ORBITER SUBSYSTEM

HARDWARE/SOFTWARE INTERACTION ANALYSIS

VOLUME VIII: AFT REACTION CONTROL SYSTEM

PART 2

JANUARY 1980.
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

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

AFT - RCS
SUBSYSTEM

FMEA # SD72-SH-0103-2

ANALYSIS DATE November 5, 1979

HARDWARE/SOFTWARE ANALYST

APPROVED:

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>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>YES</td>
<td>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</td>
<td>NO</td>
</tr>
<tr>
<td>2. Are the answers to questions 1 and 1a consistent with the FMEA evaluation of in-flight detectability?</td>
<td>YES</td>
<td>*NO</td>
</tr>
<tr>
<td>3. Does the flight software take action to negate the effects of the failure (either by commanding hardware action or implementing alternate program logic)?</td>
<td>YES</td>
<td>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</td>
<td>NO</td>
</tr>
<tr>
<td>4. As a result of this failure mode, can the software overstress the hardware or induce another failure?</td>
<td>*YES</td>
<td>NO</td>
</tr>
<tr>
<td>5. Can this failure mode, in combination with software logic, adversely affect other functions?</td>
<td>*YES</td>
<td>NO</td>
</tr>
<tr>
<td>6. How many of these hardware failures can the shuttle tolerate (consider crew action and hardware/software operation)? Note change to FMEA criticality.</td>
<td>*NO</td>
<td>*1</td>
</tr>
<tr>
<td>7. If crew action is required to respond to this failure mode, are cues provided to signal the need for intervention and the required corrective action?</td>
<td>N/A</td>
<td>YES</td>
</tr>
<tr>
<td>8. If the answer to either 1 or 3 is YES:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Can the BFS be engaged after occurrence?</td>
<td>YES</td>
<td>*NO</td>
</tr>
<tr>
<td>B. Will BFS tolerate failure without loss of crew/vehicle?</td>
<td>YES</td>
<td>*NO</td>
</tr>
</tbody>
</table>

*EXPLANATION REQUIRED (SEE BELOW)*

---

**CHANGE/RETENTION RATIONALE SUMMARY**

- NO H/S ISSUES
- HARDWARE ACCEPTS RISK
- NO SOFTWARE DETECTION
- DETECTION DURING CHECKOUT
- ACCEPTANCE RATIONALE BELOW
- RECOMMENDED CHANGES BELOW

---

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

---

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

6.0 ANALYSIS CHECKLIST SHEETS

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

Figure 4-2. Change/Retention Rationale
<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>ANALYSIS RESULT</th>
<th>ITEM/FAILURE MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The subsystem failure modes not analyzed are also identified. These failure modes were evaluated as having hardware/software interfaces. Figure 4-4 depicts the form utilized for this purpose.

5.0 ANALYSIS SUMMARY SHEETS. The analysis results are summarized on the following sheets. The failure modes have been grouped by issue/retention rationale (or change), affording an overview of the results for the entire subsystem.
FAILURE MODES NOT INCLUDED IN HARDWARE/SOFTWARE ANALYSIS
EVALUATED AS INVOLVING NO HARDWARE/SOFTWARE INTERFACE

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

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

Figure 4-4. Failure Modes Not Included In Hardware/Software Analysis
<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>AFT - RCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANALYSIS RESULT</td>
<td>ITEM/FAILURE MODE</td>
</tr>
<tr>
<td>HARDWARE ACCEPTS RISK</td>
<td>Helium Tank - External Leak (03-2A-201010-1)</td>
</tr>
<tr>
<td></td>
<td>Helium Feed Line - External Leakage (03-2A-201013-1)</td>
</tr>
<tr>
<td></td>
<td>D. C. Solenoid Valve, Helium - Fails Closed (03-2A-201020-1)</td>
</tr>
<tr>
<td></td>
<td>Line, Low Pressure Helium - External Leak (03-2A-201035-1)</td>
</tr>
<tr>
<td></td>
<td>Helium Fill Quick Disconnect - Fails Open (03-2A-201070-1)</td>
</tr>
<tr>
<td></td>
<td>Purge Quick Disconnect, Propellant - External Leakage (03-2A-201080-1)</td>
</tr>
<tr>
<td></td>
<td>Test Quick Disconnect - External Leakage (03-2A-201090-1)</td>
</tr>
<tr>
<td></td>
<td>Feedline and Fittings, Fuel - External Leakage (03-2A-202108-1)</td>
</tr>
<tr>
<td></td>
<td>Propellant Fill and Bleed Disconnect - Fails Open (03-2A-202150-1)</td>
</tr>
<tr>
<td></td>
<td>Propellant Tank Assembly - External Leak (03-2A-211110-1)</td>
</tr>
<tr>
<td></td>
<td>Propellant Tank Assembly - Bubbles in Propellant (03-2A-211110-2)</td>
</tr>
<tr>
<td></td>
<td>Injection Plate - Restricted Flow (03-2A-221311-1)</td>
</tr>
<tr>
<td></td>
<td>Thrust Chamber - Burn-Thru (03-2A-221312-1)</td>
</tr>
<tr>
<td></td>
<td>Nozzle Extension - Burn-Thru (03-2A-221313-1)</td>
</tr>
<tr>
<td></td>
<td>Vernier Thruster - Loss of Output (03-2A-231310-1)</td>
</tr>
<tr>
<td></td>
<td>Vernier Thruster - Fails to Stop Firing (03-2A-231310-2)</td>
</tr>
<tr>
<td></td>
<td>Vernier Thruster - Burn-Thru (03-2A-231310-3)</td>
</tr>
<tr>
<td>ITEM/FAILURE MODE</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Helium Pressure Regulator - Restricted Flow - Fails Closed (03-2A-201030-2)</td>
<td></td>
</tr>
<tr>
<td>Helium Quad Check Valve - Fails Closed (03-2A-201095-2)</td>
<td></td>
</tr>
<tr>
<td>Feedline and Fittings, OX - External Leakage (03-2A-202109-1)</td>
<td></td>
</tr>
<tr>
<td>Tank Isolation Valve, A. C. - Fails Closed (03-2A-202110-1)</td>
<td></td>
</tr>
<tr>
<td>Tank Isolation Valve, A. C. - Fails Closed (03-2A-202110-3)</td>
<td></td>
</tr>
<tr>
<td>Interconnect Valve, A. C. - Fails Closed (03-2A-202111-2)</td>
<td></td>
</tr>
<tr>
<td>Manifold Isolation Valve, A. C. - Fails Closed (03-2A-202120-3)</td>
<td></td>
</tr>
<tr>
<td>Manifold Isolation Valve, D. C. - Fails Closed (03-2A-202140-1)</td>
<td></td>
</tr>
<tr>
<td>Gimbal Joint - External Leakage (03-2A-211120-1)</td>
<td></td>
</tr>
<tr>
<td>Bellows Assembly - External Leakage (03-2A-221308-1)</td>
<td></td>
</tr>
<tr>
<td>Engine Inlet Valve - Fails Closed (03-2A-221310-4)</td>
<td></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>
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>☐</th>
</tr>
</thead>
</table>

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

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>☐</th>
</tr>
</thead>
</table>

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

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>☐</th>
</tr>
</thead>
</table>

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

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>☐</th>
</tr>
</thead>
</table>

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)?**

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>☐</th>
</tr>
</thead>
</table>

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

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>☐</th>
</tr>
</thead>
</table>

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

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>☐</th>
</tr>
</thead>
</table>

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

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
</table>

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?**

<table>
<thead>
<tr>
<th>N/A</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</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?**

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>☐</th>
</tr>
</thead>
</table>

*EXPLANATION REQUIRED (SEE BELOW)*

**CHANGE/RETENTION RATIONALE SUMMARY**

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

**EXPLANATION/COMMENTS:**

1. 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.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: 6G245-303 / 0331 / 0332
P/N VENDOR: 5L0-99904-0-1 / 2
QUANTITY: 2

SUBSYSTEM: AFT - REACTION CONTPL FMEA NO 03-2A -201010-1 REV: 11/08/75
ABORT: CRIT. FUNC: 1
CRIT. HD: 1
MISSIONS: HF VFX FP OF SM
PHASE(S): PL X LO X CJ X DO X LS

ITEM: TANK
HELIUM STORAGE, FILAMENT WOUND
FUNCTION:
TO STORE HELIUM AT A MAX WORKING PRESSURE OF 4000 PSI FOR
PRESURIZATION OF THE AFT RCS MODULE'S PROPULSANT SUPPLY SYSTEM. TANK
CONSISTS OF DOUBLE WELT TI LINER WITH SUPPLEMENTARY KEVLAR 49 FIBER AND EPOXY
RESIN BONDING OVERLAY. TANK IS 18.71 IN. VOLUME IS 3008 CU. IN.

FAILURES MODE: STRUCTURAL FAILURE

EXTERNAL LEAK

CAUSE(S):
MAT'L DEF, LINER DEF, FAULTY FAB, EPOXY CURING INADEQ. TEST/HANCL DAY, SHOCK, VIB, INADEQ. OVERPRESS (GMO), INADEQ. MOUNTING

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

DISPOSITION & RATIONALE (A) ENGINEERING (B) TEST (C) INSPECTION (D) FAILUR 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 50000 LBS PER INCH ALLOWING LIGHT WEIGHT WITH GREAT STRENGTH.
INCREASED STRAIN CAPABILITY IS PROVIDED BY THE COMPRESSION LOAD ON A UNPRESSURIZED LINER. VENT DOORS ARE OPEN ON ORBIT AND WILL RELIEVE ANY PRESSURE BUILDUP DUE TO LEAKAGE. THE F.S. (95% ST) IS 1.5 X WORKING PRESS.
(B) 1000 PRESSURE CYCLES ARE PERFORMED DURING QUAL WHICH IS MORE THAN 4 X ANTICIPATED OPERATING LIFE. A 90-DAY CREEP TEST UNDER PRESSURE IS ALSO PERFORMED AFTER WHICH THE TANK IS EXAMINED TO VERIFY NO PERMANENT DEFORMATION OR FLAP GROWTH. PRIOR TO PRESSURE (1.1) X WORKING PRESSURE) AND LEAKAGE TESTS ARE PERFORMED DURING ATP. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. RAW MAT'L AND PURCHASED COMPONENTS ARE VERIFIED BY RECEIVING INSPECTION STANDARDS AND TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REGENTS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY
INSPECTION POINTS - PARTS PROTECTION, HSG. PROCESSES, FINISHES, ASY AND INSTALLATION. THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77 - CORRISION PROTECTION PROVISIONS, TEST HANDLING, AND STORAGE
SUBSYSTEM : AFT - REACTION CONTROL

FMEA NO: 03-2A - 201010-1
REV: 11/03/7?

ENVIRONMENTS: TENSILE, HEAT TREAT AND WELD SAMPLES ARE TESTED DURING IN-PROCESS FABRICATION IN ADDITION TO X-RAY & DYE PENETRANT FOR THE LINES. WIND PATTERN & WINDING CONTROL ARE USED FOR THE KEVLAR FIBER DURING IN-PROCESS MANUFACTURE. WEIGHT CONTROL IS USED FOR THE EPOXY RESIN. TURNAROUND - MONITOR LEAKAGE TESTS PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND AS PART OF THE CHECKOUT PROCEDURE PRIOR TO FLIGHT. PRESSURE CYCLES ACCUMULATED ARE ALSO RECORDED. (D) NONE AVAILABLE NEW DESIGN.
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?**
   - 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. 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" V42P-2110C 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.
DETRIMENTAL EFFECTS ANALYSIS - D-1114.

PREPARED BY: JLS R C Glavirich
APPROVED BY: JLS
REL C Y AREAS

READ: RELAY LEAK CAVI_VISUAL INSPECT 7073-56-C162-1
B-100-66-C162-1

INSTRUCTION LINES

1) IF V. E. W. VALVE LEAKS, OR LEAK IS NOT VISIBLE FROM RELAY PANEL, INSPECT RELAY PRESSURIZATION SYSTEM PANEL FOR LEAKAGE (S), INTERNAL LEAKAGE (S) OR EXTERNAL LEAKAGE (S).

2) RELAY VALVE LEAK-IF LEAK IS NOT VISIBLE, INSPECT VALVE CONNECTIONS (S) FOR LEAKAGE (S) OR EXTERNAL LEAKAGE (S). INSPECT VALVE FOR LEAKAGE (S) OR EXTERNAL LEAKAGE (S).

3) TANK LEAKAGE (S) OR EXTERNAL LEAKAGE (S) CAN RESULT IN DEPRESSED PRESSURE (S). RELAY VALVE LEAK-IF LEAK IS NOT VISIBLE, INSPECT VALVE CONNECTIONS (S) FOR LEAKAGE (S) OR EXTERNAL LEAKAGE (S). INSPECT VALVE FOR LEAKAGE (S) OR EXTERNAL LEAKAGE (S).

4) RELAY VALVE LEAK-IF LEAK IS NOT VISIBLE, INSPECT VALVE CONNECTIONS (S) FOR LEAKAGE (S) OR EXTERNAL LEAKAGE (S). INSPECT VALVE FOR LEAKAGE (S) OR EXTERNAL LEAKAGE (S).

5) V. E. W. MAY BE A VER CAR IF SI. JUAN OR PRP REMAINS. ICY COCCIPES \ MAY RESULT IN DAM TO STRUCTURE. RELAY VALVE LEAK-IF LEAK IS NOT VISIBLE, INSPECT VALVE CONNECTIONS (S) FOR LEAKAGE (S) OR EXTERNAL LEAKAGE (S).

ORIGINAL PAGE IS OF POOR QUALITY.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION HELIUM
P/N INT: MG621-0059
P/N VENDOR: 73A630000
QUANTITY: 4

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

FAILURE MODE: STRUCTURAL FAILURE (S)
CAUSE(S):
- MAT' L DEF (SULPHIDE STRINGER), VIB, SHOCK, STRUT 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 ISOL) (FAIL UPSTREAM OF ISOL VALV-INABILITY TO DEplete/UTILIZE PCP)
  - (B) LOSS OF INTERFACE FUNCTION (INABIL TO DEPRESS PCP TANK - GET POD STRUCT & TPS DAM.
  - (C) ABORT DECISION (LOSS OF PRESS) (D) POSSIBLE LOSS OF CREW/VEHICLE - IF LEAK EXCESS OR POD/TPS DAM OFFERS

DISPOSITION & RATIONALE:
- DESIGN (A) TEST (B) INSPECTION (C) 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 "CRIBER TUBING VERIFICATION PLAN" (SD 75-SH-0205). THIS TESTING INCLUDED PRESSURE CYCLING AND FOR TYPICAL SHUTTLE LINES & JOINTS. SYSTEM EVALUATION TESTS AT WSTF WILL ALSO ALLOW EVALUATION IN THE INSTALLED SYSTEM CONDITION. LEAKAGE TESTS ARE PERFORMED IN-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 NOE. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAM. CONTROL PROCESSES, COPROCS, PROTECTION PROVISIONS, NOE EXAM OF WELDS AND INS. FOR SURFACE AND SUB-SURFACE DEFECTS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INS. PC ICTS. RAW MAT' L (LOT CERTIFICATION), PARTS PROTECTION, MANUF., COATING, PLATING, INSTALLATION AND ASSEMBLE OPERATIONS. HARDWARE IS INS. IN ACCORDANCE WITH QUALITY PLANNING REQUIS DOCUMENT (QPRO) WHICH HAS BEEN APPROVED BY NASA.
SUBSYSTEM : AFT - REACTION CONTROL

FMEA NO 03-ZA -201013-1  REV: 12/13/75

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

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

See Note 2.

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

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

2. Measurement numbers V42X2124X, 2126X, 3124X, and 3126X (Fu He isolation valves) needs to be added for detectability since only the measurement stimulus identification numbers for the oxidizer valves are listed now.
SYSTEM: VALVE, L.C. SUPPLE

PREPARED BY: LEL

APPROVES SYS: KURKMAR

NEL

LEAVERS

POTENTIAL HAZARD RELATED TO REACTION TIME FOR SWITChING TO ALTERNATE PATH DURING CRITICAL MODES OF OPERATION SUCH AS E.I.
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PRESSURIZATION - ABRRT:
P/N RI : MC294-0419-0011-0012
P/N VENDOR : 73835
MISSIONS : HF VF X FF CF SM
QUANTITY : 2

ITEMS LIST - 10 BITER

PREPARED BY: R. BURKHART
APPROVED BY: S. SM
RE: ASSEMBLY - PRESSURIZATION
ABORT: CRIT.
PHASE(S): PL X LO X GO X OO X LS

SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PRESSURIZATION - ABRRT:
P/N RI : MC294-0419-0011-0012
P/N VENDOR : 73835
MISSIONS : HF VF X FF CF SM
QUANTITY : 2

TWO VALVES REQ'D FOR EACH HELIUM SUPPLY RECONNECTION SCREEN: 1-PASS B-PASS C-FAIL

DESCRIPT: VALVE, D.C. SOLENOID
OPERATING, HIGH PRESSURE HELIUM (1/2") 91-STABLE (LATCHING - MAGNETIC & SPRING FORCE) LV 201/202/203/204/301/302/303/304

FUNCTION:
...UTILIZED TO CONTROL HELIUM PRESSURIZATION SYSTEM IN THE LFT MODULES. IN THE OPEN POSITION A FLOW PATH IS PROVIDED FROM THE HELIUM SUPPLY TANK(S) TO THE REGULATORS. TWO PARALLEL PATHS ARE PROVIDED FOR EACH PROPELLANT TANK. ONE PATH IS NORMALLY OPEN PER TANK. THE OPEN VALVE MAY BE CLOSED AND THE PARALLEL VALVE CLOSED 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 CRITICE.

EFFECT(S): ON (A) SUBSYSTEM (R) INTERFACES (C) MISSION (D) CREW/VEHICLE:
... (A) LOSS OF REDUNDANCY - PARALLEL PATH AVAILABLE. (S) NO EFFECT.
... (C) ABRRT DECISION - DUE TO ONLY ONE PATH REMAINING PER 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. VOLUME PRESS IS ADEQ FOR PROP FEED WITH LESS THAN 35 PERCENT PROP REMAINING. ONE VALVE IS MAINTAINED IN THE LATCHED OPEN POSITION WITH NO POWER APPLIED & THE OTHER IS LATCHED CLOSED. AN INDUCTIVE VOLTAGE SUPPRESSION CIRCUIT IS PROV. IN THE ELECTRICAL SYSTEM TO PREVENT DAMAGE TO OTHER ON-LINE COMP. REDUND DIODES LIMIT THE POSS OF DIODE FAILURE ALLOWING CURRENT SHUNT FROM THE COIL. A 100-MICRON FILTER IS PROV TO LIMIT THE POSS OF CONTAM CAUSING LEAKAGE, JAMMING MOVING PARTS - OR PLUGGING PILOT CONTROL ORIFICES. TO LIMIT THE ELECTRIC SHORT POTENTIAL, THE LEAD AND MAGNET WIRES ARE ENCAP BY POTTING AND A FIXTURE IS USED DURING ASSEMBLY TO ENSURE THAT INSUL IS NOT DAMAGED BY THE EXIT NOTCH WHEN THE COIL SLEEVE IS PRESSED ONTO THE COIL. (B) 4000 OPER CYCLES (ON-OFF-FLOW) AND RANDOM VIB AT ANTI MMISSION LEVELS ARE PERFORMED. ITEM IS USED...
During sys eval tests at WSTF allowing eval under simul mission usage
Cond. proof pressure, leakage, op and insul tests are perf during
Atp. aprop located test points allow pre/post flight leakage tests and
Op 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. Inspr. for surface and subsurface defects and proper
Elect terminations are verif by Inspr. The following items are verif by
Shop traveler mandatory inspr. Points - Raw Mat'l (Lot Cert), Parts Prot,
Manuf., Coating, Plating install and assembly op. The above items and
The foll items were verif by audit cond 8-31-77. Contam cont
Processes, Corros. Prot Prov. Turnaround - funct flow tests are
Monitored to verify that valves open and close properly upon cmd.
(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 prot on a similar valve due to
Insul damage was discov during qual and cpr as descried in item (a)
Above.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST  SD72-SH-0103-2

ITEM He Pressure Regulator  FAILURE MODE Restricted Flow - Fails Closed

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

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

EXPLANATION/COMMENTS:

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

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

6. 1 success path remaining after first failure.

7. Cathode-ray-tube and downlist is available.
PRESURE: 5124 PSI

SYSTEM 1: FUEL PUMP 1
SYSTEM 2: FUEL PUMP 2
SYSTEM 3: FUEL PUMP 3

FAILURES:
1. FUEL PUMP 1 FAULT 1
2. FUEL PUMP 2 FAULT 2
3. FUEL PUMP 3 FAULT 3

EFFECTS:
1. LOSS OF FUEL SUPPLY
2. LOSS OF CONTROL

PREPARED BY:
C. HAGGIS

APPROVED BY:
C. HAGGIS

TEST PORTS:

FUEL INLET PRESSURE: 5200 PSI
FUEL OUTFLOW PRESSURE: 5140 PSI

PREVIOUS TESTS:
- 1/3/1972-12/22/72
- 1/3/1972-12/22/72

PREVIOUS TESTS:
- 1/3/1972-12/22/72
- 1/3/1972-12/22/72

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

SUBSYSTEM : AFT - REACTION CONTROL

ASSEMBLY : PRESSURIZATION

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

P/N VENDOR: 743390Q1

QUANTITY: 2

ASSEMBLY: PRESSURIZATION

CRIT. FU'C: IQ

MISIIONS: HF VF X FF DF SM

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

P/N: MC284-041801/-0002

ASSEMBLY: PRESSURIZATION

CRIT. FWC: 1

FUNCTION:

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

FAILURE MODE: FAILS CLOSED (F)

RESTRICTED FLOW

- CONTAM (PILOT SCREEN), FLOWFMG, MIST, SPRING/STEM FRACUTURE, PISTON
  RINGS, EXCESS DOME PRESS, COCKED SPRINGS, MAT'L DET.

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

- (4, 8) LOSS OF REDUNDANCY (ONE OF 2 FLOW PATHS). (C) APGRT DECISION
  (D) NO EFFECT UNLESS SECOND PATH FAILS CLOSED, REENTRY CAPAB IS LOST IF
  FAILURE OCCURS EARLY IN ENTRY SUCH THAT ULLAGE PRESS IS NOT SUFF
  (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CREW/VEHICLE LOSS. FAILURE
  OF REDUNDANT PARALLEL FLOW PATH WOULD RESULT IN INABILITY TO SURV OR
  DEPLETE RCS PROPELLENT. THIS WOULD RESULT IN POSSIBLE INABILITY TO
  CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO USE RESERVED ENTRY
  PROPELLENT OR C-G. PROBLEMS RESULTING FROM PROPELLENT WEIGHT.

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

- (A) PARALLEL REGULATORS ARE PROVIDED. ULLAGE PRESS IS ACEG FOR PROP FED
  WITH LESS THAN 35 PERCENT PROP REMAINING. A 25-MICRON ABS GBR PLUS
  10-MICRON ABS GBR PILOT FILTER IS PROV TO LIMIT THE POSSIBILITY OF
  CONTAM CAUSING JAMMING OF MOVING PARTS OR PLUGGING PILOT CONTROL
  ORIFICES. (B) 50,000 OPER FLOW CYCLES AND PAN CM VIB AT ANTI MISSION
  LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYS EVAL TESTS AT
  WSTF ALLOWING EVAL UNDER SIMUL MISSION USAGE COND. (C) PROOF PRESS, LEAKAGE
  AND FLOW TESTING IS PERFORMED DURING ATP. FUNCT AND LEAKAGE TESTS ARE
  PERFORMED DURING PRE/POST FLIGHT CHECKOUT. (D) AN ID IS PERF AND THE
  UNIT TAGGED. MAT'L & EQUIP CONFORMANCE TO CONTRACT REQMTS IS VERIF BY
  INSPECTION. THE FOLLOW ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPECTION:
  RAW MAT'LS, PARTS PROTECTION, MAINT, COATING, PLATING, INSTALLATION AND ASSEMBLY
  OPERATIONS. THE ABOVE ITEMS AND THE FOLLOW ITEMS WERE VERIF BY AUDIT
  CONDUCTED 4-5-77 — CONTAM CONT PROCESSES AND CORROS PROD. PROV. CONTAM
  CONT PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIR. THE FOLLOWING

1002

SD75-SH-0003
SUBSYSTEM : AFT - REACTION CONTROL

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 LOGS VERIFIED BY INSPECTION. PARTS CLEANLINESS AND PASSIVATION VERIFIED BY INSPECTION. NOE INSPECTION PERFORMED AFTER ASSEMBLY. TURNAROUND - FUNCTION FLOW TESTS ARE MONITORED TO VERIFY THAT THERE IS NO RESTRICTED FLOW. NO FAILURE HISTORY OF THIS MODE FOR THIS REGULATOR.
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**

   **YES ☒ 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. Ulilage 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.
AVAILABILITY ANALYSIS - Version 3

- SYSTEM: EPE - ELECTRICAL POWER
- ASSUMED QUANTITY: 1000 ft.
- COMPONENT: EPE
- FUNCTION: ELECTRICAL

- REQUIREMENTS:
- MECHANICAL: No significant mechanical issues.
- ELECTRICAL: Potential for electrical interference with other systems.

- POTENTIAL ISSUES:
- SYSTEM: Loss of system reliability.
- MISSION: Potential loss of mission.

- SUMMARY:
- Risk Level: Low.
- Recommendation: No action required.

- PREPARED BY: A.G. CLAVINICH
- CHECKED BY: D.S. WERTZ
- APPROVED BY: D.S. WERTZ

- 12/1/13

- NOTE: The above analysis is preliminary and subject to change.

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

**SUBSYSTEM**: AFT - REACTION CONTROL  
**ASSEMBLY**: PRESSURIZATION  
**P/N RI**: MC621-0059  
**P/N VENDOR**: 73A630030  
**QUANTITY**: 4  
**MISSIONS**: HF, VF, X, FF, OF, SM  
**PHASE(S)**: PL, LD, CC, DC, LS  

###*.ASSEMBLY : PRESSURIZATION ABORT: CRIT. FUNC: PIN*.

**VENDOR**: 73A630030  
**MISSIONS**: HF, VF, X, FF, OF, SM  
**QUANTITY**: 4  
**PHASE(S)**: PL, LD, CC, DC, LS  

**PREPARED BY**: N. C. GLAVINICH  
**APPROVED BY**: NASA  
**REL**: C. M. AKERS  
**SSM**:  

**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/FATIGUE, IMPROPER INSTALLATION (WELD), STRESS CORROS, MAT'L DEFICIENCY (SULPHIDE STRINGERS)  
**EFFECT(S)**: ON (A) SUBSYSTEM (3) INTERFACES (C) MISSION (2) CREW/VEHICLE:  
(A) LOSS OF SUBSYSTEM HELIUM SUPPLY, INABILITY TO DEPLET/UTILIZE PROPELLANT, (B) LOSS OF INTERFACE FUNCTION INABILITY TO DEPRESSURE 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 SUBJECTED TO NDE. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAM. CONTROL PROCESSES, CORROS. PROTECTION PROVISIONS, NDE EXAM OF WELDS AND INSPE. FOR SURFACE AND SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPE. POINTS, RAW MAT'L (LOT CERTIFICATION), PARTS PROTECTION, MANUF., COATING, PLATING, INSTALLATION AND ASSEMBLY OPERATIONS. HARDWARE IS INSPE. IN ACCORDANCE WITH QUALITY...
SHUTTLE CRITICAL ITEMS LIST - ORBITER 1C2

SUBSYSTEM : AFT - REACTION CONTROL FMEA NG 03-2A -201035-1 REV:11/03/73
PLANNING REGNITS DOCUMENT (GPRO) 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.
SUBSYSTEM AFT - RCS
ITEM Relief Valve

FAILURE MODE External Leak -- Fails Open

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

   YES [X] NO [ ]

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

   [ ] YES [X] NO [ ]

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

   [ ] YES [X] NO [ ]

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

   [ ] YES [X] NO [ ]

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

   [ ] YES [X] NO [ ]

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

   [ ] YES [X] NO [ ]

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

   [ ] YES [X] NO [ ]

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

   [ ] 0 [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. Gross leak detection will give first indication.

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

6. Left and right AFT RCS pods provide redundancy.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N REV: 12/14/77
P/N VEND
P/N 76039-001/0002
QUANTITY: 4

MISSIONS: HF, VF, FF, 7F, SM
FUNCTION: IR
ASSEMBLY: PRESSURIZATION
CRIT. HD:
P/N
VEND
OR76D9D9-RE/076-0009-102

FUNCTION:
- PROVIDES PRESSURE RELIEF IN EVENT REGULATOR FAILS OPEN OR PROPellant PRESSURE RISES DUE TO THERMAL INCREASE. THE MAIN POPPET CRACK AND RELIEF PRESSURE IS 324-340 PSIG. THE MINIMUM RESEAT PRESSURE IS 310 PSIG. 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 OPERATIONAL CAPABILITY - ASSUMES ULLAGE PRESSURE IS ALSO VENTED OVERBOARD & PROP CANNOT BE DEPLETED.
  - (D)LOSS OF CREW ENTRY CAPABILITY - PROHIBITS USE/DEPLETION OF PROPellant.
- ABORT DECISION IF LEAK RATE IS SMALL. (0) NO EFFECT (FIRST FAILURE). (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE LOSS OF CREW VEHICLE - SEE ITEM (C) ABOVE. PROP IN ONE POD MAY NOT BE ADEQUATE FOR ENTRY. POSSIBLE ENTRY CONTROL & LANDING HAZARD. (C.G.) IF PROP CANNOT BE DEPLETED PRIOR TO LANDING.

DISPOSITION & RATIONALE:
- (A) DESIGN - 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 PRESSURE.
SUBSYSTEM : AFT - REACTION CONTROL  
FMEA NO 03-2A-201060-4  
REV: 12/14/73

Pressure and 400 pressure relief cycles are conducted during qual.  
(C) An identification is performed contamination control process,  
contamination control plan, Corros. Protection provision, NDE exam of  
WELDS, INS for Surface and subsurface defects, properly monitored  
Handling and storage environment, and Mat'l and Equip, Conformance to  
contract reqmts. are verified by INS. The following items are verified  
by shop traveler mandatory INS points-raw Mat', (LOT certification),  
PARTS protection, MANUFACTURING, 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 INS for evidence of deterioration is also  
performed. (D) Apollo failures were 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).
SELECT VALVE: 

1. Relief pressure, COLD DISC & FUEL. RV 200/600/1000, SEL 1110/1600.

INJUNCTION:
- PROVIDE PRESSURE RELIEF IN EVII. IF FUEL TANK FAILS OPEN II FUEL TANK PUMP INCREASES. THE SENSITIVE RELIEF VALVE IS 30-40 PSI. WHILE PERFECT CRACK AND RELIEF PRESSURES TO
- RELIEVES ARE THE MINIMUM RELIEF PRESSURE IS 30 PSI. A RELIEF PRESSURE REDUCING VALVE IS PROVIDED SINCE THE VALVE OUTLET IS SUBJECT TO \( \text{V} \). V.

FAILURES RESULT:
- EXTERNAL LEAK
- FUEL LEAK, MAIN PUMP OR INTERPAPE LEAKS OR MAIN SUPPLY LINES AND TANKS AS WELL AS LEAK DISC Rupture.

CAUSES:
- COMBUSTION, CONTAMINATION, FUEL TANKS IN COOLER, SPRAY PUMPS IN COLD, SEAT CRACK, INTERVENE PRESSURE, VIBRATION, SHOCK.

EFFECTS:
- (1) SUBSYSTEM (2) CONTACTABILITY (3) MISSION 4) CAUSE/AVAILABILITY
- (1) LOSS OF SYSTEM FUNCTIONALITY (2) LOSS OF INTERPAPAL FUNCTION
- (3) LACK OF INTERFACE FUNCTIONALITY (4) LOSS OF GUIDANCE CAPABILITY - ASSUMED UPLAND PRESSURE IS ALSO VENTED OVER-AND-OVER
- COMMON INTERPAPAL. IF FAILURES - FIRST IS RELIEF RELIEF. SECOND IS LEAK RUST IS SMALL. (5) NO EFFECT (FIRST FAILURES)
- (6) PROJECT CAPABILITY EFFECT - POSSIBLE LOSS OF EIGHT VEHICLE - SEE
- ITEM (I) PROPELLE PROPELLE PROP MAY NOT BE AVAILABLE FOR ENTRY. PLACE
- ENTRY CONTROLS & LANDING HALTED (E.S.) IF PROPELLE CANNOT BE DISCONNECTED PROPEL
- LANDING.

SELECTING ACTIVELY:
- ANYTHING ELSE RECOUPE? RALLIES IF E.U. PROPELLE PROP CANNOT BE DISCONNECTED IS NOT ADDED FOR ENTRY. DESELECT DISCONNECT PUMP PROPEL LEAKING.

37 ORIGINAL PAGE IS OF POOR QUALITY
SOME FAILED PACE AND EFFECTS ANALYSIS - IN J. J. J.

1. SYSTEM - ELECTRICAL CONTROL - PACE. IN J. J. J.

2. TIME - ELAPSED - PACE. IN J. J. J.

3. EQUIPMENT - ELAPSED - PACE. IN J. J. J.

4. CONCLUSION - ELAPSED - PACE. IN J. J. J.

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

SUBSYSTEM AFT - RCS

ITEM: He Fill Quick Disconnect

FAILURE MODE: Fails Open

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

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

6. Capped quick disconnect provides one redundant success path.
   Pod Redundancy

In-Flight detectability

☑ FMEA CHANGE RECOMMENDED

39
SYSTEM - PRIMARY CONTROL

1. PRESSURE INFLATORS
2. OVERPRESSURE TUBING
3. PRESSURE GLASS
4. PRESSURE COMPRESSOR
5. PRESSURE GAGES
6. PRESSURE INSTRUMENTS
7. PRESSURE REGULATORS
8. PRESSURE CAPTORS

MISSING:

PARTS THAT ARE NOT.

REPLACEMENTS:

FAA NOTE: 24-7-107-1, 24-7-107-2

TOLERANCES:

MOUNT ON SPRING LOAD

REL. FIRST PIPE:

THRU:

REPEATEDLY

VISUAL INSPECTION PRIOR TO LAUNCH:

PREPARED BY:

SPE

APPROVED BY:

rels

#1

1. DISCONNECT WITH SPRING LOADS PRIOR TO STRUTURAL SLIDE CASING.

2. SCREW ALL REAR FILL AND VIIT POINT FOR CENSER VIIT CASING

3. COUPLING IS ACCESSIBLE AT THE REAR SERVICING PORT.

4. SCREW ALL THE SEAT LEAKS.

5. SCREW ALL THE SEAT LEAKS.

6. RELEAK THE SEAT LEAKS.

7. RELEAK THE SEAT LEAKS.

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40. RELEAK THE SEAT LEAKS.

ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM : AFT - REACTION CONTROL  
ASSEMBLY : PRESSURIZATION ABORT: CRIT. FUNC: 1  
P/N RI : MC276-0017-0042/0043  
P/N VENDOR: 7537200C-0041/-0043  
MISSIONS: HF VFX FF OF SM  
QUANTITY : 4  

REDUNDANCY SCREEN: A-N/A B-N/A C-N/A  
PREPARED BY: DES G SCARLETT DES C SCARLETT 12/12/78  
REVIEWED BY: MMSS  
APPROVED BY: NASA  

ITEM: DISCONNECT, QUICKFILL, HF  
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 THRU SEE HALF, NC LINE SUPPORT - SHAFT OR GROUND BENT, RETAINING CAP LOCKS MAINTAINING CAP 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 LOSS DURING MISSION IF PROPELLANT CANNOT BE UTILIZED OR DEPLETED.  

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:  
- (A) F.S.S. IS 2.0 X WORKING PRESS. ULLAGE PRESS IS ADEQ TO EXPEL PROP WITH 35 PERCENT OR LESS REPEATING. GROUND HALF COUPLINGS AND LINES ARE SUPPORTED TO LIMIT ANY UNDESIRED STRESS ON THE COUPLING DURING SERVICE AND PREV DAMAGE TO SEALS. A SAFETY FEATURE DURING SERVICING AND PRIOR TO REMOVAL OF THE END CAP IS A PROV WHEREBY ANY LEAKAGE PAST THE AIRBORNE POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING A BLEED SCREW. COMPLETE STRESS ANAL HAS BEEN CONDUCTED. UTIL OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUNDANT SEAL EXCEPT FOR STRUCTURAL FAILURE. (B) THE COUPLING IS SUB TO 600 OPERATIONAL CYCLES (COUPLING AND UNCOUPLING) DURING QUAL. RANDOM VIB TESTING IS ALSO CONDUCTED AT ANTIC VEH LEVELS FOR 48 MINUTES IN TWO AXES. USAGE DURING SYS EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL Usage CON. PROOF PRESS TESTS ARE CONDUCTED DURING ATP AND LEAKAGE TESTS ARE PERF BEFORE AND AFTER OPER CYCLES. (C) AN IDENT IS PERF. RAW MAT'. NO EXAM, VISUAL INSPECTION FOR CRITICAL SURFACE DEFECTS, AND EQUIP CONFORMANCE TO CONTRACT REQ'TS ARE VERIF BY RECEIVING INSPECTION STANDARDS AND TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQUIREMENTS OF MIL SPEC. THE FOLLOWING ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPECTION POINTS. PARTS MFG PROCESSES, COATING, ASSY AND INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77. CORROSION PROOF, CONTAM CONT PROCESS, TEST
SHUTTLE CRITICAL ITEMS LIST - CRITER 102

SUBSYSTEM: AFT - REACTION CONTROL  FMEA NO 03-2A -201070-1  REV:12/12/78

HANDLING. AND STORAGE ENVIR. THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT
OF MARCH 6, 1978. INSPECTION VERIFIES ASSEMBLY PER INSPECTION POINTS IN
MASTER RECORD. LOG OF CLEAN ROOM AND CALIBRATION OF TOOLS VERIFIED.
CRITICAL DIMENSION 100% VERIFIED BY INSPECTION. PARTS CLEANLINESS AND
PASSIVATION VERIFIED BY INSPECTION. NDE INSPECTION PERFORMED AFTER
ASSEMBLY. TURNAROUND. COUPLINGS ARE VISUALLY INSPECT FOR EVID OF DAMAGED
SEALS AND LEAK TESTS ARE PERFORMED. (C) APOLLO FAILURE HISTORY WAS IN
THE MAIN ASSOC. WITH GROUND USAGE, IMPROPER HANDLING.

SD75-SH-0003
HARDWARE/SOFTWARE ANALYSIS CHECKLIST  SD72-SH-0103-2

ITEM  PURGE Quick Disconnect, Propellant

FMEA NUMBER  03-2A-201080-1

FAILURE MODE  External Leakage

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

   YES  X  NO  

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

   *YES  X  NO  

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

   YES  X  NO  

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

   YES  X  NO  

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

   YES  X  NO  

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

   YES  X  NO  

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

   YES  X  NO  

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

   0  X  1  2  

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

   N/A  X  YES  NO  

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

   A.  CAN THE BFS BE ENGAGED AFTER OCCURRENCE?

      YES  X  *NO  

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

      YES  X  *NO  

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1.  NO H/S ISSUES  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.  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.
COUNTERMEASURE PULL AND EFFECTS ANALYSIS - CR 11-1

[Document content not legible due to image quality]
ITEM: DISCONNECT QUICK PURGE
- VENT PROPELLANT WITH STRUCTURAL END CAP AND SPRING LOADED POPPET (1/2" & 1/4 IN.)

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

FAILURE MODE: EXTERNAL LEAKAGE
- CAP LEAKS, SEALS DAMAGED RETAINING NUT LOOSENESS NEGATING CAP SEAL REDUNDANCY

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

EFFECT(S): ON (1) SUBSYSTEM (3) INTERFACES (2) MISSION (3) CREW/VEHICLE:
- (A) LOSS OF REDUNDANCY (PROPellant MANIFOLD ISOLATION VALVE COULD ISOLATE LEAK) (C) MISSION MODIFICATION OR ABORT DECISION (G) NO EFFECT UNLESS MULTIPLE FAILURES OCCUR OR EXCESS LOSS OF PROPELLANT OCCURS (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CREW/VEHICLE LOSS - LOSS OF RCS ENTRY PROPELLANT POSITIVE LOSS OF VEHICLE CONTROL DURING ENTRY

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) F.S. IS 2.0 X WORKING PRESS. REDUNDANCY PROVIDED BY INTERNAL SEAL, CAP & MANIFOLD ISOLATION VALVE. GROUND HALF COUPLINGS AND LINES ARE ADEQUATE TO LIMIT ANY UNDUE STRESS ON THE COUPLING DURING SERVICE AND PREV DAMAGE TO SEALS. SAFETY FEATURE DURING SERVICING AND PRIOR TO REMOVAL OF THE END CAP IS A PROV WHEREBY ANY LEAKAGE PAST THE AIRBORNE POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING A BLEED SCREW. COMPLETE STRESS ANALYSIS HAS BEEN CONDUCTED. UTIL OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUNDANT SEAL EXCEPT FOR STRUCTURAL FAILURE. CAN BE ISOLATED AT MANIFOLD VALVE. (B) THE COUPLING IS SUBJ TO 600 OPER CYCLES (COUPLING AND UNCOUPLING) DURING QUL IN ADDITION TO PRESSURE CYCLING AND PROPELLANT EXPOSURE TESTS. RANDOM VIB TESTING IS ALSO CONDUCTED AT ANTI VEH LEVELS FOR 34 MINUTES IN EACH AXIS. USAGE DURING SYS EVAL TESTS AT KST INCREASES UNDER ACTUAL USAGE COND. PROOF PRESSURE TESTS ARE CONDUCTED DURING ATP AND LEAKAGE TESTS ARE PERFORMED BEFORE AND AFTER OPER CYCLES. (C) AN IDENT IS PERF. RAW MATERIAL, NCE EXAM, VISUAL INSPECTION FOR CRITICAL SURFACE DEFECTS, AND EQUIPMENT CONFORMANCE TO CONTRACT REQS ARE VERIFIED BEFORE RECEIVING INSPECTION. MEASUREMENT STANDARDS AND
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

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

TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQUIREMENTS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS - PARTS PROTON, MFG. PROCESSES, COATING, ASSEMBLY AND INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77.

CORROSION PROTECTION, PROP CONTAMINATION CONTAMINATION PROCESSES, TEST HANDLING, AND STORAGE ENVIRONMENT. THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT OF MARCH 6, 1979.

INSPECTION VERIFIES ASSEMBLY PER INSPECTION POINTS IN MASTER RECORD.

LOG OF CLEAN ROOM AND CALIBRATION OF TOOLS VERIFIED. CRITICAL DIMENSION 100% VERIFIED BY INSPECTION. PARTS CLEANLINESS AND PASSIVATION VERIFIED BY INSPECTION. NOE INSPECTION PERFORMED AFTER ASSEMBLY.

TURNAROUND COUPLINGS WILL BE VISUALLY INSPECTED FOR EVIDENCE OF CAP SEAL DAMAGE AND CAP LEAKAGE. (3) APOLLO FAILURE HISTORY WAS IN THE MAIN ASSOCIATED WITH GROUND USAGE, IMPROPER HANDLING.
**HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2**

**SUBSYSTEM** AFT - RCS  
**FMEA NUMBER** 03-2A-201090-1  
**ITEM** Test Quick Disconnect  
**FAILURE MODE** External Leakage

<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>X</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><em>YES</em></td>
<td>NO</td>
</tr>
<tr>
<td>2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?</td>
<td><em>YES</em></td>
<td>NO</td>
</tr>
<tr>
<td>3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?</td>
<td><em>YES</em></td>
<td>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><em>YES</em></td>
<td>NO</td>
</tr>
<tr>
<td>4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?</td>
<td><em>YES</em></td>
<td>NO</td>
</tr>
<tr>
<td>5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?</td>
<td><em>YES</em></td>
<td>NO</td>
</tr>
<tr>
<td>6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?</td>
<td>N/A</td>
<td>YES</td>
</tr>
<tr>
<td>8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?</td>
<td>YES</td>
<td><em>NO</em></td>
</tr>
<tr>
<td>B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?</td>
<td>YES</td>
<td><em>NO</em></td>
</tr>
</tbody>
</table>

*EXPLANATION REQUIRED (SEE BELOW)*

**CHANGE/RETENTION RATIONALE SUMMARY**

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

**EXPLANATION/COMMENTS:**

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

**FMEA CHANGE RECOMMENDED**

47
SYSTEM: 61 - ELECTRIC CONTROL
SL: CA_02-03 - C1235 - 01 - 01
ACO: 0000-0000
H: 7777-7777
U: 5555-5555
S: 2222-2222
F: 1111-1111
H: 9999-9999
M: 3333-3333
C: 4444-4444
D: 5555-5555
T: 7777-7777

1. 5% FUEL BLEED, 15% EXPANSION CAN (4) LEAKS
2. 0.1% CRYSTAL CLEAR (5) LEAKS
3. 0.01% FUEL BLEED, 0.05% LEAKS
4. 0.001% CRYSTAL CLEAR (6) LEAKS
5. 0.0001% CRYSTAL CLEAR (7) LEAKS
6. 0.00001% CRYSTAL CLEAR (8) LEAKS
7. 0.000001% CRYSTAL CLEAR (9) LEAKS
8. 0.0000001% CRYSTAL CLEAR (10) LEAKS
9. 0.00000001% CRYSTAL CLEAR (11) LEAKS
10. 0.000000001% CRYSTAL CLEAR (12) LEAKS
11. 0.0000000001% CRYSTAL CLEAR (13) LEAKS
12. 0.00000000001% CRYSTAL CLEAR (14) LEAKS
13. 0.000000000001% CRYSTAL CLEAR (15) LEAKS
14. 0.0000000000001% CRYSTAL CLEAR (16) LEAKS
15. 0.00000000000001% CRYSTAL CLEAR (17) LEAKS
16. 0.000000000000001% CRYSTAL CLEAR (18) LEAKS
17. 0.0000000000000001% CRYSTAL CLEAR (19) LEAKS
18. 0.00000000000000001% CRYSTAL CLEAR (20) LEAKS
19. 0.000000000000000001% CRYSTAL CLEAR (21) LEAKS
20. 0.0000000000000000001% CRYSTAL CLEAR (22) LEAKS
21. 0.00000000000000000001% CRYSTAL CLEAR (23) LEAKS
22. 0.000000000000000000001% CRYSTAL CLEAR (24) LEAKS
23. 0.0000000000000000000001% CRYSTAL CLEAR (25) LEAKS
24. 0.00000000000000000000001% CRYSTAL CLEAR (26) LEAKS
25. 0.000000000000000000000001% CRYSTAL CLEAR (27) LEAKS
26. 0.0000000000000000000000001% CRYSTAL CLEAR (28) LEAKS
27. 0.00000000000000000000000001% CRYSTAL CLEAR (29) LEAKS
28. 0.000000000000000000000000001% CRYSTAL CLEAR (30) LEAKS
29. 0.0000000000000000000000000001% CRYSTAL CLEAR (31) LEAKS
30. 0.00000000000000000000000000001% CRYSTAL CLEAR (32) LEAKS
31. 0.000000000000000000000000000001% CRYSTAL CLEAR (33) LEAKS
32. 0.0000000000000000000000000000001% CRYSTAL CLEAR (34) LEAKS
33. 0.00000000000000000000000000000001% CRYSTAL CLEAR (35) LEAKS
34. 0.000000000000000000000000000000001% CRYSTAL CLEAR (36) LEAKS
35. 0.0000000000000000000000000000000001% CRYSTAL CLEAR (37) LEAKS
36. 0.00000000000000000000000000000000001% CRYSTAL CLEAR (38) LEAKS
37. 0.000000000000000000000000000000000001% CRYSTAL CLEAR (39) LEAKS
38. 0.0000000000000000000000000000000000001% CRYSTAL CLEAR (40) LEAKS
39. 0.00000000000000000000000000000000000001% CRYSTAL CLEAR (41) LEAKS
40. 0.0000000000000000000000000000000000000001% CRYSTAL CLEAR (42) LEAKS
41. 0.00000000000000000000000000000000000000001% CRYSTAL CLEAR (43) LEAKS
42. 0.000000000000000000000000000000000000000001% CRYSTAL CLEAR (44) LEAKS
43. 0.0000000000000000000000000000000000000000001% CRYSTAL CLEAR (45) LEAKS
44. 0.00000000000000000000000000000000000000000001% CRYSTAL CLEAR (46) LEAKS
45. 0.000000000000000000000000000000000000000000001% CRYSTAL CLEAR (47) LEAKS
46. 0.0000000000000000000000000000000000000000000001% CRYSTAL CLEAR (48) LEAKS

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SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PRESSURIZATION

P/N: ME276-0032-0009,7,19,21

P/N VENDOR: RR42670-3,7, RR42512-15,3

MISSION: HF, VP, PP, CF, SM

QUANTITY: 36

PREPARED BY: SCARLETT

APPROVED BY: MAD

PREPARED WITH CHANGES

See Section 13.0

DISCONNECT, QUICK TEST

PT: (1/4") WITH SPRING LOADED POPPET AND STRUCTURAL END CAP.

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 ACCESSIBLE AT HE SEV Panel. THE END CAP PROVIDES REDUNDANCY FOR EXTERNAL LEAK.

FAILURE MODE: EXTERNAL LEAKAGE

CAP LEAKS, SEALS DAMAGED

CAUSE(S):

VIBRATION, PIECE PART STRUCTURAL FAILURE (POPPET, SEAL), MECHANICAL SHOCK, EXCESS TORQUE, SEAL DAMAGE, INADEQUATE MAINT OF GNE HALF, VC LINE SUPPORT - SHAFT OR BORE GENT.

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

(A) LOSS OF SUBSYSTEM PRESSURIZATION OR REDUNDANCY DEPENDING ON LOCATION - (B) LOSS OF INTERFACE FUNCTION (LOSS OF PROPELLANT FEED CAPABILITY) - (C) NO EFFECT DUE TO REDUNDANT POPPET SEALS & END CAP.

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

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

(A) F.S. IS 2.0 X WORKING PRESS. ULLAGE PRESS IS ADEQ TO EXPLO PROP WITH 35 PERCENT OR LESS REMAINING. GROUN MAL COUPLINGS AND LINES ARE ADEQ SUPPORTED TO LIMIT ANY UNDUE STRESS ON THE COUPLING DURING SERVICE AND PREV DAMAGE TO SEALS AND WELD JOINTS. A SAFETY FEATURE DURING SERVICING AND PRIOR TO REMOVAL OF THE END CAP IS A PROV WHEREBY ANY LEAKAGE PAST THE AIRBORNE POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING CAP UTL OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUNDANT EXCEPT FOR STRUCT OR WELD FAILURES. (B) THE COUPLING IS DESIGNED FOR 400 OPER CYCLES (COUPLING AND UNCOUPLING) USAGE DURING SYS EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE COND. PROOF PRESS TESTS ARE CONDUCTED DURING ATP AND LEAKAGE TESTS ARE PERF BEFORE AND AFTER OPER CYCLES. (C) AN IDENT IS PERF AND THE UNIT TAGGED.

RAW MAT'L: NO EXAM OF WELDS, VISUAL INSPE. OF WELD JOINTS FOR
SUBSYSTEM: AFT - REACTION CONTROL

Conformance to standard weld practice, surface defects, and equip
conformance to contract rights are verified by receiving insp. Measurement
standards and test equip. Standards are implemented per specs of "IL
specs." The following items are verified by shop traveler mandatory insp
points: parts prot, fpg, processes, coating, plating, assy and
installation. The above items and the following items were verified by
audit conducted 11-3-76. Cjorts prot prov, contain cnt processes, test
handling, and storage envir. Turnaround: couplings will be visually
inspected for evidence of seal damage and cap leakage. (Couplings
between the helium isol valve & regulator & those associated with prop
tank c/o are not accessible at servicing panels) (c) apollo failure
history was in the main assoc with ground usage, improper handling.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   YES [X] NO [ ]

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

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

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

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

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

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

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. [X] 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)
FUEL PUMPS FAIL AND EFFECTS ANALYSIS – 31 MAR. 73

**Original Page Is Of Poor Quality**
SUBSYSTEM : AFT -REACTION CONTROL  
ASSEMBLY : PRESSURIZATION  
P/N : MC24-3481-0021/-0002  
Quant : 4  
P/N VENDGR : RS01050-001-011  
MISSIONS : HF VF X FF CF SM  
PHASE(S) : PL 13 X OC X O O X LS  
RESONDANCY SCREEN : 8-PASS 8-FAIL C-PASS  
PREPARED BY :  
APPROVED BY :  
DEP : R. BURKHART  
REL : G. MAKERS  
APPROVED WITH CHANGES  
See Section 13.0  

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 qualification. This item is used during system evaluation tests at WSTF allowing evaluation under simulated mission usage conditions. Proof pressure, leakage & operation (cracking pressure and flow) tests are performed during ATP. Appropriately located test points allow pre/post flight leakage tests and operation tests which are conducted at this time. (C) An identification is performed and the unit tagged.
SUBSYSTEM :AFT - REACTION CONTROL  FMEA NO 03-2A -231095-2  REV:12/12/76
CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, "DE EXAM.
OF WELDS AND BRAZES. INS. FOR SURFACE AND SUBSURFACE DEFECTS ARE
VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP
TRAVELER MANDATORY INS. POINTS - RAW MATERIAL (LOT CERTIFICATION), PARTS
PROTECTION, MANUF., COATING, PLATING INSTALLATION AND ASSEMBLY
OPERATIONS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY
AUDIT CONDUCTED 12-2-77. CONTAMINATION CONTROL PROCESSES, CORROS.
PROTECTION PROVISIONS, TURNAROUND - FUNCTIONAL FLOW AND LEAKAGE
(BACK-FLOW) TESTS ARE PERFORMED. (O) NO PRIOR HISTORY FOR CLOSE FAILURE
MODE FOR THIS TYPE OF DESIGN.
<table>
<thead>
<tr>
<th>Item</th>
<th>Feedline &amp; Fittings, Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong></td>
<td>DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?</td>
</tr>
<tr>
<td>1a.</td>
<td>IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?</td>
</tr>
<tr>
<td>2.</td>
<td>ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?</td>
</tr>
<tr>
<td>3.</td>
<td>DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?</td>
</tr>
<tr>
<td>3a.</td>
<td>IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?</td>
</tr>
<tr>
<td>4.</td>
<td>AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?</td>
</tr>
<tr>
<td>5.</td>
<td>CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?</td>
</tr>
<tr>
<td>6.</td>
<td>HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.</td>
</tr>
<tr>
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<td>IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?</td>
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<td>8.</td>
<td>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?</td>
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<th>Change/Retention Rationale Summary</th>
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<tr>
<td>1. NO H/S ISSUES</td>
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<td>2. HARDWARE ACCEPTS RISK</td>
</tr>
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<td>3. NO SOFTWARE DETECTION</td>
</tr>
<tr>
<td>4. DETECTION DURING CHECKOUT</td>
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<tr>
<td>5. ACCEPTANCE RATIONALE BELOW</td>
</tr>
<tr>
<td>6. RECOMMENDED CHANGES BELOW</td>
</tr>
</tbody>
</table>

**In-flight detectability**

![FMEA CHANGE RECOMMENDED]

**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.
SPECIAL FUELS ENGINE ANALYSIS - GENERAL

1. SPECIFIC OR MODIFIED FUEL VALVES, 2) TANK ISOLATION VALVES, 3) INJECTORS

PROCEDURE:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF 
   TANK ISOLATION VALVES, AND IN LOCATION OF CATHEXIS INJECTORS.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC PROPS:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIAL ANALYSIS:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC EXPLANATION:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC WARNING:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC TURBINES:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC MACHINES:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC IMPROVEMENTS:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC COMPLAINTS:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC NEGATIVE:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC NEUTRAL:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC POSITIVE:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC FACTS:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC IMAGES:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC DATA:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC RESULTS:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.

SPECIFIC SUMMARY:
1) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
2) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
3) INSTALL CATHEXIS INJECTOR VALVE IN LOCATION OF TANK ISOLATION VALVES.
SUBSYSTEM: AFT - REACTION CONTROL  
ASSEMBLY: PROPELLANT FEED, FUEL  
P/N: MC621-0059  
P/N VENDOR: 73A560001  
QUANTITY: 2  

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

FUNCTION:  
(1) 1 1/2 X 0.283 304 L.S.S. FROM TANK TO DISTRIBUTION PANEL,  
(2) 1 1/4 X 0.283 FROM MANIFOLD ISOLATION VALVE TO THRUSTER MANIFOLD,  
(3) 5/8 X 0.28 THRUSTER MANIFOLD TO PROVIDE FEED TO APPROPRIATE PROPELLANT COMPONENTS FOR THRUSTER OPERATION.

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

CAUSE(S):  
VIB, FATIGUE, SHOCK, WELD DEF, INSTALL DAM, DYNAI-door SEAL FAILURE, "AT" DEF (SULPHIDE STRINGER).

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

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

(B) ROCKWELL PERFORMED TUBING CERTIFICATION TESTS PER "ORBITER TUBING VERIFICATION PLAN" (SD 75-SH-0205). THIS TESTING INCLUDED PRESSURE CYCLING AND FATIGUE FOR TYPICAL SHUTTLE LINES & JOINTS. 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

MANDATORY INSPECTION POINTS: RAW MATERIAL (LOT CERTIFICATION), PARTS PROTECTION, MANUFACTURING, COATING, PLATING, INSTALLATION AND ASSEMBLY OPERATIONS.

HARDWARE IS INSPECTED IN ACCORDANCE WITH QUALITY PLANNING REQUIREMENTS (QPRD) WHICH HAS BEEN APPROVED BY NASA. TURNAROUND LINES IN ACCESSIBLE AREAS ARE VISUALLY INSPECTED FOR EVIDENCE OF DAMAGE AND FLOW AND PRESSURE FUNCTIONAL TESTS ARE MONITORED FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE. (D) MINOR HISTORY - CORROSION/FOG PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.

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

   YES  X NO  

2a. 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 ALTERNATIVE 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 ALTERNATIVE PROGRAM LOGIC)?

   *YES  X NO  

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

   YES  X NO  

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

   *YES  X NO  

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

   *YES  X  NO  2

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

   YES  X  NO  

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

   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?

   YES  X  NO  

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

   YES  X  NO  

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

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

EXPLANATION/COMMENTS:

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED, OXIDIZER
P/N: MC621-0059
P/N VENDOR: 73A550002
MISSION: HF VFC X FF TC SM
MISSION: HF VFC X FF TC SM
QUANTITY: 2
PHASE(S): PL X LO X CO X DO X LS X

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

FUNCTION:
(1) 1 1/4 x 0.22 B304 L SS FROM TANK TO DISTRIBUTION PANEL,
(2) 1 1/2 x 0.28 FROM MANIFOLD ISOLATION VALVE TO THRUSTER MANIFOLD
(3) 3/4 x 0.28 MANIFOLD TO PROVIDE FEED TO APPROPRIATE PROPELLANT
COMPONENTS FOR THRUSTER OPERATION - 3 AXIS ACCELERATION CONTROL AND
ROTATIONAL CONTROL.

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

CAUSE(S):
MECHANICAL SHOCK, VIBRATION/FATIGUE, IMPROPER INSTALLATION (WELD).
DYNATUBES HAVE DUAL SEALING SURFACES. THE WELDED CONSTRUCTION
ELIMINATES JOINTS AND POSSIBLE LEAK PATHS. THE ANNEALED AREA (DUE TO
WELDING) IS BACKED UP BY A SLEEVE. FASTENING CLAMPS ALSO ALLOW FREEDOM
OF MOVEMENT. TUBING BENDS ARE CONTROLLED BETWEEN FIXED POINTS TO
ACCOMMODATE INSTALLATION AND ACCOMMODATE VEHICLE GROWTH AND MOVEMENT.
ROKWELL PERFORMED TUBING CERTIFICATION TESTS PER "ORBITER" TUBING
VERIFICATION PLAN" (SD75-SH-0205). THIS TESTING INCLUDED PRESSURE
CYCLING AND FATIGUE FOR TYPICAL SHUTTLE LINES & JOINTS.

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

(ROKWELL PERFORMED TUBING CERTIFICATION TESTS PER "ORBITER" TUBING
VERIFICATION PLAN" (SD75-SH-0205). THIS TESTING INCLUDED PRESSURE
CYCLING AND FATIGUE FOR TYPICAL SHUTTLE LINES & JOINTS.

SYSTEM EVALUATION IN THE INSTALLED SYSTEM CONDITION. LEAKAGE TESTS ARE
PERFORMED AT THIS TIME IN ADDITION TO X-RAY AND DYE PENCENTRANT.
LEAKAGE TESTS ARE ALSO PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND
ADDITIONAL WELDS ARE ALSO SUBJECTED TO NDE. (C) AN IDENTIFICATION IS
PERFORMED AND THE UNIT TAGGED. CONTAM. CONTROL PROCESSES, CORROS.
PROTECTION PROVISIONS, NDE EXAM OF WELDS AND INSPECTION. 
SUB SURFACE AND
SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE
VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS - RAW MAT'L (LOT

997
SD75-SH-0003
63
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-24 -202109-1  REV:11/30/78
CERTIFICATION; PARTS PROTECTION, MANUF., CJATING, PLATING, INSTALATION
AND ASSEMBLY OPERATIONS. HARDWARE IS INSPT. IN ACCORDANCE WITH QUALITY
PLANNING REQUIREMENTS DOCUMENT (QPRD) WHICH HAS BEEN APPROVED BY NASA.

TURNAROUND: LINES IN ACCESSIBLE AREAS ARE VISUALLY INSPECTED FOR
EVIDENCE OF DAMAGE AND FLOW AND PRESSURE FUNCTIONAL TESTS ARE MONITORED
FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE. (2) MINOR HISTORY -
CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.
ARE MONITORED FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE. (3) MINOR
HISTORY - CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND
CORRECTED.
1. Does the flight software detect this failure mode (i.e., automatically announce or take action in response)?
   - Yes [X] No [ ]

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

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

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

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

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

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

6. How many of these hardware failures can the shuttle tolerate (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 [ ] No [X]

*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

---

**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.
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1. THE ILLUSTRATED EFFECTS ANALYSIS - Continued

- SYSTEM 1 IN FLIGHT? YES
- PRIMARY VALVE POSITION INDICATION
- SECONDARY VALVE ACTUATION

PREPARED BY: ALPHABETIC.

VALOR M. GONZALEZ

DEL.

K.E.

FAILS VALVES

FAILS TO OPEN VALVES TO REMAIN OPEN.

COS (5):

1. LIMIT SOLE MALFUNCTION; PREMATURE POWER TO ACTUATE ELECTRICAL SIGNAL, NOT BEEN RECEIVED OR FALL SHORT IN CIRCUIT.

COS (S) IN DISC SYSTEMS (INTERFACES (CATEGORIES (.)) CANNOT BE:

- SYSTEMS OR SUBSYSTEMS MALFUNCTION; UNEXPECTED MALFUNCTIONS (INTEGRITY PROBLEMS) CAUSED BY INCREASED PRESSURE, ETC. INCREASED PRESSURE INCREASED MALFUNCTIONS MAY LIE THE MANIFOLDS.

- MILLION SYSTEM INTEGRITY MAFUNCTION; UNEXPECTED MALFUNCTIONS (INTEGRITY PROBLEM) CAUSED BY INCREASED PRESSURE, ETC. INCREASED PRESSURE INCREASED MANIFOLDS MAY LIE THE MANIFOLDS.

- MILLION SYSTEM INTEGRITY MAFUNCTION; UNEXPECTED MALFUNCTIONS (INTEGRITY PROBLEM) CAUSED BY INCREASED PRESSURE, ETC. INCREASED PRESSURE INCREASED MANIFOLDS MAY LIE THE MANIFOLDS.

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- MILLION SYSTEM INTEGRITY MAFUNCTION; UNEXPECTED MALFUNCTIONS (INTEGRITY PROBLEM) CAUSED BY INCREASED PRESSURE, ETC. INCREASED PRESSURE INCREASED MANIFOLDS MAY LIE THE MANIFOLDS.

- MILLION SYSTEM INTEGRITY MAFUNCTION; UNEXPECTED MALFUNCTIONS (INTEGRITY PROBLEM) CAUSED BY INCREASED PRESSURE, ETC. INCREASED PRESSURE INCREASED MANIFOLDS MAY LIE THE MANIFOLDS.

- MILLION SYSTEM INTEGRITY MAFUNCTION; UNEXPECTED MALFUNCTIONS (INTEGRITY PROBLEM) CAUSED BY INCREASED PRESSURE, ETC. INCREASED PRESSURE INCREASED MANIFOLDS MAY LIE THE MANIFOLDS.

- MILLION SYSTEM INTEGRITY MAFUNCTION; UNEXPECTED MALFUNCTIONS (INTEGRITY PROBLEM) CAUSED BY INCREASED PRESSURE, ETC. INCREASED PRESSURE INCREASED MANIFOLDS MAY LIE THE MANIFOLDS.

- MILLION SYSTEM INTEGRITY MAFUNCTION; UNEXPECTED MALFUNCTIONS (INTEGRITY PROBLEM) CAUSED BY INCREASED PRESSURE, ETC. INCREASED PRESSURE INCREASED MANIFOLDS MAY LIE THE MANIFOLDS.

- MILLION SYSTEM INTEGRITY MAFUNCTION; UNEXPECTED MALFUNCTIONS (INTEGRITY PROBLEM) CAUSED BY INCREASED PRESSURE, ETC. INCREASED PRESSURE INCREASED MANIFOLDS MAY LIE THE MANIFOLDS.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N PI: 4C284-0430-0007/6038
P/N VENDOR: 5750023/5750026
QUANTITY: 12

THREE VALVES PER PROP TANK

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

PREPARED BY: R GONZALEZ
APPROVED BY: POPEL
REL: C M AKEPS

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

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

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

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

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A-B) LOSS OF REDUNDANCY PROPellant FLOW TO TWO MANIFOLDS (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 VAL VE CLOSED MAY LOSE TWO MANIFOLDS). (D) NO EFFECT FOR SINGLE FAILURE FOR OLT 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 POOL AFT) IS CRITICAL FOR SEPARATION & MATED COAST DURING RTLS. (E) FUNCTIONAL CRITICALITY EFFECT POSSIBLE CREW/VEHICAL LOSS DUE TO UTILIZE/DEPLETE RCS PROPellant. POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO UTILIZE RESERVED PROPellant & CG 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 POTENTIAL FOR CONTAMINATION CAUSED FAILURE OR JAMMING OF MOVING PARTS.

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SHUTTLE CRITICAL ITEMS LIST - CHAPTER 102

SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A -222110-1  REV:12/12/73

(R) 2500 OPERATION CYCLES (OPEN-CLOSE-OPEN) AND RANDOM VIBRATION AT
ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED
DURING SYSTEM EVALUATION TESTS AT WSTF ALLOWING EVALUATION UNDER SIM-
ULATED MISSION USAGE CONDITION. PROOF PRESSURE, LEAKAGE, OPERATION,
CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT. (C) A VISUAL INSPECTION AND
IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL PROCESS, CORROS-
SION PROTECTION PROVISIONS, NO EXAM OF WELDS, INSPECTION FOR SURFACE AND
SUBSURFACE DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MATERIAL (LOT)
CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE
VERIFIED BY INSPECTION. MANUFACTURING, INSTALLATION, AND ASSY. OPERATIONS ARE
VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND
THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED JULY 1976;
CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE
ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIPMENT, RAW MATERIAL AND EQUIP-
MENT CONFORMANCE TO CONTRACT REQUIREMENTS. TURNCAP/FUNCTIONAL FLOW & LEAKAGE
TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON
COMMAND. (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
**SUBSYSTEM**  | AFT - RCS  | **FMEA NUMBER**  | 03-2A-202110-3  
**ITEM**  | Tank Isolation Valve, A. C.  | **FAILURE MODE**  | Fails Open  

1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY)**  
   - ANNOUNCE 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 [ ] NO [X]  

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

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

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

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


**EXPLANATION/COMMENTS:**

1A. Tank isolation valve discreets are available.


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

SUBSYSTEM: AFT - REACTION CONTROL  
ASSEMBLY: PROPELLANT FEED  
P/N: 2MC234-0430-0007/-0083  
P/N VENDOR: 575COZ575-0026  
MISSIONS: HF VF X FF CF SM  
QUANTITY: 12  
THREE VALVES PER PROP TANK  
REDOUNDANCY SCREEN: 1-PASS 8-PASS C-PASS  

PREPARED BY:  
APPROVED BY:  
APPROVED 3A (NASA)  

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

ITEM: VALVE  
TANK ISOLATION 3 PHASE 400 HZ AC MOTOR ACTUATED (L15-26) LV261-266, LV361-366.  
FUNCTION:  
THREE REDUNDANT ISOLATION VALVES ARE USED PER TANK TO ISOLATE GROUPS OF MANIFOLDS (ONE TANK ISOL VALVE CONTROLS 2 MANIFOLDS AND THE OTHER MANIFOLD CONTROLS THE REMAINING 2 PRIMARY MANIFOLDS AND THE VERTICAL MANIFOLD) THAT MAY EXHIBIT OPEN OR LEAKAGE FAILURES AND TO ISOLATE THE TANK DURING INTERCONNECT & PCS OR GMS CROSSFED OPERATIONS. ALSO USED TO PREVENT HELIUM INGESTION TO ENGINES AT PROP RUN-OUT (MANUAL SWITCH). FUEL & OXID-valves can be operated independently for C/O. LINE PRESS RELIEF TO TANK IS PROVIDED.  
FAIL MODE: INTERNAL LEAKAGE  
FAILS OPEN, FAILS TO CLOSE, FAIL TO REMAIN CLOSED.  
CAUSE(S):  
VIBRATION, LIMIT SWITCH MALFUNCTION, STRUCTURAL FAILURE, SEAT CRACKS, CONTAMINATION, CORROS, LOSS OF SIGNAL (RPC SHORTS OR OPEN).  
EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:  
(A&B) LOSS OF REDUNDANCY - MANIFOLD ISOLATION. (C) 49RT البنطلס DECISION - PROPELLANT MANAGEMENT PROBLEMS DURING CROSSFED OPERATIONS. (D) NO EFFECT - CRIT 1 FOR RTLS. IF RCS TANK ISOLATION VALVE WILL NOT CLOSE DURING OMS DEPLETION BURN THE RCS PROPELLANT MAY BE DEPLETED IF ASSOCIATED MANIFOLD ISOLATION VALVES ARE NOT CLOSED.  

ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM : AFT - REACTION CONTROL FMEA NO 03-2A -202110-3  REV:12/12/78
VERIFIED BY SHOP TRAVERLER MANDATORY INSP 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 REQS. TURNAPOUND - FUNCTIONAL FLOW & LEAKAGE
TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON
COMMAND. (G) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY)**?  
   - **YES** ☑ **NO** ☐

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)*

**CHANGE/RETENTION RATIONALE SUMMARY**

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

**EXPLANATION/COMMENTS:**

1. "Failed off" thruster gives first indication.

6. One success path remains after first failure.

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

LOAD FAILURE AND REL EFFECTS ANALYSIS – 23 May 77

PREPARED BY:  [LEO R. GONZALEZ]
APPROVED BY:  [RES. INF. L. H. MURO]

VALVE:

1. TEMPERATURE AT VALVE (0.1°C) - 50°C ± 7°C.

REL:

2. RE-TEST DEVELOPMENT IN RUN-UP.

NOTE:

1. ALTERNATE UNIT IN SERVICE. YES

S.

ALTERNATE UNIT

PREPARED BY:  [LEO R. GONZALEZ]
APPROVED BY:  [RES. INF. L. H. MURO]
SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PROPELLANT FEED

P/N: 6C236-0430-0317/003

P/N VENDOR: 5750025/5750026

QUANTITY: 8

TWO INTERCONNECT LINES PER PROPellant TANK

REGULARITY SPLIT: A-PASS B-PASS C-PASS

PREPARED BY: R. Gonzalez, R. US

APPROVED BY: C. Makers, R. USE

APPROVED WITH CHANGES See Section 13.0

ITEM: VALVE

INTERCONNECT, 3 PHASE 400 HZ AC MOTOR OPERATED (115-200V), ACS/RCS (1/12"

FUNCTION:

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

FAILURE MODE: FAILS CLOSED (F)

CAUSE(S):

VIB, LIMIT SW FAILURE, PREMIUM POWER TO MOTOR, ELECTRICAL SHORT, RCS
OPEN, JAMMING OF VALVE.

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

(A) LOSS OF REDUNDANCY, (B) DEGRADATION OF INTERFACE
FUNCTION CROSSFEED PROP CAN BE UTILIZED BY ONLY 2 OF 4 MANIFOLD BANKS.
(C) MISSION MODIFICATION - OPERATION CHANGES PROP ITEM AS ABOVE. (D) NO
EFFECT FOR OBT MISSIONS (LOSS OF THRUSTER MAY BE CRITICAL FOR RTLS IN
SUBSEQUENT MISSIONS FOR CMS DEPLETION BURN). CRIT L FOR RTLS - LOSS OF
1 MANIFOLD FORWARD & 1 MANIFOLD AFT IS CRITICAL FOR ET SEPARATION &
MATED COAST DURING RTLS. SINGLE COMPUTER FAILURE COULD RESULT IN THIS
TYPE CONDITION. (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE EARLY
MISSION TERMINATION - INABILITY TO DEMONSTRATE CMS PRed FEED TO RCS.

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

(A) AC MOTOR VALVE IS 3-PHASE - 2 OF 3 WINDINGS ARE ADEQUATE FOR VALVE FUNCTION.
SERIES (HYBRID) RELAYS PROVIDE REDUNDANCY FOR THE PREMATURE CLOSE MODE. PARALLEL
(HYBRID) RELAYS PROVIDE REDUNDANCY FOR ELECTRICAL POWER SIGNAL. ADDITIONALLY,
REDUNDANT VALVES ARE PROVIDED. A 400-MICRON FILTER IS UTILIZED ON THE INLET AND
OUTLET TO LIMIT THE POTENTIAL FOR CONTAMINATION CAUSED FAILURE OR JAMMING OF MOVING
PARTS. (B) 2500 OPERATIONAL CYCLES (OPEN-CLOSE-OPEN) AND RANDOM VIBRATION AT
ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYSTEM
EVALUATION TESTS AT WSTF ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION.
PROOF PRESSURE, LEAKAGE, OPERATION, CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT.
(C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL PROCESS.
CORDS, PROTECTION PROVISIONS, WELD 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. MANUFA,
INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION.

THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED.

1022

SD75-SE-0003
SUBSYSTEM: AFT - REACTION CONTROL  FMEA NO. 03-2A-202111-2  REV: 12/12/78
JULY 1976/CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND
STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP. AND MAT'L
AND EQUIP CONFORMANCE TO CONTRACT REQS.  TURNAROUND/FUNCTIONAL FLOW &
LEAKAGE TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY
UPON COMMAND. (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   - YES [X] NO []
   1a. IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?
   - YES [X] NO []

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY:

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

EXPLANATION/COMMENTS:

3. RCS RM automatically detects and prevents thrusting.
AN ANALYSIS OF THE EFFECTS OF RACE ON ECONOMIC OPPORTUNITIES

The original page is of poor quality.
SHUTTLE CRITICAL ITEMS LIST - CRBITER 102

SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PROPELLANT FEED

P/N: MC 284-0430-0001/-0002

P/N VENDOR: 5730023/5790024

QUANTITY: 16

ASSEMBLY: PROPELLANT FEED ABORT: AABCPT.

FUNCTION: 1) TO ISOLATE THRUSTERS FROM PROPELLANTS PRIOR TO SYSTEM ACTIVATION AND 2) TO ISOLATE FAILED OPEN THRUSTER OR DOWNSTREAM LEAK. EACH MANIFOLD ISOLATION VALVE CONTROLS 3 PRIMARY THRUSTERS.

FAILURE MODE: FAILS CLOSED-PREMA TURE OPERATION, FAILS TO REMAIN OPEN.

CAUSE(S): VIBRATION, LIMIT SWITCH MALFUNCTION, PREMATURE POWER TO MOTOR, PREMATURE MOTOR SIGNAL, POSSIBLE 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 1 OF 4 MANIFOLDS. (D) NO EFFECT FOR SINGLE FAILURE FOR 1 OF 4 MANIFOLDS. (C) (D) NO EFFECT FOR SINGLE FAILURE FOR 1 OF 4 MANIFOLDS.

MISSIONS: HF VF X FF CF SM

PHASE(S): PL LO X CC X D0 X LS

RECORDS: A PASS 3 PASS C PASS

PREPARED BY: APPROVED BY:

R. GONZALEZ C M AKERS

REL C. STORM

APPROVED

PREPARED WITH CHANGES

ITEM: VALVE

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

FUNCTION:

1) TO ISOLATE THRUSTERS FROM PROPELLANTS PRIOR TO SYSTEM ACTIVATION AND 2) TO ISOLATE A FAILED OPEN THRUSTER OR DOWNSTREAM LEAK. EACH MANIFOLD ISOLATION VALVE CONTROLS 3 PRIMARY THRUSTERS.

FAILURE MODE: FAILS CLOSED-PREMA TURE OPERATION, FAILS TO REMAIN OPEN.

CAUSE(S): VIBRATION, LIMIT SWITCH MALFUNCTION, PREMATURE POWER TO MOTOR, PREMATURE MOTOR SIGNAL, POSSIBLE 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 1 OF 4 MANIFOLDS. (D) NO EFFECT FOR SINGLE FAILURE FOR 1 OF 4 MANIFOLDS. (C) (D) NO EFFECT FOR SINGLE FAILURE FOR 1 OF 4 MANIFOLDS.

MISSIONS: HF VF X FF CF SM

PHASE(S): PL LO X CC X D0 X LS

PREPARED WITH CHANGES

PREPARED WITH CHANGES

ITEM: VALVE

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

FUNCTION:

1) TO ISOLATE THRUSTERS FROM PROPELLANTS PRIOR TO SYSTEM ACTIVATION AND 2) TO ISOLATE A FAILED OPEN THRUSTER OR DOWNSTREAM LEAK. EACH MANIFOLD ISOLATION VALVE CONTROLS 3 PRIMARY THRUSTERS.

FAILURE MODE: FAILS CLOSED-PREMA TURE OPERATION, FAILS TO REMAIN OPEN.

CAUSE(S): VIBRATION, LIMIT SWITCH MALFUNCTION, PREMATURE POWER TO MOTOR, PREMATURE MOTOR SIGNAL, POSSIBLE 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 1 OF 4 MANIFOLDS. (D) NO EFFECT FOR SINGLE FAILURE FOR 1 OF 4 MANIFOLDS. (C) (D) NO EFFECT FOR SINGLE FAILURE FOR 1 OF 4 MANIFOLDS.

MISSIONS: HF VF X FF CF SM

PHASE(S): PL LO X CC X D0 X LS

PREPARED WITH CHANGES

PREPARED WITH CHANGES

ITEM: VALVE

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

FUNCTION:

1) TO ISOLATE THRUSTERS FROM PROPELLANTS PRIOR TO SYSTEM ACTIVATION AND 2) TO ISOLATE A FAILED OPEN THRUSTER OR DOWNSTREAM LEAK. EACH MANIFOLD ISOLATION VALVE CONTROLS 3 PRIMARY THRUSTERS.

FAILURE MODE: FAILS CLOSED-PREMA TURE OPERATION, FAILS TO REMAIN OPEN.

CAUSE(S): VIBRATION, LIMIT SWITCH MALFUNCTION, PREMATURE POWER TO MOTOR, PREMATURE MOTOR SIGNAL, POSSIBLE 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 1 OF 4 MANIFOLDS. (D) NO EFFECT FOR SINGLE FAILURE FOR 1 OF 4 MANIFOLDS. (C) (D) NO EFFECT FOR SINGLE FAILURE FOR 1 OF 4 MANIFOLDS.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

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 Announce or Take Action in Response)?**
   - **YES** ☑  **NO** ☐  **X** ☐

1a. **If Not, Does the Hardware Provide Information that the Flight Software Could Use to Detect the Failure?**
   - **YES** ☑  **NO** ☐  **X** ☐

2. **Are the Answers to Questions 1 and 1a Consistent with the FMEA Evaluation of In-Flight Detectability?**
   - **YES** ☑  **NO** ☐  **X** ☐

3. **Does the Flight Software Take Action to Negate the Effects of the Failure (Either by Commanding Hardware Action or Implementing Alternate Program Logic)?**
   - **YES** ☑  **NO** ☐  **X** ☐

3a. **If Not, Does the Capability Exist for the Software to Compensate for this Failure Mode (Either by Commanding Hardware Action or Implementing Alternate Program Logic)?**
   - **YES** ☑  **NO** ☐  **X** ☐

4. **As a Result of this Failure Mode, Can the Software Overstress the Hardware or Induce Another Failure?**
   - **YES** ☑  **NO** ☐  **X** ☐

5. **Can this Failure Mode, in Combination with Software Logic, Adversely Affect Other Functions?**
   - **YES** ☑  **NO** ☐  **X** ☐

6. **How Many of these Hardware Failures Can the Shuttle Tolerate (Consider Crew Action and Hardware/Software Operation)? Note Change to FMEA Criticality.**
   - **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** ☐

*Explanations Required (See Below)*

**Change/Retention Rationale Summary**


**Explanation/Comments:**

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

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

8B. Same as primary.


- TITLE: failure, flight and collision analysis - 31st Dec

- OBJECTIVE: detect and mitigate collision threats

- TECHNIQUES: visual and radar scanning

- PHASE (I): initiation of contingency procedures

- PHASE (II): activation of RCS thrusters

- SAFETY FEATURES: redundant thruster systems

- EMERGENCY PROCEDURES:
  - (A) RCS thruster activation
  - (B) RCS thruster failure

- SAFETY VERIFICATION:
  - RCS thruster redundancy
  - RCS thruster fail-safe mechanisms

- ACTIVITY: mission continuation

- COORDINATION:
  - RCS thruster activation
  - RCS thruster failure

- POSSIBLE EFFECTS:
  - Mission continuation
  - Collision avoidance

- PREPARATION:
  - RCS thruster activation
  - RCS thruster failure

- APPROVAL:
  - RCS thruster activation
  - RCS thruster failure

- CONCLUDING STATEMENTS:
  - Mission continuation
  - Collision avoidance

- ORIGINAL PAGE IS OF POOR QUALITY
ITEM: VALVE.
MANIFOLD ISOLATION, VERNIER THRUSTER, SCLENIO (28VDC) 31-5ABLE (LATCHING) LV 258/257/357/358.

FUNCTION:
TO PROVIDE VERNIER THRUSTER ISOLATION: 1) PRIOR TO SYSTEM ACTIVATION
AND 2) IN THE EVENT OF A RUNAWAY THRUSTER OR MANIFOLD LEAK.

FAILURE MODE: Fails closed. (F)

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

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) OTHER VEHICLE:
(4) LOSS OF FUNCTION (VERNIER THRUSTER). (A) LOSS OF FUNCTION OR INTERFACE SUBSYSTEM-PAYLOAD MANIPULATION. (C) MISSION MODIFICATION OR ABORT DECISION. (D) NO EFFECT UNLESS ADDITIONAL FAILURES OCCUR.

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

100 Micron Filter is use to LIMIT THE POSS OF CONTAM CAUSING JAMMING MOVING PARTS.

The above items and the following items were verified by audit.

1018
86
SD75-SE-0003
SUBSYSTEM : AFT - REACTION CONTROLL FMEA NO 03-24 -202140-1 REV:12/12/73 3-31-77. CONTAM CONT PROG, CORROS. PROT PROV TURNAROUND- FUNCT FLOW TESTS ARE MANDIT TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON COMMAND. (D) APOLLO FAILURES WERE MAINLY ASSOCIATED WITH REVERSE POLARITY AND DEGUASSING OF MAGNETS. THE SHUTTLE VALVE UTILIZES A CONNECTOR (RATHER THAN LEAD WIRES) AND A BLOCKING DIODE WHICH PREVENTS THIS TYPE OF ERROR DURING CONN. DEVEL TEST, AND ANAL SHOWED PRESS SURGE FATIGUE PROBLEM. THIS IS BEING RESOLVED BY REDUCING THE LIFE OF THE VALVE TO 50 MISSIONS.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST

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

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th><em>Required</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1a. IF NOT, <strong>DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?</strong></td>
<td></td>
<td></td>
<td></td>
</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></td>
<td><em>YES</em></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></td>
<td><em>YES</em></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></td>
<td><em>YES</em></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><em>YES</em></td>
<td></td>
</tr>
<tr>
<td>5. <strong>CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?</strong></td>
<td></td>
<td></td>
<td></td>
</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></td>
<td></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></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. <strong>IF THE ANSWER TO EITHER 1 OR 3 IS YES:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8a. <strong>CAN THE BFS BE ENGAGED AFTER OCCURRENCE?</strong></td>
<td></td>
<td><em>YES</em></td>
<td></td>
</tr>
<tr>
<td>8b. <strong>WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?</strong></td>
<td></td>
<td><em>YES</em></td>
<td></td>
</tr>
</tbody>
</table>

| Explanation Required (See Below) | |

### CHANGE/RETENTION RATIONALE SUMMARY

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

---

**EXPLANATION/COMMENTS:**

1. Gross leak detection will give first indication.
2. There is one success path remaining after the first failure.
3. Same as primary.
4. Measurements V42P2313C, 2315C, 2313C and 3315C are not listed in the MML.

---

**In Flight Detectability**  
**FMEA CHANGE RECOMMENDED**

---

88
SHUTTLE CRITICAL ITEMS LIST - CRITERIA 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT ABORT CRIT. Func: 1
P/N: MC276-0016
P/N VENDOR: 76306000 & 76306000
MISSIONS: H= V F X FF OF SM
PHASE(S): PL LO X CO X DO X LS
QUANTITY: 12

PREPARED BY: 
APPROVED BY: 
APPROVED BY: NASA: 
APPROVED WITH CHANGES 
See Section 13.0

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 CCUPLING (FUEL-LEFT POD AND OX-RIGHT POD) SERVICES APCs AND CMS. ITEM INCORPORATES SECONDARY INTERNAL SEALS AND HAS A PRESSURE CAP WHICH IS REDUNDANT SEAL. CAP INSTALLED PRIOR TO FLIGHT.

FAILURE MODE: CAP LEAKS IN EXCESS OF ACCEPTABLE RATE, SEALS CAVAGE) RETAINING BUT LOOSENS NEGATING CAP SEAL REDUNDANCY.

CAUSE(S): VIBRATION, PIECE PART STRUCTURAL FAILURE, MECHANICAL SHOCK, EXCESS TORQUE, SEAL DAMAGE, NO LINE SUPPORT- SHAFT OR CORE SENT, INADEQ MAINT 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 ADEQ SUPPORTED TO LIMIT ANY UNDUE STRESS ON THE COUPLING DURING SERVICE AND PREV DAMAGE TO SEALS. A SAFETY FEATURE PRIOR TO REMOVAL OF THE END CAP IS A PROV WHERBY ANY LEAKAGE PAST THE FIREWE CAN BE VENTED OVERBOARD BY ROTATING A BLEED SCREW. COMPLETE STRESS ANAL HAS BEEN CONDUCTED. UTIL OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUNDANT SEAL EXCEPT FOR STRUCT 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. RANDOM VIB TESTING IS ALSO CONDUCTED AT ANTIC VEH LEVELS FOR 34 MINUTES IN EACH AXIS. USAGE DURING SYS EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE COND. PROOF PRESS TESTS ARE CONDUCTED DURING AT & LEAKAGE TESTS ARE PERF BEFORE & AFTER OPER CYCLES. (C) AN IDENT IS PERF. RAW MATIL NDE EXAM, VISUAL INSPE FOR SURFACE DEFECTS, & EQUIP CONFORMANCE TO CONTRACT REQMTS ARE VERIF BY RECEIVING INSPE. MEASUREMENT STANDARDS & TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQMTS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPE POINTS-PARTS.

SD75-SH-0003
SUBSYSTEM : AFT - REACTION CONTROL  PMA NO 03-23-202150-1 REV: 11/06/75

PROT. MFG. PROCESSES, COATING, ASSY AND INSTALLATION. THE ABOVE ITEMS
& THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77. CORPOS
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 INSPI FOR EVID OF DAMAGE SEALS & LEAK
TESTS ARE PERFORMED. (D) APOLLO FAILURE HISTORY WAS IN THE MAIN ASSOC
WITH GROUND USAGE, IMPROPER HANDLING.
<table>
<thead>
<tr>
<th>QUESTION</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>
</tr>
<tr>
<td>1a. If not, does the hardware provide information that the flight software could use to detect the failure?</td>
</tr>
<tr>
<td>2. Are the answers to questions 1 and 1a consistent with the FMEA evaluation of in-flight detectability?</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>
</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>
</tr>
<tr>
<td>4. As a result of this failure mode, can the software overstress the hardware or induce another failure?</td>
</tr>
<tr>
<td>5. Can this failure mode, in combination with software logic, adversely affect other functions?</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>
</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>
</tr>
<tr>
<td>8. If the answer to either 1 or 3 is yes:</td>
</tr>
<tr>
<td>A. Can the BFS be engaged after occurrence?</td>
</tr>
<tr>
<td>B. Will BFS tolerate failure without loss of crew/vehicle?</td>
</tr>
</tbody>
</table>

*Explanation required (see below)*

**Change/Retention Rationale Summary**

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

**Explanation/Comments:**

2. Pod redundancy.
3. Backup flight system same as primary.
VALIDITY OF FUEL AND OXIDIZER ANALYSIS - NO 19... 13... 13...
ITEM: TANK ASSY, PROPELLANT
INCLUDING ACQUISITION DEVICE AND RETENTION SCREENS (1.5 FACTOR OF SAFETY) TK 203/204/303/304.

FUNCTION:
TO STORE/SUPPLY PROPELLANT FOR REACTION CONTROL THRUSTERS. TANK SHELL CONTAINS PROPELLANT AND ACQUISITION DEVICE RETAINS PROPELLANTS FOR ADEQUATE FEED DURING 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/VT, OVERPRESS, STRESS CORRUGS, PROPER PROPEL PURITY OR TEST FLUID, OVER TEMP, PLUME OR REENTRY GASES, STRESS RISE?, VELD OR MAT'AL DEFECT, INCORRECT OR DAMAGED SEAL.

EFFECT(S):
(A) LOSS OR DEGRADATION OF SUB-SYSTEM DEPENDENT ON EXTENT OF FAILURE.
(B) LOSS OR DEGRADATION OF INTERFACE SUB-SYSTEM-AFT RCS, PPO, TPS OR VEH DAMAGE.
(C) ABORT DECISION.
(D) POSSIBLE LOSS OF C3/C4/VEHICLE (EXPLOSION, LACK OF PROPELLANT OR INABILITY TO DEPLETE OPPOSITE PROPELLANT).

DISPOSITION & RATIONALE:
(A) DESIGN
(B) TEST
(C) INSPECTION
(D) FAILURE HISTORY:
(A) THE F.S. (BURST) IS 1.5 X WORKING PRESSURE. COMPLETE STRESS ANALYSIS FOR EACH TANK SEGMENT WAS PERFORMED. TANK IS CLASSIFIED AS FRACTURE CRITICAL FOR HANDLING AND IS SUBJECT TO FRACTURE CONTROL REGMTS. ALL FITTINGS AND FLANGES USED ON THE TANK HAVE DUAL ELASTOMER SPRING LOADED SEALS. (B) QUAL Requires 900 PRESSURE WITH (INCLUDING 200 EXPULSION CYCLES AND A 90 DAY CREEP AND PROPELLANT EXPOSURE TEST). PROOF PRESSURE (1.3X WORKING PRESSURE) AND LEAKAGE TESTS ARE PERFORMED DURING ATP- RADIOPHGRAPHIC 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'AL AND PURCHASED COMPONENT AGENTS ARE VERIFIED BY RECEIVING INSPECTION AND ACCEPTANCE OF PAPERS, PROCESS, COMPONENTS, AND MANUFACTURING. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS-PARTS PROTECTION, MFG. PROCESSES, FINISHES, ASSY AND INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY...
SHUTTLE CRITICAL ITEMS LIST - ORBITER LO2

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 RECORRED. 10 APOLLO FAILURES WERE ASSOC. 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. **SUBSYSTEM** AFT - RCS  
**ITEM** Propellant Tank Assy  
**FMEA NUMBER** 03-2A-211110-2  
**FAILURE MODE** Bubbles in 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)? 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?**  
   **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. [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 may illuminate if < 40 psi is sensed 3 times 80 milliseconds apart.

5. Crossfeed.

8b. Same as primary.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N: MC232-0061-0001-0002
P/N VENDOR: 855C3310000-010,-020
MISSIONS: HF, VF X FF OF SM
PHASE(S): PL, LO X DO X DO LS
QUANTITY: 14

PREPARED BY: DES R. BEMIS
APPROVED BY: NASA
APPROVED BY: DEFENSE DES... SS... M...

ITEM: TANK ASSY, PROPELLANT
INCLUDED 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 REQU.

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

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

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) SUBSYSTEM AND INTERFACE DEGRADATION — GAS Bubbles IN PROP CAUSING REDUCED THRUST OR COMB INSTAB. (B) ABORT DECISION. (C) 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) QUALIFIES 200 EXPULSION CYCLES A 90 DAY PROPELLANT EXPOSURE TEST. DEVELOPMENT CERTIFICATION TESTS DEMONSTRATE 100 MISSION FLOW TRANSIENTS (188,800 CYCLES) AND TWO YEAR PROPELLANT COMPATIBILITY. PROPELLANT ACQUISITION DEVICE AND WELD INTEGRITY VERIFIED VIA BUBBLE POINT TESTS AT THE COMPONENT, SUBASSEMBLY & TANK ASSY LEVEL. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. RAW MATERIAL AND PURCHASED COMPONENTS ARE VERIFIED BY RECEIVING INSP. MEASUREMENT STANDARDS & TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQS. OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS-PARTS PROTECTION, MFG. PROCESSES, FINISHES, ASSY AND THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 11-1-76. CORROSION PROTECTION PROVISIONS, TEST HANDLING, AND STORAGE ENVIRONMENTS. BOTH CERTIFIED WELDERS AND CERTIFIED INSPECTORS ARE USED FOR ALL WELDS. TURNAROUND - BUBBLE POINT TESTS ARE PERIODICALLY PERFORMED IN THE SYSTEM AS PART OF CHECKOUT PROCEDURE PRIOR TO FLIGHT. PRESSURE CYCLES ACCUMULATED ARE ALSO.Recorded. (D) NO IN-FLIGHT FAILURE EXPERIENCE FOR THIS DESIGN.
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**
   - 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)?**
   - NO ☐ YES ☑

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

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:**

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.
SUBMERSION AND EFFECTS ANALYSIS - MIL-HDBK-152

STATE TRIGGER: PE - EXCESS CONDENSE
TRIGGER LEVEL: HILLOW P.
TRIGGER DELAY: TIME DELAY (TDC)

IF YES: Rca CHT (230) NOW
EMY TRIGGER HANDLED

IF NO: FIRE FROM TANK
VIA BRIDGE REBELS VS. MEDICAL PERSONNEL

STRESS: YES

X: VISUAL INSPECTION AND LEAK CHECKS

PREPARED BY: R.E. HAMM
APPROVED BY: R.E. HAMM

REL: CTK PACERS

SIGNATURES

[Signatures]

REMARKS

[Remarks]

ORIGINAL PAGE IS OF POOR QUALITY
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 (S) 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 vib-pogc effect, flt vib.

EFFECT(S): On (A) sub-system (B) Interface (C) mission (D) crew/vehicle; (A) sub-system degradation - loss of propellant. (B) degradation of interface function - poss corros damage within pod and adverse effect on tps (molecular venting). (C) launch delay cp abort decision. (D) poss possible loss of crew/vehicle - if bellows joint 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) 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 insp and identification is performed and the unit tagged. contamination control process, corros. protection provisions, nde exam of welds, insp for surface and subsurface defects, raw mat'l (lot) certification, parts protection, coating and plating processes are verified by insp. manuf, installation, and assy operations are verified by shop traveler mandatory insp points. the above items and the following items were verified by audit conducted 8-29-77. contamination control plan, properly monitored handling and storage environment, special measurement standards and equip and mat'l conformance to contract 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.
<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does the flight software detect this failure mode (i.e., automatically</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- announce or take action in response)?</td>
<td>X</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>
</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>
<td>*NO</td>
</tr>
<tr>
<td>3. Does the flight software take action to negate the effects of the failure (either by commanding hardware action or implementing alternate program logic)?</td>
<td>YES</td>
<td>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</td>
<td>NO</td>
</tr>
<tr>
<td>4. As a result of this failure mode, can the software overstress the hardware or induce another failure?</td>
<td>*YES</td>
<td>NO</td>
</tr>
<tr>
<td>5. Can this failure mode, in combination with software logic, adversely affect other functions?</td>
<td>*YES</td>
<td>NO</td>
</tr>
<tr>
<td>6. How many of these hardware failures can the shuttle tolerate (consider crew action and hardware/software operation)?</td>
<td>*0</td>
<td>*1</td>
</tr>
<tr>
<td>7. If crew action is required to respond to this failure mode, are cues provided to signal the need for intervention and the required corrective action?</td>
<td>N/A</td>
<td>YES</td>
</tr>
<tr>
<td>8. If the answer to either 1 or 3 is YES:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Can the BFS be engaged after occurrence?</td>
<td>YES</td>
<td>*NO</td>
</tr>
<tr>
<td>B. Will BFS tolerate failure without loss of crew/vehicle?</td>
<td>YES</td>
<td>*NO</td>
</tr>
</tbody>
</table>

*Explanation required (see below)*

**Change/Retention Rationale Summary**

- No H/S issues
- Hardware accepts risk
- No software detection
- Detection during checkout
- Acceptance rationale below
- Recommended changes below

**Explanation/Comments:**

SHUTTLE CRITICAL ITEMS LIST - CRITERION 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: THRUSTER/PROPELLANT FEED
P/N: MC621-009
P/N VENDOR: T73500C1-1001THRU1005
QUANTITY: 56

- ONE FUEL AND ONE OXIDIZER
- PER THRUSTER (PRI & VERN)

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

PREPARED BY: DES - N. GLAVINICH
REL - C. M. AKERS

APPROVED BY: NASA

ITEM: BELLOWS ASSEMBLY
ENGINE ALIGNMENT

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

FAILURE MODE: STRUCTURAL FAILURE (S)
EXTERNAL LEAKAGE

CAUSE(S):
- FATIGUE, SHOCK, HANDLING, (A) EQ WELD PENET, INCORP. FUSION, PROPSITY, CORROS-PROP & BI-PROP EXPOSURE, PRESS SURGE, FLOW INDUCED VIB-POOQ EFFECT, FLT VIB

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
- (A) SUBSYSTEM DEGRADATION - LOSS OF PROPELLANT.
- (B) DEGRADATION OF INTERFACE FUNCTION - POSS CORROS DAMAGE WITHIN POD AND ADVERSE EFFECT ON TPS (MOLECULAR VENTING).
- (C) LAUNCH DELAY OR ABORT DECISION.
- (D) POSSIBLE LOSS OF CREW/VEHICLE - FAILURE NOT DETECTABLE SINCE PVT MEASUREMENTS HAVE BEEN DELETED FROM SOFTWARE FOR ASCENT AND RTL'S.

(ISOLATION IS POSSIBLE DURING OTHER MISSION PHASES)

DISPOSITION & RATIONALE: (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) MULTIPLE BELLOWS ARE UTILIZED - FLOW INDUCED VIBRATION ANALYSIS AND STRESS ANALYSIS WERE CONDUCTED TO VERIFY ACCEPTABLE DESIGN. THE EXTERNAL CONSTRAINT WOULD TEND TO LIMIT ANY GROSS PROPELLANT LEAK IN EVENT OF BELLOWS FAILURE. PROPELLANT LEAK FROM LINE TO THRUSTER COULD BE ISOLATED BY MANIFOLD VALVE.
- (B) ITEM IS USED DURING SYSTEM EVALUATION TESTS AT WSTF ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. (C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NDE EXAM OF WELDS, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS, RAW MAT'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 6-29-77. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L CONFORMANCE TO CONTRACT REQ'TS. TURNAROUND - MONITOR LEAKAGE TESTS PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND AS PART OF CHECKOUT PROCEDURE PRIOR TO FLIGHT. (D) NO FAILURE HISTORY AVAILABLE ALTHOUGH THE APOLLO PROGRAM DID SHOW SOME PROBLEMS ON FLEX HOSE ASSY DUE TO PIN HOLE CORROSION ASSOC. WITH RESIDUAL SOLVENTS AND PROPELLANT.
| Item | Engine Inlet Valve | Failure Mode | Fails Closed |

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

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

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

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

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

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

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

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

7. **If crew action is required to respond to this failure mode, are cues provided to signal the need for intervention and the required corrective action?**
   - N/A [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. [X] Hardware Accepts Risk
3. [ ] No Software Detection
4. [X] Detection during Checkout
5. [ ] Acceptance Rationale Below
6. [ ] Recommended Changes Below

**FMEA Change Recommended**

**Explanation/Comments:**

1. "Failed off" thruster C&W.
**TANK FUEL SYSTEM AND EFFECTS ANALYSIS - PAGE 12**

<table>
<thead>
<tr>
<th>Failure</th>
<th>Description</th>
<th>Cause</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Fuel</td>
<td>Full fuel in fuel tank</td>
<td>Full fuel in fuel tank</td>
<td>Fuel available for use</td>
</tr>
<tr>
<td>Loss of Fuel</td>
<td>Loss of fuel from tank</td>
<td>Loss of fuel from tank</td>
<td>Fuel available for use</td>
</tr>
</tbody>
</table>

**PREPARED BY:**

| Lee | W. Sharp | M. C. Atkins |

**DATE:**

| 3/3 | 3/3 | 3/3 |

**SPECIFICATION:**

| 12/2 | 12/2 | 12/2 |

**FUNCTIONAL:**

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

---

CHANGE/RETENTION RATIONALE SUMMARY

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

---

EXPLANATION/COMMENTS:

1. "Failed off" thruster C&W.
### Original Document

**Original Page is of Poor Quality**

**PREPARED BY:**
- L. NEARY
- R. L. MAKERS

**APPROVED BY:**
- ____________________________

**Date:** 1/11/71

**PLATE**

**REVIEW**

- OPL~
- PUL~
- PROBLEM: FL. L. EXC. A. U.
- SECONDARY SYSTEM: AIRFRAME
- INJECTION IN FLIGHT, Y.
- PROBLEM: FL. L. EXC. A. U.
- SECONDARY SYSTEM: AIRFRAME
- INJECTION IN FLIGHT, Y.

**VISUAL INSPECTION**

- YES

---

**DETECTION**

- PROBLEM: INJECTION IN FLIGHT, Y.
- SECONDARY SYSTEM: AIRFRAME
- INJECTION IN FLIGHT, Y.

**SUSPECT**

- (a) LIST OF IDENTIFIED OR FUNCTIONAL DEGRADATION - OCCURRENCE
  - (b) LIST OF IDENTIFIED OR FUNCTIONAL DEGRADATION - OCCURRENCE
  - (c) LIST OF IDENTIFIED OR FUNCTIONAL DEGRADATION - OCCURRENCE
  - (d) LIST OF IDENTIFIED OR FUNCTIONAL DEGRADATION - OCCURRENCE
  - (e) FUNCTIONAL CRITICALITY, IF NOT - PROBLEM
  - (f) DETERMINATION OF SUSPECT TRAJECTORY RELEVANCE OF SUSPECT TRAJECTORY
  - (g) DETERMINATION OF SUSPECT TRAJECTORY RELEVANCE OF SUSPECT TRAJECTORY

**CONCLUSIVE ACTION**

- ACTION TO CORRECT INFLUENCE IN EFFECTIVE AXES AUTOMATIC SYSTEM OVER SYSTEM FAILURE. DETECTION SYS. VERIFY SILS, UVLS OPEN.

**THEORY/REASONS**

- POTENTIAL FAULT(S) FROM CHAMBER INJETSING OR MALFUNCTION RESULTING IN SYSTEM FAILURE. LEAK/MALFUNCTION, AUTOMATIC CONTROL, MALFUNCTION, EXPLANATION IF LEAKAGE FUMP NOT CORRECTED PRIOR TO LEAKAGE. MALFUNCTION - TRIGGER NOT CONSIDERED CRITICAL FOR AXES FOR HEATER PITTING. IN S
SHUTTLE CRITICAL ITEMS LIST - GRBITER 102

SUBSYSTEM : AFT — REACTION CONTROL
ASSEMBLY : THRUSTER, PRIMARY
P/N Rl: C467-0028
P/N VENDOR: 33338
REACTIGO CONTROL
FMEA NO: 03-2A
CRIT. NO: 221311-1 PEV:Czf7E
MISSIONS: HF, VFX FF, CF, SM
PHASE(S): PL, LD, CO, DO, LS
QUANTITY : 24

ITEM: INJECTOR, PLATE

PREPARED BY:
APPROVED BY:

DES
REL
CM AKERS
4/77

FUNCTION:
Provides injection & vaporization of fuel and oxidizer FPC: Thruster
Inlet valves and provides doublet mixing at 1:30 ox to fuel ratio for a
Hypergolic reaction which produces 825 pounds of thrust at 70,000 feet.
Also control chamber wall cooling. The injector is constructed of C-133
Columbium & welded to the CC83 chamber. Acoustic cavities are located at
the outer periphery of the inj face to prevent high freq cc83

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

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

EFFECT(S): On (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) C/VEHICLE:
(A) Loss of redundancy or functional degradation — reduced prop
flow-cham press & thrust, plugged cham/inj film cooling.
(B) Degradation of interface function — inc'd GNC & use of alt thrusters
(C) No effect.
(D) No effect.
(E) Functional criticality effect — abort decision — degraded performance of redundant thrusters would require mission abort.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
74 micron nominal filters are provided to control contamination from sys.
and subsequent hazards. Automatic switch over (and isolation) by GNC
failure detection sys. Complete thermal and stress analysis have been
completed. (B) RCS SY8 EVAL TEST AT WSTF. Thruster qual for 50,000
cycles. Spray pattern checked during ATP. (C) A visual INS and
identification is performed and the unit tagged. Contamination control
process, Corros. protection provisions. NDE EXAM OF WELDS, RA4 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 INS PINS. 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 reqts. 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 FAIL.
HISTORY AVAILABLE.

PREPARED BY: APPROVED BY:

DES
REL
CM AKERS
4/77

DELETE
See Section 13.0

1024
S675-SH-0003
### Subsystem: AFT - RCS

**Item:** Thrust Chamber

**Failure Mode:** Burn-Thru

<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>X</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>X</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>X</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>X</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>X</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>X</td>
<td></td>
</tr>
<tr>
<td>5. Can this failure mode, in combination with software logic, adversely affect other functions?</td>
<td>X</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>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>X</td>
<td></td>
</tr>
<tr>
<td>8. If the answer to either 1 or 3 is yes: A. Can the BFS be engaged after occurrence?</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B. Will BFS tolerate failure without loss of crew/vehicle?</td>
<td>X</td>
</tr>
</tbody>
</table>

**Explanation/Comments:**

1. "Failed off" thruster C&W.
**SRU L Signature - Fault and Effects Analysis - 02-13-72**

<table>
<thead>
<tr>
<th>Description</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propellant</td>
<td>Code</td>
</tr>
<tr>
<td>Initiator</td>
<td>Code</td>
</tr>
<tr>
<td>Fuel</td>
<td>Code</td>
</tr>
<tr>
<td>Oxidizer</td>
<td>Code</td>
</tr>
<tr>
<td>Igniter</td>
<td>Code</td>
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<tr>
<td>Initiator</td>
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<td>Fuel</td>
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<td>Oxidizer</td>
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<td>Oxidizer</td>
<td>Code</td>
</tr>
<tr>
<td>Igniter</td>
<td>Code</td>
</tr>
</tbody>
</table>

**SPECIFIC FAILURE MODE AND EFFECTS ANALYSIS**

- **Fault**: Propellant Initiator Failure
- **Normal of Success Fault**: Initiator Failure
- **Aircraft Failure Mode**: 
  - **Primary**: Canopy Failure
  - **Secondary**: Structure Failure
- **Probability of Failure**: 
  - **Primary**: Canopy Failure
  - **Secondary**: Structure Failure
- **Visual Inspection**: Yes

**PREPARED BY:**
- DES
- A. SANCY
- REL

**APPROVED BY:**
- DES
- C. MARKS
- REL

**CHECK:**
- TO CHECK TABLE IV SECTION 4.3.2

**INSTRUMENTATION:**
- TO INSTRUMENT II BLIND EXTENSION (CONTROL COLUMN).

**PROCEDURE:**
- **ITE SSUE**:
  - **Instrument**: Propellant Initiator Failure
  - **Action**: Visual Inspection of Canopy Failure
  - **Result**: Canopy Failure

**SPECIFIC:**
- **Failure Mode**: Structural Failure

**PRELIMINARY ACTION:**
- **Initiate Propellant Fail Thru Initiator (At Maneuver Level) and Access Initiator and Canopy to Surrounding Structure

**NOTES:**
- Canopy Failure if Propellant Initiator Deflected Prior to Canopy Failure

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

SUBSYSTEM: AFT - REACTION CONTROL  
ASSEMBLY: THRUSTER, PRIMARY  
P/N RI: MC467-0028  
P/N VENDOR: X30958  
QUANTITY: 24  
MISSIONS: HF, VF, X, FF, CF, SS  
PHASE(S): PL, LJ, XOC, DD, XLS  
REDUNDANCY SCREEN: A-4/A, B-4/A, C-4/A

ITEM: THRUST CHAMBER  
FROM INJECTOR TO NOZZLE EXTENSION (COATED COLUMNIAH)  
FUNCTION:  
TO CONTAIN HYPERGOLIC REACTION OF PROPELLANTS AND DIRECT COMBUSTION PRODUCTS THROUGH NOZZLE & EXTENSION TO PROVIDE IMPULSE TO VEHICLE. THE CHAMBER IS CONSTRUCTED OF C-103 COLUMBIUM WITH P-512 A OXIDATION RESISTANT COATING AND UTILIZES FILM COOLING. THE CHAMBER PRESSURE IS 152 PSI & IS DESIGNED TO PRODUCE A THRUST OF 870-LBS VACUUM AT A NOZZLE STEADY STATE SPECIFIC IMPULSE OF 280 SECONDS.  
FAILURE MODE: STRUCTURAL FAILURE  
CAUSE(S):  
THERMAL CYCLING/STRESS FATIGUE, VIB, COMA INSTAB, SHOCK, BLOCKED INJ ORIFICES, HIGH TEMPERATURE SPOTS/INADEQUATE COOLING NOZZLE RESTRICTION  
EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:  
(A) LOSS OF REDUNDANCY - POSSIBLE LOSS OF 3 THRUSTERS IF TPS IS DAMAGED  
(B) DEGRADATION OF INTERFACE FUNCTION - INCREASED TEMPERATURES IN USE OF ALT THRUSTERS  
(C) MISSION MODIFICATION/FUEL DECISION IF FAILURE CAUSES DAMAGE PROPAGATION  
(D) POSSIBLE LOSS OF CREW/VEHICLE BURN THRU MAY CAUSE HIGH TEMPERATURE DAMAGE TO SURROUNDING STRUCTURE & ADJACENT THRUSTERS RESULTING IN POSSIBLE ENTRY HAZ IF TPS IS DAMAGED  

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

SUBSYSTEM AFT - RCS

ITEM Nozzle Extension

FAILURE MODE Burn-Thru

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

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

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

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

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

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

8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      - NO
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      - 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:
SQUIRT FAILURE NO. AND EFFECTS ANALYSIS - I-111, GI

PREPARED BY:  

UNANALYZABLE IN CLIMATE, YET

APPROVED BY:

1.4X 72-501-250

BASELINE IS:

1.4X 72-501-250

IS THERE TURNAROUND? ......... YES

VISUAL INVESTIGATION

PREPARED BY:  

C E S

S. L. S H A R C Y

APPROVED BY:

C E S

C. E. A N D E R S

ALL

25: WET EXTENSION:

LEAK DETECTED (WITH INSULATION BLANKET).  

1. COVER EXAMINATION EXPANSION OF CONDUCTIVE MATERIAL IS IN USE.

2. THE INSULATION IS NOT PROTECTED FROM PELLED COULETS, THE INSULATED EXPANSION RATIO IS 1/2 TO 1.

3. THE ISOLATE IS INTEROW WITH THE CONE COVER AND ENDLESS IS A CYCLE WHEN ISL

4. THE CYT TEMPERATURE IS MAINTAINED FOR THE PROPERLY

5. SPECIFICATION APPROX.

FALLOUT PCC: STRUCTURAL FAILURE, (S)

...THUS:

CAUSIONS:

1. TEMP. TEMPERATURE IN LOCAL AREA CAUSING INDUCTION OF LOCAL AREA DUE TO WEATHER CONDITIONS.

2. SPECIFICATIONS:

(A) SUBSYSTEM (B) INTERFACES (C) INSTALLATION (D) HIGH

2. LESS OF THERMAL-PRESS LOSS OF 20 THREADS PER MILLimeter COLE,, ALL THREADS. THER-THRU MAY CAUSE HIGH TEMP LAMPS FIFTH STAGE, THE CHARACTERISTICS TO BE INTERWOUND, (C) INSPECT INDIVIDUAL MOUNTS AT TIMES IF FAILURE CAUSES LAMPS INTERWIND. (D) LESS OF HIGH-VOLTAGE LIMIT.

3. THER-THRU MAY CAUSE HIGH TEMP damage to SOME STRUCTURE AND STRUCTURE RESULTING IN PAGE ENTRY HAS IF THE IS DANGEROUS

CONCLUSION: ACTION:

1. LATE MOUNT AT INLET VALVE OR RADIATOR AND ACCESS FOR LEAKAGE AND LEAKAGE TO SURROUNDING STRUCTURE.

2. WORKSHEET:

LINE PAGE IF SUBSYSTEM PROPOSED INTERWIND PRIOR TO LAM (ASS.) ALSO LAM PRIOR TO SUBSYSTEM (TURN LIMIT). THERE IS NO REPORT MOUNT RAIL FROM INITIATION (DEFLINE RISK). NOT IMPORTANT TO RELATE WITH ALL

1. AND INJECTORS. TURN-THRU MAY CAUSE HIGH TEMP DUE TO LAMPS.
ORIGINAL PAGE IS OF POOR QUALITY
ITEM: NOZZLE EXTENSION, COATED COLUMBIUM (WITH INSULATION BLANKET).

FUNCTION:
To provide isentropic expansion of combustion gases for max eff in vacuum. Nozzle extension is constructed of C-103 columbiium with R-512A oxidation resistant coating. The nozzle expansion ratio is 22:1. The nozzle extension is integral with the Comb shroud and enclosed in a dyna flex insulating shroud so that the exit temp is maintained per the procurement specification reqmt.

FAILURE MODE: STRUCTURAL FAILURE, BURN-THRU.
CAUSE(S):
HIGH TEMPERATURE IN LOCAL SPOT CONTAMINATED INJECTOR COOLANT HOLES WELD OR MAT'L DEFECT.

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

DISPOSITION & RATIONALE:
(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(4) HIGH THERMAL MARGINS IN NOZZLE EXTENSION AND HIGH COOLING MARGINS 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 MIL QUAL FOR 50,000 CYCLES. (C) A VISUAL INSPECTION 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 ASY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-76. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP CONFORMANCE TO CONTRACT REQMTS. TURNAROUND INSPECTION TO INCLUDE USE OF OPTICS WHERE ACCESSIBLE TO DETERMINE EVIDENCE OF BURN-THRU. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
SUBSYSTEM AFT - RCS
ITEM Vernier Thruster

Failure Mode: Loss of Output

1. Does the flight software detect this failure mode (i.e., automatically) 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/Comments:

3. Down modes to free drift.

6. No redundancy in the verniers.
### Fault Failure Mode and Effects Analysis - Page 30

**Function:**

The pitch (axis-of-thrust) and yaw axes (plus/plus, yaw) versus the target are provided in each arcs needle to provide perception of the attitude of the vehicle. It is not at all similar to the primary thrusters cut-in limit field.

**Failure Mode:**

- Loss of function (except)  
  - 1st cavity closure due to pyramide blockage.

**Causes:**

- Fails all cavity. Auto start-fail. 1st cavity/launch structure fail. 7th cavity/launch structure fail. 1st cavity/launch structure fail. 1st cavity/launch structure fail.

**Effects:**

1. (A) System - (F) Interface (E) Mission (E) Conversion:  
   - Loss of function (vernier thrusters) - currently lost of structure.

**Ignition:***

- Loss of function (vernier thrusters) - currently lost of structure.

**Effect:**

- (C) Mission specification or abort decision (including in-flight abort). - It is impossible to fly, and the vehicle may have attitude & translation control. If so, it is possible to use 1st and any act (x-axis) engines for pitch (nose-up) motion. (9) Effect:

**Corrective Action:**

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

**Caution:**

- No hazards identified. Thrusters move vehicle to 1st cavity launch structure. Payload thrusters are 55 ft long. (They are not designed to withstand forces of primary thrusting). It is possible payload could be retrieved while in free-drift mode and in some instances payload may

---

**Prepared by:**

- LES  
- J. Taggart  
- C. M. K. C.

**Approved by:**

- LES  
- J. Taggart  
- C. M. K. C.
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : VERNIER THRUSTER
P/N/RI : MC467-0029
P/N VENDOR : MISSIONS: HF, VF, X, FF, JSF, SM
QUANTITY : 4

FUNCTION:

FAILURE MODE:

PREPARED BY: P. C. AKERS EK;
APPROVED BY: R. L. L. D.;
APPROVED WITH CHANGES:

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

FUNCTION:

FAILURE MODE:

EFFECT(S):

DISPOSITION & RATIONALE:

100 MICRON FILTRATION & HEATERS PROVIDED TO LIMIT CONTAM & PREVENT PROP FREEZING.
(B) THUSTER OVAL FOR 500,000 CYCLES, 125,000 SEC BURN TIME, INLET VALVE TESTED FOR 500,000 WET CYCLES & 5000 DRY.
(C) A VISUAL INSPEC AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED.

AND ELECTRICAL LOGIC POWER IS VERIFIED. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

SUBSYSTEM AFT- RCS

ITEM Vernier Thruster

FAILURE MODE Fails to Stop Firing

1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY 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. X NO H/S ISSUES
2. X HARDWARE ACCEPTS RISK
3. NO SOFTWARE DETECTION
4. DETECTION DURING CHECKOUT
5. ACCEPTANCE RATIONALE BELOW
6. RECOMMENDED CHANGES BELOW

EXPLANATION/COMMENTS:

1. "Failed on" thruster C& W.
6. No redundancy in the verniers.
ORIGINAL PAGE IS OF POOR QUALITY
SHUTTLE CRITICAL ITEMS LIST - CRITERION 102

SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : VERNIER THRUSTER
P/N RI : MC467-0029
P/N VENDOR : MISSIONS: HF VF XF FF JF SM
P/N VENDOR :
QUANTITY 14

SUBSYSTEM : AFT - REACTION CONTROL
ABORT: CP IT. FUNC: 2
P/N RI : MC467-0029
CP IT. HOW: 2
MISSIONS: HF VF XF FF JF SM
PHASE(S): PL LJ CC X DO LS
QUANTITY 14

SUBSYSTEM : AFT - REACTION CONTROL
APPROVED BY: NASA
PREPARED BY: J TAGGART
APPROVED BY: C M AKERS
REL
REL

ITEM: THRUSTER, ASSY, VERNIER
25 POUND THRUST LEVEL. EN 357/358/257/258.
FUNCTION:
ONE PITCH (2 AXIS-UP FIRING) AND ONE YAW (PLUS/MINUS Y AXIS) VERNIER THRUSTER ARE PROVIDED IN EACH ARCS MODULE TO PROVIDE PRECISE LOW LEVEL PULSING AND ATTITUDE HOLD READ FOR PAYLOAD POINTING. THEY ARE CONCEPTUALLY SIMILAR TO THE PRIMARY THRUSTER BUT LIMIT PLUME IMPINGEMENT AND PROP RESIDUE CONTAM TO THE PAYLOAD.
FAILURE MODE: FAILS TO STOP (F)
CAUSE(S):
CONTAMINATION, STRUCTURAL FAILURE, DUAL SHORT IN DRIVER CIRCUIT TO DUAL MOD FIRE COMMAND, YIS, SHOCK SEAL SEAT DAM, PROP RESIDUE, FLUSH SALTS, CORROS, WEAR.
EFFECT(S) ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF FUNCTION (VERNIER THRUSTERS) - CURRENTLY LOSS OF SINGLE VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL. (B) DEGRADATION OF INTERFACE SUB-SYSTEM - PROP LOSS DUE TO EXCESS BURN-TIME UNTIL MANIFOLD CAN BE ISOLATED-POSS DAMAGE TO PAYLOAD OR PAYLOAD BAY ARMS. (C) MISSION MODIFICATION OR ABORT DECISION. (D) NO EFFECT.

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

PROTECTION PROVISIONS, NDE EXAM OF WELDS, RAW MAT' L (LST) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. HANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-75. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT' L AND EQUIP CONFIRMANCE TO CONTRACT REQS. TURNAROUND - SYSTEM FLUIDS ARE ANALYSED FOR EVIDENCE OF CONTAMINATION. PROPER INLET VALVE FUNCTION AND ELECTRICAL LOGIC POWER IS VERIFIED. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
HARDWARE/SOFTWARE
ANALYSIS CHECKLIST

SUBSYSTEM AFT - RCS
ITEM Vernier Thruster
FAILURE MODE Burn Thru

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

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

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

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

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

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

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

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

7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   - N/A [ ] 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.
2. Down modes to free drift.
3. No redundancy in the verniers.

FMEA CHANGE RECOMMENDED
SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: VERNIER THRUSTER
P/N #: MC467-0C29
P/N VENDOR: MISSIONS: HF VF X HF OF SM
QUANTITY: 4
2 PER POD
1 PITCH, 1 YAW

FAILURE DETECTABLE IN FLIGHT?: YES
TIME TO EFFECT:
CHAMBER PRESSURE ON EACH ENGINE, V42P32521 THRU V42P-3254 AND V42P-3521 THRU V42P-3534
REFERENCE DOCUMENTS:
MC 621-C59

GROUND TURNAROUND?..............YES
VISUAL INSPECTION

PREPARED BY:
DES J. TAGGART
REL C M AKERS

APPROVED BY:

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

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

FAILURE MODE: STRUCTURAL FAILURE

CAUSE(S):
- THERMAL CYCLING/STRESS FATIGUE, VIB, COMB INSTAB, SHOCK, BLOCKED INJ ORIFICES, HIGH TEMP/LOCALIZED HOT SPOTS/INADEQ COOLING NOZZLE RESTRICTION.
- EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
  (A) LOSS OF FUNCTION - CURRENTLY LOSS OF SINGLE VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL. (B) DEGRADATION OF INTERFACE FUNCTION - INCR GMEC & USE OF ALT THRUSTERS (C) MISSION MODIFICATION/ABORT DECISION IF FAILURE CAUSES DAMGE PROPAGATION. (D) POSSIBLE LOSS OF CREW/VEHICLE - BURN-THRU MAY CAUSE HIGH TEMP DAMAGE TO SURR STRUCT & ADJ THRUSTERS RESULTING IN POSS ENTRY HAZ IF TPS IS DAMAGED.

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

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

**SUBSYSTEM:** AFT - REACTION CONTROL

**ASSEMBLY:** VERNIER THRUSTER

**P/N:** MC467-0029

**P/N VENDOR:** MISSIONS: HF VF X FF CF SM

**QUANTITY:** 4 PER POD

**PHASE(S):** PL LO X CO X DC X LS

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

**ITEM:** THRUSTER, ASSY, VERNIER

**FUNCTION:**

One Pitch (2 Axis-Up Firing) and one Yaw (Plus/Minus Y Axis) VERNIER THRUSTER ARE PROVIDED IN EACH APGS MODULE TO PROVIDE PRECISE LOW LEVEL PULSING AND ATTITUDE HOLD REQD FOR PAYLOAD POINTING. THEY ARE CONCEPTUALLY SIMILAR TO THE PRIMARY THRUSTERS BUT LIMIT PLUME IMPINGEMENT AND PROP RESIDUE CONTAM TO THE PAYLOAD.

**FAILURE MODE:** STRUCTURAL FAILURE

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

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

(A) LOSS OF FUNCTION - CURRENTLY LOSS OF SINGLE VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL. (B) DEGRADATION OF INTERFACE FUNCTION - INCR GN&C & USE OF ALT THRUSTERS (C) MISSION MODIFICATION/ABORT DECISION IF FAILURE CAUSES BARGE 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 CONTAM & PREVENT PROP FREEZING. (B) THRUSTER QUAL FOR 500,000 CYCLES. 125,000 SEC BURN TIME, INLET VALVE TESTED FOR 500,000 WET CYCLES & 5000 DRY. (C) A VISUAL INSPECTION & IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NDE EXAM OF WELDS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER, MANDATORY INSPECT POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT PERFORMED 9-2-76. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP. CONFORMANCE TO CONTRACT REQMTS. TURNAROUND VISUAL INSPECTION USING OPTICAL INSTRUMENTATION. SYSTEM FLUIDS ARE ANALYSED FOR EVIDENCE OF CONTAMINANTS. 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

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

- **03-2A-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-201081-1**: Change question 1 to gross leak detection. Delete question 7.
- **03-2A-201091-1**: Delete questions 1, 3a and 6.
03-2A-202110-1: Change question 1 to - First indication "failed off" thruster C&W for 1/2 leg, redundant paths on 3,4,5 leg.

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

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

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

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

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

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

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

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

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

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

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

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

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

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