ORBITER SUBSYSTEM

HARDWARE/SOFTWARE INTERACTION ANALYSIS

VOLUME VIII: FORWARD REACTION CONTROL SYSTEM

January 1980
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 Forward 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 11/4/80

Chief, Reliability Division
THE HARDWARE/SOFTWARE INTERACTION ANALYSIS IS PREPARED BY RELIABILITY. IT IS ONE OF MANY ANALYSES AND DOCUMENTS USED BY THE SEAM TEAMS AND FRAT'S IN THE PLANNING AND MANAGEMENT OF THE VERIFICATION PROCESS. THE OVERALL VERIFICATION PROCESS LEADS UP TO THE FINAL FLIGHT READINESS STATEMENT FOR EACH SUBSYSTEM AND THE VEHICLE AS A WHOLE.
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1.0 INTRODUCTION. This report documents the results of the analysis of the hardware/software interaction analysis for the Forward 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:

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<td>XVI</td>
<td>Communications &amp; Tracking</td>
</tr>
<tr>
<td>XVII</td>
<td>Instrumentation</td>
</tr>
</tbody>
</table>
3.2 REFERENCE DOCUMENTS. The primary documents used in performing the analysis included the following:


g. SD75-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.
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 over-stress 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.**

   - **N/A** □ □
   - **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** □ □

   *Explanations required (see below)

**Change/Retention Rationale Summary**

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

---

**FMEA Change Recommended**

**Explanation/Comments:**

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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 announcating 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.

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

Figure 4-3. Hardware/Software Analysis Summary
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<th>ITEM/FAILURE MODE</th>
</tr>
</thead>
<tbody>
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<td>HARDWARE ACCEPTS RISK</td>
<td>Helium Storage Tank - Rupture (03-2F-101010-1)</td>
</tr>
<tr>
<td></td>
<td>Helium Feedline - External Leakage (03-2F-101013-1)</td>
</tr>
<tr>
<td></td>
<td>Quick Fill Disconnect, He - Fails Open, Cap Leaks (03-2F-101070-1)</td>
</tr>
<tr>
<td></td>
<td>Test Quick Disconnect, Propellant - Ext. Leakage/Flight (03-2F-101090-1)</td>
</tr>
<tr>
<td></td>
<td>Propellant Line Flex Assy. - External Leakage (03-2F-102106-1)</td>
</tr>
<tr>
<td></td>
<td>Feedline and Fittings - External Leakage (03-2F-102108-1)</td>
</tr>
<tr>
<td></td>
<td>AC Motor Operated Valve (Tank) - Fails Closed (03-2F-102120-1)</td>
</tr>
<tr>
<td></td>
<td>Quick Disconnect - External Leakage (03-2F-102150-1)</td>
</tr>
<tr>
<td></td>
<td>DC Solenoid Operated Valve - Fails Closed - Premature Operation</td>
</tr>
<tr>
<td></td>
<td>Tank Assembly and Propellant Acquisition Device - Small Crack - External Leakage (03-2F-111110-2)</td>
</tr>
<tr>
<td></td>
<td>Tank Assembly and Propellant Acquisition Device - Restricted Flow (03-2F-111110-3)</td>
</tr>
<tr>
<td></td>
<td>Tank Assembly and Propellant Acquisition Device - Loss of Gas in Propellant Acquisition Device (03-2F-111110-4)</td>
</tr>
<tr>
<td></td>
<td>Flex Line and Fittings - External Leakage (03-2F-121308-1)</td>
</tr>
<tr>
<td></td>
<td>Thrust Chamber - Burn Through (03-2F-121312-1)</td>
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<td></td>
<td>Nozzle Extension - Burn-Through (03-2F-121313-1)</td>
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<td>Vernier Thruster - Erratic Operation (03-2F-131310-3)</td>
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<td>Helium Pressure Regulator - Fails Closed (03-2F-101030-2)</td>
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<td>Tank Assembly and Propellant Acquisition Device - Large Rupture (03-2F-111110-1)</td>
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<td>Purge Quick Disconnect, Propellant - External Leakage During Flight (03-2F-101080-1)</td>
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<td></td>
<td>Helium Quad Check Valve - Fails Closed (03-2F-101095-2)</td>
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<tr>
<td></td>
<td>Vernier Thruster - Loss of Output (03-2F-131310-1)</td>
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### HARDWARE/SOFTWARE ANALYSIS SUMMARY

#### SUBSYSTEM: Forward Reaction Control

<table>
<thead>
<tr>
<th>ANALYSIS RESULT</th>
<th>ITEM/FAILURE MODE</th>
</tr>
</thead>
</table>
| NO HARDWARE/SOFTWARE ISSUES | D.C. Solenoid Valve - Fails to Close (03-2F-101020-3)  
D.C. Solenoid Valve - Fails Closed (03-2F-101020-4)  
Helium Pressure Regulator - Fails Open (03-2F-101030-1)  
Relief Valve - External Leakage Overboard (03-2F-101060-1)  
Relief Valve - Burst Disc Ruptures (03-2F-101060-2)  
Relief Valve - Fails to Burst (03-2F-101060-3)  
Relief Valve - Opens Low (03-2F-101060-4)  
Relief Valve - Fails to Open (03-2F-101060-5)  
Helium Quad Check Valve - Fails Open (03-2F-101095-1)  
Injector Plate - Mixture (03-2F-121311-1) |
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<tr>
<th>Analysis Result</th>
<th>Item/Failure Mode</th>
</tr>
</thead>
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<tr>
<td>OUT OF SCOPE - GROUND ONLY</td>
<td>Manual Valve - Fails Closed or Open (03-2F-101050-1)</td>
</tr>
<tr>
<td></td>
<td>Manual Valve - Internal Leakage (03-2F-101050-2)</td>
</tr>
<tr>
<td></td>
<td>Quick Fill Disconnect, He. - Fails Closed/Ground Ops (03-2F-101070-2)</td>
</tr>
<tr>
<td></td>
<td>Purge Quick Disconnect, Propellant - Fails Closed/Ground Ops. (03-2F-101080-2)</td>
</tr>
<tr>
<td></td>
<td>Test Quick Disconnect, Propellant - Fails Closed/Ground Ops. (03-2F-101090-2)</td>
</tr>
<tr>
<td></td>
<td>Quick Disconnect - Fails Closed/Ground Ops. (03-2F-102150-2)</td>
</tr>
</tbody>
</table>
6.0 ANALYSIS CHECKLIST SHEETS

Following are the analysis checklist sheets for each failure mode evaluated.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST

**SUBSYSTEM**: Fwd Reaction Control  
**FMEA NUMBER**: SD75-SH-0016A  
**ITEM**: Helium Storage Tank  
**FAILURE MODE**: Rupture

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE</strong> (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1a. <strong>IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?</strong></td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>2. <strong>ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?</strong></td>
<td>YES</td>
<td><em>NO</em></td>
</tr>
<tr>
<td>3. <strong>DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3a. <strong>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)?</strong></td>
<td><em>YES</em></td>
<td><em>NO</em> <em>X</em></td>
</tr>
<tr>
<td>4. <strong>AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?</strong></td>
<td><em>YES</em></td>
<td><em>NO</em> <em>X</em></td>
</tr>
<tr>
<td>5. <strong>CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?</strong></td>
<td><em>YES</em></td>
<td><em>NO</em> <em>X</em></td>
</tr>
<tr>
<td>6. <strong>HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)?</strong></td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>7. <strong>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?</strong></td>
<td>N/A</td>
<td><em>YES</em></td>
</tr>
</tbody>
</table>
| 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. [X] HARDWARE ACCEPTS RISK  
3. ☐ NO SOFTWARE DETECTION  
4. ☐ DETECTION DURING CHECKOUT  
5. ☐ ACCEPTANCE RATIONALE BELOW  
6. ☐ RECOMMENDED CHANGES BELOW

[☐] FMEA CHANGE RECOMMENDED

### EXPLANATION/COMMENTS:

1. GAX will give a class 2 alert upon sensing an out-of-tolerance condition. (≤500 psi) Gross leak detection will give a class 2 alert.

8. Backup flight system same as primary.
### SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER IC2

**SUBSYSTEM :** FWD - REACTION CONTROL
**ASSEMBLY :** PRESSURIZATION

**P/N RI :** MC282-0082-0031/-0032
**P/N VENDOR :** ELD-999040
**QUANTITY :** 2

**FMEA NO :** 03-2F -10101C-1  **REV :** 12/16/7

**ABORT :** CRIT.  **FUNC :** 1
**CRIT. HW :** 1
**MISSIONS :** HF, VF, FF, UF, SN
**PHASE(S) :** PL, LQ, QU, DU, LS
**NUMBER OF SUCCESS PATHS REMAINING :** C
**REDUNDANCY SCREEN :** A-N/A, B-N/A, C-N/A

**FAILURE DETECTABLE IN FLIGHT ?** YES
**PRESSURE INDICATION :** V42P-1110C
**GROUNDBASED AROUND ?** YES
**SAME AS FLIGHT**

**PREPARED BY :** DES J T A Taggart
**APPROVED BY :** DES R Diehl

**ITEM :** TANK
**FUNCTION :** TO STORE HELIUM AT A MAX WORKING PRESSURE OF 4600 PSI FOR PRESSURIZATION OF THE FWD RCS MODULE PROPellant SUPPLY SYSTEM. TANK CONSISTS OF A DOUBLE MELT Ti LINER WITH DUPONT 49 FIBER AND EPOXY RESIN FONDING OVER WRAP.

**FAILURE MODE :** RUPTURE, EXTERNAL LEAK
**RUPTURE - LARGE CRACK WHICH PROPAGATES AROUND TANK IMMEDIATELY.
**LEAKAGE - FRACTURE WHICH DOES NOT PROPAGATE TO RUPTURE.

**CAUSE(S) :** VIBRATION, STRESS CORROSION, TEMP. RISE, FATIGUE, INADVERTENT OVER-PRESSURIZATION (GROUND OPS).

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

(A) LOSS OF PRESSURIZATION TO FUEL OR OXIDIZER, (6) EXPLOSIVE

**CORRECTING ACTION :** NONE AVAILABLE EXCEPT POSSIBLE RESCUE IF VEHICLE STILL INTACT.

**REMARKS/HAZARDS :** HAZARD OF SHRAPNEL PROPAGATION, HOWEVER, UTILIZATION OF FILAMENT WOUND TANK MINIMIZES OR ELIMINATES THIS HAZARD. ADDITIONAL HAZARD OF MODULE OVER PRESSURIZATION STILL EXISTS. NO REDUNDANCY PROVIDED FOR THIS ITEM - REFERENCE HAZARD 1YXX-0302-02.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: FWD - REACTION CONTROL
FMEA NO: 03-2F-101010-1

ASSEMBLY: PRESSURIZATION
ABORT: CRIT. FUNC: 1

P/N/RI: 4C202-0082-0031/-0032
CRIT. HDW: 1

P/N VENDOR: BLD-999040
MISSIONS: HF, VF, X, FF, OF SM

QUANTITY: 2
PHASE(S): PL, LO, DO, DO, LS

ONE REQ'D PER EACH PROPELLANT TANK

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

PREPARED BY: J TAGGART
APPROVED BY: SSM

DES J TAGGART
REL R DIEHL

ITEM: TANK
HELlUM STORAGE, FILAMENT WOUND

FUNCTION:
TO STORE HELIUM AT A MAX WORKING PRESSURE OF 4000 PSI FOR
PRESSURIZATION OF THE FWD RCS MODULE PROPELLANT SUPPLY SYSTEM. TANK
CONSISTS OF A DOUBLE MELT Ti LINER WITH DUPONT 49 FIBER AND EPOXY RESIN
BONDING OVER WRAP.

FAILURE MODE: RUPTURE, EXTERNAL LEAK (S)
RUPTURE - LARGE CRACK WHICH PROPAGATES AROUND TANK IMMEDIATELY.
LEAKAGE - FRACTURE WHICH DOES NOT PROPAGATE TO RUPTURE.

CAUSE(S):
VIBRATION, STRESS CORROSION, TEMP. RISE, FATIGUE, INADVERTENT
OVER-PRESSURIZATION (GROUND OPS).

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF PRESSURIZATION TO FUEL OR OXIDIZER. (B) EXPLOSIVE
EXPANSION OF HELIUM WITHIN RCS MODULE. (C) POTENTIAL LOSS OF
MISSILE-ABORT DECISION DEPENDANT ON EXTENT OF DAMAGE. (D) POTENTIAL
LOSS OF CREW/VEHICLE.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) FILAMENT WOUND TANKS ARE DESIGNED TO LEAK BEFORE RUPTURE WHICH
LIMITS FAILURE PROPAGATION DUE TO SCHRAPNEL. INCREASED STRAIN
CAPABILITY IS PROVIDED BY THE COMPRESSIVE LOAD ON AN UNPRESSURIZED
LINER. THE FACTOR OF SAFETY IS 1.5 X MAX WORKING PRESSURE OF 4000 PSI.
DUAL SEALS ARE PROVIDED AT TANK FLANGE. (B) TANKS ARE SUBJECTED TO
PROOF PRESSURE (1.1X WORKING PRESSURE) DURING ACCEPTANCE TESTING.
QUAL TESTS INCLUDE 1000 PRESSURE CYCLES EQUAL TO 4 TIMES LIFE REQUIREMENT,
90 DAY CREEP TEST AT MAX WORKING PRESSURE PLUS RANDOM VIBRATION AT
ANTICIPATED MISSION LEVELS FOR 48 MIN IN EACH AXiS. (C) IN PROCESS
INSPECTION INCLUDES RADIO GRAPHIC INSPECTION OF VELDS & FLUORESCENT
PENETRATION INSPECTION FOR SURFACE FLAWS. TURNAROUND CYCLE FOR EVIDENCE
OF RUPTURE. AUDIT CONDUCTED 3/9/78 VERIFIED SUPPLIER RECEIVING
INSPECTION CONTROLS RAW MATERIAL AND PURCHASED COMPONENTS AND IN-HOUSE
INSPECTION CONTROLS CORROSION PROTECTIVE PROVISIONS, TEST HANDLING
STORAGE ENVIRONMENTS, MEASUREMENT STANDARDS, TEST EQUIPMENT, NDE
TESTING, PARTS PROTECTION, MFG PROCESSES AND FINISHES. CHEMICAL ETCHING,
X-RAY AND PROOF TEST OF LINER AND MECHANICAL PROPERTIES AFTER HEAT
tREAT ALSO VERIFIED BY INSPECTION. (D) NO HISTORY AVAILABLE. TANK IS
BEING DEVELOPED FOR SHUTTLE PROGRAM.
### SUBSYSTEM: Fwd Reaction Control

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<tr>
<td>FAILURE MODE</td>
<td>External Leakage</td>
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#### Checklist:

1. **Does the flight software detect this failure mode (i.e., automatically announce or take action in response)?**
   - Yes [X] No

   a. **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

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

4. **As a result of this failure mode, can the software over-stress 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 (considering crew action and hardware/software operation)? Note change to FMEA criticality.**
   - 1 [X] 2 [ ]

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

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

*Explanation required (see below)*

#### Change/Retention: Rationale Summary:

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

#### Explanation/Comments:

1. GAX will give a class 2 alert upon sensing an out-of-tolerance condition. (<500 psi)
   Gross leak detection will give a class 2 alert.

8. Backup flight system same as primary.
SUBSYSTEM: FWD - REACTION CONTROL

ASSEMBLY: PRESSURIZATION HELIUM - ABORT:

P/N RI: V670-421701

P/N VENDOR:

QUANTITY: 2

ONE SET PER PROPPELLANT

Heliometer: CRITICAL F/N: 1

P/N POSITION: MISSIONS: HF, VF, X, FF, CH, SM

FAILURE DETECTABLE IN FLIGHT? YES

TIME TO EFFECT: IMMEDIATE

REFERENCE DOCUMENTS:

GROUND TURNAROUND? YES
SAME AS FLIGHT INSTRUMENTATION

PREPARED BY: DES A SIEGELNI

APPROVED BY: DES

REL R DIEHL

ITEM: HELIUM FEED LINE AND FLUID FITTINGS.

FUNCTION:

TO PROVIDE FEED LINE FROM HELIUM TANKS TO HELIUM REGULATION/PRESSURIZATION SYSTEM AND TO PROPPELLANT TANKS.

FAILURE MODE: EXTERNAL LEAKAGE (S)

CAUSE(S):

MECHANICAL SHOCK, VIBRATION/FATIGUE, IMPROPER INSTALLATION (WELL), FLUID FITTING SEAL FAILURE.

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

(A) LOSS OF HELIUM SUPPLY IF NOT ISOLATABLE. (IE. IF UPSTREAM OF SCREDE VALVE). (B) POTENTIAL OVERPRESSURIZATION OF FORWARD MODULE FROM GROSS LEAK. (C,D) POTENTIAL MODULE DAMAGE RESULTING IN LOSS OF MISSION/CREW/VEHICLE IF GROSS LEAK OCCURS DURING CRITICAL MANEUVERS.

CORRECTING ACTION:

INITIATE ABORT. CHECK VALVES MAINTAIN PROPPELLANT TANK RESIDUAL GAS PRESSURE TO ALLOW POTENTIAL PLUG DOWN MODE UTILIZATION.

REMARKS/HAZARDS:

NO REDUNDANCY PROVIDED FOR LINES. IF LEAK RATE IS EXCESSIVE PRESSURE BUILD-UP IN MODULE MAY RESULT IN HAZARD. SEE HAZARD IYXX-0402-02.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: FWO - REACTION CONTROL
ASSEMBLY: PRESSURIZATION HELIUM -
P/N: V070-421701
P/N VENDOR: MISSIONS: HF VF X FF OF SH
QUANTITY: 2
: ONE SET PER PROPELLANT

PREPARED BY: DES RIEHL REL
APPROVED BY: SSN
APPROVED BY: (NASA):

ITEM: HELIUM FEED LINE AND FLUID FITTINGS.
FUNCTION:
TO PROVIDE FEED LINE FROM HELIUM TANKS TO HELIUM REGULATION/PRESSURATION SYSTEM AND TO PROPELLANT TANKS.
FAILURE MODE: EXTERNAL LEAKAGE (S)

CAUSE(S):
MECHANICAL SHOCK, VIBRATION/FATIGUE, IMPROPER INSTALLATION (WELD), FLUID FITTING SEAL FAILURE.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF HELIUM SUPPLY IF NOT ISOLATABLE. (IE. IF UPSTREAM OF SOLENOID VALVE). (B) POTENTIAL OVERPRESSURIZATION OF FWD MODULE FROM GROSS LEAK. (C,D) POTENTIAL MODULE DAMAGE RESULTING IN LOSS OF MISSION/CREW/VEHICLE IF GROSS LEAK OCCURS DURING CRITICAL MANEUVERS.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) FACTOR OF SAFETY OF 4.0 WILL MINIMIZE FAILURE POTENTIAL. FLUID FITTINGS HAVE DUAL SEALS. WELD CONSTRUCTION REDUCES JOINTS AND POSSIBLE LEAK PATHS. FASTENING CLAMPS AND TUBE BEND DESIGN ALLOWS DEGREE OF MOVEMENT WHICH HELPS PREVENTING LEAKS. (B) POST INSTALLATION TEST AND OPERATIONAL CHECKOUTS WILL VERIFY SYSTEM INTEGRITY. ALL LINES SUBJECTED TO 1.25 PROOF TEST. (C) IN PROCESS INSPECTION INCLUDES NDT & LEAK CHECKS DURING INSTALLATION. TURNAROUND INSPECTION INCLUDES MONITORING FUNCTIONAL TESTS DURING PRESSURIZATION CYCLE FOR EVIDENCE OF LEAKS. WHERE ACCESSIBLE VISUALLY INSPECT FOR DAMAGE. HARDWARE INSPECTION IN ACCORDANCE WITH PLANNING REQUIREMENTS APPROVED BY NASA. (D) MINOR FAILURE HISTORY-CORROSION AND FAB PROBLEMS REPORTED DURING APOLLO PROGRAM AND CORRECTED.

WITH APPLICABLE TMO/TPC REQUIREMENT. HARDWARE INSPECTION IN ACCORDANCE WITH PLANNING REQUIREMENTS APPROVED BY NASA. (D) MINOR FAILURE HISTORY-CORROSION AND FAB PROBLEMS REPORTED DURING APOLLO PROGRAM AND CORRECTED.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101020-3

SUBSYSTEM  Fwd Reaction Control  FMEA NUMBER  SD75-SH-0016A
ITEM  D. C. Solenoid Valve - Helium  FAILURE MODE  Fails to Close

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 [ ] *

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

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

---

In-Flight Detectability
[x] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Switch scan will detect failure in OPS-2 only and only on demand. May not be used on STS-1.
SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORION IC2

SUBSYSTEM : FWD - REACTION CONTROL
ASSEMBLY : PRESSURIZATION
P/N PI : MC284-0419-0011/0012
P/N VENDOR: Y3835
QUANTITY : 4

PRESSURIZATION ABORT: CRIT. FUNC:
MISSIONS: HF VF X HF OF SM
QUANT ITY: 4
PHASE(S): PL X LD X DO X DO X LS
TWO REQ'D PER PRESSURANT
NUMBER OF SUCCESS PATHS REMAINING
FEED ASSEMBLY AFTER FIRST FAILURE: 2
REDUNDANCY SCREEN: A-PASS A-PASS C-PASS
FAILUPE DETECTABLE IN FLIGHT? YES
HELIUM TANK PRESS. V42P 1110,1112,1113,1114,
AND PRESS LINE: V42P1115, 1116 AND POSITION IND.
GROUND TURNAROUND? YES
SAME AS FLIGHT INSTR.

PREPARED BY:
R BURKHART
REL

APPROVED BY:
R DIEHL

ITEM: VALVE, D.C. SOLENOID, OPERATED, HIGH PRESSURE. HE (2600-4000 PSIA) SOLENOID ACTUATED, 1/2"-STABLE, (1/2") (LV 101/102/103/104).

FUNCTION:
THESE VALVES ARE UTILIZED TO CONTROL HELIUM PRESSURIZATION OF THE RCS MODULE. IN THE OPEN POSITION A FLOW PATH IS PROVIDED FROM THE HELIUM SUPPLY TANK(S) TO THE REGULATOR(S). TWO PARALLEL PATHS ARE PROVIDED FOR FUEL AND OXIDIZER. ONE PATH IS NORMALLY OPEN PER TANK. THE VALVE IS CLOSED AND PARALLEL VALVE OPENED SUBSEQUENT TO A DOWNSTREAM FAILURE.

FAILURE MODE: FAILS TO CLOSE (F)
WHEN COMMANDED TO ISOLATE DOWNSTREAM FAILURES

CAUSE(S):
CONTAMINATION, VIBRATION, LOSS OF ELECTRICAL INPUT, IMPROPER OPENING ACTUATION, PIECE PART FAILURE.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A,B,C) NO EFFECT, VALVE IS FUNCTIONED (CLOSED) ONLY SUBSEQUENT TO A 2ND ORDER FAILURE. (B) NO EFFECT, DOES NOT INTERFACE WITH OTHER SUBSYSTEMS.

CORRECTING ACTION:
NONE

REMARKS/HAZARDS:
NONE

OF POOR QUALITY
HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101020-4

SUBSYSTEM Fwd Reaction Control
FMEA NUMBER SD75-SH-0016A
ITEM D. C. Solenoid Valve - Helium
FAILURE MODE Fails Closed

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

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

□ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:
1. Switch scan will detect failure in OPS-2 only and only on demand.
   May not be used on STS-1.
SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PRESURIZATION
P/N: MC284-0419-0C11/-0C12
P/N VENDOR: 73E35
QUANTITY: 4
MISSIONS: HF VF X HF OF SM
PHASE(S): PL X LG X CG X DU X LS

ASSY: PRESSURIZATION ABORT
CRIT. FUNC: IIR
CRIT. HWC: 2

FAILURE DETECTABLE IN FLIGHT? YES
MISSION TANK PRESSURE AND POSITION INDICATION
V2X-I120X, I122X, I124X, 1126X
GROUND TURMAROUND?.............YES
SAME AS FLIGHT INSTR.

PREPARED BY: DES , R BURKHART
APPROVED BY: DES , R DIEHL

ITEM: VALVE, D.C. SOLENOID (Helium - Pressurization System)
OPERATED, HIGH PRESSURE. HE (3600-4400 PSIA) SOLENOID ACTIVATED,
81-STABLE, (1/2") (LV 101/102/103/104).

FUNCTION:
THESE VALVES ARE UTILIZED TO CONTROL HELIUM PRESSURIZATION OF THE RCS
MODULE. IN THE OPEN POSITION A FLOW PATH IS PROVIDED FROM THE HELIUM
SUPPLY TANK(S) TO THE REGULATOR(S). TWO PARALLEL PATHS ARE PROVIDED
FOR FUEL AND OXIDIZER. ONE PATH IS NORMALLY OPEN PER TANK. THE VALVE
IS CLOSED AND PARALLEL VALVE OPENED SUBSEQUENT TO A DOWN STREAM
FAILURE.

FAILURE MODE: FAILS CLOSED (F)

CAUSE(S):
VIBRATION, CONTAMINATION CONTINUOUS INADVERTENT CLOSING SIGNAL DUE TO
SHORT CIRCUIT, PIECE PART FAILURE.

EFFECT(S): UN (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF REDUNDANT PRESSURIZATION PATH. (B, D) NO EFFECT. (C)
ABORT DECISION DEPENDENT ON MISSION PHASE AND BLUEDOWN CAPABILITY.

CORRECTING ACTION:
IF CAUSED BY VIBRATION, THE VALVE MAY BE CAPABLE OF OPENING WITH A NEW
COMMAND OR, SWITCH TO PARALLEL REGULATION PATH - COMMAND PARALLEL
ISOLATION VALVE OPEN.

REMARKS/HAZARDS:
POTENTIAL HAZARD IN ABORT SITUATION. SEE CONSOLIDATED CONTROLS FMEA
NUMBER 73835 FMEA 1.
SUBSYSTEM: FWD - REACTION CONTROL  
ASSEMBLY: PRESSURIZATION ABORT: CRIT. FUNC: 1R
P/N Ri: MC284-0419-0011/0012  CRIT. HDW: 2
P/N VENDOR: 73835 MISSIONS: HF VF X FF OF SM
QUANTITY: 4 PHASE(S): PL X LO X 00 X DO X DO X LS

TWO REQ'D PER PRESSURANT FEED ASSEMBLY

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

PREPARED BY: APPROVED BY:
DES R BURKHART DES APPROVED BY (NASA):
REL R DIEHL REL

ITEM: VALVE, D.C. SOLENOID
OPERATED, HIGH PRESSURE. HE (3600-4000 PSIA) SOLENOID ACTUATED, BI-STABLE, (1/2") (LV 101/102/103/104).

FUNCTION:
THESE VALVES ARE UTILIZED TO CONTROL HELIUM PRESSURIZATION OF THE RCS MODULE. IN THE OPEN POSITION A FLOW PATH IS PROVIDED FROM THE HELIUM SUPPLY TANK(S) TO THE REGULATOR(S). TWO PARALLEL PATHS ARE PROVIDED FOR FUEL AND OXIDIZER - ONE PATH IS NORMALLY OPEN PER TANK. THE VALVE IS CLOSED AND PARALLEL VALVE OPENED SUBSEQUENT TO A DOWNSTREAM FAILURE.

FAILURE MODE: FAILS CLOSED

CAUSE(S):
- VIBRATION, CONTAMINATION CONTINUOUS INADVERTENT CLOSING SIGNAL DUE TO SHORT CIRCUIT, PIECE PART FAILURE.

EFFECT(S):
- (A) LOSS OF REDUNDANT PRESSURIZATION PATH. (B, D) NO EFFECT. (C) ABORT DECISION DEPENDENT ON MISSION PHASE AND BLOWDOWN CAPABILITY.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) SERIES CONTROL CIRCUITRY PROVIDED TO MINIMIZE FAILURE MODE, 100 MICRON FILTER IS PROVIDED. MEDIA HAS BEEN FILTERED TO 25 MICRON PRIOR TO ENTERING TANK. SPECIAL EMPHASIS PLACED ON THE DESIGN AND LAYOUT OF SOLENOID WIRING TO PRECLUDE SHORTS. (B) QUAL TEST INCLUDES 48 MINUTES PER AXIS OF RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS AND LIFE TESTING CONSISTING OF 2200 OPERATING CYCLES. ITEM IS USED DURING SYSTEM EVALUATION AT WHITE SANDS TESTING. (C) TURNAROUND INSPECTION INCLUDES MONITORING TESTS TO VERIFY ELECTRICAL POWER TO SOLENOID VALVE FOR EVIDENCE OF SHORT CIRCUIT. SUPPLIER AUDIT CONDUCTED 8-31-77 VERIFIED SUPPLIER INSPECTION EXERCISED CONTROL OF PARTS ID, PARTS PROTECTION, MFG PROCESSES, CONTAMINATION CONTROL, AND CORROSION PROTECTION VERIFICATION. (D) THERE IS NO FAILURE HISTORY FOR THIS SPECIFIC DESIGN.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST

SUBSYSTEM: Fwd. Reaction Control

ITEM: Helium Pressure Regulator
FAILURE MODE: Fails Open

FMEA NUMBER: SD75-SH-0016A

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY:

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

EXPLANATION/COMMENTS:

1. Detection of this failure mode is not desired as these are redundant series regulators.
SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: MC 224-0418
VENDOR: 743901
QUANTITY: 4

NUMBER OF SUCCESS PATHS REMAINING: 2

FAILURES DETECTABLE IN FLIGHT?: N/A
STANDBY UNIT

GROUND TURNAROUND?: YES
GROUND CHECKOUT TEST PORTS

PREPARED BY: DES J. TAGGART
APPROVED BY: DES R. DIEHL

ITEM: REGULATOR, PRESS, HE, SERIES REDUNDANT, SET AT UNEQUAL OUTLET PRESSURES - PRIMARY SET LOWER THAN SECONDARY (PR 101/102/103/104).

FUNCTION:
TO REGULATE STORED HELIUM PRESSURE FROM 4300 PSIG MAX TO ULLAGE PRESSURE OF 245 (+ OR -3) PSIG FOR PURPOSE OF PROPELLANT FED TO THRUSTERS. TWO PARALLEL PATHS WITH TWO SERIES REGS ARE PROVIDED FOR EACH PROPELLANT TANK.

FAILURES DETECTABLE IN FLIGHT?: N/A
OR LEAKS INTERNALLY.

CAUSE(S):
CONTAMINATION, VIBRATION, PIECE PART STRUCTURAL FAILURE - FLEXURES, SELLOWS, POPPET ASSY.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF ONE REGULATOR ELEMENT IN ONE PATH (PRIMARY) AND RISE IN PROPELLANT FEED PRESSURE TO SECONDARY REGULATOR ELEMENT PRESSURE SETTING. (B, C, D) NONE.

CORRECTING ACTION:
NONE REQUIRED - SERIES REGULATOR ELEMENT WILL AUTOMATICALLY TAKE OVER FUNCTION.

REMARKS/HAZARDS:
SEE FAIRCHILD FMEA # RR74339-12.
1. **Does the flight software detect this failure mode (i.e., automatically announce or take action in response)?**
   - Yes [x], No [ ], Not Applicable [ ]

   **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 [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?**
   - Not Applicable [ ], 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], Not Applicable [ ]

   B. **Will BFS tolerate failure without loss of crew/vehicle?**
      - Yes [x], No [x], Not Applicable [ ]

   *Explanation required (see below)*

### Change/Retention Rationale Summary

|--------------------|-------------------------------|-----------------------------|-------------------------------|-------------------------------|-------------------------------|

FMEA should be changed from "NA" to "yes" for in-flight detectability via V42P115C and 1116C.

**FMEA Change Recommended**

### Explanation/Comments:

1. V42P115C, 1116C, will sense the pressure drop initiating a class 2 alarm from GAX.

2. Failure is "hardware detectable" by V42P115C and V42P116C pressure drop.

3. Upon regulator failure the redundant parallel "leg" can be utilized.
SUBSYSTEM: FW0 - REACTION CONTROL

ASSEMBLY: PRESSURIZATION

P/N: MC284-0419

P/N VENDOR: 7435001

QUANTITY: 4

ASSEMBLY: PRESSURIZATION ASSEMBLY

P/N: R284-D41

MISSIONS: HF, VFF, XFF, OF, SM

PHASE(S): PL, LO, GO, DO, X, LS

FAILURE DETECTABLE IN FLIGHT? NA

STANDBY REDUNDANCY

GROUND TURNAROUND? YES

GROUND CHECKOUT TEST PORTS

PREPARED BY: DES J. TAGGART

APPROVED BY: DES R. DIEHL

REFERENCE DOCUMENTS:

V570-421101

MG70-6611-01E

SD72-SH-0103-2

ITEM: REGULATOR, PRESS, HE.

SERIES REDUNDANT. SET AT UNEQUAL OUTLET PRESSURES - PRIMARY SET LOWER THAN SECONDARY (PR 102/103/104).

FUNCTION:

TO REGULATE STORED HELIUM PRESSURE FROM 4000 PSIG MAX TO VACUUM 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.

FAILURE MODE: FAILS CLOSED (F)

LOW PRESSURE

CAUSE(S):

CONTAMINATION (PARTIAL BLOCKAGE OF PILOT SCREEN) FROZEN MOISTURE PIECE PART FAILURE, VIBRATION.

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

(A) LOSS OF ONE REGULATOR PATH. (B,C) POTENTIAL ABORT BECAUSE ONE ADDITIONAL FAILURE MAY CAUSE LOSS OF PRESSURIZATION AND SUBSEQUENT VEHICLE LOSS. (D) NONE. (E) FUNCTIONAL CRITICALITY EFFECTS - IF FAILURE OCCUR BEFEE SEPARATION, LOSS OF HELIUM WOULD PREVENT SEPARATION AND LOSS OF CREW/VEHICLE WOULD RESULT.

CORRECTING ACTION:

CLOSE HIGH PRESSURE ISOLATION VALVE IN EFFECTED PATH AND OPEN HIGH PRESSURE ISOLATION VALVE IN PARALLEL PATH.

REMARKS/HAZARDS:

POTENTIAL ABORT BECAUSE ONE ADDITIONAL FAILURE (CLOSED) MAY CAUSE LOSS OF PRESSURIZATION AND SUBSEQUENT VEHICLE LOSS (REQUIRES 2NO, ORLANDO FAILURE) DEPENDENT ON MISSION PHASE. SEE FAIRCHILD FMEA & RM 7435-1E.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N RI: MC284-0418
P/N VENDOR: 74339001
QUANTITY: 4

MISSIONS: HF VF XF FF SF SM
PHASE(S): PL LO X 00 X 00 X LS

PREPARED BY:
APPROVED BY:

ITEM: REGULATOR, PRESS, HE,
SERIES REDUNDANT. SET AT UNEQUAL OUTLET PRESSURES - PRIMARY SET LOWER THAN SECONDARY (PR 101/102/103/104).

FUNCTION:
TO REGULATE STORED HELIUM PRESSURE FROM 4000 PSIG MAX TO ULLAGE PRESSURE OF 245 (+ OR -3) PSIG FOR PURPOSE OF PROPELLANT FEED TO THRUSTERS. TWO PARALLEL PATHS WITH TWO SERIES PEGS ARE PROVIDED FOR EACH PROPELLANT TANK.

FAILURE MODE: FAILS CLOSED (F)

CAUSE(S):
- CONTAMINATION (PARTIAL BLOCKAGE OF PILOT SCREEN) FROZEN MOISTURE PIECE PART FAILURE, VIBRATION.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
- (A) LOSS OF ONE REGULATOR PATH. (B,C) POTENTIAL ABORT BECAUSE ONE ADDITIONAL FAILURE MAY CAUSE LOSS OF PRESSURIZATION AND SUBSEQUENT VEHICLE LOSS. (D) NONE.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) EXPERIENCE FROM PREVIOUS REGULATOR DESIGN TO BE APPLIED TO PRECLUDE PIECE PART FAILURE AND SELF GENERATED CONTAMINATION. ALSO, 25 MICRON INTEGRAL INLET FILTER PROVIDED TO MINIMIZE CONTAMINANTS. (B) QUAL TESTING INCLUDES 28 HOUR SAND AND DUST TEST, 48 MINUTES PER AXIS OF RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS AND LIFE CYCLE TESTS OF 50,000 CYCLES FOR THE MAIN STAGE AND 100,000 CYCLES FOR PILOT STAGE. (C) TURNAROUND INSPECTION INCLUDES MONITORING TESTS TO VERIFY FUNCTIONAL OPERATION IS WITHIN SPECIFIED LIMITS. SUPPLIER AUDIT CONDUCTED VERIFIES WITHIN SPECIFIED LIMITS. SUPPLIER AUDIT CONDUCTED VERIFIES SUPPLIER CONTAMINATION CONTROL, AND STORAGE ENVIRONMENT. (D) NEW DESIGN FOR SHUTTLE APPLICATION. NO FAILURE HISTORY DATA AVAILABLE FOR THIS DESIGN.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101050-I

SUBSYSTEM Fwd. Reaction Control  FMEA NUMBER SD75-SH-0016A
ITEM Manual Valve  FAILURE MODE Fails Closed or Open

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RECOMMENDATION RATIONALE SUMMARY

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

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. If valve is cracked open V42P1115A, 1116A would alarm.

6. There are no success paths remaining after first failure.
SUBSYSTEM: FWO - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: MC284-0480-0001-0002
P/N VENDOR: 5760015, 5760016
QUANTITY: 2

FAILURE DETECTABLE IN FLIGHT?: YES
TIME TO EFFECT: SECONDS TO MINUTES

PROPPELLANT TANK PRESSURE: V42P-1210, 1115, 1116, 1310
GROUND TURNAROUND?: YES
SAME AS FLIGHT

PREPARED BY: DES R. GONZALEZ
APPROVED BY: DES R DIEHL

ITEM: VALVE, MANUAL-OPERATED.
FUNCTION:
TO PROVIDE ISOLATION OF PROPPELLANT TANK(S) FROM PRESSURE CYCLES WHILE PERFORMING GROUND C/O AND/OR SERVICING OF PRESSURIZATION SYSTEM.

FAILURE MODE: FAILS CLOSED OR OPEN ( )
STRUCTURAL FAILURE.
CAUSE(S):
SEVERE MECHANICAL SHOCK OR VIBRATION CAUSING DETENT MOVEMENT ON A DEFICIENT VALVE LOSS OF INTERLOCK BY FRACTURE OF DRIVE FINGER OR RUCKER, CORROSION, CONTAMINATION, IMPROPER USE.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) (B) LOSS OF FUNCTION (IN ABILITY TO PERFORM SYS C/O). (C) LAUNCH DELAY. (D) NO EFFECT.

CORRECTING ACTION:
NONE AVAILABLE.

REMARKS/HAZARDS:
NO HAZARDS IDENTIFIED.
ITEM Manual Valve

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 COMMANING 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 COMMANING 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 ☑ 1 ☐

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. If valve is cracked open V42P1115A, 1116A would alarm.

6. There are no success paths remaining after first failure.
ITEM: VALVE, MANUAL-OPERATED.

FUNCTION:
TO PROVIDE ISOLATION OF PROPELLANT TANK(S) FROM PRESSURE CYCLES WHILE PERFORMING GROUNDC/O AND/OR SERVICING OF PRESSURIZATION SYSTEM.

FAILURE MODE: EXCESSIVE INTERNAL LEAKAGE.

CAUSE(S):
SEVERE MECHANICAL SHOCK OR VIBRATION CAUSING DETENT MOVEMENT ON A DEFICIENT VALVE LOSS OF INTERLOCK BY FRACTURE OF FIVE FINGER OR RUCKER, CORROSION, CONTAMINATION, IMPROPER USE.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACE (C) MISSION (D) CREW/VEHICLE:
(A, B) LOSS OF FUNCTION (IN ABILITY TO PERFORM SYS C/O). (C) LAUNCH DELAY. (D) NO EFFECT.

CORRECTING ACTION:
NONE AVAILABLE.

REMARKS/HAZARDS:
NO HAZARDS IDENTIFIED.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101060-1

<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>Reaction Control</th>
<th>FMEA NUMBER</th>
<th>SD75-SH-0016A</th>
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</thead>
<tbody>
<tr>
<td>ITEM</td>
<td>Relief Valve</td>
<td>FAILURE MODE</td>
<td>External Leakage Overboard</td>
</tr>
</tbody>
</table>

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

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

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

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

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

6. **HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)?**
   - 1 [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] Yes [X] No

   **B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?**
   - Yes [X] Yes [X] No

*EXPLANATION REQUIRED (SEE BELOW)*

**CHANGE/RETENTION RATIONALE SUMMARY**

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

**EXPLANATION/COMMENTS:**

1. Leakage of helium will cause a class 2 alarm.
   Gross leak detection should occur first.
SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBIT 102

SUBSYSTEM: FWD - REACTION CONTROL

ASSMEYLY: PRESSURIZATION

P/N: HC394-0421-0001/-0002

P/N VENDOR: 5760009-101, 5760010-102

QUANTITY: 2

MEASURES: HF, VF, X, FF, OF, SM

FUNCTION: ONE REQ'D PER TANK

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

FAILURDE DETECTABLE IN FLIGHT?: YES

PRESSURE DECAY IN PRESS SYSTEM VI-2P-1115C AND HOURS

GROUND TURNAROUND?: YES

TEST PORT FOR GROUND CHECKOUT AND BACK CHECK

PREPARED BY:

DES R GONZALEZ

APPROVED BY:

DES R DIEHL

ITEM: VALVE, PRESS, RELIEF

CRACKING PRESS 315 PSIG, FULL OPEN 340 PSIG, RESEAT 31C PSIG (RV 101/102)

FUNCTION:

RELIEF VALVE PROVIDED TO PREVENT RISE OF TANK AND LINE PRESSURES TO LEVELS WHICH COULD BE DETRIMENTAL TO SUBSYSTEM.

FAILUR DE MODE: EXTERNAL LEAK

CAUSES:

GALVANIC CORROSION, IMPROPER INSTALLATION/HANDLING, FATIGUE OR STRUCTURAL FAILURE.

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

(A&B) SUBSYSTEM DEGRADATION - HELIUM LEAKS OVERBOARD AT RATE CONTROLLED

BY ORIFICE. (C&D) NO EFFECT UNLESS LEAK IS EXCESSIVE.

CORRECTING ACTION:

MONITOR SYSTEM FOR HELIUM LOSS.

REMARKS/HAZARDS:

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

   - YES ☑ NO ☐

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

   - *YES ☐ NO ☐

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

   - YES ☑ *NO ☐

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

   - YES ☑ NO ☐

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

   - *YES ☐ NO ☐

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

   - *YES ☐ NO ☐

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

   - *YES ☐ NO ☐

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

   - *0 ☐ 1 ☐ 2 ☑

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

   - N/A ☑ YES ☐ NO ☐

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

   - A. **CAN THE BFS BE ENGAGED AFTER OCCURRENCE?**
     - YES ☑ NO ☐

   - B. **WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?**
     - YES ☑ NO ☐

   *EXPLANATION REQUIRED (SEE BELOW)*

---

**CHANGE/RETENTION RATIONALE SUMMARY**

1. ☐ NO H/S ISSUES

2. ☑ HARDWARE ACCEPTS RISK

3. ☐ NO SOFTWARE DETECTION

4. ☐ DETECTION DURING CHECKOUT

5. ☐ ACCEPTANCE RATIONALE BELOW

6. ☑ RECOMMENDED CHANGES BELOW

---

**In-Flight Detectability**

*FMEA CHANGE RECOMMENDED*

---

**EXPLANATION/COMMENTS:**

1. May see discrete drop in RCS quantity. V42P1115C, 1116C will give class 2 caution and warning alarm.
| SUBSYSTEM: FWD - REACTION CONTROL | FMEA NO: C3-2F-101060-2 | REV: 01/04/7 |
| ASSEMBLY: PRESSURIZATION | ABCRT: | CRIT. FUNC: |
| P/N RI: MC284-0421-0001/-0002 | | |
| P/N VENDOR: 57600109-101, 576001010-102 | MISSIONS: HF VF X HH UF SM |
| QUANTITY: 2 | PHASE(S): PL X LO X CU X DO X LS |
| | NUMBER OF SUCCESS PATHS REMAINING |
| | AFTER FIRST FAILURE: 2 |
| FAILURE DETECTABLE IN FLIGHT?: NO | REDUNDANCY SCREEN: A-PASS B-PASS C-PASS |
| GROUND TURNAROUND?: NO |
| |

**PREPARED BY:** DES R GONZALEZ  
**APPROVED BY:** DES R DIEHL

**ITEM:** VALVE, PRESS. RELIEF -  
**FUNCTION:** RELIEF VALVE PROVIDED TO PREVENT RISE OF TANK AND LINE PRESSURES TO LEVELS WHICH COULD BE DETRIMENTAL TO SUBSYSTEM.  
**FAILURE MODE:** FAILS OPEN  
**CAUSE(S):** REGULATOR PRESSURE SURGE, INCORRECT PRESSURE SETTING, FATIGUE, EXCESS PRESSURE CYCLING, VIB, MAT'TL DEFECT, PROP TEMP RISES.  
**EFFECT(S):** ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:  
(A, B) LOSS OF REDUNDANCY (LEAKAGE OR OPEN MODE), MAIN POPPET PROVIDES REDUNDANCY. (C, D) NO EFFECT.  
**REMARKS/HAZARDS:** NO HAZARDS IDENTIFIED.
**HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101060-3**  
**SUBSYSTEM**  Fwd Reaction Control  
**ITEM**  Relief Valve  
**FMEA NUMBER**  SD75-SH-0016A  
**FAILURE MODE**  Fails to Burst

<table>
<thead>
<tr>
<th>Question</th>
<th>YES</th>
<th>NO</th>
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<tbody>
<tr>
<td>1. Does the flight software detect this failure mode (i.e., automatically</td>
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<tr>
<td>1a. If not, does the hardware provide information that the flight software could</td>
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<td>2. Are the answers to questions 1 and 1a consistent with the FMEA evaluation of</td>
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<td>3. Does the flight software take action to negate the effects of the failure</td>
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<tr>
<td>3a. If not, does the capability exist for the software to compensate for this</td>
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<td>4. As a result of this failure mode, can the software overstress the hardware or</td>
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<td>7. If crew action is required to respond to this failure mode, are cues provided</td>
<td>N/A</td>
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</tr>
</tbody>
</table>
| 8. If the answer to either 1 or 3 is yes: 
  A. Can the BFS be engaged after occurrence? |     |    |   |   |
| 9. Will BFS tolerate failure without loss of crew/vehicle? |     |    |   |   |

*Explanation required (see below)*

**CHANGE/RETENTION RATIONALE SUMMARY**


**EXPLANATION/COMMENTS:**

1. Over pressurization will cause class 2 alarm; >312 psi. (GAX) V42P1115C, 1116C.
SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N R1: MC284-0421-0301/-0002
P/N VENDOR: 5760009-101, 5760010-102
QUANTITY: 2

FMEA NO 03-2F -101050-3  REV: 01/04/76

ABORT: CRIT. FUNC:
CRIT. HDD: 3

MISSIONS: HF VF XF OF SM

P/N R1: MC284-0421-0301/-0002
P/N VENDOR: 5760009-101, 5760010-102
QUANTITY: 2

ONE REQ'D PER TANK

AFTER FIRST FAILURE:

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

FAILURE DETECTABLE IN FLIGHT?: YES

MISSIONS: HF VF XF OF SM

PRESSURE RISE IN HELIUM SYSTEM V42P-1115C AND SECONDS

1115C (TANK ULLAGE PRESSURE)

GROUND TURNAROUND?...........YES

TURNAROUND TEST PORT PROVIDED

FUNCTION:

REMARKS/HAZARDS:

PREPARED BY:

APPROVED BY:

DES R GONZALEZ

DES R DIEHL

REL R DIEHL

REL

ITEM: VALVE, PRESS. RELIEF

CRCKNG PRESS 315 PSIG, FULL OPEN 340 PSIG, RESEAT 316 PSIG (KV 101/102)

FUNCTION:

RELIEF VALVE PROVIDED TO PREVENT RISE OF TANK AND LINE PRESSURES TO LEVELS WHICH COULD BE DETRIMENTAL TO SUBSYSTEM.

FAILURE MODE: FAILS TO BURST ( _ )

OK BURSTS AT A HIGHER THAN NOMINAL PRESSURE.

CAUSE(S):

IMPROPER INSTALLATION OR HANDLING DAMAGE THAT CAUSES DISC TO STICK PIECE PART FAILURE, PRESSURE BUILD UP ON REVERSE SIDE.

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

(A) NO EFFECT UNLESS MULTIPLE FAILURES OCCUR. (B) DEGRADATION OF INTERFACE SUBSYSTEM. PROP TANK ULLAGE PRESSURE MAY INCREASE ABOVE WORKING PRESSURE LIMITS. (C,D) NONE SEE (A) ABOVE.

CORRECTING ACTION:

CLOSE HELIUM ISOLATION VALVES, HOWEVER RELIEF COULD BE COMPLETED BY FIRING THRUSTERS.

REMARKS/HAZARDS:

NO HAZARDS, UNIT IS STANDBY - BACKUP FOR REGULATOR FAILURES. NO REDUNDANCY PROVIDED.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST

SUBSYSTEM: Fwd Reaction Control
FMEA NUMBER: 03-2F-101060-4
ITEM: Relief Valve
FMEA NUMBER: SD75-SH-0016A
FAILURE MODE: Opens Low

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

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

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

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

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

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

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

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

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

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

EXPLANATION REQUIRED (SEE BELOW)

In-Flight Detectability
☑ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Leakage of helium will cause an oxidizer/fuel imbalance of 12.6 percent. May get a gross leak detection alarm.
**SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102**

**SUBSYSTEM**: Reaction Control

**ASSEMBLY**: Pressurization

**P/N**: MC284-0421-0001-0002

**P/N VENDOR**: 5760C09-101, 5760010-102

**QUANTITY**: 2

**ONE REQ'D PER TANK**

**NUMBER OF SUCCESS PATHS REMAINING AFTER FIRST FAILURE**: 2

**REduNDANCy SCREEN**: A - E - C -

**FAILURE DETECTABLE IN FLIGHT?**. NO

**UNLESS EXCESSIVE PRESSURE DROP IS EVIDENT IN TANKAGE**

**GROUND TURNAROUND?**. NO

**SAME AS FLIGHT**

**PREPARED BY**: DES R. Gonzalez

**APPROVED BY**: DES R. Diehl

**ITEM**: Valve, Press. Relief

**CRACKING PRESS 315 PSIG, FULL OPEN 540 PSIG, RESEAT 315 PSIG** (RV 101/102).

**FUNCTION**: Relief Valve provided to prevent rise of tank and line pressures to levels which could be detrimental to subsystem.

**FAILURE MODE**: Premature/Erratic Operation (F)

**Tion, Internal Leakage, Open Below Nominal Cracking Pressure**

**CAUSE(S)**: Vibration, Mechanical Shock, Contamination, Piece Part Structural Failure of Poppet.

**EFFECT(S)**: ON (A) Subsystem (B) Interfaces (C) Mission (D) Crew/Vehicle:

(A) Loss of Helium or Propellant Vapors Overboard. (B) Inability To Pressurize Propellant Tanks If Leak Is Excessive. (C) Potential Abort If Early in Mission, Would Require Prior Failure (Burst Disc Open). (D) None.

**CORRECTING ACTION**: None.

**REMARKS/HAZARDS**: Would require burst disc failure before leaks overboard. No redundancy provided.

**ORIGINAL PAGE IS OF POOR QUALITY**
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
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<tbody>
<tr>
<td>1. Does the flight software detect this failure mode (i.e., automatically</td>
<td></td>
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<tr>
<td>announce or take action in response)?</td>
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<tr>
<td>1a. If not, does the hardware provide information that the flight software could</td>
<td></td>
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<tr>
<td>use to detect the failure?</td>
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<td>2. Are the answers to questions 1 and 1a consistent with the FMEA evaluation of</td>
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<td>in-flight detectability?</td>
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<td>3. Does the flight software take action to negate the effects of the failure</td>
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<td>(either by commanding hardware action or implementing alternate program logic)?</td>
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<td>3a. If not, does the capability exist for the software to compensate for this</td>
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<td>failure mode (either by commanding hardware action or implementing alternate program logic)?</td>
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<tr>
<td>(note change to FMEA criticality).</td>
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<td>7. If crew action is required to respond to this failure mode, are cues provided to signal the need for intervention and the required corrective action?</td>
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*Explanation required (see below)*

**Change/Retention Rationale Summary**

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

☐ FMEA change recommended

**Explanation/Comments:**

1. Over pressurization will cause a class 2 alarm, V42P1115C, 1116C.
SUBSYSTEM: FWD - REACTION CONTROL  
ASSEMBLY: PRESSURIZATION  
P/N: MC284-C421-0061/0002  
P/N VENDOR: 5760009-101, 5760010-102  
QUANTITY: 2  
ART:  
FRC:  
ASSEMBLY: PRESSURIZATION  
P/N: MC284-C421-0061/0002  
P/N VENDOR: 5760009-101, 5760010-102  
QUANTITY: 2  
ART:  
FRC:  
MISSIONS: HF VP FF VP SM  
PHASE(S): PL X LU X CO X CO X LS  
RECOMMENDED FAILURE DETECTABLE IN FLIGHT?: YES  
REDUNDANCY SCREEN:  
FAILRE DETECTABLE IN FLIGHT?: YES  
TANK PRESSURE MONITOR V42P-1116C, 1115C, 1215C, 1315C  
GROUN'T TURNAROUND?.............YES  
PREPARED BY:  
APPROVED BY:  
DES R Gonzalez  
REL R Diehl  
ITEM: VALVE, PRESSURE RELIEF -  
CRACKING PRESS 315 PSIG, FULL OPEN 340 PSIG, RESEAT 310 PSIG (RV 101/102).  
FUNCTION:  
RELIEF VALVE PROVIDED TO PREVENT RISE OF TANK AND LINE PRESSURES TO LEVELS WHICH COULD BE DETRIMENTAL TO SUBSYSTEM.  
FAILURE MODE: FAILS TO OPEN - (F)  
AT NOMINAL CRACKING PRESSURE  
CAUSE(S):  
CONTAMINATION, PIECE PART STRUCTURAL FAILURE, POPPET GALLING.  
EFFECT(S): ON (A) SUBSYSTEM (E) INTERFACES (C) MISSION (D) CRAW/VEHICLES:  
(A) LOSS OF RELIEF PATH. (B) NONE. (C) POTENTIAL MISSION LOSS  
(D) ABORT DECISION IF EARLY IN MISSION WOULD REQUIRE 2 PRIOR FAILURES.  
CORRECTIVE ACTION:  
FIRE ALL THRUSTERS NON-PROPULSIVELY.  
REMARKS/HAZARDS:  
POTENTIAL TANK RUPTURE ON 3RD ORDER FAILURE NO OTHER RELIEF PATH FOR SYSTEM.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY) ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   - YES ☒ NO ☐

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

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

EXPLANATION/COMMENTS:

1 & 2. V42P1110C, V42P1112C, V42P1113C and V42P1114C will detect the failure when the pressure drops to 500 psi and issue a class 3 caution and warning alert.

Gross leak indication should occur first. (12.6% Δ)

6. Capped quick disconnect provides one redundant success path.
SUBSYSTEM: FWD - REACTION CONTROL  
ASSEMBLY: PRESSURIZATION  
P/N: 75372006-0402/0403  
P/N VENDOR: 75372006-0402/0403  
QUANTITY: 2  
MISSIONS: HF VF XF EF SM  
FUNCTION: PROVIDES HELIUM TANK FILL POINT FOR GROUND OPERATIONS AND LOADING SERVICING.  
FAILURE MODE: FAILS OPEN, CAP (S) LEAKS IN EXCESS OF ACCEPTABLE RATE.  
CAUSE(S): VIBRATION, AND LOOSENING OF THE RETAINER NUT, IMPROPER HANDLING, MECHANICAL SHOCK.  
EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE: (A) LOSS OF REDUNDANCY. (B) NONE. (C) POTENTIAL LAUNCH DELAY. (D) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR TO ET SEPARATION.  
CORRECTING ACTION: REPLACE OR TIGHTEN END CAP ON GROUND. NONE AVAILABLE IN FLIGHT.  
REMARKS/HAZARDS: BECAUSE STRUCTURAL CAP IS LOADED OVER THE DISCONNECT, THIS FAILURE MODE IS VERY REMOTE IN FLIGHT.
SUBSYSTEM: FWD - REACTION CONTROL  
ASSEMBLY: PRESSURIZATION  
P/N RI: MCZ 76-0017-0402/0403  
P/N VENDOR: 75372000-0402/0403  
QUANTITY: 2  
QUANTITY/PHASE: PL X LO X DD X DD X LS X ONE REQ'D PER TANK  

REDUNDANCY SCREEN: A-N/A B-N/A C-N/A  
PREPARED BY: C SCARLETT  
APPROVED BY: NASAJ±.  
DESP. R DIEHL  

ITEM: DISCONNECT, QUICK FILL  
HELIUM WITH SPRING LOADED POPPET AND STRUCTURAL END CAP (1/4") (MD 105/106)  
FUNCTION: PROVIDES HELIUM TANK FILL POINT FOR GROUND OPERATIONS AND LOADING SERVICING.  
FAILURE MODE: FAILS OPEN, CAP LEAKS IN EXCESS OF ACCEPTABLE RATE.  
CAUSE(S): VIBRATION, AND LOOSENING OF THE RETAINER NUT, IMPROPER HANDLING, MECHANICAL SHOCK.  
EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:  
(A) LOSS OF REDUNDANCY. (B) NONE. (C) POTENTIAL LAUNCH DELAY (MISSION LCSS) IF DETECTED. (D) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR TO ET SEPARATION.  
DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:  
(A) CAP SEAL DESIGN DETERMINED TO BE ADEQUATE TO PRECLUDE LEAKAGE. DESIGN FACTOR OF SAFETY IS 2.0 X 4000 PSIG MAX WORKING PRESSURE. CAP PLUS COUPLING CONSTITUTES DUAL SEALING. ALL RETAINER NUTS ARE PROPERLY TORQUED TO PRECLUDE LOOSENING. (B) SEALS ARE EXPOSED TO OVER 600 CYCLES DURING DEVELOPMENT. COUPLINGS ARE SUBJECT TO 600 OPERATIONAL CYCLES IN QUAL TEST. ALL CAPS AND COUPLING LEAK TESTED FOR 3 MIN. AT PRESSURES UP TO 1.25 MAX WORKING PRESSURE DURING ACCEPTANCE TEST. TURNAROUND LEAK CHECKS PERFORMED BEFORE EACH FLIGHT. RANDOM VIBRATION PERFORMED DURING QUAL PROGRAM. 68 MINUTES IN TWO AXES AT ANTICIPATED MISSION LEVELS. (C) TURNAROUND INSPECTION INCLUDES VISUAL INSPECTION ALL COUPLINGS THAT HAVE BEEN USED DURING TURNAROUND FOR DAMAGE PLUS INSPECTING FOR LEAKS DURING LEAK CHECKS. ALSO, PROPER BLEED SCREW TORQUE IS VERIFIED PRIOR TO REINSTALLATION OF ANY CAPS THAT HAVE BEEN REMOVED. SUPPLIER AUDIT CONDUCTED 4-5-77 VERIFIED THAT SUPPLIER INSPECTION CONTROLS RAW MATERIAL PARTS IDENTIFICATION, MFG PROCESSES, CONTAMINATION CONTROL, AND STORAGE ENVIRONMENTS. (D) NEW DESIGN FOR SHUTTLE APPLICATION. NO FLIGHT FAILURE HISTORY.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY 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 NEGATE 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 3. [ ] NO SOFTWARE DETECTION 5. [ ] ACCEPTANCE RATIONALE BELOW
2. [ ] HARDWARE ACCEPTS RISK 4. [ ] DETECTION DURING CHECKOUT 6. [ ] RECOMMENDED CHANGES BELOW

EXPLANATION/COMMENTS:

1. Out of Scope. Ground operations only.
SUSSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N RE: YC276-0017-0402/0403
P/N VENDOR: 75372000-0402/0403
QUANTITY: 2
ONE REQ'D PER TANK
MISSIONS: HF VF X FF UH SM
PHASE(S): PL X LU DD UU LU
AFTER FIRST FAILURE:
REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
FAIiURE DETECTABLE IN FLIGHT?: N/A
TIME TO EFFECT:
REFERENCE DOCUMENTS:
MJUC-C-0001-51E
SJ72-SH-C103-2
VS70-421001

PREPARED BY:
DES C SCARLETT
REL R DIEHL
APPROVED BY:

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

FUNCTION:
PROVIDES HELIUM TANK FILL POINT FOR GROUND OPERATIONS AND LOADING SERVICING.

FAILURE MODE: RESTRICTED FLOW - (F)
FAILS CLOSED DURING GROUND FILL OPERATIONS

CAUSE(S):
VIBRATION/IMPROPER HANDLING WHICH CAUSES FILTER/POPPET DAMAGE IN DISCONNECT.

EFFECT(S):
(A) LOSS OF OR REDUCED HELIUM FILL CAPABILITY. (B) NONE. (C) LAUNCH DELAY. (D) NONE.

CORRECTING ACTION:
REMOVE/REPLACE FILL VALVE OR ATTEMPT TO RECOUPLE.

REMARKS/HAZARDS:
NONE. NO REDUNDANCY PROVIDED FOR THIS ITEM IN THIS MODE.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST

<table>
<thead>
<tr>
<th>Item</th>
<th>Purge Quick Disconnect, Propellant</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMEA Number</td>
<td>SD75-SH-0016A</td>
</tr>
<tr>
<td>Subsystem</td>
<td>Fwd. Reaction Control</td>
</tr>
<tr>
<td>Failure Mode</td>
<td>External Leakage During Flight</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)? 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. [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. Per backup flight system program requirements document MG038103, once a pre-set delta between the propellant quantities is reached a class 2 caution and warning light and tone will be annunciated. Also primary flight control requirements FSSR 0026A except OPS 1,6.

2. The above statement indicates in-flight detection.

6. Capped quick disconnect provides one redundant success path.
SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - UR887162

SUBSYSTEM : FWD - REACTION CONTROL
ASSEMBLY : PRESSURIZATION
P/N R1 : KC276-0018
P/N VENDOR : 76306006

QUANTITY : 14

: TWO INLETS AND FIVE OUTLETS FOR EACH PROP

FAILURE DETECTABLE IN FLIGHT?. NO

GROUND TURNAROUND? YES

VISUAL INSPECTION

PREPARED BY:

APPROVED BY:

ITEM: DISCONNECT, QCC, PURGE, VENT, PROPELLANT WITH STRUCTURAL END CAP AND SPRING LOADED POPPET (1/2"). (MD 117, 118, 123, 124, 127, 137, 138, 147, 161, 162, 163, 164).
FUNCTION:
TO ALLOW GROUND PURGE OF PROPELLANT TANKS AND ASSOCIATED MANIFOLDS/LINES/THRUSTERS AFTER LANDING & PROPELLANT TANKS FILL, VENT & VENT.

DURING FLIGHT

CAUSE(S):
VIBRATION AND LOOSENING OF THE RETAINER NUT, STRUCTURAL FAILURE, PIECE PART FAILURE, MECHANICAL SHOCK, IMPROPER GROUND HANDLING.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF PROPELLANT FIRST ORDER FAILURE FOR LOOSE RETAINER NUT. (B) POSSIBLE FIRE/EXPLOSION IF FUEL REACTS WITH COMPLEMENTARY OXIDIZER DUE TO EXTREME HEAT DURING RE-ENTRY. (C) POSSIBLE LOSS OF MISSION DUE TO FLUID SEPARATION. (D) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR TO SEPARATION.

CORRECTING ACTION:
NONE AVAILABLE - IN FORWARD MODULE, CRITICALITY IS LESS SEVERE IF AFT MODULES OPERATIVE.

REMARKS/HAZARDS:
POTENTIAL CORROSION OF SURROUNDING COMPONENTS. STRUCTURAL CAP CONSIDERED AS STRUCTURE.
SUBSYSTEM : FWD - REACTION CONTROL  P/N RI : MC276-0018
ASSEMBLY : PRESSURIZATION  QUANTITY : 1
MON : 76306000  PHASE(S) :
CRIT. HOW :  
* 102 INLETS AND FIVE OUTLETS FOR EACH PROP
* REDUNDANCY SCREEN: A-N/A  B-N/A  C-N/A
* PREPARED BY:  APPROVED BY:
  DES  C SCARLETT  DES  C SCARLETT  SSM  JW KANIKELI
  REL  R DIEHL  REL  R DIEHL  REL  R DIEHL
  
* ITEM: DISCONNECT, QCK, PURGE,
  VENT, PROPELLANT WITH STRUCTURAL END CAP AND SPRING LOADED POPPET
  (1/2") (MD 117, 118, 123, 124, 127, 137, 138, 147, 161, 162, 163, 164).
  FUNCTION:
  TO ALLOW GROUND PURGE OF PROPELLANT TANKS AND ASSOCIATED
  MANIFOLDS/LINES/THRUSTERS AFTER LANDING & PROPELLANT TANKS FILL, DRAIN
  & VENT
  FAILURE MODE: EXTERNAL LEAKAGE
  CAUSE(S):
  VIBRATION AND LOOSENING OF THE RETAINER NUT, STRUCTURAL FAILURE, PIECE
  PART FAILURE MECHANICAL SHOCK, IMPROPER GROUND HANDLING.
  EFFECT(S):
  (A) LOSS OF PROPELLANT FIRST ORDER FAILURE FOR LOOSE RETAINER NUT. (B)
  POSSIBLE FIRE/EXPLOSION IF FUEL REACTS WITH COMPLEMENTARY OXIDIZER (OR
  EXTREME HEAT DURING RE-ENTRY). (C) POSSIBLE LOSS OF MISSION DUE TO FLUID
  SEPARATION. (D) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR
  TO ET SEPARATION.
  DISPOSITION & RATIONALE
  (A) DESIGN
  (B) TEST
  (C) INSPECTION
  (D) FAILURE HISTORY:
  (A) CAP SEAL DESIGN DETERMINED TO BE ADEQUATE TO PRECLUDE LEAKAGE.
  DESIGN FACTOR OF SAFETY IS 3.0 x 710 PSIG MAX WORKING PRESSURE. CAP
  PLUS COUPLING CONSTITUTES DUAL SEALING. ALL RETAINER NUTS ARE PROPERLY
  TORQUED TO PRECLUDE LOOSENING. (B) SEALS ARE EXPOSED TO OVER 500 CYCLES
  DURING DEVELOPMENT. COUPLINGS ARE SUBJECT TO 600 OPERATIONAL CYCLES
  IN QUAL TEST. ALL CAPS AND COUPLINGS LEAK TESTED FOR 3 MINUTES AT
  PRESSURES UP TO MAX WORKING PRESSURE DURING ACCEPTANCE TEST.
  TURNAROUND LEAK CHECKS PERFORMED BEFORE EACH FLIGHT. RANDOM VIBRATION
  PERFORMED DURING QUAL PROGRAM. 68 MINUTES IN TWO AXES AT ANTICIPATED
  MISSION LEVELS. (C) TURNAROUND INSPECTION INCLUDES VISUAL INSPECTING
  ALL COUPLINGS USED DURING TURNAROUND FOR DAMAGE PLUS INSPECTING FOR
  LEAKS DURING LEAK CHECKS. ALSO, PROPER BLEED SCREW TORQUE IS VERIFIED
  PRIOR TO REINSTALLATION OF ANY CAPS THAT HAVE BEEN REMOVED. SUPPLIER
  AUDIT CONDUCTED 4-5-77 VERIFIED THAT SUPPLIER INSPECTION CONTROLS RAW
  MATERIAL PARTS IDENTIFICATION, MFG PROCESSES, CONTAMINATION CONTROL, AND
  STORAGE ENVIRONMENTS. (D) NEW DESIGN FOR SHUTTLE APPLICATION. NO
  FLIGHT FAILURE HISTORY.

ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM     Fwd. Reaction Control
ITEM        Purge Quick Disconnect, Propellant
FAILURE MODE  Fails Closed/Ground Ops.

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 □ 3 □

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

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:
1. Out of scope/ground operations only.
SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N RI: MG276-0018
P/N VENDOR: 76306000
QUANTITY: 14

FAILURES DETECTABLE IN FLIGHT?: N/A

TIME TO EFFECT: IMMEDIATE
REFERENCE DOCUMENTS: MJC70-0001-01E

GROUND TURNAROUND?..............YES

GSE EQUIPMENT FLOW RATE AND TANK OUTPUT
PRESSURE V42F-1210C, 1310C

PREPARED BY: DES C SCARLETT
APPROVED BY: DES ____________
REL K DIEHL REL ____________

ITEM: DISCONNECT, QCK, PURGE,

FUNCTION:
TO ALLOW GROUND PURGE OF PROPELLANT TANKS AND ASSOCIATED MANIFOLDS/LINES/THRUSTERS AFTER LANDING & PROPELLANT TANKS FILL, DRAIN & VENT

FAILURE MODE: FAILS CLOSED (F)

DURING GROUND OPERATIONS

CAUSE(S):
CUTTAMINATION PIECE PART STRUCTURAL FAILURE, MECHANICAL SHOCK

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF PURGE FUNCTION. (B) NO EFFECT. (C) POTENTIAL LAUNCH DELAY. (D) NONE

CORRECTING ACTION:
ATTEMPT TO REMOVE BLOCKAGE (BACK-FLOW) OR REMOVE COUPLING AND REPLACE

REMARKS/HAZARDS:
NONE. NO REDUNDANCY PROVIDED FOR THIS ITEM.
SUBSYSTEM: Fwd. Reaction Control  
ITEM: Test Quick Disconnect, Propellant  
FAILURE MODE: Ext. Leakage/Flight

### HARDWARE/SOFTWARE ANALYSIS CHECKLIST

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

*EXPLANATION REQUIRED (SEE BELOW)*

### CHANGE/RETENTION RATIONALE SUMMARY

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

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**EXPLANATION/COMMENTS:**

1 & 2. V42P1110C, V42P1112C and V42P1113C will detect the failure and issue class 3 alarm (system management blue light on crew-cockpit glare shield) at <500 psia. Gross leak indication is quicker (class 2).

6. Capped quick disconnect provides one redundant success path.
SUBSYSTEM : FWD - REACTION CONTROL
ASSEMBLY : PRESSURIZATION
P/N RI : ME276-0632
P/N VENDOR: XR42670-567, R642900-163
QUANTITY : 14

FUNCTION:
TO PROVIDE ACCESS TO THE HELIUM SUPPLY SYSTEM AT VARIOUS POINTS IN THE SYSTEM: (1) RELIEF VALVES/BURST DISCS (2) REGULATORS (3) CHECK VALVES. PROVIDES FOR C/O OF PRESSURIZATION SUB-SYS COMPONENTS. COMPONENT INPUTS & OUTPUTS ARE ACCESSIBLE AT HE SERVICE PANEL.

FAILUKE MODE: EXTERNAL LEAKAGE (S)

CAUSE(S):
VIBRATION, PIECE PART STRUCTURAL FAILURE (POPPET, SEAL), MECHANICAL SHOCK.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) C/0/V: (A) LOSS OF HELIUM PRESSURANT. (SECOND ORDER FAILURE). (B) LOSS OF PROPELLANT FEED CAPABILITY. (C) POTENTIAL LOSS OF MISSION DUE TO FLUID LOSS. (D) NONE. (E) FUNCTIONAL CRITICALITY EFFECTS - POTENTIAL LOSS OF HELIUM SUPPLY WHICH COULD RESULT IN LOSS OF VEHICLE IF THE LOSS OCCURRED BEFORE ET SEPARATION.

CORRECTING ACTION:
UTILIZE AFT MODULES TO ORIENT VEHICLE FOR ENTRY AND COMPLETE ABORT.

REMARKS/HAZARDS:
NONE.
SUBSYSTEM: REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N RI: ME276-0032
P/N VENDOR: RR42670-587, R642900-153
QUANTITY: 14
MISSIONS: HF, VF x FF OF SM
PHASE(S): PL, LO x CO x DD x LS

PREPARED BY: DES C. SCARLETT  REL R. DIEHL
APPROVED BY: DES C. SCARLETT  REL R. DIEHL


FUNCTION:
- TO PROVIDE ACCESS TO THE HELIUM SUPPLY SYSTEM AT VARIOUS POINTS IN THE SYSTEM: (1) RELIEF VALVES/BURST DISCS (2) REGULATORS (3) CHECK VALVES. PROVIDES FOR C/O OF PRESSURIZATION SUB-SYS COMPONENTS. COMPONENT INPUTS & OUTPUTS ARE ACCESSIBLE AT THE SERVICE PANEL.
- FAILURE MODE: EXTERNAL LEAKAGE
- DURING FLIGHT
- CAUSE(S):
  - VIBRATION, PIECE PART STRUCTURAL FAILURE (POPPET, SEAL), MECHANICAL SHOCK.
- EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
  - (A) LOSS OF HELIUM PRESSURANT. (SECOND ORDER FAILURE). (B) LOSS OF PROPELLANT FEED CAPABILITY. (C) POTENTIAL LOSS OF MISSION DUE TO FLUID LOSS. (D) NONE. (E) FUNCTIONAL CRITICALLY EFFECTS - POTENTIAL LOSS OF HELIUM SUPPLY WHICH COULD RESULT IN LOSS OF VEHICLE IF THE LOSS OCCURRED BEFORE ET SEPARATION.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) DUAL SEALING SURFACES ON CAP WILL PRECLUDE FAILURE. EACH SEALING SURFACE INDEPENDENT OF THE OTHER DESIGN BURST PRESSURE IS TWO TIMES OPER PRESSURE. (B) EACH COUPLING PROOF TESTED TO AT LEAST 1.5 OPER PRESSURE & LEAK TESTED FOR 15 MIN DURING ACCEPTANCE TESTING. (C) AUDIT CONDUCTED ON 11-3-76 VERIFI. THAT SUPPLIER INSPECT INCLUDES VERIFI. OF RAW MAT'L, PARTS MFG, IDENTIFICATION, AND PROTECTION, ASSY OPERATIONS, NO EXAM OF WELDS, BRAZES, AND MAT'L AND EQUIP CONFORMANCE. TURNAROUND INSPECTION INCLUDES VISUALLY INSPECTING ALL COUPLINGS THAT HAVE BEEN USED FOR DAMAGE AND LEAKAGE. ALONG PROPER AHC CAP TORQUE IS VERIFIED UPON REINSTALLATION OF ANY CAPS THAT HAVE BEEN REMOVED. (D) 14 NON-FLIGHT EXTERNAL LEAKAGE FAILURES EXPERIENCED ON LH/SM RCS DUE TO PROCESS DEFICIENCIES.
<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does the flight software detect this failure mode (i.e., automatically</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1a. If not, does the hardware provide information that the flight software could use to detect the failure?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Are the answers to questions 1 and 1a consistent with the FMEA evaluation of in-flight detectability?</td>
<td></td>
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</tr>
<tr>
<td>3. Does the flight software take action to negate the effects of the failure (either by commanding hardware action or implementing alternate program logic)?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3a. If not, does the capability exist for the software to compensate for this failure mode (either by commanding hardware action or implementing alternate program logic)?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. As a result of this failure mode, can the software overstress the hardware or induce another failure?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Can this failure mode, in combination with software logic, adversely affect other functions?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. How many of these hardware failures can the shuttle tolerate (consider crew action and hardware/software operation)? Note change to FMEA criticality.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. If crew action is required to respond to this failure mode, are cues provided to signal the need for intervention and the required corrective action?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. If the answer to either 1 or 3 is yes:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Can the BFS be engaged after occurrence?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Will BFS tolerate failure without loss of crew/vehicle?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Explanation Required (see below)**

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**Change/Retention Rationale Summary**

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

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**FMEA Change Recommended

**Explanations/Comments**:

1. Out of scope - ground operations only.
SUBSYSTEM : FWD - REACTION CONTROL
ASSEMBLY : PRESSURIZATION
P/N RE: ME276-0032
P/N VENDOR: RR42670-5-7, R64290C-1&3
QUANTITY: 14
MISSIONS: HF, VF, X, FF, UF, SN
PHASE(S): PL, LG, GO, DO, LS
NUMBER OF SUCCESS PATHS REMAINING
PROPELLANT: AFTER FIRST FAILURE:
REDUNDANCY SCREEN: A-PASS B-N/A C-PASS

FAILURE DETECTABLE IN FLIGHT?: N/A
FAILURE TIME TO EFFECT: SECONDS TO HOURS
REFERENCE DOCUMENTS: MJ70-C001-01B
PRESSURE READ-OUT: V42P-1112C, 1112C, 1113C, VS70-421CG

PREPARED BY:
LES C SCARLETT
REL R UEHL

APPROVED BY:

ITEM: DISCONNECT, QUICK TEST

FUNCTION:
TG PROVIDE ACCESS TO THE HELIUM SUPPLY SYSTEM AT VARIOUS POINTS IN THE SYSTEM: (1) RELIEF VALVES/BURST DISCS (2) REGULATORS (3) CHECK VALVES.
PROVIDES FOR C/O OF PRESSURIZATION SUB-SYS COMPONENTS. COMPONENT INPUTS & OUTPUTS ARE ACCESSIBLE AT HE SERVICE PANEL.

FAILURE MODE: FAILS CLOSED (F)
DURING TURN-AROUND/GROUND OPERATIONS
CAUSE(S):
CONTAMINATION, PIECE PART STRUCTURAL FAILURE (POPPET, SEAL).

EFFECT(S): (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF TEST/CHECKOUT DATA. (B) INCREASED GROUND EQUIPMENT REQUIREMENTS. (C) POTENTIAL MISSION LAUNCH DELAY. (D) NONE.
CORRECTING ACTION:
TEST AT ALTERNATE POINT (IF AVAILABLE) OR REMOVE AND REPLACE COUPLING.
REMARKS/HAZARDS:
NONE.
# HARDWARE/SOFTWARE ANALYSIS CHECKLIST

**SUBSYSTEM:** Fwd. Reaction Control  
**FMEA NUMBER:** SD75-SH-0016A  
**ITEM:** Helium Quad Check Valve  
**FAILURE MODE:** Fails Open

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?</td>
<td>*YES</td>
<td>NO</td>
</tr>
<tr>
<td>2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?</td>
<td>X</td>
<td>*NO</td>
</tr>
<tr>
<td>3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?</td>
<td>*YES</td>
<td>NO</td>
</tr>
<tr>
<td>4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?</td>
<td>*YES</td>
<td>NO</td>
</tr>
<tr>
<td>5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?</td>
<td>*YES</td>
<td>NO</td>
</tr>
<tr>
<td>6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.</td>
<td>0</td>
<td>X</td>
</tr>
<tr>
<td>7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?</td>
<td>N/A</td>
<td>YES</td>
</tr>
</tbody>
</table>

**CHANGE/RETENTION RATIONALE SUMMARY**

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

**EXPLANATION/COMMENTS:**

1. Series redundant.

SUBSYSTEM: FD - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: MC-284-0481-CC01/-GG02
P/N VENDOR: RSC10500-001/-G11
QUANTITY: 2
:ONE PER HELIUM SUPPLY

FAILURE DETECTABLE IN FLIGHT?: NO

GROUND TURNAROUND?: YES
GROUND TEST PORTS

PREPARED BY:
DES R. BURKHART
REL R. DIEHL

APPROVED BY:

ITEM: VALVE, QUAD, CHECK, HE
(CV 101/102)
FUNCTION:
TO PRECLUDE PROPELLANT VAPORS FROM MIGRATING TO REGULATORS (FROM THE PROPELLANT TANK).

FAILURE MODE: FAILS OPEN (F)
OR FAILS TO REMAIN CLOSED (INTERNAL LEAKAGE).

CAUSE(S):
CONTAMINATION, VIBRATION, PIECE PART STRUCTURAL FAILURE, MECHANICAL SHOCK, VIBRATION.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF REDUNDANCY-SERIES VALVE WILL PROTECT REGULATORS FROM VAPORS. (B,C,D) NO EFFECT UNLESS MULTIPLE FAILURES OCCUR. (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CONTAMINATION OF REGULATORS WITH PROPELLANT VAPORS IF BOTH CHECK VALVES ARE OPEN.

CORRECTING ACTION:
NONE AVAILABLE.

REMARKS/HAZARDS:
NO HAZARDS
ACTION OF PROPELLANT VAPORS AND CONTAMINATION.
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.**
   - [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. [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 & 2. Upon using the thrusters, tank ullage pressure will decay until <200 psi which will give a class 2 caution and warning alarm.
SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 1C2

SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: MC284-0481-0001/-0002
P/N VENDOR: KSO10500-001/001
QUANTITY: 2
FAILURE DETECTABLE IN FLIGHT? NO
DUE TO SMALL P THE LEAKAGE IS NOT DETECTABLE
GROUND TURNAROUND? ......... YES
SAME AS FLIGHT INSTRUMENTATION

PREPARED BY: DES R BURKHART
APPROVED BY: DES REL R DIEHL

ITEM: VALVE, QUAD, CHECK, HE
(CV 101/102)
FUNCTION:
TO PRECLUDE PROPELLANT VAPORS FROM MIGRATING TO REGULATORS (FROM THE PROPELLANT TANK).

FAILURE MODE: FAILS CLOSED (F)
RESTRICTED FLOW.
CAUSE(S):
PIECE PART STRUCTURAL FAILURE, MECHANICAL SHOCK, ACCELERATION.

EFFECT(S):
(A) LOSS OF REDUNDANCY - PARALLEL PATH PROVIDES PRESSURANT FEED.
(B, C) NO EFFECT UNLESS MULTIPLE FAILURES OCCUR.
(D) NO EFFECT.
(E) FUNCTIONAL CRITICAL EFFECTS - IF FAILURE OCCURS BEFORE ET SEPARATION, LOSS OF DOWN FIRING THRUSTERS WILL PREVENT ET SEPARATION AND RESULT IN LOSS OF CREW/VEHICLE.
CORRECTING ACTION:
NONE (BLOWDOWN MAY BE USED AFTER SECOND FAILURE).

REMARKS/HAZARDS:
MINIMUM DELTA CRACKING PRESSURE FOR CRACKING IS NECESSARY REQUIREMENT TO MINIMIZE SYSTEM PRESSURE DROP TO TANKS.

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

SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: MC284-0481-0001-0002
P/N VENDOR: RS010500-001-011
QUANTITY: 2

OREASSEMBLY: PRESSURIZATION
P/N: MC284-0481-0001-0002
P/N VENDOR: RS010500-001-011
QUANTITY: 2

CRITICAL FUNC: IR
ABORT: CRIT. HOW
ASSEMBLY: PRESSURIZATION
P/N: MC284-0481-0001-0002
P/N VENDOR: RS010500-001-011
MISSIONS: HF VF X FF OF SM
PHASE(S): PL LC X DD X DD X LS

QUANTITY: ONE PER HELIUM SUPPLY

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

PREPARED BY: DES R BURKHART DES REL R DIEL

APPROVED BY: S SM APPROVED BY NASA

APPROVED WITH CHANGES

ITEM: VALVE; QUAD; CHECK; HE
(CY 101/102)

FUNCTION:
- TO PRECLUDE PROPELLANT VAPORS FROM MIGRATING TO REGULATORS (FROM THE PROPELLANT TANK).

FAILURE MODE: FAILS CLOSED (F)

RESTRICTED FLOW.

CAUSE(S):
- PIECE PART STRUCTURAL FAILURE, MECHANICAL SHOCK, ACCELERATION.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
- (A) LOSS OF REDUNDANCY - PARALLEL PATH PROVIDES PRESSURANT FEED.
- (B, C) NO EFFECT UNLESS MULTIPLE FAILURES OCCUR. (D) NC EFFECT.
- (E) FUNCTIONAL CRITICAL EFFECTS - IF FAILURE OCCURS BEFORE ET SEPARATION, LOSS OF DOWN FIRING THRUSTERS WILL PREVENT ET SEPARATION AND RESULT IN LOSS OF CREW/VEHICLE.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) VALVE SEAT MATERIAL WILL NOT STICK CAUSING A FAILURE TO OPEN AND SPECIFIED MAXIMUM CRACKING PRESSURE IS ONLY 5 PSI. (B) CHECK VALVE TO BE CERTIFIED FOR 100,000 CYCLES WITHOUT CHANGE IN PERFORMANCE CHARACTERISTICS/ALSO, WILL CHECK OUT EACH VALVE ELEMENT (PARALLEL - SERIES) AFTER EACH FLIGHT. VALVE SUBJECTED TO 40 MIN OF 10.6 GRMS RANDOM VIBRATION PER AXIS DURING QUAL PROGRAM. (C) AN AUDIT CONDUCTED ON 1-16-78 INDICATED THAT SUPPLIER QC VERIFIED RAW MATT. CERTIFICATION TO SATISFY SHUTTLE DESIGN REQUIREMENTS, VERIFIED PROTECTION OF DETAIL PARTS FROM DAMAGE DURING MFG AND TEST, IN-PROCESS INSPECTION VERIFIED MFG TRAVELER SEQUENCES. TURNAROUND INSPECTION TO INCLUDE MONITORING FUNCTIONAL TESTS TO VERIFY FLOW AND CHECK FOR LEAKAGE. (D) NO FAILURE HISTORY. THIS IS A NEW DESIGN FOR SHUTTLE USE.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-102106-1

**SUBSYSTEM** Fwd Reaction Control  
**FMEA NUMBER** SD75-SH-0016A  
**ITEM** Propellant Line Flex Assy.  
**FAILURE MODE** External Leakage

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)?**  
   - No [x] 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 [x] No [ ]

*EXPLANATION REQUIRED (SEE BELOW)*

#### CHANGE/RETENTION RATIONALE SUMMARY

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

---

**EXPLANATION/COMMENTS:**

1. V42P1115C, 1116C will give a class 2 alert once pressure drops to a pre-determined low. Gross leak indication occurs first.

6. No redundancy available.

7. V42P1116C and V42P1115C goes to shared meter M2 and will show a large pressure drop for worst case (large leak).

FMEA Change - add V42P1116C to "failure detectable in flight".

---

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SUBSYSTEM: FWD - REACTION CONTROL
ASSMELY: PROPELLANT FEED
P/N: LRI - CRIT.
P/N VENDOR: MC271-CG95
QUANTITY: 1

FAIL. DETECTABLE IN FLIGHT?: YES
PROP. TANK PRESSURE V42P-131CC AND MANIFOLD PRESSURE 1312C&1316C
GROUND TURNAROUND?: YES
SAME AS FLIGHT INSTRUMENTATION

PREPARED BY: DES J. TAGGART
APPROVED BY: DES

ITEM: PROP LINE FLEX ASSY

FUNCTION:
TO PROVIDE PROPELLANT FEED TO APPROPRIATE PROPELLANT FEEDLINES.

FAILURE MODE: EXTERNAL LEAKAGE

CAUSE(S):
MECHANICAL SHOCK, VIBRATION, FLOW, FATIGUE, IMPROPER INSTALLATION (WELD)

EFFECT(S):
(A) LOSS OF PROPELLANTS.  (B) POTENTIAL CORROSION FROM FREE PROPELLANTS IN MODULE.
(C) POTENTIAL MISSION LOSS OR ABORT DECISION.
(D) POTENTIAL LOSS OF CREW/VEHICLE IF FAILURE RESULTS IN LOSS OF ACS FUNCTION BEFORE ET SEPARATION.

CORRECTING ACTION:
ATTEMPT TO ISOLATE AND INITIATE ABORT IF REQ'D.

REMARKS/HAZARDS:
POTENTIAL HAZARD OF FIRE/EXPLOSION FROM FREE PROPELLANTS. SOME LEAK POINTS MAY NOT BE ISOLATABLE (I.E. BEFORE/UPSTREAM OF TANK ISOLATION VALVES) NO REDUNDANCY PROVIDED FOR LINES. SEE HAZARD NO. 1YXX-0302-GA.
SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N: H00-2F-102106-1
P/N VENDOR: MC271-0095
QUANTITY: 2
MISSIONS: HF, VF, X, FF, OF, SM
PHASE(S): PL, LO, X, DD, X, LS

FUNCTION: TO PROVIDE PROPELLANT FEED TO APPROPRIATE PROPELLANT FEEDLINES.

FAILURE MODE: EXTERNAL LEAKAGE

CAUSE(S):
- MECHANICAL SHOCK, VIBRATION, FLOW, FATIGUE, IMPROPER INSTALLATION (WELD)

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
- (A) LOSS OF PROPELLANTS
- (B) POTENTIAL CORROSION FROM FREE PROPELLANTS IN MODULE
- (C) POTENTIAL MISSION LOSS OR ABORT DECISION
- (D) POTENTIAL LOSS OF CREW/VEHICLE IF FAILURE RESULTS IN LOSS OF RCS FUNCTION BEFORE ET SEPARATION.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) STRUCTURAL MARGIN OF 2.0 WILL MINIMIZE FAILURE MODE POTENTIAL.
- (B) PROOF TESTED TO 1.5 TIMES WORKING PRESSURE AND 65 MINUTES OF RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS.
- (C) IN PROCESS INSPECTIONS X-RAY OF WELDS & PENETRANT INSPECT. TURN AROUND INSPECTION INCLUDES MONITORING FUNCTIONAL TESTS DURING PRESSURIZATION CYCLE FOR EVIDENCE OF LEAKS AND DAMAGE. SUPPLIER INSPECTION DEEMED TO BE SATISFACTORY BASED ON SURVEY CONDUCTED ON 4-20-77.
- (D) NO FAILURE HISTORY FOR THIS SPECIFIC DESIGN.

APPROVED WITH CHANGES
See Section 13.0
<table>
<thead>
<tr>
<th>Item</th>
<th>Feedline and Fittings</th>
</tr>
</thead>
<tbody>
<tr>
<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 [ ] NO [ ]

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

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

   3a. **IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?**
   - *YES [X] NO [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.
   - O [X] *1 [ ] 2 [ ]

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

8. **IF THE ANSWER TO EITHER 1 OR 3 IS YES:**
   - A. **CAN THE BFS BE ENGAGED AFTER OCCURRENCE?**
     - YES [X] *NO [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. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

**EXPLANATION/COMMENTS:**

1. V42P1115C, 1116C will give a class 2 alert once pressure drops to a pre-determined low. Gross leak indication occurs first.

5. No redundancy available.

7. V42P1115C and V42P1116C goes to shared meter M2 and will show a large pressure drop for worst case (large leak).
SUBSYSTEM: FWC - REACTION CONTROL
ASSEMBLY: PROPPELLANT FEED
P/N: V070-42101
P/N VENDOR: MISSIONS: HF VF FF OF SM
QUANTITY: 1
ABORT: CRIT. Func: 1
PHASE(S): PL LO X OO X OO X LS
ONE SET PER PROPELLANT
NUMBER OF SUCCESS PATHS REMAINING
AFTER FIRST FAILURE: 0
REDUNDANCY SCREEN: A-N/A B-N/A C-N/A

FAILURE DETECTABLE IN FLIGHT?...YES
PROPELLANT TANK PRESSURE V42P-1310C AND MANIFOLD
PRESSURE 1312C & 1315C
GROUND TURNAROUND?.........YES
SAME AS FLIGHT INSTRUMENTATION

PREPARED BY: DES A SIEGELIN
APPROVED BY: DES R DIEHL

ITEM: FEEDLINE AND FITTINGS
FROM TANK TO 1) TANK VALVES TO 2) MANIFOLD VALVES, TO 3) THRUSTERS.
FUNCTION:
TO PROVIDE FEED TO APPROPRIATE PROPPELLANT COMPONENTS FOR THRUSTER
OPERATION - 3 AXIS ACCELERATION CONTROL AND ROTATIONAL CONTROL.
FAILURE MODE: EXTERNAL LEAKAGE

CAUSE(S):
MECHANICAL SHOCK, VIBRATION/FATIGUE, STRUCTURAL FAILURE, IMPROPER
INSTALLATION (WELD), FLUID FITTING SEAL FAILURE.
EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) POTENTIAL LOSS OF PROPPELLANTS. (B) POTENTIAL CORROSION FROM FREE
PROPPELLANTS IN MODULE. (C) POTENTIAL MISSION LOSS OR ABORT DECISION.
(C) POTENTIAL LOSS OF CREW/VEHICLE IF LEAKING PROPPELLANT EXPLODES DUE
TO CONTACT WITH CATALYTIC AGENT OR HEAT SOURCE WITH SUBSEQUENT LOSS OF
FORWARD MODULE OR IF LOSS OF PROPPELLANT PROHIBITS ENGINE SEPARATION.
CORRECTING ACTION:
ATTEMPT TO ISOLATE AND INITIATE ABORT IF REQ'D.
REMARKS/HAZARDS:
POTENTIAL HAZARD OF FIRE/EXPLOSION FROM FREE PROPPELLANTS. SOME LEAK
POINTS MAY NOT BE ISOLATABLE (I.E. BEFORE/UPSTREAM OF TANK ISOLATION
VALVES) NO REDUNDANCY PROVIDED FOR LINES. SEE HAZARD NO. 1YXX-0302-04.

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OF POOR QUALITY
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: Fwd - Reaction Control
FMEA NO: 03-2F -102108-1
REV: 12/08

ASSEMBLY: Propellant Feed
ABORT: CRIT.
CRIT. FUNC: 1

P/N RI: V070-421001

P/N VENDOR: MISSIONS: HF VF X FF OF SM

QUANTITY: 1
ONE SET PER PROPELLANT

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

PREPARED BY: APPROVED BY:
A. SIEGELIN
R. DIEHL

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

FUNCTION:
TO PROVIDE FEED TO APPROPRIATE PROPELLANT COMPONENTS FOR THRUSTER OPERATION - 3 AXIS ACCELERATION CONTROL AND ROTATIONAL CONTROL.

FAILURE MODE:
EXTERNAL LEAKAGE

CAUSE(S):
MECHANICAL SHOCK, VIBRATION/FATIGUE, STRUCTURAL FAILURE, IMPROPER INSTALLATION (WELD), FLUID FITTING SEAL FAILURE.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) POTENTIAL LOSS OF PROPELLANTS
(B) POTENTIAL CORROSION FROM FREE PROPELLANTS IN MODULE
(C) POTENTIAL MISSION LOSS OR ABORT DECISION
(D) POTENTIAL LOSS OF CREW/VEHICLE IF LEAKING PROPELLANT EXPLODES DUE TO CONTACT WITH CATALYTIC AGENT OR HEAT SOURCE WITH SUBSEQUENT LOSS OF FORWARD MODULE OR IF LOSS OF PROPPELLANT PROHIBITS ET SEPARATIONS

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY
(4) FACTOR OF SAFETY OF 4.0 WILL MINIMIZE FAILURE POTENTIAL. DYNATUBE FITTINGS HAVE DUAL SEALS. WELD CONSTRUCTION REDUCES JOINTS & POSSIBLE LEAK PATHS. FASTENING CLAMPS AND TUBE BEND DESIGN ALLOWS DEGREE OF MOVEMENT WHICH HELPS PREVENTING LEAKS. (B) POST INSTALLATION TEST AND OPERATIONAL CHECKOUTS WILL VERIFY SYSTEM INTEGRITY. ALL LINES SUBJECT TO PROOF TEST OF 1.25 X MAX OPERATING PRESSURE OR 1.1 X SURGE (TRANSIT) PRESSURE WHICHEVER IS GREATER. PERFORMED TUBING CERTIFICATION PER "ORBITER TUBING VERIFICATION PLAN SD75-SH-0205". (C) IN-PROCESS INSPECT INCLUDES NDT & CHECKS DURING INSTALLATION. TURNAROUND INSPECTION INCLUDES MONITORING FUNCTIONAL TESTS DURING PRESSURIZATION CYCLE FOR EVIDENCE OF LEAKS. VISUALLY INSPECT FOR DAMAGE WHERE ACCESSIBLE. HARDWARE INSPECTION IN ACCORDANCE WITH PLANNING ROUTES APPROVED BY NASA. (D) MINOR FAILURE HISTORY-CORROSION AND FAB PROBLEMS REPORTED DURING APOLLO PROGRAM AND CORRECTED WITH APPLICABLE TMO/TPC REQUIREMENT.
<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Failure Mode</th>
<th>YES</th>
<th>NO</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A</td>
<td>DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?</td>
<td>Fails Closed</td>
<td>X</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?</td>
<td></td>
<td></td>
<td>*YES</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?</td>
<td></td>
<td></td>
<td>YES</td>
<td>*NO</td>
<td>0</td>
</tr>
<tr>
<td>3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?</td>
<td></td>
<td></td>
<td>YES</td>
<td>0</td>
<td>X</td>
</tr>
<tr>
<td>3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?</td>
<td></td>
<td></td>
<td>*YES</td>
<td>0</td>
<td>X</td>
</tr>
<tr>
<td>4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?</td>
<td></td>
<td></td>
<td>*YES</td>
<td>0</td>
<td>X</td>
</tr>
<tr>
<td>5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?</td>
<td></td>
<td></td>
<td>*YES</td>
<td>0</td>
<td>X</td>
</tr>
<tr>
<td>6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)?</td>
<td></td>
<td></td>
<td>*O</td>
<td>1</td>
<td>X</td>
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<tr>
<td>6. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?</td>
<td></td>
<td></td>
<td>N/A</td>
<td>YES</td>
<td>X</td>
</tr>
<tr>
<td>7. IF THE ANSWER TO EITHER 1 OR 3 IS YES: A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?</td>
<td></td>
<td></td>
<td>YES</td>
<td>X</td>
<td>*NO</td>
</tr>
<tr>
<td>B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?</td>
<td></td>
<td></td>
<td>YES</td>
<td>X</td>
<td>*NO</td>
</tr>
</tbody>
</table>

**EXPLANATION REQUIRED (SEE BELOW)**

**CHANGE/RETENTION RATIONALE SUMMARY**

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

**EXPLANATION/COMMENTS:**

1. "RCS JETS" light on caution and warning panel.
2. The manifolds are in parallel (2 legs) giving one redundant path.
SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 1G1

SYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N: KC284-5430-0007/-3308
P/N VENDOR: 5750025/575026
QUANTITY: 4
ABORT: ABDOR; CRIT. FUNC: 1R
MISSIONS: HF VF X FF OF SM
PHASE(S): PL LO X OG X DU LS
NUMBER OF SUCCESS PATHS REMAINING
AFTER FIRST FAILURE:
REDUNDANCY SCREEN: A-PASS R-PASS C-PASS:
FAILURE DETECTABLE IN FLIGHT?: YES
THRUSTRER CHAMBER PRESS., MANIFOLD PRESSURE MONITU
Y 62P-1212-1216, 1312-1316, 1521-1522
GROUND TURNAROUND? YES
SAME AS FLIGHT

PREPARED BY:
DEP: R GONZALEZ
REL: R DIEHL

ITEM: VLV, AC MOTOR OPERATED -
TANK (1 1/2") (LV 161-164).
FUNCTION:
1) PROVIDES ISOLATION OF TANKS FROM MANIFOLDS.
2) PROVIDES BACK-UP SHUT-OFF/ISOLATION OF PROP MANIFOLDS AND ASSOCIATED THRUSTERS.
COMPONENTS. BI-STABLE, (TANK PRESSURE-245 PSI). AC MOTOR DRIVEN 3 PHASE (2 OF 3 WILL ACTUATE VALVE) 115 TO 200 VOLTS 400 HZ.
FAILURE MODE: FAILS CLOSED (F)
POSITION - INCLUDES RESTRICTED FLOW TO LEVEL THAT DOES NOT ALLOW PROPER MIXTURE RATIO.
CAUSE(S): VIBRATION, STRUCTURAL FAILURE, PREMATURE POWER TO MUTUK, ELECTRICAL SHORT.
EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(a) LOSS OF PROPellant FLOW IN TWO MANIFOLDS AND SUBSEQUENT LOSS OF THRUSTER FUNCTION (THRUSTF BURN-THRU DUE TO OXID RICH MIXTURE).
(b) POSSIBLE BURN-THRU PROPAGATION.
(c) LOSS OF MISSION. ABDOR DECISION.
(d) POTENTIAL VEHICLE DAMAGE FROM COLLISION WITH KENDAMA TARGET.
AFTER SECOND FAILURE. CRIT 1 FOR RTS ABORT.
CORRECTING ACTION:
UTILIZE REMAINING FORWARD THRUSTERS IN COUPLE WITH APPROPRIATE AFT THRUSTERS FOR BRAKING. DE-ORBIT WITH AFT MODULES.
REMARKS/HAZARDS:
POTENTIAL HAZARD OF EXPLOSION IF OX VALVE FAILS. SEE PARKER FMEA & RRK 5750025.

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SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: FW O - REACTION CONTROL
ASSEMBLY: PROPellant FEED
P/N: MC284-0430-0007/-0008
P/N VENDOR: 5750025/5750026
QUANTITY: 1

MISSIONS: HF, VF, X, FF OF SM
QUANTITY: 4 - TWO REQ'D PER PROP TANK

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

PREPARED BY: R GONZALEZ
APPROVED BY: SSM

REVIEWED WITH CHANGES
See Section 13.0

ITEM: VLV, AC MOTOR OPERATED - TANK (1 1/2") (LV 161-164).

FUNCTION:
1) PROVIDES ISOLATION OF TANKS FROM MANIFOLDS.
2) PROVIDES BACK-UP SHUT-OFF/ISOLATION OF PROP MANIFOLDS AND ASSOCIATED THRUSTERS' COMPONENTS. 81- STABLE, (TANK PRESSURE=245 PSI). AC MOTOR DRIVEN 3 PHASE (1 OF 3 WILL ACTUATE VALVE) 115 TO 200 VOLTS 400 HZ.

FAILURE MODE: FAILS CLOSED (F) POSITION - INCLUDES RESTRICTED FLOW TO LEVEL THAT DOES NOT ALLOW PROPER MIXTURE RATIO.

CAUSE(S):
VIBRATION, STRUCTURAL FAILURE, PREMATURE POWER TO MOTOR, ELECTRICAL SHORT.

EFFECT(S):
(A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF PROPellant FLOW IN TWO MANIFOLDS AND SUBSEQUENT LOSS OF THRUSTER FUNCTION (THRUSTER BURN-THRU DUE TO OXID RICH MIXTURE). (B) POSSIBLE BURN-THRU PROPAGATION. (C) LOSS OF MISSION. ABORT DECISION. (D) POTENTIAL VEHICLE DAMAGE FROM COLLISION WITH RENDEVOUS TARGET, AFTER SECOND FAILURE. CRIT I FOR RTLS ABORT.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) VALVES ARE ALWAYS OPEN. DUAL SERIES SWITCHES WILL PRECLUDE SINGLE FAILURE PREMATURE ACTUATION. SHORTED RPC WILL NOT CLOSE VALVE. (B) EACH VALVE IS SUBJECTED TO ACCEPT VIBRATION. VALVE IS SUBJECTED TO 48 MIN OR RANDOM VIB IN EACH AXIS AT ANTICIPATED MISSION LEVELS AND AN ENDURANCE TEST EQUIV. TO 100 MISSIONS DURING THE QUAL TEST PROGRAM. EACH VALVE SUBJECTED TO PROOF PRESSURE OF 1500 PSIG. MORE THAN 4 X WORKING PRESSURE. (C) AUDIT CONDUCTED 7-1-76 VERIFY SUPPLIER INSPECTION CONTROL OF PARTS ID AND PROTECTION, MFG PROCESSES, ELECT TERMINATIONS. TURNAROUND INSPECTION INCLUDES MONITORING TEST TO VERIFY ELECTRICAL POWER TO VALVE FOR EVIDENCE OF SHORT CIRCUITY. (D) NO FLIGHT FAILURE EXPERIENCE.
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<tbody>
<tr>
<td>FMEA NUMBER</td>
<td>SD75-SH-0016A</td>
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<th>HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-102150-I</th>
</tr>
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<tbody>
<tr>
<td>SUBSYSTEM</td>
</tr>
<tr>
<td>FMEA NUMBER</td>
</tr>
<tr>
<td>FAILURE MODE</td>
</tr>
</tbody>
</table>

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)*

**CHANGE/RETENTION RATIONALE SUMMARY**
- NO H/S ISSUES |
- HARDWARE ACCEPTS RISK |
- NO SOFTWARE DETECTION |
- DETECTION DURING CHECKOUT |
- ACCEPTANCE RATIONALE BELOW |
- RECOMMENDED CHANGES BELOW |

<table>
<thead>
<tr>
<th>EXPLANATION/COMMENTS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The tank pressure drop (worst case/full open) will be detected by V42P1115C, 1116C; unless regulated the gross leak indication will detect it. Also measurements 1313C, and 1314C appear obsolete and should be removed from the FMEA.</td>
</tr>
</tbody>
</table>
SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PROPELLANT
P/N: MC276-0018
P/N VENDOR: 763010LC
QUANTITY: 6
MISSION: HF VF X FF O F SM
PHASE(S): PL LG X DD X DO X LS
NUMBER OF SUCCESS PATHS REMAINING
THREE REQ PER PROPELLANT AFTER FIRST FAILURE:
REduNDANCY SCREEN: A-N/A B-N/A C-N/A

FAILURE DETECTABLE IN FLIGHT?: YES
LOSS OF TANK PRESSURE
1312C, 1313C, 1314C, 1315C TANK TEMP
1300 AND 1400
GROUND TURNAROUND?: N/A

PREPARED BY:
DES C SCARLETT
REL R DIEHL

APPROVED BY:

ITEM: DISCONNECT, QUICK, FILL
FUNCTION:
TO PROVIDE FOR DRAINING, VENTING, AND BLEEDING PROPELLANT TANKS, IN BOTH HORIZONTAL AND VERTICAL VEHICLE ORIENTATION.

FAILURE MODE: EXTERNAL LEAKAGE (S)
DURING FLIGHT
CAUSE(S):
VIBRATION, AND LOOSENING OF RETAINER NUT, PIECE PART STRUCTURAL FAILURE, MECHANICAL SHOCK.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF PROPELLANT OVERBOARD (1ST ORDER FAILURE FOR LOOSE RETAINING NUT). (B) POSSIBLE FIRE/EXPLOSION IF FUEL REACTS WITH OXIDIZER (2ND ORDER) OR EXTREME HEAT DURING RE-ENTRY. (C) POSSIBLE LOSS OF MISSION DUE TO FLUID LOSS. (C) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR TO ET SEPARATION.
CORRECTING ACTION:
INITIATE ABORT OR RESCUE OPERATIONS.

REMIX HAZARDS:
POTENTIAL HAZARD FROM FIRE, EXPLOSION, AND FREE PROPELLANTS. SEE HAZARD 1YXX-0302-05.
ITEM: DISCONNECT, QUICK, FILL

FUNCTION: TO PROVIDE FOR DRAINING, VENTING, AND BLEEDING PROPELLANT TANKS. IN BOTH HORIZONTAL AND VERTICAL VEHICLE ORIENTATION.

FAIiURE MODE: EXTERNAL LEAKAGE (S)

DURING FLIGHT

CAUSE(S): VIBRATION, AND LOOSENING OF RETAINER NUT, PIECE PART STRUCTURAL FAILURE, MECHANICAL SHOCK.

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

(A) LOSS OF PROPELLANT OVERBOARD (1ST ORDER FAILURE FOR LOOSE RETAINING NUT). (B) POSSIBLE FIRE/EXPLOSION IF FUEL REACTS WITH OXIDIZER (2ND ORDER) OR EXTREME HEAT DURING RE-ENTRY. (C) POSSIBLE LOSS OF MISSION DUE TO FLUID LOSS. (D) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR TO ET SEPARATION.

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

(A) CAP SEAL DESIGN DETERMINED TO BE ADEQUATE TO PRECLUDE LEAKAGE. DESIGN FACTOR OF SAFETY IS 3.0 X 710 PSIG MAX WORKING PRESSURE. CAP PLUS COUPLING CONSTITUTES DUAL SEALING. ALL RETAINER NUTS ARE PROPERLY TORQUED TO PRECLUDE LOOSENING. (B) SEALS ARE EXPOSED TO OVER 500 CYCLES DURING DEVELOPMENT. COUPLINGS ARE SUBJECTED TO 600 OPERATIONAL CYCLES IN QUAL TEST. ALL CAPS & COUPLINGS LEAK TESTED FOR 3 MIN. AT PRESSURES UP TO 1.25 MAX WORKING PRESSURE DURING ACCEPTANCE TEST. TURNAROUND LEAK CHECKS PERFORMED BEFORE EACH FLIGHT. RANDOM VIBRATION PERFORMED DURING QUAL PROGRAM. 68 MINUTES IN TWO EXES AT ANTICIPATED MISSION LEVELS. (C) TURNAROUND INSPECTION INCLUDES VISUAL INSPECTING ALL COUPLINGS THAT HAVE BEEN USED DURING TURNAROUND FOR DAMAGE PLUS INSPECTING FOR LEAKS DURING LEAK CHECKS. ALSO, PROPER BLEED SCREW TORQUE IS VERIFIED PRIOR TO REINSTALLATION OF ANY CAPS THAT HAVE BEEN REMOVED. SUPPLIER AUDIT CONDUCTED 4-5-77 VERIFIED THAT SUPPLIER INSPECTION CONTROLS RAW MATERIAL PARTS IDENTIFICATION, MFG PROCESSES, CONTAMINATION CONTROL, AND STORAGE ENVIRONMENTS. (D) NEW DESIGN FOR SHUTTLE APPLICATION. NO FLIGHT FAILURE HISTORY.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-102150-2

SUBSYSTEM Fwd. Reaction Control
ITEM Quick Disconnect
FMEA NUMBER SD75-SH-0016A
FAILURE MODE Fails Closed/Ground Ops

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY 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 NEGAITE 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  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:

Out of scope - ground operations only.
SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 101

SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PROPELLANT
P/N #1: MC276-0018
P/N VENDOR: 76-01000
QUANTITY: 6
MISSION(S): HF VF X FF UF SM
PHASE(S): PL X LD 00 DO LS
REDUNDANCY SCREEN: A-PASS B-N/A C-PASS

THREE REQ PER PROPELLANT AFTER FIRST FAILURE: 0

FAILURE DETECTABLE IN FLIGHT?: NA

TIME TO EFFECT:
SECONDS TO HOURS

REFERENCE DOCUMENTS:
MJC70-C011-01
SD72-Sh-0103-2
VS70-421001

GROUND TURNAROUND?..........YES
GROUND EQUIPMENT FLOW RATE READ OUT

PREPARED BY: DES C SCARLETT
APPROVED BY: DES ________________
REL R DIEHL

ITEM: DISCONNECT, QUICK, FILL
FUNCTION:
TO PROVIDE FOR GRAINING, VENTING, AND BLEEDING PROPELLANT TANKS. IN BOTH HORIZONTAL AND VERTICAL VEHICLE ORIENTATION.

FAILURE MODE: FAILS CLOSED (F)
CAUSE(S):
CONTAMINATION, PIECE PART STRUCTURAL FAILURE IMPROPER HANDLING.
EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF FILL CAPABILITY. (B) INCREASED GROUND OPERATIONS REQUIREMENTS. (C) LAUNCH DELAY. (D) NONE.
CORRECTING ACTION:
REMOVE AND REPLACE FILL VALVE OR ATTEMPT RECONNECTION.
REMARKS/HAZARDS:
NONE.
SUBSYSTEM Fwd Reaction Control
ITEM DC Solenoid Operated Valve

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 ALTERNATIVE 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 ALTERNATIVE PROGRAM LOGIC)?
   YES ☑ NO ☐

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

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

EXPLANATION/COMMENTS:

1. Manifold status on CRT and panel talk back is available.

6. One failure is all that can occur since there is no redundancy. The Shuttle can tolerate this failure since it is a criticality 3.

7. The measurements V42X1332X and V42X1232X are downlisted and available for CRT callup.
**System:** FWD - Reaction Control

**Assembly:** Propellant Feed

**P/N** M228d-G420-0011/-0012

**P/N Vendor:** 72995-0011/-0012

**Quantity:** 2

**Mission:** HF VF X HF OF SA

**Phase(S):** PL LO DG X DU LS

**Failure Mode & Effects Analysis - Orsat:R**

**Failure Detectable in Flight?** Yes

**Manifold Position Indicator V42X1232E**

**Ground Turnaround?** Yes

**Same as Flight**

**Prepared By:**

DES: R Burkhardt
REL: R Diehl

**Approved By:**

DES
REL

**Item:** Valve, DC Solen operated -

**Vernier Thruster Manifold, (1/4") 31-stable, Solenoid driven 26VDC.**

**Function:**

To provide isolation of propellant manifold and associated vernier thrusters 1) subsequent to downstream failure(s) 2) prior to system activation.

**Failure Mode:** Fails closed-premature (F)

**Operation**

**Cause(S):**

- Improper electrical signal (continuous short), piece part failure, contamination, vibration.

**Effect(S):** On (A) Subsystem (E) Interfaces (C) Mission (D) Crew/vehicle

- (A) Loss of vernier thruster function. (B) None. (C) Possible early mission termination. Because large thrusters inadequate for small rate attitude hold. (D) None.

**Correcting Action:**

Attempt to utilize large thruster in affected axis to maintain small deadband.

**Remarks/Hazards:**

- Potential for collision with or loss of payload/satellite. See consolidated controls FMEA # 73895 FMEA 1.
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<th>REACTION CONTROL</th>
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<td>PROPELLANT FEED</td>
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<td>P/N RI</td>
<td>MC284-0420-0011/-0012</td>
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<tr>
<td>P/N VENDOR</td>
<td>73895-0011/-0012</td>
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<td>2</td>
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<tr>
<td>MISSIONS</td>
<td>HF VF X FF OF SM</td>
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<tr>
<td>PHASE(S)</td>
<td>PL LD 00 X 00 LS</td>
</tr>
<tr>
<td>REDUNDANCY SCREEN</td>
<td>A-PASS B-PASS C-FAIL</td>
</tr>
</tbody>
</table>

**ITEM: VALVE, DC SOLENOID OPERATED**

- **VERNIER THRUSTER MANIFOLD, (1/4") SI-STABLE, SCLENOID DRIVEN 28VDC. (LV 157-158)**

**FUNCTION:**
- To provide isolation of propellant manifold and actuate vernier thrusters.
  1) Subsequent to downstream failure(s)
  2) Prior to system activation.

**FAILURE MODE:** Fail closed—premature (F)

**OPERATION**

**CAUSE(S):**
- Improper electrical signal (continuous short), piece part failure, contamination, vibration.

**EFFECT(S):** On (A)Subsystem (B)Interfaces (C)Mission (D)Crew/Vehicle:
  (A) Loss of vernier thruster function.
  (B) None.
  (C) Possible early mission termination, because large thrusters inadequate for small rate attitude hold.
  (D) None.

**DISPOSITION & RATIONALE**
(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) Series control circuitry provided to minimize failure mode. 100 micron filter is provided. Media has been filtered to 25 micron prior to entering tank. Special emphasis placed on the design and layout of solenoid wiring to preclude shorts. (B) Qual test includes 40 minutes per axis of random vibration at anticipated mission levels and life testing consisting of 2000 operating cycles. Item is used during system evaluation at White Sands testing. (C) Turnaround inspection includes monitoring tests to verify electrical power to solenoid valve for evidence of short circuit. Supplier audit conducted 8-31-77 verified supplier inspection exercised control of parts ID, parts protection, MFG processes, contamination control, and corrosion protection verification. (D) Failures on Apollo were mostly due to contamination resulting from in-house processing.
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 [ ] NO [X]

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

5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?
   *YES [X] NO [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 [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. V42P1115C, 1116C will give a class 2 caution and warning alert. Gross leak indication will detect failure.
   If an internal rupture occurs and helium reaches the thrusters you will get a "fail off" light from redundancy management.

6. There are no redundant tanks.

8b. Backup flight system same as primary.
SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N 51: MC262-G061-0001/0002
P/N VENDOR: 855C33200O-069/010
QUANTITY: 2

MISSIONS: HF, VF, PP, OF, SM

FAILURE DETECTABLE IN FLIGHT?: YES
FAILURE DETECTABLE IN FLIGHT TIMES TO EFFECT:
1116C
GROUND TURNAROUND: YES

PREPARED BY:

APPROVED BY:

DESCRIPTION:

REMARKS/HAZARDS:

POTENTIAL HAZARD FROM FIRE, EXPLOSION DUE TO FREE FUEL IN MODULE.
REFERENCE HAZARDS 1YXX-0302-02 AND 1YXX-0302-04.
SHUTTLE CRITICAL ITEMS LIST – ORBITER 102

SUBSYSTEM : FWD – REACTION CONTROL
ASSEMBLY : PROPELLANT FEED
P/N RI : MC282-0061-0001/0002
P/N VENDOR : 855C3020000-009/010
QUANTITY : 2

ABORT : CRIT. FUNC: 1
MISSIONS : HF VF X FF OF SM
PHASE(S) : PL X LO X ON X DO X LS

PREPARED BY: DES R BENS OES
REPLACE: R DIEHL REL

P/N : MCZ82-OC61-0001/002
VENUE: 855C3020000-009/010
MISSIONS: HP VF X FF OF SM
QUANTITY: 2
PHASE(S): PL X LO X ON X DO X LS

CREW/VEHICLE: 1

FAILURE MODE: STRUCTURAL FAILURE – (S)
CAUSE(S): VIBRATION, OVERPRESSURIZATION, MECHANICAL SHOCK, STRESS CORROSION, FATIGUE

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF PROPELLANT SUPPLY FOR MODULE THRUSTERS. (B) POTENTIAL FIRE/EXPLOSION AND CERTAIN CONTAMINATION OF SUBSYSTEMS IN RCS COMPARTMENT. (C) LOSS OF MISSION. (D) POTENTIAL LOSS OF CREW/VEHICLE FROM EXPLOSION AND/OR LACK OF PROPELLANT.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) DESIGN FACTOR OF SAFETY IS 1.5 MIN. DEVELOPMENT TESTS INCLUDE WELD CYCLE LIFE (800 CYCLES), FRACTURE MECHANICS, FORGING EVALUATION, AND TUBE SHADING. (B) TANKS SUBJECTED TO RADIOGRAPHIC, FLUORESCENT PENETRANT, PROOF PRESSURE (1.33 MAX OPER PRESSURE), AND EXTERNAL LEAK TESTS DURING ACCEPTANCE TESTING. TANKS SUBJECTED TO 90 DAY PROPELLANT EXPOSURE, 800 PRESSURE CYCLES, 48 MINUTES PER AXIS OF 3.9 GRMS RANDOM VIBRATION AND BURST PRESSURE DURING QUAL PROGRAM. (C) TURNAROUND INSPECTION INCLUDES MONITORING FUNCTIONAL TEST DURING PRESSURIZATION CYCLE FOR EVIDENCE OF LEAKS. VISUAL INSPECT WHERE ACCESSIBLE FOR DAMAGE. AUDIT CONDUCTED 11-1-76 VERIFIED SUPPLIER INSPECTION CONTROL OF MATL IDENTIFICATION PARTS PROTECTION AFG PROCESSES, CORROSION PROTECTION PROVISIONS, NDE EXAM OF WELDS AND STORAGE ENVIRONMENTS. (D) NONE [NEW DEVELOPMENT ITEM]

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

APPREO BY: APPROB
DES R BENS OES
REL R DIEHL REL

APPROVED WITH CHANGES

See Section 13.0

1975-SH-0003

SD75-SH-0003
HARDWARE/SOFTWARE ANALYSIS CHECKLIST

SUBSYSTEM: Fwd Reaction Control
FMEA NUMBER: 03-2F-111110-2
SD75-SH-0016A

ITEM: Tank Assembly and Propellant Acquisition
FAILURE MODE: Small Crack - External Leakage Device

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. V42P1115C, 1116C will give a class 2 caution and warning alert. Gross leak indication will detect failure. If an internal rupture occurs and helium reaches the thrusters you will get a "fail off" light from redundancy management.

6. There are no redundant tanks.

8b. Backup flight system same as primary.
SUBSYSTEM : FWD - REACTION CONTROL
ASSEMBLY : PROPELLANT FEED
P/N VENDOR: 2550320000-009/01C
P/N: MC282-0061-C0C1/C002
P/N VENDOR: 2550320000-009/01C
QUANTITY: 2
ONE REQ'D
NUMBER OF SUCCESS PATHS REMAINING:
REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
FAILURE DETECTABLE IN FLIGHT?: YES
MONITOR TANK PRESSURE: V42P-1310C, 1312C, 1316C
GROUND TURNAROUND?: YES
SAME AS FLIGHT AND VISUAL OBSERVATION
TIME TO EFFECT:
REFERENCE DOCUMENTS:
M077C-0061-01C
S072-SH-0103-2
VS70-421601
PREPARED BY:
DES R BEMIS
REL R DIEHL
APPROVED BY:

ITEM: TANK ASSY, PROPELLANT
INCLUDING PROPELLANT ACQUISITION DEVICE AND COMPARTMENT CARRIER.
FUNCTION:
TO STORE/SUPPLY PROPELLANT TO REACTION CONTROL ENGINE MANIFOLD.
Nominal storage pressure 245 PSIG ± 15 (1.5 SAFETY FACTOR).
FAILURE MODE: EXTERNAL LEAKAGE - (S)
TANK CRACK OR FLAW WHICH ALLOWS A LIMITED AMOUNT OF PROPELLANT TO LEAVE THE TANK.
CAUSE(S):
VIBRATION, STRESS CORROSION, PRESSURE CYCLES, FATIGUE OR FLANGE SEAL FAILURE.
EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF A QUANTITY OF PROPELLANT AND HELIUM TO AN EXTENT DEPENDENT ON SIZE AND LOCATION OF LEAK.
(B) CONTAMINATION OF SURROUNDING AREA AND SUBSYSTEMS.
(C) LOSS OF MISSION.
(D) POTENTIAL EXPLOSION AND LOSS OF CREW/VEHICLE IF IGNITION SOURCE PRESENT (SECOND FAILURE).
CORRECTING ACTION:
CLOSE HELIUM PRESSURIZATION ISOLATION VALVE TO MINIMIZE AMOUNT OF PROPELLANT/HELIUM LOST.
REMARKS/HAZARDS:
POTENTIAL HAZARD FROM FREE PROPELLANT IN MODULE. NO REDUNDANCY PROVIDED FOR THIS ITEM. REFERENCE HAZARD 1YXX-0302-05.
SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N RI: MC282-0061-0001/0002
P/N VENDOR: 855C3320000-009/010
QUANTITY: 2

ASSEMBLY: PROPELLANT
P/N VENDOR: 855C3320000-009/010
MISSIONS: HF, VF, FF, OF SM
PHASE(S): PL X LO X CO X DO X LS

PREPARED BY: APPRO-D
APPROVED BY: NAS

ITEMS: TANK ASSY, PROPELLANT
INCLUDING PROPELLANT ACQUISITION DEVICE AND COMPARTMENT BARRIER. (TK 103).
FUNCTION:
TO STORE/SUPPLY PROPELLANT TO REACTION CONTROL ENGINE MANIFOLDS. NOMINAL STORAGE PRESSURE 245 PSIG + OR -15 (1.5 SAFETY FACTOR).

FAILURE MODE: EXTERNAL LEAKAGE
TANK CRACK OR FLAW WHICH ALLOWS A LIMITED AMOUNT OF PROPELLANT TO LEAVE THE TANK.

CAUSE(S):
VIBRATION, STRESS CORROSION, PRESSURE CYCLES, FATIGUE OR FLANGE SEAL FAILURE

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF A QUANTITY OF PROPELLANT AND HELIUM TO AN EXTENT DEPENDENT ON SIZE AND LOCATION OF LEAK. (B) CONTAMINATION OF SURROUNDING AREA AND SUBSYSTEMS. (C) LOSS OF MISSION. (D) POTENTIAL EXPLOSION AND LOSS OF CREW/VEHICLE IF IGNITION SOURCE PRESENT (SECOND FAILURE).

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) DESIGN FACTOR OF SAFETY IS 1.5 MIN. DEVELOPMENT TESTS INCLUDE WELD CYCLE LIFE (800 CYCLES), FRACTURE MECHANICS, FORGING EVALUATION, AND TUBE SWAGING. (B) TANKS SUBJECTED TO RADIOGRAPHIC, FLUORESCENT PENETRANT, PROOF PRESSURE (1.33 MAX OPER PRESSURE), AND EXTERNAL LEAK TESTS DURING ACCEPTANCE TESTING. TANKS SUBJECTED TO 90 DAY PROPELLANT EXPOSURE, 800 PRESSURE CYCLES, 48 MINUTES PER AXIS OF 3.9 GMS RANDOM VIBRATION, AND BURT PRESSURE DURING QUAL PROGRAM. (C) TURNAROUND INSPECTION INCLUDES MONITORING FUNCTIONAL TEST DURING PRESSURIZATION CYCLE FOR EVIDENCE OF LEAKS. VISUAL INSPECT WHERE ACCESSIBLE FOR DAMAGE. AUDIT CONDUCTED 11-1-76 VERIFIED SUPPLIER INSPECTION CONTROL OF MALT IDENTIFICATION PARTS PROTECTION MFG PROCESSES, CORROSION PROTECTION PROVISIONS, NDE EXAM OF WELDS AND STORAGE ENVIRONMENTS. (D) NONE (NEW DEVELOPMENT ITEM).
## HARDWARE/SOFTWARE ANALYSIS CHECKLIST

**SUBSYSTEM**: Fwd. Reaction Control  
**FMEA NUMBER**: 03-2F-111110-3  
**ITEM**: Tank Assembly and Propellant  
**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** [ ]

### 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 ALTERNATIVE 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** [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?

- **Yes** [x]  
- **No** [ ]

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

   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
   - **Yes** [x]  
   - **No** [ ]

   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
   - **Yes** [x]  
   - **No** [ ]

*EXPLANATION REQUIRED (SEE BELOW)*

### CHANGE/RETENTION RATIONALE SUMMARY:

1. **No** H/S Issues  
2. Hardware Accepts Risk  
3. **No** Software Detection  
4. Detection During Checkout  
5. **Acceptance Rationale Below**  
6. **Recommended Changes Below**

**FMEA CHANGE RECOMMENDED**

**EXPLANATION/COMMENTS:**

1. "Fail Off" detection in RCS RM.

6. No redundant tanks.

7. No correcting action—abort.

8b. Same as primary.
SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 1C2

SUBSYSTEM : FWO - REACTION CONTROL
ASSEMBLY : PROPELLANT FEED
P/N RI : KC282-0061-0001/0002
P/N VENDOR : 65EC332CGC-CC9/61C
QUANTITY : 2
ONE REQ'D
PER PROPELLANT

FAILURE DETECTABLE IN FLIGHT? YES
ENGINE PERFORMANCE

GROUND TURNAROUND? NO

PREPARED BY:
DES R BEMIS
REL R DIEHL

APPROVED BY:

ORIGINAL PAGE IS OF POOR QUALITY
86
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM : FWD - REACTION CONTROL  
ASSEMBLY : PROPELLANT FEED  
P/N RI : MC282-0051-0001/0002  
P/N VENDOR: 855C332000-009/010  
QUANTITY : 2  
:ONE REQ'D  
:PER PROPELLANT  

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

-prepared by:
 DES R BEMIS DES  
 REL R DIEHL REL  

-PROPELLENT FEED ABORT:
 CRIT. FUNC: 1  
 CRIT. HDW: 1

MISSIONS: HF VFX FF OF SH'  
PHASE(S): PL LO X NO X DD X LS

PREPARED BY:
 APPROVED BY:  
 VENDOR:  
 MISSIONS:  
 QUANTITY: 2  
 PHASE(S): PL LO X NO X DD X LS

APPROVED WITH CHANGES
See Section 13.0

ITEM: TANK ASSY, PROPELLANT  
INCLUDING PROPELLANT ACQUISITION DEVICE AND COMPARTMENT BARPIER. (TK 103).  

FUNCTION:
 TO STORE/SUPPLY PROPELLANT TO REACTION CONTROL ENGINE MANIFOLDS. NOMINAL  
STORAGE PRESSURE 245 PSIG + OR -15 (1.5 SAFETY FACTOR).  

FAILURE MODE: RESTRICTED FLOW - (S)  
STRUCTURAL FAILURE OF PROPELLANT ACQUISITION DEVICE WHICH BLOCKS OR  
RETARDS RATE OF FLOW OF PROPELLANT INTO TANK OUTLET.  

CAUSE(S):  
VIBRATION, MECHANICAL SHOCK, EXCESSIVE FLOW RATES DUE TO EXCESSIVE GAS  
IN THRUSTER MANIFOLD. (SEE FAILURE MODE NO. 4 ON NEXT PAGE).  

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:  
(A) LOSS OF FULL PROPELLANT FLOW CAPABILITY/HELIUM INGESTION. (B) NONE.  
(C) LOSS OF MISSION DUE TO LOSS OF PROPELLANT. (D) NONE UNLESS FAILURE  
OCCURS WHEN MODULE REQUIRED FOR ET SEPARATION.  

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:  
(A) 1.5 DESIGN SAFETY FACTOR. DEVELOPMENT TESTS VERIFY WELD CYCLE LIFE,  
SCREEN REPAIR METHOD, SCREEN CYCLE LIFE AND SCREEN FLOW. (B) PROPELLANT  
ACQUISITION DEVICE COMPONENTS, SUBASSEMBLIES AND TANK ASSY INTEGRITY  
VERIFIED BY PERFORMING BUBBLE POINT TEST. TANKS SUBJECTED TO PROPELLANT  
EXPOSURE, 200 EXPULSION CYCLES, 48 MINUTES PER AXIS OF 3.9 GMS RANDOM  
VIBRATION AND BURST PRESSURE DURING QUAL PROGRAM. (C) TURNAROUND  
INSPECT INCLUDES MONITOR FLOW DURING FUNCTIONAL TESTS. AUDIT CONDUCTOR  
11-1-76 VERIFIED SUPPLIER INSPECTION CONTROL OF MATE IDENTIFICATION  
PARTS PROTECTION MFG PROCESSES, CORROSION PROTECTION PROVISIONS, NDE  
EXAM OF WELDS AND STORAGE ENVIRONMENTS. (D) NONE (NEW DEVELOPMENT ITEM).  

103387  
SD75-SH-0003
## HARDWARE/SOFTWARE ANALYSIS CHECKLIST

**SUBSYSTEM**  |  **FMEA NUMBER**  |  **ITEM**
--- | --- | ---
Fwd Reaction Control | SD75-SH-0016A | Tank Assembly and Propellant Acquisition Failure Mode: Loss of Gas in Propellant Device

### 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?

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?
   - **YES**
   - **NO**
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
   - **YES**
   - **NO**

### EXPLANATION/COMMENTS:

1. "Fail Off" detection in RCS RM.
2. No redundant tanks.
3. No correcting action - abort.
4. Same as primary.

---

**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. "Fail Off" detection in RCS RM.
2. No redundant tanks.
3. No correcting action - abort.
4. Same as primary.

---

**X** FMEA CHANGE RECOMMENDED
SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N: MC282-CC61-001/002
P/N VENDOR: 655C321000C-001/016
ASSEMBLY: PROPELLANT FEED ABORT: CRITICAL FUNCTION: 2
QUANTITY: 2
PER REQU'D NUMBER OF SUCCESS PATHS REMAINING
FAILURES DETECTABLE IN FLIGHT?: YES
ENGINE PERFORMANCE AND C HAMBER PRESSURE: V42P1541
GROUND TURNAROUND?: NO
PREPARED BY: DES R BEHMS
APPROVED BY: DES

ITEM: TANK ASSY, PROPELLANT
INCLUDING PROPELLANT ACQUISITION DEVICE AND COMPARTMENT BARRIERS.

FUNCTION:
TO STORE/SUPPLY PROPELLANT TO REACTION CONTROL ENGINE MANIFOLDS.
NOMINAL STORAGE PRESSURE 245 PSIG + OR -15 (1.5 SAFETY FACTOR).

FAILURE MODE: LOSS OF GAS RETENTION IN (S) PROPELLANT ACQUISITION DEVICE (PAC).

CAUSE(S):
VARIATION, SHOCK, PROPELLANT CONTAMINATION (CHEMICAL OR DIRT).

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (L) COMMON VEHICLE:
(A) EXCESSIVE GAS FLOW TO THRUSTERS COULD CAUSE TANK BARRIER FAILURE.
(B) POTENTIAL DAMAGE TO THRUSTERS IF UNDETECTED.
(C) AGENCY DECISION.
(D) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR TO SEPARATION.

CORRECTING ACTION:
SHUT DOWN RCS AND ABORT MISSION.

REMARKS/HAZARDS:
IF UNDETECTED, THE THRUSTERS COULD BE DAMAGED WHICH COULD CAUSE ENTRY UNCERTAINTY.
SUBSYSTEM: FWO - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED ABORT:
P/N RI: 4C202-0061-0001/0002 CRIT. FUNC: 2
P/N VENDOR: 855C3320000-009/010 MISSIONS: HF VF X FF DF SM
QUANTITY: 2 PHASE(S): PL X LO X CO X DO X LS
ONE REQ'D
PER PROPELLANT
REDFUNDANCY SCREEN: A-N/A B-N/A C-Y/
PREPARED BY: AP PROVERB
APPROVED BY: (N/A)
APPROVED WITH CHANGES
See Section 13.0
ITEM: TANK ASSY, PROPELLANT
INCLUDING PROPELLANT ACQUISITION DEVICE AND COMPARTMENT ARRAYS (TK 103).
FUNCTION:
TO STORE/SUPPLY PROPELLANT TO REACTION CONTROL ENGINE MANIFOLDS. NOMINAL STORAGE PRESSURE 245 PSIG + OR -15 (1.5 SAFETY FACTOR).
FAILURE MODE: LOSS OF GAS RETENTION IN (S)
PROPELLANT ACQUISITION DEVICE (PAD).
CAUSE(S):
VIBRATION, SHOCK, PROPELLANT CONTAMINATION (CHEMICAL OR DIRT).
EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) EXCESSIVE GAS FLOW TO THRUSTERS COULD CAUSE TANK BARRIER FAILURE.
(B) POTENTIAL DAMAGE TO THRUSTERS IF UNDETECTED.
(C) ABDIT DECISION.
(D) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR TO ET SEPARATION.
DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) DESIGN FACTOR OF SAFETY IS 1.5 MIN. DEVELOPMENT TESTS INCLUDE WELD CYCLE LI FE (800 CYCLES), FRACTURE MECHANICS, FORGING EVALUATION, AND TUBE SWAGING. (B) PROPELLANT ACQUISITION DEVICE COMPONENTS, SUBASSEMBLIES AND TANK ASSY INTEGRITY VERIFIED BY PERFORMING BUBBLE POINT TESTS. TANKS SUBJECTED TO PROPELLANT EXPOSURE, 200 EXPULSION CYCLES, 45 MINUTES PER AXIS OF 3.9 GRMS RANDOM VIBRATION AND BURST PRESSURE DURING QUAL PROGRAM. (C) TURNAROUND INSPECTION INCLUDES PERIODIC BUBBLE POINT CHECKS OF THE PAD. AUDIT CONDUCTED 11-1-76 VERIFIED SUPPLIER INSPECTION CONTROL OF MTL IDENTIFICATION PARTS PROTECTION MFG PROCESSES, CORROSION PROTECTION PROVISIONS, NO EXAM OF WELDS AND STORAGE ENVIRONMENTS.
(D) NONE (NEW DEVELOPMENT ITEM).
<table>
<thead>
<tr>
<th>Item</th>
<th>Flex Line and Fittings</th>
<th>Failure Mode</th>
<th>External Leakage</th>
</tr>
</thead>
</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 [ ] 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 [ ] NO [X]

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

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

7. **IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?**
   - N/A [ ] YES [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. V42P1115C, 1116C will give class 2 alarm.

Gross leak detection applies.
SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: THRUSTER
P/N Ki: MC271-0024
P/N VENDOR: 74713-Thru 74717
QUANTITY: 3
MISSIONS: HF VF FF OF X SM
PHASE(S): PL X LG X DG X LS X
REDUNDANCY SCREEN: A-N/A B-N/A C-N/A

PREPARED BY: DES J. TAGGART
APPROVED BY: DES _________ R. DIEHL ________

ITEM: LINE ASSEMBL., FLEXIBLE AND FITTINGS.
FUNCTION:
TO PROVIDE COUPLING BETWEEN PROPELLANT SUBSYSTEM AND FORWARD RCS PRIMARY AND VERNIER THRUSTER.

FAILURE MODE: EXTERNAL LEAKAGE - (5)

CAUSE(S): FATIGUE, SHOCK, VIBRATION, HANDLING.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF PROPELLANTS TO EXTENT OF LEAK SIZE; (B) INCREASED G & G; (C) CONTROL & USE OF ALTERNATE THRUSTERS; (D) POTENTIAL MISSION TERMINATION PRIOR TO PLANNED TIME; (D) NO EFFECT AFTER ASCENT UNLESS LEAK IS EXCESSIVE & RESULTS IN IGNITION WITH REACTANT (2ND ORDER FAILURE) DURING A RILS ABBERT THE LOSS OF A MANIFOLD RESULTS IN THE LOSS OF TWO DOWN FIRING THRUSTERS WHICH RESULTS IN CRIT 1. DURING ASCENT THE FAILURE CANNOT BE DETECTED AND ISOLATED WHICH RESULTS IN POSSIBLE LOSS OF VEHICLE.

CORRECTING ACTION:
ISOLATE THRUSTER AT MANIFOLD.

REMARKS/HAZARDS:
POSSIBLE HAZARD FROM FREE FUEL IN MODULE.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM : FWD - REACTION CONTROL  
ASSEMBLY : THRUSTER  
P/N RI : MC271-0084  
P/N VENDOR: 74713-THRU 74717  
QUANTITY : 30  
MISSIONS: HF VF X FF JF X SM  
PHASE(S): PL X LO X 00 X CO X LS X  
* ONE FUEL AND ONE OXIDIZER PER THRUSTER  
REduNDANCY SCREEN: A-N/A B-N/A C-V/  
PREPARED BY: J. TAGGART  
APPROVED BY: T. DIEHL  
DES  
REL  
* ITEM: LINE ASSEMBLY FLEXIBLE AND FITTINGS.  
FUNCTION: TO PROVIDE COUPLING BETWEEN PROPELLANT SUBSYSTEM AND FORWARD RCS PRIMARY AND VERNIER THRUSTERS.  
FAILURE MODE: EXTERNAL LEAKAGE - (S)  
RUPTURE OF LINE OR COUPLING.  
CAUSE(S): FATIGUE, SHOCK, VIBRATION, HANDLING.  
EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:  
(A) LOSS OF PROPELLANTS TO EXTENT OF LEAK SIZE.  
(B) INCREASED GN&C CONTROL & USE OF ALTERNATE THRUSTERS.  
(C) POTENTIAL MISSION TERMINATION PRIOR TO PLANNED TIME.  
(D) NO EFFECT AFTER ASCENT UNLESS LEAK IS EXCESSIVE & RESULTS IN IGNITION WITH REACTANT (2ND ORDER FAILURE) DURING A RTLS ABORT THE LOSS OF A MANIFOLD RESULTS IN THE LOSS OF TWO DOX NEXTERING THRUSTERS WHICH RESULTS IN CRIT 1. DURING ASCENT THE FAILURE CANNOT BE DETECTED AND ISOLATED WHICH RESULTS IN POSSIBLE LOSS OF VEHICLE.  
DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:  
(A) DESIGN BURST PRESSURE IS UP TO 3 TIMES THE MAX OPER PRESSURE OF 700 PSIG. PROOF PRESSURE IS UP TO 1.5 TIMES THE MAX OPER PRESSURE. THE DESIGN ALLOWS SUFFICIENT MOVEMENT TO PRECLUDE EXCESSIVE STRESSES DURING INSTALLATION AND OPERATION. LINES CAN BE ISOLATED AT THE MANIFOLD IN CASE OF LEAKAGE.  
(B) POST INSTALLATION TEST AND OPERATIONAL CHECKOUTS WILL VERIFY SYSTEM INTEGRITY. ALL LINES SUBJECTED TO PROOF PRESSURE DURING ATP AND RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS DURING QUAL TESTING. LINES ARE ALSO TESTED DURING SYSTEM EVALUATION AT WHITE SANDS TEST FACILITY.  
(C) SEE FMEA/CIL 102136-1.  
(DIS) NO HISTORY OF FAILURE IN FLIGHT. (NEW DEVELOPMENT ITEM FOR MANNED FLIGHT APPLICATION.)

C-2
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST

**SUBSYSTEM:** Fwd. Reaction Control  
**FMEA NUMBER:** SD75-SH-0016A  
**FAILURE MODE:** Improper Mixture Ratio

<table>
<thead>
<tr>
<th>Item</th>
<th>Failure Mode</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injector Plate</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

   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 NEGATE 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)?**

   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. "Fail Off" in RCS RM if sufficiently blocked.
SUBSYSTEM: FW - REACTION CONTROL
ASSEMBLY: THRUSTER, PRIMARY
P/N 1: MC467-0028
P/N VENDOR: X3C668
QUANTITY: 14

SYSTEM: FW
REACTION CONTROL

NO 03-2F -121311-1 REV: 11/14/7

ASSEMBLY: THRUSTER, PRIMARY
ABORT: ABORT CRIT. FUNC: 1A

P/N 1: MC467-0028
P/N VENDOR: X3C668
MISSIONS: HF VF X FF CF SM

FUNCTION: TO RECEIVE FUEL AND OXIDIZER FROM THRUSTER INLET VALVES AND PROVIDE DOUBLET MIXING AT 1.60 OX TO FUEL (WEIGHT) RATIO FOR A HYPERSONIC REACTION WHICH PRODUCES 825 POUNDS OF THRUST AT 76,000 FEET. ALSO CONTROL CHAMBER WALL COOLING.

FAILURE MODE: FAILS TO DELIVER PROPS (F) AT PROPER MIXTURE RATIO AND FAILS TO PROVIDE ADEQUATE COOLING OF THE COMBUSTOR WALL.

CAUSE(S): CONTAMINATION, BLOCKED ORIFICES.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF ONE THRUSTER IN A GIVEN AXIS. (3) GNDC CONTROL SWITCHING REQUIRED. (C,D) NO EFFECT. (E) POSSIBLE LOSS OF VEHICLE IF FAILURE OCCURS BEFORE ET SEPARATION. DOWN FIRING THRUSTERS REQUIRED FOR ET SEPARATION.

CORRECTING ACTION:
SWITCH TO REDUNDANT THRUSTER IN AFFECTED AXIS. ISOLATE MANIFOLD CONTAINING FAILED THRUSTER.

REMARKS/HAZARDS:
POSSIBLE LOCAL HOT SPOT RESULTING IN COATING DAMAGE OR COMBUSTOR BURN THROUGH.

PREPARED BY: DES W. SEARCY
APPROVED BY: DES
REL R. DIEHL

REFERENCE DOCUMENTS:
M/JT0-C001-GIA
SD72-SH-0192-2
VS70-41001

ITEM: INJECTOR, PLATE

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

SUBSYSTEM:FWD - REACTION CONTROL
ASSEMBLY:THRUSTER, PRIMARY
P/N RI:MC467-0028
P/N VENDOR:X30888
QUANTITY:14

ASSEMBLY:THRUSTER, PRIMARY
P/N: ABORT: ABORT
CRIT. Func: IR
RTLS
MISSIONS: HF VF X FF OF . S4
PHASE(S): PL LO X OO X DO X LS

P/N VENDOR: X30888
MISSIONS: HF VF X FF OF . S4

PREPARED BY: DES
REL

PREPARED BY: DES
REL

REV: 11/14/78

ASSEMBLY:THRUSTER, PRIMARY
ABORT: ABORT
CRIT. Func: IR
RTLS
MISSIONS: HF VF X FF OF . S4
PHASE(S): PL LO X OO X DO X LS

ONE INJECTOR PROVIDED FOR EACH PRIMARY THRUSTER

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

FUNCTION:
TO RECEIVE FUEL AND OXIDIZER FROM THRUSTER INLET VALVES AND PROVIDE DOUBLET MIXING AT 1.60 OX TO FUEL (WEIGHT) RATIO FOR A HYPERGOLIC REACTION WHICH PRODUCES 825 POUNDS OF THRUST AT 70,000 FEET. ALSO CONTROL CHAMBER WALL COOLING.

FAILURE MODE: Fails to deliver props (F)
AT PROPER MIXTURE RATIO AND FAILS TO PROVIDE ADEQUATE COOLING OF THE COMBUSTOR WALL.

CAUSE(S):
CONTAMINATION, BLOCKED ORIFICES.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF ONE THRUSTER IN A GIVEN AXIS. (B) GNC CONTROL SWITCHING REQUIRED. (C,D) NO EFFECT. (E) POSSIBLE LOSS OF VEHICLE IF FAILURE OCCURS BEFORE ET SEPARATION. DOWN FIRING THRUSTERS REQUIRED FOR ET SEPARATION.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) 75 MICRON FILTER PROVIDED UPSTREAM TO PRECLUDE CONTAMINATION FUEL HAS BEEN FILTERED TO 25 MICRONS PRIOR TO ENTERING TANK. ACOUSTIC CAVITIES PRECLUDE OCCURRENCE OF COMBUSTION INSTABILITY IN THE EVENT OF POOR DISTRIBUTION. (B) TOTAL FLOW & FLOW DISTRIBUTION CHECKED BY WATER FLOW TEST AND VERIFIED BY BURN TEST DURING THRUSTER ACCEPTANCE TESTS. (C) FIBER OPTICS USED TO VISUALLY INSPECT INJECTOR HOLES FOR EVIDENCE OF BURRS AND CONTAMINATION PRIOR TO ASSEMBLY AUDIT CONDUCTED ON 9-2-76 VERIFIED THAT SUPPLIER INSPECTION CONTROLS RAW MATERIAL VERIFICATION, PARTS PROTECTION, HFC FAB AND ASSY OPERATIONS, CONTAMINATION CONTROL, CORROSION CONTROL PROVISIONS AND STORAGE ENVIRONMENTS. TURN AROUND INSPECTION TO INCLUDE USE OF OPTICS INSPECTION WHERE ACCESSIBLE FOR EVIDENCE OF DAMAGE & SYSTEM FLUID SAMPLINGS FOR DETECTION OF CONTAMINATION. (D) NO FAILURES OF THIS TYPE ON APOLLO.
<table>
<thead>
<tr>
<th>Item</th>
<th>Thrust Chamber</th>
<th>Failure Mode</th>
<th>Burn Through</th>
</tr>
</thead>
</table>

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 COMMANING 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 COMMANING 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? 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

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**EXPLANATION/COMMENTS:**

FMEA change - Measurement numbers V42X1541X through V42X1556X should be listed as V42P1541A through V42P1556A.

1. RM uses thrust chamber pressure transducers to sense the low pressure in question and give a "fail off" in RCS RM.

7. The thrust chamber measurements are downlinked.
SUBSYSTEM: FHW - REACTION CONTROL
ASSEMBLY: THRUSTER, PRIMARY
P/N: MC467-0028
VENDOR: X5C958
MISSIONS: HF VF X FF OF SN
PHASE(S): PL LO X DO X DU X LS
QUANTITY: 14
P/N: 121312-I
REV: 11/10/7
FMEA NO 03-2F

FAILURE MODE: OVERHEAT/BURNTHROUGH (S)
DUE TO INADEQUATE COOLING.

CAUSE(S):
- BLOCKED (CONTAMINATED) COOLANT (FUEL) INJECTOR HOLES, POOR BOUNDARY FLOW CONDITIONS
- COMBUSTION INSTABILITY, SEPARATION OR FRACTURE OF PROTECTIVE DISILICIDE COATING.

EFFECT(S):
- (A) LOSS OF A PRIMARY THRUSTER IN A GIVEN AXIS. (B) INCREASED GNCC CONTROL AUTHORITY REQUIRED. (C) POTENTIAL LOSS OF MISSION ABORT DECISION. (D) POTENTIAL LOSS OF VEHICLE. CRITICAL DAMAGE COULD OCCUR BEFORE FAILURE IS DETECTED.

CORRECTING ACTION:
- ISOLATE THRUSTER AND UTILIZE REDUNDANT THRUSTER IN AFFECTED AXIS.

REMARKS/HAZARDS:
- POTENTIAL HAZARD FROM ESCAPING HOT GASES IN MODULE AND POTENTIAL PROPAGATION OF FAILURE IF NOT ISOLATED IN A TIMELY MANNER.

PREPARED BY: DES W SEARCY
APPROVED BY: DES R DIEHL

ITEM: THRUST CHAMBER
FROM INJECTOR TO NOZZLE EXTENSION (COATED COLUMBIUM).
FUNCTION:
- TO CONTAIN HYPERGOLIC REACTION OF PROPELLANTS AND TO EXPAND COMBUSTION PRODUCTS TO PRODUCE THRUST THROUGH NOZZLE EXTENSION TO PROVIDE IMPULSE TO VEHICLE.

END OF PAGE
SUBSYSTEM : FWD - REACTION CONTROL
ASSOCIATION : THRUSTER, PRIMARY
P/N RI : 4C467-0029
P/N VENDOR: X30958
QUANTITY : 14

ASSEMBLY : THRUSTER, PRIMARY
ABORT: CRIT. FUNC: 1
P/N VENDOR: X30958
MISSIONS: HF VF X FF OF SM
PHASE(S): PL LD X DD X DD X LS

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

PREPARED BY: DES W. SEARCY
APPROVED BY: SSM

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

FUNCTION:
TO CONTAIN HYPERGOLIC REACTION OF PROPELLANTS AND TO EXPAND COMBUSTION
PRODUCTS TO PRODUCE THRUST THROUGH NOZZLE EXTENSION TO PROVIDE IMPULSE
TO VEHICLE.

FAILURE MODE: OVERHEAT/BURNTHROUGH
DUE TO INADEQUATE COOLING.

CAUSE(S):
BLOCKED (CONTAMINATED) COOLANT (FUEL) INJECTOR HOLES, POOR BOUNDARY
FLOW CONDITIONS COMBUSTION INSTABILITY, SEPARATION OR FRACTURE OF
PROTECTIVE DISILICIDE COATING.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF A PRIMARY THRUSTER IN A GIVEN AXIS. (B) INCREASED GN&C
CONTROL AUTHORITY REQUIRED. (C) POTENTIAL LOSS OF MISSION ABORT
DECISION. (D) POTENTIAL LOSS OF VEHICLE. CRITICAL DAMAGE COULD OCCUR
BEFORE FAILURE IS DETECTED.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
INTERMETALLIC DIFFUSION LAYER FORMS AN INTEGRAL BOND BETWEEN THE
DISILICIDE COATING AND THE PARENT COLUMBIA MATERIAL AND TENDS TO RESIST
SHOCK LOADING. 75 MICRON FILTER IN VALVE INLET UPSTREAM OF INJECTOR
HOLES WILL PRECLUDE ENTRY OF CONTAMINANTS. ACOUSTIC CAVITIES DAMPEN THE
FREQUENCIES THAT EXCITE INSTABILITY. (B) SIMULATED THRUSTERS AND
THRUSTER NO. 5 VIBRATION TESTS HAVE DEMONSTRATED THE ABILITY OF THE
DISILICIDE COATING TO WITHSTAND 2.0 G SQUARED PER HERZ RANDOM VIBRATION
STRESSES. THRUSTER IS SUBJECTED TO RANDOM VIBRATION AT ANTICIPATED
MISSION LEVELS DURING THE QUAL. PROGRAM. (C) COATING THICKNESS AND
QUALITY WILL BE CONTROLLED BY SUPPLIER INSPECTION PROCEDURE MPS 525
WHICH REQUIRES CERTIFICATION THAT COATING PROCESS CONFORMS TO THE
PROCESS SPEC. VISUAL INSPECTION, VERIFICATION OF COATING THICKNESS AND A
SMOKE TEST THAT VERIFIES COAT INTEGRITY. TURNAROUND INSPECTION TO
INCLUDE VISUAL INSPECTION FOR EVIDENCE OF BURN THRU. (D) NO FLIGHT
FAILURE HISTORY. (2) DEVELOPMENT FAILURES HAVE OCCURRED ON SHUTTLE
PROGRAM. ONE FAILURE DUE TO DOUBLET DESIGN WHICH HAS BEEN CHANGED AND
ONE FAILURE DUE TO THIN COAT OF DISILICIDE COATING. THIN COAT STILL
WITHSTOOD MORE FIRING TIME THAN IS NORMALLY SEEN BY THE THRUSTER IN
NORMAL 100 MISSION LIFE.
| 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: | *EXPLANATION REQUIRED (SEE BELOW) |
| A. | CAN THE BFS BE ENGAGED AFTER OCCURRENCE? | YES | NO |
| B. | WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE? | YES | NO |

**EXPLANATION/COMMENTS:**

3a. Instrumentation is available for software redesign.
ITEM: NOZZLE EXTENSION, COATED COLUMBIUM (WITH INSULATION BLANKET).
*FUNCTION:
*TO PROVIDE FOR EXPANSION OF COMBUSTION GASES TO M>1 SUCH THAT THE REQUIRED THRUST IS PRODUCED.
*FAILURE MODE: STRUCTURAL FAILURE, (S)
*CAUSE(S):
*HIGH TEMPERATURE IN LOCAL SPOT DUE TO FILM COOLING FAILURE (CONTAMINATED INJECTOR COOLANT HOLES) VIBRATION, SHOCK, WELD OR MATERIAL DEFiCTION.
*EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
* (A) LOSS OF A THRUSTER IN A GIVEN AXIS. (B) INCREASED GN&C CONTROL AUTHORITY REQUIRED. (C) NO EFFECT. (D) NO EFFECT UNLESS FAILURE PROPAGATES-CRIT1 FOR RTLS ABORT IF THRUSTER IS ISOLATED AT MANIFOLD LEVEL
*CORRECTING ACTION:
*ISOLATE THRUSTER AT INLET VALVE OR MANIFOLD AND UTILIZE ALTERNATE IN AFFECTED AXIS.
*REMARKS/HAZARDS:
*POSSIBILITY FOR FAILURE PROPAGATION TO ADJACENT THRUSTERS IF INSULATION BLANKET DOES NOT PRECLUDE GAS/LIQUID ESCAPING. REFERENCE MAZAK REPORT IYXX-0302-01.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: FWD - REACTION CONTROL

ASSEMBLY: THRUSTER, PRIMARY
P/N REM: HC46T-0028
P/N VENDOR: X30872
QUANTITY: 14

ABORT: ABORT, CRIT. FUNC: 1
RTLS CRIT. HD: 1
MISSIONS: HF, VFX FF OF SM
PHASE(S): PL, LO X 60 X DO X LS

PREPARED BY:
DEP: W. Searcy
REL: R. Diehl

APPROVED BY:
APPROVED BY (NASA):

APPROVED WITH CHANGES
See Section 13.0

ITEM: NOZZLE EXTENSION,
COATED COLUMBIUM (WITH INSULATION BLANKET).

FUNCTION:
TO PROVIDE FOR EXPANSION OF COMBUSTION GASES TO 101 SUCH THAT THE REQUIRED THRUST IS PRODUCED.

FAILURE MODE: STRUCTURAL FAILURE,
BURN-THRU.

CAUSE(S):
HIGH TEMPERATURE IN LOCAL SPOT DUE TO FILM COOLING FAILURE (CONTAMINATED INJECTOR COOLANT HOLES) VIBRATION, SHOCK, WELD OR MATERIAL DEFECT.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF A THRUSTER IN A GIVEN AXIS. (B) INCREASED GNC CONTROL AUTHORITY REQUIRED. (C) NO EFFECT. (D) NO EFFECT UNLESS FAILURE PROPAGATES-CRITICAL FOR RTLS ABORT IF THRUSTER IS ISOLATED AT MANIFOLD LEVEL.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY
(A) INTERMETALLIC DIFFUSION LAYER FORMS INTEGRAL BOND TO RESIST SHOCK-COATING PROCESS CONTROLLED. INJECTOR DESIGN INCORPORATES ACOUSTIC CAVITIES WHICH REDUCE POSSIBILITY OF INSTABILITY. DUCTILE PROPERTIES OF C-103 COLUMBIUM PRECLUDES FRAGMENTATION OR CATASTROPHIC MODE OF FAILURE. (B) VIBRATION TESTS DEMONSTRATE ABILITY OF DISILICIDE COATING TO WITHSTAND 2.0 G SQUARED/Hz RANDOM VIBRATION. TEMP TESTS DEMONSTRATE EXCELLENT DUCTILE/BRITTLE QUALITIES FOR COATED C-103 COLUMBIUM. (C) TURNAROUND INSPECTION TO INCLUDE VISUAL INSPECTION FOR EVIDENCE OF BURN THROUGH & WHERE ACCESSIBLE, USE OF FIBER-OPTICS NDE TO INSPECT FOR SURFACE FLAWS. SUPPLIER INSPECTION INCLUDES FLUORESCENT PENETRATE INSPECTION PRIOR TO COATING TO DETECT SURFACE DEFECTS AND X-RAY INSPECTION IS REQUIRED FOR DETECTION OF INTERNAL DEFECTS. AUDIT CONDUCTED 9-2-76 VERIFIED THAT SUPPLIER INSPECTION CONTROLS. SUPPLIER, IDENTIFICATION OF PARTS, MFG PROCESSES, CORROSION PROTECTION, CONTAMINATION CONTROL AND ENVIRONMENTS. (D) 4 OCCURRENCES OF BELL FAILURES CAUSED BY BRITTLE HETEROGENEOUS_GRAIN STRUCTURE DUE TO VIBRATION FATIGUE ON APOLLO LM/SM RCS ENGINES.
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNOUNCE 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 NEGATE 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. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

---

**EXPLANATION/COMMENTS:**

1. RM uses thrust chamber pressure transducers to sense the low pressure in question and give a "fail.off" in RCS RM.

3. The GN&C RM program will automatically deselect a failed jet under certain conditions (provided it is not inhibited). See FSSR "10" paragraph 4.1.7.1.6.3 for the conditions.

6. This failure can be tolerated since it is criticality 2.

7. The thrust chamber pressures can be downlinked.
SUBSYSTEM : FWC - REACTION CONTROL
ASSEMBLY : THRUSTER ASSY
P/N R1 : MC467-0029
P/N VENDOR: MISSIONS: HF VF X FF OF SM
QUANTITY : 2 PHASE(S): PL LO DO X DO LS
(RETURNED): ONE REQ'D PER SIDE
(ITEM): (DOWN FIRING) NUMBER OF SUCCESS PATHS REMAINING
(Abort): CRIT. Func: 2
(Abort): CRIT. HW: 2

FAILURE DETECTABLE IN FLIGHT?: YES
THRUSTER CHAMBER PRESS: V42P-1555A, 1556A
GROUND TURNAROUND?: YES
POSITION INDICATION

PREPARED BY: DES J TAGGART
APPROVED BY: DES ______________
REL R DIEHL REL ______________

ITEM: THRUSTER, VERNIER (EN 157/15b).
FUNCTION:
TO PROVIDE THRUST FOR LOW LEVEL ACCELERATIONS ASSOCIATED WITH POINTING MANEUVERS AND THREE AXIS ATTITUDE HOLD. THRUSTER FIRES IN Z DIRECTION FOR + PITCH AND - Z ACCELERATION. INCLUDES INLET VALVE, INJECTOR, THRUST CHAMBER, NOZZLE EXTENSION, HEATER, INSULATION, PRESS/TEMP XSDUCERS.

FAILURE MODE: LOSS OF OUTPUT (F)
INLET VALVES/BLOCKED INJECTOR/STAND-OFF'S.
CAUSE(S):
CONTAMINATION, PIECE PART STRUCTURAL FAILURE, IMPROPER SOLVENT ACTUATION, VIBRATION.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF VERNIER FUNCTION. (B) NO EFFECT. (C) POTENTIAL EARLY MISSION TERMINATION. LOSS OF TIGHT DEADBAND ATTITUDE CONTROL. (D) NO EFFECT.

CORRECTING ACTION:
UTILIZE LARGE THRUSTERS FOR ATTITUDE CONTROL IN AFFECTED AXIS (INCREASED PROPELLANT QUANTITY DEPLETION)

REMARKS/HAZARDS:
POTENTIAL HAZARD IF FAILURE OCCURS DURING CRITICAL MANEUVERS - TIME CRITICAL. NO REDUNDANCY IS PROVIDED FOR THIS COMPONENT.
SHUTTLE CRITICAL ITEMS LIST - OPBTER 102

SUBSYSTEM: FWD - REACTION CONTROL
ASSEMBLY: THRUSTER ASSY
P/N RI: MC467-0029
P/N VENDOR:  
QUANTITY: 2

- ASSEMBLY: THRUSTER ASSY
- ABORT: CRIT. FUNC: 2
- CRIT. HDW: 2
- MISSIONS: HF VF X FF OF SM
- PHASE(S): PL LO CO X DO LS
- ONE REQ'D PER SIDE
- (DOWN FIRING)

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

PREPARED BY: DES J TAGGART REL R DIEHL
APPROVED BY: 

ITEM: THRUSTER, VERNIER
(FN 157/158)

FUNCTION:
- TO PROVIDE THRUST FOR LOW LEVEL ACCELERATIONS ASSOCIATED WITH POINTING
  MANEUVERS AND THREE AXIS ATTITUDE HOLD. THRUST IS FIRES IN +Z DIRECTION
  FOR + PITCH AND -Z ACCELERATION. INCLUDES INLET VALVE, INJECTOR,
  THRUST CHAMBER, NOZZLE EXTENSION, HEATER, INSULATION, PRESS/TEMP
  TRANSDUCERS.

FAILURE MODE: LOSS OF OUTPUT (F)
- INLET VALVES/BLOCKED INJECTOR/STAND-OFF'S.

CAUSE(S):
- CONTAMINATION, PIECE PART STRUCTURAL FAILURE, IMPROPER SCIENCE
  ACTUATION, VIBRATION

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
- (A) LOSS OF VERNIER FUNCTION. (B) NO EFFECT. (C) POTENTIAL EARLY
  MISSION TERMINATION. LOSS OF TIGHT DEADBAND ATTITUDE CONTROL. (D)
  NO EFFECT.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) VALVE INCORPORATES A 25 MICRON FILTER TO PRECLUDE CONTAMINATION.
  VALVE HAS BEEN DESIGNED TO PRECLUDE SELF GENERATED CONTAMINATES.
  SPECIAL EMPHASIS PLACED ON SOLENOID AND WIRING TO PRECLUDE SHORTS. (B)
  PRE/POST FLIGHT CHECKOUT AND VALVE SIGNATURE TESTS WHEN MODULE REMOVED.
  VALVE SUBJECTED TO RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS DURING
  QUAL PROGRAM. LENGTH OF TIME FOR VIBRATION TO EQUAL 100 MISSION LIFE
  EXPECTANCY. (C) AUDIT CONDUCTED 9-2-76 VERIFIED THAT SUPPLIER
  INSPECTION CONTROLS RAW MAT' L, IDENTIFICATION OF PARTS, MFG PROCESSES,
  CORROSION PROTECTION, CONTAMINATION CONTROL, AND ELECTRICAL
  TERMINATIONS. TURNAROUND INSPECTION INCLUDES MONITORING FUNCTIONAL TEST
  DURING PRESSURIZATION CYCLE FOR EVIDENCE OF ERRATIC OPERATION. (D) NO
  FAILURE HISTORY APPLICABLE TO THIS FAILURE MODE.
**SUBSYSTEM** Fwd Reaction Control  
**ITEM** Vernier Thruster  
**FMEA NUMBER** SD75-SH-0016A  
**FAILUR E MODE** Erratic Operation

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

*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>
<th>Recommended Changes Below</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

**EXPLANATION/COMMENTS:**

1. May not be detected unless 3 consecutive low pressures.
SUBSYSTEM: FWL - REACTION CONTROL

ASSEMBLY: THRUSTER ASSY

P/N: MG467-0029

QTY: 2

P/N VENDOR: MISSIONS: HF VF X FF OF SM

FUNCTION: 2

P/N: MC467-0029

MISSIONS: HF VF X FF OF SM

PHASE(S): PL LO DO X DD LS

NUMBER OF SUCCESS PATHS REMAINING

AFTER FIRST FAILURE:

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

FAILURE DETECTABLE IN FLIGHT?: YES

THRUSTER CHAMBER PRESS. INDICATION V42P-1555A

IMMEDIATE

FAIL Time TO EFFECT:

THRUSTER CLAMBER PRESSURE INDICATION V4ZP-1555A

REFERENCE DOCUMENTS:

MJ070-0001-01b

SD72-5Y-0103-2

VS70-421101

GROUND TURNAROUND?: NO

PREPARED BY:

DES J TAGGART

APPROVED BY:

DES R DIEHL

ITEM: THRUSTER, VERNIER

FUNCTION:

TO PROVIDE THRUST FOR LOW LEVEL ACCELERATIONS ASSOCIATED WITH POINTING MANEUVERS AND THREE AXIS ATTITUDE HOLD. THRUSTER FIRES IN Z DIRECTION FOR + PITCH AND -Z ACCELERATION. INCLUDES INLET VALVE, INJECTOR, THRUST CHAMBER, NOZZLE EXTENSION, HEATER, INSULATION, PRESS/TEMP TRANSDUCERS.

FAILURE MODE: ERRATIC OPERATION (F)

CAUSE(S):

CONTAMINATION, IMPROPER SOLENOID ACTUATION.

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

(A) LOSS OF VERNIER CONTROL (B) INTERFACE SWITCHING OF POWER AND GNC CONTROL TO LARGE THRUSTERS. (C) POSSIBLE EARLY MISSION TERMINATION IF BOTH VENIER THRUSTERS WOULD HAVE TO BE ISOLATED SUCH THAT TIGHT DEADBAND ATTITUDE CONTROL WOULD BE LOST. (D) NONE.

CORRECTING ACTION:

SHUT DOWN/ISOLATE FAILED THRUSTER AND UTILIZE LARGE THRUSTER IN AFFECTED AXIS

REMARKS/HAZARDS:

POTENTIAL HAZARD FROM COLLISION. NO REDUNDANCY IS PROVIDED FOR THIS COMPONENT.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM : Fwd - Reaction Control
ASSEMBLY : THRUSTER ASSY
P/N R/P : 4C467-0029
P/N VENDOR: MISSIONS: HF VF X FF OF SM
QUANTITY : 2

ABORT: CRIT. Func: 2
CRIT. HOd: 2
Missions: HF VF X FF OF SM
P/N R/P : MC467-0029

PREPARED BY: DES J TAGGART REL R DIERL
APPROVED BY: SSM

P/N R/P : SD75-SH-0003

FUNCTION:
- To provide thrust for low level accelerations associated with pointing maneuvers and three axis attitude hold. Thruster fires in +Z direction for +PITCH and -Z ACCELERATION. Includes inlet valve, injector, thrust chamber, nozzle extension, heater, insulation, press/TEMP sensors.

FAILURE MODE: ERRATIC OPERATION (F)
- Low/High THRUST or INTERMITTENT OPERATION

CAUSES:
- CONTAMINATION, IMPROPER SOLENOID ACTUATION.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
- (A) LOSS OF VERNIER CONTROL
- (B) INTERFACE SWITCHING OF POWER AND GN&C CONTROL TO LARGE THRUSTERS.
- (C) POSSIBLE EARLY MISSION TERMINATION, BOTH VERNIER THRUSTERS WOULD HAVE TO BE ISOLATED SUCH THAT TIGHT DEADBAND ATTITUDE CONTROL WOULD BE LOST.
- (D) NONE.

DISPOSITION & RATIONALE:
- (A) DESIGN
- (B) TEST
- (C) INSPECTION
- (D) FAILURE HISTORY:
- (A) VALVE INCORPORATES A 75 MICRON FILTER TO PRECLUDE CONTAMINATION.
- VALVE HAS BEEN DESIGNED TO PRECLUDE SELF GENERATED CONTAMINATES.
- SPECIAL EMERGENCY PLACED ON SOLENOID AND WIRING TO PRECLUDE SHORTS. (B) PRE/POST FLIGHT CHECKOUT AND VALVE SIGNATURES TESTS WHEN MODULE REMOVED.
- VALVE SUBJECTED TO RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS DURING QUAL PROGRAM. LENGTH OF TIME FOR VIBRATION TO EQUAL 100 MISSION LIFE EXPECTANCY. (C) AUDIT CONDUCTED 9-2-75 VERIFIED THAT SUPPLIER INSPECTION CONTROLS RAW MAT'L. IDENTIFICATION OF PARTS, MFG PROCESSES, CORROSION PROTECTION, CONTAMINATION CONTROL, AND ELECTRICAL TERMINATIONS. TURNAROUND INSPECTION INCLUDES MONITORING FUNCTIONAL TEST DURING PRESSURIZATION CYCLE FOR EVIDENCE OF ERRATIC OPERATION. (D) NO FAILURE HISTORY CONCERNING THIS FAILURE MODE.
### Item Vernier Thruster

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Burn-Thru</th>
</tr>
</thead>
</table>

#### Subsystem Fwd. Reaction Control

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does the flight software detect this failure mode (i.e., automatically announce or take action in response)?</td>
<td>Yes X NO</td>
</tr>
<tr>
<td>1a. If not, does the hardware provide information that the flight software could use to detect the failure?</td>
<td>Yes X NO</td>
</tr>
<tr>
<td>2. Are the answers to questions 1 and 1a consistent with the FMEA evaluation of in-flight detectability?</td>
<td>Yes X NO</td>
</tr>
<tr>
<td>3. Does the flight software take action to negate the effects of the failure (either by commanding hardware action or implementing alternate program logic)?</td>
<td>Yes X NO</td>
</tr>
<tr>
<td>3a. If not, does the capability exist for the software to compensate for this failure mode (either by commanding hardware action or implementing alternate program logic)?</td>
<td>Yes X NO</td>
</tr>
<tr>
<td>4. As a result of this failure mode, can the software overstress the hardware or induce another failure?</td>
<td>Yes X NO</td>
</tr>
<tr>
<td>5. Can this failure mode, in combination with software logic, adversely affect other functions?</td>
<td>Yes X NO</td>
</tr>
<tr>
<td>6. How many of these hardware failures can the shuttle tolerate (consider crew action and hardware/software operation)? Note change to FMEA Criticality.</td>
<td>0 X 1 2</td>
</tr>
<tr>
<td>7. If crew action is required to respond to this failure mode, are cues provided to signal the need for intervention and the required corrective action?</td>
<td>N/A Yes X NO</td>
</tr>
<tr>
<td>8. If the answer to either 1 or 3 is Yes: A. Can the BFS be engaged after occurrence?</td>
<td>Yes X NO</td>
</tr>
<tr>
<td>B. Will BFS tolerate failure without loss of crew/vehicle?</td>
<td>Yes X NO</td>
</tr>
</tbody>
</table>

*Explanation required (see below!)

#### Change/Retention Rationale Summary:

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

#### Change Summary:

- FMEA Change Recommended

#### Explanation/Comments:

1. The GN&C RM Program will automatically deselect a failed jet and issue an alert. Detectable in thrust chamber but not in nozzle.

6. This is a criticality 1 failure and cannot be tolerated.

7. The thrust chamber pressures can be downlinked.

8b. Same as primary.
SUBSYSTEM : FWD - REACTION CONTROL
ASSEMBLY : THRUSTER ASSY
P/N/ VENDOR: MC467-0029
P/N VENDOR: 
QUANTITY : 2
MISSIONS: HF VF X FF OF SM
PHASE(S): PL LO DO X DU LS
NUMBER OF SUCCESS PATHS REMAINING
AFTER FIRST FAILURE: 2
REduNDANCY SCREEN: A-N/A B-N/A C-N/A
FAILURE DETECTABLE IN FLIGHT?: YES
MINOR LEAKAGE OR INCipient FAILURE
GROUND TURNAROUND?: YES
VISUAL EXAMINATION

ITEM: THRUSTER, VERNIER (EN 157/158).
FUNCTION:
TO PROVIDE THRUST FOR LOW LEVEL ACCELERATIONS ASSOCIATED WITH POINTING
MANEUVERS AND THREE AXIS ATTITUDE HOLD. THRUSTER FIRES IN +Z DIRECTION
FOR + PITCH AND -Z ACCELERATION. INCLUDES INLET VALVE, INJECTOR,
THRUST CHAMBER, NOZZLE EXTENSION, HEATER, INSULATION, PRESS/TEMP
XSOUCERS.
FAILUERE MODE: OVERHEAT/BURNTHROUGH (F)

CAUSE(S):
MAX PRESSURE SPIKES, SURFACE DEFECTS IN THE PROTECTIVE DISILICICU
COATING FOR CHAMBER WALL AND VIBRATION.

EFFECT(S): (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF VERNIER THRUSTER (B) POTENTIAL DAMAGE (C) POTENTIAL
EARLY MISSION TERMINATION (D) POTENTIAL LOSS OF VEHICLE. CRITICAL
DAMAGE COULD OCCUR BEFORE FAILURE IS DETECTED.
CORRECTING ACTION:
ISOLATE FAILED THRUSTEK AND USE OTHER THRUSTERS.
REMARKS/HAZARDS:
POTENTIAL HAZARD FROM ESCAPING HOT GASES IN THE MODULE AND POTENTIAL
PROPAGATION OF FAILURE IF NOT ISOLATED IN A TIMELY MANNER.
SUBSYSTEM : FWD - REACTION CONTROL

ASSEMBLY : THRUSTER ASSY

P/N RI : MC467-0029

P/N VENDOR : MISSIONS: HF VF X FF OF SM

QUANTITY : 2

P/N : 03-2F-131310-4 REV: 12/08/78

ABORT: CRIT. FUNC: 1

P/N : CRIT. HDW: 1

MISSIONS: PHASE(S): PL LO 00 X DO LS

PREPARED BY:

APPROVE/BY:

PREPARED WITH CHANGES

See Section 13.0

ITEM: THRUSTER, VERNIER (EN 157/158)

FUNCTION:

TO PROVIDE THRUST FOR LOW LEVEL ACCELERATIONS ASSOCIATED WITH POINTING MANEUVERS AND THREE AXIS ATTITUDE HOLD. THRUSTER FIRES IN +Z DIRECTION FOR + PITCH AND -Z ACCELERATION. INCLUDES INLET VALVE, INJECTOR, THRUST CHAMBER, NOZZLE EXTENSION, HEATER, INSULATION, PRESS/TEMP XSDUCERS.

FAILURE MODE: OVERHEAT/BURNTHROUGH (F)

CAUSE(S):

MAX PRESSURE SPIKES, SURFACE DEFECTS IN THE PROTECTIVE DISILICIDE COATING FOR CHAMBER WALL AND VIBRATION.

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

(A) LOSS OF VERNIER THRUSTER. (B) POTENTIAL DAMAGE. (C) POTENTIAL EARLY MISSION TERMINATION. (D) POTENTIAL LOSS OF VEHICLE. CRITICAL DAMAGE COULD OCCUR BEFORE FAILURE IS DETECTED.

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

(A) INTERMETALLIC DIFFUSION LAYER FORMS AN INTEGRAL BOND BETWEEN THE DISILICIDE COATING AND THE PARENT COLUMBIUM MATERIAL (C-103) AND TENDS TO RESIST SHOCK LOADING. (B) PRIOR TESTS CONDUCTED ON THE R1-1 THRUSTER HAVE DEMONSTRATED THE ABILITY OF THE DISILICIDE COATING TO WITHSTAND IMPACT LEVELS AND THERMAL STRESSES PRODUCED BY TEMPERATURES IN EXCESS OF 2900 DEGREES F. TORCH TESTS HAVE DEMONSTRATED THE INSENSITIVITY OF THE R512A COATING TO THERMAL SHOCK. (C) AUDIT CONDUCTED 9-2-76 VERIFIED THAT THE SUPPLIER INSPECTION CONTROLS RAW Mat'l, IDENTIFICATION OF PARTS MFG. PROCESSES, CORROSION PROTECTION, CONTAMINATION CONTROL, AND FLOURESCENT PENETRANT INSPECTION PRIOR TO COATING TO DETECT SURFACE FLAWS AND X-RAY INSPECTION IS REQUIRED FOR DETECTION OF INTERNAL DEFECTS. COATING THICKNESS AND QUALITY IS CONTROLLED BY MPS 525 WHICH WILL REQUIRE CERTIFICATION THAT COATING PROCESS CONFORMS TO THE PROCESS SPECIFICATION, VISUAL INSPECTION, VERIFICATION OF COATING THICKNESS & TEST TO VERIFY COATING INTEGRITY. TURNAROUND INSPECTION TO INCLUDE VISUAL INSPECTION FOR EVIDENCE OF BURN THROUGH AND WHERE ACCESSIBLE, USE OF FIBER OPTICS NDE TO INSPECT FOR SURFACE FLAWS.

(D) NO FLIGHT FAILURE HISTORY.
Meeting Minutes


1. Meeting held at Rockwell International, Downey, 1:00PM to 2:30PM, 9/24/79.

2. Attendees
<table>
<thead>
<tr>
<th>Organization</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edward Vonusa, NASA</td>
<td>X-1470</td>
</tr>
<tr>
<td>Dave Latham, JSC Reliability</td>
<td>527-0323</td>
</tr>
<tr>
<td>(Boeing)</td>
<td>FTS</td>
</tr>
<tr>
<td>Rudy Kubica, RI Propulsion/RCS</td>
<td>X-4720</td>
</tr>
<tr>
<td>Larry Gladu, RI System Engineering</td>
<td>X-1189</td>
</tr>
<tr>
<td>Bill Meyers, RI System Engineering</td>
<td>X-1726</td>
</tr>
<tr>
<td>Bob Diehl, RI Reliability</td>
<td>X-2098</td>
</tr>
</tbody>
</table>

3. The following changes were discussed and will be incorporated in the final release of Forward Reaction Control System Hardware/Software Interaction Analysis and will be reflected in next update of Fwd RCS FMEA:

   03-2F-101010-1: Change "SMU" to "SM". Insert "SM Alert" before "blue light."

   03-2F-101013-1: Same as 03-2F-101010-1.

   03-2F-101020-3: Same as 03-2F-101010-1.

   03-2F-101020-4: Same as 03-2F-101010-1.

   03-2F-101030-1: Add "X" in No. Block, question 1a.

   03-2F-101030-2: Add V42P1116C to Explanation 1. and 2.

   03-2F-101060-1: Show class 3 alarm with blue light and class 2 alarm with red light. Add V421116C. (Explanation 1.)

   03-2F-101060-2: Add "X", No Block, question 1a.

   03-2F-101060-3: Same as 03-2F-101060-1.

   03-2F-101060-4: Same as 03-2F-101060-1.

   03-2F-101060-5: Same as 03-2F-101060-1.

   03-2F-101070-1: Under 1 & 2 Explanation, add V421113C, 1114C. Change class 2 to 3.

   03-2F-101080-1: Change FMEA to show detectability method.

   03-2F-101090-1: Under 1 & 2 Explanation, change V42P1110C, 1112C to 1113C, 1114C. Change class 2 to 3. Add gross leakage detectability (see 03-2F-101080-1).
03-2F-101095-2: Change "X" from Yes Block to No Block, question 1. Under Explanation, delete 1 & 2 (failure is one leg only - requires failure of both legs to actuate C & W).

03-2F-102106-1: Under 1 Explanation, add gross leakage detectability (see 03-2F-101080-1). Under 7 Explanation and FMEA change add V42P1115C. Change FMEA to show detectability.

03-2F-102108-1: Under 1 Explanation, add gross leakage detectability (see 03-2F-101080-1) Under 7 Explanation add V42P1115C.

03-2F-102120-1: Under 1 Explanation, add oxidizer measurement numbers, and add "failed off thruster will give "failed jet on C & W".

03-2F-102150-1: Same as 03-2F-102120-1 plus retain V42P1312C and delete 1313C and 1314C.

03-2F-102170-1: Under 1 Explanation, add measurements V42X1333X, 1233X. Change class 2 to 3.

03-2F-111110-1: Under 1 Explanation, add V42P1210C, 1212C, 1216C and add to FMEA detectability. Add X in FMEA change recommended block.

03-2F-111110-2: Same as 03-2F-111110-1.

03-2F-111110-3: Under 1 Explanation, add gross leakage detectability (see 03-2F-101080-1)

03-2F-111110-4: Change X from No Block to Yes block for question 1. Under Explanation, delete 1st paragraph and I. (White Sands Test on vernier showed complete loss chamber pressure which is detectable. Similar gas bubbles in propellant tests are planned for primary thrusters).

03-2F-121308-1: Under 1 Explanation, the class 3 alarm is doubtful. Check and verify findings with Bill Meyers RI Systems Engineering. Also add gross leakage detectability (see 03-2F-101080-1).

03-2F-121311-1: Change Failure Mode to agree with failure mode in FMEA.

03-2F-121312-1: Under 1 Explanation, add "If failure is upstream of throat it will be detected by PC; if failure is downstream of throat it will not be detected."

03-2F-121313-1: Change X from Yes Block to No Block, question 1. Delete 1. under Explanation (failure is downstream of throat and will not be detected by PC).

03-2F-131310-3: Change X from Yes Block to No Block, question 1. Add X to FMEA change recommended block. Under 1. Explanation, delete entire sentence (the pressure transducers are snubbed by an orifice and will not detect the erratic operation). Change FMEA to indicate no detectability.