPLETED. (B) RCS SYS EVAL TEST AT WSTF. THRUSTER QUAL FOR 50,000 CYCLES, SPRAY PATTERN CHECKED DURING ATM. (C) A VISUAL INSP IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NOE EXAM OF WELDS, RAQ MAL'T LOT) CERTIFICATION, PARTS PROTECTION, CODING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSP POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 7-2-76.
CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP, CORROS. PROTECTION CONFORM TO CONTRACT REQNTS. TURNAROUND INSPECTION TO INCLUDE USE OF OPTICS WHERE ACCESSIBLE TO DETERMINE EVIDENCE OF PLUGGED ORIFICE. FLUID SAMPLING TO BE PERFORMED TO DETECT CONTAMINATION. (D) NO DIRECT FAILURE HISTORY AVAILABLE.

PREPARED BY: M. SEARCY
APPROVED BY: J. M. AKERS

DISPOSITION & RATIONALE:
(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
74 MICRON NOMINAL FILTERS ARE PROVIDED TO CONTROL CONTAMINATION FROM SYS AND SUBSEQUENT HAZARD. AUTOMATIC SWITCH OVER (AND ISOLATION) BY C&GIC FAILURE DETECTION SYS. COMPLETE THERMAL AND STRESS ANALYSIS HAVE BEEN COMPLETED. (B) RCS SYS EVAL TEST AT WSTF. THRUSTER QUAL FOR 50,000 CYCLES, SPRAY PATTERN CHECKED DURING ATM. (C) A VISUAL INSP IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NOE EXAM OF WELDS, RAQ MAL'T LOT) CERTIFICATION, PARTS PROTECTION, CODING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSP POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 7-2-76.
CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP, CORROS. PROTECTION CONFORM TO CONTRACT REQNTS. TURNAROUND INSPECTION TO INCLUDE USE OF OPTICS WHERE ACCESSIBLE TO DETERMINE EVIDENCE OF PLUGGED ORIFICE. FLUID SAMPLING TO BE PERFORMED TO DETECT CONTAMINATION. (D) NO DIRECT FAILURE HISTORY AVAILABLE.

PREPARED BY: M. SEARCY
APPROVED BY: J. M. AKERS

DISPOSITION & RATIONALE:
(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
74 MICRON NOMINAL FILTERS ARE PROVIDED TO CONTROL CONTAMINATION FROM SYS AND SUBSEQUENT HAZARD. AUTOMATIC SWITCH OVER (AND ISOLATION) BY C&GIC FAILURE DETECTION SYS. COMPLETE THERMAL AND STRESS ANALYSIS HAVE BEEN COMPLETED. (B) RCS SYS EVAL TEST AT WSTF. THRUSTER QUAL FOR 50,000 CYCLES, SPRAY PATTERN CHECKED DURING ATM. (C) A VISUAL INSP IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NOE EXAM OF WELDS, RAQ MAL'T LOT) CERTIFICATION, PARTS PROTECTION, CODING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSP POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 7-2-76.
CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP, CORROS. PROTECTION CONFORM TO CONTRACT REQNTS. TURNAROUND INSPECTION TO INCLUDE USE OF OPTICS WHERE ACCESSIBLE TO DETERMINE EVIDENCE OF PLUGGED ORIFICE. FLUID SAMPLING TO BE PERFORMED TO DETECT CONTAMINATION. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
<table>
<thead>
<tr>
<th><strong>ITEM</strong></th>
<th><strong>SUBSYSTEM</strong></th>
<th><strong>FMEA NUMBER</strong></th>
<th><strong>FAILURE MODE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrust Chamber</td>
<td>AFT - RCS</td>
<td>03-2A-221312-1</td>
<td>Burn-Thru</td>
</tr>
</tbody>
</table>

1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**
   - YES ✗ NO ☑

1a. **IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?**
   - *YES ✗ NO ☑

2. **ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?**
   - YES ☑ NO ✗

3. **DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?**
   - YES ☑ NO ✗

3a. **IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?**
   - *YES ✗ NO ☑

4. **AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?**
   - *YES ☑ NO ✗

5. **CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?**
   - *YES ☑ NO ✗

6. **HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.**
   - 0 ☑ 1 ✗ 2 ✗

7. **IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?**
   - N/A ☑ YES ✗ NO ✗

8. **IF THE ANSWER TO EITHER 1 OR 3 IS YES:**
   A. **CAN THE BFS BE ENGAGED AFTER OCCURRENCE?**
      - YES ✗ NO ☑
   B. **WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?**
      - YES ✗ NO ☑

**EXPLANATION REQUIRED (SEE BELOW)**

**CHANGE/RETENTION RATIONALE SUMMARY**

1. ☑ NO H/S ISSUES
2. ☑ HARDWARE ACCEPTS RISK
3. ☑ NO SOFTWARE DETECTION
4. ☑ DETECTION DURING CHECKOUT
5. ☑ ACCEPTANCE RATIONALE BELOW
6. ☑ RECOMMENDED CHANGES BELOW

**EXPLANATION/COMMENTS:**

1. "Failed off" thruster C&W.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: THRUSTER, PRIMARY
P/N RE: MC467-002
P/N VENDOR: X30958
QUANTITY: 24

MISSIONS: HF VF X FF OF SM
PHASE(S): PL LJ X OC X DJ X LS

REDUNDANCY SCREEN: A-4/A B-4/A C-4/A

PREPARED BY: DES E. Searcy
APPROVED BY: DES S. S. Makers
RE: C. M. A. Sanders
APPROVED WITH CHANGES

ITEM: THRUST CHAMBER
FROM INJECTOR TO NOZZLE EXTENSION (COATED COLUMBIUM)

FUNCTION:
To contain hypergolic reaction of propellants and direct combustion products through nozzle & extension to provide impulse to vehicle. The chamber is constructed of C-103 columbium with P-512 A oxidation resistant coating and utilizes film cooling. The chamber pressur is 152 psi & is designed to produce a thrust of 870-lbs vacuum at a nominal steady state specific impulse of 260 seconds.

FAILURE MODE: STRUCTURAL FAILURE (5)
BURN THRU OR Rupture in chamber.

CAUSE(S):
THERMAL CYCLING/STRESS FATIGUE, VIB, COMB INSTABILITY, SHOCK, PLUGGED INJ ORIFICES, HIGH TEMP/LOCALIZED HCT SPOTS/INADEQ COOLING NOZZLE RESTRICTION.

EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
(A) LOSS OF REDUNDANCY-POSS LOSS OF 3 THRUSTERS IF INFLD ISOL VALVE MUST BE CLOSED. (B) DEGRADEMENT OF INTERFACE FUNCTION-INC GR CNL & USE OF ALT THRUSTERS (C) MISSION MODIFICATION/ABORT DECISION IF FAILURE CAUSES DAMAGE PROPAGATION. (D) POSSIBLE LOSS OF CREW/VEHICLE BURNTHRU MAY CAUSE HIGH TEMP DAMAGE TO SURR STRUCT & ADJ THRUSTERS RESULTING IN POSS ENTRY HAZ IF TPS IS DAMAGED.

DISPOSITION & RATIONALE: (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
(A) STRUCTURAL MARGINS (2.0 TO 4.0) MINIMIZE FAILURE EFFECT(S). ENG DESIGNED TO INGEST UP TO 45 CU- IN. OF GAS. (B) RCS SYS EVAL TEST AT WSTF. THRUSTER QUAL FOR 50,000 CYCLES. (C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NDE EXAM OF WELDS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION, AT INQY OPERATIONS ARE VERIFIED BY SHOP TRAVELEP MANDATORY INSP POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-76. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP CONFERENCE TO CONTRACT ReqMTS. TURNAROUND INSPECTION TO INCLUDE USE OF OPTICS WHERE ACCESSIBLE TO DETERMINE EVIDENCE OF PLUGGED ORIFICES. FLUID SAMPLING TO BE PERFORMED TO DETECT CONTAMINATION. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST

**SUBSYSTEM** AFT - RCS  
**ITEM** Nozzle Extension  
**FAILURE MODE** Burn-Thru

1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**  
   - YES ☐ NO ☑

2a. **IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?**  
   - YES ☐ NO ☑

3. **ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?**  
   - YES ☑ NO ☐

3a. **IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?**  
   - YES ☑ NO ☐

4. **AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?**  
   - YES ☐ NO ☑

5. **CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?**  
   - YES ☑ NO ☐

6. **HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.**  
   - YES ☑ NO ☐

7. **IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?**  
   - YES ☑ NO ☐

8. **IF THE ANSWER TO EITHER 1 OR 3 IS YES:**  
   - A. **CAN THE BFS BE ENGAGED AFTER OCCURRENCE?**  
     - YES ☑ NO ☐
   - B. **WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?**  
     - YES ☑ NO ☐

**EXPLANATION REQUIRED (SEE BELOW)**

---

### CHANGE/RETENTION RATIONALE SUMMARY

1. ☑ NO H/S ISSUES  
2. ☑ HARDWARE ACCEPTS RISK
3. ☑ NO SOFTWARE DETECTION  
4. ☑ DETECTION DURING CHECKOUT  
5. ☑ ACCEPTANCE RATIONALE BELOW  
6. ☑ RECOMMENDED CHANGES BELOW

---

**EXPLANATION/COMMENTS:**

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117
ITEM: NOZZLE EXTENSION

Coated Columbium (with Insulation Blanket)

FUNCTION:

To provide isentropic expansion of combustion gases for max eff in vacuum. Nozzle is constructed of C-103 Columbium with P-5124 oxidation resistant coating. The nozzle expansion ratio is 22 to 1. Nozzle is integral with the OMS engines and enclosed in a dynamic flex insulator shroud so that the temp is maintained per the procurement specification reqmt.

FAILURE MODE: STRUCTURAL FAILURE

BURN-THRU.

CAUSE(S):

HIGH TEMPERATURE IN LOCAL SPOT CONTAMINATED INJECTOR COOLANT HOLES WELD OR MAT' L DEFECT.

EFFECT(S):

ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:

(A) LOSS OF REDUNDANCY-POSS LOSS OF 3 THROTTLE ISOL VALVE MUST BE CLOSED, (B) DEGRADATION OF INTERFACE FUNCTION- INCR TPS & USE OF ALT THRUSTERS. BURN-THRU MAY CAUSE HIGH TEMP OAM TO SURR STRUCT, TPS, & ADJ THRUSTERS (C) MISSION MODIFICATION/ABORT DECISION IF FAILURE CAUSES DAMAGE PROPAGATION. (D) LOSS OF CREW/VEHICLE-BURN-THRU MAY CAUSE HIGH TEMP DAMAGE TO SURR STRUCT & ADJ STRUCTURES RESULTING IN POSS ENTRY HAZ IF TPS IS DAMAGED

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:

(4) HIGH THERMAL MARGINS IN NOZZLE EXTENSION AND HIGH COOLING MARGIN WILL MINIMIZE FAILURE EFFECT. ENG DESIGNED TO INGEST 45 CU. IN. OF GAS. THRUSTER CAN BE ISOLATED AT INLET OR MANIFOLD VALVE. (B) RCS SYS EVAL TEST AT WSTF-THRUSTER QUAL FOR 50,000 CYCLES. (C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS PROTECTION PROVISIONS, MEDIUM OF WELDS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION, MANUF INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-76. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP CONFORMANCE TO CONTRACT REGMTS.

TURNT LROUND INSPECTION TO INCLUDE USE OF OPTICS WHERE ACCESSIBLE TO DETERMINE EVIDENCE OF BURN-THRU. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST  SD72-SH-0103-2

SUBSYSTEM  AFT - RCS

ITEM  Vernier Thruster

FAILUDE MODE  Loss of Output

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   YES [x]  NO [ ]

1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?
   *YES [x]  NO [ ]

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?
   YES [x]  NO [ ]

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   YES [x]  NO [ ]

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   *YES [ ]  NO [x]

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?
   *YES [x]  NO [ ]

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?
   *YES [x]  NO [ ]

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.
   *YES [x]  NO [ ]

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   H/A [ ]  YES [x]  NO [ ]

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      YES [x]  NO [ ]

   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      YES [x]  NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [x] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

EXPLANATION/COMMENTS:

3. Down modes to free drift.

6. No redundancy in the verniers.
PHASE FAILURES AND EMERGENCY ANALYSIS - LINE 200

PREPARED BY:

APPROVED BY:

FUNCTION:

SYSTEM 1, Y (AXIS-OF-THREE) ARE SECURED TO THE PAYLOAD (PLUS ADDITIONAL PAYLOAD) VIA THIRTY SECURED IN EACH AXIAL NEEDLE TO PROVIDE VEHICLE AND PAYLOAD C2 C2 ATTITUDE STABILITY. SECURE PAYLOAD PLACE IFF Enabled

A SIMILARITY TO THE PRIMARY THRUSTER (1) FACE ATTITUDE AND PAYLOAD CONTROLLABLE TO THE PAYLOAD.

FAILING 2: LOSS OF FUNCTION (FUNCTION) (2)

JES VALVE CLOSED TO THE URGENCY PLUMBING.

CAUSAL:

SYSTEM FUEL, AUTO STABILIZATION WITH VLV/LEAK/STRUCT FAIL, THE URGENCY VALVE JES LEAK/STRUCT FAIL, THE URGENCY VALVE JES LEAK/STRUCT FAIL.

EFFECT: (A) SYSTEM (1) INTERFACES (1) MISSION (NOMINAL) (2) LOSS OF FUNCTION (VYNNER THRUSTERS) CURRENTLY C2 ATTITUDE VIA VVNNER THRUSTERS. (2) EFFECT. (C) MISSION ORIENIATION OR ABSTRACTION (PHASING), INABILITY TO ROTATE PAYLOAD. IT IS POSSIBLE PAYLOAD COULD BE REACHING JES IN FREE DRIFT MODE AND IN SOME INSTANCES PAYLOAD MAY HAVE ATTITUDE & TRANSLATION CONTROL, IF PAYLOAD SLEW FROM 1 TO 180 DEGREES (X AXIS) ENGINES FOR PITCH (FORWARD) MOTION. (O) TO EFFECT.

OPERATIONAL ACTION:

EVALUATE TO DETERMINE NEED FOR ABSTRACTION OR USE OF PRIMARY THRUSTERS, FREE DRIFT MODE OR PAYLOAD ATTITUDE CONTROL.

PHASE FAILURES:

NO PHASES IDENTIFIED. PRIMARY THRUSTERS MOVE VEHICLE TO VYNNER PLACEMENT. PAYLOAD ANY AXES ARE 55 FT LONG. THEY ARE NOT ATTACHABLE TO PAYLOAD ENCORES OF PRIMARY THRUSTING. IT IS POSSIBLE PAYLOAD COULD BE RECOVERED WHILE IN FREE DRIFT MODE AND IN SOME INSTANCES PAYLOAD MAY
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: VERNIER THRUSTER
P/N RI: MC467-0029
P/N VENDOR: 
QUANTITY: 4

AFT - REACTION CONTROL FMEA

MISSIONS: HF, V, X, FF, DF, SM

FUNCTION:

PIN 102

PREPARED BY: J. TAGGART
APPROVED BY: T. HASAS

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF FUNCTION (VERNIER THRUSTERS) - CURRENT OPERATION LOSS OF SINGLE VERNIER THRUSTER CAUSES LOSS (SHUTDOW) OF VERNIER CONTROL. (B) NO EFFECT. (C) MISSION MODIFICATION OR ABORT DECISION (POTENTIAL INABILITY TO RETRIEVE PAYLOAD) - IT IS POSSIBLE PAYLOAD COULD BE RETRIED WHILE IN FREE DRIFT MODE AND IN SOME INSTANCES PAYLOAD MAY HAVE ATTITUDE & TRANSLATION CONTROL. IT MAY BE POSSIBLE TO USE P&I & AFT PCS (X AXIS) ENGINES FOR PITCH (DOWNWARD) MOTION. (D) NO EFFECT.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) PASS REDUND MODES IN X AXIS PRIMARY THRUSTER, PAYLOAD ATTITUDE CONTROL & FREE DRIFT MODES. 100 MICRON FILTRATION & HEATERS PROVIDED TO LIMIT CONTAM & PREVENT PROP FREEZING. (B) THRUSTER DUAL FOR 500,000 CYCLES, 125,000 SEC BURN TIME, INLET VALVE TESTED FOR 500,000 WET CYCLES & 5000 DRY. (C) A VISUAL INSPEC AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NO EXAM OF WELDS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPE POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-76. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP CONFORMANCE TO CONTRACT-REQS. TURNAROUND - VISUAL INSPE USING OPTICAL INSTRUMENTATION. SYSTEM FLUIDS ARE ANALYSED FOR EVIDENCE OF CONTAMINATION. PROPER INLET VALVE FUNCTION AND ELECTRICAL LOGIC POWER IS VERIFIED. (D) NO DIRECT FAILURE HISTORY AVAILABLE.

1020
SD75 SL-022

123
HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

SUBSYSTEM   AFT- RCS

ITEM   Vernier Thruster

FAILURE MODE   Fails to Stop Firing

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   - YES   X   NO

1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?
   - *YES   X   NO

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?
   - YES   X   NO

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   - YES   X   NO

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   - *YES   X   NO

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?
   - *YES   X   NO

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?
   - *YES   X   NO

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.
   - O   X   1   2

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   - N/A   YES   X   NO

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      - YES   X   *NO
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      - YES   X   *NO

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. □ NO H/S ISSUES   3. □ NO SOFTWARE DETECTION   5. □ ACCEPTANCE RATIONALE BELOW
2. □ HARDWARE ACCEPTS RISK   4. □ DETECTION DURING CHECKOUT   6. □ RECOMMENDED CHANGES BELOW

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. "Failed on" thruster C&W.
2. □
3. □
4. □
5. □
6. No redundancy in the verniers.
PREPARED BY:


APPROVED BY:


REMARKS:

IT WAS DECIDED THAT THE FLIGHT TESTS WOULD BE CONTINUED WITHOUT THE PROPOSED REVISIONS TO THE SYSTEM. THE REASONS FOR THIS DECISION WERE AS FOLLOWS:

1. The flight test data indicated that the proposed modifications would not provide the expected improvements.
2. The cost of implementing the revisions was deemed too high.
3. The potential risk associated with making the changes was considered unacceptable.

It was therefore decided to proceed with the existing configuration for the time being, pending further analysis and consideration of alternative solutions.

In conclusion, the decision to continue with the current system configuration was based on the evaluation of the flight test data and the careful consideration of the associated costs and risks. Further modifications to the system may be considered in the future based on new information and developments.
SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: VERNIER THRUSTER

P/N VENDOR: MC467-0029

QUANTITY: 14

P/N: 102

MISSIONS: HF, VF, X, FF, J, SM

PHASE(S): PL, LJ, CC, X, DD, LS

PREPARED BY:
DES: J. Taggart
REL: C. Makr

APPROVED BY:

DEP: S. Schaeffer

Approved by Nasa

PRINTING ORDER OF SHUTTLE CRITICAL ITEMS LIST - CRITERIA 102

ITEM: THRUSTER, ASSY, VERNIER

25 POUND THRUST LEVEL. EN 357/358/257/258.

FUNCTION:

ONE PITCH (2 AXIS-UP FIRING) AND ONE YAW (PLUS/MINUS Y AXIS) VERNIER THRUSTER ARE PROVIDED IN EACH ARCS MODULE TO PROVIDE PRECISE LON LEVEL PULLING AND ATTITUDE HOLD REQD FOR PAYLOAD POINTING. THEY ARE CONCEPTUALLY SIMILAR TO THE PRIMARY THRUSTER BUT LIMIT PLUME IMPINGEMENT AND PROP RESIDUE CONTAM TO THE PAYLOAD.

FAILURE MODE: FAILS TO STOP (F)

CAUSE(S):

CONTAMINATION, STRUCTURAL FAILURE, DUAL SHORT IN DRIVER CIRCUIT TO DUAL MOD FIRE COMMAND, VIS, SHOCK SEAL SEAT DAM, PROP RESIDUE, FLUSH SALTS, CORROS, WEAR.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREEK/VEHICLE:

(A) LOSS OF FUNCTION (VERNIER THRUSTERS) - CURRENTLY LOSS OF ONE VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL. (B) DEGRADATION OF INTERFACE SUB-SYSTEM - PROP LOSS DUE TO EXCESS BURN-TIME UNLESS MANIFOLD CAN BE ISOLATED - POSS DAMAGE TO PAYLOAD OR PAYLOAD BAY ARMS. (C) MISSION MODIFICATION OR ABORT DECISION. (D) NO EFFECT.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:

(A) ISOLATION CAPABILITY IS AN AUTOMATIC FUNCTION WHICH WILL MINIMIZE FAILURE EFFECT. POSS REDUND M ODES OF OPERATION. (PRIMARY THRUSTERS, FREE DRIFT MODE & PAYLOAD ATTITUDE CONTROL MAY PROVIDE ADDITIONAL CONTROL POTENTIAL). 100 MICRON FILTRATION PROVIDED. INADVERTENT FIRE SIGNAL IS IMPROBABLE DUE TO GPC/MOD DESIGN. (B) THRUSTER QUAL FOR 500,000 CYCLES, 125,000 SEC BURN TIME, INLET VALVE TESTED FOR 500,000 WET CYCLES & 5000 DRY. (C) A VISUAL INSPECTION OR IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS.

PROTECTION PROVISIONS, NDE EXAM OF WELDS, RAW MAT'L (LOJ) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION.

(H) MANUFACT, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-75. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP CONFORMANCE TO CONTRACT REQUIREMENTS. TURNAROUND - SYSTEM FLUIDS ARE ANALYSED FOR EVIDENCE OF CONTAMINATION.

PROPER INLET VALVE FUNCTION AND ELECTRICAL LOGIC POWER IS VERIFIED. (D) NO DIRECT FAILURE HISTORY AVAILABLE.

DELETION - 000a
HARDWARE/SOFTWARE ANALYSIS CHECKLIST

SUBSYSTEM: AFT - RCS
ITEM: Vernier Thruster

FAILURE MODE: Burn Thru

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   YES [X] NO [ ]

1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?
   YES [X] NO [ ]

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?
   YES [X] NO [ ]

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   YES [X] NO [ ]

3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   YES [X] NO [ ]

4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?
   YES [X] NO [ ]

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?
   YES [X] NO [ ]

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? *NOTE CHANGE TO FMEA CRITICALITY.
   0 [X] 1 [ ] 2 [ ]

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   N/A [X] YES [ ] NO [ ]

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      YES [X] *NO [ ]
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      YES [X] *NO [ ]

*EXPLANATION REQUIRED (SEE BELOW).

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

EXPLANATION/COMMENTS:
1. "Failed off" thruster C&W.
2. Down modes to free drift.
3. No redundancy in the verniers.

FMEA CHANGE RECOMMENDED
ITEM: THRUSTER, ASSY, VERNIER
25 POUND THRUST LEVEL. EN 357/358/257/258.

FUNCTION:
ONE PITCH (2 AXIS-UP FIRING) AND C'VE YAW (PLUS/MINUS Y AXIS) VERNIER THRUSTER ARE PROVIDED IN EACH ARCS MODULE TO PROVIDE PRECISE LOW LEVEL PULSING AND ATTITUDE HOLD REQ'D FOR PAYLOAD POINTING. THEY ARE CONCEPTUALLY SIMILAR TO THE PRIMARY THRUSTER BUT LIMIT PLUME IMPINGEMENT AND PROP RESIDUE CONTAM TO THE PAYLOAD.

FAILURE MODE: STRUCTURAL FAILURE
(B) BURN THRU OR RUPTURE IN CHAMBER.

CAUSE(S):
THERMAL CYCLING/STRESS FATIGUE, VIB, COMP INSTAB, SHOCK, BLOCKED INJ ORIFICES; HIGH TEMP/LOCALIZED HOT SPOTS/INADEQ COOLING NOZZLE RESTRICTION.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF FUNCTION-CURRENTLY LOSS OF SINGLE VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL. (B) DEGRADATION OF INTERFACE FUNCTION-INCRED GNC & USE OF ALT THRUSTERS (C) MISSION MODIFICATION/ABORT DECISION IF FAILURE CAUSES DAMAGE PROPAGATION. (D) POSSIBLE LOSS OF CREW/VEHICLE-BURN THRU MAY CAUSE HIGH TEMP DAMAGE TO SURR STRUT & ADJ THRUSTERS RESULTING IN POSS ENTRY HAZ IF TPS IS DAMAGED.

CORRECTING ACTION:
ISOLATE PROPELLANTS FROM THRUSTER (AT MANIFOLD LEVEL) AND ASSESS FOR LEAKAGE AND DAMAGE TO SURROUNDING STRUCTURE.

REMARKS/HAZARDS:
THERE IS NO AUTO THRUSTER ISOL AFTER BURN INITIATION (DURING FIRING). PUT IMPACT OF HLT GASES ON MODULE STRUT & ADJ THRUSTERS. BURN-THRU MAY CAUSE HIGH TEMP DAM TO SURR STRUT & ADJ THRUSTERS RESULTING IN POSS ENTRY HAZ IF TPS IS DAMAGED.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : VERNIER THRUSTER
P/N : MC467-0029
P/N VENDGR: MISSIONS: HF VF X FF CF SM

SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : VERNIER THRUSTER
P/N : MC467-0029
P/N VENDGR: MISSIONS: HF VF X FF CF SM

FAILURE NODE: STRUCTURAL FAILURE
CAUSE(S): THERMAL CYCLING/STRESS FATIGUE, VIB, CGYA INSTAB. SHOCK, A/LOCKED INJ ORIFICES, HIGH TEMP/LOCALIZED HTC SPOTS/INADEO COOLING NCZLLE RESTRICTION.

FAILURE NODE: STRUCTURAL FAILURE
CAUSE(S): THERMAL CYCLING/STRESS FATIGUE, VIB, CGYA INSTAB. SHOCK, A/LOCKED INJ ORIFICES, HIGH TEMP/LOCALIZED HTC SPOTS/INADEO COOLING NCZLLE RESTRICTION.

RECONCIL SCIENCE: A-N/IA B-N/4 C-N/a

EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
(A) LOSS OF FUNCTION-CURRENTLY LOSS OF SINGLE VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL. (B) DEGRADATION OF INTERFACE FUNCTION-INC AUTOMIZATION/USE OF ALT THRUSTERS (C) MISSION MODIFICATION/ABORT DECISION IF FAILURE CAUSES CAPGE PROPAGATION. (D) POSSIBLE LOSS OF CREW/VEHICLE-BURN-THRU MAY CAUSE HIGH TEMP DAMAGE TO SURR STRUCT & ADJ THRUSTERS RESULTING IN POSS ENTRY HAZ IF TPS IS DAMAGED.

DISPOSITION & RATIONALE: (A) DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
(A) STRUCTURAL MARGINS (2.0 TO 4.0) MINIMIZE FAILURE EFFECT(S). POSS
RECONCIL MODOES IN X AXIS PRIMARY THRUSTER, PAYLOAD ATTITUDE CONTROL & FREE DRIFT MODOES. 100 MICRON FILTRATION & HEATERS PROVIDED TO LIMIT CONTAM & PREVENT PROP FREEZING. (B) THRUSTER QUAL FOR 500,000 CYCLES. 125,000 SEC BURN TIME. INLET VALVE TETED FOR 500,000 WET CYCLES & 5000 DRY. (C) A VISUAL INSP AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED-COOLANT CONTROL PROCESS, CORES PROTECTION PROVISIONS, NDE EXAM OF WELDS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION. AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER. MANDATORY INSQ POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-76. CONTAMINATION CONTROL PLAN, PROPERLY MOUNTED HANDLING AND STORAGE ENVIRONMENTS, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP. CONFORMANCE TO CONTRACT REQMTS. TURNAROUND - VISUAL INSP USING OPTICAL INSTRUMENTATION. SYSTEM FLUIDS ARE ANALYSED FOR EVIDENCE OF CONTAMINATION. PROPER INLET VALVE FUNCTION AND ELECTRICAL LOGIC POWER IS VERIFIED. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
MEETING MINUTES

Review of JSC 14651, Hardware/Software Interaction Analysis Volume VIII,
AFT Reaction Control System Part 2 of 2.

1. Telecon held between Boeing-Houston/Rockwell, Downey 11/5/79 12:30 PM
to 2:00 PM.

2. Attendees

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<thead>
<tr>
<th>Name</th>
<th>Organization</th>
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<tbody>
<tr>
<td>Lonnie Jenkins</td>
<td>NASA/JSC</td>
<td>X 3851'</td>
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<tr>
<td>Dave Latham</td>
<td>Boeing/Reliability</td>
<td>527-0323 (FTS)</td>
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<td>Don Cagle</td>
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<td>527-0323 (FTS)</td>
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<td>Herb Saxton</td>
<td>Rockwell Propulsion/RCS</td>
<td>X 4503</td>
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<tr>
<td>Larry Gladu</td>
<td>Rockwell Systems Engineering</td>
<td>X 1189</td>
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3. The following changes were discussed and will be incorporated in the final
release of AFT Reaction Control System Hardware/Software Interaction Analysis
and will be reflected in the next update of AFT RCS FMEA.

03-2A-20101-1: Change SM to RM GAX, change 400 psi to 500. Add gross leak
detection. Add crossfeed.

03-2A-201013-1: No. 1 same as 201010-1. Add crossfeed. Add gross leak detection.

03-2A0201020-1: Change question 1 to ullage transducer will give C&W alert
< 200 psi. Change no to yes.

03-2A-201030-2: Question 1 same as 201020-1

03-2A-201035-1: Question 1 same as 201020-1. Add gross leak detection.

03-2A-201060-4: Change question 1 no to yes and "No Software-Detection" to
"Hardware Accepts Risk". Add gross leak detection.

03-2A-201070-1: Change question 1 and 2 to gross leak detection. Add POD
Redundancy to question 6.

03-2A-201080-1: Change question 1 to gross leak detection. Change question 6
from 2 to 0 and add "Need minimum of 2 yaw thrusters. Crossfeed is available. Pods are redundant.

03-2A-201090-1: Change question 1 to gross leak detection. Add question 6 -
Pod redundancy.

03-2A-201095-2: Change question 6 from 1 to 2 and delete comments.

03-2A-202108-1: Change question 1 to gross leak detection. Delete question 7.

03-2A-202109-1: Delete questions 1, 3a and 6.
03-2A-202110-1: Change question 1 to - First indication "failed off" thruster C&W for 1/2 leg, redundant paths on 3,4,5 leg.

03-2A-202111-2: Question 1 change no to yes. Add "failed off" thruster gives first indication.

03-2A-202120-3: Change question 1 from yes to no and delete comments. Change question 3 from no to yes and add "RCS RM automatically detects and prevents thrusting".

03-2A-202150-1: Change question 1 to gross leak detection. Change question 6 from 0 to 1 and add "There is one success path remaining after first failure.

03-2A-211110-1: Change question 1 to gross leak detection. Change question 6 to POD Redundancy.

03-2A-211110-2: Delete la/3a add question 1 "failed off" thruster may illuminate if < 40 psi is sensed 3 times, 80 milliseconds apart. Change no to yes. Question 2 change yes to no. Change question 3a from yes to no. Change question 6 from 0 to 1. Add crossfeed.

03-2A-211120-1: Change question 1 to gross leak detection. Change question 6 from 0 to 1. Add crossfeed.

03-2A-221308-1: Change question 1 to gross leak detection. Delete comments question 2. Delete comments question 3 and change yes to no.

03-2A-221310-4: Delete la/3a, add question 1 "failed off" thruster C&W. Change no to yes. Question 3 change no to yes.

03-2A-221311-1: Same as 221310-4.

03-2A-221312-1: Same as 221310-4.

03-2A-221313-1: Question 1a change yes to no. Question 3a change yes to no.

03-2A-231310-1: Change no to yes, question 1 change no to yes, question 3 and add "down modes to free drift". Change yes to no, question 3a. Question 6 change 2 to 0 and add "No redundancy in the verniers".

03-2A-231310-2: Question 1 change no to yes, add "failed on" thruster C&W. Question 3a change yes to no. Question 6 change 2 to 0 and add "down modes to free drift."

03-2A-231310-3: Question 1 change no to yes. Change comments to "failed off" thruster C&W. Question 2, delete comments. Question 3, change no to yes and add "down modes to free drift". Question 6 change 2 to 0 and add "No redundancy in the verniers."
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