PREFACE

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 11/12/92
Chief, Reliability Division

NB
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:

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Rockwell Reliability

Joseph Jenkins 11/14/79
JSC Engineering - FRAT Sponsor

Rockwell Engineering - FRAT Sponsor
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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>
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<tr>
<th>Volume</th>
<th>Subsystem</th>
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</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>
</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:**

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:**

---

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 annunciating 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
redundance 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.
<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>ANALYSIS RESULT</th>
<th>ITEM/FAILURE MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</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>
<tbody>
<tr>
<td>ITEM</td>
<td>FAILURE MODE</td>
</tr>
</tbody>
</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.

Figure 4-4. Failure Modes Not Included In Hardware/Software Analysis
<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>AFT - RCS</th>
<th>ITEM/FAILURE MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HARDWARE ACCEPTS RISK</strong></td>
<td></td>
<td>Helium Tank - External Leak (03-2A-201010-1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Helium Feed Line - External Leakage (03-2A-201013-1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D. C. Solenoid Valve, Helium - Fails Closed (03-2A-201020-1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Line, Low Pressure Helium - External Leak (03-2A-201035-1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Helium Fill Quick Disconnect - Fails Open (03-2A-201070-1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Purge Quick Disconnect, Propellant - External Leakage (03-2A-201080-1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Test Quick Disconnect - External Leakage (03-2A-201090-1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Feedline and Fittings, Fuel - External Leakage (03-2A-202108-1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Propellant Fill and Bleed Disconnect - Fails Open (03-2A-202150-1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Propellant Tank Assembly - External Leak (03-2A-211110-1)</td>
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<td></td>
<td>Propellant Tank Assembly - Bubbles in Propellant (03-2A-211110-2)</td>
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<tr>
<td></td>
<td></td>
<td>Injection Plate - Restricted Flow (03-2A-221311-1)</td>
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<tr>
<td></td>
<td></td>
<td>Thrust Chamber - Burn-Thru (03-2A-221312-1)</td>
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<tr>
<td></td>
<td></td>
<td>Nozzle Extension - Burn-Thru (03-2A-221313-1)</td>
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<tr>
<td></td>
<td></td>
<td>Vernier Thruster - Loss of Output (03-2A-231310-1)</td>
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<td>Vernier Thruster - Fails to Stop Firing (03-2A-231310-2)</td>
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<td></td>
<td></td>
<td>Vernier Thruster - Burn-Thru (03-2A-231310-3)</td>
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<tr>
<td>ANALYSIS RESULT</td>
<td>ITEM/Failure Mode</td>
<td></td>
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<tr>
<td>------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>DETECTION DURING CHECKOUT</td>
<td>Helium Pressure Regulator - Restricted Flow - Fails Closed (03-2A-201030-2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Helium Quad Check Valve - Fails Closed (03-2A-201095-2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Feedline and Fittings, OX - External Leakage (03-2A-202109-1)</td>
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</tr>
<tr>
<td></td>
<td>Tank Isolation Valve, A. C. - Fails Closed (03-2A-202110-1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tank Isolation Valve, A. C. - Fails Closed (03-2A-202110-3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interconnect Valve, A. C. - Fails Closed (03-2A-202111-2)</td>
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<td></td>
<td>Manifold Isolation Valve, A. C. - Fails Closed (03-2A-202120-3)</td>
<td></td>
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<tr>
<td></td>
<td>Manifold Isolation Valve, D. C. - Fails Closed (03-2A-202140-1)</td>
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<tr>
<td></td>
<td>Gimbal Joint - External Leakage (03-2A-211120-1)</td>
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<tr>
<td></td>
<td>Bellows Assembly - External Leakage (03-2A-221308-1).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Engine Inlet Valve - Fails Closed (03-2A-221310-4)</td>
<td></td>
</tr>
<tr>
<td>ANALYSIS RESULT</td>
<td>ITEM/Failure Mode</td>
<td></td>
</tr>
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<td>----------------------</td>
<td>--------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>NO SOFTWARE DETECTION</td>
<td>Relief Valve - External Leak - Fails Open (03-2A-201060-4)</td>
<td></td>
</tr>
<tr>
<td>Item</td>
<td>Failure Mode</td>
<td>FMEA Number</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>He Tank</td>
<td>External Leak</td>
<td>SD72-SH-O103-2</td>
</tr>
</tbody>
</table>

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 [X]

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 [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)?**
   - Not Applicable [X] Yes [ ]

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?**
   - Not Applicable [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. [X] 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.
A new flexible approach to

-4

..../.C.. 

C.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: 4C282-06G2-0331-0032
P/N VENDOR: RL0-99994-0-1-2
QUANTITY: 4
SUBSYSTEM: AFT - REACTION CONTROL FMEA NO 03-2A -201010-1 REV: 11/08/76
ABORT: CRIT. FUNC: 1
CRIT. HDs: 1
MISSIONS: HF VF X FF OF SH
PHASE(S): PL X LD X CJ X DJ X LS
PREPARED BY: J. TAGGART
APPROVED BY: NASA
APPROVED WITH CHANGES
See Section 13.0

ITEM: TANK
HELIUM STORAGE, FILAMENT WOUND
FUNCTION:
TO STORE HELIUM AT A MAX WORKING PRESSURE OF 4000 PSI FOR PRESSURIZATION OF THE AFT RCS MODULE'S PROPELLANT SUPPLY SYSTEM. TANK CONSISTS OF DOUBLE HILT Ti LINER WITH SUPPLEMENT KEVLAR 49 FIBER AND EPOXY RESIN BONDING OVERKAP. WALL IS 0.71 IN. VOLUME IS 3008 CU. IN.
FAILURE MODE: STRUCTURAL FAILURE
EXTERNAL LEAK
CAUSE(S):
MAT'L DEF, LINER DEF, FAULTY FAB, EPOXY CURE INADEQ, TEST/HANCL DAY, SHOCK, VIB, INADEQ OVERPRESS (GNO), INADEQ MOUNTING
EFFECT(S):
(A) LOSS OF FUNCTION/SUBSYSTEM (B) LOSS OF INTERFACE FUNCTION - INABILITY TO DEPLETE/UTILIZE PROP, POSSIBLE DAMAGE TO POD STRUCTURE & TPS. (C) MISSION MODIFICATION - X-Feed FROM OMS OF RCS. (D) POSSIBLE LOSS OF CREW VEHICLE EXCESS RATE OF LEAK MAY EXCEED POD VENT CAPAB. CAUSING DAMAGE TO POD STRUCT & DEGRAD OF THERMAL PROT SYS. EXCESS RETENTION OF PROP MAY ADVERSELY EFFECT VEH OY. DURING ENTRY & LANDING
DISPOSITION & RATIONALE (A) TEST (B) DESIGN (C) INSPECTION (D) FAILURE HISTORY:
(A) FILAMENT WOUND TANKS ARE DESIGNED TO LEAK BEFORE RUPTURE WHICH LIMITS FAILURE PROPAGATION DUE TO SHRAPNEL. KEVLAR 49 FIBER HAS A TENSILE STRENGTH OF 900KSI ALLOWING LIGHT WEIGHT WITH GREAT STRENGTH. INCREASED STRAIN CAPABILITY IS PROVIDED BY THE COMpressive LOAD ON A UNPRESSURIZED LINER. VENT DOORS ARE OPEN ON ORBIT AND WILL RELIEVE ANY PRESSURE BUILDUP DUE TO LEAKAGE. THE F.S. (400PSI) 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 FLAME GROWTH. PRESSURE (1.1) X WORKING PRESSURE) AND LEAKAGE TESTS ARE PERFORMED DURING ART. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. RAW MAT'L AND PURCHASED COMPONENTS ARE VERIFIED BY RECEIVING INSPECTION STANDARDS AND TEST EQUIP. STANDARDS ARE IMplemented PER REQMTS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS - PARTS PROTECTION, HVAC, PROCESSES, FINISHES, ASSY AND INSTALLATION. THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 10-23-77 - CORROSION PROTECTION PROVISIONS, TEST HANDLING, AND STORAGE
ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM: AFT - REACTION CONTROL  FMEA NO 03-2A-201010-1  REV:11/03/7?

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 KEVLA? 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) NCHE AVAILABLE NEW DESIGN.
**SUBSYSTEM**  AFT - RCS  
**ITEM**  He Feed Line  
**FAILURE MODE**  External Leakage

1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE 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** ☐  |  **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** ☑  |  **NO** ☐  |  **X** ☑

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** ☑

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** ☑  |  **X** ☑

   b. **WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?**  
      - **YES** ☑  |  **NO** ☑  |  **X** ☑

*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 G&W is first indication.

2. FMEA Change - For "failure detectable in flight" V42P2110C through 2114C and 3110C through 3114C should be V42P2110G, 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.
SHELL FAILURE AND EFFECTS ANALYSIS - Page 1

PREPARED BY: K. C. GARAYRICH

APPROVED BY: 

FIRE PUMP LINES

1/4 X .125 IS DESIGNED TO PROVIDE RELIABILITY FROM FIRE TO RELIABLE FIRE PUMP TO RELIABLE PRESSURIZATION SYSTEM PANEL.

STRUCTURAL FAILURES \( \times \)

NOTE:

(1) RELIABLE SYSTEM PRESSURIZATION RELIABILITY TO DEFLATE/UTILIZE FIRE.

(2) USER CONTROL FUNCTION: (a) RELIEVE PRESSURE FOR TANK - PUT FIRE STRUCTURE OF TANK.

(3) TLC TURNTABLE (LESS OF PRESS) TO POSSIBLE DRAIN OR VEHICLES OR POLICE/TRANSPORT OCCURS

CONTACT:

(1) RELIEVE PRESSURE TO RELIEVE PRESSURE FROM PRESSURE.

(2) FIRE PUMP LINES FOR REFILL TANK.

(3) RELIEVE PRESSURE TO RELIEVE PRESSURE FROM PRESSURE.

L.L. A. M. HAZARD.

ORIGIAL PAGE IS OF POOR QUALITY.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION HELIUM
P/N: MC621-0059
P/N VENDOR: 73A630000
QUANTITY: 4

PREPARED BY: ZPP
APPROVE BY: APPROVE
REL: C M AKERS

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)
CAUSE(S):
- WEL'D DEF (SULPHIDE STRINGER), VIB; SHOCK, STRUCT FAIL, FATIGUE, WELD DEF, STRESS CORROS, IMP INSTALL.

EFFECT(S):
- CN (A) SUBSYSTEM (B) INTERFACE (C) MISSION (D) CREW/VEHICLE:
- (A) LOSS OF SUBSYSTEM PRESSURIZATION CAPABILITY IF NOT ISPL (FAIL UPSTREAM OF ISOL VLV-INABILITY TO DEPLETE/UTILIZE PPCP).
- (B) LOSS OF INTERFACE FUNCTION (INABIL TO DEPRESS PPCP TANKS - PDT POD STRUCT & TPS DAM.
- (C) ABORT DECISION (LOSS OF PRESSURES) (D) POSSIBLE LOSS OF CREW/VEHICLE - IF LEAK EXCESS OR POD/TPS DAM OCCURS

DISPOSITION & RATIONALE:
- DESIGN (A) TEST (B) 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 ACCEMODATE VEHICLE GROWTH AND MOVEMENT.
- (3) REELOWELL PERFORMED TUBING CERTIFICATION TESTS PER "CRITERION 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 INS.
- FCP SURFACE AND SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION.
- THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INS.
- HC Rich.
- WEL'T (LOT CERTIFICATION), PARTS PROTECTION, MANUF., COATING, PLATING, INSTALLATION AND ASSEMBLE OPERATIONS.
- HARDWARE IS INS.
- ACCORDING WITH QUALITY PLANNING REQMTS DOCUMENT (QPRD) WHICH HAS BEEN APPROVED BY NASA.
SHUTTLE CRITICAL ITEMS LIST - COLUMBUS 1.02

SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-ZA-201013-1  REV: 12/13/75

TURNAROUND - LINES IN ACCESSIBLE AREAS ARE VISUALLY INSPECTED FOR
EVIDENCE OF DAMAGE AND FLCH AND PRESSURE FUNCTIONAL TESTS ARE MONITORED
FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE.

MINOR HISTORY -
CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.
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)?
   - 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 ☒

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 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.
   - NO ☒ 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 ☒

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
   - YES X ☐
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
   - YES X ☐

*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

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 (Hu He isolation valves) needs to be added for detectability since only the measurement stimulus identification numbers for the oxidizer valves are listed now.
SYSTEM ISSUE - FLIGHT CONTROL

STRESS IN RELATION TO ALTITUDE

WATER LEVEL SENSOR

VALVES CONTROLLED

VALVES OPEN IF EXCESS FUEL PRESSURE OF SUBSEQUENT VALVE

FUEL SUPPLY PRESSURE

VALVE FAILURE:

PREPARED BY:

LEL

K FURKHART

APPROVED BY:

LEL

C W PETERS

D. "W" VALVE, L.C. SULPHURIC

B. PRESSURE INjection NELPHU (4/24) 51-TABLE

POLARISATION:

FAILURE CONTROL:

FAILURE MODE: FAILS CLOS

EFFECT:

- VULNERABLE TO VALVE ELECTRIC SIGNAL DUE TO SHORT CIRCUIT. Steering
  CONNECTOR PIN OR ELECTRIC DAMAGE, DAMAGING OF FUEL; SYSTEM CRITICAL.

FUNCTIONS:

- (A) SUBSYSTEM (B) INFLAMES (C) PROP. LIQUID/VEHICLE

- (D) LOSS OF RECONCERN - PARALLEL PATH AVAILABLE. (E) NO EFFECT.

- G. PRESSURE - NOT TO OPEN ONE PATH REMAINING OPEN 1. CRITICAL
  EFFECT. (F) FUNCTIONAL LIMITATION EFFECT - FAILURE
  CAUSED VEHICLE LOSS - FAILURE OF RECONCEIVED PARALLEL PATH WITH
  RESULT IN INABILITY TO CORRECT 1 INFLAMES PROP. LIQUID.

- G. NO EFFECT IN POSSIBLE INABILITY TO CONTROL VEHICLE DURING 54, 113. NO
  INABILITY TO USE RECONCEIVED 1 INFLAMES PROP. LIQUID 4, 10. PROBLEMS RESULTING

- FROM RECONCERN.

CORRECTION ACTION:

- IF CAUSED BY VIBRATION, THE VALVE MAY BE CAPABLE OF OPENING WITH A NEW
  COMPRESSIBLE, OR SWITCH TO PARALLEL PATH.

- HAZARDS:

- POTENTIAL TIME CRITICAL HAZARD RELATED TO REACTION TIME FOR SWITCHING
  TO ALTERNATE PATH DURING CRITICAL MODES OF OPERATION SUCH AS ETC.

ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PRESSURIZATION

P/N RI: MC294-0419-0011-0012

P/N VENDOR: 73835

MISSIONS: HF, VF, FF, CF, SM

PHASE(S): PL, LO, CO, 00, LS

QUANTITY: 8

ITEM: VALVE, D.C. SOLENOID

OPERATED, HIGH PRESSURE, HELIUM (1/2") 91-STABLE. (LATCHING - MAGNETIC & SPRING FORCE) LV 201/202/203/204/301/302/303/304.

FUNCTION:

.. UTILIZED TO CONTROL HELIUM PRESSURIZATION SYSTEM IN THE 4G 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

FAILURE EFFECT:

(A) LOSS OF REDUNDANCY - PARALLEL PATH AVAILABLE. (B) NO EFFECT. (C) ABORT DECISION - DUE TO ONLY ONE PATH REMAINING IN A CRITICAL EFFECT. (D) NO EFFECT. (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CREW VEHICLE LOSS - FAILURE OF REDUNDANT PARALLEL FLOW PATH WOULD RESULT 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) PARALLEL VALVES AND REDUNDANT POWER SOURCES ARE PROVIDED. ULLAGE 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. REDUND 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 ENCAP BY PUTTING 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 MISSIO N LEVELS ARE PERF DURING qual. ITEM IS USED.

24 1000  SD75-SH-0003
SUBSYSTEM : AFT - REACTION CONTROL

DURING SYM EVA TESTS AT WSTF 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 ICENT 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 FOLLOWING ITEMS ARE VERIF BY
SHOP TRAVELER MANDATORY INSPE POINTS - RAW MAT'LL (LOT CERT), PARTS PROT,
MANUF., COATING, PLATING INSTALL AND ASSEMBLY OP7R. THE ABOVE ITEMS AND
THE FOLL ITEMS WERE VERIF BY AUDIT COND 8-31-77. CONTAM CONT
PROCESSES, CORROS. PROT PROV. TURNAROUND - FUNCT FLOW TESTS ARE
MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON COM-AND.
(0) APOLLO FAILURES WERE MAINLY ASSOC WITH REVERSE POLARITY AND
DEGAUSING OF MAGNETS. THE SHUTTLE VALVE UTILIZES A CONNECTOR (RATHER
THAN LEAD WIRES) AND BLOCKING DIODE WHICH PREVENTS THIS TYPE OF ERROR
DURING CONN. A POTENT ELECT SHOR'TING PROB ON A SIMILAR VALVE DUE TO
INSUL DAMAGE WAS DISCOV DURING QUAL AND CORR AS DESCRIP IN ITEI (A).
ABOVE.
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, 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 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.

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.

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Paragraphs of text are not clearly legible due to poor quality of the image, making it difficult to accurately transcribe the content. Further assistance may be required to accurately handle this page.
SHUTTLE CRITICAL ITEMS LIST - CRIBTER 102

SUBSYSTEM : AFT - REACTION CONTROL

ASSEMBLY : PRESSURIZATION

P/N 'RI : MC-284-0418-0001/-0002

P/N VENDOR : 74339001

QUANTITY : 28

ASSEMBLY : PRESSURIZATION ABGRT: CRITICAL

MISSIONS: HF VF X FF OF SY

PHASE(S): PL LO X CC X UC X LS

PHASE(S): PL LO X CC X UC X LS

PREPARED BY: J. TAGGART

APPROVED BY: SSM

PREPARED WITH CHANGES

ITEM: REGULATOR PRESS. HE

SERIES REDUNDANT. SET AT UNEQUAL OUTLET PRESSURES (PP

201/302/303/304).

FUNCTION: 

TO REGULATE STORED HELIUM PRESSURE FROM 4600 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 10 PSI LOWER THAN SECONDARY.

FAILURE MODE: FAILS CLOSED (F)

RESTRICED FLOW.

CAUSE(S):

CONTAM (PILOT SCREEN, FOUZEN NOIST, SPRING/STEM FRACTURE, PISTON

RINGS, EXCESS DOME PRESS, COCKED SPRINGS, "MATT" NET.

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

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

(D) NO EFFECT UNLESS SECOND PATH FAILS CLOSED, ENTRY CAPABLITY IS LOST IF

FAILURE OCCURS EARLY IN ENTRY SUCH THAT ULLAGE PRESS IS NOT SUFF.

(E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CREW/VEHICLE LOSS. FAILURE

OF REDUNDANT PARALLEL FLOW PATH WOULD RESULT 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 PROVIDED WEIGHT.

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

(A) PARALLEL REGULATORS ARE PROVIDED. ULLAGE PRESS IS ACES FOR PROP RECIP

WITH LESS THAN 35 PERCENT PROP REMAINING. 25-MICRON ABS GBR PLUS

10-MICRON ABS GBR PILOT FILTER IS PROVIDING THE POSSIBILITY OF

CONTAM CAUSING JAMMING OF MOVING PARTS OR PLUGGING PILOT CONTROL

ORIFICES. (B) 50,000 OPER FLOW CYCLES AND RANDOM VIB AT ANTIC MISSION

LEVELS ARE PERFORMED DURING OPEM. ITEM IS USED DURING SYS EVAT TESTS AT

WSTF ALLOWING EVAL UNDER SIMUL MISSION USAGE COND. PROOF PRESS, LEAKAGE

AND FLOW TESTING IS PERFORMED DURING ATP. FUNCT AND LEAKAGE TESTS ARE

PERFORMED DURING PRE/POST FLIGHT CHECK. (C) AN ID IS PERFORMED AND THE

UNIT TAGGED. MATT & EQUIP CONFORMANCE TO CONTRACT REGMTS IS VERIF BY

INSPEC. THE FOLLOWING ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPEC POINTS -

RAW MATT, PARTS PROTECTION, MANUF, COATING, PLATING, INSTALL AND ASSY

OPERATIONS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIF BY AUDIT

CONDUCTED 4-5-77 - CONTAM CONT PROCESS AND CORROS PPGT PROV, CONTAM

CONT PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIR. THE FOLLOWING
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A -201030-2  REV:11/01/75
ITEMS WERE VERIFIED BY AUDIT OF MARCH 6, 1975. INSPECTION VERIFIES
ASSEMBLY PER INSPECTION POINTS IN MASTER RECORD. LOG OF CLEAN ROOM AND
CALIBRATION OF TOOLS VERIFIED. CRITICAL DIMENSION LOOPS VERIFIED BY
INSPECTION. PARTS CLEANLINESS AND PASSIVATION BY INSPECTION. NOE
INSPECTION PERFORMED AFTER ASSEMBLY. TURNOVER - NUCLE FLOW TESTS ARE
MONITORED TO VERIFY THAT THERE IS NO RESTRICTED FLOW. (C) NO FAILURE
HISTORY OF THIS MODE FOR THIS REGULATOR.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

ITEM: Line, Low Pressure He
FAILURE MODE: External Leak

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY YES X NO)
   ANNOUNCE OR TAKE ACTION IN RESPONSE)?
   1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD *YES X NO
       USE TO DETECT THE FAILURE?
       2. ARE THE ANSWERS TO QUESTIONS 1 AND 1A CONSISTENT WITH THE FMEA EVALUATION OF YES X *NO
          IN-FLIGHT DETECTABILITY?
   3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE *YES X NO
      (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
     3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS *YES X NO
         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 *YES X NO
      INDUCE ANOTHER FAILURE?
   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 *YES X NO
      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? 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 downlink available.
8B. Same as primary.
### GENERAL REQUIREMENTS

- **System:** GA-40-2, GA-40-3, GA-40-5, GA-40-6, GA-40-7, GA-40-8
- **Usage:** General Instrumentation
- **Approve:** Ops
- **Usage:** Flight Instrumentation

<table>
<thead>
<tr>
<th>Preface</th>
<th>Y: A. C. Cleveland</th>
<th>Ops</th>
<th>Y: P</th>
<th>R. L.</th>
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</thead>
</table>

### GENERAL REQUIREMENTS

- **Structural Failure**
  - **Class:** (5)
  - **Type:** Original Leak.

- **Reason:**

- **Reason:**

- **Reason:**

- **Potential Loss of Mission:**
  - Early Mission Termination
  - Early Mission Termination
  - Early Mission Termination
  - Early Mission Termination
  - Early Mission Termination

### General Layout

- **Potential Loss of Mission:**
  - Early Mission Termination
  - Early Mission Termination
  - Early Mission Termination
  - Early Mission Termination
  - Early Mission Termination

- **Vehicle Impact:**
  - Impact may be adversely affected or significantly cross if impact cross. The mis-impact may result in damage to structure. This

### General Layout

- **Potential Loss of Mission:**
  - Early Mission Termination
  - Early Mission Termination
  - Early Mission Termination
  - Early Mission Termination
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- **Vehicle Impact:**
  - Impact may be adversely affected or significantly cross if impact cross. The mis-impact may result in damage to structure. This

### General Layout

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### General Layout

- **Potential Loss of Mission:**
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### General Layout

- **Potential Loss of Mission:**
  - Early Mission Termination
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  - Early Mission Termination
  - Early Mission Termination
  - Early Mission Termination

- **Vehicle Impact:**
  - Impact may be adversely affected or significantly cross if impact cross. The mis-impact may result in damage to structure. This
SHUTTLE CRITICAL ITEMS LIST - CRR.TER 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: MC621-0059
P/N VENDOR: 73A630030
QUANTITY: 1

MISSIONS: HF, VF, X, FF, OF, SM
PHASE(S): PL X, LC X, CO X, DC X, LS X

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

PREPARED BY: D. C. GLAVINICH
APPROVED BY: D. C. GLAVINICH

ASSEMBLY: LOW PRESSURE HE.
FEED LINE (3/4"

FAILURE MODE: STRUCTURAL FAILURE

CAUSE(S):
MECHANICAL SHOCK, VIBRATION/FATIGUE, IMPROPER INSTALLATION (WELD). STRESS CORR. MAT' L DEFICIENCY (SULPHIDE STRINGER)

EFFECT(S): ON (A) SUBSYSTEM (C) INTERFACES (B) MISSION (2) SPACECRAFT
(A) LOSS OF SUBSYSTEM HELOM SUPPLY. INABILITY TO DELETS/UTILIZE PROPELLANT. (B) LOSS OF INTERFACED FUNCTION INABILITY TO REPRESSU RE PROP TANK-POTENT ND STRUC. & 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 & RATIONAL (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 SLOVES 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 TUBE 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 SUBMITTED TO NDE. (C) AN IDENTIFICATION IS PREFORMED 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

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SD75-SH-0003

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SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: AFT - REACTION CONTROL FMEA NG 03-2A - 201035-1 REV: 11/03/73
PLANNING REGNIT'S DOCUMENT (CPRO) WHICH HAS BEEN APPROVED BY NASA.

TURNOAROUND. 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.

(0) HISTORY - CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.

HISTORY - CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.
## HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

**SUBSYSTEM** AFT - RCS  
**FMEA NUMBER** 03-2A-201060-4  
**ITEM** Relief Valve  
**FAILURE MODE** External Leak -- Fails Open

1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**
   - **YES** X  |  **NO**
   - **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.**
   - **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?**
   - **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.
SUBSYSTEM: AFT - REACTION CONTROL  
ASSEMBLY: PRESSURIZATION  
P/N: MCZ-04-0420-0001/0002  
QUANTITY: 1  
ZONE: ONE PER PROPellant TANK  

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'Q AFTER BURST DISC RUPTURE.

CAUSE(S):
- CORROSION, CONTAMINATION, PoppET BINDS IN GUIDE, SPRING BREAKS OR COcks, SEAT CRACKS, MOISTURE FREEZES, VIBRATION, SHCK.

EFFECT(S):
- ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
  (A) LOSS OF SUBSYSTEM PRESSURIZATION. (B) LOSS OF INTERFACE FUNCTION. (INABILITY TO RE-PRESSURIZE PROPellant TANKS DUE TO HELIUM LOSS). POSSIBLE INABILITY TO USE/DEPLETE PROPellant. (C) LOSS OF ENTRY CAPABILITY - ASSUMES ULLAGE PRESSURE IS ALSO VENTED OVERBOARD & PROP CANNOT BE DEPLETED. (2 FAILURES - FIRST IS RELIEF REq'MT). ABBRT DECISION IF LEAK RATE IS SMALL. (D) NO EFFECT (FIRST FAILURE). (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE LOSS OF CREW/VEHICLE - SEE ITEM (C) ABOVE. PROP IN ONE POD MAY NOT BE ADEQUATE FOR ENTRY. POSS ENTRY CONTROL & LANDING HAZARD (C.G.) IF PROP CANNOT BE DEPLETED PRIOR TO LANDING.

DISPOSITION & RATIONALE:
- (A) 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 & 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, INSPI FOR SURFACE AND SUBSURFACE DEFECTS, PROPERLY MONITORED
HANDLING AND STORAGE ENVIRONMENT, AND MAT'IL AND EQUIP, CONFORMANCE TO
CONTRACT REQMTS. ARE VERIFIED BY INSPI. THE FOLLOWING ITEMS ARE VERIFIED
BY SHOP TRAVELER MANDATORY INSPI POINTS-RAW MAT'IL, (LOT CERTIFICATION),
PARTS PROTECTION, MANUF., COATING, PLATING, INSTALLATION AND ASSY
OPERATIONS. TURNAROUND - LEAKAGE TESTS ARE MONITORED TO VERIF. THAT THE
BURST DISC IS STILL INTACT AND THAT THE MAIN POPPET LEAK RATE IS WITHIN
SPECIFICATION REQMTS. VISUAL INSPI FOR EVIDENCE OF DETERIORATION IS ALSO
PERFORMED. (D) APOLLO FAILURES WERE DO LARGELY TO GALVANIC CORROS. &
CONTAMINATION CORRECTED BY DESIGN & TEST PROCESSING CHANGES. (THE
SHUTTLE RELIEF VALVE IS A NEW DESIGN WHICH CONTAINS A FILTER & DOES NOT
USE DISSIMILAR METALS).
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 [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 [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.
   - *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?
   - 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/RETIERTION 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:
1. Gross leak detection will give first indication.
2. Capped quick disconnect provides one redundant success path.

Pod Redundancy
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: MC276-0017-0402/-0403
P/N VENDOR: 7537200C-0401/-0403
MISSIONS: HF VF X FF OF SM
QUANTITY: 4

REV: 12/12/78

ASSEMBLY: PRESSURIZATION ABORT: CRIT. FUNC: 1
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

PREPARED BY: DES G SCARLETT DES C SCARLETT 12/12/78
APPROVED BY: APPROVED BY NASA
A DES SCARLETT
REL C MAKERS REL C SCARLETT 12/12/78
APPROVED WITH CHANGES
See Section 13.0

ITEM: DISCONNECT, QUICKFILL, HE
(1/4") WITH SPRING LOADED POPPET AND STRUCTURAL END CAP. #0 219/220
FUNCTION:
- PROVIDE HELIUM TANK FILL AND VENT POINT FOR GROUND SERVICING OPERATIONS AND LOADING. COUPLING IS ACCESSIBLE AT THE HELIUM SERVICING PANEL.
FACILITY MODE: FAILS OPEN (S)
EXCESS OF ACCEPTABLE RATE, SEALS DAMAGED.
CAUSE(S):
- CONTAMINATION, VIBRATION, MECHANICAL SHOCK, PIECE-PART STRUCTURAL FAILURE, EXCESS OR IMPROPER USE, INADEQUATE MAINT UP SEE HALF, NC LINE SUPPORT - SHAFT OR 300X BENT. RETAINING CAP LOSES NEGATING GAP SEAL REDUNDANCY.
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 HELIUM LOSS). (C) LAUNCH DELAY OR ABORT. (D) POTENTIAL CREW LOSS DURING MISSION IF PROPELLANT CANNOT BE UTILIZED OR DEPLETED

DISPOSITION & RATIONALS (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) F.S. IS 2.0 X WORKING PRESS. ULLAGE PRESS IS ADEQ TO EXPEL PROP WITH 35 PERCENT OR LESS REMAINING. GROUND HALF COUPLINGS AND LINES ARE SUPPORTED TO LIMIT ANY UNDESIRED 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 LEED SCREW. COMPLETE STRESS ANALYSIS HAS BEEN CONDUCTED. UTIL OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUND SEAL EXCEPT FOR STRUCTURE FAILURE. (B) THE COUPLING IS SUB TO 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 SYS. EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE CON. PROOF PRESS TESTS ARE CONDUCTED DURING ATP AND LEAKAGE TESTS ARE PERF BEFORE AND AFTER OPER CYCLES. (C) AN IDENT IS PERF. RAW MAT'L, NDE EXAM, VISUAL INSPECTION CRITICAL SURFACE DEFECTS, AND EQUIP CONFORMANCE TO CONTRACT REQS ARE VERIF BY RECEIVING INSPECTION STANDARDS AND TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQS OF MIL SPEC. THE FOLLOWING ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPECTION POINTS - PARTS MFG. PROCESSES, COATING, ASSY AND INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIF BY AUDIT CONDUCTED 5-23-77. CORROS PROT. PROT, CONTAM CONT. PROCESSES, 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. NO INSPECTION PERFORMED AFTER
ASSEMBLY. TURNAROUND. COUPLINGS ARE VISUALLY INSPL FOR EVID OF DAMAGED
SEALS AND LEAK TESTS ARE PERFORMED. (C) APOLLO FAILURE HISTORY WAS IN
THE MAIN ASSOC WITH GROUND USAGE, IMPROPER HANDLING.
<table>
<thead>
<tr>
<th>Item</th>
<th>Purge Quick Disconnect, Propellant</th>
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<tbody>
<tr>
<td>Failure Mode</td>
<td>External Leakage</td>
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</table>

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 [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.**  
   - N/A [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. 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.
# Contingency/Partial Loss and Effects Analysis

**Failure:** Single-Loop System

**Location:** Engine Section, Forward

**Configuration:** Safety Line Open, Normal System Controls

**Effects:** Uncontrollable Engine Section,
- Loss of Thrust
- Loss of Contour
- Loss of Control of Vehicle
- Loss of Isolation
- Loss of Controllability
- Loss of Vehicle Latching
- Loss of Vehicle

**Preparation:**
- Check Engine Section
- Check Isolation Valve
- Check Controls
- Check Latching
- Check Systems

**Approved:** Yes

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LES</td>
<td>00086</td>
</tr>
<tr>
<td>C/MAKERS</td>
<td>TCC</td>
</tr>
</tbody>
</table>

**Interim Leaks:**
- Loss of Engine Section
- Loss of Isolation Valve
- Loss of Controls

**Potential Compartment:**
- Engine Section
- Fuel Tank

**Precautions:**
- Keep the area clear of personnel
- Wear appropriate protective gear

**Original Page is of Poor Quality**
### SHUTTLE CRITICAL ITEMS LIST - CRITER IO2

#### SUBSYSTEM
- **Shaft - Reaction Control**
- **Assembly**: Pressurization Abort
- **P/N**: MC276-0013
- **P/N Vendor**: 76361000 & 76316000
- **Quantity**: 28

#### FUNCTION:
- **P/N RI**: MCZ7-0001
- **P/N VENDOR**: 76361000
- **Quantity**: 8

#### PREPARED BY:
- **DES**: C Scarlett
- **REL**: C MAKERS

#### APPROVED BY:
- **APPROVED BY NASA**: 1/5/08
- **APPROVED WITH CHANGES**: See Section 13.0

#### ITEM:
- **Disconnect, Quick, Purge**
- **Vent, Propellant with Structural End Cap and Spring Loaded Poppet**

#### FUNCTION:
- To allow ground purge of propellant manifolds during turnaround operations.

#### FAILURE MODE:
- External Leakage
- Cap Leaks, Seals damaged retaining nut looseens negating cap seal

#### CAUSE(S):
- Vibration, Pie Part Structural Failure, Contamination, Mechanical Shock, Seal Damage, Inadequate Maintenance, Ejector Failure, Nut Line Support - Shaft or bore bent

#### EFFECT(S):
- On (A) Subsystem (3) Interfaces (2) Mission (D) Crew/vehicle

#### DISPOSITION & RATIONALE
- **(A)** Design
- **(B)** Test
- **(C)** Inspection
- **(D)** Failure History

#### P.S. IS 2.0 X WORKING PRESS. REDUNDANCY PROVIDED BY INTERNAL SEAL, CAP MANIFOLD ISOLATION VALVE. GROUND HALF COUPLINGS AND LINES ARE ADEQ 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 BLED SCREW. COMPLETE STRESS ANALYSIS HAS BEEN CONDUCTED. USE OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUNDANT SEAL EXCEPT FOR STRUCT FAILURE. FAILURE CAN BE ISOLATED AT MANIFOLD VALVE. (B) THE COUPLING IS SUBJ TO 600 OPER CYCLES (COUPLING AND UNCOUPLING) DURING OQL IN ADDITION TO PRESSURE CYCLING AND PROP EXPOSURE TESTS. RANDOM VIB TESTING IS ALSO CONDUCTED AT ANTIC VEH LEVELS FOR 34 MINUTES IN EACH-AXIS. USAGE DURING SYS EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE CONDITIONS. PROOF PRESS TESTS ARE CONDUCTED DURING ATP AND LEAKAGE TESTS ARE PERF BEFORE AND AFTER OPER CYCLES. (C) AN IDENT IS PERF. RAW MATCH, NCE EXAM, VISUAL INSPECT FOR CRITICAL SURFACE DEFECTS, AND EQUIP CONFORMANCE TO CONTRACT REQS ARE VERIF BY RECEIVING INSPECTION. MEASUREMENT STANDARDS AND PROBLETS ARE USED TO VERIF CONFORMITY TO SPECIFICATIONS.
SUBSYSTEM: AFT - REACTION CONTROL  FMEA NO 03-2A-201080-1  REV:11/09/78

TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIF 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. 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 WILL BE VISUALLY INSPECTED FOR EVIDENCE OF CAP SEAL DAMAGE AND CAP LEAKAGE. (DO) APOLO FAILURE HISTORY WAS IN THE MAIN ASSOC WITH GROUND USAGE, IMPROPER HANDLING.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>RCS</th>
<th>FMEA NUMBER</th>
<th>03-2A-201090-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITEM</td>
<td>Test Quick Disconnect</td>
<td>FAILURE MODE</td>
<td>External Leakage</td>
</tr>
</tbody>
</table>

#### 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** [ ]  **N** [ ]

#### 2. **Are the Answers to Questions 1 and 1a Consistent with the FMEA Evaluation of In-Flight Detectability?**

- **YES** [x]  **NO** [ ]  **N** [ ]

#### 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** [ ]  **N** [ ]

#### 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** [ ]  **N** [ ]

#### 4. **As a Result of This Failure Mode, Can the Software Overstress the Hardware or Induce Another Failure?**

- **YES** [x]  **NO** [ ]  **N** [ ]

#### 5. **Can This Failure Mode, in Combination with Software Logic, Adversely Affect Other Functions?**

- **YES** [x]  **NO** [ ]  **N** [ ]

#### 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** [ ]  **N** [ ]

#### 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** [ ]  **N** [ ]

#### 8. **If the Answer to Either 1 or 3 is YES:**

- **A.** Can the BFS Be Engaged After Occurrence?  
  - **YES** [x]  **NO** [ ]  **N** [ ]

- **B.** Will BFS Tolerate Failure Without Loss of Crew/Vehicle?  
  - **YES** [x]  **NO** [ ]  **N** [ ]

*Explanations Required (See Below)*

---

### CHANGE/RETENTION RATIONALE SUMMARY

<table>
<thead>
<tr>
<th>1. <strong>No H/S Issues</strong></th>
<th>3. <strong>No Software Detection</strong></th>
<th>5. <strong>Acceptance Rationale Below</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>2. <strong>Hardware Accepts Risk</strong></td>
<td>4. <strong>Detection During Checkout</strong></td>
<td>6. <strong>Recommended Changes Below</strong></td>
</tr>
</tbody>
</table>

- **X** FMEA Change Recommended

---

### EXPLANATION/COMMENTS:


2. FMEA change - in-flight detectability should include above measurement numbers.

6. Pod redundancy.

---

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ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PRESSURIZATION
P/N/RI : ME270-0032-0009,7,19,21
P/N VENDOR: R.R42670-3,-78442690-15-3
MISSIONS: HF VP XP CF SM
QUANTITY : 36

PREPARED BY:
APPR. C. SCARLETT
REL. C. MAKERS

APPROVED BY:
SSM

APPROVED WITH CHANGES
See Section 13.0

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 SUB-SYS COMPONENTS. COMPONENT INPUTS & OUTPUTS ARE ACCESSIBLE AT HE SEP 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, INADEQ MAINT OF OSE HALF, VC 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.
- (E) 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) P.S. = 2.0 X WORKING PRESS. ULLAGE PRESS IS ADEQ TO EXPLO PROP WITH 35 PERCENT OR LESS REMAINING. HSVY MALD 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. UTIL. OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUN 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. PROOF 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 INSPEL. OF WELD JOINTS FOR
SUBSYSTEM AFT - REACTION CONTROL

CONFORMANCE TO STANDARD WELD PRACTICE, SURFACE DEFECTS, AND EQUIP
CONFORMANCE TO CONTRACT REGS ARE VERIFIED BY RECEIVING INSPECTION. MEASUREMENT
STANDARDS AND TEST EQUIPMENT STANDARDS ARE IMPLEMENTED PER REGS OF MIL
SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION
POINTS - PARTS PROCT, WPG, PROCESSES, COATING, PLATING, ASSEMBLY AND
INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY
AUDIT CONDUCTED 11-3-76. CJP REGS PROCT PROCT CONTAIN CONT PROCESS CONT.
TEST HANDLING, AND STORAGE ENVIRONMENT. 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) (C) APOLLO FAILURE HISTORY WAS IN THE MAIN ASSOC WITH GROUND USAGE, IMPROPER HANDLING.
**HARDWARE/SOFTWARE ANALYSIS CHECKLIST**

**SD72-SH-0103-2**

**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** [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?**
   - **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 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 & 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)


**WAFFLE VALVE**

**PROBLEM:**

* Check and adjust valve.

**CAUSE:**

Valve causes pump system to operate at lower pressure.

**EFFECTS:**

- Loss of system reliability due to pump system failure.
- Reduced system efficiency due to increased system resistance.
- Increased wear and tear on system components due to suboptimal operation.

**SOLUTION:**

Adjust valve set point to recommended pressure range.

**CAUTION:**

Adjustments should be made in accordance with manufacturer's specifications to avoid system instability and potential damage.

**REFERENCE:**

Manufacturer's manual for valve adjustment procedures.

**DURABILITY:**

Valve durability is enhanced with proper maintenance and adherence to recommended settings.

**APPENDIX:**

Table of valve settings and recommended usage conditions.
null.
SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PRESSURIZATION

P/N/RI: MC224-3411-0001/0002

P/N VENDGR: RS010600-001-011

QUANTITY: 4

ONE PER HELIUM SUPPLY

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

PREPARED BY: R. BURKHART

APPROVED BY: S M

APPROVED WITH CHANGES

See Section 13.0

ITEM: VALVE, QUAD, CHECK, HE

FUNCTION:

- EACH CHECK VALVE QUAD WITH 4 POPPETS IN SERIES - PARALLEL ARRANGEMENT PROVIDES PARALLEL REDUNDANCY FOR HELIUM 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

CAUSE(S):

- STRUCTURAL FAILURE, SHOCK, VIB, POPPET BINDS IN GUIDE, CONTAM, VALVE FREEZES IN COLD VALVE, COPROS

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 UTIL/DEPLETION OF ALL RCS PROPellant IN ADDITION TO MIXTURE PROBLEMS WITH RESIDUAL THRUSTER FIRING PROBLEMS. POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO UTILIZE RESERVED PROPPELLANT 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 ALLOWING 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.
SUBSYSTEM : AFT - REACTION CONTROL  PMEA 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. TURNAROUND - FUNCTIONAL FLOW AND LEAKAGE
(BACK-FLOW) TESTS ARE PERFORMED. (O) NO PRIOR HISTORY FOR CLOSE FAILURE
MODE FOR THIS TYPE OF DESIGN.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

SUBSYSTEM AFT - RCS

ITEM: Feedline & Fittings, Fuel

FAILURE MODE: External Leakage

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?

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 ☑ 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 ☑ 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

CHANGE/RETENTION RATIONALE:

1. No H/S issues
2. No software detection
3. Acceptance rationale below
4. Recommended changes below

EXPLANATION/COMMENTS:

2. V42P2115 and 3115 should be deleted from this FMEA page as they are in the oxidizer system and not the fuel system.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED, FUEL
P/N: MC621-0059
P/N VENDOR: 73A560001
QUANTITY: 2

PREPARED BY: N. G. GLAVINICH
REL: C. M. A. KERS

ITEM: FEEDLINE AND FITTINGS
FROM TANK TO 1) TANK VALVES, TO 2) MANIFOLD VALVES, TO 3) THRUSTERS.

FUNCTION:
1) 1 1/2 X .028 304 L S.S. FROM TANK TO DISTRIBUTION PANEL;
2) 1 1/4 X .028 FROM MANIFOLD ISOLATION VALVE TO THRUSTER MANIFOLD;
3) 3/4 X .028 THRUSTER MANIFOLD TO PROVIDE FUEL TO APPROPRIATE PROPELLANT
COMPONENTS FOR THRUSTER OPERATION; SPEED ACCELERATION CONTROL AND
ROTATIONAL CONTROL.

FAILURE MODE: STRUCTURAL FAILURE
CAUSE(S):
VIB., FATIGUE, SHOCK, WELD DEF., INSTALL DRA, DYNA TURE 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 PROP. (C) LAUNCH DELAY
OR ABORT DECISION. (D) POSSIBLE LOSS OF CREW/VEHICLE IF LINE FROM
TANK OUTLET RUPTURES RESULTING IN INABILITY TO UTILIZE/DRENCHED PROP OR
PROP REACTS WITH FUEL OR OX CAUSING FIRE OR EXPLOSION.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) F.G.S. IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF).
DYNAMICS 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 "ORBITEP TUBING
VERIFICATION PLAN" (SD 75-SH-0205). THIS TESTING INCLUDED PRESSURE CYCLING AND FATIGUE FOR TYPICAL SHUTTLE LINES & JOINTS. SYSTEM
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
SUBJECTED TO NDE. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT
TAGGED. 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

589
59
SD75-SH-0003
SUBSYSTEM: AFT - REACTION CONTROL  FMEA NO 03-2A - 202103-1  REV:11/03/72
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. [D] MINOR HISTORY - CORROSION/PIG PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e. AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**

   YES [ ] NO [ ]

2. **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 [x] NO [ ]

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

   YES [ ] NO [ ]

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

   *YES [x] NO [ ]

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

   YES [ ] NO [ ]

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

   YES [x] NO [ ]

8. **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 [ ]

9. **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 [ ]

10. **IS 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:**

PREPARED BY:
LES N. GOLVINICH
PRL C. WALTERS

APPROVED BY:

PERFORMANCE OF TANK ISOLATION VALVES

IN ORDER TO PREVENT LOSS OF PROPELLANTS
DURING CONTINUOUS FLIGHT OPERATION - 9 \( \times \) ACCELERATION, CONTROL, AND THERMAL CONTROL.

STRUCTURAL FAILURE

- Mission, external

- Functional check, verification/installation, internal installation (WIL).

- Thermal, EMI, Vibration/Wave, internal installation (VAL).

- Electromagnetic interference (EMI).

- Possible loss of propellant, initial online testing (BATTERIES).
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED, OXIDIZER
P/N: MC621-0059
P/N VENDOR: 73A550002
MISSION: HF V/ SSM
QUANTITY: 2
PHASE(S): PL X LQ X CO X DO X LS X

ITEM: FEEDLINE AND FITTINGS
CT#: 1
QUANTITY: 7
PHASE(S): PL X LQ X CO X DO X LS X

REdundancy Screen: 4-N/A 9-N/A C-N/A

Prepared By:
APPROVED BY:
APPROVED BY: NASA

DES: N C GLAVINICH
REL: C M AKERS

FUNCTION:
(1) 1 1/4 x .323 304L S.S. FROM TANK TO DISTRIBUTION PANEL, (2) 1 1/2 x .023 FROM MANIFOLD ISOLATION VALVE TO THRUSTER MANIFOLD, (3) 3/8 x .023 THRUSTER MANIFOLD TO PROPELANT COOLANT COMPONENTS FOR THRUSTER OPERATION - 3 AXIS ACCELERATION CONTROL AND ROTATIONAL CONTROL.

FAILURE MODE: STRUCTURAL FAILURE

RUPTURE: EXTERNAL LEAKAGE

CAUSE(S):
- MECHANICAL SHOCK, VIBRATION/FATIGUE, IMPROPER INSTALLATION (WELD), DYNATUBE SEAL FAILURE MAT'L DEFICIENCY (SULPHIDE STRINGER).

EFFECT(S):
(4) SUB-SYSTEM DEGRADATION - LOSS OF PROPELLANT, (5) DEGRADATION OF INTERFACE FUNCTION - POTENTIAL CORROSION FROM FREE PROPELLANTS IN MODULE, (6) ABDT DECISION, (7) POSSIBLE LOSS OF GROUND VEHICLE - IF LINE FROM TANK OUTLET RUPTURES RESULTING IN INABILITY TO UTILIZE/DEPLETE PROPELANT OR PROPELANT REACTS WITH FUEL OR OXIDIZER CAUSING FIRE OR EXPLOSION.

DISPOSITION & RATIONALE
(8) DESIGN, (9) TEST, (10) INSPECTION, (11) FAILURE HISTORY:
(1) F.S. IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF), DYNATUBES 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.
(2) 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 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 SUBJECT TO NDE. (IC) 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 MAT' L (LOT
SUBSYSTEM : AFT - REACTION CONTROL

CMEA NO 03-24 - 202109-1   REV: 11/03/75

CERTIFICATION, PARTS PROTECTION, MANUF., CTSING, PLATING, INSTALLATION
AND ASSEMBLY OPERATIONS. HARDWARE IS INSPI. 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 FLOW AND PRESSURE FUNCTIONAL TESTS ARE MONITORED
FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE. (D) MINOR HISTORY -
CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT ARE MONITORED
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 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 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. ☑ DETECTION DURING CHECKOUT 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.

3A. Software could be designed to automatically position the appropriate tank isolation valve.

6. One success path remains after first failure.

8B. Same as primary.
ORIGINAL PAGE IS OF POOR QUALITY

TABLE 1. ISSUES, LOCS. AND EFFECTS ANALYSIS - MARCH 30.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Location</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Valve</td>
<td>Fails</td>
</tr>
<tr>
<td>2.</td>
<td>Valve</td>
<td>Fails</td>
</tr>
<tr>
<td>3.</td>
<td>Valve</td>
<td>Fails</td>
</tr>
<tr>
<td>4.</td>
<td>Valve</td>
<td>Fails</td>
</tr>
<tr>
<td>5.</td>
<td>Valve</td>
<td>Fails</td>
</tr>
</tbody>
</table>

**PREPARED BY:**

**APPROVED BY:**

**DATE:**

**SIGNED:**

**ACTION:**
SHUTTLE CRITICAL ITEMS LIST - CRITERION 102

SUBSYSTEM: FFT - REACTION CONTROL

ASSEMBLY: PROPELLANT FEED

P/N PI: MC284-0430-0007/-0038

P/N VENDOR: 3750023/3750026

QUANTITY: 12

TANK ASSEMBLY: PROPELLANT FEED

P/N: HC284-0430-0007/-003

REV: I Z/S

ASSEMBLY: PROPELLANT FEED

P/N VENDOR: 5750023/5750026

MISSIONS: HF, V, L, X, P, F, OF SY

PHASE(S): PL, LQ, CO X DQ X LS

372-IR 102

PREPARED BY:

APPROVED BY:

R. GONZALEZ

C. M. AKERS

C. R. GOBIN

PREPARED WITH CHANGES

See Section 13.0

ITEM: VALVE

TANK ISOLATION 3 PHASE 400 HZ AC MOTOR ACTUATED (115-230V) LV361-366,
LV 361-366. (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 THE PARALLEL
ISOL VALVES CONTROL THE REMAINING 2 PRIMARY MANIFOLDS AND THE VERNIER
MANIFOLD) THAT MAY EXHIBIT OPEN OR LEAKAGE FAILURES AND TO ISOLATE THE
TANK DURING INTERCONNECTS RCS OR OMS CROSSFEED OPERATIONS. ALSO USED
TO PREVENT HELIUM INGESTION TO ENGINE AT EXHIBITION (MANUAL SWITCH).
FUEL & OXIC VALVES CAN BE OPERATED INDEPENDENTLY FOR C/O LINE PRESS
RELIEF TO TANK IS PROVIDED.

FAILURE MODE: FAILS CLOSED (F)
FAILS TO OPEN, FAILS TO REMAIN OPEN.

CAUSE(S):

LIMIT SWITCH MALFUNCTION, PREMATURE POWER TO MOTOR, ELECTRICAL SHORT,
RPC OPEN, JAMMING OF BALL SHAFT OR CAM.

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

(1-8) LOSS OF REDUNDANCY PROPellant FLOW TO TWO MANIFOLDS (ON ONE SIDE)
AND SUBSEQUENT LOSS OF THRUSTER FUNCTION, POTENTIAL THRUST AND DAMAGE
FROM INDUCED SURGE. (C) ABORT DECISION (DEPENDING ON WHICH TANK ISOL
VALVE FAILS, ONE TANK ISOL VLY CLOSED MAY LOSE TWO MANIFOLDS). (D) NO
EFFECT FOR SINGLE FAILURE FOR RTLS MISSIONS (LOSS OF THRUSTER MAY BE
CRITICAL FOR RTLS IN SUBSEQUENT MISSIONS FOR OMS DEPLETION BURN). CRIT
1 FOR RTLS - LOSS OF TWO MANIFOLDS (PER PPO AFT) IS CRITICAL FOR SEPARATION & MATED COAST DURING RTLS. (E) FUNCTIONAL CRITICALITY EFFECT
POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO
UTILIZE RESERVOIR PROPellant & C.G. PROBLEMS DUE TO PROP WEIGHT.

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

(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.
SHUTTLE CRITICAL ITEMS LIST - CHAPTER 102

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. THIS IS USED
DURING SYSTEM EVALUATION TESTS AT HSTF ALLOWING EVALUATION UNDEP SIM-
ULATED 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, CORS,
PROTECTION PROVISIONS, NOE EXAM OF WELDS, INSPECT FOR SURFACE AND
SUBSURFACE DEFECTS AND PROPER ELECTRICAL TERMINATIONS. RAW MATEL (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 EQUIP AND MATEL AND EQUIP
CONFORMANCE TO CONTRACT REQS. TURBINE/ENGINE FLOW & LEAKAGE
TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON
COMMAND. (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.

69 SD75-SH-0003
<table>
<thead>
<tr>
<th>ITEM</th>
<th>Tank Isolation Valve, A/C</th>
<th>FAILURE MODE</th>
<th>Fails Open</th>
</tr>
</thead>
</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

<table>
<thead>
<tr>
<th>NO H/S ISSUES</th>
<th>NO SOFTWARE DETECTION</th>
<th>Acceptance Rationale Below</th>
</tr>
</thead>
<tbody>
<tr>
<td>HARDWARE ACCEPTS RISK</td>
<td>DETECTION DURING CHECKOUT</td>
<td>RECOMMENDED CHANGES BELOW</td>
</tr>
</tbody>
</table>

EXPLANATION/COMMENTS:

1A. Tank isolation valve discreets are available.
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valve 1</td>
<td>Closed</td>
</tr>
<tr>
<td>Valve 2</td>
<td>Open</td>
</tr>
</tbody>
</table>

**WARNING:**

- DO NOT OPERATE RCS VALVES WHILE SYSTEM IS IN SERVICE. IF RCS VALVES MUST BE OPERATED DURING SYSTEM SERVICE, USE CAUTION AND FOLLOW ALL SAFETY PROCEDURES.

**CAUTION:**

- DO NOT OPERATE RCS VALVES WITHOUT PROPER TRAINING AND AUTHORIZATION.

**NOTICE:**

- RCS VALVES MUST BE OPERATED IN ACCORDANCE WITH THE OPERATING INSTRUCTIONS PROVIDED WITH THE VALVES.

**SPECIFICATIONS:**

- RCS VALVES COMPLY WITH ALL APPLICABLE SAFETY REGULATIONS AND STANDARDS.

**Approval by:**

[Signature]

[Name]

[Date]
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N RI: MC234-0430-0007/0008
P/N VENDOR: 7853025/7850026
QUANTITY: 12

THREE VALVES PER PROP TANK

REDOUNDANCY SCREEN: 1-PASS 8-PASS C-PASS

PREPARED BY:
APPROVED BY:

PREPARED 3/4/21 (NAA)

ITEM: VALVE

TANK ISOLATION 3 PHASE 400HZ AC MOTOR ACTUATED (115-230V) LV261-266, LV 361-366.

FUNCTION:

THREE REDUNDANT ISOLATION VALVES ARE USED PER TANK TO ISOLATE GROUPS OF
MANIFOLDS (ONE TANK ISOL VALVE CONTROLS 2 MANIFOLDS AND THE PARALLEL
ISOL VALVES CONTROL THE REMAINING 2 PRIMARY MANIFOLDS AND THE VERT MANIFOLD)
THAT MAY EXHIBIT OPEN OR LEAKAGE FAILURES AND TO ISOLATE THE
TANK DURING INTERCONNECT & FIS OR RMS CROSSFEED OPERATIONS. ALSO USED
TO PREVENT HELIUM INGESTION TO ENGINE AT PROP TIME OUT (MANUAL SWITCH).
FUEL & OXID VALVES CAN BE OPERATED INDEPENDENTLY FOR C/O. LINE PRESS
RELIEF TO TANK IS PROVIDED.

FAILURE MODE: INTERNAL LEAKAGE (P)
FAILS OPEN, FAILS TO CLOSE, FAIL TO REMAIN CLOSED.

CAUSE(S):

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

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

(A, B) LOSS OF REDUNDANCY - MANIFOLD ISOLATION. (C) ABORT DECISION -
PROPELLANT MANAGEMENT PROBES DURING CROSSFEED OPERATIONS. (D) NO
EFFECT - CRIT 1 FOR RTLS. IF RCS TANK ISOLATION VALVE WILL NOT CLOSE
DURING RMS DEPLETION BURN THE RCS PROPELLANT MAY BE DEPLETED IF ASSOC
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 20SF ALLOWING EVALUATION UNDER
SIMULATED MISSION USAGE CONDITION. PROOF PRESSURE, LEAKAGE, OPERATION,
CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT. (C) A VISUAL INSPECT
AND IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL PROCESS, CORRO,
PROTECTION PROVISIONS, NDE EXAM OF WELDS, INSPECT FOR SURFACE AND
SUBSURFACE DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MTL (LOT)
CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE
VERIFIED BY INSPECTION. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE

ORIGINAL PAGE IS OF POOR QUALITY

12/16  SD75-0003
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 MATERIEL AND EQUIPMENT
CONFORMANCE TO CONTRACT REQUIREMENTS. TURNAROUND - FUNCTIONAL FLOW & LEAKAGE
TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON
COMMAND. (G) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST

SUBSYSTEM   APT - RCS

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 ☑ 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.
   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:

1. "Failed off" thruster gives first indication.
6. One success path remains after first failure.
8. Same as primary.

In Flight Detectability

X FMEA CHANGE RECOMMENDED
SHUTTLE CRITICAL ITEMS LIST - CRITERIA L02

SUBSYSTEM: AFT - REACTION CONTROL ASSEMBLY: PROPellant FEED

P/N: AC204-0430-J037-0003 P/N VENDOR: 5750025/5750026
QUANTITY: 8

FUNCTION:
- TO PROVIDE CONTROL OF INTERCONNECT LINE FOR VARIOUS CASES OF PROPELLANT FEED: 1) OPEN FOR OMS TO RCS, 2) OPEN FOR RCS TO OMS, 3) CLOSED FOR RCS TO SAME SIDE RCS AND OMS TO RCS. 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 TO OPEN

CAUSE(S):
- VIOLATION OF LIMITS: PREMATURE POWER TO MOTOR, ELECTRICAL SHORT, ROCKET BANKS, JAMMING OF VALVES

EFFECT(S):
- (A) LOSS OF REDUNDANCY (B) DEGRADATION OF INTERFACES (C) MISCONICION (D) MISCONICION/VEHICLE

F U N C T I O N - C R I T I C A LITY EFFECTS CAN BE UTILIZED BY ONLY 2 OF 3 MANIFOLD BANKS.
- (C) MESSION MODIFICATION-OPERATION CHANGES FOR ITEM B ABOVE.
- (D) NO EFFECT FOR O/M MESSIONS (LOSS OF THRUSTER MAY BE CRITICAL FOR RTLS IN SUBSEQUENT MESSIONS FOR O/M DEPLETION BURN). CRITICAL FOR RTLS - LOSS OF 1 MANIFOLD FORWARD & 1 MANIFOLD AFT IS CRITICAL FOR RTLS SEPARATION & MATED COAST DURING RTLS. SINGLE COMPUTER FAILURE COULD RESULT IN THIS CONDITION.
- (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE EARLY MESSION TERMINATION - INABILITY TO DEMONSTRATE MESS DEPFEED TO RCS.

DISPOSITION & RATIONALE:
- (A) A VISUAL INSPECT AND IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL 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.
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>
</tr>
</thead>
<tbody>
<tr>
<td>FAILURE MODE</td>
<td>Fails Closed</td>
</tr>
</tbody>
</table>

1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**
   - YES [ ] NO [ ]
   - QUESTION 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 [ ]
   - QUESTION 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 [ ]
   - QUESTION 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. [X] DETECTION DURING CHECKOUT 6. [ ] RECOMMENDED CHANGES BELOW

**EXPLANATION/COMMENTS:**

3. RCS RM automatically detects and prevents thrusting.
ACTIONS TO BE TAKEN AT IMPACT:

1. Engage emergency water diving vest.
2. Use emergency auto-bailer and de-watering apparatus.
3. If necessary, use emergency bilge pump.
5. Close all bilge hatches.
6. Close emergency bilge vents.
7. Close all emergency bilge outlets.
8. Close all emergency bilge fill valves.
9. Close all emergency bilge pumps.
10. Close all emergency bilge strainers.
11. Close all emergency bilge valves.
12. Close all emergency bilge ports.
13. Close all emergency bilge outlets.
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75. Close all emergency bilge ports.
76. Close all emergency bilge outlets.
77. Close all emergency bilge valves.
78. Close all emergency bilge ports.
79. Close all emergency bilge outlets.
80. Close all emergency bilge valves.
AN EFFECTS ANALYSIS OF POOR QUALITY.
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 AND
2) TO ISOLATE A FAILED OPEN THRUSTER OR DOWNSTREAM LEAK. EACH
MANIFOLD ISOLATION VALVE CONTROLS 3 PRIMARY THRUSTERS.

FAILURE MODE: FAILS CLOSED-PREMASTU 

OPERATION, FAILS TO REMAIN OPEN.

CAUSE(S):
- VIBRATION, LIMIT SWITCH MALFUNCTION, PREMASTU POWER TO MOTOR.
- PREMASTU MOTOR SIGNAL, OCC SHORT.

EFFECT(S):
(A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
- (A) LOSS OF REDUNDANCY-LOSS OF PROP FLOW & USE OF 3 PRIMARY
  THRUSTERS (1 OF 4 MANIFOLDS). (C) NO EFFECT FOR SINGLE FAILURE FOR
  OPT MISSIONS (LOSS OF THRUSTER MAY BE CRITICAL FOR RTLS IN SUBSEQUENT
  MISSIONS FOR CMS DEPLETION BURN). (C) FOR RTLS LOSS OF 3 MANIFOLDS
  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 PREMASTU 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 WSTAL, ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION.
  PROOF PRESSURE, LEAKAGE, OPERATION, CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT.
  (C) A VISUAL INSPECT AND IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL PROCESS,
  CORROS. PROTECTION PROVISIONS, NDE EXAM OF WELDS, INSPECT FOR SURFACE AND SUBSURFACE
  DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MAT'L (LOT) CERTIFICATION, PARTS
  PROTECTION, COATING AND PLATING PROVISIONS ARE VERIFIED BY INSPECTION. MANUFACTURE,
  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
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO. 03-2A-202120-3  REV: 12/12/78

TO CONTRACT REQMTS.  TURNAOUND/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. **HARDWARE/SOFTWARE ANALYSIS CHECKLIST**

**SUBSYSTEM** AFT - RCS

**ITEM** Manifold Isolation Valve, D.C.

**FAILURE MODE** Fails Closed

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE 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] [X]

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

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

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

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

*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

---

**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.
### Configuration Analysis - Fault Tree

<table>
<thead>
<tr>
<th>Event</th>
<th>Failure Mode</th>
<th>Cause</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>FE04</td>
<td>Zone 1 - Fire</td>
<td>Electrical</td>
<td>System Failure</td>
</tr>
<tr>
<td>FE04</td>
<td>Zone 2 - Water</td>
<td>Mechanical</td>
<td>System Failure</td>
</tr>
</tbody>
</table>

### Causes
- Electrical failure due to electrical shorts in the control panel.
- Mechanical failure due to malfunctioning of the control panel.

### Corrective Action
- Attempt to manually override the valve by use of manual control.
- In case of collision risk, use RCS thrusters.
- Use RCS thrusters to perform orbit correction

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**Original Page Is of Poor Quality**
ITEM: VALVE MANIFOLD ISOLATION, VERNIER THRUSTER, SCIENCE (28VDC) 3L-STABLE (LATCHING) LV 258/257/357/358.

FUNCTION: TO PROVIDE VERNIER THRUSTER ISOLATION; 1 PRIOR TO SYSTEM ACTIVATION AND 21 IN THE EVENT OF A RUNAWAY THRUSTER OR MANIFOLD LEAK.

FAILURE MODE: FAILS CLOSED. (F)

CAUSE(S): IMPROPER ELECTRICAL SIGNAL (CONTINUOUS SHORT) OR LC + MAGNETIC FORCE FROM LATCHING MAGNET, MECH LOCK, VIB., CONTAM (AIR GAP).

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) OPER/VEHICLE; (A) LOSS OF FUNCTION (VERNIER THRUSTER). (B) OPERATION OF INTERFACE SYSTEM-PAYLOAD MANIPULATION. (C) MISSION MODIFICATION OR ACEPT DECISION. (D) NO EFFECT UNLESS ADDITIONAL FAILURES OCCUR.

DISPOSITION & RATIONALE: (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY; (A) SERIES SWITCHES (RPC'S) MINIMIZE POTENT FOR INADVER ACTUATION. PARAL SWITCHES (RPC'S) PROVIDE ELECT REDUND FOR THE OPENING STS. AN INDUCT VOLTAGE SUPRES CIRCUIT IS PROV IN THE ELECTRICAL SYSTEM TO PREV DAMAGE TO OTHER ON-LINE COMP. REDUN DIODES LIMIT THE POSS OF DIODE FAILURE ALLOWING CURRENT SHUNT FROM THE COIL.

300 MICRON FILTER IS PROV TO LIMIT THE POSS OF CONTAM CAUSING JAMMING MOVING PARTS. (B) PROV TO LIMIT THE SHORT POTENT. THE LEAD AND MAGNET WIRES ARE ENCAP B Y QPING 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) 2000 CYCLES (ON-OFF-FLOW) AND RANDOM VIB AT ANTIC MISSION LEVELS ARE PERF DURING OAL. ITEM IS USED DURING SYS EVAL TESTS AT WSTF ALLOWING EVAL UNDER SIMUL MISSION USAGE COND. PROOF PRESS, LEAKAGE, OPER AND INSUL TESTS ARE PERF DURING ATP. APPPOP LOCATED TEST POINTS ALLOW P/C POST FLIGHT LEAKAGE TESTS AND OPER TESTS ARE ALSO COND AT THIS TIME. (C) AND IDENTF IF IS PERF AND THE UNIT TAGGED. CONTAM CONT PROCESS, CORROS, PROT PROV, NDE EXAM-OF WELDS AND BRAZES, INSPECT. FOR SURFACE AND SUBSURFACE DEFECTS AND PROPER ELECT TERMINATIONS ARE VERIF BY INSPECT. THE FOLLOWING ITEMS ARE VERIF BY SHOP TRAELER INSPECT. POINTS- RAW MAT'L (LOT CERTIF); PARTS PROD, MANUF., COATING, PLATING, INSTALL AND ASY OPER. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIF BY AUDIT COND.
Tests are conducted to verify that valves open and close properly upon command. Apollo failures were mainly associated with reverse polarity and degaussing 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.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST

SUBSYSTEM: AFT - RCS
ITEM: Propellant Fill & Bleed Disconnect
FAILURE MODE: Fails Open

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 [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 [X] 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 [ ] **NO [X]

*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.
2. There is one success path remaining after the first failure.
3. Same as primary.
4. Measurements V42P2313C, 2315C, 2313C and 3315C are not listed in the MML.
DETONATION INSPECTION

PREPARED BY: CEL
C SCALAPT
PEL
C WORKERS

APPROVED BY:

1. UNLOCK SILL (L) LATCH
2. UNLOCK SPECIFIC LUG FROM HINGE AND STRUCTURAL (POINT A) LATCH

3. UNLOCK SPECIFIC LUG FROM CABLE AND STRUCTURAL (POINT B) LATCH

4. UNLOCK SPECIFIC LUG FROM CABLE AND STRUCTURAL (POINT C) LATCH

5. UNLOCK SPECIFIC LUG FROM CABLE AND STRUCTURAL (POINT D) LATCH

6. UNLOCK SPECIFIC LUG FROM CABLE AND STRUCTURAL (POINT E) LATCH

7. UNLOCK SPECIFIC LUG FROM CABLE AND STRUCTURAL (POINT F) LATCH

8. UNLOCK SPECIFIC LUG FROM CABLE AND STRUCTURAL (POINT G) LATCH

9. UNLOCK SPECIFIC LUG FROM CABLE AND STRUCTURAL (POINT H) LATCH

WARNING:
DETONATION IMPACT IF PARKING LIMIT ATTEMPT TO LATCH LINKS AT ORBITY FOR NIGHT.

TABLES/CHARTS:
- EXPLOSIVE DATA
- FLIGHT HISTORY
- EXPLOSIVE DIAGRAMS

THERMAL INSPECTION:
- THERMAL DATA
- FLIGHT HISTORY
- THERMAL DIAGRAMS

COMMENTS:
- COMMENTS
- FLIGHT HISTORY
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPellant
P/N: M276-0016
P/N VENDOR: T6301000 & 76306000
QUANTITY: 12

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

FAILURE MODE: VALVES OPEN.

FAILURE HISTORY:
(A) LOSS OF SUBSYSTEM PROPellant. (B) DEGRADATION OF INTERFACE SUBSYSTEM (PROPellant EFFECTS). (C) LAUNCH DELAY OR ABORT DECISION.

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 UNDUE STRESS ON THE COUPLING DURING SERVICE AND PREV DAMAGE TO SEALS. A SAFETY FEATURE PRIOR TO REMOVAL OF THE END CAP IS A PROV WHERBY 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 STRUCTURAL FAILURE.
(B) THE COUPLING IS SUBJECT TO 600 OPER CYCLES (COUPLING AND UNCOUPLING) DURING QUAL. IN ADDITION TO PRESSURE CYCLING AND PROP EXPOSURE TESTS. RANDOM VIB TESTING IS ALSO ConDUCTED AT ANTIC VEH LEVELS FOR 34 MINUTES IN EACH AXIS. USAGE DURING SYS EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE COND. PROOF PRESSURE TESTS ARE CONducted DURING ATQ & LEAKAGE TESTS ARE PERF BEFORE & AFTER OPER CYCLES. (C) AN IDENT IS PERF. RAW MATERIAL NDE EXAM, VISUAL INSPECTION FOR SURFACE DEFECTS, & EQUIP CONFORMANCE TO CONTRACT REQS ARE VERIFIED BY RECEIVING INSPECTION. MEASUREMENT STANDARDS & TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS- PARTS.
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-24-20215-1 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
PROT 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-COUPLINGS ARE VISUALLY INSPEF FOR EVID OF DAMAGE SEALS & LEAK
TESTS ARE PERFORMED. (D) APOLLO FAILURE HISTORY WAS IN THE MAIN ASSOC
WITH GROUND USAGE, IMPROPEH HANDLING.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

SUBSYSTEM AFT - RCS

ITEM Propellant Tank Assy.

FMEA NUMBER 03-2A-211110-1

FAILURE MODE External Leak

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 NEGLE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?

   YES [ ] NO [ ]

3a. IF NOT, DOES THE CAPABILITY EXIT 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, AVERSELY 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 [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 [ ] NO [X]

*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

EXPLANATION/COMMENTS:


6. Pod redundancy.

8B. Backup flight system same as primary.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N: MC282-0061-0001-0002
P/N VENDOR: 355C3310000-010-020
MISSIONS: V7, V8, F7, FF, JF, SM
QUANTITY: 4

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. TANK SHELL
CONTAINS PROPELLANT AND ACQUISITION DEVICE RETAINS PROPELLANTS FOR ADEQUATE FEED
DURING 1G, 0G, 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): MACH SHOCK, FATIGUE/V(I), OVERPRESS, STRESS CONCAJS, IMPROPER PROP Purity
OR TEST FLUID, OVER TEMP, PLUMES, OR REENTRY GASES, STRESS RISE?, VELD
OR MAT' L DEFECT, INCORRECT OR DAMAGED SEAL.

EFFECT(S): ON: (A) SUBSYSTEM, (B) INTERFACES, (C) MISSION, (D) CREW/VEHICLE:
(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) ABOUt DECISION. (D) POSSIBLE LOSS OF CREW/VEHICLE
(EXPLOSION, LACK OF PROPELLANT OR INABILITY TO DEPLETE OPPOSITE
PROPELLANT).

DISPOSITION & RATIONALE (A) DESIGN, (B) TEST, (C) INSPECTION, (D) FAILURE 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
FRACURE CRITICAL FOR HANDLING AND IS SUBJECT TO FATIGUE CONTROL
REOMTS. 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 PROPELLANT EXPOSURE TEST-
PROOF PRESSURE (1.3X WORKING PRESSURE) AND LEAKAGE TESTS ARE PERFORMED
DURING AT'READIGRAPHIC 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 MAT' L AND
PURCHASED COMPONENT RELMENTS ARE VERIFIED BY RECEIVING INSPECTION STANDARDS
AND TEST EQUIP. STANDARDS ARE IMPLEMENTED ON RELMENTS OF MIL
SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY
INSPECTION POINTS- PARTS PROTECTION, MFG. PROCESSES, FINISHES, ASSY AND
INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY
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 penetrant 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. 10 Apollo failures were associated with incorrect test fluid
(methyl alcohol), improper propellant no content, stress rise or test
error resulting in creation of vacuum. Corrective action was taken for
all of above failures and also implemented on Shuttle.
SUBSYSTEM AFT - RCS  
ITEM Propellant Tank Assy

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.
   [ ] 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.
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 REQ'D. 245 PSI (±15) (17.95 CUBIC FEET).

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

CAUSE(S):
FATIGUE, STRESS CORRCS, CONTAM, VIB, MECH SHOCK, SCREEN COLLAPSE, FROZEN PROP, PROP SLOSH LOADS, FASTENING HARDWARE FAILS

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) 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 MATERIAL AND PURCHASED COMPONENT REQMTS ARE VERIFIED BY RECEIVING INSPECTION. 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 ALSORecorded. (D) NO IN-FLIGHT FAILURE EXPERIENCE FOR THIS 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 [ ] 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 [x] 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.**

   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 [x] NO [ ]

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

      YES [ ] NO [x]

   *EXPLANATION REQUIRED (SEE BELOW)*

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**EXPLANATION/COMMENTS:**


2. Fuel tank outlet pressure measurements V42P2310, 33110 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 RI: 73P559015-1016102 (HDAC) P/N VENDOR: 1003099-1016102 (SSP) QUANTITY: 12

SUBSYSTEM: ASSEMBLY: PROPELLANT FEED CRITICAL FEnC Ill: L MISS: HF YF X FF OF SM PHASE(S): PL X L3 X CO X DO X LS X

PREPARED BY: N GLAVINICH APPROVED BY: SSM REL. C MAKERS REL

ITEM: CONNECTOR FLEXIBLE, GIMBAL JOINT

FUNCTION:

AN EXTERNALLY CONSTRAINED BELLOWS (UNIVERS: S 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 (S) EXTERNAL LEAKAGE.

CAUSE(S):

PATIGUE, SHOCK, HANDLING, INDEEO WELD PENET., INCOMP. FUSION, POROSITY, CORROS RESULTING IN PIN HOLE LEAK throug CONVOLUTE, PROP & SI-PROP EXPOSURE PRESSURE SURGES, FLOW INDUCED YIP-PGC EFFECT, FLT VIB.

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

(A) SUBSYSTEM DEGRADATION - LOSS OF PROPellant. (B) DEGRADATION OR INTERFACE FUNCTION - POSS CORROS DAMAGE WITHIN PCD AND ADVERSE EFFECT ON TPS (MOLECULAR VENTING). (C) LAUNCH DELAY CP ABORT DECISION. (D) POSSIBLE LOSS OF CREW/VEHICLE - IF BELLOWS JOINT TRUPTURES 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) MULTIPLE BELLows ARE UTILIZED. FLOW INDUCED VIBRATION ANALYSIS AND STRESS ANALYSIS ARE CONDUCTED TO VERIFY ACCEPTABLE DESIGN. THE EXTERNAL CONSTRAINT (UNIVERS: S 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 WSTF ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. (C) A VISUAL INSP AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, PROGRESS, PROTECTION PROVISIONS, NOE EXAM OF WELDS, INSP FOR SURFACE AND SUBSURFACE DEFECTS, 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 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ホール
CORROSION ASSOCIATED WITH RESIDUAL SOLVENTS AND PROPELLANT.
**SUBSYSTEM**  AFT-RCS  
**ITEM**  Bellows Assy.  

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

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**EXPLANATION/COMMENTS:**

PRELIMINARY INSPECTION

PROJECT #:

USE #: F1000-148

REL #: 72-4870

POOR QUALITY
SHUTTLE CRITICAL ITEMS LIST - CRITERION 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: THRUSTER/PROPELLANT FEED ABORT:
P/N RI: MC621-0059
P/N VENDOR: 73P550C1-1001THR1005
QUANTITY: 56

ONE FUEL AND ONE OXIDIZ.
# PER THRUSTER [PRI & VERN]

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

PREPARED BY:  DES N GLAVINICH  REL C M AKERS
APPROVED BY:  DES  SSM  REL

ITEM: BELLOWS ASS'Y
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 PROPPELLANT SYSTEM.

FAILURE MODE: STRUCTURAL FAILURE (S)
EXTERNAL LEAKAGE.

CAUSE(S):
FATIGUE, SHOCK, HANDLING, (N)EQ WELD, PENET, INCOMP FUSION, PORosity, CORROS-PROP & BI-PROP EXPOSURE, PRESS SURGE, FLOW INDUCED VIB-POGG EFFECT, FLT VIA.

EFFECT(S) ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) SUBSYSTEM DEGRADATION — LOSS OF PROPellant. (B) DEGRADATION OF INTERFACE FUNCTION - POSS CORROS DAMAGE WITHIN POO AND ADVERSE EFFECT ON TPS (MOLECULAR VENTING). (C) LAUNCH DELAY OR ABDORT DECISION. (D) POSSIBLE LOSS OF CREW/VEHICLE — FAILURE NOT DETECTABLE SINCE PVT 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 PROPPELLANT LEAK IN EVENT OF BELLows FAILURE. PROPPELLANT LEAK FROM LINE TO THRUSTER COULD BE ISOLATED BY MANIFOLD VALVE. (B) ITEM IS USED DURING SYSTEM EVALUATION TESTS AT NSTF ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. (C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NDE EXAM OF WELDS, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS, RAW-MAT'LL (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUFACTURING, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANUFACTURER INSPECTION 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'LL CONFORMANCE TO CONTRACT REQUIS. 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 ASS'Y DUE TO PINHOLE CORROSION ASS'Y WITH RESIDUAL SOLVENTS AND PROPPELLANT.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST

SUBSYSTEM  AFT - RCS
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 X

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

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

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?
   *YES X 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 X *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 X 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 X
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      YES X *NO X

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

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

EXPLANATION/COMMENTS:

1. "Failed off" thruster C&W.
Safety Evaluation \& Effects Analysis - Ronghua IC

PREPARED BY:
C. V. AKERS

ORIGINAL PAGE IS OF POOR QUALITY
**HARDWARE/SOFTWARE ANALYSIS CHECKLIST**

**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** [ ] **NO** [X]

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)?**
   - **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?**
   - **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. [X] RECOMMENDED CHANGES BELOW

---

**In-Flight Detectability**

[X] FMEA CHANGE RECOMMENDED

**EXPLANATION/COMMENTS:**

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

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: THRUSTER, PRIMARY
P/N: M467-0026
P/N VENDOR: X30928
QUANTITY: 24

FUNCTION:
Provides injection & vaporization of fuel and oxidizer for thrust

INLET VALVES AND PROVIDES DOUBLE MIXING AT 1.50 OX TO FUEL RATIO FOR A
HYPERGOLIC REACTION WHICH PRODUCES 850 POUNDS OF THRUST AT 75,000 FEET.

ALSO, CONTROL CHAMBER WALL COOLING. THE INJECTOR IS CONSTRUCTED OF C-103
COLUMBIA & WELDED TO THE CMB CHAMBER. ACOUSTIC CAVITIES ARE LOCATED AT
THE OUTER PERIPHERY OF THE INJ FACE TO PREVENT HIGH PRESS CMB
INSTAB.

FAILURE MODE: FAILS OUT OF TOLERANCE

FLOW AT RESTRICTED FLOW.

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

EFFECT(S):
ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF REDUNDANCY OR FUNCTIONAL DEGRADATION - REDUCED PROP
FLOW - CHAM PRESS & THRUST, INJ/INJ FILM COOLING. (B) DEGRADATION OF INTERFACE FUNCTION - INCD OF ALT THUSTERS (C)
NO EFFECT. (D) NO EFFECT. (E) FUNCTIONAL CRITICALITY EFFECT - ABORT
DECISION - Degrade 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 GN&C
FAILURE DETECTION SYS. COMPLETE THERMAL AND STRESS ANALYSIS HAVE BEEN
COMPLETED. (B) RCS SYS EVAL TEST AT WSTF. THRUST QUAL FOR 50,000
CYCLES, SPRAY PATTERN CHECKED DURING ATP. (C) A VISUAL INSPECTION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL
PROCESS, CORROS PROTECTION PROVISIONS, NDE EXAM OF WELDS, RAH M & 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 REGTS. TURNAROUND INSPECTION TO INCLUDE USE OF
OPTICS WHERE ACCESSIBLE TO DETERMINE EVIDENCE OF PLUGGED ORIFICE. PLUG
SAMPLING TO BE PERFORMED TO DETECT CONTAMINATION. (D) NO DIRECT FAILURE
'HISTORY AVAILABLE.
SUBSYSTEM AFT - RCS

ITEM Thrust Chamber

FAILURE MODE Burn-Thru

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

1a. 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 MITIGATE THE EFFECTS OF THE FAILURE
   (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?

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)?

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)

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.
Sr

ULYS

PREFACE BY: 
LES
REL

APPROVED BY: 
LES
REL

CHAPTER 4 STRUCTURAL FAILURE (E)

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OF POOR QUALITY
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 CIXATION 
RESISTANT COATING AND UTILIZES FILM COOLING. THE CHAMBER PRESS IS 152 
PSI & IS DESIGNED TO PRODUCE A THRUST OF 870-LBS VACUUM AT A MAXINAL 
STEADY STATE SPECIFIC IMPULSE OF 280 SECONDS.

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

CAUSE(S):
THERMAL CYCLING/STRESS FATIGUE, VIB, COMA 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 REDUNDANCY-POSS LOSS OF 3 THRUSTERS IF W/FULL ISOL VALVE 
MUST BE CLOSED. (B) DEGRADATION OF INTERFACE FUNCTION-INCRED GBLC & 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 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 (B) TO (C) (D) 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 INSPEC. AND 
IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL 
PROCESS, CORROS. PROTECTION PROVISIONS, NOE 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 SHIP TRAVELEP MANDATORY INSPE. POINTS. THE ABOVE ITEMS AND 
THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-78. 
CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE 
ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP 
COMPONANCE TO CONTRACT REQS. TURNAROUND INSPECTION TO INCLUDE USE OF 
OPTICS WHERE ACCESSIBLE TO DETERMINE EVIDENCE OF PLUGGED ORIFICE. FLUID 
SAMPLEING TO BE PERFORMED TO DETECT CONTAMINATION. (D) NO DIRECT FAILURE 
HISTORY AVAILABLE.
**HARDWARE/SOFTWARE ANALYSIS CHECKLIST**  
**SUBSYSTEM** AFT - RCS  
**ITEM** Nozzle Extension  
**FMEA NUMBER** 03-2A-221313-1  
**FAILURE MODE** Burn-Thru

1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE 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 ☒ [X]

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

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

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

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

*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:**
SNAIL FAILURE IN AND EFFECTS ANALYSIS - UNIT 10

PROPOSED DURATION: 1995-1998

Three main failure modes:
1. Excessive Inlet Valve Wear
2. Inlet Valve Wear
3. Inlet Valve Wear

PREPARED BY:

KS SELVER

V. G. ANGEL

APPROVED BY:

KS

V. G. ANGEL

DETERMINATION:

1. LOCAL EXTENSION
   2. COLUMNS AND INSULATION BLANKET
   3. GENERAL LOCATION

EFFECTS:

1. Thermal Expansion (Conduction)
2. Thermal Expansion (Convection)
3. Thermal Expansion (Convection)

SOLUTION:

1. Insulation blanket
2. Insulation blanket
3. Insulation blanket

APPLICATION:

1. Insulation blanket
2. Insulation blanket
3. Insulation blanket

CONCLUSION:

1. Local extension at inlet valve or manifold and assess for leakage and erosion to surrounding structure.
2. Local extension at inlet valve or manifold and assess for leakage and erosion to surrounding structure.
3. Local extension at inlet valve or manifold and assess for leakage and erosion to surrounding structure.

NOTES:

1. Local extension at inlet valve or manifold and assess for leakage and erosion to surrounding structure.
2. Local extension at inlet valve or manifold and assess for leakage and erosion to surrounding structure.
3. Local extension at inlet valve or manifold and assess for leakage and erosion to surrounding structure.

SOURCES:

1. Local extension at inlet valve or manifold and assess for leakage and erosion to surrounding structure.
2. Local extension at inlet valve or manifold and assess for leakage and erosion to surrounding structure.
3. Local extension at inlet valve or manifold and assess for leakage and erosion to surrounding structure.
ITEM: NOZZLE EXTENSION
COATING: COATED COLUMBIA (WITH INSULATION BLANKET)
FUNCTION: TO PROVIDE ISENTROPIC EXPANSION OF COMBUSTION GASES FOR MAX EFF IN VACUUM. NOZZ EXT IS CONSTRUCTED OF C-103 COLUMBIA WITH P-5124 OXIDATION RESISTANT COATING. THE NOZZLE EXPANSION RATIO IS 22 TO 1. THE NOZ EXT IS INTEGRAL WITH THE COMBO CHAM AND ENCLODED IN A DYNX FLEX INSUL SHROUD SO THAT THE EXT 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 CR MAT' DEFECT"

EFFECT(S): ON: (A) SYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF REDUNDANCY- POSS LOSS OF 3 THRUSTERS IF K-FOLD ISOL VALVE MUST BE CLOSED, (B) DEGRADE OF INTERFACE FUNCTION- INCR SHRE & USE OF ALT THRUSTERS, (C) BURN-THRU MA Y CAUSE HIGH TEMP ON SURF STRUC, 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 SURF STRUC & ADJ STRUCTURES RESULTING IN POSS ENTRY HAZ IF TPS IS DAMAGED

DISPOSITION & RATIONALE: (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) 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 IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NOE 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 INSPECTION POINTS. 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 COMPLIANCE TO CONTRACT REQS. TURNAROUND INSPECTION TO INCLUDE USE OF OPTICS WHERE ACCESSIBLE TO DETERMINE EVIDENCE OF BURN-THRU. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
<table>
<thead>
<tr>
<th>Item</th>
<th>Vernier Thruster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure Mode</td>
<td>Loss of Output</td>
</tr>
</tbody>
</table>

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?**
   - No [ ] 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.
original page is of poor quality

PERIOD FAILURE AND EFFECTS ANALYSIS - L-801

FUNCTION:

The pitch axis (fixing) and yaw yaw (plus/less than 360°) yaw axis functions are provided in each arc's needle to provide pitch and yaw.

Loss of pitch and yaw function will result in loss of payload position.

LOSS OF function:

- Loss of pitch function (failure) (c)
- Loss of yaw function (failure) (f)

EFFECTS:

- (a) Mission is terminated due to loss of function (payload failure).
- (b) Mission is terminated due to loss of function (payload failure).
- (c) Mission is terminated due to loss of function (payload failure).
- (d) Mission is terminated due to loss of function (payload failure).
- (e) Mission is terminated due to loss of function (payload failure).
- (f) Mission is terminated due to loss of function (payload failure).

ACTION:

- Evaluate to determine need for abort versus use of primary thrusters.
- Use drift mode or payload attitude control.

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DETAILS FAILURE MODE AND EFFECTS ANALYSIS - Cont'd
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: VERNIER THRUSTER
P/N: MC467-0029
P/N VENDOR: MISSIONS: HF, VF, X, FF, DF, SM
PHASE(S): PL, LO, CO, X, DS

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 low level pulsing 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: Loss of output (thrust) (F). Inlet valves closed or inj orifice plugged.

CAUSE(S):
- Open sol coil, auto shut-down, inlet vlv leak/struct fail, inj contam/residue or frozen prop blocking orifice, cong chaw/ngi struct fail.

EFFECT(S): On (A) subsystem (B) interfaces (C) mission (D) crew/vehicle: (A) Loss of function (vernier thrusters) — currently loss of single vernier thruster causes loss (shutdown) of vernier control. (B) No effect. (C) Mission modification or abort decision (potential inability to retrieve payload). (D) It is possible payload could be retrieved while in free drift mode and in some instances payload may have attitude & translation control. It may be possible to use F & AFT pcs (x axis) engines for pitch (downward) motion. (D) No effect.

DISPOSITION & RATIONALE: (A) Design (B) Test (C) Inspection (D) Failure history: (A) POS thruster modes in x axis primary thrust. payload attitude control and 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 vlv tested for 500,000 wet cycles & 5000 dry. (C) A visual insp 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, and Assy operations are verified by shop traveler 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 by contract" reqts. turnaround — visual insp using optical instrumentation. System fluids are analyzed for evidence of contamination. Proper inlet vlv function and electrical logic power is verified. (D) No direct failure history available.

PREPARED BY: J. TAGGART
APPROVED BY: SM

TASK: 1030
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HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

SUBSYSTEM: AFT- RCS

ITEM: Vernier Thruster

FMEA NUMBER: 03-2A-231310-2

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 ☒ 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 on" thruster C&W.

6. No redundancy in the verniers.

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**ORIGINAL PAGE IS OF POOR QUALITY**

<table>
<thead>
<tr>
<th>PREPARED BY:</th>
<th>J. Taubert</th>
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<td>FEL:</td>
<td>C. MARKERS</td>
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- **PREPARED BY:**
- **APPROVED BY:**

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**DESCRIPTION:**

- Ejection: Assy, Vinate.
- Flight test level: 257/257/257/257.

**EXPLANATIONS:**

- Ejection: Fails to Jettison.

**CONNECTIONS:**

- Isolate FEL & RCS TRAJECTORY.

**COMMANDS:**

- 1. Engage RCS to Paylcn or Paylcn Bay Arms.
- 2. Primary Thrusters for Vehicle Integrity.
- 3. Paylcn Bay Arms D/E.
- 4. Fire RCS.
- 5. AFT RCS.

**APPLICATIONS:**

- VMS: SFH-10-51.

**ACKNOWLEDGEMENTS:**

- 1. LCS.
- 2. LCS.

125
SHUTTLE CRITICAL ITEMS LIST - CRITERIA 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: VERNIER THRUSTER
P/N RI: MC467-0029
P/N VENDOR: MISSIONS: HF VF X FF DF SF
QUANTITY: 14

ABORT: CP IT. FUNC: 2
MISSIONS: HF VF X FF DF SF
PHASE(S): PL LJ CO X DO LS

SUBSYSTEM: AFT - REACTION CONTROL
PMEA NC 03-2A -231310-2 REV: 11/03/77
P/N RI: MC467-0029
CP IT. How: 2

ABORT: CP IT. FUNC: 2
MISSIONS: HF VF X FF DF SF
P/N: 70

PREPARED BY: J TAGGART
APPROVED BY: JES
REL: AV

DETAILED DESCRIPTION:

ITEM: THRUSTER, ASSY, VERNIER

FUNCTION:
ONE PITCH (2 AXIS-UP FIRING) AND ONE YAW (PLUS/MINUS Y AXIS) VERNIER THRUSTERS 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 THRUSTERS BUT LIMIT PLUME IMPINGEMENT AND PROP RESIDUE CONTAMINATION TO THE PAYLOAD.

FAILURE MODE: FAILS TO STOP (F)
FAILS OPEN, FAILS TO CLOSE (THRUSTER CONTINUES Firing).

CAUSE(S):
CONTAMINATION, STRUCTURAL FAULTS, DUALLY SHORT IN DRIVER CIRCUIT TO DUAL YOM FIRE COMMAND, VIS, SHOCK SEALS, SEAT DAM, PROP RESIDUE, FLUSH SALTS, CORROS, WEAR.

EFFECT(S) ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF FUNCTION (VERNIER THRUSTERS) - CURRENTLY LOSS OF SINGLE VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL. (B) DEGRADATION OF INTERFACE SUB-SYSTEM - PROP LOSS DUE TO EXCESS BURN-TIME UNTIL 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 REDUNDANT MODES 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/MOM 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 OF THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS, PROTECTION PROVISIONS, NDE EXAM OF WELDS, RAW MATERIAL (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. SHUT 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 MATERIAL AND EQUIP CONFERENCE TO CONTRACT REQS. TURNOVER - SYSTEM FLUIDS ARE ANALYSED FOR EVIDENCE OF CONTAMINATION. PROPER INLET VALVE FUNCTION AND ELECTRICAL LOGIC POWER IS VERIFIED. (D) NO DIRECT FAILURE HISTORY AVAILABLE.

ITEM: THRUSTER, ASSY, VERNIER

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

FUNCTION:

25 POUND THRUST LEVEL. EN 357/358/257/258.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST

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 ☒ 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 C&W.
2. Down modes to free drift.
3. No redundancy in the verniers.

FMEA CHANGE RECOMMENDED
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : VERNIER THRUSTER
P/N PI : MC467-0C29
P/N VENDOR : MISSIONS: HF VF X HF DF SM
QUANTITY : 4
FUNCTION : 3
P/N : 104467-0C29 CRIT. PROP : 1
MISSIONS : PL LO X 00 X 00 X LS
FAILURE DETECTABLE IN FLIGHT? : YES
CHAMBER PRESSURE ON EACH ENGINE: V42P32521 THRU V42P-3521 & V42P-3534 THRU V42P-3534
TIME TO EFFECT : SECONDS
REFERENCE DOCUMENTS : MC 621-C59
GND TURNAROUND? ................. YES
VISUAL INSPECTION

PREPARED BY: DES J. TAGGART
APPROVED BY: DES C. M. AKERS

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 THRUSTERS ARE PROVIDED IN EACH ARC'S MODULE TO PROVIDE PRECISE LOW LEVEL PULSING AND ATTITUDE HOLD REQ'D FOR PAYLOAD POINTING. THEY ARE CONCEPTUALLY SIMILAR TO THE PRIMARY THRUSTERS BUT LIMIT PLUME IMPINGEMENT AND PROP RESIDUE CONTAM TO THE PAYLOAD.

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

CAUSE(S):
THERMAL CYCLING/STRESS FATIGUE, VIB, COMB INSTAB, SHOCK, BLOODED 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-INCREDIBLE 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 STRUCT & 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).
PLT IMPACT OF HLT GASES ON MODULE STRUCT & ADJ THRUSTERS. BURN-THRU MAY CAUSE HIGH TEMP DAM TO SURR STRUCT & ADJ THRUSTERS RESULTING IN POSS ENTRY HAZ IF TPS IS DAMAGED.
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : VERNIER THRUSTER
P/N RI : MC467-0029
P/N VENDGR: 
QUANTITY: 4
PREPARED BY: DES
APPROVED BY: DES
REL C M AKERS REL

ITEM: THRUSTER, ASSY, VERNIER
25 POUND THRUST LEVEL, EN 357/358/257/258
FUNCTION:
ONE PITCH (2 AXES-UP FIRING) AND ONE YAW (PLUS/MINUS Y AXIS) VERNIER THRUSTER ARE PROVIDED IN EACH APCS MODULE TO PROVIDE PRECISE LOWER LEVEL PULSING AND ATTITUDE HOLD REQ'TD 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

CAUSE(S):
THERMAL CYCLING/STRESS FATIGUE, VIB, CCMA INSTAB, SHOCK, ALIGNED INJ
ORIFICES, HIGH TEMP/LOCALIZED HCT SPOTS/INADEQUATE COOLING NCZILE 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-INCR GN & USE OF ALT THRUSTERS (C) MISSION MODIFICATION/ABORT DECISION IF FAILURE CAUSES CABIN 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 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 QUAL FOR 500,000 CYCLES, 125,000 SEC BURN TIME, INLET VALVE TESTED FOR 500,000 WET CYCLES & 5000 DRY. (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, 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 REQMTS. TURNAROUND - VISUAL INSPECTION USING OPTICAL INSTRUMENTATION. SYSTEM FLUIDS ARE ANALYZED FOR EVIDENCE OF CONTAMINATION. PROPER INLET VALVE FUNCTION AND ELECTRICAL LOGIC POWER IS VERIFIED. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
MEETING MINUTES


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

2. Attendees
   - Lonnie Jenkins NASA/JSC X 3851'
   - Dave Latham Boeing/Reliability 527-0323 (FTS)
   - Don Cagle Boeing Reliability 527-0323 (FTS)
   - Herb Saxton Rockwell Propulsion/RCS X 4503
   - Larry Gladu Rockwell Systems Engineering X 1189

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-201010-1**: 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.
   - **03-2A-201020-1**: 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-202112-2: 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-211101-1: 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."
Approved by:

Larry Gladu, RI
System Engineering

Lonnie Jenkins
JSC Propulsion

Dave Latham
JSC Reliability (Boeing)

Don Cagle
JSC Reliability (Boeing)