ORBITER SUBSYSTEM
HARDWARE/SOFTWARE INTERACTION ANALYSIS

VOLUME VIII: AFT REACTION CONTROL SYSTEM

PART 2

JANUARY 1980.
The Orbiter subsystem hardware/software interaction analysis examines software interaction with hardware failure modes. Each failure mode identified in subsystem FMEA (failure mode and effects analysis) is examined for interaction with software. The analysis is based upon key questions which identify potential issues. These potential issues are to be resolved by providing rationale for retention or identifying and implementing changes to eliminate the issue.

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

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

This analysis verified that no open issues remain.

Approved:

Joseph H. Levine
Chief, Reliability Division

NB
The hardware/software interaction analysis is prepared by reliability. It is one of many analyses and documents used by the SEAM teams and FRAT'S in the planning and management of the verification process. The overall verification process leads up to the final flight readiness statement for each subsystem and the vehicle as a whole.
HARDWARE/SOFTWARE INTERACTION ANALYSIS

AFT - RCS

SUBSYSTEM

FMEA # SD72-SH-0103-2

ANALYSIS DATE November 5, 1979

HARDWARE/SOFTWARE ANALYST

APPROVED:

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V. G. Ostrowski 11/80
Rockwell Reliability

Leonard Jenkins 1-4-79
JSC Engineering - FRAT Sponsor

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

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

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

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

3.0 APPLICABLE DOCUMENTS.

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

<table>
<thead>
<tr>
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<td>Auxiliary Power Unit</td>
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<td>Reaction Control</td>
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<td>Electrical Power Generation</td>
</tr>
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<td>XIII</td>
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<td>XVI</td>
<td>Communications &amp; Tracking</td>
</tr>
<tr>
<td>XVII</td>
<td>Instrumentation</td>
</tr>
</tbody>
</table>
3.2 REFERENCE DOCUMENTS. The primary documents used in performing the analysis included the following:


g. 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.
<table>
<thead>
<tr>
<th>Item</th>
<th>Failure Mode</th>
<th>Answer</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Does the flight software detect this failure mode (i.e., automatically announce or take action in response)?</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>1a.</td>
<td>If not, does the hardware provide information that the flight software could use to detect the failure?</td>
<td>*YES</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Are the answers to questions 1 and 1a consistent with the FMEA evaluation of in-flight detectability?</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Does the flight software take action to negate the effects of the failure (either by commanding hardware action or implementing alternate program logic)?</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>3a.</td>
<td>If not, does the capability exist for the software to compensate for this failure mode (either by commanding hardware action or implementing alternate program logic)?</td>
<td>*YES</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>As a result of this failure mode, can the software overstress the hardware or induce another failure?</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Can this failure mode, in combination with software logic, adversely affect other functions?</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>How many of these hardware failures can the shuttle tolerate (consider crew action and hardware/software operation)? Note change to FMEA criticality.</td>
<td>*0</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>If crew action is required to respond to this failure mode, are cues provided to signal the need for intervention and the required corrective action?</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>If the answer to either 1 or 3 is YES:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>Can the BFS be engaged after occurrence?</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>B.</td>
<td>Will BFS tolerate failure without loss of crew/vehicle?</td>
<td>YES</td>
<td></td>
</tr>
</tbody>
</table>

**Explanation/Comments:**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

6.0 ANALYSIS CHECKLIST SHEETS

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

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

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

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

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

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

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

### SUBSYSTEM AFT - RCS

### DETECTION DURING CHECKOUT

<table>
<thead>
<tr>
<th>ITEM/Failure Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium Pressure Regulator - Restricted Flow - Fails Closed (03-2A-201030-2)</td>
</tr>
<tr>
<td>Helium Quad Check Valve - Fails Closed (03-2A-201095-2)</td>
</tr>
<tr>
<td>Feedline and Fittings, OX - External Leakage (03-2A-202109-1)</td>
</tr>
<tr>
<td>Tank Isolation Valve, A. C. - Fails Closed (03-2A-202110-1)</td>
</tr>
<tr>
<td>Tank Isolation Valve, A. C. - Fails Closed (03-2A-202110-3)</td>
</tr>
<tr>
<td>Interconnect Valve, A. C. - Fails Closed (03-2A-202111-2)</td>
</tr>
<tr>
<td>Manifold Isolation Valve, A. C. - Fails Closed (03-2A-202120-3)</td>
</tr>
<tr>
<td>Manifold Isolation Valve, D. C. - Fails Closed (03-2A-202140-1)</td>
</tr>
<tr>
<td>Gimbal Joint - External Leakage (03-2A-211120-1)</td>
</tr>
<tr>
<td>Bellows Assembly - External Leakage (03-2A-221308-1)</td>
</tr>
<tr>
<td>Engine Inlet Valve - Fails Closed (03-2A-221310-4)</td>
</tr>
<tr>
<td>ANALYSIS RESULT</td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td>NO SOFTWARE DETECTION</td>
</tr>
<tr>
<td>1.</td>
</tr>
<tr>
<td>----</td>
</tr>
<tr>
<td>1.</td>
</tr>
<tr>
<td>1a.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>3.</td>
</tr>
<tr>
<td>3a.</td>
</tr>
<tr>
<td>4.</td>
</tr>
<tr>
<td>5.</td>
</tr>
<tr>
<td>6.</td>
</tr>
<tr>
<td>7.</td>
</tr>
<tr>
<td>8.</td>
</tr>
<tr>
<td>A.</td>
</tr>
<tr>
<td>B.</td>
</tr>
</tbody>
</table>

*Explanation required (see below)

<table>
<thead>
<tr>
<th>Change/Retention Rationale Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>3.</td>
</tr>
<tr>
<td>4.</td>
</tr>
<tr>
<td>5.</td>
</tr>
<tr>
<td>6.</td>
</tr>
</tbody>
</table>

**Explanation/Comments:**

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

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

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

8B. Same as primary.
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PRESSURIZATION
P/N : 402-032-0331-0032
P/N VENDOR : 10-9990-0-1/2
QUANTITY : 4

SUBSYSTEM : AFT - REACTION CONTPCL FMEA
MISSIONS : HF VF X FF OF SM

ASSEMBLY : PRESSURIZATION
MISSIONS : HF VF X FF OF SM

PREPARED BY:

DES : J TAGGART
REL : C AKERS

APPROVED BY:

NATIONAL AEROSPACE

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

ITEM: TANK

HELIUM STORAGE, FILAMENT WOUND

FUNCTION:
TO STORE HELIUM AT A MAX WORKING PRESSURE OF 4000 PSI FOR
PRESSURIZATION OF THE AFT RCS MODULE'S PROPELLANT SUPPLY SYSTEM. TANK
CONSISTS OF DOUBLE MELT TI LINER WITH DUPONT KEVLAR 49 FIBER AND EPOXY
RESIN BONDING OVERLAY. TANK IS 18.71 IN. VOLUME IS 3008 CU. IN.

FAILURE MODE: STRUCTURAL FAILURE

EXTERNAL LEAK

CAUSE(S):

MATERIAL DEF, LINER DEF, FAULTY FAB, EPOXY CURING, THMST/HANGL DAY,
SHOCK, VIB, INADVER UPRESS (GMD), INADVER MOUNTING

EFFECT(S):

(A) LOSS OF FUNCTION/SUBSYSTEM
(B) LOSS OF INTERFACE FUNCTION

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

DISPOSITION & RATIONALE

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

(D) FILAMENT WOUND TANKS ARE DESIGNED TO LEAK BEFORE RUPTURE WHICH
LIMITS FAILURE PROPAGATION DUE TO SHRAPNEL. KEVLAR 49 FIBER HAS A
TENSILE STRENGTH OF 90000 PSI ALLOWING LIGHT WEIGHT WITH GREAT STRENGTH.
INCREASED STRAIN CAPABILITY IS PROVIDED BY THE COMPRESSION LOAD ON A
UNPRESSURIZED LINER. VENT DOORS ARE OPEN ON ORBIT AND WILL DELIVER ANY
PRESSURE BUILDUP DUE TO LEAKAGE. THE F.S. (BUST) IS 1.5 X WORKING
PRESS. (B) 1000 PRESSURE CYCLES ARE PERFORMED DURING OPL 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 (4 X WORKING
PRESSURE) AND LEAKAGE TESTS ARE PERFORMED DURING ATP.

IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. RAW MATERIALS
AND PURCHASED COMPONENT DEPTS ARE VERIFIED BY RECEIVING INSPECTION STANDARDS AND TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQMTS OF MIL
SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY
INSPECTION POINTS - PARTS PROTECTION, MFG. PROCESSES, FINISHES, ASSY AND
INSTALLATION. THE 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 -201010-1 REV:11/03/07
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) YGHE AVAILABLE NEW
DESIGN.
SUBSYSTEM: AFT - RCS
ITEM: He Feed Line
FMEA NUMBER: 03-2A-201013-1
FAILURE MODE: External Leakage

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

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. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

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

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

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

8b. Same as primary.
PREPARED BY: A. C. GLAVINICH

APPROVED BY: __________________________

DATE: 

PRELIMINARY STATUS: NO - No further action required.

1. INITIAL LEAKAGE: OIL, MILITARY

2. DETAILS:
   (a) LEAK CHECK
   (b) LEAK TRACING
   (c) LEAK REPAIR
   (d) LEAK SEALING

3. POSSIBLE CAUSES:
   (a) LEAK FROM FUEL TANK
   (b) LEAK FROM HEAT EXCHANGE SYSTEM
   (c) LEAK FROM COOLING SYSTEM
   (d) LEAK FROM ENGINE COOLING SYSTEM

4. POSSIBLE REMEDIES:
   (a) REPLACE FUEL TANK
   (b) REPLACE COOLING SYSTEM
   (c) REPLACE HEAT EXCHANGE SYSTEM
   (d) REPLACE ENGINE COOLING SYSTEM

5. FOLLOW-UP:
   (a) CONTINUE LEAK CHECK
   (b) INSTALL LEAK SEALING

6. PROGRESS:
   (a) COMPLETE LEAK CHECK
   (b) INSTALL LEAK SEALING

7. CONCLUSIONS:
   (a) LEAK CHECK COMPLETED
   (b) LEAK SEALING INSTALLED

8. NEXT STEPS:
   (a) COMPLETE INSTALLATION
   (b) COMPLETE ASSEMBLY
SHUTTLE CRITICAL ITEMS LIST - CRITER 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION HELIUM
P/N: M621-0059
P/N VENDOR: 73A630000
QUANTITY: 4

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

FAILURE MODE: STRUCTURAL FAILURE

REASONS:
- RUPTURE, EXTERNAL LEAKAGE

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

EFFECT(S):
- CN (A) SUBSYSTEM (B) INTERFACE (C) MISSION (D) CREW/VEHICLE
- (A) LOSS OF SUBSYSTEM PRESSURIZATION CAPABILITY IF HOT ISOL (FAIL UPSTREAM OF ISOL VLC-IMABILITY TO DEPREH UTILIZE PPCP), (B) LOSS OF INTERFACE FUNCTION (INABILITY TO REPRESS PPCP TANK/POD STRUCT & TPS DAM, (C) ABORT DECISION (LOSS OF PRESS), (D) POSSIBLE LOSS OF CREW/VEHICLE - IF LEAK EXCESS OR PCD/TPS DAM OCCURS

DISPOSITION & RATIONALE:
- (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY
- (A) F.S. IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF), THE WELDED CONSTRUCTION ELIMINATES JOINTS AND POSSIBLE LEAK PATHS. THE ANNEALED AREA (DUE TO WELDING) IS BACKED UP BY A SLEEVE. FASTENING CLAMPS ALLOW FREEDOM OF MOVEMENT. TUBING BENDS ARE CONTROLLED BETWEEN FIXED POINTS TO FACILITATE INSTALLATION AND ACCOMMODATE VEHICLE GROWTH AND MOVEMENT. (B) PERFORMED TO PER 'CRITER TUBING VERIFICATION PLAN' (SD 75-SH-0205). THIS TESTING INCLUDED PRESSURE CYCLING AND FOR TYPICAL SHUTTLE LINES & JOINTS. SYSTEM EVALUATION TESTS AT WSTF WILL ALLOW EVALUATION IN THE INSTALLED SYSTEM CONDITION. LEAKAGE TESTS ARE PERFORMED IN-PROCESS FOR TUBING SECTIONS. OPTICAL INSPECTIONS ARE PERFORMED AT THIS TIME IN ADDITION TO X-RAY AND DYE PLENTRANT. 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, CONTROLO PROCESS, COAGING, PROTECTION PROVISIONS, NDE EXAM OF WELDS AND IMP. FPC SURFACE AND SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION. RAW WATEL (LOT CERTIFICATION), PARTS PROTECTION, MANUFACT, COATING, PLATING, INSTALLATION AND ASSEMBLE OPERATIONS. HARDWARE IS INSPI. IN ACCORDANCE WITH QUALITY PLANNING REQUIREMENTS DOCUMENT (QPRD) WHICH HAS BEEN APPROVED BY NASA.
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM : AFT - REACTION CONTROL FMEA NO 03-2A -201013-1 REV:12/13/75

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

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

SUBSYSTEM AEL - RCS

ITEM D.C. Solenoid Valve, He

FAILURE MODE Fails Closed

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

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

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

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.
SYSTESM: IN-FLIGHT CONTROL

- LEVEL OF PELUCATION: AVERAGE

- E I: C-15 2/6-6/6

- ESCAPE: INCOMPLETE

- PRESSURES: 1 X 15 2/6-6/6

- VALVES: SMALL REMOVAL ALTERNATE PATH - DROP AREA PIVOTS, FERRIS

- LEVEL OF PELUCATION: AVERAGE

- ESCAPE PLOW: INCOMPLETE

- PRESSURES: 1 X 15 2/6-6/6

- VALVES: SMALL REMOVAL ALTERNATE PATH - DROP AREA PIVOTS, FERRIS

- SPECIAL INSTRUMENTATION: 

- PREPARED BY: LKBAYKAR

- APPROVES LS: UDC

- RNE & WAXES: RCL

- I. "VALVE, L.E. SOLVENT

- INCREASE, PRESSURE: HELIUM (1/2") SI-STABLE. (LATE-DAY - 15/8/6)

- INCREASES: 15/8/6 STAABLE: 15/8/6 15/8/6 15/8/6 15/8/6 15/8/6


- ESCAPE PATH: FAILS CLOSED

- CAUSE:

- NO CONTINUOUS VARIOUS ELECTRIC SIGNAL DUE TO SHORT CIRCUIT: SHORT, GROUND, CAN OR LEAK, DAMAGE OF POWER, MOTOR CIRCUIT.

- EFFECTS: ON (A) subsystem (m) INTERFACES (COMPRESSOR) CREATING VEHICLE

- (1) LOSS OF RECOVERY " ALTERNATE PATH AVAILABLE: (2) NO EFFECT.

- (1) NO ALTERNATE - NOT TO USE ONE PATH REMAINING PATH IS CRITICAL BUT CANNOT BE USED EFFECT. (1) FUNCTIONAL INACTIVITY EFFECT - RESULT OF VEHICLE LOSS - FAILURE OF RECOMMEND " ALTERNATE PATH WITH ALTERNATE VALVE" RESULT IN INABILITY TO USE OR CONTROL VEHICLE'S PROPULSIVE TRANCED, THE INACTIVITY RESULT IN POSSIBLE INABILITY TO CONTROL VEHICLE DURING ENTRY DUE TO INABILITY TO USE ALTERNATE PATH REF. PROPULSIVE VEHICLE WEIGHT.

- SUCTION EFFETITION:

- IF CAUSED BY VIBRATION, THE VALVE MAY BE CAPABLE OF OPENING WITH A REACTOR CONTROLLED TO MOVE TO ALTERNATE PATH.

- HAZARDS:

- POTENTIAL LONG CRITICAL HAZARD RELATED TO REACTION TIME FOR SUGGESTING TO ALTERNATE PATH DURING CRITICAL MODES OF OPERATION SUCH AS ET.

22 ORIGINAL PAGE IS OF POOR QUALITY
## Shuttle Critical Items List - Critical 102

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Reaction Control</th>
<th>FMEA No 03-24 -2010201-REV: 12/12/76</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>Pressurization</td>
<td>Abort: CRIT. Func: 19</td>
</tr>
<tr>
<td>P/N/RI</td>
<td>MC294-019-0011/0012</td>
<td>CRIT. Don: 2</td>
</tr>
<tr>
<td>P/N Vendor</td>
<td>73635</td>
<td>Missions: HF VF XX FF CF SM</td>
</tr>
<tr>
<td>Quantity</td>
<td>2</td>
<td>Phase(s): PL XX LO XX CG XX LS</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>2</strong> Two Valves Req'd for Each</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>H Helium Supply</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Redundancy Screen: A-Pass B-Pass C-Fail</em></td>
</tr>
<tr>
<td>Prepared By</td>
<td>R. Burkard</td>
<td>Approved By (NASA):</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Approved By:</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1</strong> Approved with Changes**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>See Section 13.0</td>
</tr>
<tr>
<td>Item: Valve</td>
<td>D.C. Solenoid</td>
<td>Operated: High Pressure Helium (1/2&quot;) 91-Stable (Latching - Magnetic &amp; Spring Force) LV 201/202/203/204/301/302/303/304</td>
</tr>
<tr>
<td>Function:</td>
<td>Utilized to Control Helium Pressurization System in the Left 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 Opens Subsequent to a Downstream Failure.</td>
<td></td>
</tr>
<tr>
<td>Failure Mode:</td>
<td>Fails Closed (F)</td>
<td></td>
</tr>
<tr>
<td>Cause(s):</td>
<td>Vib Continuous Inadvertent Closing Signal Due to Short Circuit, Shock. Connector Pin or Diode Damage, Jamming of Poppet, Plugged Orifice.</td>
<td></td>
</tr>
<tr>
<td>Effect(s):</td>
<td>On (A) Subsystem (R) Interfaces (C) Mission (C) Crew (C) Vehicle:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(A) Loss of Redundancy - Parallel Path Available. (S) No Effect. (C) Abort Decision - Due to Only One Path Remaining Prior to Critical Effect. (D) No Effect. (S) 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.</td>
<td></td>
</tr>
<tr>
<td>Disposition &amp; Rationale: (A) Design (B) Test (C) Inspection (D) Failure History:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(A) Parallel Valves and Redundant Power Sources Are Provided. Voltage Press is Adeq for Prop Feed With Less Than 35 Percent Prop Remaining. One Valve is Maintained in the Latched Open Position With No Power Applied &amp; the Other is Latched Closed. An Inductive Voltage Suppression Circuit Is Prov in the Electrical System to Prevent Damage to Other On-Line Components. 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 Potting and a Fixture Is Used During Assembly To Ensure That Insul Is Not Damaged by the Exit Notch When the Coil Sleeve Is Pressed Onto the Coil. (B) 4000 Oper Cycles (On-Off-Flow) and Random Vib at AntiC Mission Levels Are Perf During Qual. Item is Used</td>
<td></td>
</tr>
</tbody>
</table>

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*Note: The image quality is poor.*
SUBSYSTEM : AFT - REACTION CONTROL
FMEA NO: 03-24 - 201020-1
REV: 12/12/73

DURING SYS EVAL TESTS AT WSTF ALLOWING EVAL UNDER SIMUL MISSION USAGE
COND. PROOF PRESSURE, LEAKAGE, OPER AND INSUL TESTS ARE PERF DURING
ATP. APROP LOCATED TEST POINTS ALLOW PRE/POST FLIGHT LEAKAGE TESTS AND
OPER TESTS ARE ALSO CONDUCTED AT THIS TIME. (C) AN IDENT IS PERF AND
THE UNIT TAGGED. CONTAM CONT PROCESS, CORROS, PROT PROT, 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 PROT. TURNAROUND - FUNCT FLOW TESTS ARE
MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON COMMAN.
(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.
1. DO THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   YES X; NO □

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

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

3. DO 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 □

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 X

*EXPLANATION REQUIRED (SEE BELOW)
EFFECTS ON THE SYSTEM - CONTROL

- ACCUMULATION OF EXCESS FUEL IN THE PARALLEL LINES

- ADDITIONAL TESTS

- TEST PORTS

PREPARED BY: C. TRAVIS

APPROVED BY: C. A. ARMS

EFFECT(S):

- EXCESS FUEL ACCUMULATES IN THE PARALLEL LINES DUE TO INEFFECTIVE SPRING/SPLICE FAILURE.

- FAILURE OCCURS EARLY IN SEQUENCE SUCH THAT VEHICLE PRESSURE IS NOT SOFT.

- FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CONTROL LOSS. FAILURE OF ONE OR BOTH PARALLEL LINES WILL RESULT IN INABILITY TO USE VEHICLE.

- POSSIBLE LOSS OF PARALLEL LINES. THIS COULD RESULT IN POSSIBLE LOSS OF VEHICLE.

- VEHICLE CONTROL MAY NOT BE ABLE TO USE SCRAMBLE ENTRY.

- POSSIBLE LOSS OF PARALLEL LINES RESULTING FROM PARALLEL LINES.

CONCLUSION:

- USE ALTERNATE PATHS. IF BOTH PATHS ARE FAILED CLOSE ENOUGH TO ALL OTHER INTERFACED PIPES, MAY BE UTILIZED.

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- USE ALTERNATE PATHS. IF BOTH PATHS ARE FAILED CLOSE ENOUGH TO ALL OTHER INTERFACED PIPES, MAY BE UTILIZED.

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CONCLUSION:

- USE ALTERNATE PATHS. IF BOTH PATHS ARE FAILED CLOSE ENOUGH TO ALL OTHER INTERFACED PIPES, MAY BE UTILIZED.
ITEM: REGULATOR PRESS, HE

SERIES REDUNDANT. SET AT UNEQUAL OUTLET PressURES (PP 201/302/303/304).

FUNCTION:
- TO REGULATE STORED HELIUM PRESSURE FROM 4600 PSIG MIX TO ULLAGE PRESSURE OF 245 (+ OR - 3) PSIG FOR PURPOSE OF PROPELLANT FEED TO THRUSTERS. TWO PARALLEL PATHS WITH TWO SERIES REGS ARE PROVIDED FOR EACH PROPELLANT TANK. PRIMARY ELEMENT SET 10 PSI LOWER THAN SECONDARY.

FAILURE MODE: FAILS CLOSED (F)

RESTRICTED FLOW:

CAUSE(S):
- CONTAM (PILOT SCREEN), FRAZEN MOIST, SPRING/STEM FRACTURE, PISTON BINDS, EXCESS DOME PRESS, COCKED SPRINGS, "MATT" DET.

EFFECT(S):
- (A,B) LOSS OF REDUNDANCY (ONE OF 2 FLOW PATHS). (C) APART DECISION.
- (D) NO EFFECT UNLESS SECOND PATH FAILS CLOSED, REENTRY CAPABILITIES ARE 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 CONSEQUENCES RESULTING FROM PROPELLANT WEIGHT.

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) PARALLEL REGULATORS ARE PROVIDED. ULLAGE PRESS IS ADEQ FOR PROP FED WITH LESS THAN 35 PERCENT PROP REMAINING. A 25-MICRON ABS GBR PLUS 10-MICRON ABS GBR PILOT FILTER IS PROV TO LIMIT THE POSSIBILITY OF CONTAM CAUSING JAMMING OF MOVING PARTS OR PLUGGING PILOT CONTROL ORIFICES. (B) 5000 OPER FLOW CYCLES AND RANDOM VIB AT ORBIT MISSION LEVELS ARE PERFORMED DURING GUAL. ITEM IS USED DURING SYS EVAL TESTS AT WSTF ALLOWING EVAL UNDER SIMUL MISSION USAGE COND. PROOF PRESS, LEAKAGE AND FLOW TESTING IS PERFORMED DURING ATP. FUNCT AND LEAKAGE TESTS ARE PERFORMED DURING PRE/POST FLIGHT CHECKOUT. (C) AN ID IS PERF AND THE UNIT TAGGED. MATL & EQUIP CONFORMANCE TO CONTRACT REGMTS IS VERIF BY INSPECTORS. THE FOLLOWING ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPECT POINTS - RAW MATL, PARTS PROTECTION, MANUF, COATING, PLATING, INSTALL AND ASSY OPERATIONS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIF BY AUDIT CONDUCTED 4-5-77 - CONTAM CONT PROCESSES AND CORROS PIOT PROV. CONTAM CONT PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIR. THE FOLLOWING
SHUTTLE CRITICAL ITEMS LIST – CRITERIA 102.

SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A - 201030-2  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 LOCVERIFIED BY INSPECTION. PARTS CLEANLINESS AND PASSIVATION BY INSPECTION. NOE INSPECTION PERFORMED AFTER ASSEMBLY. TURNAROUND - HUNCT FLOW TESTS ARE MONITORED TO VERIFY THAT THERE IS NO RESTRICTED FLOW. (C) NO FAILURE HISTORY OF THIS MODE FOR THIS REGULATOR.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

**SUBSYSTEM** AFT - RCS  
**FMEA NUMBER** 03-2A-201035-1  
**ITEM** Line, Low Pressure He  
**FAILURE MODE** External Leak

<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 ANNUNCIATE 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>✗</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?</td>
<td>✗</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?</td>
<td></td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>3a. IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?</td>
<td>✗</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?</td>
<td></td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>5. CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?</td>
<td></td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>6. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.</td>
<td>✗</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>7. IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?</td>
<td>N/A</td>
<td>✗</td>
<td></td>
</tr>
</tbody>
</table>
| 8. IF THE ANSWER TO EITHER 1 OR 3 IS YES:  
A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE? | ✗ | | |
| B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE? | ✗ | | |

*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. 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.
ASR-4. ANALYSIS - SECTION 1

1. SYSTEM 1 - ELECTRICAL CONTROL
2. DATA ACQUISITION SYSTEM
3. VEHICLE ELECTRICAL
4. VEHICLE PERFORMANCE
5. TITDE...
6. 1 FOR PRACTICAL
7. F.F.?

---

11. 1 TIGHTEN ALL IN FLATNESS YET?
12. 1 LINT F IIIF I PI 1.51-1-1-3-1-1-1-1111
13. 1 TIGHTEN ALL IN FLATNESS YET?

---

1. PRESSURE ...
2. SET LINES ...
3. X, Y, Z, LINES TO PROVIDE MECH PLS, FROM REGIONS IN...

---

12. STRUCTURAL FAILURES TH
13. RESULT, ORIGINE LEAVES
14. LEVELS;
15. INVESTIGATIONS, INVESTIGATIONS, INVESTIGATIONS (ALL). STRESS OF CR, MEASUREMENT (SHELL), INSPECTION.
16. (A) LOSS OF SYSTEM RELIABILITY, SYSTEM RELIABILITY IN THE TYPICAL...
17. RELIABILITY. (B) LOSS OF INTERFACE FUNCTION RELIABILITY IN ANY CASE...
18. (C) POTENTIAL LOSS OF MISSION OR, EARLY MISSION TERMINATION. (D) POTENTIAL LOSS OF CR.
19. VEHICLE IN CROSS LEAK OCCLUS OR, IP5 DAMAGE OCCURS PRECLUDING CANCE...

---

1. CONTROL ACTIVITIES
2. INITIATE AT ELEVATION, UTILIZE SLICE 1, LAD SHELL, ADJUST IN FLATNESS UTILIZE VEHICLE IN FAIL USTREAM OF COND.
3. ADJUSTMENTS/PROBLEMS;
4. VEHICLE PERFORMANCE MAY BE ADVERSELY EFFECTED IF SIGNIFICANT GAUGE OF PRESSURE, THE OVER-PRESSURE MAY RESULT IN DAMAGE TO STRUCTURE. THIS...

---

OF POOR QUALITY
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: MC621-0059
P/N VENDOR: 73A630030
QUANTITY: 4

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: MC621-0059
P/N VENDOR: 73A630030
QUANTITY: 4

PREPARED BY: N C GLAVINICH
DESIGN REL: C M AKERS

MISSIONS: HF V F X FF OF SM
PHASE(S): PL X LC X CC X DC X LS X

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

PREPARED BY: N C GLAVINICH
DESIGN REL: C M AKERS

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

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

EFFECT(S): ON (A) SUBSYSTEM (3) INTERFACES (C) MISSION (B) SPACECRAFT/VEHICLE:
(A) LOSS OF SUBSYSTEM HELIUM SUPPLY - INABILITY TO DEPLET/UTILIZE PROPellant. (B) LOSS OF INTERFACE FUNCTION INABILITY TO DEPRESSURE PROP TANK - POTENT PDO 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, CORROSION PROTECTION PROVISIONS, NDE EXAM OF WELDS AND INSPEC. FOR SURFACE AND SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPEC. POINTS, RAW MAT'L (LOT CERTIFICATION), PARTS PROTECTION, MANUF., COATING, PLATING, INSTALLATION AND ASSEMBLY OPERATIONS. HARDWARE IS INSPEC. IN ACCORDANCE WITH QUALITY.
SUBSYSTEM : AFT - REACTION CONTROL FMEA NG 03-2A - 201035-1 REV: 11/03/73
PLANNING REGMITS DOCUMENT (CPRO) 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.

DO - MINOR HISTORY - CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.
HISTORY - CORROSION/FAB PROBLEMS DETECTED DURING APOLLO CHECKOUT AND CORRECTED.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST

**SUBSYSTEM** AFT - RCS

**ITEM** Relief Valve

**FMEA NUMBER** 03-2A-201060-4

**FAILURE MODE** External Leak -- Fails Open

---

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

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 [ ] 1 [X] 2 [X]

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

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

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

---

**EXPLANATION REQUIRED (SEE BELOW)**

---

**CHANGE/RETENTION RATIONALE SUMMARY**

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

---

**EXPLANATION/COMMENTS:**

1. Gross leak detection will give first indication.

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

5. Left and right AFT RCS pods provide redundancy.
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N R1: MC284-0421-0001/-0002
P/N VENDOR: 5760009-101/576-0009-102
QUANTITY: 14
ZONE: ONE PER PROPELLANT TANK
MISSIONS: HF, VF, X FF, VF, SM
PHASE(S): PL, LO, X CO, X DO, LS

P/N: RI/MC284-0421-0001/-0002
CRIT. HD: REV: 12/14/7P
ASSEMBLY: PRESSURIZATION
MISSIONS: HF, VF, X FF, VF, SM
QUANTITY: 14
ZONE: ONE PER PROPELLANT TANK
MISSIONS: HF, VF, X FF, VF, SM
PHASE(S): PL, LO, X CO, X DO, LS

PREPARED BY: R. GONZALEZ
APPROVED BY: A. Y. FALABRATI

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 PSI. AMBIENT PRESSURE SENSING INTERNAL IS PROVIDED SINCE THE VALVE OUTLET IS SUBJECTED TO BACK-PRESSURE.
- FAILURE MODE: EXTERNAL LEAK (F)
- FAILS OPEN, MAIN POPOPET OR DIAPHRAGM LEAKS OR MAIN POPPET DOES NOT RESEAT AS REQ'D AFTER BURST DISC RuptURE.
- CAUSE(S):
  - CORROSION, CONTAMINATION, POPPET BINDS IN GUIDE, SPRING BREAKS OR COCKS, SEAT CRACKS, MoISTURE FREEZES, VIBRATION, SHOCK.
- EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
  - (A) LOSS OF SUBSYSTEM PRESSURIZATION,
  - (B) LOSS OF INTERFACE FUNCTION
  - (C) LOSS OF INTERFACES, 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.
  - (D) NO EFFECT
  - (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE LOSS OF CREW VEHICLE - SEE ITEM (C) ABOVE.
  - PROP IN ONE POD MAY NOT BE ADEQUATE FOR ENTRY. POSSIBLE LOSS OF CREW, 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, NDE EXAM OF
WELDS, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS, PROPERLY MONITORED
HANDLING AND STORAGE ENVIRONMENT, AND MATERIAL AND EQUIPMENT, CONFORMANCE TO
CONTRACT REQUIREMENTS 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. TURNAROUND - LEAKAGE TESTS ARE MONITORED TO VERIFY THAT THE
BURST DISC IS STILL INTACT AND THAT THE MAIN POPPET LEAK RATE IS WITHIN
SPECIFICATION REQUIREMENTS. VISUAL INSPECTION FOR EVIDENCE OF DETERIORATION IS ALSO
PERFORMED. (D) APOLLO FAILURES WERE DUE LARGELY TO GALVANIC CORROSION AND
CONTAMINATION CORRECTED BY DESIGN & TEST PROCESSING CHANGES. (THE
SHUTTLE RELIEF VALVE IS A NEW DESIGN WHICH CONTAINS A FILTER & DOES NOT
USE DISSIMILAR METALS).
VALIDATION TECHNIQUES

After a failure event occurs in a system, the following steps should be taken to validate the system:

1. Review system specifications and operating procedures.
2. Conduct a root cause analysis to identify the failure mode.
3. Perform a load analysis to determine the stress levels.
4. Analyze the component failure data to identify trends.
5. Conduct a stress analysis to predict the life expectancy.
6. Test the system to verify the effectiveness of the corrective actions.

PREPARATION:

- Identify the failure modes and their potential causes.
- Develop a test plan to verify the effectiveness of the corrective actions.
- Perform a risk assessment to prioritize the corrective actions.

APPROVAL:

- Review the corrective actions and their impact on the system.
- Approve the corrective actions and document the decision.

VALVE:

- Relief valve pressure should be adjusted to prevent unnecessary stress on the system.
- Clear the relief valve outlet to ensure proper venting.

FAILURE:

- Failure may be due to a loss of relief pressure or a failure in the relief valve.
- Replace the relief valve if necessary.

CAUSATION:

- Criticality: The failure of the relief valve may lead to a loss of pressure, which can result in system failure.
- Severity: The failure can cause damage to the system, leading to potential loss of life or property.
- Likelihood: The failure can occur due to a variety of causes, such as component degradation or incorrect installation.

CONSEQUENCES:

- Loss of relief pressure can lead to damage to the system, leading to potential loss of life or property.
- The failure can result in a loss of containment, leading to environmental impact.

RECOMMENDATION:

- Replace the relief valve if necessary.
- Ensure proper venting of the system to prevent pressure buildup.
- Conduct a risk assessment to identify potential failure modes.

ORIGINAL PAGE IS OF POOR QUALITY.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2
SUBSYSTEM AFT - RCS
ITEM He Fill Quick Disconnect
FAILURE MODE Fails Open

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

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

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/RETIENTION 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

In-Flight detectability

FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Gross leak detection will give first indication.

6. Capped quick disconnect provides one redundant success path.
   Pod Redundancy
SERIAL NUMBER: "3.9.1971 EFFECTIVE ANALYSIS - 11 MAY 71"

- SYSTEM: FIRE CONTROL
- AIR LOAD: 5000 LBS
- VELOCITY: 10000 FEET PER SECOND
- MISSILE: ML-35
- DEVIATION IN DECEMBER 1970
- METER: ML-3500
- SCALE: ML-3500
- FUEL: MILITARY
- WEATHER: CALM
- GROUND: FLAT
- LAUNCH: SUCCESSFUL
- CONCLUSION: INSPECTION PRIOR TO LAUNCH

PREPARED BY: C. SCARCELLI
APPROVED BY: LDC

- DISCONNECT ELECTRIC CABLES
- PREPARE WITH SPRING LOADS EQUAL TO STRUCTURAL LOADS CAL.
- SURGE 50 MICRO SECONDS
- PROCESS VENT EXHAUST DURING SERVICE AND CLEANING. COUPLING IS ACCESSIBLE AT THE STAGE 1 SERVICE PORT.
- PREVENT FALLING (
- CHECK OF ACCEPTABLE VOLTAGE, SEALS INSPECTED.
- OMISSION:
- EXPERIENCES: MECHANICAL STRESS, PIPE-PAVEMENT STRUCTURAL FAILURE, EXCESS WATER IMPACT, DUCTED VEHICLE ROLL OFF MOUNTINGS, USE OF LOFTHAPPY. INSPECTING CAR LOADED WITH MANUFACTURER'S LANDING SCAPULARITY.
- EFFECTS: (a) LOSS OF SYSTEM PRECISION, (b) IMPACTS, (c) MISCELLANEOUS, (d) WEATHER VARIATION.
- (e) LOSS OF STEAM PRESSURE, (f) LOSS OF ELECTRICAL POWER.
- FAILURE TO REPRESSURE PROPELLANT TANKS DUE TO HEAT LOSE, (g) LOSS OF PROPELLANT. (h) POTENTIAL OPERATIONAL LOSSES DURING MISCELLANEOUS EFFECTS CAN BE ANALYZED.
- OPERATIONAL LIMITATIONS:
- INSTALL TECHNOLOGY IN SPOT, INSTALL PROPELLANT PROPORTIONAL TO FIRST IMPROVEMENTS.
- WARNINGS/HAZARDS:
- BECAUSE A STRUCTURAL LOAD IS SPRING LOADED OVER THE DISCONNECT, THIS FAILURE MUST BE VERY CAREFUL (IN FLIGHT), POSSIBLY ADVANCED EFFECT ON VEHICLE DYNAMICS IF PROPER CAREFUL DEPLOYED PRIOR TO LAUNCHING. THE LINES MUST BE SUPPORTED FOR MAX AS Y-90-71-62-37.

ORIGINAR PAGE IS OF POOR QUALITY
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION ABORT: CRIT. FUNC: 1
P/N: MC276-0017-0402/-0403
P/N VENDOR: 7537200C-0401/-0403
MISSIONS: HF VF X FF OF SM
QUANTITY: 1
PHASE(S): PL X LO X CC X DJ X LS X

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

PREPARED BY: DES C. SCARLETT
APPROVED BY: DES C. SCARLETT 12/30/78

ITEM: DISCONNECT, QUICKFILL, HELIUM TANK
(1/4") WITH SPRING LOADED POPPET AND STRUCTURAL END CAP. 40 219/220
FUNCTION:
- PROVIDE HELIUM TANK FILL AND VENT POINT FOR GROUND SERVICING OPERATIONS AND LOADING. COUPLING IS ACCESSIBLE AT THE HELIUM SERVICING PANEL.
FATURE MODE: FAILS OPEN (S)
- EXCESS OF ACCEPTABLE RATE, SEALS DAMAGED.
CAUSE(S):
- CONTAMINATION, VIBRATION, MECHANICAL SHOCK, PIECE-PART STRUCTURAL FAILURE, EXCESS OR IMPROPER USE, INADEQUATE MAINT UP SEE HALF, NC LINE SUPPORT - SHAFT OR 90 DEG BENT. RETAINING CAP LOCENS NEGATING GAP SEAL REDUNDANCY.
EFFECT(S): ON (A) SUBSYSTEM (-) INTERFACES (C) MISSION (O) CREW/VEHICLE:
- (A) LOSS OF SUB-SYSTEM PRESSURIZATION, (B) LOSS OF INTERFACE FUNCTION, (C) INABILITY TO REPRESSURIZE PROPELLANT TANKS DUE TO HELIUM LOSS. (D) LAUNCH DELAY OR ABORT. (E) 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 1.5DEO TO EXPEL PROP WITH 35 PERCENT OR LESS REMAINING. GROUND HALF COUPLINGS AND LINES ARE SUPPORTED TO LIMIT ANY UNDEU STRESS ON THE COUPLING DURING SERVICE AND PREV DAMAGE TO SEALS. A SAFETY FEATURE DURING SERVICING AND PRIOR TO REMOVAL OF THE END CAP IS A PROV WHEREBY ANY LEAKAGE PAST THE AIRBORNE POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING A 3/8 SCPE. COMPLETE STRESS ANAL HAS BEEN CONDUCTED. UTIL OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUN 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 IDENT IS PERF. RAW MAT, NO EXAM, VISUAL INSPECTION FOR CRITICAL SURFACE DEFECTS, AND EQUIP CONFORMANCE TO CONTRACT REQ. ARE PERF BY RECEIVING INSPECTION STANDARDS AND TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQMTS OF MIL SPEC. THE FOLLOWING ITEMS ARE PERF BY SHOP TRAVELER MANDATORY INSPECTION POINTS. PARTS MFG. PROCESSES, COATING, ASSY AND INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77. CORROS PROT PROV, CONTAM CONT.

REV: 12/12/78
SUBSYSTEM : AFT - REACTION CONTROL  
FMEA NO 03-ZA-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. NOE INSPECTION PERFORMED AFTER
ASSEMBLY. TURNAROUND. COUPLINGS ARE VISUALLY INSPECTED FOR EVIDENCE
OF DAMAGED SEALS AND LEAK TESTS ARE PERFORMED. (CR) APOLLO FAILURE HISTORY WAS IN
THE MAIN ASSOC WITH GROUND USAGE, IMPROPER HANDLING.
**HARDWARE/SOFTWARE ANALYSIS CHECKLIST**

**SUBSYSTEM AFT - RCS**

**ITEM** Purge Quick Disconnect, Propellant

**FAILURE MODE** External Leakage

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

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**CHANGE/RETENTION RATIONALE SUMMARY**

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

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**EXPLANATION/COMMENTS:**

1. Gross leak detection will give first indication.
2. The above statement indicates in-flight detection.
3. Need minimum of 2 yaw thrusters. Cross-feed is available. Pods are redundant.
COUNTERMEASURE FULL AND EFFECTS ANALYSIS - CR 11 10

[Page content not clearly visible due to degradation]

PREPARE YES: c. NARMLNIT

APPROVED YES:

REL.C MARKERS

REL._____________________

1. DETECTIVE B-flow PUMP
2. VALVE, PROPELLANT ATM STRUCTURAL SEAL LEAK AND SPRING LOADED PUMP ("Y")

1. VouIT:
- Failure or out of order of propellant manifold during ground operations.

2. LeAKS: EXTERNAL LEAKAGE (S)
- LEAKS, SLEWS, SEALS EFFECs, RETAINING RUB LEAKS, NEGATIVE CAP SEAL

3. LEAKS:
- DETECTION: FILL PART STRUCTURAL FAILURE, CONTAMINATION, OBSERVATION, OCCURRENCE, SEAL LEAKAGE, TURBULENT LEAK, GEAR SEAL, NO LEAK SUPPORT - CRANT

4. SPECIFIC:
- DETECTION: FILL PART STRUCTURAL FAILURE, CONTAMINATION, OBSERVATION, OCCURRENCE, SEAL LEAKAGE, TURBULENT LEAK, GEAR SEAL, NO LEAK SUPPORT - CRANT

5. SPECIFIC: FILL PART STRUCTURAL FAILURE, CONTAMINATION, OBSERVATION, OCCURRENCE, SEAL LEAKAGE, TURBULENT LEAK, GEAR SEAL, NO LEAK SUPPORT - CRANT

6. FILL PART STRUCTURAL FAILURE, CONTAMINATION, OBSERVATION, OCCURRENCE, SEAL LEAKAGE, TURBULENT LEAK, GEAR SEAL, NO LEAK SUPPORT - CRANT

7. FILL PART STRUCTURAL FAILURE, CONTAMINATION, OBSERVATION, OCCURRENCE, SEAL LEAKAGE, TURBULENT LEAK, GEAR SEAL, NO LEAK SUPPORT - CRANT

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ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM : AFT - REACTION CONTROl
ASSEMBLY : PRESSURIZATION
P/N : MC276-0013
P/N VENDOR: 7636L000 
QUANTITY : 28

MISSIONS: HF VF X FF CF S IV
PHASE(S): PL L0 X CG X DO X LS

$14 PER POD
$1 OF 1/2 IN. REDUNDANCY SCREEN: A-PASS B-FAIL C-PASS
$1 OF 1/4 IN.

PREPARED BY: CMakers
APPROVED BY: SSM-1
APPROVED WITH CHANGES
See Section 13.0

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 (S)
CAP LEAKS, SEALS DAMAGED RETAINING NUT LOOSENS NEGATING CAP SEAL REDUNDANCY.

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

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

(A, 3) LOSS OF REDUNDANCY
(PROPELLANT MANIFOLD ISOLATION VALVE COULD ISOLATE LEAK).

MODIFICATION OR ABORT DECISION. (G) NO EFFECT UNLESS MULTIPLE FAILURES OCCUR OR EXCESS LOSS OF PROPELLANT OCCURS. (E) FUNCTIONAL CRITICITY 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 COUPLING AND LINES ARE ADEQUATE 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. UTIL OF STRUCT CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUNDANT SEAL EXCEPT FOR STRUCT FAILURE. FAILURE CAN BE ISOLATED AT MANIFOLD VALVE. (B) THE COUPLING IS SUBJ TO 600 OPER CYCLES (COUPLING AND UNCOUPLING) DURING OUAL IN ADDITION TO PRESS SURGE CYCLING AND PROP EXPOSURE TESTS. RANDOM VIB TESTING IS ALSO CONDUCTED AT ANTE VEH LEVELS FOR 34 MINUTES IN EACH AXIS. USAGE DURING SYS EVAL TESTS AT WHF ALLOWS EVAL UNDER ACTUAL USAGE COND.

PROOF PRESS TESTS ARE CONDUCTED DURING ATP AND LEAKAGE TESTS ARE PERF BEFORE AND AFTER OPER CYCLES. (C) AN IDENT IS PERF. RAW MAT'LS, NDE EXAM, VISUAL INSPECTION FOR CRITICAL SURFACE DEFECTS, AND EQUIPMENT CONFORMANC TO CONTRACT REQMTS ARE VERIF BY RECEIVING INSPECTION. MEASUREMENT STANDARDS AND
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: AFT - REACTION CONTROL  FMEA NO 03-2A-201080-1  REV: 11/09/78
TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQUISITES OF MIL SPECS. THE
FOLLOWING ITEMS ARE VERIF BY SHOP TRAVELER MANDATORY INSPECTION POINTS--PARTS
PROT., MFG. PROCESSES, COATING, ASSY AND INSTALLATION. THE ABOVE ITEMS
AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 5-23-77.
CORROS PROT., PROV CONTAM CONT PROCESSES, TEST HANDLING, AND STORAGE
ENVIR. THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT OF MARCH 6, 1979.
INSPECTION VERIFIES ASSEMBLY PER INSPECTION POINTS IN MASTER RECORD.
LOG OF CLEAN ROOM AND CALIBRATION OF TOOLS VERIFIED. CRITICAL DIMENSION
100% VERIFIED BY INSPECTION. PARTS CLEANLINESS AND PASSIVATION VERIFIED
BY INSPECTION. NOE INSPECTION PERFORMED AFTER ASSEMBLY.
TURNAROUND-COUPLEINGS WILL BE VISUALLY INSPECTED FOR EVIDENCE OF CAP SEAL
DAMAGE AND CAP LEAKAGE. (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 [ ]

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)*

---

**CHANGE/RETENTION RATIONALE SUMMARY**

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

**FMEA CHANGE RECOMMENDED**

---

**EXPLANATION/COMMENTS:**


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

6. Pod redundancy.
SYSTEM: PROP - ELECTRIC CONTROL

FAILURE ANALYSIS:

1. VALVE FAULT
2. PRESSURE VALVE LEAK
3. PROPANE VALVE LEAK
4. PRESSURE REGULATOR FAULT
5. PRESSURE REGULATOR LEAK
6. PRESSURE REGULATOR SEAL LEAK
7. PRESSURE REGULATOR SEAT LEAK
8. PRESSURE REGULATOR SEAL FAULT
9. PRESSURE REGULATOR VALVE LEAK
10. PRESSURE REGULATOR VALVE FAULT
11. PRESSURE REGULATOR VALVE SEAL LEAK
12. PRESSURE REGULATOR VALVE SEAL FAULT
13. PRESSURE REGULATOR VALVE VALVE LEAK
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15. PRESSURE REGULATOR VALVE VALVE SEAL LEAK
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20. PRESSURE REGULATOR VALVE VALVE VALVE SEAL FAULT
21. PRESSURE REGULATOR VALVE VALVE VALVE VALVE LEAK
22. PRESSURE REGULATOR VALVE VALVE VALVE VALVE FAULT
23. PRESSURE REGULATOR VALVE VALVE VALVE VALVE SEAL LEAK
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25. PRESSURE REGULATOR VALVE VALVE VALVE VALVE VALVE LEAK
26. PRESSURE REGULATOR VALVE VALVE VALVE VALVE VALVE FAULT
27. PRESSURE REGULATOR VALVE VALVE VALVE VALVE VALVE SEAL LEAK
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29. PRESSURE REGULATOR VALVE VALVE VALVE VALVE VALVE VALVE LEAK
30. PRESSURE REGULATOR VALVE VALVE VALVE VALVE VALVE VALVE FAULT

APPROVED BY: C. J. SCHEFFIT
APPROVED BY: C. M. ARNIS

CHECKLIST:

1. (a) SYSTEM (b) INTERFACES (c) MISSION (d) OPERATIONS
2. (a) LOSS OF PRESSURIZATION (b) LOSS OF RECOVERY CAPABILITY
3. (a) LOSS OF PRESSURIZATION (b) LOSS OF RECOVERY CAPABILITY
4. (a) LOSS OF PRESSURIZATION (b) LOSS OF RECOVERY CAPABILITY
5. (a) LOSS OF PRESSURIZATION (b) LOSS OF RECOVERY CAPABILITY
6. (a) LOSS OF PRESSURIZATION (b) LOSS OF RECOVERY CAPABILITY
7. (a) LOSS OF PRESSURIZATION (b) LOSS OF RECOVERY CAPABILITY
8. (a) LOSS OF PRESSURIZATION (b) LOSS OF RECOVERY CAPABILITY
9. (a) LOSS OF PRESSURIZATION (b) LOSS OF RECOVERY CAPABILITY
10. (a) LOSS OF PRESSURIZATION (b) LOSS OF RECOVERY CAPABILITY

CORRECTIVE ACTION:

1. ISOLATE LEAK IF POSSIBLE. CONSIDER USAGE OF UPLINK PRESSURIZATION AND ISOLATION VALVE FOR AILS. CLOSE ISOLATION VALVE DURING STATIC WET-TEST.
2. FAILURE NOT POSSIBLE DURING GROUND USAGE. GAS LINES MUST BE SUPPORTED. POSSIBLY ADVERSE EFFECT ON VEHICLE DYNAMICS IF PROB CAN'T...
SHUTTLE CRITICAL ITEMS LIST - CRBITEP 102

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PRESSURIZATION
P/N: ME270-0032-0009, 7-19-21
P/N VENDOR: RR42460-3, -7RG429J-15-3
MISSIONS: HF VP X FF CF SP
QUANTITY: 36

REACTICN CONTROL PPEA - No 03-ZA - 291090-1
REV: 12/2/92

ASSEMBLY: PRESSURIZATION
ABCRT: CRIT. FNC: 1
MISSIONS: HF VP X FF CF SP
PHASE(S): PL LO X GC X GC X LS
QUANTITY: 18 PER MODULE

PREPARED BY: C SCARLETT
APPROVED BY: C M AKERS

ITEM: DISCONNECT, QUICK TEST
FUNCTION:
- TO PROVIDE ACCESS TO THE HELIUM SUPPLY SYSTEM AT VARIOUS POINTS IN THE SYSTEM (RELIEF VALVES/BURST DISCS REGULATORS, CHECK VALVES). PROVIDES FOR C/O OF PRESS SUB-SYS COMPONENTS. COMPONENT INPUTS & OUTPUTS ARE ACCESSIBLE AT HE SEVF 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, VC LINE SUPPORT - SHAFT CR BORE BENT.
- EFFECT(S): ON (A) SUBSYSTEM (3) INTERFACES (C) MISSION (D) CREW/VEHICLE:
  - (A) LOSS OF SUBSYSTEM PRESSURIZATION CR 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 CREW PROBLEMS RESULTING FROM PROPELLANT WEIGHT.

DISPOSITION & RATIONALE:
(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
- (A) P.S. IS 2.0 X WORKING PRESS. ULLAGE PRESS IS ADEQ TO EXPEL PROP WITH 35 PERCENT OR LESS REMAINING. GROUNDED COUPLINGS AND LINES ARE ADEQ SUPPORTED TO LIMIT ANY UNDUE STRESS ON THE COUPLING DURING SERVICE AND PREV DAMAGE TO SEALS AND WELD JOINTS. A SAFETY FEATURE DURING SERVICING AND PRIOR TO REMOVAL OF THE END CAP IS A PROV WHEREBY ANY LEAKAGE PAST THE AIRBORNE POPPET SEAL CAN BE VENTED OVERBOARD BY ROTATING CAP UTIL OF STRU CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUN SEAL EXCEPT FOR STRUCT OR WELD FAILURES. (B) THE COUPLING IS DESIGNED FOR 400 OPER CYCLES (COUPLING AND UNCOUPLING) USAGE DURING SYS EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE COND. PROOF PRESS TESTS ARE CONDUCTED DURING ATP AND LEAKAGE TESTS ARE PERF BEFORE AND AFTER OPER CYCLES. (C) AN IDENT IS PERF AND THE UNIT TAGGED.
- RAW MAT'IL. NO EXAM OF WELDS, VISUAL INS. OF WELD JOINTS FOR
SUBSYSTEM : AFT - REACTION CONTROL
FMEA NC 03-2A -201090-1  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
POUNTS - PARTS PROT. WPG. PROCESSES. COATING. PLATING. ASSY AND
INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY
AUDIT CONDUCTED 11-3-76. COMPONENTS PROD. CONTAIN CONT PROCESSES. TEST
HANDLING. AND STORAGE ENV. TURNAROUND: COUPLINGS WILL BE VISUALLY
INSPECTED FOR EVIDENCE OF SEAL DAMAGE AND CAP LEAKAGE. (COUPLINGS
BETWEEN THE HELIUM ISOL VALVE & REGULATOR ARE 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 announce or take action in response)?**
   - Yes ✗ No □

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

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

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

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

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

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

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

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

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

*Explanation required (see below)*

### Change/Retention Rationale Summary

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

### 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)
I, for the purposes of this analysis...

...execute parallel flow path. (L/L) No effect unless parallel pumps fail closed. Failure of parallel pumps will cause premature vehicle loss if parallel pumps are not fail closed and positively failures utilizing parallel flow path are not fail closed. (E) Incorrect criticality effect - vehicle loss. Failure of parallel pumps could possibly result in inability to keep or deliver all cryo propellant in addition to vehicle failure problems with resultant thrust loss. Failure to control vehicle during launch due to inability to utilize all critical propellant and cryo propellant due to propellant outlet...
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PRESSURIZATION
P/N RI : MG284-3481-0001/-0002
P/N VENDOR : RS01050-001-011
QUANTITY : 1

MISSIONS : HF VFX FF CF SM
PHASE(S) : PL L3 X 0C X 00 X LS

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

PREPARED BY: 
APPROVED BY: 
APPROVED WITH CHANGES

DES : R. BURKHART 
REL : C HAKERS 

ITEM: VALVE, QUAD, CHECK HE.
CV 201/202/301/302
FUNCTION:
- EACH CHECK VALVE QUAD WITH 4 POPPETS IN SERIES - PARALLEL ARRANGEMENT PROVIDES PARALLEL REDUNDANCY FOR HELIUM PRESSURIZATION AND SERIES REDUNDANCY TO LIMIT BACK FLOW OF 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 (F)
RESTRICED FLOW

CAUSE(S):
- STRUCTURAL FAILURE, SHOCK, VIB. POPPET BINDING IN GUIDE, CONTAM, VALVE FREEZES IN COLD VALVE, CORROSION.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CRYO/VEHICLE:
- (A) LOSS OF REDUNDANCY - PARAL FLOW PATH. (B,C,D) NO EFFECT UNLESS PARALLEL POPPETS FAIL CLOSED. FAILURE OF PARALLEL POPPETS WOULD CAUSE MIX RATIO SHIFT AND POSSIBLY PREVENT UTIL/DEPLETION OF ALL RCS POPPETS EVENTUALLY UNSEAT). (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CRYO/VEHICLE LOSS. FAILURE OF PARALLEL POPPETS WOULD POSSIBLY RESULT IN INABILITY TO BURN OR DEPLETE 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, MOE EXAM.
OF WELDS AND BRAZES, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS ARE
VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP
TRAVELER MANDATORY INSPECTION POINTS - RAW MATERIAL (LOT CERTIFICATION), PARTS
PROTECTION, MANUFACTURING, COATING, PLATING INSTALLATION AND ASSEMBLY
OPERATIONS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY
AUDIT CONDUCTED 12-2-77. CONTAMINATION CONTROL PROCESSES, CORROS.
PROTECTION PROVISIONS, TURNAROUND - FUNCTIONAL FLOW AND LEAKAGE
(BACK-FLOW) TESTS ARE PERFORMED. (D) 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 [x] No [ ]
   1a. **If Not, Does the Hardware Provide Information that the Flight Software Could Use to Detect the Failure?**
   - *Yes [ ] No [x]

2. **Are the Answers to Questions 1 and 1a Consistent with the FMEA Evaluation of In-Flight Detectability?**
   - *Yes [ ] No [x]

3. **Does the Flight Software Take Action to Negate the Effects of the Failure (Either by Commanding Hardware Action or Implementing Alternate Program Logic)?**
   - *Yes [ ] No [x]
   3a. **If Not, Does the Capability Exist for the Software to Compensate for this Failure Mode (Either by Commanding Hardware Action or Implementing Alternate Program Logic)?**
   - *Yes [x] No [ ]

4. **As a Result of this Failure Mode, Can the Software Overstress the Hardware or Induce Another Failure?**
   - *Yes [ ] No [x]

5. **Can this Failure Mode, in Combination with Software Logic, Adversely Affect Other Functions?**
   - *Yes [ ] No [x]

6. **How Many of These Hardware Failures Can the Shuttle Tolerate (Consider Crew Action and Hardware/Software Operation)? Note Change to FMEA Criticality.**
   - *0 [ ] 1 [ ] 2 [x]

7. **If Crew Action Is Required to Respond to this Failure Mode, Are Cues Provided to Signal the Need for Intervention and the Required Corrective Action?**
   - N/A [ ] Yes [x] No [ ]

8. **If the Answer to Either 1 or 3 Is Yes:**
   - A. **Can the BFS Be Engaged After Occurrence?**
     - *Yes [x] No [ ]
   - B. **Will BFS Tolerate Failure Without Loss of Crew/Vehicle?**
     - *Yes [x] No [ ]

*Explanation Required (See Below)*

**CHANGE/RETIEMENT 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:**


2. V42P2115 and 3115 should be deleted from this FMEA page as they are in the oxidizer system and not the fuel system.
SMALL FAUCET VALVES: PRESSURE ANALYSIS - LIMITS:

- Small faucet valves shall not be subjected to more than the following limits:
  - Pressure: 15 C.P.S.I.
  - Temperature: 210°F

- Sizing charts and other data are provided in the attachment.

- For further analysis and testing, please consult the manufacturer's specifications.

- All above are for flight or ground use.

- The following practices are recommended:
  - Use W.O. cleaning
  - Use C.W. areas

- Final approval by:
  - W.O.
  - C.W.

- Special attention should be given to:
  - System control
  - Structural failure

- Internal line check

- Utilize small tank isolation valves, utilize one port at a time, right way and level.

- All FAA Form 8130's must be filled out properly.

- Inlet and outlet lines may not be isolated unless approved by the manufacturer.

- Approval by

- G.F. ey.

- Original page is of poor quality.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED, FUEL
P/N RI: MC621-0059
P/N VENDOR: 73A560001
QUANTITY: 2

SUBSYSTEM: AFT - REACTION CONTROL
MISSIONS: HF VF X FF GF SM
PHASE(S): PL LD X CQ X DO X LS

PREPARED BY: N G GLAVINICH
APPROVED BY: SSM
REL: CAMAKERS

ITEM: FEEDLINE AND FITTINGS
FROM TANK TO 1) TANK VALVES, TO 2) MANIFOLD VALVES, TO 3) THRUSTERS.
FUNCTION:
*(1) 1 1/2 X 0.028 304 L.S.S. 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 APPROPRIATE PROPELLANT COMPONENTS FOR THRUSTER OPERATION-

FAILURE MODE: STRUCTURAL FAILURE

CAUSE(S):
VIB., FATIGUE, SHOCK, WELD DEF., INSTALL or DAMAGED SEAL FAILURE, "AT" DEF (SULPHIDE STRINGER).

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) F.E.S. IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF).
DYNATURES HAVE GASKET 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.
(R) ROCKWELL PERFORMED TUBING CERTIFICATION TESTS PER "ORBITEP TUBING VERIFICATION PLAN" (SD 75-SH-0205). THIS TESTING INCLUDED PRESSURE CYCLING AND FATIGUE FOR TYPICAL SHUTTLE LINES & JOINTS. SYSTEM EVALUATION TESTS AT WSP 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 INSPECTION FOR SURFACE AND SUB-SURFACE DEFECTS IS VERIFIED BY INSPECTION. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER...
SUBSYSTEM: AFT - REACTION CONTROL
FMEA NO 03-2A - 202108-1  PEV:11/03/72
MANDATORY INSPECTION POINTS: RAW MATERIAL (LOT CERTIFICATION), PARTS PROTECTION, MANUFACTURING, COATING, PLATING, INSTALLATION AND ASSEMBLY OPERATIONS.
HARDWARE IS INSPECTED IN ACCORDANCE WITH QUALITY PLANNING REQUIREMENTS (QPRD) WHICH HAS BEEN APPROVED BY NASA. TURNAROUND LINES IN ACCESSIBLE AREAS ARE VISUALLY INSPECTED FOR EVIDENCE OF DAMAGE AND FLOW AND PRESSURE FUNCTIONAL TESTS ARE MONITORED FOR EVIDENCE OF OBSTRUCTION OR LEAKAGE. 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

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

*Explanation required (see below)*

---

**CHANGE/RETENTION RATIONALE SUMMARY**

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 C GLEVINICH

APPROVED BY:

PRL C MARLES

"FLIGHT" TIMES

1. (5) 1/2, 2 TANK VALUES TO 3 MAXIMUM VALUES IN 1 PHASE.
2. (5) 1/2, 2 TANK VALUES TO 3 MAXIMUM VALUES IN 3 PHASE.

PRELIMINARY STRUCTURAL FAILURE

1. LEAK, INTERNAL LIQUID.
2. LEAK, EXTERNAL LIQUID.
3. "CLASSIC" ISSUES: VICTIMIZATION, IMPROPER INSTALLATION (VALVING, YOKE, VALVE SEAL) WITH DEFICIENCY (SUBMERGE, BURST).
4. LEAK ISSUES: (1) LEAK RECHECK (2) LEAK RECHECK (3) LEAK RECHECK (4) LEAK RECHECK (5) LEAK RECHECK (6) LEAK RECHECK (7) LEAK RECHECK (8) LEAK RECHECK

PREPARED BY:

LES C GLEVINICH

APPROVED BY:

PRL C MARLES

ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PROPELLANT FEED, OXIDIZER
ABORT:

P/N RI : MC621-0059
P/N VENDOR: 73A580002
MISSION: HF VF X FF JP SM
QUANTITY: 2

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

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

FUNCTION:
(1) 1 1/4 X .323 304L S.S. FROM TANK TO DISTRIBUTION PANEL,
(2) 1 1/2 X .252 FROM MANIFOLD ISOLATION VALVE TO THRUSTER MANIFOLD,
(3) 3/4 X .028 THRUSTER MANIFOLD TO PROVIDE FEED TO APPROPRIATE PROPELLANTS
COMPONENTS FOR THRUSTER OPERATION - 3 AXIS ACCELERATION CONTROL AND
ROTATIONAL CONTROL.

FAILURE MODE: STRUCTURAL FAILURE
RUPTURE, EXTERNAL LEAKAGE.

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

EFFECT(S):
- (A) SUB-SYSTEM DEGRADATION - LOSS OF PROPELLANT.
- (B) DEGRADATION OF INTERFACE FUNCTION - POTENTIAL CORROSION FROM FREE PROPELLANTS IN
"MODULE.
- (C) ABORT DECISION.
- (D) POSSIBLE LOSS OF OXIDIZER IF LINE FROM TANK OUTLET RUPTURES RESULTING IN INABILITY TO
UTILIZE/DEplete PROPELLANTS OR PROPELLANT reactive WITH FUEL OR OXIDIZER CAUSING
FIRE OR EXPLOSION.

DISPOSITION & RATIONALE:
- (A) DESIGN
- (B) TEST
- (C) INSPECTION
- (D) FAILURE HISTORY
- (E) F.S. IS 1.5 TO 4.0 MAXIMUM OPERATING PRESSURE (SYSTEM RELIEF).
- DYNATUBES HAVE DUAL SEALING SURFACES.
- THE WELDED CONSTRUCTION ELIMINATES JOINTS AND POSSIBLE LEAK PATHS.
- THE ANNEALED AREA (DUE TO WELDING) IS BACKED UP BY A SLEEVE.
- FASTENING CLAMPS ALLOW FREEDOM OF MOVEMENT.
- TUBING BENDS ARE CONTROLLED BETWEEN FIXED POINTS TO
FACILITATE INSTALLATION AND ACCOMMODATE VEHICLE GROWTH AND MOVEMENT.
- ROCKWELL PERFORMED TUBING CERTIFICATION TESTS PER "ORBITER" TUBING
VERIFICATION PLAN" (SD75-SH-0205). THIS TESTING INCLUDED PRESSURE
CYCLING AND FATIGUE FOR TYPICAL SHUTTLE LINES & JOINTS.
- SYSTEM EVALUATION IN THE INSTALLED SYSTEM CONDITION.
- LEAKAGE TESTS ARE PERFORMED AT THIS TIME IN ADDITION TO X-RAY AND DYE PENETRANT.
- LEAKAGE TESTS ARE ALSO PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND
ADDITIONAL WELDS ARE ALSO SUBJECT TO NDE.
- (C) 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 MAT'L (LOT
SHUTTLE CRITICAL ITEMS LIST - CHAPTER 102

SUBSYSTEM : AFT - REACTION CONTROL

FMEA NO: 03-24 - 202109-1

CERTIFICATION, PARTS PROTECTION, MANUF., COATING, PLATING, INSTALLATION
AND ASSEMBLY OPERATIONS. HARDWARE IS INSPECTED IN ACCORDANCE WITH QUALITY
PLANNING REQUIREMENTS DOCUMENT (QPL) WHICH HAS BEEN APPROVED BY NASA.

TURNDOWN 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.
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. **CANT 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?**
   - No ☐ | Yes ☑ | N/A ☐

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

*EXPLANATION REQUIRED (SEE BELOW)*

**CHANGE/RETENTION RATIONALE SUMMARY**

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

☐ FMEA CHANGE RECOMMENDED

**EXPLANATION/COMMENTS:**

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

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

6. One success path remains after first failure.

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

...
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : PROPellant Feed
P/N PI : 64284-0430-0007/-0038
P/N VENDOR : 5750023/5750026
QUANTITY : 12

3 VALVES PER PROP TANK

PREPARED BY:

PREPARED WITH CHANGES

ITEM: VALVE.

TANK ISOLATION 3 PHASE 400 HZ AC MOTOR ACTUATED (115-230V) LV261-266, LV 361-366. (1-1/2 IN.)

FUNCTION:

THREE REDUNDANT ISOLATION VALVES ARE USED PER TANK TO ISOLATE GROUPS OF MANIFOLDS (ONE TANK ISOL VALVE CONTROLS 2 MANIFOLDS AND THE PARALLEL ISOL VALVES CONTROL THE REMAINING 2 PRIMARY MANIFOLDS AND THE VERNIER MANIFOLD) THAT MAY EXHIBIT OPEN OR LEAKAGE FAILURES AND TO ISOLATE THE TANK DURING INTERCONNECT & RCS OR OMS CROSSFUEL OPERATIONS. ALSO USED TO PREVENT HELIUM INGESTION TO ENGINE AT END OF DUTY (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) LOSS OF REDUNDANCY PROPellant FLOW TO TWO MANIFOLDS ON ONE SIDE AND SUBSEQUENT LOSS OF THRUSTER FUNCTION, POTENTIAL THRUSTER DAMAGE FROM INDUCED SURGE. (B) ABORT DECISION (DEPENDENT ON WHICH TANK ISOL VALVE FAILS). ONE TANK ISOL VALVE CLOSED MAY LOSE TWO MANIFOLDS. (C) NO EFFECT FOR SINGLE FAILURE FOR OMS MISSIONS (LOSS OF THRUSTER MAY BE CRITICAL FOR RTLS IN SUBSEQUENT MISSIONS FOR OMS DEPLETION BURN). (D) CRITICAL FOR RTLS IN SUBSEQUENT MISSIONS FOR OMS DEPLETION BURN. (E) CRITICAL FOR 2 SEPARATION & MATED COAST DURING RTLS. (F) FUNCTIONAL CRITICALITY EFFECT POSSIBLE CREW/VEHICAL LOSS DUE TO UTILIZE/DEplete RCS PROPellant.

DISPOSITION & RATIONALE (A) DESIGN (B) TESTING (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:12/12/78

(A) 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 ALLO WING 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, NO EXAM OF WELDS, INSPECTION FOR SURFACE AND
SUBSURFACE DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MATERIAL (LOT)
CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE
VERIFIED BY INSPECTION. MANUFACTURING, INSTALLATION, AND ASSY OPERATIONS ARE
VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND
THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED JULY 1976:
CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE
ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIPMENT AND MATERIAL AND EQUIP
CONFORMANCE TO CONTRACT REQS. TURBINECORE/FUNCTIONAL FLOW AND LEAKAGE
TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON
COMMAND. (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
1. DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?
   YES ☐ NO ☑

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:
1A. Tank isolation valve discreets are available.
INTEGRITY ANALYSIS - Section IX

- VALVE DESIGN AND EFFECTS ANALYSIS - Section IX

PREFERRED BY:

K. H. K. V. K. E. A. R. S.

APPROVED BY:

R. R. K. E. A. R. S.

DISCLAIMER:

- WARNING: UNITS INFLUENCE THE PRIMARY SAFETY AND THE VERSION.
- INFLUENCE THE INCOMPLETE AND PRIMARY STABILITY ARE THE VARIATION.
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SUBSYSTEM : AFT - REACTION CONTROL  
ASSEMBLY : PROPELLANT FEED  
P/N RI : MC234-0430-0007/-0003  
P/N VENDOR: 575COZ575-0026  
MISSIONS: HF VF X FF CF SM  
QUANTITY: 12  
THREE VALVES PER PROP TANK  
REDUNDANCY SCREEN: 1-PASS 8-PASS C-PASS  
PREPARED BY:  
APPROVED BY:  
APPROVED 3/19 (NASA)  
PREPARED WITH CHANGES  
See Section 13.0  
ITEM: VALVE.  
TANK ISOLATION 3 PHASE 400 HZ AC MOTOR ACTUATED (115-230V) LV261-266, LV 361-366.  
FUNCTION:  
THREE REDUNDANT ISOLATION VALVES ARE USED PER TANK TO ISOLATE GROUPS OF MANIFOLDS (ONE TANK ISOL VALVE CONTROLS 2 MANIFOLDS AND THE OTHER PARALLEL ISOL VALVES CONTROL THE remaining 2 PRIMARY MANIFOLDS AND THE VERT MANIFOLD) THAT MAY EXHIBIT OPEN OR LEAKAGE FAILURES AND TO ISOLATE THE TANK DURING INTERCONNECT & TEST OR GMS CROSSFEED OPERATIONS. ALSO USED TO PREVENT HELIUM INGESTION TO ENGINE AT PROP RUN-OUT (MANUAL SWITCH). FUEL & OXID VALVES CAN BE OPERATED INDEPENDENTLY FOR C/O. LINE PRESS RELIEF TO TANK IS PROVIDED.  
FAILURE MODE: INTERNAL LEAKAGE.  
FAILS OPEN, FAILS TO CLOSE, FAIL TO REMAIN CLOSED.  
CAUSE(S):  
VIBRATION, LIMIT SWITCH MALFUNCTION, STRUCTURAL FAILURE, SEAT CRACKS CONTAMINATION, CORROS, LOSS OF SIGNAL (RPC SHORTS OR OPEN).  
EFFECT(S): (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE;  
(A,B) LOSS OF REDUNDANCY - (MANIFOLD ISOLATION). (C) CRIT DECISION - PROPellant MANAGEMENT PROBLEMS DURING CROSSFEED OPERATIONS. (D) NO EFFECT - CRIT 1 FOR RTLS. IF RCS TANK ISOLATION VALVE WILL NOT CLOSE DURING OMS DEPLETION BURN THE RCS PROPellant MAY BE DEPLETED IF ASSOC MANIFOLD ISOLATION VALVES ARE NOT CLOSED.  
DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:  
(A) AC MOTOR VALVE IS 3-PHASE - 2 OF 3 WINDINGS ARE ADEQUATE FOR VALVE FUNCTION. PARALLEL (HYBRID) RELAYS PROVIDE REDUNDANCY FOR ELECTRICAL POWER SIGNAL. A 400-MICRON FILTER IS UTILIZED ON THE INLET AND OUTLET TO LIMIT THE POTENTIAL FOR CONTAMINATION CAUSED FAILURE OR JAMMING OF MOVING PARTS. (B) 2500 OPERATION CYCLES (OPEN-CLOSE-OPEN) AND RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYSTEM EVALUATION TESTS AT WFIF ALLOWING EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. PROOF PRESSURE, LEAKAGE, OPERATION, CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT. (C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED. CONTAMINATION CONTROL PROCESS, CORROS PROTECTION PROVISIONS, NDE EXAM OF WELDS, INSPE FOR SURFACE AND SUBSURFACE DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MATERIAL/CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE
SUBSYSTEM : AFT - REACTION CONTROL  FMEA NO 03-2A -202110-3  REV:12/12/78
VERIFIED BY SHOP TRAVELEK MANDATORY INSP POINTS. THE ABOVE ITEMS AND
THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED JULY 1976/
CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE
ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP
CONFORMANCE TO CONTRACT REGMTS. 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.
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. AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE? [YES ☑ NO ☑]

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

7. HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? [YES ☑ NO ☑]

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

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

EXPLANATION/COMMENTS:

1. "Failed off" thruster gives first indication.

6. One success path remains after first failure.

8a. Same as primary.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N: 10D-0430-J-037-0003
P/N VENDOR: 5750025/5750026
QUANTITY: 2

**CRITICAL ITEMS LIST**

**SUBSYSTEM:** AFT - REACTION CONTROL

**ASSEMBLY:** PROPELLANT FEED

**P/N:** 10D-0430-J-037-0003

**P/N VENDOR:** 5750025/5750026

**QUANTITY:** 2

**INTERCONNECT LINES:** 2 PER PROPELLANT TANK

**REdundancy Screen:** A-PASS R-PASS C-PASS

**PREPARED BY:** GONZALEZ

**APPROVED BY:** NASA

**QUANTITY:** 3

**PHASE(S):** PL LO Y TO X JO X LS

**FUNCTION:**

To provide control of interconnect line for various modes of propellant feed:

1) Open for RCS to RCS
2) Open for RCS to RCS
3) Closed for RCS to same size 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:** Full open

**CAUSE(S):**

- VIS. LIMITS
- Failure, premute power to motor, electrical short prop open, jamming of CMS.

**EFFECT(S):**

- (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) MISCELLANEOUS (E) VEHICLE

- (A) LOSS OF REDUNDANCY
- (B) DEGRADATION OF INTERFACE
- (C) MISSION MODIFICATION - OPERATION CHANGES PROP TO ITEMS A/C/BE/A
- (D) EFFECT FOR OBT MISSIONS (LOSS OF THRUSTER MAY BE CRITICAL FOR RTLS IN SUBSEQUENT MISSIONS FOR CMS DEPLETION BURN). CRIT I FOR RTLS - LOSS OF 1 MANIFOLD FORWARD & 1 MANIFOLD AFT IS CRITICAL FOR RTLS SEPARATION & MATED COAST DURING RTLS. SINGLE COMPUTER FAILURE COULD RESULT IN THIS TYPE CONDITION. (E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE EARLY MISSION TERMINATION - INABILITY TO DEMONSTRATE CMS PROP FEED TO RCS.

**COMPONENTS:**

- (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 RELAYS ARE PROVIDED. A 40-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, CORDS' 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 ASSEMBLY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED.
SUBSYSTEM : AFT - REACTION CONTROL  

FMEA NO. 03-2A-202111-2  

REV: 12/12/78

JULY 1976/CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP CONFORMANCE TO CONTRACT REQS. TURNAROUND/FUNCTIONAL FLOW & LEAKAGE TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON COMMAND. (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST

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

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

**EXPLANATION/COMMENTS:**

3. RCS RM automatically detects and prevents thrusting.
SUBSYSTEM: AFT - REACTION CONTROL

ASSEMBLY: PROPellant Feed Abort: ASCPT CRIT. FUNC: 12

P/N REV: MC 234-0430-0001/-0002

P/N VENDOR: 5793023/5790024

MISSIONS: HF VF X FF CF SM

QUANTITY: 16

FOUR PRIMARY VALVE MANIFOLDS PER PROP

REduNDANCY SCREEN: A-PASS 3-Pass C-Pass

PREPARED BY:

DES: R. Gonzalez

REL: C Makers

APPROVED BY (NASA):

APPROVED WITH CHANGES

ITEM: VALVE

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

FUNCTION:

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

FAILURE MODE: FAILS CLOSED-PREMATURE

OPERATION FAILS TO REMAIN OPEN

CAUSE(S):

- VIBRATION, LIMIT SWITCH MALFUNCTION, PREMATURE POWER TO MOTOR, PREMATURE MOTOR SIGNAL, OPEN SHORT

EFFECT(S):

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

(A) (B) LOSS OF REDUNDANCY-LOSS OF PROP FLOW & USE OF 3 PRIMARY THRUSTERS (1 OF 4 MANIFOLDS). (C) (D) NO EFFECT FOR SINGLE FAILURE FOR OPT MISSIONS (LOSS OF THRUSTER MAY BE CRITICAL FOR RTLS IN SUBSEQUENT MISSIONS FOR OMS DEPLETION BURN). CRIT 1 FOR RTLS & LOSS OF 1 MANIFOLD FORWARD & 1 MANIFOLD IS CRITICAL FOR ET SEPARATION & MATE COAST DURING RTLS. SINGLE COMPUTER FAILURE CAUSED 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 PREMATURE CLOSE MODE. PARALLEL (HYBRID) RELAYS PROVIDE REDUNDANCY FOR ELECTRICAL POWER SIGNAL. ADDITIONALLY, REDUNDANT VALVES ARE PROVIDED. A 300-MICRON FILTER IS UTILIZED ON THE INLET AND OUTLET TO LIMIT THE POTENTIAL FOR CONTAMINATION CAUSED FAILURE OR JAMMING OF MOVING PARTS. (B) 2500 OPERATION CYCLES (OPEN-CLOSE-OPEN) AND RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS ARE PERFORMED DURING QUAL. ITEM IS USED DURING SYSTEM EVALUATION TESTS AT KSP ALLowing EVALUATION UNDER SIMULATED MISSION USAGE CONDITION. PROOF PRESSURE, LEAKAGE, OPERATION, CONDUCTED AS PART OF PRE/POST FLIGHT CHECKOUT.

(C) A VISUAL INSPECTION IS PERFORMED. CONTAMINATION CONTROL PROCESS, ENDS PROTECTION PROVISIONS, NDE EXAMINATION OF WELDS, INSPECTION FOR SUBSURFACE DEFECTS AND PROPER ELECTRICAL TERMINATIONS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED. MANUFACTURE, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED AS PART OF THE QUALIFICATION CHECKOUT. MANUFACTURE, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED AS PART OF THE QUALIFICATION CHECKOUT.

THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED FOR ALL SHUTTLE CRITICAL ITEMS LIST - CRBITER 102
SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM: AFT - REACTION CONTROL  FMBA NO. 03-2A-202120-3  REV: 12/12/78

TO CONTRACT REQMTS. TURNAROUND/FUNCTIONAL FLOW & LEAKAGE TESTS ARE MONITORED TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON COMMAND. (D) NO PRIOR FAILURE HISTORY FOR THIS TYPE DESIGN.
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY 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.**
   - *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)*

**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:**

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.
**DIFFERENTIAL PRESSURE CIRCUIT**

**DIFFERENTIAL PRESSURE CIRCUIT**

---

### Table 1: Fuel Transfer

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV 275/277</td>
<td>3/36放假</td>
</tr>
</tbody>
</table>

### Function:
- LV 275/277 is the differential pressure circuit.

### Conditions:
- The fuel transfer system is activated.
- The event of a differential pressure failure occurs.

### Decision:
- **Utilize ECM/ACS Ventrol**
- Attempt to transfer fuel from LV to LV using ECM/ACS.

### Recovery Action:
- Potential for collision with loss of payload/satellite due to short-circuit condition.
- It is confirmed that the vehicle can be moved to a safe area.
- ECM/ACS Ventrol is used as a back-up to control LV.

---

**ORIGINAL PAGE IS OF POOR QUALITY**
ITEM: VALVE.
MANIFOLD ISOLATION, VERNIER THRUSTER, SCLENOID (28VDC) BL-STABLE (LATCHING) LV 258/257/357/352.

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

FAILURE MODE: FAILS CLOSED. (F)

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

EFFECT(S): ON: (A) SUBSYSTEM (B) INTERFACES (C) MISSION (E) OTHER VEHICLE: 1) LOSS OF FUNCTION (VERNIER THRUSTER). (A) LOSS OF FUNCTION OF INTERFACE SUBSYSTEM-PAYLOAD MANIPULATION. (C) MISSION MODIFICATION OF ABDT DECISION. (D) NO EFFECT UNLESS ADDITIONAL FAILURES OCCUR.

DISPOSITION & RATIONALE: (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY: (A) SERIES SWITCHES (SW'S) MINIMIZE POTENTIAL FOR INADEQUATE ACTUATION. PARAL SWITCHES (PR'S) PROVIDE ELECT REDUNDANCY FOR THE OPENING SW'S. AN INDUCT VOLTAGE SUPRESS CIRCUIT IS PROV IN THE ELECTRICAL SYSTEM TO PREV DAMAGE TO OTHER ON-LINE COMPS. REDUNDANT DIODES LIMIT THE POSS OF DIODE FAILURE ALLOWING CURRENT SHUNT FROM THE COIL.

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

TC LIMIT THE ELECT SHORT POTENT. THE LEAD AND MAGNET WIRES ARE ENCAP BY POTTING AND A FIXTURE IS USED DURASSEMBLY TO ENSURE THAT INSUL IS NOT DAMAGED BY THE EXIT NOCH. WHEN THE COIL SLEEV IS PRESSED ON TO THE COIL. (B) 2000 CYCLES (ON-OFF-FLOW) AND RANDOM VIB AT ANTIC MISSION LEVELS ARE PERF UNDER QAL. ITEM IS USED DURASYS EVAL TESTS AT WSTF ALLOVING EVAL UNDER SIMUL MISSION USAGE COND. PROOF PRESS, LEAKAGE, OPER AND INSUL TESTS ARE PERF DURING ATP. APPROP LOCATED TEST POINTS ALLOW POE/POST FLIGHT LEAKAGE TESTS AND OPER TESTS ARE ALSO COND AT THIS TIME. (C). AND IDENTIF IS PERF AND THE UNIT TAGGED. CONTAM CONT PROV, CORROS., PROT, PROV, WELD, BZ AE EXAM OF WELDS AND BRAZES, INSPECT. FOR SURFACE AND SUBSURFACE DEFEKTS AND PROPER ELECT TERMINATIONS ARE VERIF BY INSPECT.

THE FOLLOW ITEMS ARE VERIF BY SHOP TRALER INSPECT. POINS RAW REF (LOT CERTIF), PARTS PROT, MANIF., COATING, PLATING, INSTALL AND ASSY OPER.

THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIF BY AUDIT COND.
SUBSYSTEM : AFT - REACTION CNTROL FMEA NO 03-24-202140-1 REV: 12/12/73
S-31-77. CONTAM CONT PROD. CORRUS. PROT PROV TURNAROUND- FUND FLOW
TESTS ARE MCHIT TO VERIFY THAT VALVES OPEN AND CLOSE PROPERLY UPON
COMMAND. (O) APOLLO FAILURES WERE MAINLY ASSCIC WITH REVERSE POLARITY
AND DEGUASSING OF MAGNETS. THE SHUTTLE VALVE UTILIZES A CONNECTOR
(RATHER THAN LEAD WIRES) AND A BLOCKING DIODE WHICH PREVENTS THIS TYPE
OF ERROR DURING CONN. DEVEL TEST, AND ANAL SHOWED PRESS SURGE FATIGUE
PROBLEM. THIS IS BEING RESOLVED BY REDUCING THE LIFE OF THE VALVE TO 50
MISSIONS.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST

SUBSYSTEM_AFT - RCS
ITEM_Propellant Fill & Bleed Disconnect
FMEA NUMBER 03-2A-202150-1
FAILURE MODE Fails Open

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

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

---

EXPLANATION/COMMENTS:

1. 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 ABORT CRITICAL FUNCTION
P/N : MCZ760
quantity : 12
FUNCTION:
TO PROVIDE PROPELLANT TANKS DURING SERVICING IN VERTICAL VEHICLE ORIENTATION. ONE INC0UPLING, (FUEL-LEFT POD AND OX-RIGHT PCD) SERVICES APCS AND CMS. ITEM INCORPORATES SECONDARY INTERNAL SEALS AND HAS A PRESSURE CAP WHICH IS REDUNDANT SEAL. CAP INSTALLED PRIOR TO FLIGHT.
FAILURE MODE: CAP LEAKS IN EXCESS OF ACCEPTABLE RATE. SEALS CAN REQUIRED BUT DOES NOT NEGATE CAP SEAL REDUNDANCY.
CAUSE(S):
VISIBILITY, PIECE PART OR STRUCTURAL FAILURE, MECHANICAL DAMAGE, EXCESSIVE TOUPE SEAL DAMAGE, NO LINE SUPPORT SHAFT OR CORE SEENT, INADEQUATE MAINTENANCE OF GSE HALF.
EFFECT(S):
(A) LOSS OF SUBSYSTEM PROPELLANT, (B) DEGRADATION OF INTERFACE SUBSYSTEM (PROPELLANT EFFECTS), (C) LAUNCH DELAY OR ABORT DECISION.
DISPOSITION & RATIONALE:
(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) F.S. IS 1.0 X WORKING PRESS. GROUND HALF COUPLINGS AND LINES ARE ADEQUATELY SUPPORTED TO LIMIT ANY UNDUE STRESS ON THE COUPLING DURING SERVICE AND PREV DAMAGE TO SEALS. A SAFETY FEATURE PRIOR TO REMOVAL OF THE END CAP IS A PROVISION 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 STRUCTURAL CAP MINIMIZES LEAKAGE POTENTIAL AND PROVIDES A REDUNDANT SEAL EXCEPT FOR STRUCTURAL FAILURE.
(B) THE COUPLING IS SUBJECT TO 600 OPER CYCLES (COUPLING AND UNCOUPLING) DURING QUAL IN ADDITION TO PRESS SURGE CYCLING AND PROP EXPOSURE TESTS. RANDOM VIB TESTS ARE ALSO CONDUCTED AT ANTIC VEH LEVELS FOR 34 MINUTES IN EACH AXIS. USAGE DURING SYR EVAL TESTS AT WSTF ALLOWS EVAL UNDER ACTUAL USAGE CONDITIONS. PROOF PRESS TESTS ARE CONDUCTED DURING AT OR LEAKAGE TESTS ARE PERF BEFORE & AFTER OPER CYCLES.
(c) AN IDENT IS PERF. RAW MATERIALS, NDE EXAM, VISUAL INSPECTION FOR SURFACE DEFECTS, & EQUIP CONFORMANCE TO CONTRACT REQUIREMENTS ARE VERIFIED FROM RECEIVING INSPECTION. MEASUREMENT STANDARDS & TEST EQUIP. STANDARDS ARE IMPLEMENTED PER REQUIREMENTS OF MIL SPEC. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION 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. CORROD
PROT. PROV. CONTAM CONT PROCESSES, TEST HANDLING, & STORAGE ENVIR.
THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT OF MARCH 6, 1978. INSPECTION
VERIFIES ASSEMBLY PER INSPECTION POINTS IN MASTER RECORD. LOG OF CLEAN
ROOM AND CALIBRATION OF TOOLS VERIFIED. CRITICAL DIMENSION 100%
VERIFIED BY INSPECTION. PARTS CLEANLINESS AND PASSIVATION BY
INSPECTION. NOE INSPECTION PERFORMED AFTER ASSEMBLY.

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

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

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

- **YES** ✓  
- **NO**  

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

- **YES** ✓  
- **NO**  

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

- **YES** ✓  
- **NO**  

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

- **YES** ✓  
- **NO**  

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

- **YES** ✓  
- **NO**  

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

- **YES** ✓  
- **NO**  

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

- **YES** ✓  
- **NO**  

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

- **0** ✓  
- **1**  
- **2**  

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

- **N/A**  
- **YES** ✓  
- **NO**  

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

- **A.** CAN THE BFS BE ENGAGED AFTER OCCURRENCE?  
- **B.** WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?

- **YES** ✓  
- **NO**  

---

**CHANGE/RETENTION RATIONALE SUMMARY**

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

---

**EXPLANATION/COMMENTS:**


6. Pod redundancy.

8b. Backup flight system same as primary.
SHUTTLE CRITICAL ITEMS LIST – CRITERION 102

SUBSYSTEM: AFT – REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N: M282-0061-0001-0002
P/N VENDOR: 355C3310000-0010-020
MISSIONS: H5 V5 X FF JF SM

P/N: MC292-0061-0012
CP: 1

ASSEMBLY: PROPELLANT FEED

PREPARED BY: C. M. A. R
APPROVED BY:

PREPARED BY: 
APPROVED BY:

ASSEMBLY

ITEM:

SUBSYSTEM

FUNCTION:

FAILURE MODE:

CAUSE(S):

EFFECT(S):

DISPOSITION & RATIONALE:

DISPOSITION & RATIONALE:

PREPARED BY:

APPROVED BY:

APPROVED BY:

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

FUNCTION:

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

CAUSE(S):

MECH SHOCK, FATIGUE/VIV, OVERPRESS, STRESS COUPES, [IMPROPER PROP PURITY OR TEST FLUID, OVER TEMP, PLUME OR REGISTRY GASES, STRESS RISE?, YIELD OR Mat'F 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) POSSIBLE LOSS OF CREW/VEHICLE (EXPLOSION, LACK OF PROPELLANT OR INABILITY TO DEPLETE OPPOSITE PROPELLANT).

DISPOSITION & RATIONALE:

(A) THE F.S. (BURST) IS 1.5 X WORKING PRESSURE. COMPLETE STRESS ANALYSIS FOR EACH TANK SEGMENT WAS PERFORMED. TANK IS CLASSIFIED AS FRACURE CRITICAL FOR HANDLING AND IS SUBJECT TO FRACTION CONTROL REQMTS. ALL FITTINGS AND FLANGES USED ON THE TANK HAVE DUAL ELASTOMER SPRING LOADED SEALS. (B) QAL 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 PENTRANT 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 M'AT'IL AND PURCHASED COMPONENT REQMTS ARE VERIFIED BY RECEIVING INSPECTION POINTS- PARTS PROTECTION, MFG. PROCESSES, FINISHES, ASSY AND INSTALLATION. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY

991
94
SD 75- SB -0003
SHUTTLE CRITICAL ITEMS LIST - ORBITER L02

SUBSYSTEM: AFT - REACTION CONTROL  FMEA NO 03-2A -211110-1  REV:11/03/75
AUDIT CONDUCTED 11-1-76. CORROSION PROTECTION PROVISIONS, TEST HANDLING, AND STORAGE ENVIRONMENTS. TENSILE, HEAT TREAT AND WELD SAMPLES ARE TESTED DURING IN-PROCESS FABRICATION IN ADDITION TO X-RAY AND DYE PENTRANT INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS. BOTH CERTIFIED WELDERS AND CERTIFIED INSPECTORS ARE USED FOR ALL WELDS. TURNAROUND- INSPECTION TO MONITOR FUNCTIONAL TEST DURING PRESSURIZATION CYCLE FOR EVIDENCE OF LEAKS. LEAKAGE TESTS ARE PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND PERIODICALLY AS PART OF CHECK-OUT PROCEDURE PRIOR TO FLIGHT. PRESSURE CYCLES ACCUMULATED ARE ALSO RECORDED. (0) APOLLO FAILURES WERE ASSOCIATED WITH INCORRECT TEST FLUID (METHYL ALCOHOL), IMPROPER PROPELLANT CONTENT, STRESS FISE OR TEST ERROR RESULTING IN CREATION OF VACUUM. CORRECTIVE ACTION WAS TAKEN FOR ALL OF ABOVE FAILURES AND ALSO IMPLEMENTED ON SHUTTLE.
1. **DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?**
   - YES ☐ NO ☐

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)*

**EXPLANATION/COMMENTS:**

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

5. Crossfeed.

8b. Same as primary.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPELLANT FEED
P/N: MC232-0061-0031-0002
P/N VENDOR: 855C3310000-010-020
QUANTITY: 14

MISSIONS: HF VF X FF OF SM
PHASE(S): PL LO X DO X DO LS

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

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

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) SAFETY FACTORS OF 1.5 (MINIMUM) IN SCREEN WILL MINIMIZE FAILURE POTENTIAL. (B) QUAL REQUIRES 200 EXPULSION CYCLES A 90 DAY PROPELLANT EXPOSURE TEST. DEVELOPMENT CERTIFICATION TESTS DEMONSTRATE 100 MISSION FLOW TRANSIENTS (188,800 CYCLES) AND TWO YEAR PROPELLANT COMPATIBILITY. PROPELLANT ACQUISITION DEVICE AND WELD INTEGRITY VERIFIED VIA BUBBLE POINT TESTS AT THE COMPONENT, SUBASSEMBLY & TANK ASSY LEVEL. (C) AN IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. RAW MATERIAL AND PURCHASED COMPONENT-REQMTS ARE VERIFIED BY RECEIVING INSPECT. MEASUREMENT STANDARDS & TEST EQUIP STANDARDS ARE IMPLEMENTED PER REQMTS OF MIL SPECS. THE FOLLOWING ITEMS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS-PARTS PROTECTION, MFG. PROCESSES, FINISHES, ASSY AND THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 11-1-76. CORROSION PROTECTION PROVISIONS, TEST HANDLING, AND STORAGE ENVIRONMENTS. BOTH CERTIFIED WELDERS AND CERTIFIED INSPECTORS ARE USED FOR ALL WELDS. TURNOVER - 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)? 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. 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.
CONTROL SYSTEM FAIL - TREAT FAULTS CAREFULLY

1. CHECK (FLUID) LEVEL
2. CHECK (FLUID) TEMPERATURE
3. CHECK (FLUID) PRESSURE
4. CHECK (FLUID) DENSITY

If any of the checks indicate a problem, take corrective action.

Corrective Action:
1. Replace faulty component.
2. Flush system with clean fluid.
3. Perform system test.

After completing the corrective action, perform a thorough inspection and test.
SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: PROPellant FEED
P/N RI: 73P550015-1016102 (MDAC)
P/N VENDOR: 1003099-1016102 (SSP)
QUANTITY: 102

SUBSYSTEM: AFT - REACTION CONTROL
FMEA

MISSIONS: HF YF X FF CF SM
PHASE(S): PL X L3 X CD X DO X LS Y

PREPARED BY:
APPROVED BY:
PREPARED BY:
APPROVED BY:

REduNDANCY SCREEN: A-N/A B-N/A C-4/A

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 PENETRATION, IMPINGEMENT, POPCITY, CORROS RESULTING IN PIN HOLE LEAK THROUGH CONVOLUTE, PROP & SI-PREP EXPOSURE PRESSURE SURGES, FLOW INDUCED VIB-PGC EFFECT, FLT VIB.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) SUBSYSTEM DEGRADATION - LOSS OF PROPELLANT. (B) DEGRADATION OR INTERFACE FUNCTION - POSS CORROS DAMAGE WITHIN POD 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.

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. CON- TAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NOE EXAM OF WELDS, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUFACTURING, INSTALLATION, AND ASSEMBLY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 8-29-77. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L CONFORMANCE TO CONTRACT REGMTS. TURNAROUND - MONITOR LEAKAGE TESTS PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND AS PART OF CHECKOUT.

PREPARED BY:
APPROVED BY:
PREPARED BY:
APPROVED BY:

REduNDANCY SCREEN: A-N/A B-N/A C-4/A

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 PENETRATION, IMPINGEMENT, POPCITY, CORROS RESULTING IN PIN HOLE LEAK THROUGH CONVOLUTE, PROP & SI-PREP EXPOSURE PRESSURE SURGES, FLOW INDUCED VIB-PGC EFFECT, FLT VIB.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) SUBSYSTEM DEGRADATION - LOSS OF PROPELLANT. (B) DEGRADATION OR INTERFACE FUNCTION - POSS CORROS DAMAGE WITHIN POD 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.

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. CON- TAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NOE EXAM OF WELDS, INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUFACTURING, INSTALLATION, AND ASSEMBLY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 8-29-77. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L CONFORMANCE TO CONTRACT REGMTS. TURNAROUND - MONITOR LEAKAGE TESTS PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND AS PART OF CHECKOUT.
SUBSYSTEM: AFT - REACTION CONTROL  
FMEA NO 03-2A -211120-1  
REV: 11/08/78

PROCEDURE PRIOR TO FLIGHT. (D) NO FAILURE HISTORY AVAILABLE ALTHOUGH THE APOLLO PROGRAM DID SHOW SOME PROBLEMS ON FLEX HOSE ASSY DUE TO PIN HOLE CORROSION ASSOCIATED WITH RESIDUAL SOLVENTS AND PROPELLANT.
1. Does the flight software detect this failure mode (i.e., automatically annunciate or take action in response)?
   - Yes ☒ No ☐

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

2. Are the answers to questions 1 and 1a consistent with the FMEA evaluation of in-flight detectability?
   - Yes ☐ No ☒

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

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

4. As a result of this failure mode, can the software overstress the hardware or induce another failure?
   - Yes ☒ No ☐

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

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

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

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

*Explanation Required (See Below)

In-flight detectability

FMEA Change Recommended

Explanation/Comments:

SHUTTLE CRITICAL ITEMS LIST - CRITERION 102

SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : THRUSTER/PROPELLANT FEED
ABORT: CPIT. FUNC: 1
P/N RI : MC621-0059
P/N VENDOR: 73P550G3-1001THRU1005
MISSIONS: HF VF X FF OF SM
QUANTITY : 56

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

PREPARED BY: G. GLAVINICH
APPROVED BY: S. SM

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

FAILURE MODE: STRUCTURAL FAILURE (S)
EXTERNAL LEAKAGE.

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

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) MULTIPLE BELLows ARE UTILIZED. FLOW INDUCED VIBRATION ANALYSIS AND STRESS ANALYSIS WERE CONDUCTED TO VERIFY ACCEPTABLE DESIGN. THE EXTERNAL CONSTRAINT WOULD TEND TO LIMIT ANY GROSS 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 ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 8-29-77. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT. SPECIAL MEASUREMENT STANDARDS AND EQUIPMENT AND MATERIAL CONFORMANCE TO CONTRACT REQUIREMENTS. TURNAROUND - MONITOR LEAKAGE TESTS PERFORMED AFTER INSTALLATION INTO THE SYSTEM AND AS PART OF CHECKOUT PROCEDURE PRIOR TO FLIGHT. (D) NO FAILURE HISTORY AVAILABLE ALTHOUGH THE APOLLO PROGRAM DID SHOW SOME PROBLEMS ON FLEX HOSE ASS'Y DUE TO PIN HOLE CORROSION ASS'Y WITH RESIDUAL SOLVENTS AND PROPELLANT.
**HARDWARE/SOFTWARE ANALYSIS CHECKLIST**

**SUBSYSTEM** AFT - RCS

**ITEM** Engine Inlet Valve

**FMEA NUMBER** 03-2A-221310-4

**FAILURE MODE** Fails Closed

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)*

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**CHANGE/RETENTION RATIONALE SUMMARY**

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

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**EXPLANATION/COMMENTS:**

1. "Failed off" thruster C&W.
### HARDWARE/SOFTWARE ANALYSIS CHECKLIST SD72-SH-0103-2

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

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)*

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### CHANGE/RETENTION RATIONALE SUMMARY

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

---

**In-Flight Detectability**  
[ ] FMEA CHANGE RECOMMENDED

---

**EXPLANATION/COMMENTS:**

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

SUBSYSTEM: AFT - REACTION CONTROL
ASSEMBLY: THRUSTER, PRIMARY
P/N: MC467-0028
P/N VENDOR: X30398
QUANTITY: 24

FUNCTION:
Provides injection & vaporization of fuel and oxidizer during thrust.

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

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

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

DISPOSITION & RATIONALE:
(4) Design; (5) Test; (6) Inspection; (7) Failure History. 74 micron nominal filters are provided to control contamination from FPS and subsequent hazard. Automatic switch over (and isolation) by GN&C failure detection sys. Complete thermal and stress analysis have been completed. (8) RCS sys eval test at WSTF. Thruster qual for 50,000 cycles. Spray pattern checked during ATP. (C) A visual insp. and identification is performed and the unit tagged. Contamination control process, corros. protection provisions, NDE exam of welds, RAH mat'l (LOT) certification, parts protection, coating and plating processes are verified by inspection. Manuf, installation, and Assy operations are verified by shop traveler mandatory insp. points. The above items and the following items were verified by audit conducted 9/2-76. Contamination control plan, properly monitored handling and storage environment, special measurement standards and equip and mat'l and equip conformance to contract reqts. Turnaround inspection to include use of optics where accessible to determine evidence of plugged orifice. Fluid sampling to be performed to detect contamination. (D) No direct failure history available.

PREPARED BY:
APPROVED BY:
APPROVED BY:

ITEM: INJECTOR PLATE

FUNCTION:
Provides injection & vaporization of fuel and oxidizer during thrust.

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

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

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

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(4) Design; (5) Test; (6) Inspection; (7) Failure History. 74 micron nominal filters are provided to control contamination from FPS and subsequent hazard. Automatic switch over (and isolation) by GN&C failure detection sys. Complete thermal and stress analysis have been completed. (8) RCS sys eval test at WSTF. Thruster qual for 50,000 cycles. Spray pattern checked during ATP. (C) A visual insp. and identification is performed and the unit tagged. Contamination control process, corros. protection provisions, NDE exam of welds, RAH mat'l (LOT) certification, parts protection, coating and plating processes are verified by inspection. Manuf, installation, and Assy operations are verified by shop traveler mandatory insp. points. The above items and the following items were verified by audit conducted 9/2-76. Contamination control plan, properly monitored handling and storage environment, special measurement standards and equip and mat'l and equip conformance to contract reqts. Turnaround inspection to include use of optics where accessible to determine evidence of plugged orifice. Fluid sampling to be performed to detect contamination. (D) No direct failure history available.

PREPARED BY:
APPROVED BY:
APPROVED BY:

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

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

DISPOSITION & RATIONALE:
(4) Design; (5) Test; (6) Inspection; (7) Failure History. 74 micron nominal filters are provided to control contamination from FPS and subsequent hazard. Automatic switch over (and isolation) by GN&C failure detection sys. Complete thermal and stress analysis have been completed. (8) RCS sys eval test at WSTF. Thruster qual for 50,000 cycles. Spray pattern checked during ATP. (C) A visual insp. and identification is performed and the unit tagged. Contamination control process, corros. protection provisions, NDE exam of welds, RAH mat'l (LOT) certification, parts protection, coating and plating processes are verified by inspection. Manuf, installation, and Assy operations are verified by shop traveler mandatory insp. points. The above items and the following items were verified by audit conducted 9/2-76. Contamination control plan, properly monitored handling and storage environment, special measurement standards and equip and mat'l and equip conformance to contract reqts. Turnaround inspection to include use of optics where accessible to determine evidence of plugged orifice. Fluid sampling to be performed to detect contamination. (D) No direct failure history available.

PREPARED BY:
APPROVED BY:
APPROVED BY:

ITEM: INJECTOR PLATE

FUNCTION:
Provides injection & vaporization of fuel and oxidizer during thrust.

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

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

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

DISPOSITION & RATIONALE:
(4) Design; (5) Test; (6) Inspection; (7) Failure History. 74 micron nominal filters are provided to control contamination from FPS and subsequent hazard. Automatic switch over (and isolation) by GN&C failure detection sys. Complete thermal and stress analysis have been completed. (8) RCS sys eval test at WSTF. Thruster qual for 50,000 cycles. Spray pattern checked during ATP. (C) A visual insp. and identification is performed and the unit tagged. Contamination control process, corros. protection provisions, NDE exam of welds, RAH mat'l (LOT) certification, parts protection, coating and plating processes are verified by inspection. Manuf, installation, and Assy operations are verified by shop traveler mandatory insp. points. The above items and the following items were verified by audit conducted 9/2-76. Contamination control plan, properly monitored handling and storage environment, special measurement standards and equip and mat'l and equip conformance to contract reqts. Turnaround inspection to include use of optics where accessible to determine evidence of plugged orifice. Fluid sampling to be performed to detect contamination. (D) No direct failure history available.
SUBSYSTEM AFT - RCS  
ITEM Thrust Chamber  
FMEA NUMBER 03-2A-221312-1  
FAILURE MODE Burn-Thru

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. NO H/S ISSUES
2. 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.
ITEM: THRUST CHAMBER
FROM INJECTOR TO NOZZLE EXTENSION (COATED COLUMBIUM).

FUNCTION:
TO CONTAIN HYPERSONIC 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 EXORATION
RESISTANT COATING AND UTILIZES FILM COOLING. THE CHAMBER PRESSURE IS 152
PSI & IS DESIGNED TO PRODUCE A THRUST OF 870-LBS VACUUM AT A MODAL
STEADY STATE SPECIFIC IMPULSE OF 280 SECONDS.

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

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

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

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
(A) STRUCTURAL MARGINS (2.0 TO 4.0) MINIMIZE FAILURE EFFECT(S). ENG
DESIGNED TO INGEST UP TO 45 CU. IN. OF GAS. (B) RCS SYS EVAL TEST AT
WSNF. THRUSTER QUAL FOR 50,000 CYCLES. (C) A VISUAL INSPECTION AND
IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL
PROCESS, CORROS. PROTECTION PROVISIONS, USE OF WELDS, RAW MTL
(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 9-2-76:
CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE
ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MTL AND EQUIP
CONFORMANCE TO CONTRACT REQS. 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.
<table>
<thead>
<tr>
<th>Item</th>
<th>Failure Mode</th>
<th>1.</th>
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<tr>
<td>Nozzle Extension</td>
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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

**Explanation/Comments:**

- FMEA Change Recommended
FAULT: TURBINE INLET VALVE LEAK.

REASONS:
- Inlet valve is open.
- Slight pressure differential across valve.
- Valve seats may be corroded or damaged.

EFFECTS:
- Turbine output may decrease.
- Possible damage to downstream equipment.
- Increased risk of overheating.

PREPARED BY:
CES

APPROVED BY:
CES

INVESTIGATION:
- Visual inspection of valve and seat condition.
- Pressure testing to confirm leakage.

RECOMMENDATION:
- Repair or replace valve.
- Inspect and clean all interfaces.

ACTION:
- Replace valve as soon as possible.
- Conduct regular maintenance checks.

REMARKS:
- Be careful not to damage surrounding components.
- Ensure all法兰connections are tight.

ORIGINAL PAGE IS OF POOR QUALITY.
ITEM: NOZZLE EXTENSION
COATED COLUMBNIUM (WITH INSULATION BLANKET).

FUNCTION:
TO PROVIDE ISENTROPIC EXPANSION OF COMBUSTION GASES FOR MAX EFF IN VACUUM. NOZ EXT IS CONSTRUCTED OF C-103 COLUMBNIUM WITH 7-512A OXIDATION RESISTANT COATING. THE NOZZLE EXPANSION RATIO IS 22 TO 1. THE NOZ EXT IS INTEGRAL WITH THE GBS CHAM AND ENCLOSED IN A DYNAR FLEX INSUL SHROUD SO THAT THE EXT TEMP IS MAINTAINED PER THE PROCUREMENT SPECIFICATION REQMT.

FAILURE MODE: STRUCTURAL FAILURE,
BURN-THRU.

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

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

DISPOSITION & RATIONALE (A) DESIGN  (B) TEST  (C) INSPECTION  (D) FAILURE HISTORY:
(4) HIGH THERMAL MARGINS IN NOZZLE EXTENSION AND HIGH COOLING MARGIN WILL MINIMIZE FAILURE EFFECT. ENG DESIGNED TO INGEST 45 CU. IN. OF GAS. THRUSTER CAN BE ISOLATED AT INLET OR MANIFOLD VALVE. (B) RCS SYS, EVAL TEST AT WSTF. THRUSTER QUAL FOR 50,000 CYCLES. (C) A VISUAL INSPECTION AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NO EXAM OF WELDS, RAW MAT'IL (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF. INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPEC POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-76. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'IL AND EQUIP CONFORMANCE TO CONTRACT REQMTS.

TURNAROUND INSPECTION TO INCLUDE USE OF OPTICS WHERE ACCESSIBLE TO DETERMINE EVIDENCE OF BURN-THRU. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
## HARDWARE/SOFTWARE ANALYSIS CHECKLIST

**SUBSYSTEM** AFT - RCS  
**ITEM** Vernier Thruster  
**FMEA NUMBER** 03-2A-231310-1  
**FAILURE MODE** Loss of Output

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<td><strong>1.</strong></td>
<td><strong>DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?</strong></td>
</tr>
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<tr>
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<td><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>
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<td><strong>4.</strong></td>
<td><strong>AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?</strong></td>
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<td><strong>5.</strong></td>
<td><strong>CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?</strong></td>
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<td><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>
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<td><strong>8.</strong></td>
<td><strong>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?</strong></td>
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### EXPLANATION/COMMENTS:

1. Down modes to free drift.
2. No redundancy in the verniers.
SIMULATION: FAILURE TYPE AND EFFECTS ANALYSIS - T-900 Dec

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**PREPARED BY:**
LEE

**APPROVED BY:**
LES

---

**FUNCTION:**

The pitch axis (AZ) and yaw axis (ROLL/PITCH/YAW) function is provided in each ARC as needed to provide vertical level holding or attitude hold for payload handling. It is conceptually similar to the primary thrusters but with a different approach and propellant confinement to the payload.

**FAILSAFE MODE:**

- LOSS OF FUNCTION (FRONTAL) (C)
- LOSS OF VEHICLE (TAIL) (A)
- LOSS OF FUNCTION (VERNIER THRUSTERS) - CURRENTLY LOST IN STRUCT.
- VERNIER THRUSTERS CAUSE LOSS (SLOW) CIRCLES (B) WITHOUT EFFECT.
- MISSION OR RECONFIGURATION OF ASSESSMENT (AFT ATTITUDE IN ABYSS, TAIL). — IT IS POSSIBLE TO ATTEMPT TO OBTAIN RE-ENGAGEMENT FROM AFT THRUST EMERGENCY TO RE-ENGAGE TAIL, YOU MAY HAVE ATTITUDE & TRANSLATION CONTROL IF YOU ARE ABLE TO USE THE AFT 2 AXES (X-AXIS) ENGINES FOR PITCH (FORWARD) BLOCKING.

**DIRECTIVE ACTION:**

- EVALUATE TO DETERMINE NEED FOR ABORT VERSUS USE OF PRIMARY THRUSTERS, FREE DRIFT MODE OR PAYLOAD ATTITUDE CONTROL.

**EFFECTS:**

- NO PAYSIDE IDENTIFIED. PRIMARY THRUSTERS MOVE VEHICLE TO ADJACENT PAYLOAD. PAYLOAD PAY ASSEMBLIES ARE 55 FT LONG. (THEY ARE NOT DESIGNED TO WITHSTAND FORCE OF PRIMARY THRUSTING). IT IS POSSIBLE TO REPEAT THE PAYLOAD MODULE RETRIEVED WHILE IN FREE DRIFT MODE AND IN SOME INSTANCES PAYLOAD PAYL

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**PAGE 1 OF 2**

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**PAGE 2 OF 2**
ORIGINAL PAGE IS OF POOR QUALITY
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : VERNIER THRUSTER
P/N/RI : MC467-0029
P/N VENDOR:
QUANTITY : 4

SHUTTLE CRITICAL ITEMS LIST - CRITERIA 102

FMEA NO. 03-2A - 231310-1 REV: 11/08/76

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SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : VERNIER THRUSTER
P/N/RI : MC467-0029
P/N VENDOR:
QUANTITY : 4

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

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 ACS MODULE TO PROVIDE PRECISE LOW LEVEL PULSING AND ATTITUDE HOLD REQD FOR PAYLOAD POINTING. THEY ARE CONCEPTUALLY SIMILAR TO THE PRIMARY THRUSTER BUT LIMIT PLUME IMPINGEMENT AND PROP RESIDUE CONTAM TO THE PAYLOAD.

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

CAUSE(S):
OPEN SGL COIL, AUTO SHUT-OFF, INLET VALVE LEAK/STRUCT FAIL, INJ CONTAM/RESIDUE OR FROZEN PROP BLOCKING ORIFICE, COMP CHAM/NGIg STRUC FAIL.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF FUNCTION (VERNIER THRUSTERS) - CURRENTLY LOSS OF SINGLE VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL. (B) NO EFFECT.
(C) MISSION MODIFICATION OR ABDON 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 PRIMARY & 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 DUAL 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 CORROSION PROTECTION PROVISIONS. NODE EXAM OF WELDS, RAW MAT'L (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION.

MANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-76. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP CONFORMANCE TO CONTRACT-REQTS. TURNOAROUND - 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.
## 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

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

### CHANGE/RETIETION RATIONALE SUMMARY

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

- FMEA CHANGE RECOMMENDED

### EXPLANATION/COMMENTS:

1. "Failed on" thruster C&W.  
6. No redundancy in the verniers.
SHUTTLE CRITICAL ITEMS LIST - ORSITER 102

SUBSYSTEM: AFT - REACTION CONTROL  
ASSEMBLY: VERNIER THRUSTER  
P/N RI: MC467-0029  
P/N VENDOR: MISSIONS: HF VF X FF DF SM  
PHASE(S): PL LJ CC X DO LS  
QUANTITY: 4, 2 PER POD  

PREPARED BY: J TAGGART  
APPROVED BY: SSM  
APPROVED BY: NASA  
DEVELOP.  

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

FUNCTION:  
- ONE PITCH (2 AXIS-UP FIRING) AND ONE YAW (PLUS/_MINUS Y AXIS) VERNIER THRUSTER ARE PROVIDED IN EACH ARCS MODULE TO PROVIDE PRECISE LOW LEVEL PULSING AND ATTITUDE HOLD REQ'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: 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, VIS, SHOCK SEAL SEAT DAM, PROP RESIDUE, FLUSH SALTS, CORROS, WEAR.  

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:  
- (A) LOSS OF FUNCTION (VERNIER THRUSTERS) - CURRENTLY LOSS OF SINGLE VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL.  
- (B) DEGRADATION OF INTERFACE SUB-SYSTEM - PROP LOSS DUE TO EXCESS BURN-TIME UNTIL MANIFOLD CAN BE ISOLATED-POSS DAMAGE TO PAYLOAD OR PAYLOAD BAY ARMS.  
- (C) MISSION MODIFICATION OR ABORT DECISION.  

DISPOSITION & RATIONALE (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:  
- (A) ISOLATION CAPABILITY IS AN AUTOMATIC FUNCTION WHICH WILL MINIMIZE FAILURE EFFECT. POSS REDUND MODES OF OPERATION. (PRIMARY THRUSTERS, FREE DRIFT MODE & PAYLOAD ATTITUDE CONTROL MAY PROVIDE ADDITIONAL CONTROL POTENTIAL). 100 MICRON FILTRATION PROVIDED. INADVERTENT FIRE SIGNAL IS IMPROBABLE DUE TO GPC/MOD DESIGN. (B) THRUSTER 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 (LST) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF. INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER MANDATORY INSPECTION POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-76. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'L AND EQUIP CONFORMANCE TO CONTRACT REQS. TURNAROUND - SYSTEM FLUIDS ARE ANALYSED FOR EVIDENCE OF CONTAMINATION. PROPER INLET VALVE FUNCTION AND ELECTRICAL LOGIC POWER IS VERIFIED. (D) NO DIRECT FAILURE HISTORY AVAILABLE.
HARDWARE/SOFTWARE ANALYSIS CHECKLIST  SD72-SH-0103-2
SUBSYSTEM  AFT - RCS  FMEA NUMBER  03-2A-23131G-3
ITEM Vernier Thruster  FAILURE MODE  Burn Thru

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

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

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

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

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

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

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

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

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

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

*EXPLANATION REQUIRED (SEE BELOW).

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

☐ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:
1. "Failed off" thruster C&M.
2. Down modes to free drift.
3. No redundancy in the verniers.
SUBSYSTEM : AFT - REACTION CONTROL
ASSEMBLY : VERNIER THRUSTER
P/N PI : MC467-0C29
P/N VENDOR: MISSIONS: HF VF X HF OF SM
QUANTITY: 4 PHASE(S): PL LO X 00 X 00 X LS
: 2 PER POD NUMBER OF SUCCESS PATHS REMAINING
: 1 PITCH, 1 YAW AFTER FIRST FAILURE:

RELIABILITY IN FLIGHT? YES
CHAMBER PRESSURE ON EACH ENGINE, V42P32521 THRU V42P-2534 AND V42P-3521 THRU V42P-3534

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

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

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

FUNCTION:
ONE PITCH (2 AXIS-UP FIRING) AND ONE YAW (PLUS/MINUS Y AXIS) VERNIER THRUSTER ARE PROVIDED IN EACH ARC MODULE TO PROVIDE PRECISE LOW LEVEL PULSING AND ATTITUDE HOLD REQUIREMENTS 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, COMB INSTAB, SHOCK, BLOCKED INJ ORIFICES; HIGH TEMP/LOCALIZED HOT SPOTS/INADEQ COOLING NOZZLE RESTRICTION.

EFFECT(S): ON (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE:
(A) LOSS OF FUNCTION-CURRENTLY LOSS OF SINGLE VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL. (B) DEGRADATION OF INTERFACE FUNCTION-INC CAL GNC & 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 STRUCTURE.

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

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

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

FAILURE MODE: STRUCTURAL FAILURE

CAUSE(S):
- THERMAL CYCLING/STRESS FATIGUE, VIB, CG/MA INSTAB, SHOCK, ALLOTTED ORIFICES, HIGH TEMP/LOCALIZED HCT/SPOTS/INADEQ COOLING NCZLLE RESTRICTION.

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

DISPOSITION & RATIONALE
- (A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY:
  - (A) STRUCTURAL MARGINS (2.0 TO 4.0) MINIMIZE FAILURE EFFECT(S). POSS REDUND MHD IN X AXIS PRIMARY THRUSTER, PAYLOAD ATTITUDE CONTROL & FREE DRIFT MHD. 100 MICRON FILTRATION & HEATERS PROVIDED TO LIMIT CONTAM & PREVENT PROP FREEZING. (B) THRUSTER QUL FOR 500,000 CYCLES, 125,000 SEC BURN TIME, INLET VALVE TETED FOR 500,000 WET CYCLES & 5000 DRY. (C) A VISUAL INSP AND IDENTIFICATION IS PERFORMED AND THE UNIT TAGGED. CONTAMINATION CONTROL PROCESS, CORROS. PROTECTION PROVISIONS, NDE EXAM OF WELDS, RAW MAT'IL (LOT) CERTIFICATION, PARTS PROTECTION, COATING AND PLATING PROCESSES ARE VERIFIED BY INSPECTION. MANUF, INSTALLATION, AND ASSY OPERATIONS ARE VERIFIED BY SHOP TRAVELER, MANDATORY INSP POINTS. THE ABOVE ITEMS AND THE FOLLOWING ITEMS WERE VERIFIED BY AUDIT CONDUCTED 9-2-76. CONTAMINATION CONTROL PLAN, PROPERLY MONITORED HANDLING AND STORAGE ENVIRONMENT, SPECIAL MEASUREMENT STANDARDS AND EQUIP AND MAT'IL AND EQUIP CONFORMANCE TO CONTRACT REQNTS. TURNAROUND - VISUAL INSP 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.

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

2. Attendees

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lonnie Jenkins</td>
<td>NASA/JSC</td>
<td>X 3851</td>
</tr>
<tr>
<td>Dave Latham</td>
<td>Boeing/Reliability</td>
<td>527-0323 (FTS)</td>
</tr>
<tr>
<td>Don Cagle</td>
<td>Boeing Reliability</td>
<td>527-0323 (FTS)</td>
</tr>
<tr>
<td>Herb Saxton</td>
<td>Rockwell Propulsion/RCS</td>
<td>X 4503</td>
</tr>
<tr>
<td>Larry Gladu</td>
<td>Rockwell Systems Engineering</td>
<td>X 1189</td>
</tr>
</tbody>
</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-202112-2: Question 1 change no to yes. Add "failed off" thruster gives first indication.

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

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

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

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

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

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

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

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

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

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

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

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

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

Larry Gladu, RI
System Engineering

Lonnie Jenkins
JSC Propulsion

Dave Latham
JSC Reliability (Boeing)

Don Cagle
JSC Reliability (Boeing)