ORBITER SUBSYSTEM
HARDWARE/SOFTWARE INTERACTION ANALYSIS

VOLUME VIII: AFT REACTION CONTROL SYSTEM

PART 2

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HARDWARE/SOFTWARE INTERACTION ANALYSIS.
VOLUME 8: FORWARD REACTION CONTROL SYSTEM
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PREFACE

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

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

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

This analysis verified that no open issues remain.

Approved: Joseph H. Levine
Chief, Reliability Division
VERIFICATION PLANNING AND MANAGEMENT

- VERIFICATION PLAN
  - VERIFICATION ROADMAP
  - REQUIREMENTS VERIFICATION

- IMPLEMENTING DOCUMENTATION
  - TRD
  - TRSD
  - TCP

- ANALYSIS

- TEST

- VCN

- FLIGHT READINESS STATEMENT

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

AFT - RCS SUBSYSTEM

FMEA # SD72-SH-0103-2

ANALYSIS DATE November 5, 1979

HARDWARE/SOFTWARE ANALYST

APPROVED:

[Signatures]

JSC Reliability

JSC Engineering - FRAT Sponsor

Rockwell Reliability

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

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

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

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

3.0 **APPLICABLE DOCUMENTS.**

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

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

3.2 REFERENCE DOCUMENTS. The primary documents used in performing the analysis included the following:


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

4.0 DESCRIPTION.

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

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

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

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

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

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

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

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

**SUBSYSTEM**

**ITEM**

**FMEA NUMBER**

**FAILURE MODE**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer Options</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 ☐ 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 ☐ 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 ☐ 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 ☐ 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 ☐ 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 ☐ NO ☐</td>
</tr>
<tr>
<td>5. Can this failure mode, in combination with software logic, adversely affect other functions?</td>
<td>YES ☐ 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 ☐ 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 ☐ NO ☐</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. ☐ Hardware accepts risk  
3. ☐ No software detection  
4. ☐ Detection during checkout  
5. ☐ Acceptance rationale below  
6. ☐ Recommended changes below

☐ FMEA change recommended

**EXPLANATION/COMMENTS:**

---

Figure 4-1. Hardware/Software Analysis Checklist

3
The questions in the checklist body are answered using the following guidelines:

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

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

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

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

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

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

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

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

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

h. 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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

6.0 ANALYSIS CHECKLIST SHEETS

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

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

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

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

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

Failure modes analyzed included only those items currently on the critical items list. All other failure modes will be analyzed at a future date.

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

HARDWARE/SOFTWARE ANALYSIS CHECKLIST

FMEA NUMBER: 03-2A-201010-1

ITEM: He Tank

FAILURE MODE: External Leak

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

   YES X NO

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

   *YES [X] NO [X]

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

   YES [X] *NO [X]

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

   YES [X] NO [X]

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

   *YES [X] NO [X]

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

   *YES [X] NO [X]

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

   *YES [X] NO [X]

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

   0 [X] *1 [X] 2 [X]

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

   N/A [X] YES [X] NO [X]

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

   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?

      YES [X] *NO [X]

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

      YES [X] *NO [X]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. □ NO H/S ISSUES

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

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

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

8B. Same as primary.
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SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: C282-002-0317-0032
P/N VENDOR: RL-99904-0-1-2
QUANTITY: 4

Two bottles rec'd per module: one per prop. tank.

Assembled: PRESSURIZE ABORT: CR

FUNCTION: TO STORE HELIUM AT A MAX WORKING PRESSURE OF 4000 PSI FOR PRESSURIZATION OF THE AFT RCS MODULE'S PROPELLANT SUPPLY SYSTEM.

TANK CONSISTS OF DOUBLE HILT TI LINER WITH DUPLAC KEVLAR 49 FIBER AND EPOXY RESIN BONDING OVERLAY.  O.D. IS 18.71 IN.  VOLUME IS 3008 CU. IN.

FAILURE MODE: STRUCTURAL FAILURE (S)

EXTERNAL LEAK

CAUSE(S):

- MATERIAL DEF, LINER DEF, FAULTY FAB, EPOXY CURE IMPROPER, TFST/HANCL DAY, SHOCK, VIS, INADVER UPRESS (GMO), IMADER MOUNTING

EFFECT(S):

- (A) LOSS OF FUNCTION/SUBSYSTEM (B) LOSS OF INTERFACE FUNCTION - INABILITY TO DEplete/UTILIZE PROP, POSSIBLE DAMAGE TO POD STRUCTURE & TPS.  (C) MISSION MODIFICATION - X-Feed FROM OMS OF RCS.  (D) POSSIBLE LOSS OF CREW VEHICLE EXCESS RATE OF LEAK MAY EXCEED POD VENT CAPAB CAUSING DAMAGE TO POD STRUCT & DEGRAD OF THERMAL PGT SYS. EXCESS RETENTION OF PROP MAY ADVERSELY AFFECT VEH OXY. DURING ENTRY & LANDING.

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

- (A) FILAMENT WOUND TANKS ARE DESIGNED TO LEAK BEFORE RUPTURE WHICH LIMITS FAILURE PROPAGATION DUE TO SHRAPNEL. KEVLAR 49 FIBER HAS A TENSILE STRENGTH OF 500KSI ALLOWING LIGHT WEIGHT WITH GREAT STRENGTH. INCREASED STRAIN CAPABILITY IS PROVIDED BY THE COMpressive LOAD ON A UNPRESSURIZED LINER. VENT DOORS ARE OPEN ON ORBIT AND WILL RELIEVE ANY PRESSURE BUILDUP DUE TO LEAKAGE. THE F.S. (9UPST) IS 1.5 X WORKING PRESS.

- (B) 1000 PRESSURE CYCLES ARE PERFORMED DURING QUAL WHICH IS MORE THAN 4X ANTICIPATED OPERATING LIFE. A 90-DAY CREEP TEST UNDER PRESSURE IS ALSO PERFORMED AFTER WHICH THE TANK IS EXAMINED TO VERIFY NO PERMANENT DEFORMATION OR FLAW GROWTH. PRESSURE (1.1) X WORKING PRESSURE AND LEAKAGE TESTS ARE PERFORMED DURING ATP.  (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. RAW MATERIALS AND PURCHASED COMPONENTS ARE VERIFIED BY RECEIVING INSPECTION STANDARDS AND TEST EQUIP. STANDARDS ARE IMPLEMENTED PER RECOMMENDATIONS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS - PARTS PROTECTION, FAB. PROCESSES, FINISHES, ASSY AND INSTALLATION. THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77 - CORROSION PROTECTION PROVISIONS, TEST HANDLING, AND STORAGE
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A -2010-10-1  REV:11/03/79
ENVIRONMENTS. TENSILE, HEAT TREAT AND WELD SAMPLES ARE TESTED DURING
IN-PROCESS FABRICATION IN ADDITION TO X-RAY & DYE PENETRANT FOR THE
LINES. WIND PATTERN & WINDING CONTROL ARE USED FOR THE KEVLAR FIBER
DURING IN-PROCESS MANUFACTURE. WEIGHT CONTROL IS USED FOR THE EPOXY
RESIN. TURNAROUND - MONITOR LEAKAGE TESTS PERFORMED AFTER INSTALLATION
INTO THE SYSTEM AND AS PART OF THE CHECKOUT PROCEDURE PRIOR TO FLIGHT.
PRESSURE CYCLES ACCUMULATED ARE ALSO RECORDED. (D) NHE AVAILABLE NEW
DESIGN.
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 ☒ X

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

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

EXPLANATION/COMMENTS:

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

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

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

8b. Same as primary.
ORIGINAL PAGE IS OF POOR QUALITY.
SHUTTLE CRITICAL ITEMS LIST – CRITER 102

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

ABORT: CRIT. FUNC±
MISSIONS: HF, VF, FF, CF, SM
PHASE(S): PL X LO X 00 X 00 X LS X

ONE SET PER PROPELLANT
PER MODULE

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

PREPARED BY: DES N C GLAVINICH DES
APPROVED BY: APPROVE BY: APPROVE NA:
REL C M AKERS REL

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

FAILURE MODE: STRUCTURAL FAILURE

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

EFFECT(S):
- CN (A) SUBSYSTEM (B) INTERFACE (C) MISSION (D) CREW/VEHICLE:
- (A) LOSS OF SUBSYSTEM PRESSURIZATION CAPABILITY IF NOT ISPL (FAIL UPSTREAM OF ISOL VALV-IMABILITY TO DEPLETE/UTILIZE PPCP)
- (B) LOSS OF INTERFACE FUNCTION (INABIL TO REPRESS PPCP TANK – OPT POD STRUCT & TPS DAM
- (C) ABORT DECISION (LOSS OF PRESS)
- (D) POSSIBLE LOSS OF CREW/VEHICLE – IF LEAK EXCESS OR POD/TPS DAM OCCURS

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) F.S. IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF)

THE WELDED CONSTRUCTION ELIMINATES JOINTS AND POSSIBLE LEAK PATHS
- THE ANNEALED AREA (DUE TO WELDING) IS BACKED UP BY A SLEEVE
- FASTENING CLAMPS ALLOW FREEDOM OF MOVEMENT
- TUBING BENDS ARE CONTROLLED BETWEEN FIXED POINTS TO FACILITATE INSTALLATION AND ACCOMMODATE VEHICLE GROWTH AND MOVEMENT
- (B) POCKWELL PERFORMED TUBING CERTIFICATION TESTS PER "CRITER TUBING VERIFICATION PLAN" (SD 75-SH-0205) – THIS TESTING INCLUDED PRESSURE CYCLING AND FOR TYPICAL SHUTTLE LINES & JOINTS
- SYSTEM EVALUATION TESTS AT WSTF WILL ALSO ALLOW EVALUATION IN THE INSTALLED SYSTEM CONDITION
- LEAKAGE TESTS ARE PERFORMED IN-PROCESS FOR TUBING SECTIONS
- OPTICAL INSPECTIONS ARE ALSO PERFORMED AT THIS TIME IN ADDITION TO X-RAY AND DYE PENETRANT
- LEAKAGE TESTS ARE ALSO PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND ADDITIONAL WELDS ARE ALSO SUBJECTED TO NDE
- (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED
- CONTAM. CONTROL PROCESSES, CORROS., PROTECTION PROVISIONS, NDE EXAM OF WELDS AND INS.
- FCP SURFACE AND SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION
- THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELEER MANDATORY INS.
- HARDWARE IS INS.

V79 19 SD75-SH-0003
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-ZA - 201013-1  REV: 12/13/73

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

ORIGINAL PAGE IS OF POOR QUALITY
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 EFFECT 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.
   - NO X. 1.

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED
   TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   - N/A 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. NO H/S ISSUES</th>
<th>3. NO SOFTWARE DETECTION</th>
<th>5. ACCEPTANCE RATIONALE BELOW</th>
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<tr>
<td>2. HARDWARE ACCEPTS RISK</td>
<td>4. DETECTION DURING CHECKOUT</td>
<td>6. RECOMMENDED CHANGES BELOW</td>
</tr>
</tbody>
</table>

See Note 2.

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

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

2. Measurement numbers V42X2124X, 2126X, 3124X, and 3126X (Fu He isolation valves) needs to
   be added for detectability since only the measurement stimulus identification numbers for
   the oxidizer valves are listed now.
SAFETY CHART - SYSTEM CONTROL

1. ONLY EMERGENCY PATH AVAILABLE

2. VALVE CLOSING BALANCE VALVE PLUNGE绘画T

3. PRESSURE LEAK

4. SYSTEM PRESSURE

5. VALVE CLOSING BALANCE VALVE PLUNGE

6. FAILURE DETECTED IN VALVE, REL

7. SIGNAL TO INSTRUMENTATION

8. PREPARED BY: K. BURKHART

9. APPROVES SYS: L. S.

10. "Y" VALVE; L.C. SALTICE

11. PRESSURE, PATH PRESSURE, helium (1/16") SI-TABLE: (LATINO) - (G00gary) & CONT 

12. VENT TO CONTROL HULL腔压IZATION SYSTEM: 1. THE & VALVES

13. SIGNAL TO INSTRUMENTATION: (A) PATH X, Y, Z, R, O,

14. LOSS OF REDUNDANCY - PARALLEL PATH AVAILABLE.

15. VENT TO CONTROL HULL腔压IZATION SYSTEM: (A) PATH X, Y, Z, R, O,

16. LOSS OF REDUNDANCY - PARALLEL PATH AVAILABLE.

17. VENT TO CONTROL HULL腔压IZATION SYSTEM: (A) PATH X, Y, Z, R, O,

18. VENT TO CONTROL HULL腔压IZATION SYSTEM: (A) PATH X, Y, Z, R, O,
SHUTTLE CRITICAL ITEMS LIST - CRITERION 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: MC294-0419-0011/0012
P/N VENDOR: 73835
QUANTITY: 2

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

RE: PRESSURIZATION ABORT CRIT. FUNC: LR
P/N: RI8754-0419-0011/0012

FUNCTION:
- Utilized to control helium pressurization system in the aft modules.
- In the open position a flow path is provided from the helium supply tank(s) to the regulators. Two parallel paths are provided for each propellant tank. One path is normally open per tank. The open valve may be closed and the parallel valves opened subsequent to a downstream failure.

FAILURE MODE: Fails closed

CAUSE(S):
- Vib continuous inadvertent closing signal due to short circuit, shock, connector pin or diode damage, jamming of poppet, plugged orifice.

EFFECT(S):
- (A) Loss of redundancy - parallel path available.
- (B) No effect.
- (C) Abort decision - due to only one path remaining good to critical effect.
- (D) No effect.
- (E) Functional criticality effect - possible crew vehicle loss - failure of redundant parallel flow path would result in inability to burn or deplete RCS propellant. This would result in possible inability to control vehicle during entry due to inability to use reserved entry propellant or C.G. problems resulting from propellant weight.

DISPOSITION & RATIONALE:
- (A) Design
- (B) Test
- (C) Inspection
- (D) Failure History:
- (A) Parallel valves and redundant power sources are provided. Voltage press is adeq for prop feed with less than 35 percent prop remaining. One valve is maintained in the latched open position with no power applied & the other is latched closed. An inductive voltage suppression circuit is prov in the electrical system to prevent damage to other on-line comp. Redund diodes limit the pos of diode failure allowing current shunt from the coil. A 100-micron filter is prov to limit the poss of contam causing leakage, jamming moving parts - or plugging pilot control orifices. To limit the electric short potential, the lead & magnet wires are encap by potting & a fixture is used during assembly to ensure that insul is not damaged by the exit notch when the coil sleeve is pressed onto the coil. (B) 4000 oper cycles (on-off-flow) and random vib at antic mission levels are perf during qual. Item is used

24
1000
SD75-SH-0003
SUBSYSTEM: AFT - REACTION CONTROL
FMEA NO 03-24 - 201023-1
REV: 12/12/73
DURING SYS EVAL TESTS AT STF ALLOHNG EVAL UNDER SIMUL MISSION USAGE
COND. PROOF PRESSURE, LEAKAGE, OPER AND INSUL TESTS ARE PERF DURING
ATP. APROP LOCATED TEST POINTS ALLOW PRE/POST FLIGHT LEAKAGE TESTS AND
OPER TESTS ARE ALSO CONDUCTED AT THIS TIME. (C) AN IDENT IS PERF AND
THE UNIT TAGGED. CONTAM CONT PROCESS, CORROS. PROT PROV, NDE EXAM. OF
WELDS AND BRAZES, INSPE. FOR SURFACE AND SUBSURFACE DEFECTS AND PROPER
ELECT TERMINATIONS ARE VERIF BY INSPE. THE FOLLOWING ITEMS ARE VERIF BY
SHOP TRAVELER MANDATORY INSPE. POINTS - RAD MAT'IL (LOT CERT), PARTS PROT,
MANUF., COATING, PLATING INSTALL AND ASSEMBLY OPER. THE ABOVE ITEMS AND
THE FOLL ITEMS WERE VERIF BY AUDIT COND 8-31-77. CONTAM CONT
PROCESSES, CORROS. PROT PROV. TURNAROUND - FUNCT FLOW TESTS ARE
MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY U/PON COM-MAND.
(D) APOLLO FAILURES WERE MAINLY ASSOC WITH REVERSE POLARITY AND
DEGAUSSING OF MAGNETS. THE SHUTTLE VALVE UTILIZES A CONNECTOR (RATHER
THAN LEAD WIRES) AND BLOCKING DIODE WHICH PREVENTS THIS TYPE OF ERROR
DURING CONN. A POTENT ELECT SHORTING PROP ON A SIMILAR VALVE DUE TO
INSUL DAMAGE WAS DISCOV DURING QUAL AND CORR AS DESCRIBED IN ITEM (A)
ABOVE.
**ITEM** He Pressure Regulator  
**FAILURE MODE** Restricted Flow - Fails Closed

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

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

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

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

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

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

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

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

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

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

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

   *EXPLANATION REQUIRED (SEE BELOW)

   *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. Uillage transducer will give C&W alert < 200 psi.

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

6. 1 success path remaining after first failure.

7. Cathode-ray-tube and downlist is available.
SIZMEL TOOLS AND EFFECTS ANALYSIS - UNTESTED

SYNOPSIS:
- SYSTEM TEST - FUEL \& \# 3
- ONLY TEST 0.45UT
- 9M 746-104
- VALVE - 746-104
- VALVE \& 746-104
- VALVE
- 102 PARALLEL VALVE
- TITLE UNIT FOR FUEL
- TANKS
- RESULT OF SECOND PATH REACHING
- PRIMARY ELEMENT HIGH

WILL THE PATHS IN FLIGHT? YES
- SECOND TANK VOLUME PRESS VAL = 214.614 5155 3115

WILL THE PATHS CLOSED? YES
- C/D TEST POINTS

PREPARED BY:
- LSS  C. WARWICK
- REL  C. M. WARWICK

APPROVED BY:
- LSS
- REL

RELATION PRESS. P:
- 3500 - 37500 SET AT INITIAL OUTLET PRESSURE \( P \)
- 5980 - 7262

VERIFICATION:
- TANKS: SET END STATION FUEL PRESSURE FROM 4000 P.S.I. TO LIM
- THERM OF L20 (1+ 2) PLUS FOR PURPOSE OF PREPARATION FUEL \( P \)
- TANKS: 102 PARALLEL TANKS WITH 20 SERIES PRESS \( P \) PROVE
- FUEL ELEMENT IN FLIGHT. PRIMARY ELEMENT SET II PS \( P \) LOWER.
- TANKS IN FLIGHT.

SYNOPSIS:
- SYSTEM TEST - FUEL \& \# 3
- ONLY TEST 0.45UT
- 9M 746-104
- VALVE - 746-104
- VALVE \& 746-104
- VALVE
- 102 PARALLEL VALVE
- TITLE UNIT FOR FUEL
- TANKS
- RESULT OF SECOND PATH REACHING
- PRIMARY ELEMENT HIGH

WILL THE PATHS IN FLIGHT? YES
- SECOND TANK VOLUME PRESS VAL = 214.614 5155 3115

WILL THE PATHS CLOSED? YES
- C/D TEST POINTS

PREPARED BY:
- LSS  C. WARWICK
- REL  C. M. WARWICK

APPROVED BY:
- LSS
- REL

RELATION PRESS. P:
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- TANKS IN FLIGHT.
ITEM: REGULATOR PRESS, HE
- SERIES REDUNDANT, SET AT UNEQUAL OUTLET PRESSURES (PP 301/302/303/304).

FUNCTION:
TO REGULATE STORED HELIUM PRESSURE FROM 4600 PSIG MAX TO ULLAGE PRESSURE OF 245 (+ OR - 3) PSIG FOR PURPOSE OF PROPELLANT FEED TO THRUSTERS. TWO PARALLEL PATHS WITH TWO SERIES REGS ARE PROVIDED FOR EACH PROPELLANT TANK. PRIMARY ELEMENT SET 11 PSI LOWER THAN SECONDARY.

FAILURE MODE: FAILS CLOSED (F)
- RESTRICTED FLOW*

CAUSE(S):
- CONTAM (PILOT SCREEN), FAZED MGIST, SPRING/STEM FRACTURE, PISTON BINDS, EXCESS DOME PRESS, COCKED SPRINGS, MATT NET.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (U) CREW/VEHICLE:
- (4,8) LOSS OF REDUNDANCY (ONE OF 2 FLOW PATHS), (C) ABRPT DECISION
- (D) NO EFFECT UNLESS SECOND PATH FAILS CLOSED, REENTRY CAPABILITIES LOST IF FAILURE OCCURS EARLY IN ENTRY SUCH THAT ULLAGE PRESS IS NOT SUFF.
- (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CREW/VEHICLE LOSS. FAILURE OF REDUNDANT PARALLEL FLOW PATH WOULD RESULT IN INABILITY TO SURVIVE OR DEplete RCS PROPELLANT. THIS WOULD RESULT IN POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO USE PRESERVED ENTRY PROPellant OR C-G PROBLEMS RESULTING FROM LOW PRESS.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) PARALLEL REGULATORS ARE PROVIDED. ULLAGE PRESS IS ACCEP FOR PROP FED WITH LESS THAN 35 PERCENT PROP REMAINING. 4 25-MICRON ABS GBR PLUS 10-MICRON ABS GBR PILOT FILTER IS PROV TO LIMIT THE POSSIBILITY OF CONTAM TO JAMMING OF MOVING PARTS OR PLUGGING PILOT CONTROL ORIFICES. (B) 50,000 OPER FLOW CYCLES AND RANDOM VIB AT ANTI MISHION LEVELS ARE PERFORMED DURING GUAL. ITEM IS USED DURING SYS EVAL TESTS AT WSTF ALLOWING EVAL UNDER SIMUL MISSION USAGE COND. PROOF PRESS, LEAKAGE AND FLOW TESTING IS PERFORMED DURING ATP. FUNCTION AND LEAKAGE TESTS ARE PERFORMED DURING PRE/POST FLIGHT CHECKOUT. (C) AN ID IS PERF AND THE UNIT TAGGED. MATT & EQUIP CONFORMANCE TO CONTRACT REQMTS IS VERIF BY INSPECTION. THE FOLL ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPECTION POINTS - RAW MATT, PARTS PROTECTION, MANUF, COATING, PLATING, INSTALL AND ASSEMBLY OPERATIONS. THE FOLLOWING ITEMS AND THE FOLL ITEMS WERE VERIF BY AUDIT:

CONDUCTED 4-5-77 - CONTAM CONTROL PROCESSES AND CORROS PPOT PROT, CONTAM CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIR.
SUBSYSTEM : AFT - REACTION CONTROL   PMA No 03-2A - 201030-2   REV:11/08/73

ITEMS WERE VERIFIED BY AUDIT OF MARCH 6, 1978. INSPECTION VERIFIES
ASSEMBLY PER INSPECTION PLANTS IN MASTER RECORD. LOG OF CLEAN ROOM AND
CALIBRATION OF TOOLS VERIFIED. CRITICAL DIMENSION 100% VERIFIED BY
INSPECTION. PARTS CLEANLINESS AND PASSIVATION BY INSPECTION. NOE
INSPECTION PERFORMED AFTER ASSEMBLY. TURNAROUND - JUNCT FLOW TESTS ARE
MONITORED TO VERIFY THAT THER IS NO RESTRICTED FLOW. NO FAILURE
HISTORY OF THIS MODE FOR THIS REGULATOR.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

**SUBSYSTEM AFT-RCS**

**ITEM** Line, Low Pressure He  

**FAILURE MODE** External Leak

<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>
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</tr>
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<td></td>
<td></td>
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<td>2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA. EVALUATION OF IN-FLIGHT DETECTABILITY?</td>
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<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>
</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>
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<td>5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?</td>
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<td>6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.</td>
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<td>8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:</td>
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<td>A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?</td>
<td></td>
<td></td>
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<tr>
<td>B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?</td>
<td>*NO</td>
<td></td>
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</tbody>
</table>

**EXPLANATION/COMMENTS:**

1. ullage transducer will give C&W alert < 200 psi. Gross leak detection will give first indication.

3A. The helium insolation valves could be automatically closed by software upon sensing a caution and warning low pressure of 200 psi.

6. Initiate cross-feed function.

7. Caution and warning low pressure light - "Right RCS" - cathode-ray tube and downlink available.

8B. Same as primary.
SYSTEM - SEE 1 - ELECTRICAL CONTROL

SYSTEM - SEE 2 - OVERPRESSURE

NOTE - SEE 1 - OVERPRESSURE

SYSTEM - SEE 3 - HYDRAULIC

SYSTEM - SEE 4 - STRUCTURAL

SYSTEM - SEE 5 - VEHICLE

SYSTEM - SEE 6 - GROUND
SHUTTLE CRITICAL ITEMS LIST - CRR.TER 102

SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PRESSURIZATION
P/N REV: 11/08/7O
P/N VENDOR: 73A630030
QUANTITY: 4

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

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

PREPARED BY: DES N C GLAVINICH
REL C M AKERS

ITEM: LINE, LOW PRESSURE HE-

FEED LINE (3/4")

FUNCTION:
3/4" X .020 304L S.S LINES TO PROVIDE HELIUM FEED FROM REGULATORS TO PROP TANK.

FAILURE MODE: STRUCTURAL FAILURE

CAUSE(S):
MECHANICAL SHOCK, VIBRATION/PATIGUE, IMPROPER INSTALLATION (WELD), STRESS CORROSION, M At L DEFICIENCY (SULPHIDE STRINGER)

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) VEHICLE-
(A) LOSS OF SUBSYSTEM HELIUM SUPPLY - inability to deplete/utilize propellant, (B) LOSS OF INTERFACE FUNCTION - inability to depressurize prop tank - potent POD structure & TPS damage, (C) POTENTIAL LOSS OF MISSION OR EARLY MISSION TERMINATION, (D) POTENTIAL LOSS OF CREW/VEHICLE IF GROSS LEAK OCCURS OR TPS DAMAGE OCCURS PRECLUDING SAFE ENTRY.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
( A) F.S. IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF).
THE WELDED CONSTRUCTION ELIMINATES JOINTS AND POSSIBLE LEAK PATHS.
THE ANNEALED AREA (DUE TO WELDING) IS BACKED UP BY A SLEEVE.
FASTENING CLAMPS ALLOW FREEDOM OF MOVEMENT. TUBING BENDS ARE CONTROLLED BETWEEN FIXED POINTS TO FACILITATE INSTALLATION AND ACCOMMODATE VEHICLE GROWTH AND MOVEMENT. (B) ROCKWELL PERFORMED TUBING CERTIFICATION TESTS PER "ORBITER TUBING VERIFICATION PLAN" (SD75-SH-0205). THIS TESTING INCLUDED PRESSURE CYCLING AND FATIGUE FOR TYPICAL SHUTTLE LINES & JOINTS. SYSTEM EVALUATION TESTS AT WSTF WILL ALSO ALLOW EVALUATION IN THE INSTALLED SYSTEM CONDITION. LEAKAGE TESTS ARE PERFORMED IN-PROCESS FOR TUBING SECTIONS. OPTICAL INSPECTIONS ARE ALSO PERFORMED AT THIS TIME IN ADDITION TO X-RAY AND DYE PENETRANT.
LEAKAGE TESTS ARE ALSO PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND ADDITIONAL WELDS ARE ALSO SUBJECT TO NDE. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAM. CONTROL PROCESSES, CORROSION, PROTECTION PROVISIONS, NDE EXAM OF WELDS AND INSPE. FOR SURFACE AND SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPE. POINTS, RAW M At L (LOT CERTIFICATION), PARTS PROTECTION, MANUF., COATING, PLATING, INSTALLATION AND ASSEMBLY OPERATIONS. HARDWARE IS INSPE. IN ACCORDANCE WITH QUALITY
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM : AFT - REACTION CONTROL FMEA NG 03-2A -201035-1 REV:11/03/73
PLANNING REGMITS DOCUMENT (CPRO) WHICH HAS BEEN APPROVED BY NASA.
TURNOAROUND. LINES IN ACCESSIBLE AREAS ARE VISUALLY INSPECTED FOR
EVIDENCE OF DAMAGE AND FLOW AND PRESSURE FUNCTIONAL TESTS ARE MONITORED
FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE. (D) MINOR HISTORY -
CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.
HISTORY - CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND
CORRECTED.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   YES X NO
   1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?
   *YES 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 NO X
   3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   *YES X NO
   4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?
   *YES X NO
   5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?
   *YES X NO
   6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.
   0 1 2 X
   7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   N/A YES X NO
   8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      YES X *NO
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      YES X *NO
   *EXPLANATION REQUIRED (SEE BELOW)

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

EXPLANATION/COMMENTS:
1. Gross leak detection will give first indication.

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

5. Left and right AFT RCS pods provide redundancy.
SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PRESSURIZATION

P/N: MC284-0421-0001/0002

P/N VENDOR: 5760009-101/576-0009-102

QUANTITY: 4

MISSIONS: HF, VF X FF 7F SM

ASSEMBLY: PRESSURIZATION

P/N: R1:MC284-0421-0001/0002

P/N VEND: OR76D9D9-R1O_j/576-009-102

MISSIONS: HF, VF X FF 7F SM

ASSEMBLY: PRESSURIZATION

P/N: R1:MC284-0421-0001/0002

P/N VEND: OR76D9D9-R1O_j/576-009-102

MISSIONS: HF, VF X FF 7F SM

ASSEMBLY: PRESSURIZATION

P/N: R1:MC284-0421-0001/0002

P/N VEND: OR76D9D9-R1O_j/576-009-102

MISSIONS: HF, VF X FF 7F SM

FUNCTION:

- PROVIDES PRESSURE RELIEF IN EVENT REGULATOR FAILS OPEN OR PROPELLANT PRESSURE RISES DUE TO THERMAL INCREASE. THE S.S. BURST DISC RELIEF PRESSURE IS 325-340 PSIG. THE MAIN POPPET CRACK AND RELIEF PRESSURE IS 315 PSIG AND THE MINIMUM RESEAT PRESSURE IS 311 PSI. AMBIENT PRESSURE SENSING INTERNAL IS PROVIDED SINCE THE VALVE OUTLET IS SUBJECTED TO BACK-PRESSURE.

- FAILURE MODE: EXTERNAL LEAK (F)
  - FAILS OPEN, MAIN POPPET OR DIAPHRAGM LEAKS OR MAIN POPPET DOES NOT RESEAT AS REQUIRED AFTER BURST DISC RUPTURE.

- CAUSE(S):
  - CORROSION, CONTAMINATION, POPPET BINDS IN GUIDE, SPRING BREAKS OR COCKS, SEAT CRACKS, MOISTURE FREEZES, VIBRATION, SHOCK.

- EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
  - (A) LOSS OF SUBSYSTEM PRESSURIZATION
  - (B) LOSS OF INTERFACE FUNCTION
  - (C) LOSS OF INTERFACE FUNCTION
  - (D) LOSS OF INTERFACE FUNCTION

- FUNCTIONAL CRITICALITY EFFECT - POSSIBLE LOSS OF CREW/VEHICLE - SEE ITEM (C) ABOVE. PROP IN ONE POD MAY NOT BE ADEQUATE FOR ENTRY. POSS ENTRY CONTROL & LANDING HAZARD (C.G.) IF PROP CANNOT BE DEPLETED PRIOR TO LANDING.

- DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
  - (A) BURST DISC IS REDUNDANT TO THE MAIN POPPET FOR THE EXTERNAL LEAKAGE MODE. MAIN POPPET LEAKAGE WOULD NOT BE SENSED UNTIL AFTER BURST DISC ACTUATION OR FAILURE. A 25-MICRON FILTER DOWNSTREAM OF THE BURST DISC WILL REDUCE THE POTENTIAL FOR CONTAMINATION CAUSED LEAKAGE FAILURE. THE HELIUM ISOLATION VALVE COULD BE CLOSED DURING STATIC PERIODS. THIS WOULD PREVENT CONTINUING LOSS OF SOURCE PRESSURE. THE MAIN POPPET STEM IS A SEPARATE PIECE FROM THE MAIN SENSING SPRING ACTUATION MECHANISM. THIS PROVIDES CLOSE TOLERANCE CONTROL OF OPENING PRESSURE & ALLOWS THE POPPET TO SEAT INDEPENDENTLY OF THE LARGE SENSOR SPRING FORCE. (B) 36,000 PRESSURE EXCURSION CYCLES AT SYSTEM OPERATING
SUBSYSTEM : AFT - REACTION CONTROL FMEA NO 03-24-20060-4 REV: 12/14/72

Pressure and 400 pressure relief cycles are conducted during qual. An identification is performed contamination control process, contamination control plan, Corros., protection provision, NDE exam of welds, InsP for surface and subsurface defects, properly monitored handling and storage environment, and mat'l and equip. Conformance to contract reqmts. Are verified by InsP. The following items are verified by shop traveler mandatory InsP points—raw mat', (lot certification), parts protection, manuf., coating, plating, installation and assy operations. Turnaround - leakage tests are monitored to verify that the burst disc is still intact and that the main poppet leak rate is within specification reqmts. Visual InsP for evidence of deterioration is also performed. (d) Apollo failures were do largely to galvanic corros. & contamination corrected by design & test processing changes. (The shuttle relief valve is a new design which contains a filter & does not use dissimilar metals).
SHIELD PATHS AND EFFECTS ANALYSIS

SPECIAL CONTROL

GENERAL

DISCUSSION

ORIGINAL PAGE IS OF POOR QUALITY
HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

ITEM: He Fill Quick Disconnect

FMEA NUMBER: 03-28-201070-1

FAILURE MODE: Fails Open

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

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

EXPLANATION/COMMENTS:

1. Gross leak detection will give first indication.

6. Capped quick disconnect provides one redundant success path.

Pod Redundancy

In-Flight detectability

FMEA CHANGE RECOMMENDED

39
SYSTEM TEST AND EFFECTS ANALYSIS - CONT.

**MISSILE MEASUREMENTS**

- **VACCUUM**
- **AMPLITUDE**
- **NUMBERS OF SUCCESSFUL OPERATIONS**
- **FIRST FIRED**

- **MISSILE ATTITUDE TO FLIGHT**

**VISUAL INSPECTION PRIOR TO LAUNCH**

**PREPARING SYS:**
- **CII**
- **C. SCARLETT**
- **MG**
- **C. WIGGERS**
- **HEL**

**APPROVED SYS:**
- **HEL**

**NOTE:**

- **DISCONNECT JUICER Libre**
- **LAP** with **SPRING LOADED FORD** and **STRUCTURAL AIR CAV** by **COX**

- **NO**
- **DET**

- **EQUIPMENTS REAR**
- **VEHICLE**
- **COMPARTMENT**

- **COUPLING IS ACCESSIBLE AT THE HELICOPTER SERVICING PANEL**

- **FAIL**

- **SCREW CAP**, **SEALS DETERMINED**

- **EFFECT:**

  - **A**
  - **B**
  - **C**
  - **D**

  - **LOSS OF**
  - **MISSES**
  - **LOSS OF**
  - **NO**

**SUCCESS CONDITIONS:**

- **MISSILES**
- **LAP**

**CAUTIONS:**

- **ATTENTION**
- **MECHANICAL**
- **PIPE**

**DISCONNECT**

- **FAILURE**

**ALWAYS:**

- **MISSILES**
- **LAP**

**HAZARDS:**

- **A**
- **B**

**NOTE:**

- **MISSILES**
- **LAP**

**ORIGINAL PAGE IS OF POOR QUALITY**
SUBSYSTEM : AFT - REACTION CONTROL   FMEA NO 03-2A - 221070-1   REV: 12/12/78
ASSEMBLY : PRESSURIZATION ABORT: CRIT. FUNC: 1
P/N RI : MC276-0017-0402/-0403 CRIT. MDM: 1
P/N VENDOR: 7537200C-0401/-0403 MISSIONS: HF VF X FF OF SM
QUANTITY : 4 PHASE(S): PL X LO X CC X DJ X LS X
REDUNDANCY SCREEN: A-N/A  B-N/A  C-N/A

PREPARED BY: DES C SCARLETT DES C SCARLETT 12/12/78
APPROVED BY: SMP W RATHBUN 12/12/78
APPROVE 0Y A

ITEM: DISCONNECT, QUICK-FILL, HE
(1/4") WITH SPRING LOADED POPPET AND STRUCTURAL END CAP. #0 219/220

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

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

CAUSE(S):
- CONTAMINATION, VIBRATION, MECHANICAL SHOCK, PIECE-PART STRUCTURAL
- FAILURE, EXCESS OR IMPROPER USE, INADEQUATE MAINT USE, NC LINE
- SUPPORT - SHAFT OR 300E BENT. RETAINING CAP LOCENS NEGATING GAP SEAL
- REDUNDANCY.

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

DISPOSITION & RATIONALS (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) F.S. IS 2.0 X WORKING PRESS. ullAGE PRESS IS ADEQ TO EXP EP PROP
- WITH 35 PERCENT OR LESS REAMAINING. GROUND HALF COUPLINGS AND LINES ARE
- SUPPORTED TO LIMIT ANY UNJUE STRESS ON THE COUPLING DURING SERVICE AND
- PREV DAMAGE TO SEALS, A SAFETY FEATURE DURING SERVICING AND PRIOR TO
- REMOVAL OF THE END CAP IS A PROV WHEREBY ANY LEAKAGE PAST THE AIRBORNE
- POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING A 3/4E SCREW. COMPLETE
- STRESS ANAL HAS BEEN CONDUCTED. UTIL OF STRUCT CAP MINIMIZES LEAKAGE
- POTENTIAL AND PROVIDES A REDUND SEAL EXCEPT FOR STRUCT FAILURE. (B) THE
- COUPLING IS SUB TO 600 OPERATIONAL CYCLES (COUPLING AND UNCOUPLING)
- DURING QUAL. RANDOM VIB TESTING IS ALSO CONDUCTED AT ANTIC VEH LEVELS
- FOR 48 MINUTES IN TWO AXES. USAGE DURING SYS EVAL TESTS AT WS/T ALLOWS
- EVAL UNDER ACTUAL USAGE CON. PROOF PRESS TESTS ARE CONDUCTED DURING ATP
- AND LEAKAGE TESTS ARE PERF BEFORE AND AFTER OPER CYCLES. (C) AN ICENT
- IS PERF. RAW MALT, NDE EXAM, VISUAL INSPI FOR CRITICAL SURFACE DEFECTS,
- AND EQUIP CONFORMANCE TO CONTRACT REQ. ARE VEEF BY RECEIVING INS.
- MEASUREMENT STANDARDS AND TEST EQUIP. STANDARDS ARE IMPLEMENTED PER
- REQMTS OF MIL SPEC. THE FOLLOWING ITEMS ARE VEEF BY SHOP TRAVELER
- MANDATORY INSPI POINTS. PARTS MFG, PROD. COATING, ASSY AND
- INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY
- AUDIT CONDUCTED 5-23-77. CORROS PROT PROT, CONTAM CONT PROCESSES, TEST

SD75-SH-0003

SHUTTLE CRITICAL ITEMS LIST - CRITER 102
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A-201070-1  REV:12/12/75
HANDLING, AND STORAGE ENVIR. THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT
OF MARCH 6, 1978. INSPECTION VERIFIES ASSEMBLY PER INSPECTION POINTS IN
MASTER RECORD. LOG OF CLEAN ROOM AND CALIBRATION OF TOOLS VERIFIED.
CRITICAL DIMENSION 100% VERIFIED BY INSPECTION. PARTS CLEANLINESS AND
PASSIVATION VERIFIED BY INSPECTION. NOE INSPECTION PERFORMED AFTER
ASSEMBLY. TURNAROUND. COUPINGS ARE VISUALLY INSPECTED FOR EVIDENCE OF DAMAGED
SEALS AND LEAK TESTS ARE PERFORMED. (C) APOLLO FAILURE HISTORY WAS IN
THE MAIN ASSOC WITH GROUND USAGE, IMPROPER HANDLING.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST

SUBSYSTEM AFT - RCS

ITEM Purge Quick Disconnect, Propellant

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>External Leakage</th>
</tr>
</thead>
</table>

1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**
   - **YES X NO**
   
2a. **IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?**
   - **YES X NO**

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

3a. **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**

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 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**

1. **NO H/S ISSUES**

2. **HARDWARE ACCEPTS RISK**

3. **NO SOFTWARE DETECTION**

4. **DETECTION DURING CHECKOUT**

5. **ACCEPTANCE RATIONALE BELOW**

6. **RECOMMENDED CHANGES BELOW**

---

**EXPLANATION/COMMENTS:**

1. Gross leak detection will give first indication.
2. The above statement indicates in-flight detection.
6. Need minimum of 2 yaw thrusters. Cross-feed is available. Pods are redundant.
ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: MC276-001B
P/N VENDOR: 763610CQ & 76316000
QUANTITY: 28

P/N: RI, MCZ7-0077
CR: TT, H1, J:
P/N: VENON: 763610CQ
F:
76316000: ASSIGN: HF X FF CF S1

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

FAILURE MODE: EXTERNAL LEAKAGE
CAP LEAKS, SEALS DAMAGED RETAINING NUT LOGENS NEGATING CAP SEAL REDUNDANCY.

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

EFFECT(S): ON (A) SUBSYSTEM (3) INTERFACES (2) MISSION (D) CREW/VEHICLE:
(A, 3) LOSS OF REDUNDANCY

(PROPELLANT MANIFOLD ISOLATION VALVE COULD ISOLATE LEAK.)

MODIFICATION OR ABORT DECISION.

NO EFFECT UNLESS MULTIPLE FAILURES OCCUR OR EXCESS LOSS OF PROPELLANT OCCURS.

FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CREW/VEHICLE LOSS - LOSS OF RCS ENTRY PROPELLANT.

POSSIBLE LOSS OF VEHICLE CONTROL DURING ENTRY.

DISPOSITION & RATIONALE

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

(A) P.S. IS 2.0 X WORKING PRESS. REDUNDANCY PROVIDED BY INTERNAL SEAL, CAP & MANIFOLD ISOLATION VALVE.

GROUND HALF COUPLINGS AND LINES ARE ADEQ SUPPORTED TO LIMIT ANY UNDUE STRESS ON THE COUPLING DURING SERVICE AND PREV DAMAGE TO SEALS. A SAFETY FEATURE DURING SERVICING AND PRIOR TO REMOVAL OF THE END CAP IS A PROV WHEREBY ANY LEAKAGE PAST THE AIRBORNE POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING A BLEED SCREW.

COMPLETE STRESS ANALYSIS HAS BEEN CONDUCTED FOR STRUCTURAL CAPS MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUN SEAL EXCEPT FOR STRUCTURE FAILURE.

FAILURE CAN BE ISOLATED AT MANIFOLD VALVE.

(B) THE COUPLING IS SUBJ TO 600 OPER CYCLES (COUPLING AND UNCOUPLING) DURING QUAL IN ADDITION TO PRESSUR CYCLING AND PROP EXPOSURE TESTS. RANDOM VIB TESTING IS ALSO CONDUCTED AT ANTI VEH LEVELS FOR 34 MINUTES IN EACH AXIS. USAGE DURING SYS EVAL TESTS AT KTF ALLOWS EVAL UNDER ACTUAL USAGE COND.

PROOF PRESS TESTS ARE CONDUCTED DURING ATP AND LEAKAGE TESTS ARE PERF BEFORE AND AFTER OPER CYCLES. (C) AN IDENT IS PERF. RAW MAT'L, NDE EXAM, VISUAL INSPECTION FOR CRITICAL SURFACE DEFECTS, AND EQUIP CONFORMANCE TO CONTRACT REQmts ARE VERIFIED BY RECEIVING INSPECTION.

MEASUREMENT STANDARDS AND

1006 SD75-SH-0003

45
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A -201080-1  REV:11/09/78
TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQUIREMENTS OF MIL SPEC. THE
FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS - PARTS
PROT, MFG. PROCESSES, COATING, ASSY AND INSTALLATION. THE ABOVE ITEMS
AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77.
CORROS PROT, PROV CONTAM CONT PROCESSES, TEST HANDLING, AND STORAGE
ENVIR. THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT OF MARCH 6, 1978.
INSPECTION VERIFIES ASSEMBLY PER INSPECTION POINTS IN MASTER RECORD.
LOG OF CLEAN ROOM AND CALIBRATION OF TOOLS VERIFIED. CRITICAL DIMENSION
100% VERIFIED BY INSPECTION. PARTS CLEANLINESS AND PASSIVATION VERIFIED
BY INSPECTION. NDE INSPECTION PERFORMED AFTER ASSEMBLY.
TURNAROUND COUPLINGS WILL BE VISUALLY INSPECTED FOR EVIDENCE OF CAP SEAL
DAMAGE AND CAP LEAKAGE. (O) APOLLO FAILURE HISTORY WAS IN THE MAIN
ASSOC WITH GROUND USAGE, IMPROPER HANDLING.
**SUBSYSTEM** AFT - RCS  
**FMEA NUMBER** 03-2A-201090-1  
**ITEM** Test Quick Disconnect  
**FAILURE MODE** External Leakage

<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</td>
</tr>
<tr>
<td>1a. If not, does the hardware provide information that the flight software could use to detect the failure?</td>
<td><em>YES</em></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</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</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><em>YES</em></td>
</tr>
<tr>
<td>4. As a result of this failure mode, can the software over-stress the hardware or induce another failure?</td>
<td>YES</td>
</tr>
<tr>
<td>5. Can this failure mode, in combination with software logic, adversely affect other functions?</td>
<td><em>YES</em></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><em>1</em></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>
</tr>
<tr>
<td>8. If the answer to either 1 or 3 is YES:</td>
<td></td>
</tr>
<tr>
<td>A. Can the BFS be engaged after occurrence?</td>
<td><em>YES</em></td>
</tr>
<tr>
<td>B. Will BFS tolerate failure without loss of crew/vehicle?</td>
<td><em>YES</em></td>
</tr>
</tbody>
</table>

**EXPLANATION REQUIRED (SEE BELOW)**

**CHANGE/RETENTION RATIONALE SUMMARY**

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

**FMEA CHANGE RECOMMENDED**

**EXPLANATION/COMMENTS:**

2. FMEA change - in flight detectability should include above measurement numbers.
6. Pod redundancy.
FAILURE MODE: EXTERNAL LEAKAGE

CAUSE:
- CAUTION: NO FAST STRUCTURAL DAMAGE (FUEL LEAKS)
- CAUTION: NO LEAKING STRUCTURAL FAILURES (FUEL LEAKS)
- CAUTION: NO EXCESS LEAKAGE, SEAL DAMAGED, INADEQUATE SEAL MATERIAL, DAMAGED SEAL SUPPORT - SPARE OR REPLACE

CONCLUSION:
- (A) SUBSYSTEM (B) COMPONENT (C) MISSION (D) ENTRY/DEPLOYMENT
- (E) LESS OF SUBSYSTEM PRESSURIZATION OR REDUNDANCY DEPENDS ON小さく
- (F) LESS OF INTERFACE FUNCTION (LESS OF PROPPELLANT FEED)
- (G) LESS EFFECT ON REDUNDANT COMPONENTS
- (H) POSSIBLE CRITICALITY EFFECT - POSSIBLE CRACK/VEHICLE COLLISION
- (I) POSSIBLE RESULT IN INABILITY TO USE RESERVED ENTRY PROPELLANT OR線上 PROGRESSIVE LEAVING PROPELLANT WEIGHT

RECOMMENDATIONS:
- ISOLATE LEAK IF POSSIBLE. CONSISTENT USAGE OF UPLACEMENT PRESSURIZATION AT VITAL SITES FOR ALL SYSTEMS. CLOSE ISOLATION VALVE DURING STATIC PREP.
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PRESSURIZATION
P/N RI : ME270-0032-0009, 7, 19, 21
P/N VENDOR: RR42670-3, -7RG4293-15-3
MISSIONS: HF VP X FP CF SM
QUANTITY : 36

ASSEMBLY : PRESSURIZATION
ABORT: CIT. FUNC: 1
P/N ME270-0032-0009
MISSIONS: HF VP X FP CF SM
QUANTITY : 18 PER MODULE

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

PREPARED BY: C. SCARLETT
APPROVED BY: SSM
APPROVED WITH CHANGES

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

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

FAILURE MODE: EXTERNAL LEAKAGE (S)
- CAP LEAKS, SEALS DAMAGED
- VIBRATION, PIECE PART STRUCTURAL FAILURE (POPPET, SEAL), MECHANICAL SHOCK, EXCESS TORQUE, SEAL DAMAGE, INADEQUATE MAINT OF ASE HALF, VC LINE SUPPORT - SHAFT CR BORE BENT

CAUSE(S):
- VIBRATION
- PIECE PART STRUCTURAL FAILURE (POPPET, SEAL), MECHANICAL SHOCK
- EXCESS TORQUE
- SEAL DAMAGE
- INADEQUATE MAINT OF ASE HALF
- VC LINE SUPPORT - SHAFT CR BORE BENT

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
- (A) LOSS OF SUBSYSTEM PRESSURIZATION OR REDUNDANCY DEPENDING ON LOCATION
- (B) LOSS OF INTERFACE FUNCTION (LOSS OF PROPELLANT FEED CAPABILITY)
- (C, D) NO EFFECT
- (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CREW/VEHICLE LOSS
- LOSS OF PROPRESSANT RESULTS IN INABILITY TO BURN OR DEPLETE RCS PROPELLANT
- THIS WOULD RESULT IN POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO USE RESERVED ENTRY PROPELLANT OR C.G. PROBLEMS RESULTING FROM PROPELLANT WEIGHT

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) F.S. IS 2.0 X WORKING PRESS. ULLAGE PRESS IS ADEQ TO EXPLOD PROP WITH 35 PERCENT OR LESS REMAINING. GROUND MFG COUPLINGS AND LINES ARE ADEQ SUPPORTED TO LIMIT ANY UNDE LEAKAGE TO COUPLINGS AND WELD JOINTS. A SAFETY FEATURE DURING SERVICING AND PRIOR TO REMOVAL OF THE END CAP IS A PROV WHEREBY ANY LEAKAGE PAST THE AIRBORNE POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING CAP UTIL OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUNDANT SEAL EXCEPT FOR STRUCT OR WELD FAILURES. (B) THE COUPLING IS DESIGNED FOR 400 OPER CYCLES (COUPLING AND UNCOUPLING). USAGE DURING SYS EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE COND.
- PROOF PRESS TESTS ARE CONDUCTED DURING ATP AND LEAKAGE TESTS ARE PERFORMED BEFORE AND AFTER OPER CYCLES. (C) AN IDENT IS PERF AND THE UNIT TAGGED. RAW MATERIALS EXAM OF WELDS, VISUAL INSPE. OF WELD JOINTS FOR
SUBSYSTEM: AFT - REACTION CONTROL

FMEA NO. 03-2A -201040-1   REV: 12/12/76

CONFORMANCE TO STANDARD WELD PRACTICE, SURFACE DEFECTS, AND EQUIP
CONFORMANCE TO CONTRACT REQS ARE VERIF BY RECEIVING INSPECTION.
MEASUREMENT
STANDARDS AND TEST EQUIP. STANDARDS ARE IMPLEMENTED PER PGMTS OF MIL
STANDARDS. THE FOLLOWING ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPECTION
POINTS - PARTS MFG., MFG. PROCESSES, COATING, PLATING, ASSY AND
INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY
AUDIT CONDUCTED 11-3-76. C.M.Rajan PROT PROV, CONTAIN CONT PROCESSES, TEST
HANDLING, AND STORAGE ENVIRONMENT. TURNAROUND - COUPLINGS WILL BE VISUALLY
INSPECTED FOR EVIDENCE OF SEAL DAMAGE AND CAP LEAKAGE. (COUPLINGS
BETWEEN THE HELIUM ISOL VALVE & REGULATOR & THOSE ASSOCIATED WITH PROP
TANK C/O ARE NOT ACCESSIBLE AT SERVICING PANELS) (C) APOLLO FAILURE
HISTORY WAS IN THE MAIN ASSOC WITH GROUND USAGE, IMPROPER HANDLING.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

SUBSYSTEM AFT - RCS

ITEM He Quad Check Valve

FAILURE MODE Fails Closed

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

   YES ☑ 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. Upon using the thrusters, propellant tank ullage pressure will decay until <200 psi which will give a class 2 alarm, caution and warning. (Red Light)
FUELS VALVE: OPEN, CHECK AS.

CVIC 1/17/71

STICK FAILURE, STICK, VALVE; NO PUPPET GAINS IN COIL; CATCH, VALVE; VALVE CLOSING IN COIL VALVE, CONTIN.

FAILURE(S): (A) SUBSYSTEM (F) INTERFACES (C) MISSION (VEHICLE/VEHICLE)

(F) LOSS OF REDUNDANCY - PARALLEL FLOW PATH. (LEAK OFF) UNLESS PARALLEL PORTS FAIL CLOSED. FAILURE OF PARALLEL PORTS WOULD CAUSE INTERFACE ON INDIVIDUAL AND POSITIVELY PREVENT, UTILIZATION OF ALL GAIN (PORTS EVENTUALLY CLOSED). (E) ASCENT /DECEL CRITICALITY EFFECT - WHERE AS THE PORTS, VEHICLE LOSS; FAILURE OF PARALLEL PORTS WOULD POSSIBLY RESULT IN INABILITY TO OPEN OR DELIVER ALL PAY FUEL TO PROPULSANT. IN ADDITION TO VEHICLE LOSS PROBLEMS WITH RECURRING THROTTLE FUELING PRESSES, POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO UTILIZE AVAILABLE PROPELLANT AND OTHER PROBLEMS DUE TO PROPULSANT.

FUELS: ACIDS

IF PRESSURE IS RECOGNIZED, CLOSE VALVE ISOLATE FUEL AND USE PORTS, UTILIZE NORMAL FUEL PORTS.

FAILURE(S):

LEAKAGE FUEL WILL RAID UNPILLATE FLOW TO CATCH. POSS CHARGE IN FUEL COULD CAUSE FUEL START. FAILURE NOT DETECTABLE UNLESS PARALLEL PORTS.
SUBSYSTEM: AFT - REACTION CONTROL  
ASSEMBLY: PRESSURIZATION  
P/N: MC24-3741-0021/0002  
P/N VENDOR: RS010500-001-017  
QUANTITY: 4  

ITEM: VALVE, QUAD. CHECK. HE.  
CV 201/202/301/302  
FUNCTION:  
- EACH CHECK VALVE QUAD WITH 4 POPPETS IN SERIES - PARALLEL ARRANGEMENT PROVIDES PARALLEL REDUNDANCY FOR HELIUM PRESSURIZATION AND SERIES REDUNDANCY TO LIMIT BACK FLOW OF PROPPELLANT VAPORS FROM THE PROPPELLANT TANKS TO THE REGULATOR. A 304L 25 MICRON FILTER IS UTILIZED AT THE INLET. VALVE UTILIZES CUTTER SEAL DESIGN CONCEPT (TWO SEALING SURFACES PER POPPET)  

FAILURE MODE: FAILS CLOSED (F)  

CAUSE(S):  
- STRUCT. FAILURE, SHOCK, VIB. POPPET BINGS IN GUIDE. CONTACT VIB. FREEZES IN COLD VALVE, COPROs.  

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CRY/VEHICLE:  
- (A) LOSS OF REDUNDANCY - PARAL FLOW PATH. (B, C, D) NO EFFECT UNLESS PARAL POPPETS FAIL CLOSED. FAILURE OF PARAL POPPETS WOULD CAUSE MIX RATIO SHIFT AND POSSIBLY PREVENT UTIL/DEPLETION OF ALL RCS POPPETS EVENTUALLY UNSEAT. (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CRY/VEHICLE LOSS. FAILURE OF PARALLEL POPPETS WOULD POSSIBLY RESULT IN INABILITY TO BURN OR DEPLETE ALL RCS PROPPELLANT IN ADDITION TO MIXTURE RATIO PROBLEMS WITH RESULTANT THRUSTER FIRING PROBLEMS. POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO UTILIZE RESERVED PROPPELLANT AND C.G. PROBLEMS DUE TO PROPPELLANT WEIGHT.  

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:  
- (A) SERIES-PARALLEL REDUNDANT POPPETS PROVIDE REDUNDANCY FOR THE CLOSED FAILURE MODE. TO LIMIT THE POTENTIAL FOR POPPET SHAFT BINDING, OR GENERATION OF CONTAMINATION THE GUIDE PINS UTILIZE SAPPHIRE AS A WEAR RESISTANT SURFACE. A 25-MICRON INLET FILTER WILL ALSO REDUCE THE POTENTIAL FOR A CLOSED FAILURE BY LIMITING THE POTENTIAL FOR CONTAMINATION TO CAUSE BINDING OF MOVING PARTS. (B) 100,000 OPERATION CYCLES (FLOW) AND RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYSTEM EVALUATION TESTS AT WSTF ALONG WITH SIMULATION TESTS. PROOF PRESSURE, LEAKAGE, & OPERATION (CRACKING PRESSURE AND FLOW) TESTS ARE PERFORMED DURING ATP. APPROPRIATELY LOCATED TEST POINTS ALLOW PRE/POST FLIGHT LEAKAGE TESTS AND OPERATION TESTS WHICH ARE CONDUCTED AT THIS TIME. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED.  

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

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**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

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**EXPLANATION/COMMENTS:**


2. V42P2115 and 3115 should be deleted from this FMEA page as they are in the oxidizer system and not the fuel system.
Simplified analytical methods for engine analysis:

1. Thrust vector alignment
2. Fuel flow measurement
3. Exhaust gas analysis
4. Engine test cell monitoring
5. Diagnostic software analysis

Approved Eye:

Approved Eye:

1. Fuel flow, should ensure correct fuel flow to engines,
2. Turbocharger monitoring,
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For engines with turbochargers:

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SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED, FUEL
P/N RI: MC621-0059
P/N VENDOR: F3A550001
QUANTITY: 2

ONE SET PER PROPELLANT PER MODULE

REDUNDANCY SCREEN: A-N/A 9-N/A C-N/A

PREPARED BY: N G GLAVINICH
APPROVED BY: W M. MAY

DES REL
C MAKERS REL

ASSEMBLY: PROPELLANT FUEL
ABORT: CPIT. FUNC:
CRIT. P/N: MC6121-0059
CRIT. HOW:
MISSIONS: HF VF X FF OF SM
PHASE(S): PL L3 X CQ X DD X LS

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

FUNCTION:
(1) 1 1/2 x .028 304 SS from tank to distribution panel
(2) 1 1/4 x .028 from manifold isolation valve to thrust manifold
(3) 5/8 x .028 thrust manifold to provide feed to appropriate propellant components for thrust operation

FAILURE MODE: STRUCTURAL FAILURE

CAUSE(S):
VIB, FATIGUE, SHOCK, WELD DEF, INSTALL D44, DYNAMIC SEAL FAILURE, WELD DEF (SULPHIDE STRINGER)

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE
(A) SUBSYSTEM DEGRADATION - LOSS OF PROP
(B) DEGRADATION OF INTERFACE FUNCTION - POSS CORROS DAMAGE IN PO
(C) LAUNCH DELAY OR ABORT DECISION
(D) POSSIBLE LOSS OF CREW/VEHICLE IF LINE FROM TANK OUTLET RUPTURES RESULTING IN INABILITY TO UTILIZE/DEPLETE PROP OR PROP REACTS WITH FUEL OR OX CAUSING FIRE OR EXPLOSION

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY
(A) FEAT IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF)

DYNATURES HAVE SPLIT SEALING SURFACES. THE WELDED CONSTRUCTION ELIMINATES JOINTS AND POSSIBLE LEAK PATHS. THE ANNEALED AREA (DUE TO WELDING) IS BACKED UP BY A SLEEVE. FASTENING CLAMPS ALLOW FREEDOM OF MOVEMENT. TUBING BENDS ARE CONTROLLED BETWEEN FIXED POINTS TO FACILITATE INSTALLATION AND ACCOMMODATE VEHICLE GROWTH AND MOVEMENT.

ROCKWELL PERFORMED TUBING CERTIFICATION TESTS PER "ORBITER TUBING VERIFICATION PLAN" (SD 75-SH-0025). THIS TESTING INCLUDED PRESSURE CYCLING AND FATIGUE FOR TYPICAL SHUTTLE LINES & JOINTS. SYSTEM EVALUATION TESTS AT WSTP WILL ALSO ALLOW EVALUATION IN THE INSTALLED SYSTEM CONDITION. LEAKAGE TESTS ARE PERFORMED IN-PROCESS FOR TUBING SECTIONS. OPTICAL INSPECTIONS ARE ALSO PERFORMED AT THIS TIME IN ADDITION TO X-RAY AND DYE PENETRANT. LEAKAGE TESTS ARE ALSO PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND ADDITIONAL WELDS ARE ALSO SUBJECT TO NDE. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAM CONTROL PROCESSES, CORROS. PROTECTION PROVISIONS. NDE EXAM OF WELDS AND INSPECTION FOR SURFACE AND SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER
SUBSYSTEM: AFT - REACTION CONTROL  FMEA NO 03-2A -202108-1  PEV:11/03/72
MANDATORY INSPECTION POINTS - RAW MATERIAL (LOT CERTIFICATION), PARTS PROTECTION, MANUFACTURING, COATING, PLATING, INSTALLATION AND ASSEMBLY OPERATIONS.
HARDWARE IS INSPECTED IN ACCORDANCE WITH QUALITY PLANNING REGULATIONS (OPRD) WHICH HAS BEEN APPROVED BY NASA. TURNAROUND LINES IN ACCESSIBLE AREAS ARE VISUALLY INSPECTED FOR EVIDENCE OF DAMAGE AND FLOW AND PRESSURE FUNCTIONAL TESTS ARE MONITORED FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE. (O) MINOR HISTORY - CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.
**SUBSYSTEM** AFT - RCS  
**ITEM** Feedline & Fittings, OX  
**FMEA NUMBER** 03-2A-202109-1  
**FAILURE MODE** External Leakage

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

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

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

4. **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** ☑

5. **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** ☑

**EXPLANATION REQUIRED (SEE BELOW)**

**CHANGE/RETENTION RATIONALE SUMMARY**

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

**EXPLANATION/COMMENTS:**

PREPARED BY:  

LES N. COLEMAN  
PCL C. MARKS  

APPROVED BY:  

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ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED, OXIDIZER
P/N: MC621-0059
P/N VENDOR: 73A550002
MISSION: HF VF X FF TP SM
QUANTITY: 2

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

FAILURE MODE: STRUCTURAL FAILURE
RUPTURE, EXTERNAL LEAKAGE

CAUSE(S):
- MECHANICAL SHOCK, VIBRATION/FATIGUE, IMPROPER INSTALLATION (WELD)
- DYNAMOTUBE SEAL FAILURE W/ DIR DEFICIENCY (SULPHIDE STRINGER)

EFFECT(S):
- ON: (1) SUBSYSTEM (5) INTERFACES (5) MISSION (5) P/N/Vehicle
- (4) SUB-SYSTEM DEGRADATION - LOSS OF PROPELLANT.
- (3) DEGRADATION OF INTERFACE FUNCTION - POTENTIAL CORROSION FOR FREE PROPELLANTS IN MODULE.
- (C) ABORT DECISION
- (D) POSSIBLE LOSS OF CONFIG VEHICLE IF LINE FROM TANK OUTLET RUPTURES RESULTING IN INABILITY TO UTILIZE/DEplete PROP OR PROP REACTS WITH FUEL OR OXIDIZER CAUSING FIRE OR EXPLOSION

DISPOSITION & RATIONALE
- (A) DESIGN
- (B) TEST
- (C) INSPECTION
- (D) FAILURE HISTORY
- (A) F.S. IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF)
- DYNAMOTUBES HAVE DUAL SEALING SURFACES. THE WELDED CONSTRUCTION ELIMINATES JOINTS AND POSSIBLE LEAK PATHS. THE ANNEALED AREA (DUE TO WELDING) IS BACKED UP BY A SLEEVE, FASTENING CLAMPS ALLOWS FREEDOM OF MOVEMENT. TUBING BENDS ARE CONTROLLED BETWEEN FIXED POINTS TO FACILITATE INSTALLATION AND ACCOMMODATE VEHICLE GROWTH AND MOVEMENT
- (B) ROCKWELL PERFORMED TUBING CERTIFICATION TESTS PER "ORBITE0 TUBING VERIFICATION" (SD75-SH-0205). THIS TESTING INCLUDED PRESSURE CYCLING AND FATIGUE FOR TYPICAL SHUTTLE LINES & JOINTS
- SYSTEM EVALUATION IN THE INSTALLED SYSTEM CONDITION. LEAKAGE TESTS ARE PERFORMED AT THIS TIME IN ADDITION TO X-RAY AND DYE PENETRANT. LEAKAGE TESTS ARE ALSO PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND ADDITIONAL WELDS ARE ALSO SUBJECTED TO NDE. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAM CONTROL PROCESSES, CORROSION PROTECTION PROVISIONS, NDE EXAM OF WELDS AND INSPECTION FOR SURFACE AND SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS - RAW MATERIAL (LOT
SHUTTLE CRITICAL ITEMS LIST - CHAPTER 102

SUBSYSTEM : AFT – REACTION CONTROL FMEA NO 03-24-202109-1 REV:11/03/75
CERTIFICATION, PARTS PROTECTION, MANUF., EQTING, PLATING, INSTALLATION AND ASSEMBLY OPERATIONS. HARDWARE IS INSPECTED IN ACCORDANCE WITH QUALITY PLANNING REQUIREMENTS DOCUMENT (JPRO) WHICH HAS BEEN APPROVED BY NASA.

TURNAROUND LINES IN ACCESSIBLE AREAS ARE VISUALLY INSPECTED FOR EVIDENCE OF DAMAGE AND FLOW AND PRESSURE FUNCTIONAL TESTS ARE MONITORED FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE. (D) MINOR HISTORY – CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED. ARE MONITORED FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE. (D) MINOR HISTORY – CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY)
   ANNUNCIATE OR TAKE ACTION IN RESPONSE?)  YES X NO 0

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

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

3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE
   (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?
   YES □ NO 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 □ *1X 2□

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

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

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

☐ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. First indication "failed off" thruster C&W for 1/2 leg. Redundant paths on 3,4,5 leg.

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

6. One success path remains after first failure.

8B. Same as primary.
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PROPELLANT FEED
P/N PI : 4628-0430-0045/0038
P/N VENDOR : 5750025/5750026
QUANTITY : 4

SUBSYSTEM : AFT - REACTION CONTROL FMEA NC 03-ZA - 201110-1 REV : IZ/
SUBSYSTEM : AFT - REACTION CONTROL FMEA NC 03-ZA - 201110-1 REV : IZ/
SUBSYSTEM : AFT - REACTION CONTROL FMEA NC 03-ZA - 201110-1 REV : IZ/
SUBSYSTEM : AFT - REACTION CONTROL FMEA NC 03-ZA - 201110-1 REV : IZ/

PREPARED BY: R Gonzalez DES C M AKEP REL
APPROVED BY: WANGI 88
APPROVED BY: SMW
APPROVED WITH CHANGES
See Section 13.0

ITEM: VALVE
TANK ISOLATION: 3 PHASE 400 HZ AC MOTOR ACTUATED (115-230V) LV361-366.
LV 361-366. (1-1/2 IN.)

FUNCTION:
THREE REDUNDANT ISOLATION VALVES ARE USED PER TANK TO ISOLATE GROUPS OF MANIFOLDS.
ONE TANK ISOL VALVE CONTROLS 2 MANIFOLDS AND THE PARALLEL ISOL VALVES CONTROL THE REMAINING 2 PRIMARY MANIFOLDS AND THE VERNIER MANIFOLD
THAT MAY EXHIBIT OPEN OR LEAKAGE FAILURES AND THE ISOLATE THE TANK DURING INTERCONNECT 5 RCS OR OMS CROSSFEED OPERATIONS. ALSO USED
TO PREVENT HELIUM INGESTION TO ENGINE AT 3000 PSI IN-OUT (MANUAL SWITCH).
FUEL & OXID VALVES CAN BE OPERATED INDEPENDENTLY FOR C/O. LINE PRESS RELIEF TO TANK IS PROVIDED.

FAILURE MODE:
FAILS CLOSED
FAILS TO OPEN, FAILS TO REMAIN OPEN.

CAUSE(S):
LIMIT SWITCH MALFUNCTION, PREMATURE POWER TO MOTOR, ELECTRICAL SHORT,
RPC OPEN, JAMMING OF BALL SHAFT OR CAMS.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A-B) LOSS OF REDUNDANCY PROPellant FLOW TO TWO MANIFOLDS (ON ONE SIDE)
AND SUBSEQUENT LOSS OF THRUSTER FUNCTION, POTENTIAL THRUSTER DAMAGE
FROM INDUCED SURGE. (C) ABORT DECISION (DEPENDENT ON WHICH TANK ISOL
VALVE FAILS, ONE TANK ISOL VALVE CLOSED MAY LOSS TWO MANIFOLDS). (D) NO
EFFECT FOR SINGLE FAILURE FOR OIC MISSIONS (LOSS OF THRUSTER MAY BE
CRITICAL FOR RTLS IN SUBSEQUENT MISSIONS FOR OMS DEPLETION BURN). CRIT
1 FOR RTLS - LOSS OF TWO MANIFOLDS (PER PPD AFT) IS CRITICAL FOR ET
SEPARATION & MATED COAST DURING RTLS. (E) FUNCTIONAL CRITICALITY EFFECT
POSSIBLE CREW/VEHICAL LOAD DUE TO UTILIZE/DEplete RCS PROPellant.
POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO
UTILIZE RESERVED PROPellant & C.G. PROBLEMS DUE TO PROP WEIGHT.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) AC MOTOR VALVE IS 3-PHASE - 2 OF 3 WINDINGS ARE ADEQUATE FOR VALVE
FUNCTION. SERIES (HYBRID) RELAYS PROVIDE REDUNDANCY FOR THE PREMATURE
CLOSE MODE. PARALLEL (HYBRID) RELAYS PROVIDE REDUNDANCY FOR ELECTRICAL
POWER SIGNAL. ADDITIONALLY, REDUNDANT VAlVES ARE PROVIDED. (ONE TANK
ISOL VALVE CONTROLS 2 OF 4 MANIFOLDS AND TWO PARALLEL TANK ISOL VALVES
CONTROL THE REMAINING 2 PRIMARY MANIFOLDS AND THE VERNIER MANIFOLD.
A 400-MICRON FILTER IS UTILIZED ON THE INLET AND OUTLET TO LIMIT THE
POSSIBILITY OF CONTAMINATION CAUSED FAILURE OR JAMMING OF MOVING PARTS.

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SUBSYSTEM : AFT - REACTION CONTROL

ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYSTEM EVALUATION TESTS AT WSTF ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. PROOF PRESSURE, LEAKAGE, OPERATION, CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT. (C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL PROCESS, CORROSION PROTECTION PROVISIONS, NOE EXAM OF WELDS, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MATERIAL (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION, MANUFACTURING, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED JULY 1976/ CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIPMENT AND MATERIALS AND EQUIPMENT CONFORMANCE TO CONTRACT REQUIREMENTS. TURBINE/PERFECT FUNCTIONAL FLOW & LEAKAGE TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON COMMAND. (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
1. **Does the flight software detect this failure mode (i.e., automatically 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)? Not change to FMEA criticality.**
   - *0 ☑ 1 ☐ 2 ☑

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

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

**Explanation/Comments:**

1A. Tank isolation valve discreets are available.
SHUTTLE CRITICAL ITEMS LIST - CREITER 102

SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PROPELLANT FEED

P/N VENDOR: 575025/575026

QUANTITY: 12

PREPARED BY: R. GONZALEZ

APPROVED BY: L. SM

PREPARED WITH CHANGES

See Section 13

SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PROPELLANT FEED

P/N VENDOR: 575025/575026

QUANTITY: 12

THREE VALVES PER PROPタンK

PREPARED BY: R. GONZALEZ

APPROVED BY: L. SM

PREPARED WITH CHANGES

See Section 13

SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PROPELLANT FEED

P/N VENDOR: 575025/575026

QUANTITY: 12

THREE VALVES PER PROPタンK

PREPARED BY: R. GONZALEZ

APPROVED BY: L. SM

PREPARED WITH CHANGES

See Section 13
SUBSYSTEM : AFT - REACTION CONTROL FMEA NO 03-2A -202110-3 REV:12/12/78
VERIFIED BY SHOP TRAVELER MANDATORY INSPIR POINTS. THE ABOVE ITEMS AND
THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED JULY 1976/
CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE
ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT' L AND EQUIP
CONFORMANCE TO CONTRACT REGS. TURNAPOUND - FUNCTIONAL FLOW & LEAKAGE
TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON
COMMAND. (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
## HARDWARE/SOFTWARE ANALYSIS CHECKLIST

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

### ITEM: Interconnect Valve, A.C.

#### FAILURE MODE: Fails Closed

1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY) AND 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)?**
   - 0 ☑ 1 ☒ 2 ☒

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

8. **IF THE ANSWER TO EITHER 1 OR 3 IS YES: A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?**
   - YES ☑ NO ☒

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

**EXPLANATION REQUIRED (SEE BELOW)**

---

**CHANGE/RETENTION RATIONALE SUMMARY**

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

**EXPLANATION/COMMENTS:**

1. "Failed off" thruster gives first indication.

6. One success path remains after first failure.

88. Same as primary.
SHUTTLE CRITICAL ITEMS LIST - CRITERION 1D2

SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PROPELLANT FEED
P/N R1 : MC284-0430-J007-J003
P/N VENDOR : 5750025/5750026
QUANTITY : 8

**ITEM: VALVE**

FUNCTION:
- TO PROVIDE CONTROL OF INTERCONNECT LINE FOR VARIOUS WAYS OF PROPELLANT FEED: 1) OPEN FOR CMG TO RCS 2) OPEN FOR RCS TO CMG 3) CLOSED FOR RCS TO SAME SIDE RCS AND CMG TO CMG. TWO INTERCONNECT VALVES PER PROP TANK ARE USED. EACH GOES INDEPENDENTLY TO SEPARATE MANIFOLD BANKS. LINE PRESSURE RELIEF TOWARDS PROP TANK IS PROVIDED.
- FAILURE MODE: FAILS CLOSE IN CASE OF VALVE ACTUATION FAILURE OR LOSS OF COMMUNICATION, PREMATURE POWER TO MOTOR, ELECTRICAL SHORT TO RCS, MJ:N, OR LIMIT SWITCH JAMMING OF VALVE.
- CAUSE(S):
  - VIS: LIMIT SWITCH FAILURE, PREMATURE POWER TO MOTOR, ELECTRICAL SHORT TO RCS, MJ:N, OR LIMIT SWITCH JAMMING OF VALVE.
  - EFFECT(S):
    - (A) LOSS OF REDUNDANCY
    - (B) DEGRADATION OF INTERFACE FUNCTION - CROSS FEED PROPELLANT CAN BE UTILIZED BY ONLY 2 OF 4 MANIFOLD BANKS.
    - (C) MISSION MODIFICATION - OPERATION CHANGES ARE MADE AS PER SHEET.
    - (D) NO EFFECT ON CFT MISSIONS.

- MISSION CRITICALITY EFFECT - POSSIBLE EARLY MISSION TERMINATION - INABILITY TO DEMONSTRATE CMS PROP FEED TO RCS.

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

1. (A) AC MOTOR VALVE IS 3-PHASE - 2 OF 3 WINDINGS ARE ADEQUATE FOR VALVE FUNCTION.
2. (B) HYBRID RELAYS PROVIDE REDUNDANCY FOR THE PREMATURE CLOSE MODE.
3. (C) PARALLEL HYBRID RELAYS PROVIDE REDUNDANCY FOR ELECTRICAL BURN.
4. (D) ADDED WINDINGS PROVIDE REDUNDANCY FOR THE PREMATURE CLOSE MODE.
5. (E) 2500 OPERATION CYCLES (OPEN-CLOSE-OPEN) AND RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL.
6. (F) VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL PROCESSES, COORDINATION, PROTECTION, NDE EXAM OF WELDS, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MATERIAL CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUFACTURING, INSTALLATION, AND ASSEMBLY ARE VERIFIED BY SHOP TRAVELER MANDATORY POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED.

1022 77 SD75-SE-0003
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO. 03-2A-202111-2  REV: 12/12/78
JULY 1976/CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND
STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L
AND EQUIP CONFORMANCE TO CONTRACT REQMTS. TURNAROUND/FUNCTIONAL FLOW &
LEAKAGE TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY
UPON COMMAND. (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST

SUBSYSTEM: AFT - RCS
ITEM: Manifold Isolation Valve, A. C.
FMEA NUMBER: 03-2A-202120-3
FAILURE MODE: Fails Closed

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

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

3. RCS RM automatically detects and prevents thrusting.
OF POOR QUALITY.
ITEM: VALVE

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

FUNCTION:
1) TO ISOLATE THRUSTERS FROM PROPELLANTS PRIOR TO SYSTEM ACTIVATION AND
2) TO ISOLATE A FAILED OPEN THRUSTER OR DOWNSTREAM LEAK. EACH MANIFOLD ISOLATION VALVE CONTROLS 3 PRIMARY THRUSTERS. LINE PRESSURE RELIEF TOWARDS PROP TANK IS PROVIDED.

FAILURE MODE: FAILS CLOSED-PREMIATURE (F)
OPERATION FAILS TO REMAIN OPEN.

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

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) AC MOTOR VALVE IS 3-PHASE - 2 OF 3 WINDINGS ARE ADEQUATE FOR VALVE FUNCTION.
SERIES (HYBRID) RELAYS PROVIDE REDUNDANCY FOR THE PREMIATURE CLOSE MODE. PARALLEL (HYBRID) RELAYS PROVIDE REDUNDANCY FOR ELECTRICAL POWER SIGNAL. ADDITIONALLY, REDUNDANT VALVES ARE PROVIDED. A 400-MICRON FILTER IS UTILIZED ON THE INLET AND OUTLET TO LIMIT THE POTENTIAL FOR CONTAMINATION CAUSED FAILURE OR JAMMING OF MOVING PARTS. (B) 2500 OPERATION CYCLES (OPEN-CLOSE-OPEN) AND RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYSTEM EVALUATION TESTS AT KSP ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. PROOF PRESSURE, LEAKAGE, OPERATION, CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT. (C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NDE EXAM OF WELDS, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MATERIAL (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUFACTURING, INSTALLATION, AND ASSEMBLY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED JULY 1976/CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP CONFORMANCE.
SUBSYSTEM : AFT - REACTION CONTROL  FMBA NO. 03-2A-202120-3  REV: 12/12/78
TO CONTRACT REQMTS. TURNAROUND/FUNCTIONAL FLOW & LEAKAGE TESTS ARE MONITORED
TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON COMMAND. (D) NO PRIOR
FAILURE HISTORY FOR THIS TYPE DESIGN.
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**
   - YES ☐ NO ☐ X

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)*

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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
7. ☐ FMEA CHANGE RECOMMENDED

**EXPLANATION/COMMENTS:**

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

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

8. Same as primary.
IN THE EVENT: VEHICLE DECELERATES AND ENGAGES AUTOMATIC LANDING GEAR, VEH LAW/SLOW, COMPLETES LANDING, THEN TAKES OFF AUTOMATICALLY (FLAP UP).

COMMENTS:

1. IF VERIFICATION OF ISOLATION IS DILICATED 1) PRIOR TO SYSTEM ACTIVATION, AND 2) AT THE EVENT OF A VERIFICATION OF ISOLATION L/E.

FAILURE NO: FAILS CLOSER.

CASE (I):

IN CASE ELECTRICAL SIGNAL CONTINUES (SMART) IS LOSS OF ELECTRIC POWER TO LADING GEAR, VEH LAW/SLW, COMPLETES LANDING, THEN TAKES OFF AUTOMATICALLY (FLAP UP).

CASE (II):

(A) SUB-SYSTEM (B) SUB-PHASE (C) MISS. (D)分け (E) AUTOMATIC CONTROLLER (F)

1. AVOIDANCE OF INTER-EVENT, PAYLOAD MANIPULATION, (G) MISS. REPLICATION OF VEHICLE Solution (H) NO EFFECT UNLESS ADDITIONAL FAILURE SCHEDULE

COUNS TING ACTION:

UTILIZE SUB-STEP RGB VEHICLES AND ATTEMPT TO REGAIN VEHICLE MANDATORY USE OF VEHICLE LIGHT.

CONSIDER:

THEREFORE, FOR COLLISION WITH OR LOSES OF PAYLOAD/LATHELITE, DUE ATTEMPT WILL MINIMIZE INADVERATATION AT ANY CONSIDERATIONS.

CASE (III):

UTILE OF SEARED RGB VEHICLES. SAME URPRW AS EACH-MAN MANEUVERED AT VEHICLE REQUEST.
**SHUTTLE CRITICAL ITEMS LIST - ORBITER LOZ**

**SUBSYSTEM**: AFT - REACTION CONTROl

**ASSEMBLY**: PROPELLANT FEED

**P/N RI**: MC234-0422-0011/-0012

**P/N VENDOR**: 73895

**QUANTITY**: 4

**MISSIONS**: H, V, X, FF, JP, S4

**PHASE**: PL, LD, CC X DO LS

**PREPARED BY**: E. BURKHART

**APPROVED BY**: J. M. KERSHNER

**DES**: R. BURKHART

**REL**: C. M. AKERS

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

**ITEM**: VALVE

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

**FAILURE MODE**: FAILS CLOSED.

**CAUSE(S)**:

- IMPROPER ELECTRICAL SIGNAL (CONTINUOUS SHORT), OR LC + MAGNETIC FORCE FROM LATCHING MAGNET, MECH SNAP, VIB., CONTAM (AIR GAP).

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

- (A) LOSS OF FUNCTION (VERNIER THRUSTER).
- (B) OPERATION OF INTERFACE SUBSYSTEM-PAYLOAD MANIPULATION.
- (C) MISSION MODIFICATION OR ABDCT DECISION.
- (D) NO EFFECT UNLESS ADDITIONAL FAILURES OCCUR.

**DISPOSITION & RATIONALE**

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

- SERIES SWITCHES (RPC'S) MINIMIZE POTENTIAL FOR ANOTHER ACTUATION.
- PARALLEL SWITCHES (RPC'S) PROVIDE ELECT REDUNDANCY FOR THE OPENING SIS.

**AN INDUCT VOLTAGE SUPPRESS CIRCUIT IS PROV IN THE ELECTRICAL SYSTEM TO PREV DAMAGE TO OTHER ON-LINE CIRCUITS. REDUNDANT DIODES LIMIT THE POSS OF DIODE FAILURE ALLOWING CURRENT SHUNT FROM THE COIL.

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

**1018**

**SD75-SE-0003**
TESTS ARE INCLUDED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON COMMAND. (3) APOLLO FAILURES WERE MAINLY ASSOCIATED WITH REVERSE POLARITY AND DEGUASSING OF MAGNETS. THE SHUTTLE VALVE UTILIZES A CONNECTOR (RATHER THAN LEAD WIRES) AND A BLOCKING DIODE WHICH PREVENTS THIS TYPE OF ERROR DURING SYSTEM TESTS AND ANALYSIS SHOWED PRESSURE SURGE FATIGUE PROBLEM. THIS IS BEING RESOLVED BY REDUCING THE LIFE OF THE VALVE TO 50 MISSIONS.
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY)**
   - ANNUNCIATE OR TAKE ACTION IN RESPONSE? [YES ☒ NO ☐]

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)*

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**CHANGE/RETENTION RATIONALE SUMMARY**

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

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**EXPLANATION/COMMENTS:**

1. Gross leak detection will give first indication.

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

8B. Same as primary.

2. Measurements V42P2313C, 2315C, 2313C and 3315C are not listed in the MML.
ORIGINAL PAGE IS OF POOR QUALITY

PROPOSED BY:

APPROVED BY:

[Incomplete or unrecognizable text]

[Incomplete or unrecognizable text]
SHUTTLE CRITICAL ITEMS LIST - CRITERION 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT ABORT FUNCTION
P/N: 1MCZ760
P/N VENDOR: 7630000 & 76306000
QUANTITY: 12

ASSEMBLY: PROPELLANT ABORT FUNCTION
P/N: VEIlGQP: T301000
MISSIONS: V = FF X FF OF SH

QUANTITY: 12

PREPARED BY: 
APPROVED BY: 
APPROVED BY (NASA):

ITEM: DISCONNECT, FILL & BLEED PROPELLANT, SPRING LOADED POPPET WITH STRUCTURAL CAP (1/4" & 1/2"

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

FAILURE MODE: FAILS OPEN

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

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) F.S. IS 2.0 X WORKING PRESS. GROUND HALF COUPLINGS AND LINES ARE ADEQUATELY SUPPORTED TO LIMIT ANY UNDUE STRESS ON THE COUPLING DURING SERVICE AND PREV DAMAGE TO SEALS. A SAFETY FEATURE PRIOR TO REMOVAL OF THE END CAP IS A PROV HINDER ANY LEAKAGE PAST THE AIRBORNE POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING A BLEED SCREW. COMPLETE STRESS ANALYSIS HAS BEEN CONDUCTED. UTIL OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUNDANT SEAL EXCEPT FOR STRUCTURAL FAILURE.
(B) THE COUPLING IS SUBJECT TO 600 OPER CYCLES (COUPLING AND UNCOUPLING) DURING QUAL. IN ADDITION TO PRESS SURGE CYCLING AND PROP EXPOSURE TESTS. RAMP VIB TESTING IS ALSO CONDUCTED AT ANTIC VEH LEVELS FOR 34 MINUTES IN EACH AXIS. USAGE DURING SYS EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE COND. PROOF PRESS TESTS ARE CONDUCTED DURING AT & LEAKAGE TESTS ARE PERFORMED BEFORE & AFTER OPER CYCLES. (C) AN IDENT IFIES PERF. RAW MATERIALS EXAM, VISUAL INSPECTION FOR SURFACE DEFECTS, & EQUIP CONFORMANCE TO CONTRACT REQUIREMENTS ARE VERIF BY RECEIVING INSPECTION. MEASUREMENT STANDARDS & TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQUIREMENTS OF MIL SPEC. THE FOLLOWING ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPECTION POINTS-PARTS.
SUBSYSTEM: AFT - REACTION CONTROL

PROT, MFG. PROCESSES, COATING, ASSY AND INSTALLATION. THE ABOVE ITEMS
& THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77. COPROS
PROT PROV, CONTAM CONT PROCESSES, TEST HANDLING, & STORAGE ENVIR.
THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT OF MARCH 6, 1978. INSPECTION
VERIFIES ASSEMBLY PER INSPECTION POINTS IN MASTER RECORD. LOG OF CLEAN
ROOM AND CALIBRATION OF TOOLS VERIFIED. CRITICAL DIMENSION 100%
VERIFIED BY INSPECTION. PARTS CLEANLINESS AND PASSIVATION BY
INSPECTION. NOE INSPECTION PERFORMED AFTER ASSEMBLY.

TURNAROUND-COUPLINGS ARE VISUALLY INSPECTED FOR EVIDENCE OF DAMAGE SEALS & LEAK
TESTS ARE PERFORMED. (D) APOLLO FAILURE HISTORY WAS IN THE MAIN ASSOC
WITH GROUND USAGE, IMPROPER HANDLING.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

SUBSYSTEM AFT - RCS

ITEM Propellant Tank Assy.

FAILURE MODE External Leak

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.
   - 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 ☐

*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:


6. Pod redundancy.

8B. Backup flight system same as primary.
ITEM: TANK ASSY, PROPELLANT INCLUDING ACQUISITION DEVICE AND RETENTION SCREENS (1.5 FACTOR OF SAFETY) TK 203/204/303/304.

FUNCTION:
TC STORE/SUPPLY PROPELLANT FOR REACTION CONTROL THRUSTERS. TANK SHELL CONTAINS PROPPELLANT AND ACQUISITION DEVICE RETAINS PROPPELLANTS FOR ADEQUATE FEED DURING 1"G, 0"G AND HIGH "G" CONDITIONS. REGULATED HELIUM IS SUPPLIED TO THE ULLAGE TO FORCE PROPELLANT TO THE THRUSTERS AS REQ'D. 245 PSIA (+ OR -15) (17.95 CUBIC FEET).

FAILURE MODE: STRUCTURAL FAILURE (F): EXTERNAL LEAK, TANK WALL Crack OR SEAL FAILURE.

CAUSE(S):
MECH SHOCK, FATIGUE/VR, OVERPRESS. STRESS CONDS, [INPROPER PROP Purity OR TEST FLUID, OVER TEMP, PLUMES OR REGISTRY GASES, STRESS RISE?], WELD OR M'AL DEFECT, INCORRECT OR DAMAGED SEAL.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OR DEGRADATION OF SUB-SYSTEM DEPENDENT ON EXTENT OF FAILURE.
(B) LOSS OR DEGRADATION OF INTERFACE SUB-SYSTEM-AFT RCS, POD, TPS OR VEH DAMAGE.
(C) ABOIT DECISION.
(D) POSSIBLE LOSS OF CREW/VEHICLE (EXPLOSION, LACK OF PROPPELLANT OR INABILITY TO DEPLETE OPPOSITE PROPPELLANT).

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) THE F.S. (BURST) IS 1.5 X WORKING PRESSURE. COMPLETE STRESS ANALYSIS FOR EACH TANK SEGMENT WAS PERFORMED. TANK IS CLASSIFIED AS FRACTURE CRITICAL FOR HANDLING AND IS SUBJECT TO FRACTURE CONTROL REQMTS. ALL FITTINGS AND FLANGES USED ON THE TANK HAVE DUAL ELASTOMER SPRING LOADED SEALS. (B) QULAB REQUIRES 900 PRESSURE WITH (INCLUDING 200 EXPULSION CYCLES AND A 90 DAY CREEP AND PPCPPELLANT EXPOSURE TEST- PROOF PRESSURE (1.3X WORKING PRESSURE) AND LEAKAGE TESTS ARE PERFORMED DURING ATP- RADIOGRAPHIC AND DYE PENETRANT TESTS ARE PERFORMED TO VERIFY NO PERMANENT DEFORMATION OR FLAW GROWTH. WELDS ARE VISUALLY INSPECTED FOR EVIDENCE OF STRESS RISER OR OTHER FLAWS. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. RAW 'MAT'IL AND PURCHASED COMPONENT REQMTS ARE VERIFIED BY RECEIVING INSPECTION STANDARDS AND TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQMTS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS- PARTS PROTECTION, MFG. PROCESSES, FINISHES, ASSY AND INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY
SUBSYSTEM: AFT - REACTION CONTROL  FMEA NO 03-2A -211110-1  REV:11/03/75

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

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

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

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

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

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

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

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

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

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

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

**EXPLANATION REQUIRED (SEE BELOW)**

**CHANGE/RETENTION RATIONALE SUMMARY**

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

**EXPLANATION/COMMENTS:**

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

5. Crossfeed.

8b. Same as primary.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N: MC232-0061-0031-0002
P/N VENDOR: 855C331000-010-020
QUANTITY: 1

PREPARED BY:
prepared by

APPROVED BY:
approved by NASA

ITEM: TANK ASSY, PROPELLANT

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

FUNCTION:
TO STORE/SUPPLY PROPELLANT FOR REACTION CONTROL THRUSTERS. ACQUISITION DEVICE RETAINS PROPELLANTS FOR ADEQUATE FEED DURING 1"G", 0"G" AND HIGH "G" CONDITIONS. REGULATED HELIUM IS SUPPLIED TO THE ULLAGE TO FORCE PROPELLANT TO THE THRUSTERS AS REQ'D. 245 PSIA (+ OR -15) (17.95 CUBIC FEET).

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

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

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) SAFETY FACTORS OF 1.5 (MINIMUM) IN SCREEN WILL MINIMIZE FAILURE POTENTIAL. (B) QUAL REQUIRES 200 EXPULSION CYCLES A 90 DAY PROPELLANT EXPOSURE TEST. DEVELOPMENT CERTIFICATION TESTS DEMONSTRATE 100 MISSION FLOW TRANSIENTS (188,800 CYCLES) AND TWO YEAR PROPELLANT COMPATIBILITY. PROPELLANT ACQUISITION DEVICE AND WELD INTEGRITY VERIFIED VIA BUBBLE POINT TESTS AT THE COMPONENT, SUBASSEMBLY & TANK ASSY LEVEL. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. RAW MAT'L AND PURCHASED COMPONENT-REMTS ARE VERIFIED BY RECEIVING INSPE. MEASUREMENT STANDARDS & TEST-EQUIP STANDARDS ARE IMPLEMENTED PER REQMTS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS-PARTS PROTECTION, MFG. PROCESSES, FINISHES, ASSY AND THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 11-1-76. CORROSION PROTECTION PROVISIONS, TEST HANDLING, AND STORAGE ENVIRONMENTS. BOTH CERTIFIED WELDERS AND CERTIFIED INSPECTORS ARE USED FOR ALL WELDS. TURNAROUND - BUBBLE POINT TESTS ARE PERIODICALLY PERFORMED IN THE SYSTEM AS PART OF CHECKOUT PROCEDURE PRIOR TO FLIGHT. PRESSURE CYCLES ACCUMULATED ARE ALSO RECORDED. (D) NO IN-FLIGHT FAILURE EXPERIENCE FOR THIS DESIGN.
SUBSYSTEM AFT - RCS
ITEM Gimbal Joint

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>YES</th>
<th>NO</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does the flight software detect this failure mode (i.e., automatically announce or take action in response)?</td>
<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>YES</td>
<td>NO</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>
<td></td>
<td></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></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>
<td></td>
</tr>
<tr>
<td>4. As a result of this failure mode, can the software over-stress 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>X</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>N/A</td>
<td>YES</td>
<td>NO</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>YES</td>
<td>X</td>
<td>NO</td>
</tr>
<tr>
<td>B. Will BFS tolerate failure without loss of crew/vehicle?</td>
<td>YES</td>
<td>X</td>
<td>NO</td>
</tr>
</tbody>
</table>

**EXPLANATION REQUIRED:**

2. Fuel tank outlet pressure measurements V42P2310, 3310 were omitted from the FMEA and need to be added.
3A. Low pressure transducer signals could be used by software to isolate the system automatically if desired.
6. There is one success path remaining after first failure. Cross-feed.
8B. Same as primary.

**EXPLANATION/COMMENTS:**

- In-flight detectability
  - X FMEA change recommended

**CHANGE/RETENTION RATIONALE SUMMARY**

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

**EXPLANATION/COMMENTS:**

2. Fuel tank outlet pressure measurements V42P2310, 3310 were omitted from the FMEA and need to be added.
3A. Low pressure transducer signals could be used by software to isolate the system automatically if desired.
6. There is one success path remaining after first failure. Cross-feed.
8B. Same as primary.
GENERAL SOLUTION

1. VISUAL CHECK:
   a. System:
   b. Components:
   c. Lines:

2. STRUCTURAL FAILURE:
   a. Visual Inspection:
   b. Pressure Test:
   c. Leak Detection:
   d. Diagnostics:

3. POSSIBLE CAUSE:
   a. Propellant:
   b. Vehicle:
   c. System:
   d. Environmental:

4. CORRECTIVE ACTION:
   a. Removal:
   b. Repair:
   c. Replacement:

5. PREVENTION:
   a. Training:
   b. Maintenance:
   c. Inspection:

6. DOCUMENTATION:
   a. Records:
   b. Reports:
   c. Forms:

7. RENEWAL:
   a. Quality Control:
   b. Compliance:
   c. Certification:
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPellant FEED
P/N: 73F550015-1016102 (MDAC)
P/N VENDOR: 1003099-1016102 (SSP)
MISSIONS: HF VF XF OF GM SM
PHASE(S): PL LX D0 X LS X
QUANTITY: 12

PREPARED BY: N. GLAVINICH
APPROVED: C. MAKERS

ITEM: CONNECTOR
FLEXIBLE, GIMBAL JOINT.

FUNCTION:
An externally constrained bellows (universal socket joint ass'Y) is provided for the propellant tank outlet lines to allow movement during pressure surges. Connecting tubes are welded to the bellows and to the prop lines.

FAILURE MODE: STRUCTURAL FAILURE
EXTERNAL LEAKAGE

CAUSE(S):
Fatigue, shock, handling induced weld penet., incmp. fusion, porosity, corros resulting in pin hole leak thru convolute, prop & si-prop exposure press surge, flow induced yib-pgc effect, flt vib

EFFECT(S):
(A) SUBSYSTEM DEGRADATION - LOSS OF PROPellant. (B) DEGRADATION OR INTERFACE FUNCTION - POSS CORROS DAMAGE WITHIN POD AND ADVERSE EFFECT ON TPS (MOLECULAR VENTING). (C) LAUNCH DELAY CP ABORT DECISION. (D) POSSIBLE LOSS OF CREW/VEHICLE - IF BELLows JCT RPTURES RESULTING IN INABILITY TO UTILIZE/DEPLETE PROP OR PROP REACTS WITH FUEL OR OX
CAUSING FIRE OR EXPLOSION

DISPOSITION & RATIONALE
(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY
(M) MULTIPLE BELLows ARE UTILIZED. FLOW INDUCED VIBRATION ANALYSIS AND STRESS ANALYSIS ARE CONDUCTED TO VERIFY ACCEPTABLE DESIGN. THE EXTERNAL CONSTRAINT (UNIVERSAL SOCKET JOINT ASS'Y) WOULD TEND TO LIMIT ANY gross PROPellant LEAK IN EVENT OF BELLows FAILURE.
ITEM IS USED DURING SYSTEM EVALUATION TESTS AT WSTF ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. (C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, MDE EXAM OF WELDS, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUFACTURING, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 8-29-77. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L CONFORMANCE TO CONTRACT REQMTS. TURNAROUND - MONITOR LEAKAGE TESTS PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND AS PART OF CHECKOUT:
SUBSYSTEM: AFT - REACTION CONTROL

FMEA NO 03-2A -211120-1  REV:11/08/78

- PROCEDURE PRIOR TO FLIGHT. (D) NO FAILURE HISTORY AVAILABLE ALTHOUGH THE
APOLLO PROGRAM DID SHOW SOME PROBLEMS ON FLEX HOSE ASSY DUE TO PIN HOLE
CORROSION ASSOC. WITH RESIDUAL SOLVENTS AND PROPELLANT.
| 1. | DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)? | YES | NO |
| 1a. | IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE? | YES | NO |
| 2. | ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY? | YES | NO |
| 3. | DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)? | YES | NO |
| 3a. | IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)? | YES | NO |
| 4. | AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE? | *YES | NO |
| 5. | CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS? | *YES | NO |
| 6. | HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? | *0 | 1 | 2 |
| 7. | IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION? | N/A | YES | NO |
| 8. | IF THE ANSWER TO EITHER 1 OR 3 IS YES: | | |
| | A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE? | YES | *NO |
| | B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE? | YES | *NO |

**EXPLANATION/COMMENTS:**

18CFL-10-16

CONCURRANCE SIGNATURES:

PREPARED AS:

Doe W. Grabacker

REL C. W. Adams

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

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: THRUSTER/PROPELLANT FEED ABORT:
P/N RI: MC621-0099 MISSIIONS: HH VF FF OF SM
P/N VENDOR: 73P500C3-1001THRU1005
QUANTITY: 56

FUNCTION:

FAILURE MODE: STRUCTURAL FAILURE (S)
CAUSE(S):

 EFFECT(S):

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

ITEM: BELLows ASSEMBLY

ENGINE ALIGNMENT.

FATIGUE, SHOCK, HANDLING, ENE WELD, PENET, INCOMP. FUSION
CORROS-PROP & BI-PROP EXPOSURE, PRESS, SURGE, FLOW INDUCED VIB-PODQ EFFECT, FLT VIB.

(A) MULTIPLE BELLows ARE UTILIZED. FLOW INDUCED VIBRATION ANALYSIS AND STRESS ANALYSIS WERE CONDUCTED TO VERIFY ACCEPTABLE DESIGN. THE EXTERNAL CONSTRAINT WOULD TEND TO LIMIT ANY GROSS PROPELLANT LEAK IN EVENT OF BELLows FAILURE. PROPELLANT LEAK FROM LINE TO THRUSTER COULD BE ISOLATED BY MANIFOLD VALVE. (B) ITEM IS USED DURING SYSTEM EVALUATION TESTS AT WSTF ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. (C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NO EXAM OF WELDS, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS, RAW MATERIAL (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUFACTURING, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 8-29-77. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'1 CONFORMANCE TO CONTRACT REQS. TURNAROUND - MONITOR LEAKAGE TESTS PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND AS PART OF CHECKOUT PROCEDURE PRIOR TO FLIGHT. (D) NO FAILURE HISTORY AVAILABLE ALTHOUGH THE APOLLO PROGRAM DID SHOW SOME PROBLEMS ON FLEX HOSK ASSY DUE TO PIN HOLE CORROSION ASSO. WITH RESIDUAL SOLVENTS AND PROPELLANT.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST

**SUBSYSTEM** AFT - RCS  
**ITEM** Engine Inlet Valve  
**FMEA NUMBER** 03-2A-221310-4  
**FAILURE MODE** Fails Closed

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>*</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Does the Flight Software detect this failure mode (i.e., automatically announce or take action in response)?</strong></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>X</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 detectability?</strong></td>
<td>X</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 alternate program logic)?</strong></td>
<td>X</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 alternate program logic)?</strong></td>
<td>X</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>X</td>
</tr>
<tr>
<td>5. <strong>Can this failure mode, in combination with Software logic, adversely affect other functions?</strong></td>
<td>X</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>6. <strong>How many of these Hardware failures can the Shuttle tolerate (consider crew action and Hardware/Software operation)? Note change to FMEA criticality.</strong></td>
<td>*0</td>
<td>*1</td>
<td>2X</td>
<td></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>YES</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
| 8. **If the answer to either 1 or 3 is YES:**  
A. **Can the BFS be engaged after occurrence?** | X   |    |   | * |
| B. **Will BFS tolerate failure without loss of crew/vehicle?** | X   |    |   | * |

*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

106
SUBSYSTEM  AFT - RCS  
ITEM  Injection Plate  
FMEA NUMBER  03-2A-221311-1  
FAILRE MODE  Restricted Flow  

### HARDWARE/SOFTWARE ANALYSIS CHECKLIST  

<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 □ 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 □ *NO X</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 □ NO</td>
</tr>
<tr>
<td>4. As a result of this failure mode, can the software over-stress the hardware or induce another failure?</td>
<td>*YES □ NO X</td>
</tr>
<tr>
<td>5. Can this failure mode, in combination with software logic, adversely affect other functions?</td>
<td>*YES □ NO X</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 □ *1 □ 2X</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>
</tbody>
</table>
| 8. If the answer to either 1 or 3 is YES:  
A. Can the BFS be engaged after occurrence?  
B. Will BFS tolerate failure without loss of crew/vehicle? | YES X □ *NO |
| *Explanation required (see below) | YES X □ *NO |

#### 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

---

**Explanations/Comments:**

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

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: THRUSTER, PRIMARY
P/N RL: MC647-002B
P/N VENDOR: X30938
QUANTITY: 24

ITEM: INJECTOR PLATE

FUNCTION:
Provides injection & vaporization of fuel and oxidizer for thruster.

FAILURE MODE:
Fails out of tolerance (F) at restricted flow.

CAUSE(S):
Contamination, products of combustion blocking orifices, freezing of propellants.

EFFECT(S):
(A) Subsystem (B) Interfaces (C) Mission (D) Crew/vehicle:
(A) Loss of redundancy or functional degradation - reduced propellant flow, chamber press & thrust, imaged chamber/injector film cooling.
(B) Degradation of interface function - incorrect GN&C & use of ALT thrusters.
(C) No effect.
(D) No effect.
(E) Functional criticality effect - abort decision - degraded performance of redundant thrusters would require mission abort.

DISPOSITION & RATIONALE:
(A) Design (B) Test (C) Inspection (D) Failure History:
74 micron nominal filters are provided to control contamination from system and subsequent hazards. Automatic switch-over (and isolation) by GN&C failure detection systems. Complete thermal and stress analysis have been completed.
(6) RCS SYS EVAL TEST AT WSTF. THRUSTER QUAL FOR 50,000 CYCLES. SPRAY PATTERN CHECKED DURING ATP. (C) A VISUAL INSPECTION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NO EXAM OF WELDS, RAW MATERIAL CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUFACTURING, INSTALLATION, AND ASSEMBLY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 7-2-76.
Contamination control plan, properly monitored handling and storage environment, special measurement standards and equip. and materials, and equip. conformance to contract reigs. Turnaround inspection to include use of optics where accessible to determine evidence of plugged orifice. Fluid sampling to be performed to detect contamination. (D) No direct failure history available.

PREPARED BY: DES
APPROVED BY: NASA

DELETE

ITEM: INJECTOR PLATE

See Section 13.0
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY
   ANNUNCIATE OR TAKE ACTION IN RESPONSE)?.
   YES [ ] NO [X] *

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

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

EXPLANATION/COMMENTS:

1. "Failed off" thruster C&W.
Sr

hält - PAUSE AND EFFECTS ANALYSIS - (continued)

FILE NUMBER - C2-622 - (document number)

INITIAL REVIEW - PRIMARY

ASSIGN: LH & RH

REPLACEMENT - PRIMARY (multiple)

SOLUTIONS: PRP & PTP

APPROVED BY:

TESTER

START TEST: 7/12/62

END TEST: 7/15/62

TEST CONDITIONS:

Thermocouple readings:

- 7/16/62

VISUAL INSPECTION

PREPARED BY:

DSC

APPROVED BY:

DSC

Figure 5:

TEST 5:

1. INJECTION INTO NOZZLE EXTENSION (CONTROL COLUMN).

PROCEDURE:

- Lasers may be used to divide the propellant and initiate the burn.

- Nozzle through nozzle extension to provide injection.

- Throat is controlled via control cylinders with 7.5% A mixture.

- Injection timing and utilization film cooling. The laser is activated.

- Throat to produce a thrust of 55.2 LBS utilizing a single study site.

- Specific impulse of 760 seconds.

Figure 6:

STRUCTURAL FAILURE (2)

- Using injection to fatigue in chapter.

Figure 7:

THERMAL CYCLING/STRESS FATIGUE, VIRT. COMB INSTAB, (SUGG. PROCEDURE TO MODIFY WITH TEMPERATURE LOCALIZED AT SPOTS/FRAGILE LOCATIONS). 

PROCEDURE:

- (a) SUBSYSTEM (L) INTERFACE COMMISSION (L) COMMISSION:
- (b) LOCAL BURN-IN/POST THRUSTING IT SELF TEST VALUE
- (c) DECOMMISSION OF INTERFACE FUNCTIONALLY (L) LOCALIZATION / LOCALIZATION OF INTERFACE LOCALIZATION
- (d) DECISION OF INTERFACE LOCALIZATION (L) LOCALIZATION OF INTERFACE LOCALIZATION
- (e) DECISION OF INTERFACE LOCALIZATION (L) LOCALIZATION OF INTERFACE LOCALIZATION
- (f) POSSIBLE LOSS OF CIRCULATORY SYSTEM

- PREVENTIVE MANY CAUSE HIGH TEMP DAMAGE TO SURROUNDING STRUCTURE & ALLOY INSTRUMENTS RESULTING IN POSSIBLE RAZ OR IF LES IS DAMAGED.

COMPLIANCE ACTION:

- SERVICE PROPELLANT FROM THRUSTOR (AT MANIFOLD LEVEL) AND ASSESS FOR LOCALIZATION AND DAMAGE TO SURROUNDING STRUCTURE

REFERENCES:

- NO RAZ IF VACUUM OR DEFECTED PRIOR TO LENS (BLIND). ALSO GIL
- FOR RAIL (ALG) IN DAMAGE. THERE IS NO AUTO THRUSTOR LEVEL AFTER GIL/INITIATION (LARGE FILLING). PUT IMPLANT OF RAIL GAGES OR MANIFOLD STAND OFF THRUSTORS. SURF-THRU MAY CAUSE HIGH TEMP DAMAGE TO SURF
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : THRUSTER, PRIMARY
P/N RI : MC467-0028
P/N VEND: X30958
QUANTITY : 24

PREPARED BY: DES
APPROVED BY: DES
REL

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

FUNCTION:
TO CONTAIN HYPERGOLIC REACTION OF PROPELLANTS AND DIRECT COMBUSTION PRODUCTS THROUGH NOZZLE & EXTENSION TO PROVIDE IMPULSE TC VEHICLE. THE CHAMBER IS CONSTRUCTED OF C-103 COLUMBIUM WITH P-512 A CUIALATION RESISTANT COATING AND UTILIZES FILM COOLING. THE CHAMBER PRESS IS 152 PSI & IS DESIGNED TO PRODUCE A THRUST OF 870.8 LBS VACUUM AT A MAXINAL STEADY STATE SPECIFIC IMPULSE OF 280 SECONDS.

FAILURE MODE: STRUCTURAL FAILURE (5)
BURN THRU OR RUPTURE IN CHAMBER.

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

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

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

APPROVED WITH CHANGES

See Section 13.0
SUBSYSTEM AFT - RCS

ITEM Nozzle Extension

FAILURE MODE Burn-Thru

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

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

☐ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

116
**SCOT: FAILURE NO. AND EFFECTS ANALYSIS - TRGT.**

**PREPARED BY:**

G. S. NEAL
L. P. STEPHENSON

**APPROVED BY:**

G. S. NEAL
L. P. STEPHENSON

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**Type of Failure:**

- Structural Failure

**Reason:**

- Temperature in Local Hot Cell, Equipment Impact

**Corrective Action:**

- Close the cluster and assess for leakage and damage to surrounding structure.

**Remarks:**

- May cause high temp damage to structure and cause structural failure in pump entry area if the pump is damaged.

---

**PREPARED BY:**

- G. S. Nealy
- L. P. Stephen

**APPROVED BY:**

- G. S. Nealy
- L. P. Stephen

---

**Type of Failure:**

- Structural Failure

**Reason:**

- Temperature in Local Hot Cell, Equipment Impact

**Corrective Action:**

- Close the cluster and assess for leakage and damage to surrounding structure.

**Remarks:**

- May cause high temp damage to structure and cause structural failure in pump entry area if the pump is damaged.

---

**PREPARED BY:**

- G. S. Nealy
- L. P. Stephen

**APPROVED BY:**

- G. S. Nealy
- L. P. Stephen

---

**Type of Failure:**

- Structural Failure

**Reason:**

- Temperature in Local Hot Cell, Equipment Impact

**Corrective Action:**

- Close the cluster and assess for leakage and damage to surrounding structure.

**Remarks:**

- May cause high temp damage to structure and cause structural failure in pump entry area if the pump is damaged.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: THRUSTER, PRIMARY
P/N: X30872
P/N VENDOR: X30872
QUANTITY: 24

FUNCTION:
TO PROVIDE ISENTROPIC EXPANSION OF COMBUSTION GASES FOR MAX EFF IN VACUUM. NOZ EXT IS CONSTRUCTED OF C-103 COLUMBIUM WITH R-512A OXIDATION RESISTANT COATING. THE NOZZLE EXPANSION RATIO IS 22 TO 1. THE AGZ EXT IS INTEGRAL WITH THE COMB CHAM AND ENCLOSED IN A DYNA FLEX INSUL SHROUD SO THAT THE EXT TEMP IS MAINTAINED PER THE PROCUREMENT SPECIFICATION REQMT.

FAILURE MODE: STRUCTURAL FAILURE, (S)
BURN-THRU.

CAUSE(S):
HIGH TEMPERATURE IN LOCAL SPOT CONTAMINATED INJECTOR COOLANT HOLES WELD OR MAT'L DEFECT.

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

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

TURNOVER. INSPECTION TO INCLUDE USE OF OPTICS WHERE ACCESSIBLE TO DETERMINE EVIDENCE OF BURN-THRU. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
<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 announce or take action in response)?</td>
<td>☑️</td>
<td></td>
</tr>
<tr>
<td>1a. If not, does the hardware provide information that the flight software could use to detect the failure?</td>
<td>☑️</td>
<td></td>
</tr>
<tr>
<td>2. Are the answers to questions 1 and 1a consistent with the FMEA evaluation of in-flight detectability?</td>
<td>☑️</td>
<td></td>
</tr>
<tr>
<td>3. Does the flight software take action to negate the effects of the failure (either by commanding hardware action or implementing alternate program logic)?</td>
<td>☑️</td>
<td></td>
</tr>
<tr>
<td>3a. If not, does the capability exist for the software to compensate for this failure mode (either by commanding hardware action or implementing alternate program logic)?</td>
<td>☑️</td>
<td></td>
</tr>
<tr>
<td>4. As a result of this failure mode, can the software overstress the hardware or induce another failure?</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>
</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>
</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>
</tr>
<tr>
<td>8. If the answer to either 1 or 3 is yes:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Can the BFS be engaged after occurrence?</td>
<td>☑️</td>
<td></td>
</tr>
<tr>
<td>B. Will BFS tolerate failure without loss of crew/vehicle?</td>
<td>☑️</td>
<td></td>
</tr>
</tbody>
</table>

**EXPLANATION/COMMENTS:**

3. Down modes to free drift.

6. No redundancy in the verniers.
DECEL. FAILURE ONE AND EJECTS ANALYSIS - Sheet 30

14. CRASH - ATTITUDE CONTROL
   14.1 LATERAL TRANSFER

15. EXCESSIVE

16. LIMIT

17. FLIGHT PATH

18. EFFECT

PREPARED BY: LEE J. MANGARD
APPROVED BY: LES G. MILLER

FUNCTION:
THE PITCH AXIS-UP THRUSTS ARE NOT OPERATIONAL IN THIS VEHICLE. THE TH AND ATTITUDES WAS PROVIDED IN EACH ARC'S NEEDLE TO PROHIBIT POSSIBLE LIVE VOLTAGE ON THE ATTITUDE WAS PROVIDED FOR PAYLOAD CONTROL IF VHF CABLE PRIORISIMILAR TO THE PRIMARY THRUSTERS BUT LIMIT FLEX.

ERRORS:
15. LOSS OF ATTITUDE
15.1 LOSS OF COMUTATION (a)
15.2 LOSS OF VOLTAGE IN THE CONTROL CABLE AND CONNECTION BETWEEN POWER SUPPLIES. [3]
15.3 LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [4]
15.4 LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [5]
15.5 LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [6]

EFFECT:
(a) LOSS OF COMUTATION IS CAUSED LOSS OF CONTROL (b) LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [3]
(b) LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [4]
(c) LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [5]
(d) LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [6]
(e) LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [7]

ERRATIC ACTION:
15.1 LOSS OF ATTITUDE CONTROL IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [3]
15.2 loss OF COMUTATION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [4]
15.3 LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [5]
15.4 LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [6]
15.5 LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [7]
15.6 LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [8]
15.7 LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [9]
15.8 LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [10]
15.9 LOSS OF FUNCTION IN THE PRIMARY THRUSTERS AND CONSUMER BATTERIES. [11]
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: VERNIER THRUSTER
P/N: 5C4-67-0029
P/N VENDOR:
MISSIONS: HF, VP, X FF, DF, SM
PHASE(S): PL, LO, CO, X, OO, LS

PREPARED BY: PP-CVE
APPROVED BY: PP-PR-4

ITEM: THUSTER, ASSY, VERNIER
25 POUND THRUST LEVEL: EN 357/358/257/258

FUNCTION:

One pitch (2 axis-up firing) and one yaw (plus/minus y axis) VERNIER THRUSTER ARE PROVIDED IN EACH ARCS MODULE TO PROVIDE PRECISE LOW LEVEL PULSING AND ATTITUDE HOLD REQD FOR PAYLOAD POINTING. THEY ARE CONCEPTUALLY SIMILAR TO THE PRIMARY THRUSTER BUT LITTLE PLUME IMPINGEMENT AND PROP RESIDUE CONTAM TO THE PAYLOAD.

FAILURE MODE: LOSS OF OUTPUT (THRUST) (F)
INLET VALVES CLOSED OR INJ ORIFICE PLUGGED

CAUSE(S):
OPEN SOL COIL, AUTO SHUT-CW, INLET VLV LEAK/STRUCT FAIL, INJ CONTAM/RESIDUE OR FROZEN PROP BLOCKING ORIFICE, COMB CHAM/NGI STRUCT FAIL

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE: (A) LOSS OF FUNCTION (VERNIER THRUSERS)—CURRENTLY LOSS OF SINGLE VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL. (B) NO EFFECT. (C) MISSION MODIFICATION OR ABORT DECISION (POTENTIAL INABILTY TO RETRIEVE PAYLOAD). — IT IS POSSIBLE PAYLOAD COULD BE RETRIEVED WHILE IN FREE DRIFT MODE AND IN SOME INSTANCES PAYLOAD MAY HAVE ATTITUDE & TRANSLATION CONTROL. IT MAY BE POSSIBLE TO USE FWD & AFT PCS (X AXIS) ENGINES FOR PITCH (DOWNWARD) MOTION. (D) NO EFFECT.

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

APPROVED WITH CHANGES
See Section 13.0
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNOUNCE OR TAKE ACTION IN RESPONSE)?**
   - **YES** ☑  **NO** ☐

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

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

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

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

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

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

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

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

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

   *EXPLANATION REQUIRED (SEE BELOW)*

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**EXPLANATION/COMMENTS:**

1. "Failed on" thruster C&W.
2. No redundancy in the verniers.
ORIGIN OF POOR QUALITY...
SUBSYSTEM: AFT - REACTION CONTROL   PMEA NC 03-2A -231310-2   REV:11/03/79
ASSEMBLY: VERNIER THRUSTER   ABORT: CP IT. FUNC: 2
P/N RI: MC467-0029   CRIT. HOW: 2
P/N VENDOR: MISSIONS: HF  VF  X  FF  DF  SM
QUANTITY: 4   PHASE(S): PL  LJ  CO  X  DO  LS

SUBSYSTEM: AFT - REACTION CONTROL   PMEA NC 03-2A -231310-2   REV:11/03/79
ASSEMBLY: VERNIER THRUSTER   ABORT: CP IT. FUNC: 2
P/N RI: MC467-0029   CRIT. HOW: 2
P/N VENDOR: MISSIONS: HF  VF  X  FF  DF  SM
QUANTITY: 4   PHASE(S): PL  LJ  CO  X  DO  LS

PREPARED BY: J TAGGART   APPROVED BY: SSM
REL: CM AKERS   REL 102-75-5H-0003

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

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

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

CAUSE(S):
CONTAMINATION, STRUCTURAL FAULT, DUAL SHORT IN DRIVER CIRCUIT TO PRIMARY VERNIER THRUSTER CONTROL nonafe, SHOCK SEAL SEAT DAMAGED, PROP RESIDUE, FLUSH SALT, CORROS, WEAR.

EFFECT(S) ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF FUNCTION (VERNIER THRUSTERS) - CURRENTLY LOSS OF SINGLE VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL. (B) DEGRADATION OF INTERFACE SUB-SYSTEM - PROP LOSS DUE TO EXCESS BURN-TIME UNTIL MANIFOLD CAN BE ISOLATED POSS DAMAGE TO PAYLOAD OR PAYLOAD BAY ARMS. (C) MISSION MODIFICATION OR ABORT DECISION. (D) NO EFFECT.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) ISOLATION CAPABILITY IS AN AUTOMATIC FUNCTION WHICH WILL MINIMIZE FAILURE EFFECT. POSS REDUND MDES OF OPER.ATION. (B) PRIMARY THRUSTERS, FREE DRIFT MODE & PAYLOAD ATTITUDE CONTROL MAY PROVIDE ADDITIONAL CON IROL POTENTIAL. 100 MICRON FILTRATION PROVIDED. inadvertent FIRE SIGNAL IS IMPOSSIBLE DUE TO GPC/MOM DESIGN. (B) THRUSTER QUAL FOR 500,000 CYCLES, 125,000 SEC BURN TIME, INLET VALVE TESTED FOR 500,000 WET CYCLES & 5000 DRY. (C) A VISUAL INSPECTION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS, PROTECTION PROVISIONS, NDE EXAM OF WELDS, RAW MAT' L (LST) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-76. CONTAMINATION CONTROL PLAN, PROPERLY HANDLED AND MONITOR THE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT' L AND EQUIP CONFORMANCE TO CONTRACT REQUIREMENTS. TURNOAROUND - SYSTEM FLUIDS ARE ANALYSED FOR EVIDENCE OF CONTAMINATION. PROPER INLET VALVE FUNCTION AND ELECTRICAL LOGIC POWER IS VERIFIED. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
1. **Does the flight software detect this failure mode** (i.e., automatically announce or take action in response)?
   - **Yes** [X] **No**

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

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

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

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

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

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

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

7. **If crew action is required to respond to this failure mode, are cues provided to signal the need for intervention and the required corrective action?**
   - **N/A** [ ] **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. "Failed off" thruster C&W.
2. Down modes to free drift.
3. No redundancy in the verniers.
SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - CRITERION 102

SUBSYSTEM: AFT - REACTION CONTROL  
ASSEMBLY: VERNIER THRUSTER  
P/N: MC467-0629  
P/N VENDOR:  
QUANTITY: 4  
2 PER POD  
:1 PITCH, 1 YAW  
NUMBER OF SUCCESS PATHS REMAINING  
2  
RECONCILABILITY SCREEN: A-N/A  
B-N/A  
C-N/A  
FUNO: CRIT. FUNC: 1  
CRIT. HND: 1  
MISSIONS: HF Vf Hf OF SM  
PRESSURE ON EACH ENGINE: V42P-2534 THRU V42P-3521 THRU V42P-3534  
REFERENCE DOCUMENTS:  
MC 621-C59  
GMUND  
TURNAROUND? .............YES  
VISUAL INSPECTION  
PREPARED BY: DES  
J. TAGGART  
REL  
C M AKERS  
APPROVED BY: DES  
REL  

ITEM: THRUSTER, ASSY, VERNIER  
25 POUND THRUST LEVEL. EN 357/358/257/258.  
FUNCTION:  
ONE PITCH (2 AXIS-UP FIRING) AND YAW (PLUS/MINUS Y AXIS) VERNIER THRUSTER ARE PROVIDED IN EACH ARCS MODULE TO PROVIDE PRECISE LOW LEVEL PULSING AND ATTITUDE HOLD REQ'D FOR PAYLOAD POINTING. THEY ARE CONCEPTUALLY SIMILAR TO THE PRIMARY THRUSTERS BUT LIMIT FLAME IMPINGEMENT AND PROP RESIDUE CONTAM TO THE PAYLOAD.  
FAILURE MODE: STRUCTURAL FAILURE (S)  
BURN THRU OR RUPTURE IN CHAMBER.  
CAUSE(S):  
THERMAL CYCLING/STRESS FATIGUE, VIB, COMP INSTAB, SHOCK, BLOCKED INJ ORIFICES; HIGH TEMP/LCLIZED HOT SPOTS/INADEQ COOLING NOZZLE RESTRICTION.  
EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:  
(A) LOSS OF FUNCTION-CURRENTLY LOSS OF SINGLE VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL. (B) DEGRADATION OF INTERFACE FUNCTION-INCREDI. GNEC & USE OF ALT THRUSTERS (C) MISSION MODIFICATION/ABORT DECISION IF FAILURE CAUSES DAMAGE PROPAGATION. (D) POSSIBLE LOSS OF CREW/VEHICLE-BURN-THRU MAY CAUSE HIGH TEMP DAMAGE TO SURF STRUCT & ADJ THRUSTERS RESULTING IN POSS ENTRY HAZ IF TPS IS DAMAGED.  
CORRECTING ACTION:  
ISOLATE PROPELLANTS FROM THRUSTER (AT MANIFOLD LEVEL) AND ASSESS FOR LEAKAGE AND DAMAGE TO SURROUNDING STRUCTURE.  
REMARKS/HAZARDS:  
THERE IS NO AUTO THRUSTER ISOL AFTER BURN INITIATION (DURING FIRING).  
BURN-THRU MAY CAUSE HIGH TEMP DAM TO SURF STRUCT & ADJ THRUSTERS RESULTING IN POSS ENTRY HAZ IF TPS IS DAMAGED.
ITEM: THRUSTER, ASSY, VERNIER
25 POUND THRUST LEVEL. EN 357/358/257/258.

FAILURE MODE: STRUCTURAL FAILURE
BURNT THRU OR RUPTURE IN CHAMBER.

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

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) STRUCTURAL MARGINS (2.0 TO 4.0) MINIMIZE FAILURE EFFECT(S). POSS REDUND MDES IN X AXIS PRIMARY THRUSTER, PAYLOAD ATTITUDE CONTROL & FREE DRIFT MDES. 100 MICRON FILTRATION & HEATERS PROVIDED TO LIMIT CONT & PREVENT PROP FREEZING. (B) THRUSTER QUAL FOR 500,000 CYCLES. 125,000 SEC BURN TIME, INLET VALVE TESTED FOR 500,000 WET CYCLES & 5000 DRY. (C) A VISUAL INSPECTION IS PERFORMED AND THE UNIT TAGGED.

CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NDE EXAM OF WELDS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER, MANDATORY INSPECTION POINTS.
THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-76. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'LL AND EQUIP CONFORMANCE TO CONTRACT REQS. TURNOAROUND - VISUAL INSPECTION USING OPTICAL INSTRUMENTATION. SYSTEM FLUIDS ARE ANALYSED FOR EVIDENCE OF CONTAMINATION. PROPER INLET VALVE FUNCTION AND ELECTRICAL LOGIC POWER IS VERIFIED. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
MEETING MINUTES


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

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

3. The following changes were discussed and will be incorporated in the final release of AFT Reaction Control System Hardware/Software Interaction Analysis and will be reflected in the next update of AFT RCS FMEA.
   - 03-2A-201010-1: Change SM to RM GAX, change 400 psi to 500. Add gross leak detection. Add crossfeed.
   - 03-2A-201013-1: No. 1 same as 201010-1. Add crossfeed. Add gross leak detection.
   - 03-2A0201020-1: Change question 1 to ullage transducer will give C&W alert < 200 psi. Change no to yes.
   - 03-2A-201030-2: Question 1 same as 201020-1
   - 03-2A-201035-1: Question 1 same as 201020-1. Add gross leak detection.
   - 03-2A-201060-4: Change question 1 no to yes and "No Software" Detection" to "Hardware Accepts Risk". Add gross leak detection.
   - 03-2A-201070-1: Change question 1 and 2 to gross leak detection. Add POD Redundancy to question 6.
   - 03-2A-201080-1: Change question 1 to gross leak detection. Change question 6 from 2 to 0 and add "Need minimum of 2 yaw thrusters. Crossfeed is available. Pods are redundant.
   - 03-2A-201090-1: Change question 1 to gross leak detection. Add question 6 - Pod redundancy.
   - 03-2A-201095-2: Change question 6 from 1 to 2 and delete comments.
   - 03-2A-202108-1: Change question 1 to gross leak detection. Delete question 7.
   - 03-2A-202109-1: Delete questions 1, 3a and 6.
03-2A-202110-1: Change question 1 to - First indication "failed off" thruster C&W for 1/2 leg, redundant paths on 3,4,5 leg.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Larry Gladu, RI
System Engineering

Lonnie Jenkins
JSC Propulsion

Dave Latham
JSC Reliability (Boeing)

Don Cagle
JSC Reliability (Boeing)