ORBITER SUBSYSTEM
HARDWARE/SOFTWARE INTERACTION ANALYSIS

VOLUME VIII: AFT REACTION CONTROL SYSTEM

PART 2

(NASA-TH-80959) ORBITER SUBSYSTEM
HARDWARE/SOFTWARE INTERACTION ANALYSIS.
VOLUME VIII: FORWARD REACTION CONTROL SYSTEM
(NASA) 119 p HC A06/MP A01

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

AFT - RCS
SUBSYSTEM

FMEA # SD72-SH-0103-2
ANALYSIS DATE November 5, 1979

HARDWARE/SOFTWARE ANALYST

APPROVED:

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JSC Reliability

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Rockwell Reliability

JSC Engineering - FRAT Sponsor

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

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

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

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

3.0 APPLICABLE DOCUMENTS.

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

<table>
<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>
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<tr>
<td>IV</td>
<td>Main Propulsion</td>
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<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.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY:

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

□ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

Figure 4-1. Hardware/Software Analysis Checklist
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.
HARDWARE/SOFTWARE ANALYSIS SUMMARY

SUBSYSTEM ___________________________

ANALYSIS RESULT

ITEM/Failure MODE

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

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

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

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

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

Figure 4-4. Failure Modes Not Included In Hardware/Software Analysis
<table>
<thead>
<tr>
<th>ITEM/FAILURE MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium Tank - External Leak (03-2A-201010-1)</td>
</tr>
<tr>
<td>Helium Feed Line - External Leakage (03-2A-201013-1)</td>
</tr>
<tr>
<td>D. C. Solenoid Valve, Helium - Fails Closed (03-2A-201020-1)</td>
</tr>
<tr>
<td>Line, Low Pressure Helium - External Leak (03-2A-201035-1)</td>
</tr>
<tr>
<td>Helium Fill Quick Disconnect - Fails Open (03-2A-201070-1)</td>
</tr>
<tr>
<td>Purge Quick Disconnect, Propellant - External Leakage (03-2A-201080-1)</td>
</tr>
<tr>
<td>Test Quick Disconnect - External Leakage (03-2A-201090-1)</td>
</tr>
<tr>
<td>Feedline and Fittings, Fuel - External Leakage (03-2A-202108-1)</td>
</tr>
<tr>
<td>Propellant Fill and Bleed Disconnect - Fails Open (03-2A-202150-1)</td>
</tr>
<tr>
<td>Propellant Tank Assembly - External Leak (03-2A-211110-1)</td>
</tr>
<tr>
<td>Propellant Tank Assembly - Bubbles in Propellant (03-2A-211110-2)</td>
</tr>
<tr>
<td>Injection Plate - Restricted Flow (03-2A-221311-1)</td>
</tr>
<tr>
<td>Thrust Chamber - Burn-Thru (03-2A-221312-1)</td>
</tr>
<tr>
<td>Nozzle Extension - Burn-Thru (03-2A-221313-1)</td>
</tr>
<tr>
<td>Vernier Thruster - Loss of Output (03-2A-231310-1)</td>
</tr>
<tr>
<td>Vernier Thruster - Fails to Stop Firing (03-2A-231310-2)</td>
</tr>
<tr>
<td>Vernier Thruster - Burn-Thru (03-2A-231310-3)</td>
</tr>
<tr>
<td>ANALYSIS RESULT</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>DETECTION DURING CHECKOUT</td>
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<tr>
<td>SUBSYSTEM</td>
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</tr>
</tbody>
</table>
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST

<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>AFT - RCS</th>
<th>FMEA NUMBER</th>
<th>SD72-SH-0103-2</th>
<th>03-2A-201010-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITEM</td>
<td>He Tank</td>
<td>FAILURE MODE</td>
<td>External Leak</td>
<td></td>
</tr>
</tbody>
</table>

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

- **YES** X NO □

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

- **YES** □ NO □

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

- **YES** X □

#### 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 X □

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

- **YES** □ NO □

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

- **YES** X □ NO □

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

- **0** □ 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

- □ NO H/S ISSUES
- □ HARDWARE ACCEPTS RISK
- 3. □ NO SOFTWARE DETECTION
- 5. □ ACCEPTANCE RATIONALE BELOW
- 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.

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

GER: 102 REV: 11/08/75

ASSEMBLY : PRESSURIZATION

P/N : 4C282-0022-0231-0232

P/N VENDOR: 330-999040-1/2

MISSIONS: HF VF X FP OF SH

QUANTITY : 4 PHASE(S): PL X LO X CJ X DO X LS

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

PREPARED BY: J TAGGART DEP... SSM REL C AKERS

ITEM: TANK

HELIOUM STORAGE, FILAMENT WOUND

FUNCTION:

TO STORE HELIOUM AT A MAX WORKING PRESSURE OF 4000 PSI FOR
PRESSURIZATION OF THE AFT RCS MODULE'S PROPULSANT SUPPLY SYSTEM.
TANK CONSISTS OF DOUBLE HELIUM LINER WITH SUPPLEMENT KEVLAR 49 FIBER AND EPOXY
RESIN BONDING OVERLAY. IS 18.71 IN. VOLUME 3308 cu. in.

FAILURE MODE: STRUCTURAL FAILURE

CAUSE(S):

- MAT' L DEF, LINER DEF, FAULTY FAB, EPOXY CURING INADEQUATE, TEST/HANCL DAY,
- SHOCK, VIB, INADEQUATE OVERPRESS (GKO), INADEQUATE MOUNTING

EFFECT(S):

- INABILITY TO DEPLETE/UTILIZE PROP, POSSIBLE DAMAGE TO POD STRUCTURE &
- TPS. (C) MISSION MODIFICATION - X-FEED FROM OMS OF RCS. (D) POSSIBLE
- LOSS OF CREW VEHICLEx EXCESS RATE OF LEAK MAY EXCEED POD VENT CAPAB
- CAUSING DAMAGE TO POD STRUCT & DEGRAD OF THERMAL POST SYS. EXCESS
- RETENTION OF PROP MAY ADVERSELY AFFECT VEH OXY. DURING ENTRY & LANDING

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

- FILAMENT WOUND TANKS ARE DESIGNED TO LEAK BEFORE RUPTURE WHICH
- LIMITS FAILURE PROPAGATION DUE TO SHRAPNEL. KEVLAR 49 FIBER HAS A
- TENSILE STRENGTH OF 500KSI ALLOWING LIGHT WEIGHT WITH GREAT STRENGTH.
- INCREASED STRAIN CAPABILITY IS PROVIDED BY THE COMPRESSIVE LOAD ON A
- UNPRESSURIZED LINER. VENT DOORS ARE OPEN ON ORBIT AND WILL RELIEVE ANY
- PRESSURE BUILDUP DUE TO LEAKAGE. THE PI (9 UST) IS 1.5 X WORKING
- PRESS. (B) 1000 PRESSURE CYCLES ARE PERFORMED DURING OVAL 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 FLAT GROWTH. PRESSURE (1.1) X WORKING
- PRESSURE) AND LEAKAGE TESTS ARE PERFORMED DURING OVAL. (C) AN
- IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. RAW MATERIAL 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, H/P, PROCESSES, FINISHES, ASSY AND
- INSTALLATION. THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT Conducted
- 5-23-77 - CORROSION PROTECTION PROVISIONS, TEST HANDLING, AND STORAGE

ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A-2010/10-L  REV:1/03/72
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) NOHE 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.
   - 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. 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 V42P2110G, 2112C, 2112C, 2113C, 2114C and 3110C, 3112C, 3113C 3114C dropping out 2111C and 3111C which do not exist.

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

8b. Same as primary.
ORIGINAL PAGE IS OF POOR QUALITY.
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PRESSURIZATION HELIUM
P/N RI : MC621-0059
P/N VENDOR: T3A630000
QUANTITY : 4

- ONE SET PER PROPELLANT
- PER MODULE

FUNCTION:
- 1/2 X .042 304L SS LINES TO PROVIDE HELIUM FEED FROM HELIUM TANKS TO HELIUM REGULATION/PRESSURIZATION SYSTEM PANEL
- FAILURE MODE: STRUCTURAL FAILURE (2)
- RUPTURE, EXTERNAL LEAKAGE

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

EFFECT(S):
- CN (A) SUBSYSTEM (B) INTERFACE (C) MISSION (D) CREW/VEHICLE
- (1) LOSS OF SUBSYSTEM PRESSURIZATION CAPABILITY IF NOT ISOL (FAIL UPSTREAM OF ISOL VLV- INABILITY TO DEPLETE/UTILIZE PCP.)(2) LOSS OF INTERFACE FUNCTION (INABILITY TO REPRESS PCP TANK - POT POOL STRUCT & TPS DAM.)(C) ABORT DECISION (LOSS OF PRESS) (2) POSSIBLE LOSS OF CREW/VEHICLE - IF LEAK EXCESS OR POOL/TPS DAM OCCURS

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY
- (A) F.S. IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF). THE WELDED CONSTRUCTION ELIMINATES JOINTS AND POSSIBLE LEAK PATHS. THE ANNEALED AREA (DUE TO WELDING) IS BACKED UP BY A SLEEVE. FASTENING CLAMPS ALLOW FREEDOM OF MOVEMENT. TUBING BENDS ARE CONTROLLED BETWEEN FIXED POINTS TO FACILITATE INSTALLATION AND ACCOMMODATE VEHICLE GROWTH AND MOVEMENT. (3) POCKWELL PERFORMED TUBING CERTIFICATION TESTS PER "CRIBBER TUBING VERIFICATION PLAN" (SD 75-SH-0205). THIS TESTING INCLUDED PRESSURE CYCLING AND FOR TYPICAL SHUTTLE LINES & JOINTS. SYSTEM EVALUATION TESTS AT WSTF WILL ALSO ALLOW EVALUATION IN THE INSTALLED SYSTEM CONDITION. LEAKAGE TESTS ARE PERFORMED IN-PROCES FOR TUBING SECTIONS. OPTICAL INSPECTIONS ARE ALSO PERFORMED AT THIS TIME IN ADDITION TO X-RAY AND DYE PENETRANT. LEAKAGE TESTS ARE ALSO PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND ADDITIONAL WELDS ARE ALSO SUBJECTED TO NDE. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAM. CONTRO PROCS., COPROS., PROTECTION PROVISIONS, NDE EXAM OF WELDS AND NDE INSPECT. FCP SURFACE AND SUB-SURFACE DEFECTS IF VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION. RAW MATT (LOT CERTIFICATION), PARTS PROTECTION, MANUF., COATING, PLATING, INSTALLATION AND ASSEMBLY OPERATIONS. HARDWARE IS INSPE. IN ACCORDANCE WITH QUALITY PLANNING REQUIREMENTS DOCUMENT (QPRO) WHICH HAS BEEN APPROVED BY NASA.
SHUTTLE CRITICAL ITEMS LIST - CRSITE 102

SUBSYSTEM: AFT - REACTION CONTROL  FMEA NO. 03-ZA-201013-1  REV: 12/13/79

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

ORIGINAL PAGE IS OF POOR QUALITY

20  SD75-SH-0003
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. *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 □ *NO □
   B. Will BFS tolerate failure without loss of crew/vehicle? YES □ *NO □

*Explanations 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

---

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 NAME: ALTITUDE CONTROL

TYPE OF OBSERVATION:

DATA GENERATOR PLATE

PRESSES:

PRESSURE: 0000.00000/0000.0000

VALVES CLOSING PEL EXC.

CLOSING SPEED:

PRESSES RATES:

SECURITY SURVEY:

FAILURE OCCURRED?

FAILURE LOCATION:

SPECIAL FLIGHT INSTRUMENTATION

PREPARED BY:

K. BURKHART

APPROVES SYS:

G. W. KIRSCHNER

G. W. KIRSCHNER

12. VALVES, Etc. SOLVENT

12. VALVES, PUMPS, PRESSURE, HELIUM (1/2 M2) 51-TABLE.

(ALTITUDE - 120-30-73.)(120-73.)

FAILURE:

AVALUATION TO CONTROL FOLLOW PRESSURIZATION SYSTEM. 1. THE ALT DEVICES IN THE LESS POSITION A OPEN PATH IS PROVIDED FROM THE PRESSURE SUPPLY TO A REGULATOR. THE PARALLEL PATHS ARE PROVIDED FOR ENSURE HARDWARE IN THE EVENT OF A FAULT. THE OPEN VALVE MAY BE CLOSED AND THE PARALLEL VALVE OPENED SUBSEQUENTLY TO A HARDWARE FAULT.

FAILURE MODE: FAILS CLOSED

CAUSIS:

12. CONTINUOUS VALVES CLOSING SIGNAL DUE TO SHORT CIRCUIT. SWING, CONNECTOR PIN OR LEAK DAMAGE, DAMAGING OF HARMONIC PRESSURE CRITICAL.

EXTRACTION ON (A) SUBSYSTEM (B) INTERFACES (C) PRESSURE (D) VELOCITY.

(1) LOSS OF CLOSING - PARALLEL PATH AVAILABLE.

(2) CLOSING PATH.

(3) NO EFFECT.

(4) OPEN PATH DUE TO ONLY ONE PATH REMAINING. FIDELITY CRITICAL.

(5) IN HARMONY CRITICAL.

(6) FUNCTIONAL CRITICALITY CRITICAL - FAILURE. CLOSING VEHICLE LOSS - FAILURE OF NEUTRAL PARALLEL PATH WITH VEHICLE RESULT IN INABILITY TO CONTROL VEHICLE BY CONTROLLING MOMENT ARMS. INABILITY TO USE RESERVED ENTRY PROPULSIVE USE DUE TO INABILITY TO USE RESIDUAL ENTRY PROPULSIVE VEHICLE DUE TO PROBLEMS RESULTING FROM CLOSING VEHICLE.

FUNCTIONAL ACTION:

12. CAUSE OF VIBRATION, THE VALVE MAY BE CAUSAL OF OPENING WITH A NO.

COMPANY, TO CLOSE TO PARALLEL PATH.

12. PAVILION, MANNIUS

FUTUROUS TIME CRITICAL HAZARD RELATED TO REACTION TIME FOR SIGNIFICANCE TO ALTERNATE PATH DURING CRITICAL MODES OF OPERATION SUCH AS E. T.
SHUTTLE CRITICAL ITEMS LIST - CRITERIA 102

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

ITEM: VALVE, D.C. SOLENOID

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

FAILURE MODE: FAILS CLOSED
CAUSE(S):
- VIB CONTINUOUS (INADVER CLOSING SIGNAL DUE TO SHORT CIRCUIT, SHOCK, CONNECTOR PIN OR DIODE DAMAGE, JAMMING OF POPPET, PLUGGED CRITICE.
EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) C/E (E) VEHICLE:
- (A) LOSS OF REDUNDANCY - PARALLEL PATH AVAILABLE.
- (B) NO EFFECT.
- (C) ABORT 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. ULLAGE PRESS IS ADEQ FOR PROP FEED WITH LESS THAN 35 PERCENT PROP REMAINING. ONE VALVE IS MAINTAINED IN THE LATCHED OPEN POSITION WITH NO POWER APPLIED & THE OTHER IS LATCHED CLOSED. AN INDUCTIVE VOLTAGE SUPPRESSION CIRCUIT IS PROV IN THE ELECTRICAL SYSTEM TO PREVENT DAMAGE TO OTHER ON-LINE COMPS. REDUN DIODES LIMIT THE POSS OF DIODE FAILURE ALLOWING CURRENT SHUNT FROM THE COIL. A 100-MICRON FILTER IS PROV TO LIMIT THE POSS OF CONTAM CAUSING LEAKAGE, JAMMING MOVING PARTS OR PLUGGING PILOT CONTROL ORIFICES. TO LIMIT THE ELECT SHORT POTENTIAL, THE LEAD AND MAGNET WIRES ARE ENCAP BY POTING AND A FIXTURE IS USED DURING ASSEMBLY TO ENSURE THAT INSUL IS NOT DAMAGED BY THE EXIT NOTCH WHEN THE COIL SLEEVE IS PRESSED ONTO THE COIL. (B) 4000 OPER CYCLES (ON-OFF-FLOW) AND RANDOM VIB AT ANTIC MISSION LEVELS ARE PERF DURING QUAL. ITEM IS USED.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-24 -201022-1  REV: 12/12/73
DURING SYS EVQ TESTS AT STF ALLOWING EVQ UNDER SIMUL MISSION USAGE COND. PROOF PRESSURE, LEAKAGE, OPER AND INSUL TESTS ARE PERF DURING ATPT. APROP LOCATED TEST POINTS Allow PRE/POST FLIGHT LEAKAGE TESTS AND OPER TESTS ARE ALSO CONDUCTED AT THIS TIME. (C) AN IDENT IS PERF AND THE UNIT TAGGED. CONTAM CONT PROCESS, CORROS. PROT PROV, NDE EXAM. OF WELDS AND BRAZES, INSPE. FOR SURFACE AND SUBSURFACE DEFECTS AND PROPER ELECT TERMINATIONS ARE VERIF BY INSPE. THE FOLLOWING ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPE. POINTS - RAW MAT'L (LOT CERT), PARTS PROT, MANUF., COATING, PLATING INSTALL AND ASSEMBLY OPER. THE ABOVE ITEMS AND THE FOLL ITEMS WERE VERIF BY AUDIT COND 8-31-77. CONTAM CONT PROCESSES, CORROS. PROT PROV. TURNAROUND - FUNCT FLOW TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON COMAND. (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 CORR AS DESCRIBED IN ITEM (A). ABOVE.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

SUBSYSTEM AFT - RCS

ITEM He Pressure Regulator

FAILURE MODE Restricted Flow - Fails Closed

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

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

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

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 O *NO O

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 O

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

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

6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.
   X0 O 1 X 2 O

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 O YES X *NO O

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY
1. O NO H/S ISSUES
2. O HARDWARE ACCEPTS RISK
3. O NO SOFTWARE DETECTION
4. X DETECTION DURING CHECKOUT
5. O ACCEPTANCE RATIONALE BELOW
6. O 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.
SYSTEM TEST - CONTROLLER

1. ONLY 28VDC X 100A
2. 1 28VDC X 100A
3. 1 28VDC X 100A
4. 1 28VDC X 100A
5. 1 28VDC X 100A
6. 1 28VDC X 100A
7. 1 28VDC X 100A
8. 1 28VDC X 100A
9. 1 28VDC X 100A
10. 1 28VDC X 100A

PREPARED BY:

C. HARRIS

APPROVED BY:

C. L. HARRIS

ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM: AFT - REACTION CONTROL  
ASSEMBLY: PRESSURIZATION  
P/N: MC284-0418-0001/0002  
P/N VENDOR: 7433QOL  
QUANTITY: 28  

SUBSYSTEM: AFT - REACTION CONTROL  
ASSEMBLY: PRESSURIZATION  
P/N: MC284-0418-0001/0002  
P/N VENDOR: 7433QOL  
QUANTITY: 28  

ITEM: REGULATOR PRESS, HE  
SERIES REDUNDANT, SET AT UNEQUAL OUTLET PRESSURES (PP201/302/303/304).  

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

FAILURE MODE: FAILS CLOSED (F)  
RESTRICTED FLOW.  

CAUSE(S):  
CONTAM (PILOT SCREEN), FAULTY MOIST, SPRING/STEM FRACURE, PISTON RINGS, EXCESS DOME PRESS, COCKED SPRINGS, MAT'L NET.  

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:  
(A, B) LOSS OF REDUNDANCY (ONE OF 2 FLOW PATHS). (C) APPRT DECISION.  
(D) NO EFFECT UNLESS SECOND PATH FAILS CLOSED, REENTRY CAPA8 IS LOST IF FAILURE OCCURS EARLY IN ENTRY SUCH THAT ULLAGE PRESS IS NOT SUFF.  
(E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CREW/VEHICLE LOSS. FAILURE OF REDUNDANT PARALLEL FLOW PATH WOULD RESULT IN INABILITY TO BURN OR DEPLETE RCS PROPELLANT. THIS WOULD RESULT IN POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO USE PRESERVED ENTRY PROPellant OR C-G PROBLEMS RESULTING FROM PROPELLANT 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 PROVIDED TO LIMIT THE POSSIBILITY OF CONTAM CAUSING JAMMING OF MOVING PARTS OR PLUGGING PILOT CONTROL ORIFICES. (B) 50,000 OPER FLOW CYCLES AND RESOCM VIB AT ANTIC MISSION LEVELS ARE PERFORMED DURING GUAL. ITEM IS USED DURING SYS EVAL TESTS AT WSTF ALLOWING EVAL UNDER SIMUL MISSION USAGE COND. PCRF PRESS, LEAKAGE AND FLOW TESTING IS PERFORMED DURING ATP. FUCT AND LEAKAGE TESTS ARE PERFORMED DURING PRE/POST FLIGHT CHECKOUT. (C) AN ID IS PERF AND THE UNIT TAGGED. MAT'L & EQUIP CONFORMANCE TO CONTRACT REQMTS IS VERIF BY INSPE. THE FOLL ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPE POINTS - RAW MAT'L, PARTS PROTECTION, MANUF, COATING, PLATING, INSTALL AND ASSY OPERATIONS. THE ABOVE ITEMS AND THE FOLL ITEMS WERE VERIF BY AUDIT CONDUCTED 4-5-77 - CONTAM CONT PROCESSES AND CORROS PPGT, CONTAM CONT PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIR. THE FOLLOWING
SUBSYSTEM: AFT - REACTION CONTROL  FMEA NO 02-2A-2010302  REV:11/08/73

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. NO
INSPECTION PERFORMED AFTER ASSEMBLY. TURNAROUND - VENT FLOW TESTS ARE
MONITORED TO VERIFY THAT THERE IS NO RESTRICTED FLOW. (C) NO FAILURE
HISTORY OF THIS MODE FOR THIS REGULATOR.
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY, ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**
   
<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>N/A</th>
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<tbody>
<tr>
<td>X</td>
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1a. **IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?**

<table>
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<tr>
<th>YES</th>
<th>NO</th>
<th>N/A</th>
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</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>N/A</th>
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<tr>
<td>X</td>
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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>
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<th>YES</th>
<th>NO</th>
<th>N/A</th>
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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>N/A</th>
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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>N/A</th>
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5. **CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?**

<table>
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<tr>
<th>YES</th>
<th>NO</th>
<th>N/A</th>
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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>YES</th>
<th>NO</th>
<th>N/A</th>
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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>YES</th>
<th>NO</th>
<th>N/A</th>
</tr>
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</table>

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

   A. **CAN THE BFS BE ENGAGED AFTER OCCURRENCE?**

      | YES | NO | N/A |
      |-----|----|-----|
      | X   |    |     |

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

      | YES | NO | N/A |
      |-----|----|-----|
      | X   |    |     |

**EXPLANATION/COMMENTS:**

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

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

6. Initiate cross-feed function.

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

8B. Same as primary.
GENERAL NOTE: THIS LABORATORY TEST WAS CONDUCTED AS A PART OF THE OVERALL TEST PROGRAM TO ENSURE THE SAFETY AND RELIABILITY OF THE VEHICLE SYSTEMS. THE TEST WAS PERFORMED IN ACCORDANCE WITH THE SPECIFIED PROCEDURE AND STANDARDS.

TEST SUMMARY:
- OBJECTIVE: TO ASSESS THE CAPABILITY OF THE VEHICLE SYSTEM TO WITHSTAND AN OVERPRESSURE EVENT.
- TEST CONDITIONS: OVERPRESSURE LEVEL = 150 PSI, TEST DURATION = 10 MIN.
- RESULTS: THE VEHICLE SYSTEM WITHSTOOD THE OVERPRESSURE EVENT WITHOUT FAILURE.

ANALYSIS:
- FAILURE MODES IDENTIFIED:
  1. Leaks at connection points.
  2. Structural failure of the vessel.
- CONTRIBUTING FACTORS:
  1. Over-pressure./
  2. Inadequate design.

CONCLUSION:
- The vehicle system is capable of withstanding overpressure conditions similar to those encountered during testing.
- Additional measures may be required to further enhance system reliability.

RECOMMENDATIONS:
- Review and update the design specifications to withstand higher over-pressure events.
- Conduct regular maintenance and inspection to ensure system integrity.

DATE: [DATE]

[Signature]
[Name]
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PRESSURIZATION
P/N: MC621-0059
P/N VENDOR: 73A6300030
QUANTITY: 4

NO3-2A - 201035-i
REV: 11/08/70

MISSIONS: HF VF X FF OF SM
PHASE(S): PL X L3 X CC X OC X LS X

ASSEMBLY : PRESSURIZATION ABORT: CRIT. FUNC: PIN

PREPARED BY: N G GLAVINICH
REL: C M AKERS

ITEM: LINE, LOW PRESSURE HE.
FEED LINE (3/4")
FUNCTION:
3/4" X .020 304L S.S LINES TO PROVIDE HELIUM FEED FROM REGULATORS TO PROP TANK.

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

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

EFFECT(S): ON (A) SUBSYSTEM (3) INTERFACES (C) MISSION (2) VEHICLE:
(A) LOSS OF SUBSYSTEM HELIUM SUPPLY, INABILITY TO DEPLET/UTILIZE PROPellant.
(B) LOSS OF INTERFACE FUNCTION, INABILITY TO REPRESSURE PROP TANK-POTENT POOL 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 INSP. FOR SURFACE AND
SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE
VERIFIED BY SHOP TRAVELER MANDATORY INSPECT. POINTS, RAW MAT'L (LOT
CERTIFICATION), PARTS PROTECTION, MANUF., COATING, PLATING, INSTALLATION
AND ASSEMBLY OPERATIONS. HARDWARE IS INSP. IN ACCORDANCE WITH QUALITY
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NG 03-2A -201035-1  REV:11/05/73
PLANNING REGNITS DOCUMENT (CPRD) WHICH HAS BEEN APPROVED BY NASA.

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

HISTORY - CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND
CORRECTED.
1. **Does the flight software detect this failure mode (i.e., automatically, automatically)**
   - Annunciate or take action in response? **YES X NO □**

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

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

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

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

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

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

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

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

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

*Explanation required (see below)*

**Change/Retention Rationale Summary**

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

**Explanation/Comments:**

1. Gross leak detection will give first indication.

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

6. Left and right AFT RCS pods provide redundancy.
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PRESSURIZATION
P/N REV : MC284-0421-0001/0002
P/N VEND : 5760009-101/576-0009-102
QUANTITY : 4
ONE PER PROPellant TANK

ITEM: VALVE
RELIEF, PRESSURE, BURST DISC & POPPET.

FUNCTION:
- PROVIDES PRESSURE RELIEF IN EVENT REGULATOR FAILS OPEN OR PROPellant PRESSURE RISES DUE TO THERMAL INCREASE. THE S.S. BURST DISC RELIEF PRESSURE IS 324-340 PSIG. THE MAIN POPPET CRACK AND RELIEF PRESSURE IS 315 PSIG AND THE MINIMUM RESEAT PRESSURE IS 310 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. (INABILITY TO RE-PRESSURIZE PROPellant TANKS DUE TO HELIUM LOSS). POSSIBLE INABILITY TO USE/DEPLETE PROPellant. (C) LOSS OF ENTRY CAPABILITY - ASSUMES ULLAGE PRESSURE IS ALSO VENTED OVERBOARD & PROP CANNOT BE DEPLETED. (2 FAILURES - FIRST IS RELIEF REQTMT). ABORT DECISION IF LEAK RATE IS SMALL. (D) NO EFFECT (FIRST FAILURE). (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE LOSS OF CREW VEHICLE - SEE ITEM (C) ABOVE. PROP IN ONE POD MAY NOT BE ADEQUATE FOR ENTRY. POSS ENTRY CONTROL & LANDING HAZARD (C.G.). IF PROP CANNOT BE DEPLETED PRIOR TO LANDING.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) THE BURST DISC IS REDUNDANT TO THE MAIN POPPET FOR THE EXTERNAL LEAKAGE MODE. (MAIN POPPET LEAKAGE WOULD NOT BE SENSED UNTIL AFTER BURST DISC ACTUATION OR FAILURE). A 25-MICRON FILTER DOWNSTREAM OF THE BURST DISC WILL REDUCE THE POTENTIAL FOR CONTAMINATION CAUSED LEAKAGE FAILURE. THE HELIUM ISOLATION VALVE COULD BE CLOSED DURING STATIC PERIODS. THIS WOULD PREVENT CONTINUING LOSS OF SOURCE PRESSURE. THE MAIN POPPET STEM IS A SEPARATE PIECE FROM THE MAIN SENSING SPRING ACTUATION MECHANISM. THIS PROVIDES CLOSE TOLERANCE CONTROL OF OPENING PRESSURE & ALLOWS THE POPPET TO SEAT INDEPENDENTLY OF THE LARGE SENSOR SPRING FORCE. (B) 36,000 PRESSURE EXCURSION CYCLES AT SYSTEM OPERATING
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A -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, NOE EXAM OF WELDS, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, AND MAT'IL AND EQUIP. CONFORMANCE TO CONTRACT REOHTS. ARE VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS: RAW MAT', (LOT CERTIFICATION), PARTS PROTECTION, MANUF., COATING, PLATING, INSTALLATION AND ASSY OPERATIONS. TURNAROUND - LEAKAGE TESTS ARE MONITORED TO VERIFY THAT THE BURST DISC IS STILL INTEGRAL AND THAT THE MAIN POPPET LEAK RATE IS WITHIN SPECIFICATION REOHTS. VISUAL INSPECTION FOR EVIDENCE OF DEGRADATION IS ALSO PERFORMED. (D) APOLLO FAILURES WERE DUE LARGELY TO GALVANIC CORROSION & CONTAMINATION CORRECTED BY DESIGN & TEST PROCESSING CHANGES. (THE SHUTTLE RELIEF VALVE IS A NEW DESIGN WHICH CONTAINS A FILTER & DOES NOT USE DISSIMILAR METALS).
1. **Does the flight software detect this failure mode (i.e., automatically announce or take action in response)?**
   - Yes [X] No [ ]

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

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

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

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

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

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

6. **How many of these hardware failures can the shuttle tolerate (consider crew action and hardware/software operation)? Note change to FMEA criticality.**
   - Yes [X] No [ ]

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

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

   *Explanation required (see below)*

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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

---

**In-Flight detectability**

[X] FMEA Change recommended

**Explanation/Comments:**

1. Gross leak detection will give first indication.

6. Capped quick disconnect provides one redundant success path.

   Pod Redundancy
SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PRESSURIZATION

P/N: MC276-0017-0401/-0403

P/N VENDOR: 7537200C-0401/-0403

MISSIONS: HF VF X FF OF SM

QUANTITY: 4

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

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

PREPARED BY:

APPROVED BY:

DES  G SCARLETT  DES  G SCARLETT 12/12/78  SSJ

REL  C MAKERS  REL  C MAKERS 12/12/78

DISCONNECT, QUICKFILL, HE (1/4") WITH SPRING LOADED POPPET AND STRUCTURAL END CAP. 4D 219/220

FUNCTION:

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

FAILURE MODE: FAILS OPEN (S)

EXCESS OF ACCEPTABLE RATE, SEALS DAMAGED.

CAUSE(S):

- CONTAMINATION, VIBRATION, MECHANICAL SHOCK, PIECE-PART STRUCTURAL
- FAILURE, EXCESS OR IMPROPER USE, IMPROPER MAINT OR SEE HALF, NC LINE SUPPORT - SHAFT OR G00E BENT. RETAINING CAP LOCKS, NEATING CAP SEAL REDUNDANCY.

EFFECT(S): ON (A) SUBSYSTEM (-4) INTERFACES (C) MISSION (C) 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. IS 2.0 X WORKING PRESS. ULLAGE PRESS IS ADEQ TO EXPEL PROP WITH 35 PERCENT OR LESS REMAINING. GROUND HALF COUPLINGS AND LINES ARE SUPPORTED TO LIMIT ANY UNDUE STRESS ON THE COUPLING DURING SERVICE AND PREV DAMAGE TO SEALS. A SAFETY FEATURE DURING SERVICING AND PRIOR TO REMOVAL OF THE END CAP IS A PROV WHEREBY ANY LEAKAGE PAST THE AIRBORNE POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING A BLEED SCPE. COMPLETE STRESS ANAL HAS BEEN CONDUCTED. UTIL OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUND SEAL EXCEPT FOR STRUCT FAILURE. (B) THE COUPLING IS SUB TO 600 OPERATIONAL CYCLES (COUPLING AND UNCOUPLING) DURING QUAL. RANDOM VIB TESTING IS ALSO CONDUCTED AT ANTIC VEH LEVELS FOR 48 MINUTES IN TWO AXES. USAGE DURING SYS EVAL TESTS AT 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 ISENT IS PERF. RAW MALT, NOE EXAM, VISUAL INSP FOR CRITICAL SURFACE DEFECTS, AND EQUIP CONFORMANCE TO SECRET REGS ARE PERF BY RECEIVING INSPECTION STANDARDS AND TEST EQUIP STANDARDS ARE IMPLEMENTED PER REGS OF MIL SPEC. THE FOLLOWING ITEMS ARE PERF BY SHCP TRAVELER MANDATORY INSP POINTS. (D) PARTS MFG. PROCESSES, COATING, ASSY AND INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77. CORROS PROT PROV, CONTAM CONT PROCESSES, TEST
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. TURNDOWN. COUPLINGS ARE VISUALLY INSPECTED FOR EVID OF DAMAGED
SEALS AND LEAK TESTS ARE PERFORMED. (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  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.
   N/A ☐ YES X NO ☐
7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?
   8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:
   A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?
      YES X *NO
   B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
      YES X *NO

*EXPLANATION REQUIRED (SEE BELOW)

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

EXPLANATION/COMMENTS:

1. 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.
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 (5)
- CAP LEAKS, SEALS DAMAGED RETAINING NUT LOoses NEGATING CAP SEAL REDUNDANCY.

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

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) F.S. IS 2.0 X WORKING PRESS. REDUNDANCY PROVIDED BY INTERNAL SEAL, CAP & MANIFOLD ISOLATION VALVE. GROUND HALF COUPLINGS AND LINES ARE ADEQ SUPPORTED TO LIMIT ANY UNDUE STRESS ON THE COUPLING DURING SERVICE AND PREV DAMAGE TO SEALS. A SAFETY FEATURE DURING SERVICING AND PRIOR TO REMOVAL OF THE END CAP IS A PROV WHEREBY ANY LEAKAGE PAST THE AIRBORNE POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING A BLEED SCREW. COMPLETE STRESS ANALYSIS HAS BEEN CONDUCTED. USE OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUND SEAL EXCEPT FOR STRUCT FAILURE.
- (B) THE COUPLING IS SUBJ TO 600 OPER CYCLES (COUPLING AND UNCOUPLING) DURING QUILT IN ADDITION TO PRESSURE CYCLING AND PROP EXPOSURE TESTS. RANDOM VIB TESTING IS ALSO CONDUCTED AT ASD VEHICLE LEVELS FOR 34 MINUTES IN EACH AXIS. USAGE DURING SYS EVAL TESTS AT KSTF ALLOWS EVAL UNDER ACTUAL USAGE CONDITIONS. PROOF PRESS TESTS ARE CONDUCTED DURING ATP AND LEAKAGE TESTS ARE PERF BEFORE AND AFTER OPER CYCLES. (C) AN IDENT IS PERF. RAW MAT'L, NCE EXAM, VISUAL INSPECTION FOR CRITICAL SURFACE DEFECTS, AND EQUIP CONFORMANCE TO CONTRACT REQS ARE VERIF BY RECEIVING INSPECTION STANDARDS.
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A -201080-1  REV:11/09/78

TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQmts OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPECTION POINTS—PARTS PROT, MFG. PROCESSES, COATING, ASSY AND INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77. CORROS PROT, PROV CONTAM CONT PROCESSES, TEST HANDLING, AND STORAGE ENVIR. THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT OF MARCH 6, 1979. INSPECTION VERIFIES ASSEMBLY PER INSPECTION POINTS IN MASTER RECORD.

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

TURNAROUND-COUPLED WILL BE VISUALLY INSPECTED FOR EVIDENCE OF CAP SEAL DAMAGE AND CAP LEAKAGE. (2) APOLLO FAILURE HISTORY WAS IN THE MAIN ASSOC WITH GROUND USAGE, IMPROPER HANDLING.
<table>
<thead>
<tr>
<th><strong>ITEM Test Quick Disconnect</strong></th>
<th><strong>FAILURE MODE External Leakage</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY):</strong> ANNUNCIATE OR TAKE ACTION IN RESPONSE?</td>
<td><strong>YES</strong> CONTACT</td>
</tr>
<tr>
<td>1a. <strong>IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?</strong></td>
<td><strong>YES</strong> CONTACT</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><strong>YES</strong> CONTACT</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><strong>YES</strong> CONTACT</td>
</tr>
<tr>
<td>3a. <strong>IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?</strong></td>
<td><strong>YES</strong> CONTACT</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><strong>YES</strong> CONTACT</td>
</tr>
<tr>
<td>5. <strong>CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?</strong></td>
<td><strong>YES</strong> CONTACT</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><strong>1</strong> CONTACT</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><strong>N/A</strong> CONTACT</td>
</tr>
<tr>
<td>8. <strong>IF THE ANSWER TO EITHER 1 OR 3 IS YES:</strong></td>
<td><strong>YES</strong> CONTACT</td>
</tr>
<tr>
<td>A. <strong>CAN THE BFS BE ENGAGED AFTER OCCURRENCE?</strong></td>
<td><strong>YES</strong> CONTACT</td>
</tr>
<tr>
<td>B. <strong>WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?</strong></td>
<td><strong>YES</strong> CONTACT</td>
</tr>
</tbody>
</table>

**EXPLANATION/COMMENTS:**

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

**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**

**X FMEA Change Recommended**
PRELIMINARY AND EFFECTS ANALYSIS - 11/11/11

SYSTEM: P-1 - ELECTRIC CONTROL

FAILURE 3: SYSTEM LOSS OF VOLTAGE

ASSUMPTION:
- All systems are operational unless otherwise noted.

FAILURE CAUSE:
- Power loss due to system fault.

FAILURE EFFECTS:
- Loss of system functionality.
- Possible mission failure.
- Possible safety concerns.

FUNCTIONAL CRITERIA:
- Vehicle must maintain nominal operation.

FUNCTIONAL CRITERIA EFFECT:
- Possible mission failure.

PREPARED BY:
- C. Scarlett

APPROVED BY:
- C. Marks

DATE:
- 11/11/11

CONDITION:
- System operational.

VITAL LEAKS:
- No leaks detected.

FAILURE MODE:
- Internal leakage

VITAL LEAKS:
- No leaks detected.

PREPARED BY:
- C. Scarlett

APPROVED BY:
- C. Marks

DATE:
- 11/11/11

CONDITION:
- System operational.

VITAL LEAKS:
- No leaks detected.

FAILURE MODE:
- External leakage

ORIGINAL PAGE IS OF POOR QUALITY
SOME RESULTS FROM AN EFFECTS ANALYSIS - Continued

[Text continues here]

REVISED PAGE IS
OF POOR QUALITY
SHUTTLE CRITICAL ITEMS LIST - CRBITEP LO2

SUBSYSTEM: AFT - REACTION CONTROL  P/N: 03-2A-201090-1  REV: 12/12/76
ASSEMBLY: PRESSURIZATION  ABGT:  CRIT. FUNC.: 1
P/N/RI: ME270-0032-0009, 7, 19, 21  CRIT. HOW: 3
QUANTITY: 36  PHASE(S): PL, LC, OC, OX
I: 15 PER MODULE

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

PREPARED BY:  APPROVED BY:  APPROVED BY (NAS): 1
DES: C. SCARLETT  DES: 12/15/80  SSM
REL: C. MACKERS  REL 12/15/80

PERPARED WITH CHANGES
See Section 13.0

ITEM: 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 PRESSU SUB-SYS COMPONENTS. COMPONENT INPUTS & OUTPUTS ARE ACCESSIBLE AT THE SEAP 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 GSE, HALF, YC LINE SUPPORT - SHAFT OR BORE GENT.

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) F.S. IS 2.0 X WORKING PRESS. ULLAGE PRESS IS ADEQ TO EXPLO PROP WITH 35 PERCENT OR LESS REMAINING. GROUND HALF COUPLINGS AND LINES ARE ADEQ SUPPORTED TO LIMIT ANY UNDUE STRESS ON THE COUPLING DURING SERVICE AND PREV DEMAQUE TO SEALS AND WELD JOINTS. A SAFETY FEATURE DURING SERVICING AND PRIOR TO REMOVAL OF THE END CAP IS A PROV WHEREBY ANY LEAKAGE PAST THE AIRBORNE POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING CAP. UTIL OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDU EN SEAL EXCEPT FOR STRUCT OR WELD FAILURES. (9) THE COUPLING IS DESIGNED FOR 400 OPER CYCLES (COUPLING AND UNCOUPLING) USAGE DURING SYS EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE COND. PRESS TESTS ARE CONDUCTED DURING ATP AND LEAKAGE TESTS ARE PERF BEFORE AND AFTER OPER CYCLES. (C) AN IDENT IS PERF AND THE UNIT TAGGED.
RAW MAT'L. NOE EXAM OF WELDS, VISUAL INSPE. OF WELD JOINTS FOR
SUBSYSTEM: AFT - REACTION CONTROL FMEA NO 03-2A -271090-1 REV:12/12/76

CONFORMANCE TO STANDARD WELD PRACTICE, SURFACE DEFECTS, AND EQUIP

CONFORMANCE TO CONTRACT RIGHTS ARE VERIF BY RECEIVING INSPECTION. MEASUREMENT
STANDARDS AND TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQUIREMENTS OF "MIL
SPECs. THE FOLLOWING ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPECTION

POINTS - PARTS PROT, MFG, PROCESSES, COATING, PLATING, ASSY AND

INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY

AUDIT CONDUCTED 11-3-76. CORRECTS PROV, CONTAINMENT PROCESSES, TEST

HANDLING, AND STORAGE ENVIRON. TURNAROUND - COUPLINGS WILL BE VISUALLY

INSPECTED FOR EVIDENCE OF SEAL DAMAGE AND CAP LEAKAGE. COUPLINGS

BETWEEN THE HELIUM ISOL VALVE & REGULATOR & THOSE ASSOCIATED WITH PROP

TANK C/O ARE NOT ACCESSIBLE AT SERVICING PANELS) (D) APOLLO FAILURE

HISTORY WAS IN THE MAIN ASSOC WITH GROUND USAGE, IMPROPER HANDLING.
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**

   - YES [x] 
   - NO [ ]

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

   - YES [ ]
   - NO [x]

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

   - YES [x]
   - NO [ ]

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

   - YES [ ]
   - NO [x]

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

   - YES [x]
   - NO [ ]

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

   - YES [x]
   - NO [ ]

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

   - YES [x]
   - NO [ ]

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

   - 0 [ ]
   - 1 [ ]
   - 2 [x]

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

   - N/A [ ]
   - YES [ ]
   - NO [x]

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

   A. **CAN THE BFS BE ENGAGED AFTER OCCURRENCE?**

   - YES [x]
   - NO [ ]

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

   - YES [x]
   - NO []

*EXPLANATION REQUIRED (SEE BELOW)*

---

**CHANGE/RETENTION RATIONALE SUMMARY**

1. [ ] NO H/S ISSUES
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)
ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N/RI: MC244-3481/001/0002
P/N VENDOR: RS01050-001-011
QUANTITY: 4

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

FAILURE MODE: FAILS CLOSED

FAILURE MODE:
- STRUCTURAL FAILURE, SHOCK, VIB. POPPET BINS IN GUIDE, CONTAM, VALVE FREEZES IN COLD VALVE, COPR.
- EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
  - (A) LOSS OF REDUNDANCY - PARAL FLOW PATH: (B,C,D) NO EFFECT UNLESS PARAL POPPETS FAIL CLOSED. FAILURE OF PARAL POPPETS WOULD CAUSE MIX RATIO SHIFT AND POSSIBLY PREVENT UTIL/DEPLETION OF ALL RCS PROPellant IN ADDITION TO MIXTURE RATIO PROBLEMS WITH RESULTANT THRUSTER FIRING PROBLEMS. POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO UTILIZE RESERVED PROPellant AND C.G. PROBLEMS DUE TO PROPELLANT WEIGHT.
- DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
  - (A) SERIES-PARALLEL REDUNDANT POPPETS PROVIDE REDUNDANCY FOR THE CLOSED FAILURE MODE. TO LIMIT THE POTENTIAL FOR POPPET SHAFT BINDING OR GENERATION OF CONTAMINATION THE GUIDE PINS UTILIZE SAPPHIRE AS A WEAR RESISTANT SURFACE. A 25-MICRON INLET FILTER WILL ALSO REDUCE THE POTENTIAL FOR A CLOSED FAILURE BY LIMITING THE POTENTIAL FOR CONTAMINATION TO CAUSE BINDING OF MOVING PARTS. (B) 100,000 operation CYCLES (FLOW) AND RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYSTEM EVALUATION TESTS AT WSTF 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, 'DIE EXAM.
OF WELDS AND BRAZES, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS ARE
VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP
TRAVELER MANDATORY INSPECTION POINTS - RAW MATERIAL (LOT CERTIFICATION), PARTS
PROTECTION, MANUFACTURING, COATING, PLATING, INSTALLATION AND ASSEMBLY
OPERATIONS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY
AUDIT CONDUCTED 12-2-77. CONTAMINATION CONTROL PROCESSES, CORROS-
PROTECTION PROVISIONS, TURNAROUND - FUNCTIONAL FLOW AND LEAKAGE
(BACKFLOW) TESTS ARE PERFORMED. (Q) NO PRIOR HISTORY FOR CLOSE FAILURE
MODE FOR THIS TYPE OF DESIGN.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST  SD72-SH-0103-2

SUBSYSTEM AFT - RCS

ITEM Feedline & Fittings, Fuel

FAILURE MODE External Leakage

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

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

2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF
   IN-FLIGHT DETECTABILITY? 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 3. NO SOFTWARE DETECTION 5. ACCEPTANCE RATIONALE BELOW
2. HARDWARE ACCEPTS RISK 4. DETECTION DURING CHECKOUT 6. RECOMMENDED CHANGES BELOW

EXPLANATION/COMMENTS:


2. V42P2115 and 3115 should be deleted from this FMEA page as they are in the oxidizer
   system and not the fuel system.
SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PROPELLANT FEED, FUEL

P/N: MC621-0059

P/N VENDOR: 73A560001

QUANTITY: 2

PREPARED BY: N G GLAVINICH

RE: MC621-0059

CRIT. HOW:

ITEM: FEEDLINE AND FITTINGS

FROM TANK TO 1) TANK VALVES, TO 2) MANIFOLD VALVES, TO 3) THRUSTERS.

FUNCTION:

(1) 1 1/2 x 0.028 SS, FROM TANK TO DISTRIBUTION PANEL.
(2) 1 1/4 x 0.028 FROM MANIFOLD ISOLATION VALVE TO THRUSTER MANIFOLD.
(3) 5/8 x 0.028 THRUSTER MANIFOLD TO PROVIDE FEED TO APPOSITE PROPELLANT COMPONENTS FOR THRUSTER OPERATION.

FAILURE MODE: STRUCTURAL FAILURE

RUPTURE, EXTERNAL LEAKAGE.

CAUSE(S):

VIB, FATIGUE, SHOCK, WELD DEF, INSTALL DAMP, DYNA TUBE SEAL FAILURE, WELD DEF (SULPHIDE STRINGER).

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

(A) SUBSYSTEM DEGRADATION - LOSS OF PROP.
(B) DEGRADATION OF INTERFACE FUNCTION - POSS CORROS DAMAGE IN PO.
(C) LAUNCH DELAY OR ABORT DECISION.
(D) POSSIBLE LOSS OF CREW/VEHICLE IF LINE FROM TANK OUTLET RUPTURES RESULTING IN INABILITY TO UTILIZE/DEPLET PROE OR PROPE ACTS WITH FUEL OR OX CAUSING FIRE OR EXPLOSION.

DISPOSITION & RATIONALE:

(A) DESIGN
(B) TEST
(C) INSPECTION

(A) F.S IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF).

DYNAMITE 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 "ORBIT " 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 SUBMITTED TO NDE. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAM CONTROL PROCESSES, CORROS. PROTECTION PROVISIONS. NDE EXAM OF WELDS AND INSPECT FOR SURFACE AND SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER.
SUBSYSTEM: AFT - REACTION CONTROL
FMEA NO 03-2A-202103-1 PEV: 11/03/72
MANDATORY INSPECTION POINTS: RAW MATERIAL (LOT CERTIFICATION), PARTS PROTECTION, MANUFACTURING, COATING, PLATING, INSTALLATION AND ASSEMBLY OPERATIONS.
HARDWARE IS INSPECTED IN ACCORDANCE WITH QUALITY PLANNING REGULATION (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/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST

**SUBSYSTEM**  AFT - RCS  
**ITEM**  Feedline & Fittings, OX  
**FMEA NUMBER**  03-2A-202109-1  
**FAILURE MODE**  External Leakage

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

*Explanation required (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:

**PREPARED BY:**
LES N. GELVINICH

**APPROVED BY:**

PRL C. MARRA

---

**PRELIMINARY ACTIONS**

- **FOLLOW-THE-LEAD.**
- **MISSION COUNTERMEASURES:**
  - Set up initial countermeasures
  - Communicate with mission control

**MAYBE NEEDED TO:**

- **AID MANNED SPACECRAFT:**
  - Communicate with mission control
  - Initiate emergency procedures

**RECOMMENDATIONS TO:**

- **GREEN-MAN-TO-NAVIGATING-NAVIGATION-INITIATION:**
  - Ensure communication with mission control
  - Initiate emergency procedures

**DETERMINATION:**

- **AID MANNED SPACECRAFT:**
  - Communicate with mission control
  - Initiate emergency procedures

**PRELIMINARY ACTIONS:**

- **FOLLOW-THE-LEAD.**
- **MISSION COUNTERMEASURES:**
  - Set up initial countermeasures
  - Communicate with mission control

**MAYBE NEEDED TO:**

- **AID MANNED SPACECRAFT:**
  - Communicate with mission control
  - Initiate emergency procedures

**RECOMMENDATIONS TO:**

- **GREEN-MAN-TO-NAVIGATING-NAVIGATION-INITIATION:**
  - Ensure communication with mission control
  - Initiate emergency procedures

**DETERMINATION:**

- **AID MANNED SPACECRAFT:**
  - Communicate with mission control
  - Initiate emergency procedures

---

**ORIGINAL PAGE IS OF POOR QUALITY**
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PROPELLANT FEED, OXIDIZER
P/N MANUFACTURER : 73A560002
P/N VENDOR : 73A560002
QUANTITY : 2
ITEM : FEEDLINE AND FITTINGS

FUNCTION:
1) 1 1/2 X .032 X 204L S.S. FROM TANK TO DISTRIBUTION PANEL, (2) 1 1/2
X .032 FROM MANIFOLD ISOLATION VALVE TO THRUSTER MANIFOLD (3) 3/
X .028 THRUSTER MANIFOLD TO PROVIDE FEED TO APPROPRIATE PROPELLANT
COMPONENTS FOR THRUSTER OPERATION - 3 AXIS ACCELERATION CONTROL AND
ROTATIONAL CONTROL.

FAILURE MODE: STRUCTURAL FAILURE

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

DYNAMATE SEAL FAILURE MATEL DEFICIENCY (SULPHIDE STRINGER).

EFFECT(S): ON (A) SUBSYSTEM (B) PARTS AND COMPONENTS (C) MDM, CM, SM,
(D) PROPELLANT, (E) SUB-SYSTEM DEGRADATION, (F) MISSION, (G) VEHICLE,
(H) SUB-SYSTEM DEGRADATION, (I) LOSS OF PROPELLANT, (J) LOSS OF VEHICLE.

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).
(B) DYNAMATES HAVE DUAL SEALING SURFACES. THE WELDED CONSTRUCTION
ELIMINATES JOINTS AND POSSIBLE LEAK PATHS. THE ANNEXED 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.
(C) ROCKWELL PERFORMED TUBING CERTIFICATION TESTS PER "ORBITE" TUBING
VERIFICATION PLAN" (SD75-SH-0003). THIS TESTING INCLUDED PRESSURE
CYCLING AND FATIGUE FOR TYPICAL SHUTTLE LINES & JOINTS. SYSTEM
EVALUATION IN THE INSTALLED SYSTEM CONDITION. LEAKAGE TESTS ARE
PERFORMED AT THIS TIME IN ADDITION TO X-RAY AND DYE PENETRANT. LEAKAGE
TESTS ARE ALSO PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND
ADDITIONAL WELDS ARE ALSO SUBJECTED TO NDE. (D) IN IDENTIFICATION IS
PERFORMED AND THE UNIT TAGGED. CONTAM. CONTROL PROCESSES, CORROS.
PROTECTION PROVISIONS, NDE EXAM OF WELDS AND INSPECTION. SURFACE AND
SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE
VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS - RAW MATERIAL (LOT
SUBSYSTEM : AFT – REACTION CONTROL

FMEA NO 03-24 -202109-1
REV:11/08/75

CERTIFICATION, PARTS PROTECTION, MANUF., COATING, PLATING, INSTALLATION
AND ASSEMBLY OPERATIONS. HARDWARE IS INSPECTED 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. (C) MINOR HISTORY –
CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.
ARE MONITORED FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE. (D) MINOR
HISTORY – CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND
CORRECTED.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

ITEM Tank Isolation Valve, A.C.

FAILURE MODE Fails Closed

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

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

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

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

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

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

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

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

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

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 X ☒

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

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

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.
SHUTTLE CRITICAL ITEMS LIST - CRITERION 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N/P: MC284-0430-0007 / 6038
P/N VENDOR: 5750523 / 5750026
QUANTITY: 12

THREE VALVES PER PROP TANK

REdundancy Screen: A-Pass B-Pass C-Pass

PREPARED BY:
DES: R Gonzalez
REL: C M Akeps

APPROVED:

APPROVED WITH CHANGES

See Section 13.0

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

FUNCTION:

THREE REDUNDANT ISOLATION VALVES ARE USED PER TANK TO ISOLATE GROUPS OF MANIFOLDS. ONE TANK ISOL VALVE CONTROLS 2 MANIFOLDS AND THE PARALLEL ISOL VALVES CONTROL THE REMAINING 2 PRIMARY MANIFOLDS AND THE VERNIER MANIFOLD. THIS MANIFOLD MAY EXHIBIT OPEN OR LEAKAGE FAILURES AND TO ISOLATE THE Tank DURING INTERCONNECT & RCS OR OMS CROSSFIEED OPERATIONS, ALSO USED TO PREVENT HELIUM INGESTION TO ENGINE AT PCG PULL-OUT (MANUAL SWITCH). FUEL & OXIC VALVES CAN BE OPERATED INDEPENDENTLY FOR C/2. LINE PRESS RELIEF TO TANK IS PROVIDED.

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

CAUSE(S):
LIMIT SWITCH MalFUNCTION, PREMATURE POWER TO MOTOR, ELECTRICAL SHORT, RPC OPEN, JAMMING OF BALL SHAFT OR 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 VALVE CLOSED MAY LOSE TWO MANIFOLDS). (D) NO EFFECT FOR SINGLE FAILURE FOR O/F MISSIONS (LOSS OF THRUSTER MAY BE CRITICAL FOR RTLS IN SUBSEQUENT MISSIONS FOR OMS DEPLETION BURN). CRIT I FOR RTLS - LOSS OF TWO MANIFOLDS (PER PGO AFT) IS CRITICAL FOR SEPARATION & MATED COAST DURING RTLS. (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CREW/VEHICAL LOSS DUE TO UTILIZE/CLOSE RCS PROPELLANT. POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO UTILIZE RESERVED PROPELLANT & C/G PROBLEMS DUE TO PROP WEIGHT.

DISSPONITION & 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.
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 HSTF 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, CORRO,
PROTECTION PROVISIONS, NDE EXAM OF WELDS, INSPECTION FOR SURFACE AND
SUBLVSURFACE DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MATERIAL (LOT)
CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE
VERIFIED BY INSPECTION.  MANUFACTURING, INSTALLATION, AND ASSY. OPERATIONS ARE
VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND
THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED JULY 1976/
CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE
ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIPMENT AND MATERIAL AND EQUIP
CONFORMANCE TO CONTRACT REQUIREMENTS. TURBINE/COMPRESSOR FLOW & LEAKAGE
TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON
COMMAND.  (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
SHARDWARE/SOFTWARE ANALYSIS CHECKLIST  SD72-SH-0103-2

<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>AFT - RCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITEM</td>
<td>Tank Isolation Valve, A. C.</td>
</tr>
<tr>
<td>FMEA NUMBER</td>
<td>03-2A-202110-3</td>
</tr>
<tr>
<td>FAILURE MODE</td>
<td>Fails Open</td>
</tr>
</tbody>
</table>

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

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

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)?  
   **0 [O]** 1 [I] 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 [N]** 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  

□ FMEA CHANGE RECOMMENDED  

EXPLANATION/COMMENTS:  

1A. Tank isolation valve discretes are available.
...
SHUTTLE CRITICAL ITEMS LIST - CREITER L02

SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PROPELLANT FEED
P/N : MC234-0450-0007/-0083
P/N VENDOR : 575 COZ 575-0026
MISSIONS : HF VF X FF CF SM
QUANTITY : 12

- THREE VALVES PER PROP TANK

TANK ISOLATION
3 PHASE 400 Hz AC MOTOR ACTUATED (L15-2530) LV261-266.

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

FAILURE MODE: INTERNAL LEAKAGE, TANK ISOLATION VALVES CLOSE, TIMES.
- FAILS OPEN, FAILS TO CLOSE, FAIL TO REMAIN CLOSED.

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

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
- (A, B) LOSS OF REDUNDANCY - MANIFOLD ISOLATION. (C) ABORT DECISION - PROPELLANT MANAGEMENT PROBLEMS DURING CROSSFEED OPERATIONS. (D) NO EFFECT - CRIT 1 FOR RTLS. IF RMS TANK ISOLATION VALVE WILL NOT CLOSE DURING DMS DEPLETION BURN THE RCS PROPELLANT MAY BE DEPLETED IF ASSOCIATED MANIFOLD ISOLATION VALVES ARE NOT CLOSED.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) AC MOTOR VALVE IS 3-PHASE - 2 OF 3 WINDINGS ARE ADEQUATE FOR VALVE FUNCTION. PARALLEL (HYBRID) RELAYS PROVIDE REDUNDANCY FOR ELECTRICAL POWER SIGNAL. A 400-MICRON FILTER IS UTILIZED ON THE INLET AND OUTLET TO LIMIT THE POTENTIAL FOR CONTAMINATION CAUSED FAILURE OR JAMMING OF MOVING PARTS. (B) 2500 OPERATION CYCLES (OPEN-CLOSE-OPEN) AND RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYSTEM EVALUATION TESTS AT WSTF ALLOWING EVALUATION UNDER SIMILAR MISSION USAGE CONDITION. PROOF PRESSURE, LEAKAGE, OPERATION, CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT. (C) A VISUAL INSPECTION IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL PROCESS, COORS, PROTECTION PROVISIONS, NDE EXAM OF WELDS, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MATERIAL (LOT) CERTIFICATION, PARTS PROTECTION, COATING, AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUFACTURING, INSTALLATION, AND ASSY. OPERATIONS ARE

ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM :: AFT - REACTION CONTROL FMEA NO 03-2A -202110-3 REV:12/12/78
VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND
THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED JULY 1976/
CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE
ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIPMENT AND MALT' AND EQUIP
CONFORMANCE TO CONTRACT REQUIREMENTS. TURNAPOUND - FUNCTIONAL FLOW & LEAKAGE
TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON
COMMAND. (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
**SUBSYSTEM** APT - RCS  
**FMEA NUMBER** 03-2A-202111-2  
**ITEM** Interconnect Valve, A.C.  
**FAILURE MODE** Fails Closed

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<tbody>
<tr>
<td>1.</td>
<td>DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY).</td>
<td>YES ☒ NO ☐</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>ANNUNCIATE OR TAKE ACTION IN RESPONSE?</td>
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<tr>
<td>1a.</td>
<td>IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?</td>
<td>☐ YES ☐ NO ☒</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?</td>
<td>☒ YES ☐ NO ☐</td>
<td></td>
<td></td>
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<tr>
<td>2.</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>
<td>☒ YES ☐ NO ☐</td>
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<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>
<td>☒ YES ☐ NO ☐</td>
<td></td>
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<tr>
<td>3.</td>
<td>AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?</td>
<td>☒ YES ☐ NO ☐</td>
<td></td>
<td></td>
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<tr>
<td>4.</td>
<td>CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?</td>
<td>☐ YES ☐ NO ☒</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5.</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>
<td>☒ 0 ☐ 1 ☒ 2 ☐</td>
<td></td>
<td></td>
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<tr>
<td>6.</td>
<td>IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?</td>
<td>N/A ☐ YES ☒ NO ☐</td>
<td></td>
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<tr>
<td>8.</td>
<td>IF THE ANSWER TO EITHER 1 OR 3 IS YES:</td>
<td></td>
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<tr>
<td>A.</td>
<td>CAN THE BFS BE ENGAGED AFTER OCCURRENCE?</td>
<td>☒ YES ☐ NO ☐</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.</td>
<td>WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?</td>
<td>☒ YES ☐ NO ☒</td>
<td></td>
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</tbody>
</table>

*EXPLANATION REQUIRED (SEE BELOW)*

---

**CHANGE/RETENTION RATIONALE SUMMARY**

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

---

**EXPLANATION/COMMENTS:**

1. "Failed off" thruster gives first indication.
6. One success path remains after first failure.
8B. Same as primary.
SHUTTLE CRITICAL ITEMS LIST - CRITERIA 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N RR: M28-0600-0001/0003
P/N VENDOR: 5750025/5750026

QUANTITY: 6

1. TWO INTERCONNECT LINES
   PER PROPellant TANK

REGUNDANCY SCREEN: 1-PASS 2-PASS 3-PASS

PREPARED BY: R GONZALEZ, REL C MAKERS

APPROVED BY: NASA SM

APPROVED WITH CHANGES
See Section 13.0

ITEM: VALVE

INTERCONNECT, 3 PHASE 400 Hz AC MOTOR OPERATED (115-200V), RMS/RCS (1/2")

FUNCTION:

TO PROVIDE CONTROL OF INTERCONNECT LINE FOR VARIOUS USES OF PROPELLANT
FEED: 1) OPEN FOR RMS TO RCS 2) OPEN FOR RCS TO RMS 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 BANKS. LINE
PRESSURE RELIEF TOWARDS PROP TANK IS PROVIDED.

FAILURE MODE: FAILS CLOSE

FAILS TO REMAIN OPEN

CAUSE(S):

1. UL, LIMIT SET FAILURE, PREMATURE POWER TO MOTOR, ELECTRICAL SHORT RCS
OPEN, JAMMING OF VALVE

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

(1) LOSS OF REDUNDANCY. (2) DEGRADED FUNCTION - CROSSFEED PROP CAN BE UTILIZED BY ONLY 2 OF 3 MANIFOLD BANKS.
(C) MISSION MODIFICATION - OPERATION CHANGES PC? ITEM 8 ABOVE.
(D) NO EFFECT FOR OEF 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 PROP FEED TO RCS.

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

(1) AC MOTOR VALVE IS 3-PHASE - 2 OF 3 WINDINGS ARE ADEQUATE FOR VALVE FUNCTION.
SERIES (HYBRID) RELAYS PROVIDE REDUNDANCY FOR THE PREMATURE CLOSE MODE. PARALLEL
(HYBRID) RELAYS PROVIDE REDUNDANCY FOR ELECTRICAL POWER SIGNAL. ADDITIONALLY,
REDUNDANT VALVES ARE PROVIDED. A 400-MICRON FILTER IS UTILIZED ON THE INLET AND
OUTLET TO LIMIT THE POTENTIAL FOR CONTAMINATION CAUSED FAILURE OR JAMMING OF MOVING
PARTS. (B) 2500 OPERATION CYCLES (OPEN-CLOSE-OPEN) AND RANDOM VIBRATION AT
ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYSTEM
EVALUATION TESTS AT WSTF ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION.
PROOF PRESSURE, LEAKAGE, OPERATION, CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT.
(C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL PROCESS,
PROTECTION, PROVISIONS, NDE EXAM OF WELDS, INSPECTION FOR SURFACE AND SUBSURFACE
DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MATERIAL (LOT) CERTIFICATION, PARTS
PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. 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.

1022

SD75-SM-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 REQMTS. TURNAROUND/FUNCTIONAL FLOW & LEAKAGE TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON COMMAND. (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST

**ITEM:** Manifold Isolation Valve, A.C.  
**FAILURE MODE:** Fails Closed

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

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

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

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

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

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

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

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

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

8. **IF THE ANSWER TO EITHER 1 OR 3 IS YES:**  
   A. **CAN THE BFS BE ENGAGED AFTER OCCURRENCE?**  
      - [ ] YES  
      - [ ] 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. [x] DETECTION DURING CHECKOUT  
5. [ ] ACCEPTANCE RATIONALE BELOW  
6. [ ] RECOMMENDED CHANGES BELOW  

**FMEA CHANGE RECOMMENDED**

### EXPLANATION/COMMENTS:

3. RCS RM automatically detects and prevents thrusting.
THE REASON IS AN ENGINE ANALYSIS - EXPLOSION.
AN 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: 5730323/5730024

QUANTITY: 16

FOUR PRIMARY VALVE MANIFOLDS PER PROP

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. LINES PRESSURE
RELIEF TOWARDS PROP TANK IS PROVIDED.

FAILURE MODE: FAILS CLOSED-PREMIATURE (F)

OPERATION FAILS TO REMAIN OPEN.

CAUSE(S):

- VIBRATION, LIMIT SWITCH MALFUNCTION, PREMIATURE MOTOR SIGNAL, CPU SHORT.

EFFECT(S):

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

(A) (B) LOSS OF REDUNDANCY-LOSS OF PROP FLOW & USE OF 2 PRIMARY
THRUSTERS (1 OF 4 MANIFOLDS). (C) (D) NO EFFECT FOR SINGLE FAILURE FOR
OPT MISSIONS (LOSS OF THRUSTER MAY BE CRITICAL FOR RLS IN SUBSEQUENT
MISSIONS FOR POST DEPLETION BURN). (D) FOR RLS - LOSS OF 1 MANIFOLD
REDUNDANT & 1 MANIFOLD IS CRITICAL FOR ET SEPARATION & MATED COAST
DURING RLS. SINGLE COMPUTER FAILURE COULD RESULT IN THIS TYPE
CONDITION.

(E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CREW/VEHICLE
LOSS DUE TO INABILITY TO USE RCS IF ALL MANIFOLD VALVES FAIL CLOSED.

DISPOSITION & RATIONALE:

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

(A) AC MOTOR VALVE IS 3-PHASE - 2 OF 3 WINDINGS ARE ADEQUATE FOR VALVE FUNCTION.

SERIES (HYBRID) RELAYS PROVIDE REDUNDANCY FOR THE PREMIATURE CLOSE MODE. PARALLEL
(HYBRID) RELAYS PROVIDE REDUNDANCY FOR ELECTRICAL POWER SIGNAL. ADDITIONALLY,
REDUNDANT RELAYS ARE PROVIDED. A 400-MICRON FILTER IS UTILIZED ON THE INLET AND
OUTLET TO LIMIT THE POTENTIAL FOR CONTAMINATION CAUSED FAILURE OR JAMMING OF MOVING
PARTS. (B) 2500 OPERATION CYCLES (OPEN-CLOSE-OPEN) AND RANDOM VIBRATION AT
ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYSTEM
EVALUATION TESTS AT MSTR ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION.
PROOF PRESSURE, LEAKAGE, OPERATION, CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT.

(C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL PROCESS.
CORROSION PROTECTION PROVISIONS, NDE EXAM OF WELDS, INSPECTION FOR SURFACE AND SUBSURFACE
DEFFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MAT' L (LOT) CERTIFICATION, PARTS
PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUFACTURING,
INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION
POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED
JULY 1976/CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE
ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT' L AND EQUIP CONFORMANCE

1034

SD75-5H-0003
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
history failure history for this type design.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
YES ☐ NO ☑ X

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

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

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 ☑ X ☐

B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?
YES ☑ X ☐

*EXPLANATION REQUIRED (SEE BELOW)

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

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.
### ANALYSIS - FLIGHT 1

**MISSION:**
- Rail 1
- Rail 2
- Rail 3

**POST-FLIGHT:**

1. **REASONS FOR FAILURE,**
   - Electrical Signal (Continuous Status)
   - Loss of Signal
   - Failure of Actuator
   - Collision

2. **REASONS FOR COLLISION:**
   - Loss of Payload/Satellite
   - Collision will result in Inadvertent Actuation

**SURFACE CONTROL:**
- Rail 1: RAF 4D-153
- Rail 2: RAF 4D-154
- Rail 3: RAF 4D-155

**ACTION:**
- Utilize Backup RCS Valves
- Attempt to regain control through use of backup RCS.

**PREPARE FOR:**
- YES
- APPROVED

<table>
<thead>
<tr>
<th>YES</th>
<th>S. SURHART</th>
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<tbody>
<tr>
<td>YES</td>
<td>C. ARLES</td>
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</table>

**ORIGINAL PAGE IS OF POOR QUALITY**
ITEM: VALVE

MANIFOLD ISOLATION, VERNIER THRUSTER, SCIENCE (28VDC) 31-STABLE
(LATCHING) LV 258/257/357/353.

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 LOW MAGNETIC FORCE
FROM LATCHING MAGNET, MECH SPACK, VIB., CONTAM (AIR GAP).]

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) SERIES SWITCHES (RPS) MINIMIZE POTENT FOR INADVER ACTUATION.
PARALLEL SWITCHES (RPS) PROVIDE ELECT REDUND FOR THE OPENING SET.
AN INDUCT VOLTAS CIRCUITS IS PROV IN THE ELECTRICAL SYSTEM TO
PREV DAMAGE TO OTHER ON-LINE COMP. REDUNDANT DIODES LIMIT THE POSS OF
DIODE FAILURE ALLOWING CURRENT SHUNT FROM THE COIL.

100 MICRON FILTER IS PROV TO LIMIT THE POSS OF CONTAM CAUSING
JAMMING MOVING PARTS. (A) TO LIMIT THE ELECT SHORT POTENT. 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 NOSE. WHEN THE COIL SLEEVE IS PressED ON THE COIL. (B)
200 CYCLES (ON-OFF-LOW) AND RAMP VIB AT ANIT MISSION LEVELS ARE
PERF DURING OAL. ITEM IS USED DURING SY SEM EVAL TESTS AT WSTF ALLOWING
EVAL UNDER SIMUL MISSION USAGE COND. PRESS, LEAKAGE, OPER AND
INSUL TESTS ARE PERF DURING ATP. APPROPRIATE TEST POINTS ALLOW
PRE/POST FLIGHT LEAKAGE TESTS AND OPER TESTS ARE ALSO COND AT THIS TIME.
(C) AND IDENTIF IS PERF AND THE UNIT TAGGED. CONTAM CONT PRO,L
CORROS.. PROT PROV NDE EXAM OF WELDS AND BRAZES, INSPI. FOR SURFACE AND
SUBSURFACE DEFECTIONS AND PROPER ELECT TERMINATIONS ARE VERIF BY INSPECT.
THE FOLLOW ITEMS ARE VERIF BY SHOP TRAELER INSPI. POINTS RAW MAT'L (LOT
CERTIF), PARTS PROT, MANUF, COATING, PLATING, INSTALL AND ASYM. OPER.
THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT COND.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: AFT - REACTION CCNTPOL  FMEA NO 03-24 -202140-1  REV:12/12/73
3-31-77. CONTAM CONT PROD, CORROS. PROT PROV TURNAROUND- FUNC FLOW
TESTS ARE MCNIT TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON
COMMAND. (O) APOLLO FAILURES WERE MAINLY ASSOC WITH REVERSE POLARITY
AND DEGUASSING OF MAGNETS. THE SHUTTLE VALVE UTILIZES A CONNECTOR
(RATHER THAN LEAD WIRES) AND A BLOCKING DIODE WHICH PREVENTS THIS TYPE
OF ERROR DURING CONN. DEVEL TEST, AND ANAL SHOWED PRESS SURGE FATIGUE
PROBLEM. THIS IS BEING RESOLVED BY REDUCING THE LIFE OF THE VALVE TO 50
MISSIONS.
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY 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
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. There is one success path remaining after the first failure.

8B. Same as primary.

2. Measurements V42P2313C, 2315C, 2313C and 3315C are not listed in the MML.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT
P/N: MCZ760
MISSIONS: H=VF X FF OF SM
QUANTITY: 12

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

FAILURE MODE: FAILS OPEN.

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

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (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 SYM EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE CONDITION. PROOF PRESS TESTING IS CONDUCTED DURING ATC & LEAKAGE TESTS ARE PERF BEFORE & AFTER OPER CYCLES. (C) AN IDENT IS PERF. RAW MAT RL NDE EXAM, VISUAL INSPECT FOR SURFACE DEFECTS, & EQUIP CONFORMANCE TO CONTRACT REQMTS ARE VERIF BY RECEIVING INSPECT OR PROOF TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQMTS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPECT POINTS-PARTS.
SUBSYSTEM : AFT - REACTION CONTROL

FMEA NO: 03-24 -202150-1

REV: 11/08/75

PROT, MFG. PROCESSES, COATING, ASSY AND INSTALLATION. THE ABOVE ITEMS

& THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77. CORROS

PROT PROV, CONTAM CONT PROCESSES, TEST HANDLING, & STORAGE ENVIR.

THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT OF MARCH 6, 1972. 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.

TURNOAROUND-COUPINGS ARE VISUALLY INSPECTED FOR EVIDENCE OF DAMAGE SEALS & LEAK

TESTS ARE PERFORMED. (D) APOLLO FAILURE HISTORY WAS IN THE MAIN ASSOCIATED

WITH GROUND USAGE, IMPROPER HANDLING.
**HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2**

**SUBSYSTEM** AFT - RCS  
**FMEA NUMBER** 03-2A-211110-1  
**ITEM** Propellant Tank Assy.  
**FAILURE MODE** External Leak

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
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<tbody>
<tr>
<td>1. Does the flight software detect this failure mode (i.e., automatically announce or take action in response)?</td>
<td>Yes Y</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 Y</td>
</tr>
<tr>
<td>2. Are the answers to questions 1 and 1a consistent with the FMEA evaluation of in-flight detectability?</td>
<td>Yes X</td>
</tr>
<tr>
<td>3. Does the flight software take action to negate the effects of the failure (either by commanding hardware action or implementing alternate program logic)?</td>
<td>Yes X</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 Y</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 Y</td>
</tr>
<tr>
<td>5. Can this failure mode, in combination with software logic, adversely affect other functions?</td>
<td>Yes Y</td>
</tr>
<tr>
<td>6. How many of these hardware failures can the shuttle tolerate (consider crew action and hardware/software operation)? Note change to FMEA criticality.</td>
<td>*0 X</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 X</td>
</tr>
<tr>
<td>8. If the answer to either 1 or 3 is yes:</td>
<td></td>
</tr>
<tr>
<td>A. Can the BFS be engaged after occurrence?</td>
<td>Yes X</td>
</tr>
<tr>
<td>B. Will BFS tolerate failure without loss of crew/vehicle?</td>
<td>Yes X</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. [ ] DETECTION DURING CHECKOUT  
5. [ ] ACCEPTANCE RATIONALE BELOW  
6. [ ] RECOMMENDED CHANGES BELOW  

[ ] FMEA CHANGE RECOMMENDED

**EXPLANATION/COMMENTS:**

2. Pod redundancy.
3. Backup flight system same as primary.
ORIGINAL PAGE IS OF POOR QUALITY

The failed fuel and chemical analysis - on the 12th.

PREVIOUSLY:

C.S.

C.\.

APPROVED BY:

C.S.

C.\.

UNIVERSAL ACTIVATION DRILL AND RELATION SCARE (U.

F.B.I.

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C.S.
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PROPELLANT FEED
P/N RI : MC282-0001-0001-0002
P/N VENDOR: 355C331000-010-020
MISSION: W/F V/F X FF JF SM
QUANTITY : 1

ITEM: TANK ASSY, PROPELLANT
INCLUDING ACQUISITION DEVICES AND RETENTION SCREENS (1.5 FACTOR OF SAFETY)

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

FAILURE MODE: STRUCTURAL FAILURE
EXTERNAL LEAK, TANK WALL CRACK OR SEAL FAILURE.

CAUSE(S):
MECH SHOCK, FATIGUE, OVERPRESS, STRESS CONCENTRATIONS, PROPER PROPELLANT
OR TEST FLUID, OVER TEMP, PLUME OR REENTRY GASES, STRESS RISE?, YIELD
OR MATT'\ DEFECT, INCORRECT OR DAMAGED SEAL.

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) THE F.S. (BURST) IS 1.5 X WORKING PRESSURE. COMPLETE STRESS
ANALYSIS FOR EACH TANK SEGMENT WAS PERFORMED. TANK IS CLASSIFIED AS
FRACUTURE CRITICAL FOR HANDLING AND IS SUBJECT TO FRACUTURE CONTROL
REOMTS. ALL FITTINGS AND FLANGES USED ON THE TANK HAVE DUAL ELASTOMER
SPRING LOADED SEALS. (B) QUAL REQUIRES 900 PRESSURE WITH (INCLUDING
200 EXPLOSION CYCLES AND A 90 DAY CREEP AND PROPELLANT EXPOSURE TEST.
PROOF PRESSURE (1.3X WORKING PRESSURE) AND LEAKAGE TESTS ARE PERFORMED
DURING ATP- RADIOGRAPHIC AND DYE PENETRANT TESTS ARE PERFORMED TO
VERIFY NO PERMANENT DEFORMATION OR FLAW GROWTH. WELDS ARE VISUALLY
INSPECTED FOR EVIDENCE OF STRESS RISER OR OTHER FLAWS. (C) AN
IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. RAW 'MAT'\ AND
PURCHASED COMPONENT REOMTS ARE VERIFIED BY RECEIVING INSPECTION.
MEASUREMENT STANDARDS AND TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REOMTS OF MIL
STANDARDS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY
INSPECTION POINTS - PARTS PROTECTION, MFG. PROCESSES, FINISHES, ASSEMBLY
INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A -211110-1  REV:11/03/73

AUDIT CONDUCTED 11-1-76. CORROSION PROTECTION PROVISIONS, TEST HANDLING, AND STORAGE ENVIRONMENTS. TENSILE, HEAT TREAT AND WELD SAMPLES ARE TESTED DURING IN-PROCESS FABRICATION IN ADDITION TO X-RAY AND DYE PENTRANT INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS. BOTH CERTIFIED WELDERS AND CERTIFIED INSPECTORS ARE USED FOR ALL WELDS. TURNAROUND- INSPECTION TO MONITOR FUNCTIONAL TEST DURING PRESSURIZATION CYCLE FOR EVIDENCE OF LEAKS. LEAKAGE TESTS ARE PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND PERIODICALLY AS PART OF CHECK-OUT PROCEDURE PRIOR TO FLIGHT. PRESSURE CYCLES ACCUMULATED ARE ALSO RECORDED.  10 APOLLO FAILURES WERE ASSOCIATED WITH INCORRECT TEST FLUID (METHYL ALCOHOL), IMPROPER PROPELLANT NO CONTENT, STRESS RISE OR TEST ERROR RESULTING IN CREATION OF VACUUM. CORRECTIVE ACTION WAS TAKEN FOR ALL OF ABOVE FAILURES AND ALSO IMPLEMENTED ON SHUTTLE.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUCIENTE OR TAKE ACTION IN RESPONSE)? 
   - YES ☑ NO ☐

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

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

EXPLANATION/COMMENTS:

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

5. Crossfeed.

8b. Same as primary.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N: MC32-0061-0031-0002
P/N VENDOR: 855C3310000-010-020
MISSIONS: WF Vf X FF OF SM
PHASE(S): PL LO X DO X DO LS
QUANTITY: 4

PREPARED BY: DES R BEMIS DES C MAKERS
APPROVED BY: SSM, NASA

ITEM: TANK ASSY, PROPELLANT
INCLUDING ACQUISITION DEVICE AND RETENTION SCREENS (1.5 FACTOR OF SAFETY) TK 203/204/303/304.

FUNCTION:
TO STORE/SUPPLY PROPELLANT FOR REACTIOM CONTROL THRUSTERS. ACQUISITION DEVICE RETAINS PROPELLANT 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 (S)
FAILS TO FEED PROPELLANT DUE TO RETENTION DEVICE FAILURE, GAS BUBBLES IN PROPELLANT.

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

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) SAFETY FACTORS OF 1.5 (MINIMUM) IN SCREEN WILL MINIMIZE FAILURE POTENTIAL. (B) QUAL kleine 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 INSPECTION STANDARDS & TEST EQUIPMENT STANDARDS ARE IMPLEMENTED PER REQUIREMENTS 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 ☐

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)?**
   - NO ☑ 1 ☑ 2 ☐

7. **IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?**
   - N/A ☑ YES ☑ 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
2. ☐ HARDWARE ACCEPTS RISK
3. ☐ NO SOFTWARE DETECTION
4. ☑ DETECTION DURING CHECKOUT
5. ☐ ACCEPTANCE RATIONALE BELOW
6. ☐ RECOMMENDED CHANGES BELOW

In-flight detectability

**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.
<table>
<thead>
<tr>
<th>Description</th>
<th>Action</th>
</tr>
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<tbody>
<tr>
<td>Structural Failure</td>
<td>(S)</td>
</tr>
<tr>
<td>General Failure</td>
<td>(G)</td>
</tr>
</tbody>
</table>

**Initial Actions:**
- Engage INTRA-CELL & INT'L PENET, Increase impact velocity.
- Certain resulting in five-hole leak thru convoluted F5C-72560.
- Immediate (SP) film induction: Via fuel-prep. F3R-4069.

**Interface Function:**
- Pass crush-lapage within fuel & ablation of F3C-72560.
- Inflame propellant.
- Possible loss of cryogenic fuel - if FVPS joint swells due to
- Inability to utilize/retain propellant that could result in a
- Causing fire or explosion.

**Supporting Action:**
- Engage LVS at tank exit valves.
- Utilize OMS pump as needed. Avoid flow at engine.

**Precautions:**
- Contamination due free propellants. Cut, Toxic gas to the skin. Ensure
- Right flame strip of cryogenic fuel such as the catalyst preheat.
- For
- Gas SGLS, ENV in SGLS. RLP M82 NO. 1-4X-532-02.
SHUTTLE CRITICAL ITEMS LIST - CRITERION 102

SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PROPELLANT FEED
P/N REF : 73P550015-1016102 (HDAC)
P/N VENDOR: 1003099-1016102 (ISS)
MISSIONS: HF VF XF CF SM
PHASES: PL X L3 X CC X DO X LS X

ASSEMBLY : PROPELLANT FEED A4CRT: CRIT. FUNC: 1
P/N REF : 73P550015-1016102 (HDAC)
P/N VENDOR: 1003099-1016102 (ISS)
MISSIONS: HF VF XF CF SM
PHASES: PL X L3 X CC X DO X LS X

QUANTITY : 12
3 PER PROP TANK

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

PREPARED BY: GLAVINICH DES
APPROVED BY: SSM
REL M A KERS REL

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ペンタ, Incomplete Fusion, Pop-Cap,
Corros resulting in pin hole leak thru Convolute, Prop & Si-Prop
Exposure Press Surge, Flow Induced Vib-Pog 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 PCD AND ADVERSE EFFECT
ON TPS (MOLECULAR VENTING). (C) LAUNCH DELAY CP ABORT DECISION. (D)
POSSIBLE LOSS OF CREW/VEHICLE - IF BELLows JOINT RUPTURES RESULTING IN
INABILITY TO UTILIZE/DEPLETE Prop OR Prop REACTS 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.
ITM IS USED DURING SYSTEM EVALUATION TESTS AT WSTF ALLOWING
EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. (C) A VISUAL
INSPI AND IDENTIFICATION IS PERFORMED AND THE UNIT TAgGED. CON-
CONTAMINATION CONTROL PROCESS, Corros. PROTECTION PROVISIONS, MDE
EXAM OF WELDS, INSPI 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 INSPI POINTS. THE
ABove ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED
&-29-77. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND
STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L
CONFORMANCE TO CONTRACT REGMTS. TURNAROUND - MONITOR LEAKAGE TESTS
PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND AS PART OF CHECKOUT.
SUBSYSTEM: AFT - REACTION CONTROL - FMEA NO 03-2A-211120-1 REV: 11/08/78

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

*EXPLANATION REQUIRED (SEE BELOW)*

**EXPLANATION/COMMENTS:**

INVESTIGATE CAUSE OF CONTROL LOSS AT STAGE SEPARATION:

1. PULL 200 PSI LEVEL INCREASE.

2. PULL 200 PSI LEVEL DECREASE.

3. INCREASE IN INSTRUMENTS.

4. DECREASE IN INSTRUMENTS.

5. EMERGENCY VALVE OPEN.

6. EMERGENCY VALVE CLOSED.

7. INVESTIGATE BY-

8. PHYSICAL MEASURES.

9. PHYSICAL MEASURES.

10. PHYSICAL MEASURES.

11. PHYSICAL MEASURES.

PREPARED BY:

DEB W. GUMMEL

REL. C. BAKERS

APPROVED BY:

JES

REL.

INVESTIGATION:

1. NO ABNORMALITIES.

2. NO ABNORMALITIES.

3. NO ABNORMALITIES.

4. NO ABNORMALITIES.

5. NO ABNORMALITIES.

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10. NO ABNORMALITIES.

INVESTIGATION:

1. NO ABNORMALITIES.

2. NO ABNORMALITIES.

3. NO ABNORMALITIES.

4. NO ABNORMALITIES.

5. NO ABNORMALITIES.

6. NO ABNORMALITIES.

7. NO ABNORMALITIES.

8. NO ABNORMALITIES.

9. NO ABNORMALITIES.

10. NO ABNORMALITIES.

INVESTIGATION:

1. NO ABNORMALITIES.

2. NO ABNORMALITIES.

3. NO ABNORMALITIES.

4. NO ABNORMALITIES.

5. NO ABNORMALITIES.

6. NO ABNORMALITIES.

7. NO ABNORMALITIES.

8. NO ABNORMALITIES.

9. NO ABNORMALITIES.

10. NO ABNORMALITIES.

INVESTIGATION:

1. NO ABNORMALITIES.

2. NO ABNORMALITIES.

3. NO ABNORMALITIES.

4. NO ABNORMALITIES.

5. NO ABNORMALITIES.

6. NO ABNORMALITIES.

7. NO ABNORMALITIES.

8. NO ABNORMALITIES.

9. NO ABNORMALITIES.

10. NO ABNORMALITIES.

INVESTIGATION:

1. NO ABNORMALITIES.

2. NO ABNORMALITIES.

3. NO ABNORMALITIES.

4. NO ABNORMALITIES.

5. NO ABNORMALITIES.

6. NO ABNORMALITIES.

7. NO ABNORMALITIES.

8. NO ABNORMALITIES.

9. NO ABNORMALITIES.

10. NO ABNORMALITIES.
SHUTTLE CRITICAL ITEMS LIST - CRITER 102

SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : THRUSTER/PROPELLANT FEED
P/N RI : 73P55000-1-0101THRU1005
P/N VENDOR : C-400
QUANTITY : 56

ABORT: CPIT. FUNC: 1
P/N : NC621-0059 CRIT. HOW: 1
VENDOR: 73P55000-1-0001THRUI000 MISSIONS: HF VF X FF OF SM
PHASE(S): PL X LD X CO X DO X LS X

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

PREPARED BY: DES  N. GLAVINICH
APPROVED BY: DES  C. M. AKERS

ITEM: BELLows ASSEMBLY
ENGINE ALIGNMENT.
FUNCTION:
A STAINLESS STEEL EXternally (Cylinder) CONSTRAINED BELLows WITH RIGID
TUBE END CONNECTIONS IS PROVIDED AS A MEANS OF CONNECTING AND ALIGNING
THE THRUSTER VALVES TO THE PROPELLANT SYSTEM.

FAILURE MODE: STRUCTURAL FAILURE (S)
EXTERNAL LEAKAGE.

CAUSE(S):
FATigue, SHock, Handling, [A]eq WELD PeneT, INCOm-P Fusion, PROpositY,
CORROS-PROP & Bi-PROP Exposure, PRESS SURGE, FLOW INDUCED Vib-PoOq
EFFECT, FLY 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 ABOPT DECISION, (D)
POSSIBLE LOSS OF CREW/VEHICLE - FAILURE NOT DETECTABLE SINCE PVT
MEASUREMENTS HAVE BEEN DELETED FROM SOFTWARE FOR ASCENT AND RTLS.
(ISOLATION IS POSSIBLE DURING OTHER MISSION PHASES).

DISPOSITION & RATIONAL (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 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
AFOBE 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 EQUIPMENT AND MATERIAL
CONFORMANCE TO CONTRACT REQUIREMENTS. TURBOPUMP - MONITOR LEAKAGE TESTS
PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND AS PART OF CHECKOUT
PROCEDURE PRIOR TO FLIGHT. (D) NO FAILURE HISTORY AVAILABLE ALTHOUGH
THE APOLLO PROGRAM DID SHOW SOME PROBLEMS ON FLEX HOSE ASSY DUE TO PIN
HOLE CORROSION ASSOCIATED WITH RESIDUAL SOLVENTS AND PROPELLANT.
SUBSYSTEM AFT - RCS
ITEM Engine Inlet Valve
FMEA NUMBER 03-2A-221310-4
FAILURE MODE Fails Closed

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

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

EXPLANATION/COMMENTS:
1. "Failed off" thruster C&W.
TANK FUEL TANK AND EFFECTS ANALYSIS - POSSIBLE EFFECTS

PREPARED BY: W. SWARTZ
DATE: 9/1/73

DESCRIPTION:
- FUEL VALVES FAIL TO OPEN
- FUEL VALVES FAIL TO CLOSE
- FUEL SYSTEM FAILS TO FILL

EFFECT:
- LOSS OF FUEL IN TANKS
- INABILITY TO START ENGINE

CONDITIONAL EFFECT:
- LOSS OF FUEL IN TANKS
- INABILITY TO START ENGINE

IF FUEL VALVES FAIL TO CLOSE:
- LOSS OF FUEL IN TANKS
- INABILITY TO START ENGINE

GENERAL ACTION:
- IF FUEL VALVES FAIL TO CLOSE, UTILIZE EMERGENCY IN TANKS (IF LIVABLE)
- IF FUEL VALVES FAIL TO CLOSE, UTILIZE EMERGENCY IN TANKS (IF LIVABLE)

FUEL SYSTEMS
- FUEL SYSTEMS IDENTIFIED FOR NORMAL MISSION. LEAKING FUEL, TRANSPORT
- FUEL SYSTEMS IDENTIFIED FOR NORMAL MISSION. LEAKING FUEL, TRANSPORT

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<table>
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<tr>
<th>Item</th>
<th>Injection Plate</th>
<th>Failure Mode</th>
<th>Restricted Flow</th>
</tr>
</thead>
</table>

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

**EXPLANATION REQUIRED (SEE BELOW)**

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

**In-Flight Detectability**
- ☑ FMEA CHANGE RECOMMENDED

**EXPLANATION/COMMENTS:**

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

SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : THRUSTER, PRIMARY
P/N REL : MC467-0028
P/N VENDOR : 330938
QUANTITY : 24

PREPARED BY: C M AKERS
APPROVED BY: NASA

ITEM: INJECTOR, PLATE

FUNCTION:
Provides injection & vaporization of fuel and oxidizer for propellant mixing at 1.50 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-103 columbium and welded to the CCB CHAMB. Acoustic cavities are located at the outer periphery of the inj face to prevent high freq CCB instab.

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

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

EFFECT(S): On (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) VEHICLE:
(A) Loss of redundancy or functional degradation - Reduced propellant flow - CHAM PRESS & THRUST, imaged CHAM/INJ FILM COOLING. (B) Degradation of interface function - Inc. GNC & use of all 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 syringe and subsequent hazard. Automatic switch over (and isolation) by GNC failure detection system. Complete thermal and stress analysis have been completed. (B) RCS SYM EVAL TEST AT WSTF, THRUSTER QUAL FOR 50,000 CYCLES. SPRAY PATTERN CHECKED DURING ATP. (C) A VISUAL INSPECTION IS PERFORMED AND THE UNIT TAGGED, CONTAMINATION CONTROL PROCESSES, PROTECTION PROVISIONS, NO EXAM OF WELDS, RAH MATT (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-76. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MATT AND EQUIP CONFORMANCE TO CONTRACT REGS, TURNAROUND INSPECTION TO INCLUDE USE OF OPTICS WHERE ACCESSIBLE TO DETERMINE EVIDENCE OF PLUGGED ORIFICE, FLUID SAMPLING TO BE PERFORMED TO DETECT CONTAMINATION (D) NO DIRECT FAILURE HISTORY AVAILABLE.

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5755-TH-0003
<table>
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<tr>
<th>Item Number</th>
<th>Failure Mode</th>
<th>Status</th>
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<tbody>
<tr>
<td></td>
<td>Burn-Thru</td>
<td>☑</td>
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**HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2**

**SUBSYSTEM AFT - RCS**

**ITEM** Thrust Chamber

**FMEA NUMBER** 03-2A-221312-1

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**

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

**FMEA CHANGE RECOMMENDED**

**EXPLANATION/COMMENTS:**

1. "Failed off" thruster C&W.
Sr
[Image 0x0 to 611x795]

ORIGINAL PAGE IS OF POOR QUALITY
ITEM: THRUST CHAMBER  
FROM INJECTOR TO NOZZLE EXTENSION (COATED COLUMBIUM).

FUNCTION:  
TO CONTAIN HYPERGOLIC REACTION OF PROPELLANTS AND DIRECT COMBUSTION PRODUCTS THROUGH NOZZLE & EXTENSION TO PROVIDE IMPULSE TO VEHICLE. THE CHAMBER IS CONSTRUCTED OF C-103 COLUMBIUM WITH P-512 A RIOXIATION RESISTANT COATING AND UTILIZES FILM COOLING. THE CHAMBER PRESSURE IS 152 PSI & IS DESIGNED TO PRODUCE A THRUST OF 780 LBS VACUUM AT A MAXINAL STEADY STATE SPECIFIC IMPULSE OF 280 SECONDS.  

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

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

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

DISPOSITION & RATIONALE:  
(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:  
(A) STRUCTURAL MARGINS (2.1 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 PROCESSES, CORROS. PROTECTION PROVISIONS, NDE EXAM OF HELDS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELEP MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-78. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP CONFORMANCE TO CONTRACT REQS. TURNAROUND INSPECTION TO INCLUDE USE OF OPTICS WHERE ACCESSIBLE TO DETECT EVIDENCE OF PLUGGED ORIFICES. FLUID SAMPLING TO BE PERFORMED TO DETECT CONTAMINATION. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

**SUBSYSTEM** AFT - RCS  
**FMEA NUMBER** 03-2A-221313-1  
**ITEM** Nozzle Extension  
**FAILURE MODE** Burn-Thru

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

*EXPLANATION REQUIRED (SEE BELOW)*

**CHANGE/RETENTION RATIONALE SUMMARY**

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

FMEA CHANGE RECOMMENDED

**EXPLANATION/COMMENTS:**
**SIMPLE FAULT: LOW AND EFLECTS ANALYSIS**

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<tr>
<th>EFFECT</th>
<th>CAUSE(S)</th>
<th>CORRECTIVE ACTION</th>
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</table>
| #1: NUCLEAR HEAT EXCHANGER MALFUNCTION | NUCLEAR HEAT EXCHANGER MALFUNCTION | STOP REACTOR |}
| #2: NUCLEAR HEAT EXCHANGER MALFUNCTION | NUCLEAR HEAT EXCHANGER MALFUNCTION | STOP REACTOR |}

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**PREPARED BY:**

<table>
<thead>
<tr>
<th>CES</th>
<th>M. SANCY</th>
<th>APPROVED BY:</th>
<th>L.E.</th>
<th><strong>APPROVED BY:</strong></th>
<th>L.E.</th>
<th><strong>APPROVED BY:</strong></th>
<th>L.E.</th>
</tr>
</thead>
</table>

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**SPECIFICATIONS:**

- Universal Code of Practice (U.S.C.) for Nuclear Power Plants
- ASME Section III, Division 1
- API 510, Pressure Vessel Inspection Code

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**REMARKS:**

- All welds shall be examined by radiography or ultrasonic testing.
- All nozzles and flanges shall be tested for leakage.
- All vessels shall be pressure tested to 1.5 times the design pressure.

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**ORIGINAL PAGE IS OF POOR QUALITY.**
ITEM: NOZZLE EXTENSION, COATED COLUMBIA WITH INSULATION BLANKET.

FUNCTION:
To provide isentropic expansion of combustion gases for max eff in vacuum. Nozzle extension is constructed of C-103 columbium with 7-512 alloy oxidation resistant coating. The nozzle expansion ratio is 22 to 1. The nozzle extension is integral with the comb chamber and enclosed in a Mylar flex insulation shroud so that the ext temp is maintained per the procurement specification reqmt.

FAILURE MODE: STRUCTURAL FAILURE, BURN-THRU.

CAUSE(S): HIGH TEMPERATURE IN LOCAL SPOT CONTAMINATED INJECTANT HOLES IN WELD OR MAT' L DEFOCUT.

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY: (A) HIGH THERMAL MARGINS IN NOZZLE EXTENSION AND HIGH COOLING MARGIN WILL MINIMIZE FAILURE EFFECT. ENG DESIGNED TO INGEST 45CU. IN. OF GAS. THRUSTER CAN BE ISOLATED AT INLET OR MANIFOLD VALVE. (B) RCS SYS. EVAL TEST AT WSTF. THRUSTER QUAL FOR 50,000 CYCLES. (C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, WELD EXAM. 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 OR 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 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 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  3. ☐ NO SOFTWARE DETECTION  5. ☐ ACCEPTANCE RATIONALE BELOW
2. ✗ HARDWARE ACCEPTS RISK  4. ☐ DETECTION DURING CHECKOUT  6. ☐ RECOMMENDED CHANGES BELOW

EXPLANATION/COMMENTS:

3. Down modes to free drift.

6. No redundancy in the verniers.
TITLE: FAILURES AND EFFECTS ANALYSIS

LOCATION: [Unknown]

FAILURES AND EFFECTS

1. PRIMARY THRUSTERS

   a. VEHICLE: [Unknown]

   b. FAILURES:

      i. LOSS OF PRIMARY TRU"STERS

Effect:

   a. LOSS OF PRIMARY THRUSTERS CAUSES LOSS OF VEHICLE ATTITUDE CONTROL. MAY HAVE ATTITUDE TRANSITION.

   b. IF PAYLOAD ATTACHMENT IS UNSTABLE, PAYLOAD MAY HAVE ATTITUDE AND TRANSLATION CONTROL.

   c. IF PAYLOAD ATTACHMENT IS STABLE, PRIMARY THRUSTERS MOVE VEHICLE TO STABLE ATTITUDE.

   d. PAYLOAD MAY BE RETRIEVED WHILE IN FREE DRIFT MODE AND IN SOME INSTANCES PAYLOAD MAY BE RETRIEVED WHILE IN STABLE ATTITUDE MODE.

   e. PAYLOAD MAY BE RETRIEVED WHILE IN FREE DRIFT MODE AND IN SOME INSTANCES PAYLOAD MAY BE RETRIEVED WHILE IN STABLE ATTITUDE MODE.

PREPARED BY: [Unknown]

APPROVED BY: [Unknown]
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: VERNIER THRUSTER
P/N RE: MC467-0029
P/N VENDOR: MISSIONS: HF
QUANTITY: 4

FUNCTION:
VERNIE R THRUSTERS ARE PROVIDED IN EACH ARES 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:
LOSS OF OUTPUT (THrust)
INLET VALVES CLOSED OR INJ ORIFICE PLUGGED.

CAUSE(S):
OPEN SOL COIL, AUTO SHUT-OFF, INLET VALVE LEAK/STRUCT FAL!, INJ ORIFICE PLUGGED.

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) POSS REDUND MODES IN X AXIS PRIMARY THRUSTERS, PAYLOAD ATTITUDE CONTROL & FREE DRIFT MODES. 100 MICRON FILTRATION & HEATERS PROVIDED TO LIMIT CONTAM & PREVENT PROP FREEZING. (B) THRUSTER OAL FOR 500,000 CYCLES, 125,000 SEC BURN TIME. INLET VALVE TESTED FOR 500,000 WET CYCLES & 5000 DRY. (C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS CONFORMS PROTECTION PROVISIONS, NOE EXAM OF WELDS, RAW MAT' L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION.

MANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION. 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. TERNARROW dummy, INSPECTION USING OPTICAL INSTRUMENTATION. SYSTEM FLUIDS ARE ANALYSED FOR EVIDENCE OF CONTAMINATION. PROPER INLET VALVE FUNCTION AND ELECTRICAL LOGIC POWER IS VERIFIED. (D) NO DIRECT FAILURE HISTORY AVAILABLE.

PREPARED BY: J. TAGGART
APPROVED BY: E. A. J. R. L.

APPROVED WITH CHANGES
See Section 13.0
HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

SUBSYSTEM: AFT-RCS
ITEM: Vernier Thruster
FMEA NUMBER: 03-2A-231310-2
FAILURE MODE: Fails to Stop Firing

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

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

---

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. "Failed on" thruster C&W.
2. No redundancy in the verniers.

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ORIGINAL PAGE IS OF POOR QUALITY

PREPARED BY: J. TAGGART
APPROVED BY: C. WILKINS

IF SYSTEM, ASSEMBLY, OR VEHICLE
- INCREASE FLUID LEVEL, 3/1-5/7/57/80.
- NO
SYSTEM:
- IF PRESSURE (IN APPLIED PLUGS) ALL BUT V24 (PLUG/HAVEL AND) VENTED
- PRESSURE IS PREREQED TO EACH ARC3 VOLTAGE TO PROVIDE PRECISE LEB \ SMALL
- PRESSURE RELATIONSHIPS FOR PUMPING, SALTS
- UNCONDITIONALLY SIMILAR TO THE PRIMARY THUSTER BUT LEFT TO \ PRESSURE
- VENTS, 1 AND 3 PIP HEAD, CATIONS TO THE PUMP.
- LOCK PLUS: FAILS TO STOP
- FIELD ITEM FAILS TO COOL (THUSTER CONTINUES FIring).
- LOCK PLUS:
1. EXISTING, STRUCTURAL FAILURE, BOLT SHORT IN LEBL (1/11/11) - SAME
- AS ALL CRAWL, VAP, SPARK SEAL SEAT CAP, PROP RETAINER, FIELD SALTS,
- CUSTOMARY.
2. C.T.E.: (A) SUBSYSTEM, (B) INTERFACES, (C) VEHICLES (D) VEHICLE:
- (D) LOSS OF FUNCTION (VAPOR THRUSTERS) - IMMEDIATE LOSS OF VEHICLE.
- VAPOR THRUSTER CAUSES LOSS (FUNCTION) OF VEHICLE CONTROL. 1.
- IMMEDIATE INTERFACES SUBSYSTEM - PROB LEAK HAVING UP. ACTS AS TIME.
- VAPOR THRUSTERS ISOLATION CAP TO PUMP AT 0.05 YIELD TO
- VAP. 1. FIELD (C) ISOLATION MODIFICATION OR ACTUAL DECLINE. (5) AND EFFECT.
- CONNECTIVE ACTIVITY:
1. ISOLATE VAPOR THRUSTER WITH UPSTREAM MANIFOLD ISOLATION VALVE.
   VALVE TO DETERMINE ZEC FOR RPEL VERSUS USE OF PRIMARY THRUSTERS.
   FIELD PUMP OR PUMP AT ATTITUDE CONTROL.
- FIELD (A) RCS:
- PRESSURE PUMP TO PUMP OR PUMP AT BAY ARMS. PRIMARY THRUSTERS FOR
   VEHICLE unwanted FT OF PUMP. PUMP AT BAY ARMS ARE 1/2 FT LONG, I
   NO ENTRANCE PUMP COULD BE RETRIEVED WHILE IN THE PUMP AT BAY INSTANCES PUMP AT
   HAVE ATTITUDE OR TRANSITION CONTROL. IT MAY BE USE OF PUMP AT AFT RCS (X AXIS) ENGINES FOR PUMPT.
SHUTTLE CRITICAL ITEMS LIST - CRITERIA 102

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

ABORT: CPIT. FUNC: 2
CPIT. HOW: 2
MISSIONS: HF VF X FF DF SM
P/N: MC467-0029
CPIT.
HOW: 2
MISSIONS: HF VF X FF DF SM

QUANTITY: 4
PHASE(S): PL LJ CO X DO LS

PREPARED BY: J TAGGART
APPROVED BY: SSM

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 REQUIRED FOR PAYLOAD POINTING. THEY ARE CONCEPTUALLY SIMILAR TO THE PRIMARY THRUSTER BUT LIMIT PLUME IMPINGEMENT AND PROP RESIDUE CONTAMINATION TO THE PAYLOAD.

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

CAUSE(S):
- CONTAMINATION, STRUCTURAL 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) CRITICAL/VITAL,

(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 SE 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/MDM DESIGN. (B) THRUSTER QUAL FOR 500,000 CYCLES, 125,000 SEC BURN TIME, INLET VALVE TESTED FOR 500,000 WET CYCLES & 5000 DRY. (C) A VISUAL INSPECTION 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. MANUFACTURER, INSTALLATION, AND ASSEMBLY 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 REQUIREMENTS. TURNAROUND - SYSTEM FLUIDS ARE ANALYSED FOR EVIDENCE OF CONTAMINATION. PROPER INLET VALVE FUNCTION AND ELECTRICAL LOGIC POWER IS VERIFIED. (D) NO DIRECT FAILURE HISTORY AVAILABLE.

1021 127 SD75-SH-0003
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   YES [X] NO [ ]

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW).

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

EXPLANATION/COMMENTS:
1. "Failed off" thruster C&W.
2. Down modes to free drift.
3. No redundancy in the verniers.
ITEM: THRUSTER, ASSY, VERNIER
25 POUND THRUST LEVEL. EN 357/358/257/258.

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

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

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

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

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

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 RI : MC467-0029
P/N VENDOR: MISSIONS: HF VS X FF CF SM

FUNCTION:

1. ONE PITCH (2 AXIS-UP FIRING) AND ONE YAW (PLUS/MINUS Z AXIS) VERNIER THRUSTER ARE PROVIDED IN EACH AFCS MODULE TO PROVIDE PRECISE LOW LEVEL PULSING AND ATTITUDE HOLD REQUIRED FOR PAYLOAD POINTING. THEY ARE CONCEPTUALLY SIMILAR TO THE PRIMARY THRUSTERS BUT LIMIT PLUME IMPINGEMENT AND PROP RESIDUE CONTAMINATION TO THE PAYLOAD.

FAILURE MODE: STRUCTURAL FAILURE(s)

CAUSE(S):

- THERMAL CYCLING/STRESS FATIGUE, VIB, CG/M INSTAB, SHOCK, DROPPED INJ

- DRIFTS, HIGH TEMP/LONIZED H2/SPOTS/MANGED COOLING NOZZLE RESTRICTION.

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

- (A) LOSS OF FUNCTION - CURRENT LOSS OF SINGLE VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL. (B) DEGRADATION OF INTERFACE FUNCTION INCR GNSS & USE OF ALT THRUSTERS (C) MISSION MODIFICATION/ABORT DECISION IF FAILURE CAUSES DANGEROUS 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 MIVES IN X AXIS PRIMARY THRUSTER, PAYLOAD ATTITUDE CONTROL & FREE DRIFT MODES. 100 MICRON FILTRATION & HEATERS PROVIDED TO LIMIT CONTAM & PREVENT PROP FREEZING. (B) THRUSTER QUAL FOR 500,000 CYCLES, 125-000 SEC BURN TIME, INLET VALVE TESTED FOR 500,000 WET CYCLES & 5000 DRY. (C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NDE EXAM OF WELDS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUFACTURING, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER, MANDATORY INSPECT 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 EQ'T AND MAT'L AND EQUIP. CONFORMANCE TO CONTRACT REQS. TURNAROUND - VISUAL INSPECTION USING OPTICAL INSTRUMENTATION. SYSTEM FLUIDS ARE ANALYZED FOR EVIDENCE OF CONTAMINATION. - PROPER INLET VALVE FUNCTION AND ELECTRICAL LOGIC POWER IS VERIFIED. (D) NO DIRECT FAILURE HISTORY AVAILABLE.

PREPARED BY: DES: J Taggart REL: C Makers
APPROVED BY: DES: SSM: W. Kendall

See Section 13.0
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>Organization</th>
<th>Phone</th>
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</thead>
<tbody>
<tr>
<td>Lonnie Jenkins</td>
<td>NASA/JSC</td>
</tr>
<tr>
<td>Dave Latham</td>
<td>Boeing/Reliability</td>
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<td>Don Cagle</td>
<td>Boeing Reliability</td>
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<tr>
<td>Herb Saxton</td>
<td>Rockwell Propulsion/RCS</td>
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<tr>
<td>Larry Gladu</td>
<td>Rockwell Systems Engineering</td>
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</table>

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

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

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

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

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

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

03-2A-211111-2: 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-211112-1: Change question 1 to gross leak detection. Change question 6 from 0 to 1. Add crossfeed.

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

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

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

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

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

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

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

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