# INDEPENDENT ORBITER ASSESSMENT

## ASSESSMENT OF THE ELECTRICAL POWER GENERATION/FUEL CELL POWERPLANT SUBSYSTEM FMEA/CIL

20 MARCH 1987

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
HOUSTON DIVISION

SPACE TRANSPORTATION SYSTEM ENGINEERING AND OPERATIONS SUPPORT

WORKING PAPER NO. 1.0-WP-VA86001-24

# INDEPENDENT ORBITER ASSESSMENT ASSESSMENT OF THE ELECTRICAL POWER GENERATION/FUEL CELL POWERPLANT SUBSYSTEM FMEA/CIL

20 March 1987

This Working Paper is Submitted to NASA under
Task Order No. VA86001, Contract NAS 9-17650

PREPARED BY: _____
K.L. Brown
Lead Analyst
Independent Orbiter
Assessment

PREPARED BY: _____
P.J. Bertsch
Lead Analyst
Independent Orbiter
Assessment

APPROVED BY: _____
M.R. Hiott
EPG/FCP Lead
Independent Orbiter
Assessment

APPROVED BY: _____
G.W. Knori
Technical Manager
Independent Orbiter
Assessment

APPROVED BY: _____
W.F. Huning
Deputy Program Manager
STSEOS

CONTENTS

## List of Figures



## List of Tables

# Independent Orbiter Assessment
# Assessment of the Electrical Power Generation/Fuel Cell Powerplant Subsystem FMEA/CIL

## 1.0 EXECUTIVE SUMMARY

The McDonnell Douglas Astronautics Company (MDAC) was selected in June 1986 to perform an Independent Orbiter Assessment (IOA) of the Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL). Direction was given by the STS Orbiter and GFE Projects Office to perform the hardware analysis using the instructions and ground rules defined in NSTS 22206, Instructions for Preparation of FMEA and CIL, 10 October 1986.

The IOA effort first completed an analysis of the Electrical Power Generation/Fuel Cell Powerplant (EPG/FCP) hardware, generating draft failure modes and potential critical items. To preserve independence, this analysis was accomplished without reliance upon the results contained within the NASA FMEA/CIL documentation. The IOA results were then compared to the proposed Post 51-L NASA FMEA/CIL baseline. A resolution of each discrepancy from the comparison was provided through additional analysis as required. This report documents the results of that comparison for the Orbiter EPG/FCP hardware.

The IOA product for the EPG/FCP independent analysis consisted of sixty-two failure mode "worksheets" that resulted in thirty-two potential critical items being identified. A comparison was made of the IOA product to the NASA FMEA/CIL baseline dated 15 December 1986 which consisted of forty-three FMEAs and twenty-three CIL items. The difference in the number of IOA analysis worksheets and NASA FMEAs can be explained by the different levels of analysis detail performed to identify failure modes. The comparison determined if there were any results found by the IOA that were not included in the NASA baseline. The IOA analysis had identified seven failure modes, one of which was a CIL item, for components not covered by the NASA FMEAs. It was recommended that these failure modes be added to the NASA FMEA baseline. After discussions with the NASA subsystem manager on 13 March 1987, the IOA recommended failure modes and criticalities were agreed upon and added to the NASA proposed changes of the FMEA/CIL baseline. Figure 1 presents a comparison of the proposed Post 51-L NASA baseline with the IOA recommended baseline and any issues.

# EPG/FCP ASSESSMENT OVERVIEW

## EPG/FCP ASSESSMENT SUMMARY

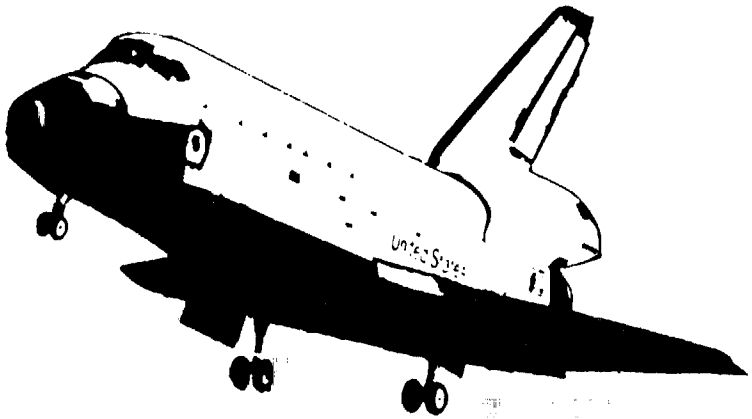
| | ORIGINAL ASSESSEMENT * | | | FINAL RESOLUTION** | | |
|---|---|---|---|---|---|---|
| | IOA | NASA | ISSUES | IOA | NASA | ISSUES |
| FMEA | 50 | 43 | 7 | 50 | 50 | 0 |
| CIL | 24 | 23 | 1 | 24 | 24 | 0 |

### FUEL CELL POWERPLANT SYSTEM

| | IOA | NASA | ISSUES |
|---|---|---|---|
| FMEA | 3 | 3 | 0 |
| CIL | 3 | 3 | 0 |

### POWER SECTION ASSEMBLY

| | IOA | NASA | ISSUES |
|---|---|---|---|
| FMEA | 4 | 3 | 1 |
| CIL | 3 | 3 | 1 |



### REACTANT CONTROL SUBSYSTEM

| | IOA | NASA | ISSUES |
|---|---|---|---|
| FMEA | 13 | 13 | 0 |
| CIL | 6 | 6 | 0 |

### THERMAL CONTROL SUBSYSTEM

| | IOA | NASA | ISSUES |
|---|---|---|---|
| FMEA | 7 | 2 | 5 |
| CIL | 0 | 0 | 0 |

### WATER REMOVAL SUBSYSTEM

| | IOA | NASA | ISSUES |
|---|---|---|---|
| FMEA | 23 | 22 | 1 |
| CIL | 11 | 11 | 0 |

** NASA PROPOSED BASELINE AS OF 15 DECEMBER 1986*

*** FINAL NASA BASELINE AS OF 13 MARCH 1987*

Figure 1 - EPG/FCP FMEA/CIL ASSESSMENT

## 2.0 INTRODUCTION

### 2.1 Purpose

The 51-L Challenger accident prompted the NASA to readdress safety policies, concepts, and rationale being used in the National Space Transportation System (NSTS). The NSTS Office has undertaken the task of reevaluating the FMEA/CIL for the Space Shuttle design. The MDAC is providing an independent assessment of the proposed Post 51-L Orbiter FMEA/CIL for completeness and technical accuracy.

### 2.2 Scope

The scope of the independent FMEA/CIL assessment activity encompasses those Shuttle Orbiter subsystems and GFE hardware identified in the Space Shuttle Independent FMEA/CIL Assessment Contractor Statement of Work. Each subsystem analysis addresses hardware, functions, internal and external interfaces, and operational requirements for all mission phases.

### 2.3 Analysis Approach

The independent analysis approach is a top-down analysis utilizing as-built drawings to breakdown the respective subsystem into components and low-level hardware items. Each hardware item is evaluated for failure mode, effects, and criticality. These data are documented in the respective subsystem analysis report, and are used to assess the proposed Post 51-L NASA and Prime Contractor FMEA/CIL. The IOA analysis approach is summarized in the following Steps 1.0 through 3.0. Step 4.0 summarizes the assessment of the NASA and Prime Contractor FMEA/CIL which is documented in this report.

Step 1.0 Subsystem Familiarization
- 1.1 Define subsystem functions
- 1.2 Define subsystem components
- 1.3 Define subsystem specific ground rules and assumptions

Step 2.0 Define subsystem analysis diagram
- 2.1 Define subsystem
- 2.2 Define major assemblies
- 2.3 Develop detailed subsystem representations

Step 3.0 Failure events definition
- 3.1 Construct matrix of failure modes
- 3.2 Document IOA analysis results

Step 4.0 Compare IOA analysis data to NASA FMEA/CIL
- 4.1 Resolve differences
- 4.2 Review in-house
- 4.3 Document assessment issues
- 4.4 Forward findings to Project Manager

## 2.4 Ground Rules and Assumptions

The ground rules and assumptions used in the IOA are defined in Appendix B.

## 3.0 SUBSYSTEM DESCRIPTION

### 3.1 Design and Function

The EPG/FCP consists of hardware that is required for electrical power generation and Fuel Cell (FC) product water collection and distribution in the Orbiter. Reference Figures 2 and 3. The EPG/FCP consists of the following divisions:

1. The Power Section Assembly (PSA) which is also called Cell Stack Assembly (CSA) combines hydrogen and oxygen through an electrochemical conversion to produce electrical power, water, and heat. Each PSA cell stack consists of cell plates, pressure plates, end cell heater/insulator plates, tie rods, and individual cell voltage harness. Each cell plate is made up of Unitized Electrode Assembly (UEA) and separator plates. The cell stack consists of 96 cell plates grouped electrically into three substacks connected in parallel. The substack contains 32 cell plates connected electrically in series. The PSA also contains a cell performance monitor which provides continuous analog data outputs to the Orbiter. The outputs transmit individual cell performance problems or imminent failures. Reference Figure 4.

2. The Reactant Control Subsystem (RCS) consists of preheaters, coupled reactant regulator, hydrogen pump-separator, condenser, hydrogen/water purge/vent line and oxygen purge/vent line. The RCS heats cryogenic-temperature gaseous reactants (oxygen and hydrogen) from the Power Reactant Storage and Distribution System (PRSDS) to an acceptable temperature for delivery to the coupled reactant regulator. The RCS delivers reactant gases to the PSA on demand and controls the reactant pressure within the cell plates. The RCS provides for purging of inert gases from reactant lines. The RCS circulates hydrogen for water removal from the PSA and also prevents water from entering the PSA. Reference Figure 5.

3. The Thermal Control System (TCS) contains a coolant pump, thermal control valve, coolant accumulator, start/sustaining heater, and condenser. The TCS controls the FCP operating temperatures and electrolyte concentration. The TCS removes waste heat from the PSA and heat from the moist hydrogen recycle flow to condense water vapor. The TCS transfers heat to the inlet reactant gases passing through preheaters and rejects heat to the Orbiter vehicle cooling system. Reference Figure 6.

4. The Water Removal Subsystem (WRS) consists of a condenser, hydrogen pump-separator, water purity sensor, water trap and water discharge line. The WRS removes

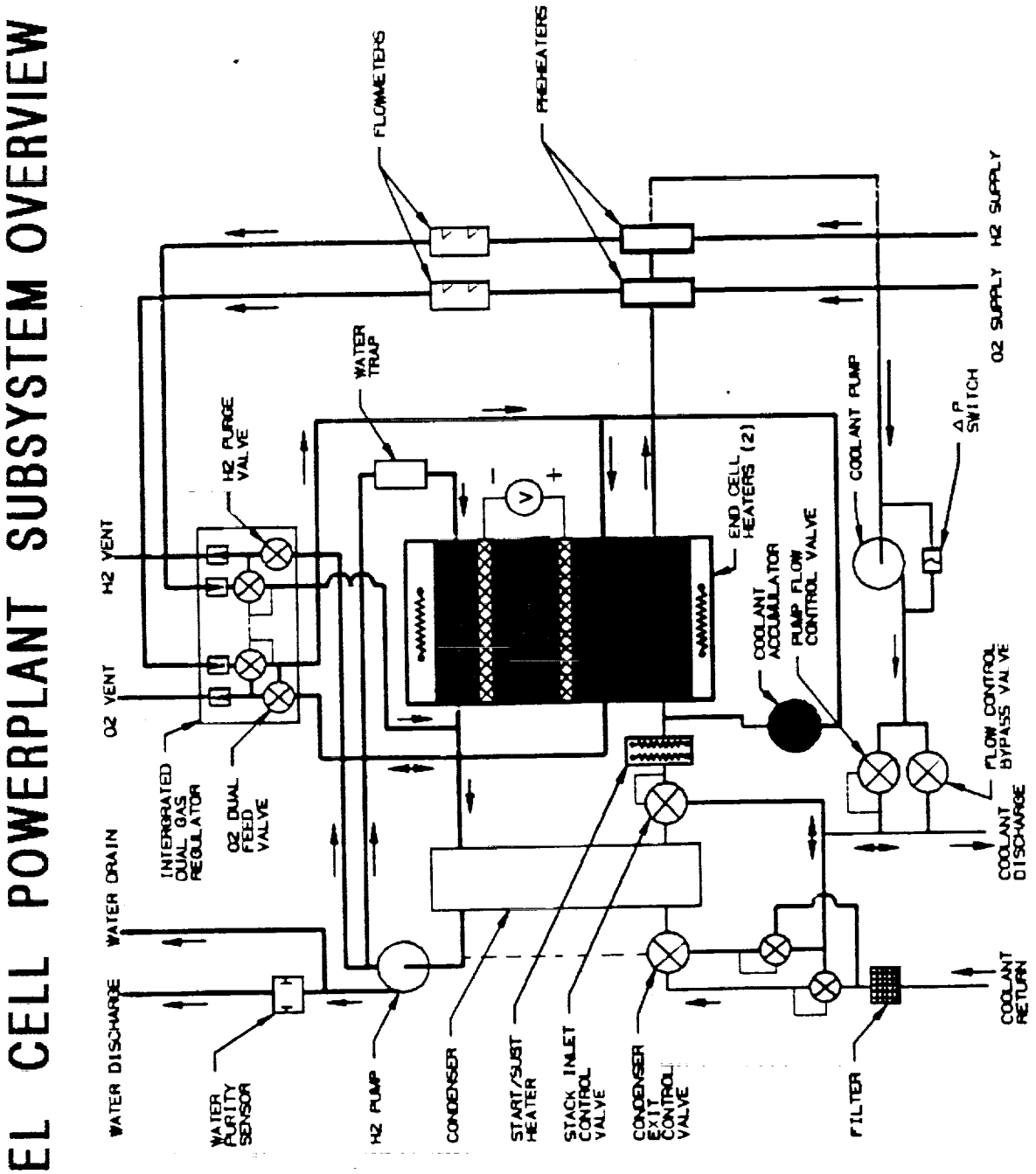



Figure 2 - FUEL CELL POWERPLANT SUBSYSTEM OVERVIEW

# FUEL CELL POWERPLANT SUBSYSTEM OVERVIEW

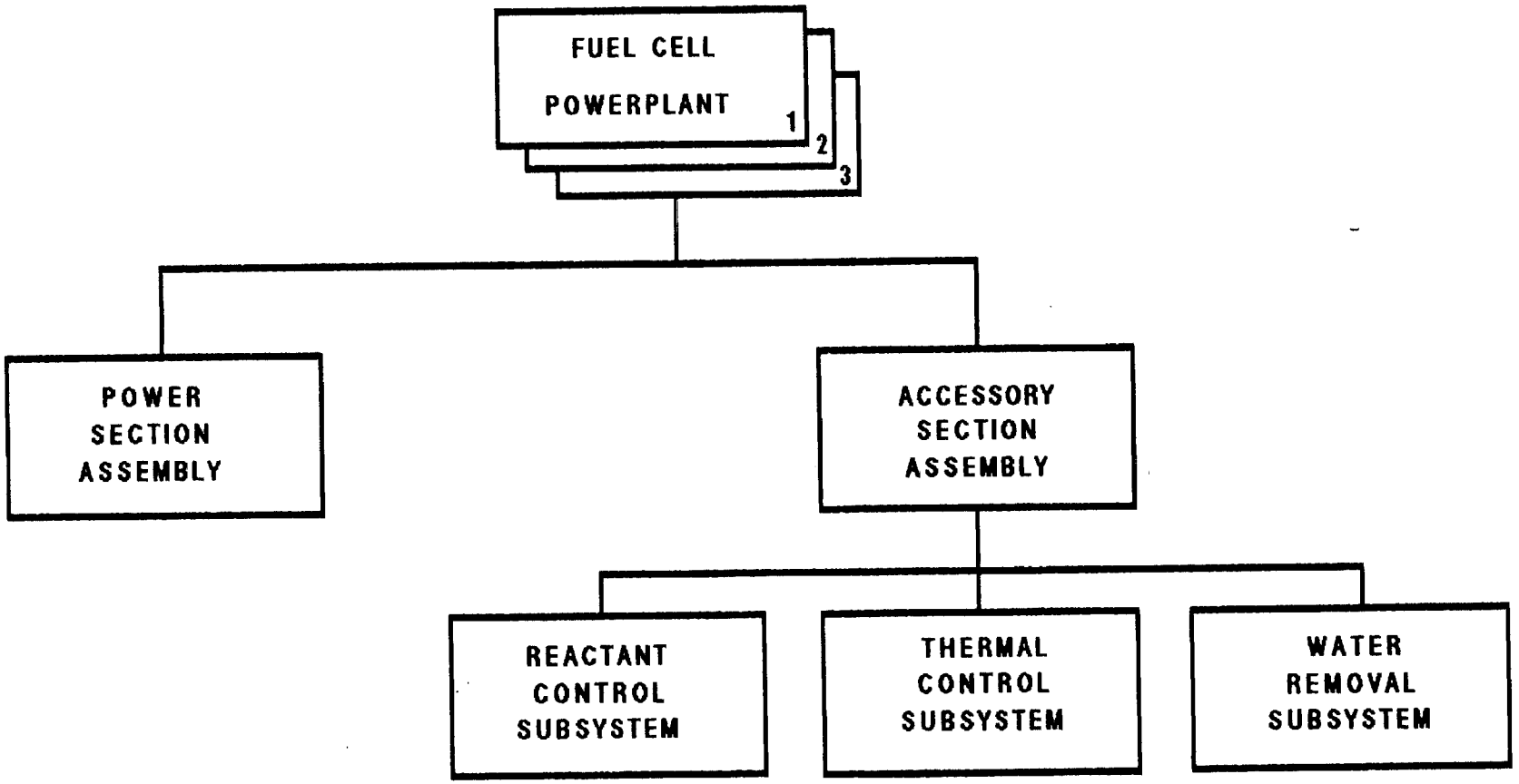



Figure 3 - FCP SUBSYSTEM OVERVIEW

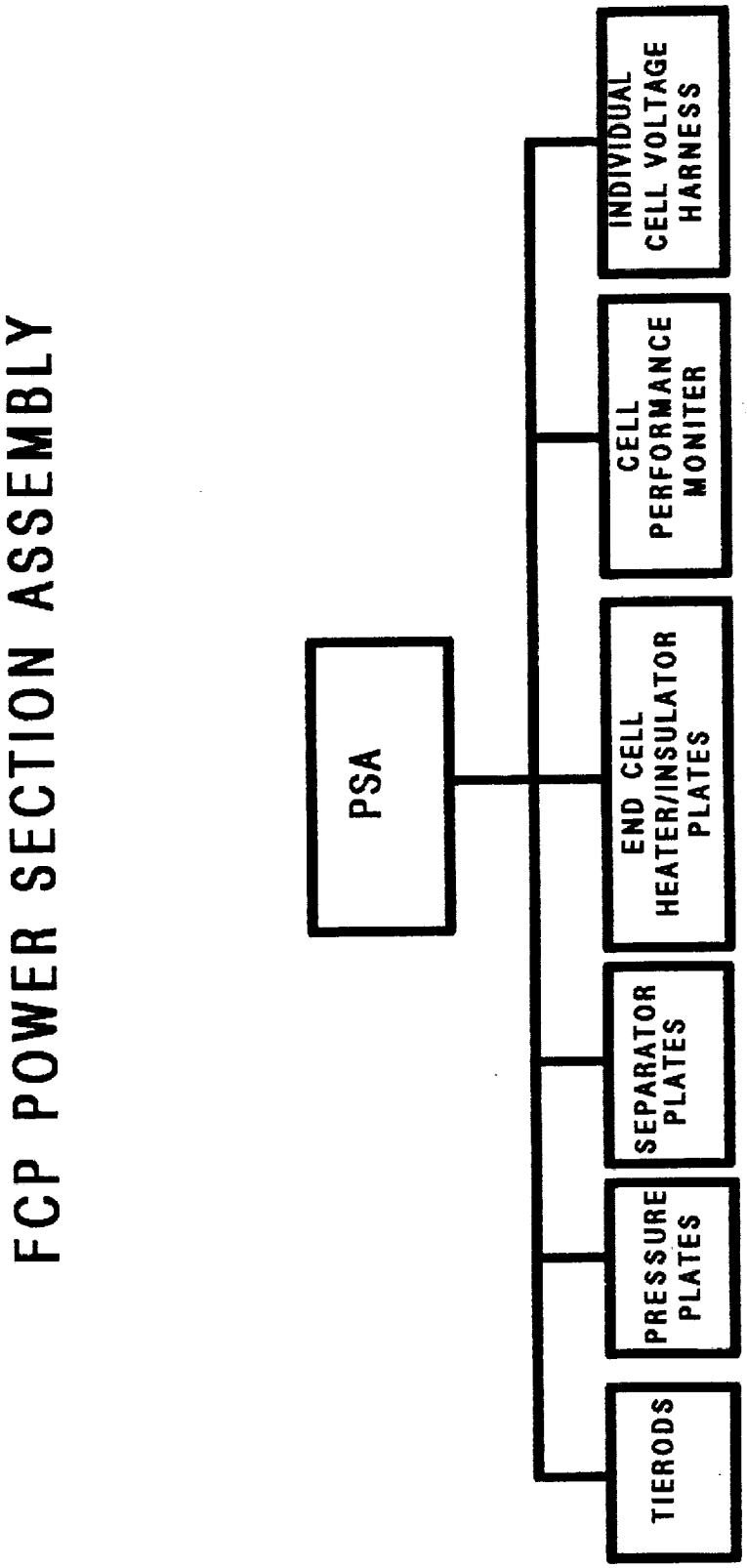



Figure 4 - FCP POWER SECTION ASSEMBLY (PSA)

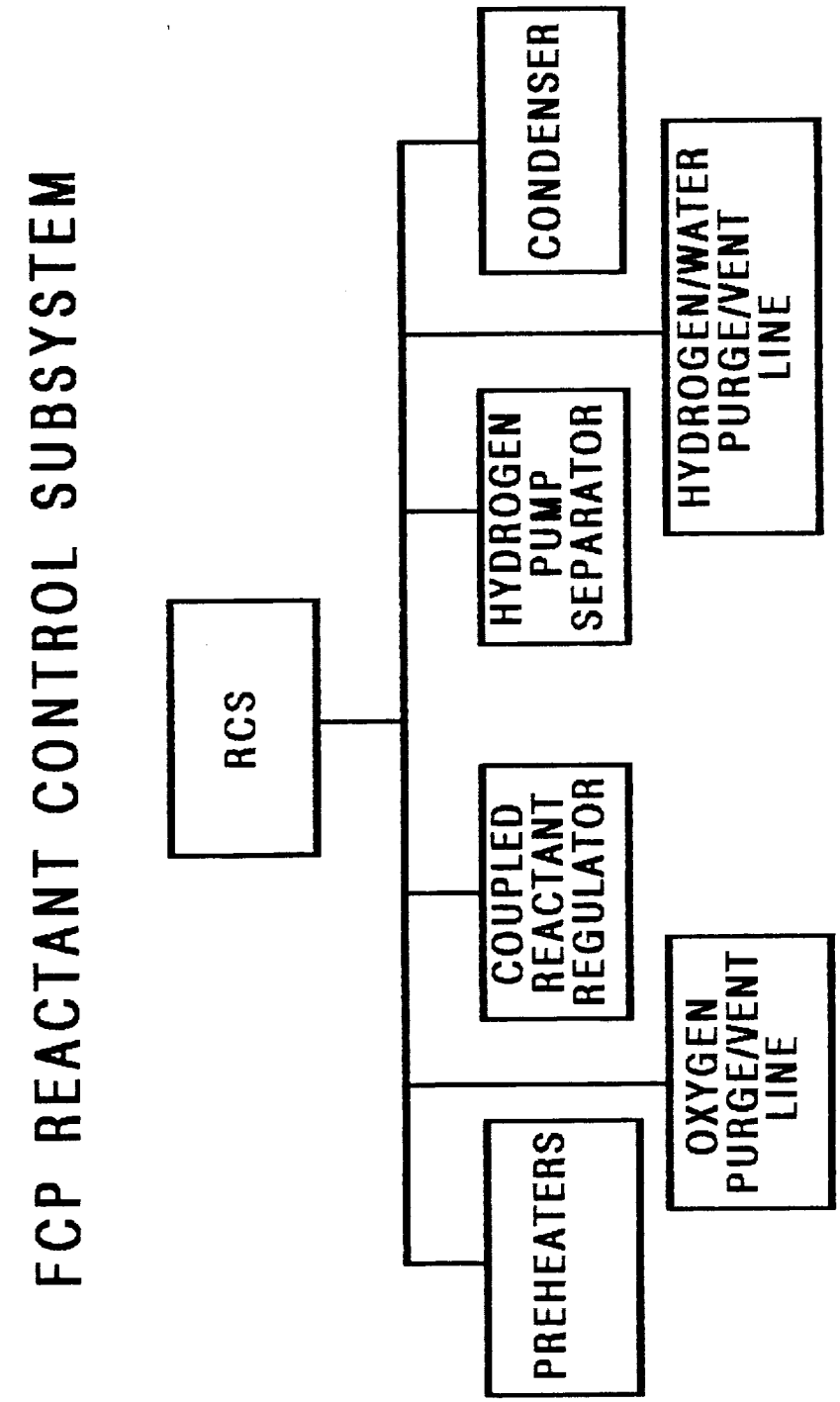



Figure 5 - FCP REACTANT CONTROL SUBSYSTEM (RCS)

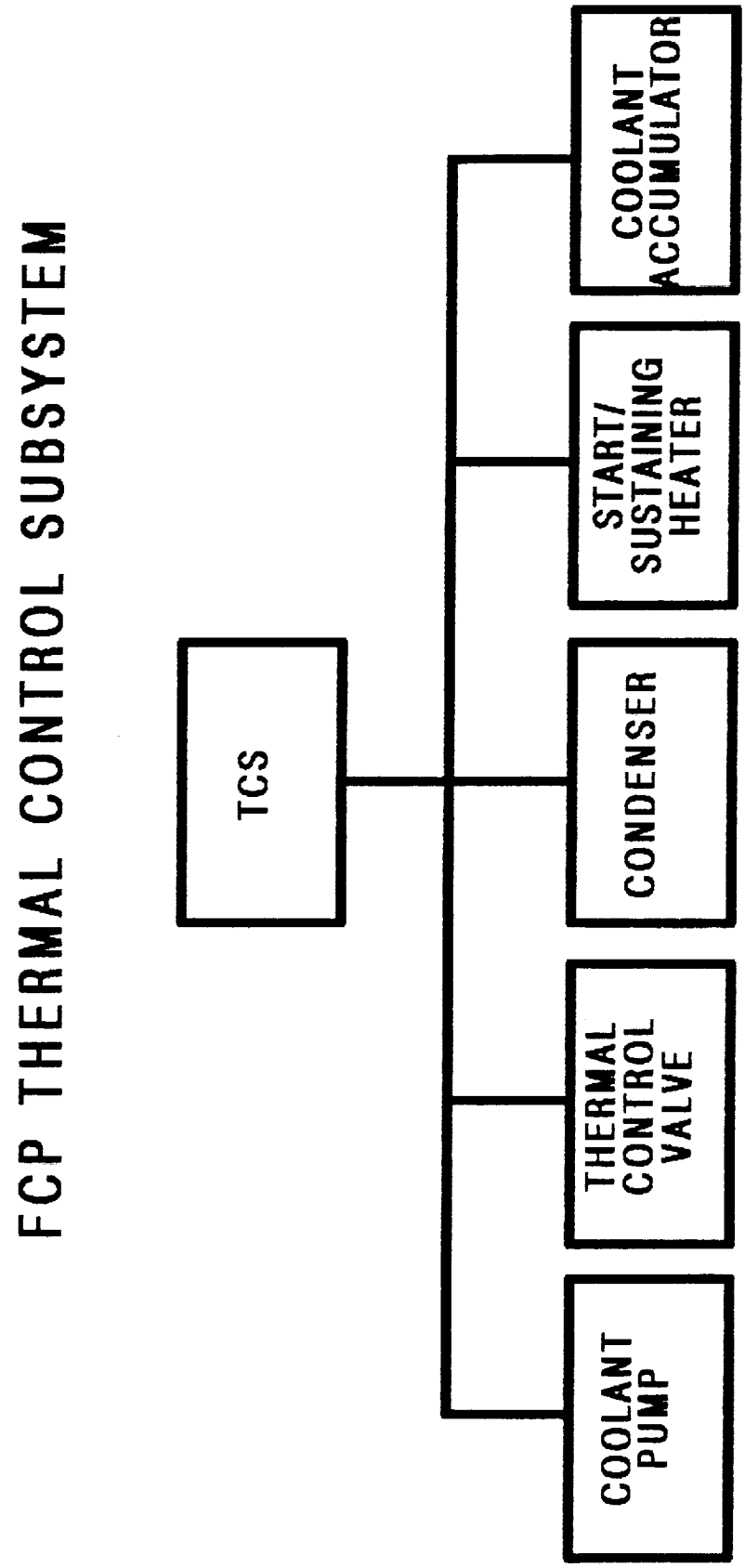



Figure 6 - FCP THERMAL CONTROL SUBSYSTEM (TCS)

water produced in the PSA during the FCP operation. The FCP produces water vapor which is converted to a liquid in the condenser. The hydrogen pump-separator centrifugally separates the water from the hydrogen. The WRS delivers the water to the Orbiter vehicle potable water storage system or to the water relief line. Reference Figure 7.

## 3.2 Interfaces and Locations

The three EPG/FCPs are installed in the midbody of the Orbiter beneath the payload bay liner. Fuel Cell 1 (FC1) is located on the left-hand side of the payload bay. Whereas, FC2 and FC3 are located forward and aft respectively, on the right-hand side of the payload bay. Reference Figure 8. The FCPs PSA receives the hydrogen and oxygen reactants from the Power Reactants Storage and Distribution System (PRSDS). The product water from the PSA is transported to the Environmental Control and Life Support System (ECLSS) for storage. The waste heat produced by the PSA is rejected to the Orbiter vehicle cooling system through the FC40 coolant in the TCS. The FCP receives three-phase ac electrical power from the Orbiter to power the coolant pump, hydrogen pump-separator, and the water purity sensor. The FCP generates dc electrical power which is distributed to the Orbiter electrical power system. Reference Figure 9.

## 3.3 Hierarchy

Figures 2 and 3 illustrate the hierarchy of the EPG and FCP systems, respectively. The FCP subsystems are depicted in Figures 4 through 7.

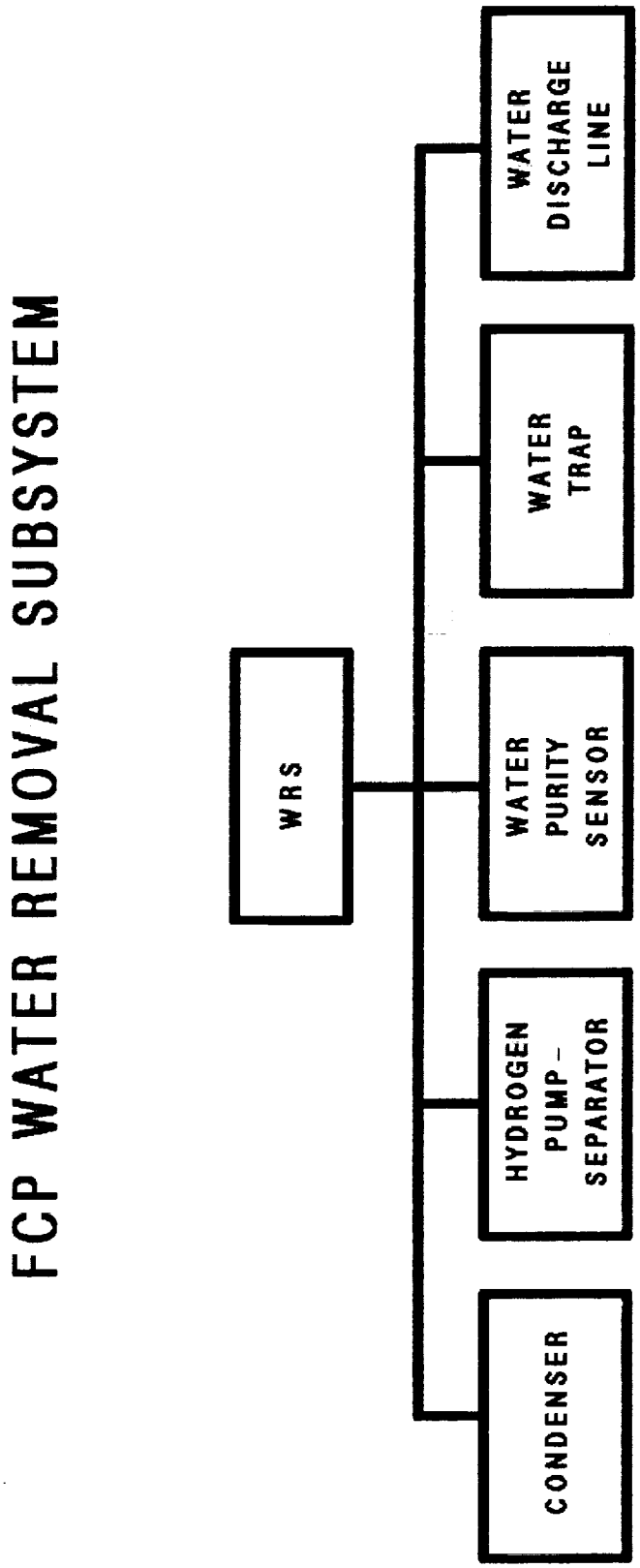
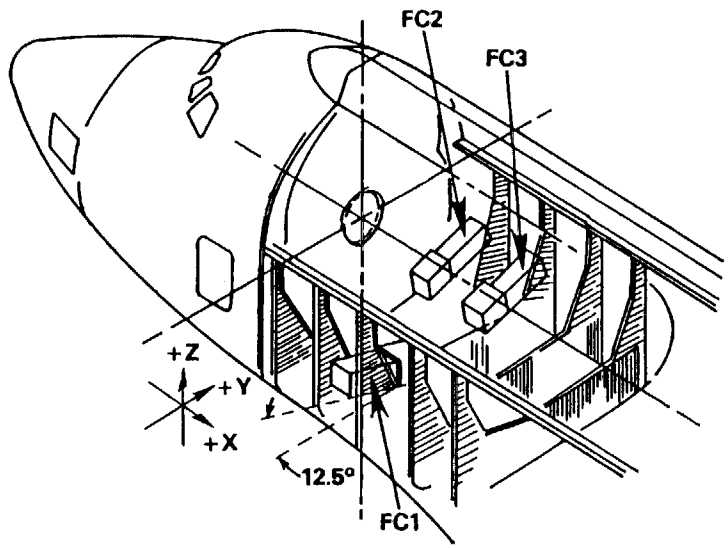



Figure 7 - FCP WATER REMOVAL SUBSYSTEM (WRS)

## FUEL CELL POWERPLANT

# LOCATION IN THE ORBITER VEHICLE




- Three Orbiter FCP's installed in the Orbiter vehicle mid-body beneath the payload liner
  - FC1 installed on left-hand side
  - FC2 installed forward on right-hand side
  - FC3 installed aft on right-hand side

Figure 8 - FCP LOCATION IN THE ORBITER VEHICLE

# FCP LOCATION AND INTERFACES

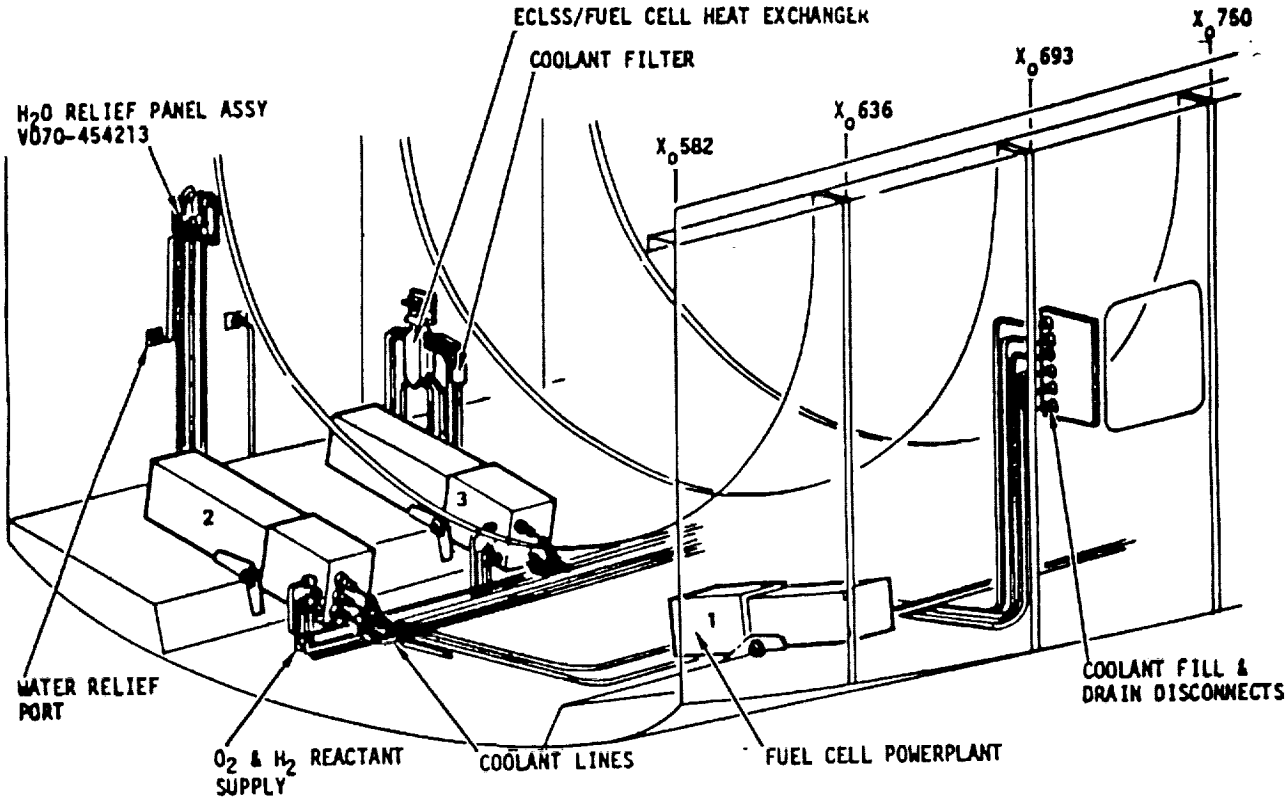



Figure 9 - FCP LOCATION AND INTERFACES

## 4.0 ASSESSMENT RESULTS

The IOA analysis of the EPG/FCP hardware initially generated sixty-two failure mode worksheets and identified thirty-two Potential Critical Items (PCIs) before starting the assessment process. In order to facilitate comparison, five additional failure mode analysis worksheets were generated. These analysis results were compared to the proposed NASA Post 51-L baseline (22 May 1986) of forty-six FMEAs and twenty-two CIL items and to the updated (22 December 1987) version of forty-three FMEAs and twenty-three CIL items. The discrepancy between the number of IOA and NASA FMEAs can be explained by the different approach used by NASA and IOA to group failure modes. Upon completion of the assessment, and after a discussion with the NASA subsystem manager, an agreement between the NASA FMEAs and IOA failure modes was reached. Seven failure modes were generated by the IOA analysis that were not covered by the NASA FMEAs. The IOA recommended the addition of these failure modes to the NASA FMEA baseline. After discussions with the NASA subsystem manager the failure modes and criticalities were accepted and added to the NASA FMEA baseline.

In the analysis report, the FCP was divided into four sections according to hardware and function. However, in the assessment report the FCP has been divided into the four original sections plus a new section called FCP system (FCPS). The FCPS contains hardware from all four of the original sections. This new section was generated in order to facilitate comparison to the NASA FMEAs.

In the following, the unmapped IOA column is the raw number of IOA failure modes. The mapped IOA column is the number of IOA failure modes after they have been mapped into the NASA FMEAs. The issues column is the IOA failure modes that were unable to be mapped onto NASA FMEAs.

| EPG/FCP Sections | IOA Unmapped | IOA Mapped | NASA | ISSUES |
|---|---|---|---|---|
| PSA | 4 | 4 | 3 | 1 |
| RCS | 16 | 13 | 13 | - |
| TCS | 7 | 7 | 2 | 5 |
| WRS | 23 | 22 | 22 | 1 |
| FCPS | 12 | 3 | 3 | - |
| Total | 62 | 50 | 43 | 7 |

Appendix C presents the detailed assessment worksheets for each failure mode identified and assessed. Appendix D highlights the NASA Critical Items and corresponding IOA worksheet ID. Appendix E contains IOA analysis worksheets supplementing previous analysis results reported in Space Transportation System Engineering and Operations Support (STSEOS) Working Paper No. 1.0-WP-VA86001-10, Analysis of the EPG/FCP, 05 December 1986. Appendix F provides a cross reference between the NASA FMEA and corresponding IOA worksheet(s). IOA recommendations are also summarized.

A summary of the quantity of NASA FMEAs assessed, versus the recommended IOA baseline, and any issues identified is presented in Table I.

Table I Summary of IOA FMEA Assessment

| Component | NASA | IOA | Issues |
|---|---|---|---|
| PSA | 3 | 4 | 1 |
| RCS | 13 | 13 | - |
| TCS | 2 | 7 | 5 |
| WRS | 22 | 23 | 1 |
| FCPS | 3 | 3 | - |
| TOTAL | 43 | 50 | 7 |

A summary of the quantity of NASA CIL items assessed, versus the recommended IOA baseline, and any issues identified is presented in Table II.

Table II Summary of IOA CIL Assessment

| Component | NASA | IOA | Issues |
|---|---|---|---|
| PSA | 3 | 4 | 1 |
| RCS | 6 | 6 | - |
| TCS | - | - | - |
| WRS | 11 | 11 | - |
| FCPS | 3 | 3 | - |
| TOTAL | 23 | 24 | 1 |

Table III presents a summary of the IOA recommended failure criticalities for the Post 51-L FMEA baseline. Further discussion of each of these subdivisions and the applicable failure modes is provided in subsequent paragraphs.

TABLE III Summary of IOA Recommended Failure Criticalities

| Criticality: | 1/1 | 2/1R | 2/2 | 3/1R | 3/2R | 3/3 | TOTAL |
|---|---|---|---|---|---|---|---|
| PSA | 1 | 3 | - | - | - | - | 4 |
| RCS | - | 6 | - | 3 | - | 4 | 13 |
| TCS | - | - | - | - | - | 7 | 7 |
| WRS | 1 | 7 | 2 | 5 | 1 | 7 | 23 |
| FCPS | 1 | 2 | - | - | - | - | 3 |
| TOTAL | 3 | 18 | 2 | 8 | 1 | 18 | 50 |

Of the failure modes analyzed, twenty-four were determined to be critical items. A summary of the IOA recommended critical items is presented in Table IV.

TABLE IV Summary of IOA Recommended Critical Items

| Criticality: | 1/1 | 2/1R | 2/2 | 3/1R | 3/2R | 3/3 | TOTAL |
|---|---|---|---|---|---|---|---|
| PSA | 1 | 3 | - | - | - | - | 4 |
| RCS | - | 6 | - | - | - | - | 6 |
| TCS | - | - | - | - | - | - | - |
| WRS | 1 | 7 | 2 | - | 1 | - | 11 |
| FCPS | 1 | 2 | - | - | - | - | 3 |
| TOTAL | 3 | 17 | 2 | - | 1 | - | 24 |

The scheme for assigning IOA assessment (Appendix C) and analysis (Appendix E) worksheet numbers is shown in Table V.

Table V IOA Worksheet Numbers

| Component | IOA ID Number |
|---|---|
| PSA | FCP-101, FCP-105, FCP-107, FCP-109, FCP-110 |
| RCS | FCP-111 TO FCP-116, FCP-118 TO FCP-127 |
| TCS | FCP-128, FCP-129, FCP-134 TO FCP-137, FCP-166X TO FCP-167X |
| WRS | FCP-144 TO FCP-165, FCP-168X TO FCP-170X |
| FCPS | FCP-104, FCP-106, FCP-108, FCP-117, FCP-130 TO FCP-133, FCP-138 TO FCP-143 |

## 4.1 PSA Assessment Results

The first assessment between the IOA failure modes and the Post 51-L NASA FMEA baseline produced two issues. The issues were failure modes on the separator plates (MDAC ID 109) and cell performance monitor (MDAC ID 110) that had no corresponding NASA FMEAs. The new NASA baseline (15 December 1986) did not include any new FMEAs to resolve the existing issues.

A meeting with the NASA subsystem manager was held on 5 January 1987 and all PSA issues were discussed. The IOA agreed with the NASA subsystem manager that reactant blockage of the separator plates was not a credible failure and decided to resolve the issue by canceling analysis worksheet MDAC ID 109. The NASA subsystem manager agreed with the IOA analysis that the fail on mode of the self-test output of the cell performance monitor was a viable failure mode. This failure mode (MDAC ID 110) was submitted to Rockwell for addition to the NASA FMEA/CIL baseline on 16 March 1987 as a criticality 2/1R.

## 4.2 RCS Assessment Results

The IOA analysis generated seventeen failure modes from the RCS components. The initial assessment between the RCS failure modes and the Post 51-L NASA FMEA/CIL baseline produced four issues. The four issues were the failure modes on the integrated dual-gas regulator (MDAC ID 112, 114 and 116) and the hydrogen/oxygen (H2/O2) flowmeters (MDAC ID 127) that had no corresponding NASA FMEAs. In the course of reviewing the updated FMEA/CIL list (15 December 1986), MDAC ID 112 and 114, for hydrogen and oxygen overpressurization respectively, were compared to NASA FMEA 04-1A-0101-8. The new version of FMEA 04-1A-0101-8 included updated information to allow comparison and resolve the two issues. The new NASA baseline did not include any new FMEAs to resolve the remaining two issues. The IOA agreed with the NASA subsystem manager that the effect of a purge failure of the integrated dual-gas regulator was covered by EPD&C/FCP NASA FMEA 05-6M5-2088-1, and EPG/FCP FMEAs 04-1A-0104-1 and 04-1A-0105-1. The IOA also agreed with the NASA subsystem manager that the effect of erroneous output from the H2/O2 flowmeters was covered by EPD&C/FCP NASA FMEA 05-6MA-2012-1. The IOA decided to resolve the previous two issues by canceling failure modes MDAC ID 109 and 127. The assessment also produced the cancellation of two RCS failure modes, MDAC ID 124 and 126. The IOA agreed with NASA's results that a heater could not fail "on". One failure mode was transferred to the FCPS section.

## 4.3 TCS Assessment Results

During the initial assessment, eleven TCS failure modes were compared to the Post 51-L NASA FMEA/CIL baseline which produced seven issues. The seven issues were failure modes on the stack temperature sensors (MDAC ID 134-137), coolant-pressure switch (MDAC ID 133), start-up heater (MDAC ID 128) and the thermal-control valve (MDAC ID 141). The updated version (15 December 1986) of FMEA 04-1A-0101-2 included new information to allow comparison and resolution of the MDAC ID 141 issue, erroneous output of the thermal-control valve. The IOA recommended that failure modes for high and low output of the stack inlet and outlet temperature sensors and the fail open failure of the coolant pressure switch be added to the baseline of the NASA FMEA. These five failure modes were agreed upon by the NASA subsystem manager and were incorporated into the NASA FMEA baseline 16 March 1987. The IOA agreed with the NASA subsystem manager that the effect of a failed "off" start-up heater was covered by NASA FMEA 05-6MA-2035-4.

During the IOA analysis process, failure modes were not generated for two failures of the coolant return temperature sensor. Two NASA FMEAs were written on the coolant return temperature sensor for erroneous output and open or shorted sensor failures. During the IOA assessment, two analysis worksheets were developed to cover the two failure modes. The IOA analysis results agreed with the NASA FMEA findings.

The assessment also produced the cancellation of the failure mode MDAC ID 129. The IOA agreed with NASA's results that a heater could not fail "on". Failure modes MDAC 130, 131 and 132 were transferred to the FCPS section.

## 4.4 WRS Assessment Results

The IOA analysis produced twenty-six failure modes from the WRS components. The initial assessment between the WRS failure modes and the Post 51-L NASA FMEA/CIL baseline produced seven issues. The assessment also produced the cancellation of four WRS failure modes, MDAC ID 146, 156, 161 and 162. The IOA agreed with NASA's results that a heater could not fail "on". Four other failure modes were transferred to the FCPS section.

The IOA agreed with NASA FMEAs 04-1A-0138-1 and 04-1A-0106-2 which correspond with the IOA failure modes MDAC ID 155 and 163. The IOA analysis had not considered the water relief heaters as standby redundant systems. The NASA results had considered the WRS as standby redundant and had screen B as NA. The updated version (15 December 1986) of FMEA 04-1A-0101-3 included information to allow resolution of issues with MDAC ID 139, restricted flow of the water separator pump. This failure mode was transferred to the FCPS section. The NASA subsystem manager agreed with the IOA analysis (MDAC ID 144) that erroneous output of the pH sensor was a viable failure. This failure mode was recommended to Rockwell for addition to the NASA FMEA/CIL

baseline. It was officially added to the baseline in February 1987.

The discussion with the NASA subsystem manager resulted in a decision to change the MDAC ID 149, 152, and 153 analysis results to agree with the NASA FMEAs 04-1A-0122-3, 04-1A-0119-3, and 04-1A-0119-2 respectively.

During the IOA analysis process, failure modes were not generated for two failures of the FCP product water-line. These were failures of the heater and a gross external leakage failure of the FCP water lines, fittings and components. The two heater failures were inadvertently turned on (FMEA 04-1A-0144-3) and turned on during FCP shutdown (FMEA 04-1A-0144-4). During the IOA assessment, two failure modes (MDAC ID 168X and 169X) were developed to cover the two heater failure modes. The updated FCP FMEA/CIL list did not include FMEA 04-1A-0144-3 which had been deleted. The NASA subsystem manager also agreed to delete FMEA 04-1A-0144-4 in agreement with the IOA analysis. Another failure mode (MDAC ID 170X) was generated for the gross external leakage failure of the water lines, fittings, and components. The IOA agreed with NASA's criticality of 1/1 for FMEA 04-1A-0137-1, but recommended an analysis be performed to validate that the failure is credible.

## 4.5 FCPS Assessment Results

Twelve failure modes were transferred to the FCPS section from the other four sections. The initial assessment between the FCPS worksheets and Post 51-L NASA FMEA/CIL baseline produced no issue.

## 5.0 REFERENCES

Reference documentation available from NASA and Rockwell was used in the analysis. The documentation used included the following:


1. JSC-12820, PCN-1 STS Operational Flight Rules, 12-16-85

2. V45 File III, Operations and Maintenance Requirements and Specification Document - Orbiter OMRSD - Electrical Power Generation/Power Reactant Storage and Distribution, 5-29-86

3. TD268, Shuttle Flight Operations Manual, Vol 2, EPS, 11-84

4. JSC-12830, EGIL Console Procedure Handbook, Rev. C, 10-83

5. NSTS 22206, Instructions for Preparation of Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL), 10 October 1986

6. 100-2G, Rockwell International Reliability Desk Instruction Flight Hardware FMEA and CIL, 1-31-84

7. Orbiter Fuel Cell Powerplant Review and Training Course, International Fuel Cells (IFC), 5-86

8. JSC-18691, Flight Data File Malfunction Procedures, Rev. B, 10-10-85

9. JSC-18540, Flight Data File Entry Checklist, Rev. B, 3-17-86

10. JSC-18547, Flight Data File Ascent checklist, Rev. B, 5-28-85

11. JSC-18541, Flight Data File Orbit Operations Checklist, Rev. B, 5-22-85

12. M4001002, JSC Orbiter Full Problem Record Report, EPG Subsystem, 7-22-86.

13. VS70-945099, Integrated System Schematic Electrical Power System (EPS) Orbiter Vehicles -099, 103, 104, 7-18-85

14. VS70-945102, Integrated System Schematic Orbiter OV-102 EPS, 9-19-84

15. Magnesium Plate Status Review and Proposed Investigations to Improve Reliability, IFC, 7-15-86

16. EPA Ban on Future Use of Asbestos Creates Serious Orbiter Fuel Cell Availability Problem, IFC, 7-16-86

17. Orbiter Fuel Cell Powerplant Improved Coolant Accumulator, IFC, 7-15-86

18. Orbiter Fuel Cell Powerplant Improved Cell Performance Monitoring, IFC, 7-15-86

19. Review of IFC Product Improvement Recommendations and Problems and Concerns, (Orbiter Operational Program), IFC, 7-16-86

20. N2 Diagnostic Test Data Review (Comparison of CPM Data to Single Cell Data), IFC, 7-16-86

21. Program Review Orbiter Operational Improvement Program, IFC, 7-15-86

22. Operational Program Powerplant(s) Failure Review, IFC, 7-15-86

23. Rockwell Specifications for Fuel Cells

| | |
|---|---|
| a. MC 464-0115 | Fuel Cell |
| b. ME 363-0042-0003 | Water Nozzle & Heater Assembly |
| c. MC 284-0431-0001 | Water Pressure Relief Valve |
| d. ME 284-0475-0001 | Water Supply Check Valve |
| e. MC 363-0037-0001 | Strip Heater EPG |
| f. MC 363-0038-0014 | Line Heater H20 Relief Vent Line |
| g. MC 363-0038-0001-0004 | Line Heater Oxygen Purge Line |
| h. MC 363-0038-0003-0004 | Line Heater Hydrogen Purge Line |
| i. MC 363-0037-0002 | Strip Heater Hydrogen Purge Port |
| j. MC 363-0038-0006 | Line Heater, FCP Product Water Line |
| k. ME 449-0160-0003 | Temperature Sensors for Product Water Line, Water Relief Valve, Coolant Return, Oxygen Vent Line, Hydrogen Vent Line and Water Relief Line |

24. Rockwell International Drawings

| | |
|---|---|
| a. VS70-450-102 | Orbiter Fuel Cell Control Subsystem |
| b. VS70-450-109 | Orbiter Fuel Cell Control Subsystem |
| c. VS70-450-112 | Orbiter Fuel Cell Control Subsystem |
| d. VS70-450-119 | Orbiter Fuel Cell Control Subsystem |
| e. V070-454-765 | Panel - Water Relief Assembly |

25. Pratt and Whitney Aircraft Drawings

a. 752153 Plate - Fuel Electrode
b. 752154 Plate - Oxidizer Electrode
c. 752158 Plate - Oxidizer Electrode
d. 754930 Electrode - Fuel Cell Assembly
e. 755422 Plate - Fuel Electrode Terminal
f. 768429 Heater Coolant Start-up
g. 769016 Regulator, Reactant
h. 769288 Accumulator and Strap Coolant Assembly
i. 769546 Filter Coolant (Ref Drawing 14336 501 Change B)
j. 770488 Transducer - Oxidizer Flow
k. 770489-91 Transducer - Fuel Flow
l. 770598-99 Components Assembly - Fuel Cell
m. 782900 Power Plant Assembly - Fuel Cell
n. 787900 Power Plant Assembly - Fuel Cell
o. 788400 Power Plant Assembly - Fuel Cell
p. 796798 Components Assembly - Fuel Cell
q. 800634 Cable - Fuel Cell Output Assembly
r. 800635 Wiring Harness, Fuel Cell Input
s. 800636 Wiring Harness, Fuel Cell
t. 822998 Cable Routing - Component Assembly
u. 823098 Component Assembly - Fuel Cell
v. 823100 Power Plant Assembly - Fuel Cell

26. MDAC IOA EPG/FCP Working Paper No. 1.0-WP-VA86001-10, 12-05-86

27. NASA-JSC FMEAs and CILs, Pre 51-L

28. NASA-JSC FMEA and CIL Review Comments for the EPG/FCP Post 51-L, 5-1986

29. NASA-JSC FMEAs and CIL, 12-15-86

# APPENDIX A
# ACRONYMS

| | | |
|---|---|---|
| AOA | - | Abort-once-Around |
| ATO | - | Abort-to-Orbit |
| CIL | - | Critical Items List |
| CPM | - | Cell Performance Monitor |
| CRIT | - | Criticality |
| CSA | - | Cell Stack Assembly |
| C&W | - | Caution and Warning System |
| ECLSS | - | Environmental Control and Life Support System |
| EPA | - | Environmental Protection Agency |
| EPG | - | Electrical Power Generation |
| EPS | - | Electrical Power System |
| F | - | Functional |
| FC | - | Fuel Cell |
| FCP | - | Fuel Cell Powerplant |
| FCPS | - | Fuel Cell Powerplant System |
| FMEA | - | Failure Mode and Effect Analysis |
| FSSR | - | Flight System Software Requirement |
| GFE | - | Government Furnished Equipment |
| HW | - | Hardware |
| IFC | - | International Fuel Cells |
| IOA | - | Independent Orbiter Assessment |
| MDAC | - | McDonnell Douglas Astronautics Company |
| NASA | - | National Aeronautics and Space Administration |
| NSTS | - | National Space Transportation System |
| NA | - | Not Applicable |
| OMRSD | - | Operations and Maintenance Requirements and Specification Document |
| PCI | - | Potential Critical Item |
| PRCB | - | Program Requirements Control Board |
| PRSDS | - | Power Reactant Storage & Distribution System |
| PSA | - | Power Section Assembly |
| RCS | - | Reactant Control Subsystem |
| RI | - | Rockwell International |
| RTLS | - | Return to Launch Site |
| SM | - | System Management |
| STS | - | Space Transportation System |
| TAL | - | Transatlantic Abort Landing |
| TCS | - | Thermal Control Subsystem |
| UEA | - | Unitized Electrode Assembly |
| WRS | - | Water Removal Subsystem |

# APPENDIX B

## DEFINITIONS, GROUND RULES, AND ASSUMPTIONS

B.1 Definitions
B.2 Project Level Ground Rules and Assumptions
B.3 Subsystem-Specific Ground Rules and Assumptions

# APPENDIX B
# DEFINITIONS, GROUND RULES, AND ASSUMPTIONS

## B.1 Definitions

Definitions contained in NSTS 22206, Instructions For Preparation of FMEA/CIL, 10 October 1986, were used with the following amplifications and additions.

INTACT ABORT DEFINITIONS:

RTLS - begins at transition to OPS 6 and ends at transition to OPS 9, post-flight

TAL - begins at declaration of the abort and ends at transition to OPS 9, post-flight

AOA - begins at declaration of the abort and ends at transition to OPS 9, post-flight

ATO - begins at declaration of the abort and ends at transition to OPS 9, post-flight

CREDIBLE (CAUSE) - an event that can be predicted or expected in anticipated operational environmental conditions. Excludes an event where multiple failures must first occur to result in environmental extremes

CONTINGENCY CREW PROCEDURES - procedures that are utilized beyond the standard malfunction procedures, pocket checklists, and cue cards

EARLY MISSION TERMINATION - termination of onorbit phase prior to planned end of mission

EFFECTS/RATIONALE - description of the case which generated the highest criticality

HIGHEST CRITICALITY - the highest functional criticality determined in the phase-by-phase analysis

MAJOR MODE (MM) - major sub-mode of software operational sequence (OPS)

MC - Memory Configuration of Primary Avionics Software System (PASS)

MISSION - assigned performance of a specific Orbiter flight with payload/objective accomplishments including orbit phasing and altitude (excludes secondary payloads such as GAS cans, middeck P/L, etc.)

MULTIPLE ORDER FAILURE - describes the failure due to a single cause or event of all units which perform a necessary (critical) function

OFF-NOMINAL CREW PROCEDURES - procedures that are utilized beyond the standard malfunction procedures, pocket checklists, and cue cards

OPS - software operational sequence

PRIMARY MISSION OBJECTIVES - worst case primary mission objectives are equal to mission objectives

PHASE DEFINITIONS:

PRELAUNCH PHASE - begins at launch count-down Orbiter power-up and ends at moding to OPS Major Mode 102 (liftoff)

LIFTOFF MISSION PHASE - begins at SRB ignition (MM 102) and ends at transition out of OPS 1 (Synonymous with ASCENT)

ONORBIT PHASE - begins at transition to OPS 2 or OPS 8 and ends at transition out of OPS 2 or OPS 8

DEORBIT PHASE - begins at transition to OPS Major Mode 301 and ends at first main landing gear touchdown

LANDING/SAFING PHASE - begins at first main gear touchdown and ends with the completion of post-landing safing operations

## B.2 IOA Project Level Ground Rules and Assumptions

The philosophy embodied in NSTS 22206, Instructions for Preparation of FMEA/CIL, 10 October 1986, was employed with the following amplifications and additions.

1. The operational flight software is an accurate implementation of the Flight System Software Requirements (FSSRs).

   RATIONALE: Software verification is out-of-scope of this task.

2. After liftoff, any parameter which is monitored by system management (SM) or which drives any part of the Caution and Warning System (C&W) will support passage of Redundancy Screen B for its corresponding hardware item.

   RATIONALE: Analysis of on-board parameter availability and/or the actual monitoring by the crew is beyond the scope of this task.

3. Any data employed with flight software is assumed to be functional for the specific vehicle and specific mission being flown.

   RATIONALE: Mission data verification is out-of-scope of this task.

4. All hardware (including firmware) is manufactured and assembled to the design specifications/drawings.

   RATIONALE: Acceptance and verification testing is designed to detect and identify problems before the item is approved for use.

5. All Flight Data File crew procedures will be assumed performed as written, and will not include human error in their performance.

   RATIONALE: Failures caused by human operational error are out-of-scope of this task.

6. All hardware analyses will, as a minimum, be performed at the level of analysis existent within NASA/Prime Contractor Orbiter FMEA/CILs, and will be permitted to go to greater hardware detail levels but not lesser.

   RATIONALE: Comparison of IOA analysis results with other analyses requires that both analyses be performed to a comparable level of detail.

7. Verification that a telemetry parameter is actually monitored during AOS by ground-based personnel is not required.

   RATIONALE: Analysis of mission-dependent telemetry availability and/or the actual monitoring of applicable data by ground-based personnel is beyond the scope of this task.

8. The determination of criticalities per phase is based on the worst case effect of a failure for the phase being analyzed. The failure can occur in the phase being analyzed or in any previous phase, whichever produces the worst case effects for the phase of interest.

   RATIONALE: Assigning phase criticalities ensures a thorough and complete analysis.

9. Analysis of wire harnesses, cables, and electrical connectors to determine if FMEAs are warranted will not be performed nor FMEAs assessed.

   RATIONALE: Analysis was substantially complete prior to NSTS 22206 ground rule redirection.

10. Analysis of welds or brazed joints that cannot be inspected will not be performed nor FMEAs assessed.

    RATIONALE: Analysis was substantially complete prior to NSTS 22206 ground rule redirection.

11. Emergency system or hardware will include burst discs and will exclude the EMU Secondary Oxygen Pack (SOP), pressure relief valves and the landing gear pyrotechnics.

    RATIONALE: Clarify definition of emergency systems to ensure consistency throughout IOA project.

## B.3 EPG-Specific Ground Rules and Assumptions

1. Component age life will not be considered in the analysis.

   RATIONALE: Component age life analysis is beyond the scope of this task.

2. Cryogenic system pressure to the fuel cell will be assumed lost if unable to maintain minimum supply conditions of 100 PSI for H2 and/or O2 tanks.

   RATIONALE: Minimum requirements definition. Flight rule definition.

3. An O2 cryo tank will be assumed lost if both of its heaters fail to function (i.e., neither heater will function with the delta current sensors enabled).

   RATIONALE: Systems failure definition. Flight rule definition.

4. An H2 cryo tank will be assumed lost if neither of its heaters will function.

   RATIONALE: Systems failure definition. Flight rule definition.

5. An impending loss of all cryo O2 or all cryo H2 tanks will be cause to exercise the highest-priority abort mode the loss/leak will allow.

   RATIONALE: Flight rule definition.

6. Continue nominal ascent if 2/3/4 O2 (H2) tanks fail when flying 3/4/5.

   Enter next PLS daily go/no-go if two O2 (H2) tanks fail during lift-off and on-orbit.

   RATIONALE: Flight rules go/no-go criteria.

7. Ascent abort decision will be needed for any EPG/PRSD/FCP problems that will not support four hours on-orbit plus entry time.

   RATIONALE: Flight operations rules.

8. A fuel cell will be considered failed if the following conditions exist.

   a. An abnormal or unexplained voltage versus current performance loss of $\geq$0.5 volts for a single FC based on predicted performance data.

   b. Coolant pump or H2 pump/H2O separator is lost.

   c. Fuel cell stack-coolant temperature >255 degrees (242.5) degrees F or <175 degrees (182.5) degrees F.

   d. Coolant pressure >75 (71.4) PSIA and increasing.

   e. Fuel cell unable to discharge water to the ECLSS H2O storage tanks or overboard via the fuel cell H2O relief system.

   f. Local KOH concentration >48 percent (45 percent) dry or <24 percent (29 percent) wet as indicated by fuel cell stack-coolant temperature, condenser exit temperature, and current relationship.

   g. Fuel cell reactant valve fails closed.

   h. Cannot be connected to a main bus.

   i. Fuel cell H2O pH high confirmed.

   j. Fuel cell O2 reaction chambers cannot be purged.

   k. Fuel cell end-cell heater failing on.

   l. Fuel cell substack delta volts >150 millivolts and increasing.

   RATIONALE: Systems failure definition.

9. Loss of one fuel cell is considered cause for priority flight and abort decision.

   RATIONALE: Mission flight rule definition.

10. Loss of two fuel cells is considered cause for abort mission.

    RATIONALE: Contingency action summary. Flight Rule definition.

11. Loss of three fuel cells is considered loss of life/vehicle in all mission phases.

    RATIONALE: Flight rule definition.

12. Loss of two fuel cells in the first stage of ascent is considered loss of life/vehicle.

    RATIONALE: SRB loads are too high for one fuel cell to support. Voltage may go <25v which will shut down the GPCs.

13. Although the ECLSS product-water storage is a separate system from EPG, it will be considered as a failable redundant product-water relief line for purposes of the EPG functional criticality scenarios.

    RATIONALE: This assumption violates general ground rule 2.3.2.d but is essential for evaluating failures associated with the water relief line.

14. Filter failure will only be considered in the case of total flow blockage. Cases of improper/insufficient filtering will not be considered except where obvious.

    RATIONALE: The effect of 'poor' filter performance on downstream components is beyond the scope of our efforts.

15. The start/sustaining heater on the left-hand FCP (FCP #1) is assumed to be disconnected. Thus, this FCP cannot be maintained operational at no-load, and will be considered shutdown if the load cannot be maintained at greater than 2 KW.

    RATIONALE: Load needed to maintain operating temperature. Right hand FCP uses sustaining heater to maintain temperature at no-load.

16. For all "failed open" failure modes for valves which are normally open, redundancy screen B will be assumed failed.

    RATIONALE: The failure is not detectable until the valve is required to be closed.

17. Five 02 and H2 tanks are being used as the baseline configuration under study.

    RATIONALE: The configuration for all redundant components is being considered for this analysis.

18. Inadvertent Fuel Cell shutdown during RTLS and TAL abort is considered loss of crew/vehicle.

    RATIONALE: Loss of FCP 1/Bus A is loss of OMS Engine Purge Capability (required for TAL) and Aft Compartment MPS Helium Purge Capability (required for RTLS and TAL).

# APPENDIX C
# DETAILED ASSESSMENT

This section contains the IOA assessment worksheets generated during the assessment of this subsystem. The information on these worksheets facilitates the comparison of the NASA FMEA/CIL (Pre and Post 51-L) to the IOA detailed analysis worksheets included in Appendix E. Each of these worksheets identifies the NASA FMEA being assessed, corresponding MDAC Analysis Worksheet ID (Appendix E), hardware item, criticality, redundancy screens, and recommendations. For each failure mode, the highest assessed hardware and functional criticality is compared and discrepancies noted as "N" in the compare row under the column where the discrepancy occurred.

## LEGEND FOR IOA ASSESSMENT WORKSHEETS

Hardware Criticalities:

- 1 = Loss of life or vehicle
- 2 = Loss of mission or next failure of any redundant item (like or unlike) could cause loss of life/vehicle
- 3 = All others

Functional Criticalities:

- 1R = Redundant hardware items (like or unlike) all of which, if failed, could cause loss of life or vehicle
- 2R = Redundant hardware items (like or unlike) all of which, if failed, could cause loss of mission

Redundancy Screens A, B and C:

- P = Passed Screen
- F = Failed Screen
- NA = Not Applicable

NASA Data :

- Baseline = NASA FMEA/CIL
- New = Baseline with Proposed Post 51-L Changes

CIL Item :

- X = Included in CIL

Compare Row :

- N = Non compare for that column (deviation)

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/26/86
ASSESSMENT ID: FCP-101
NASA FMEA #: 04-1A-0101-5

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 101
ITEM: FUEL CELL

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/26/86
ASSESSMENT ID: FCP-104
NASA FMEA #: 04-1A-0101-3

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 104
ITEM: END CELL HEATER

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-105
NASA FMEA #: 04-1A-0101-6

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 105
ITEM: END CELL HEATER

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-106
NASA FMEA #: 04-1A-0101-4

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 106
ITEM: SEPARATOR PLATES/UEA

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 1 /1 ] | [ NA] | [ NA] | [ NA] | [ X ] * |
| IOA | [ 1 /1 ] | [ NA] | [ NA] | [ NA] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
## ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-107
NASA FMEA #: 04-1A-0101-9

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 107
ITEM: SEPARATOR PLATES/UEA

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 1 /1 ] | [ NA] | [ NA] | [ NA] | [ X ] * |
| IOA | [ 1 /1 ] | [ NA] | [ NA] | [ NA] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-108
NASA FMEA #: 04-1A-0101-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 108
ITEM: SEPARATOR PLATES

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-109
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 109
ITEM: SEPARATOR PLATES

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
REACTANT BLOCKAGE WOULD ONLY CAUSE REDUCED FLOW IN ONLY ONE OXYGEN PORT. THE FAILURE WOULD NOT CAUSE HYDROGEN OVERPRESSURE SINCE THE DELTA IN OXYGEN PRESSURE IS MINIMAL. WITH REDUCED OXYGEN FLOW THE CELL PERFORMANCE WOULD BE REDUCED. THE IOA ANALYSIS FOR REACTANT BLOCKAGE HAS BEEN CANCELLED BECAUSE OF THE ABOVE INFORMATION RECEIVED DURING A DISCUSSION WITH THE FUEL CELL SUBSYSTEM MANAGER.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-110
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 110
ITEM: CELL PERFORMANCE MONITOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ A ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
AN EPD&C FMEA, 05-6MA-2019-1, WAS FOUND WRITTEN ON A 3A FUSE WHICH PROVIDES POWER INPUT AND CIRCUIT PROTECTION FOR THE CELL PERFORMANCE MONITOR (CPM). THIS FMEA COVERS THE FAILURE OF THE FUSE NOT THE CPM. A FMEA NEEDS TO BE GENERATED FOR THE ERRONEOUS OUTPUT FAILURE OF THE CPM. ERRONEOUS CPM OUTPUT WOULD CAUSE LOSS OF ABILITY TO MONITOR THE CELL PERFORMANCE OR CELL FAILURE. IF THE CPM IS LOST, THE AFFECTED CELL CAN BE BUS TIED FOR PERFORMANCE MONITORING. IF ALL CPM'S ARE LOST, REACTANT CROSSOVER WOULD BE UNDETECTABLE.
THE NASA SUBSYSTEM MANAGER AGREED WITH THE IOA ANALYSIS FOR THIS COMPONENT AND WILL RECOMMEND THIS FAILURE MODE TO ROCKWELL FOR ADDITION TO THE NASA FMEA/CIL LIST.

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-111
NASA FMEA #: 04-1A-0101-8

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 111
ITEM: INTEGRATED DUAL GAS REGULATOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-112
NASA FMEA #: 04-1A-0101-8

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 112
ITEM: INTEGRATED DUAL GAS REGULATOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-113
NASA FMEA #: 04-1A-0101-7

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 113
ITEM: INTEGRATED DUAL GAS REGULATOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-114
NASA FMEA #: 04-1A-0101-8

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 114
ITEM: INTEGRATED DUAL GAS REGULATOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-115
NASA FMEA #: 04-1A-0101-7

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 115
ITEM: INTEGRATED DUAL GAS REGULATOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-116
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 116
ITEM: INTEGRATED DUAL GAS REGULATOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ N ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
THE FAILURE OF THE REGULATOR TO PURGE DEGRADES THE FUEL CELL PERFORMANCE. THIS FAILURE IS THE OPPOSITE OF NASA FMEA 04-1A-0101-8. AN ADDITIONAL FAILURE RESULTING IN THE NEED TO VENT WOULD CAUSE REACTANT OVERPRESSURIZATION, WHICH REQUIRES FUEL CELL SHUTDOWN.
THE EFFECT FOR THIS ANALYSIS HAS BEEN COVERED BY NASA FMEAs 05-6MA-2088-1, 04-1A-0104-1 AND 04-1A-0105-1, THEREFORE, THE IOA ANALYSIS HAS BEEN CANCELLED.

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-117
NASA FMEA #: 04-1A-0101-4

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 117
ITEM: H2/O2 LINES AND FITTINGS AND ACCESSORY COMPONENTS

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 1 /1 ] | [ NA] | [ NA] | [ NA] | [ X ] * |
| IOA | [ 1 /1 ] | [ NA] | [ NA] | [ NA] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-118
NASA FMEA #: 04-1A-0104-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 118
ITEM: O2/H2 PURGE-VENT LINES AND VENT NOZZLES

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-118A
NASA FMEA #: 04-1A-0105-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 118
ITEM: O2/H2 PURGE-VENT LINES AND VENT NOZZLES

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-118B
NASA FMEA #: 04-1A-0107-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 118
ITEM: O2/H2 PURGE-VENT LINES AND VENT NOZZLES

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FPC-118C
NASA FMEA #: 04-1A-0108-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 118
ITEM: O2/H2 PURGE-VENT LINES AND VENT NOZZLES

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-119
NASA FMEA #: 04-1A-0131-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 119
ITEM: O2 PURGE LINE TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

RECOMMENDATIONS: (If different from NASA)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-120
NASA FMEA #: 04-1A-0131-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 120
ITEM: O2 PURGE LINE TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-121
NASA FMEA #: 04-1A-0132-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 121
ITEM: H2 PURGE LINE TEMPERATURE SENSORS 1 & 2

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-122
NASA FMEA #: 04-1A-0132-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 122
ITEM: H2 PURGE LINE TEMP. SENSORS 1 & 2

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-123
NASA FMEA #: 04-1A-0142-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 123
ITEM: O2 PURGE LINE HEATERS (6)

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] * |
| IOA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
## ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-124
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 124
ITEM: O2 PURGE LINE HEATERS (6)

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
A HEATER CANNOT FAIL ON BY ITSELF. FOR A HEATER TO RECEIVE CONTINUOUS POWER, A SWITCH OR THERMOSTAT MUST FAIL CLOSED. THE FAILURE OF A SWITCH OR THERMOSTAT HAS BEEN EVALUATED IN OTHER NASA FMEAs. THE IOA ANALYSIS WORKSHEET 124 HAS BEEN CANCELLED.

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-125
NASA FMEA #: 04-1A-0143-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 125
ITEM: H2 PURGE LINE HEATERS (6) AND NOZZLE HEATERS (2)

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] * |
| IOA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-125B
NASA FMEA #: 04-1A-0149-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 125
ITEM: H2 PURGE LINE HEATERS (6) AND NOZZLE HEATERS (2)

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] * |
| IOA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-126
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 126
ITEM: H2 PURGE LINE HEATERS (6) AND NOZZLE HEATERS (2)

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
A HEATER CANNOT FAIL ON BY ITSELF. FOR A HEATER TO RECEIVE CONTINUOUS POWER, A SWITCH OR THERMOSTAT MUST FAIL CLOSED. THE FAILURE OF A SWITCH OR THERMOSTAT HAS BEEN EVALUATED IN OTHER NASA FMEAs. THE IOA ANALYSIS WORKSHEET 126 HAS BEEN CANCELLED.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-127
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 127
ITEM: O2/H2 FLOWMETER

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
IF A FLOWMETER MALFUNCTIONS, THEN LEAKING REACTANT WOULD BE UNDETECTABLE WHICH COULD POSSIBLY BE CATASTROPHIC. THE FUSES WHICH PROTECT THE FLOWMETERS ELECTRICALLY HAVE BEEN EVALUATED BY NASA FMEAs BUT THE FLOWMETERS HAVE NOT.
THE EFFECT FOR THIS ANALYSIS HAS BEEN COVERED BY NASA FMEA 05-6MA-2012-1, THEREFORE, THE IOA ANALYSIS HAS BEEN CANCELLED.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-128
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 128
ITEM: START-UP HEATER

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
THE START/SUSTAINING HEATERS ON FUEL CELL NO. ONE HAVE BEEN DISCONNECTED. THE FUEL CELL START-UP PROCESS WOULD TAKE LONGER WITH A FAILED HEATER. THE FUEL CELL PERFORMANCE COULD POSSIBLY BE DEGRADED DUE TO THE LOSS OF THE SUSTAINING HEATERS THAT MAINTAIN THE COOLING TEMPERATURE.
THE EFFECT OF THIS ANALYSIS HAS BEEN COVERED BY NASA FMEA 05-6MA-2035-4, THEREFORE, THE IOA ANALYSIS HAS BEEN CANCELLED.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-129
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 129
ITEM: START-UP HEATER

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
A HEATER CANNOT FAIL ON BY ITSELF. FOR A HEATER TO RECEIVE CONTINUOUS POWER, A SWITCH OR THERMOSTAT MUST FAIL CLOSED. THE IOA ANALYSIS WORKSHEET 129 HAS BEEN CANCELLED.

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-130
NASA FMEA #: 04-1A-0101-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 130
ITEM: H2/02 PREHEATER

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-131
NASA FMEA #: 04-1A-0101-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 131
ITEM: H2/02 PREHEATER, PUMP, THERMAL CONTROL VALVE, CONDENSER, FILTERS, START/SUSTAIN HEATER, ACCUMULATOR, FLEXIBLE INTERFACES, ECLSS HEAT EXCHANGERS

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-132
NASA FMEA #: 04-1A-0101-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 132
ITEM: COOLANT PUMP

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-133
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 133
ITEM: COOLANT PRESSURE SWITCH

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
THE COOLANT PRESSURE SWITCH SENSES THE HEAD RISE OF THE COOLANT PUMP AND SEQUENCES THE FUEL CELL START. THE COOLANT PRESSURE SWITCH ALSO PROVIDES THE INDICATION THAT THE COOLANT PUMP IS OPERATING. THE FAILURE OF THE COOLANT PRESSURE SWITCH WILL CAUSE THE LOSS OF SEVERAL IMPORTANT BUT NOT CRITICAL MEASUREMENTS. THE EVENT INDICATOR FOR THE COOLANT PRESSURE SWITCH IS EVALUATED IN NASA FMEA 05-6MA-2155-1, BUT THE PRESSURE SWITCH IS NOT. THE GENERATION OF A NASA FMEA FOR ANALYSIS WORKSHEET 133 IS REQUESTED TO DOCUMENT THE COOLANT PRESSURE SWITCH HARDWARE AND ITS LEVEL OF CRITICALITY.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-134
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 134
ITEM: STACK INLET TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
THE SENSOR DETECTS THE CELL STACK INLET TEMPERATURE. THE SENSOR OUTPUT IS USED BY THE START-UP HEATER ELECTRONICS. A SENSOR FAILED HIGH PREVENTS START-UP HEATER OPERATION WHICH SLOWS DOWN THE START-UP PROCESS. THE START-UP HEATER FOR FUEL CELL NO. ONE IS DISCONNECTED. THE GENERATION OF A NASA FMEA FOR ANALYSIS WORKSHEET 134 IS REQUESTED TO DOCUMENT THE FAILURE OF THE STACK INLET TEMPERATURE SENSOR.
THE NASA SUBSYSTEM MANAGER AGREED WITH THE IOA ANALYSIS FOR THIS COMPONENT AND WILL RECOMMEND THIS FAILURE MODE TO ROCKWELL FOR ADDITION TO THE NASA FMEA LIST.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-135
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 135
ITEM: STACK INLET TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ 3 /3 ] [ NA] [ NA] [ NA] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
THE SENSOR DETECTS THE CELL STACK INLET TEMPERATURE. THE SENSOR OUTPUT IS USED BY THE START-UP HEATER ELECTRONICS. A SENSOR FAILED LOW WOULD LOSE ONE PATH FOR START-UP HEATER SHUTDOWN. THE REMAINING PATH TO SHUTDOWN THE HEATERS IS THE STACK OUTLET TEMPERATURE SENSOR AND ELECTRONICS AND THE MANUAL SWITCHES. A FAILURE OF THE REDUNDANT PATHS COULD CAUSE THE START-UP HEATER TO FAIL ON WHICH COULD REQUIRE FUEL CELL SHUTDOWN. THE GENERATION OF A NASA FMEA AND CIL FOR ANALYSIS WORKSHEET 135 IS REQUESTED BECAUSE OF THE POSSIBLE SHUTDOWN OF A FUEL CELL. THE NASA SUBSYSTEM MANAGER AGREED WITH THE IOA ANALYSIS AS A 3/3 FOR THIS COMPONENT AND WILL RECOMMEND THIS FAILURE MODE TO ROCKWELL FOR ADDITION TO THE NASA FMEA LIST.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-136
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 136
ITEM: STACK OUTLET TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
THE SENSOR DETECTS THE CELL STACK OUTLET TEMPERATURE. THE SENSOR OUTPUT IS USED BY THE START-UP/SUSTAINING HEATER ELECTRONICS. A SENSOR FAILED HIGH PREVENTS THE START-UP OR SUSTAINING HEATERS FROM OPERATING. A FAILED OFF START-UP HEATER WILL SLOW THE FUEL CELL START-UP PROCESS. A FAILED OFF SUSTAINING HEATER COULD DEGRADE THE FUEL CELL PERFORMANCE. THE GENERATION OF A NASA FMEA FOR ANALYSIS WORKSHEET 136 IS REQUESTED TO DOCUMENT THE FAILURE OF THE SENSOR.
THE NASA SUBSYSTEM MANAGER AGREED WITH THE IOA ANALYSIS FOR THIS COMPONENT AND WILL RECOMMEND THIS FAILURE MODE TO ROCKWELL FOR ADDITION TO THE NASA FMEA LIST.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-137
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 137
ITEM: STACK OUTLET TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
THE SENSOR DETECTS THE CELL STACK OUTLET TEMPERATURE. THE SENSOR OUTPUT IS USED BY THE START-UP/SUSTAINING HEATER ELECTRONICS. A SENSOR FAILED LOW PREVENTS START-UP OR SUSTAINING HEATER SHUTDOWN, WHICH WOULD REQUIRE FUEL CELL SHUTDOWN. THE GENERATION OF A NASA FMEA AND CIL FOR ANALYSIS WORKSHEET 137 IS REQUESTED BECAUSE OF A POSSIBLE FUEL CELL SHUTDOWN.
THE NASA SUBSYSTEM MANAGER AGREED WITH THE IOA ANALYSIS AS A 3/3 FOR THIS COMPONENT AND WILL RECOMMEND THIS FAILURE MODE TO ROCKWELL FOR ADDITION TO THE NASA FMEA LIST.

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-138
NASA FMEA #: 04-1A-0101-3

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 138
ITEM: WATER SEPARATOR PUMP

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-139
NASA FMEA #: 04-1A-0101-3

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 139
ITEM: WATER SEPARATOR PUMP/WATER CONDENSATE TRAP

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-141
NASA FMEA #: 04-1A-0101-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 141
ITEM: THERMAL CONTROL VALVE

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-142
NASA FMEA #: 04-1A-0101-3

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 142
ITEM: WATER DISCHARGE VALVE

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-143
NASA FMEA #: 04-1A-0101-3

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 143
ITEM: H2O DISCHARGE LINE

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-144
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ ]

SUBSYSTEM: EPG
MDAC ID: 144
ITEM: PH WATER SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
IF THE pH SENSOR FAILS, THEN THE pH CAN BE TESTED MANUALLY WITH LITMUS PAPER. THE GENERATION OF A NASA FMEA AND CIL FOR ANALYSIS WORKSHEET 144 IS REQUESTED TO DOCUMENT THE FAILURE OF THE pH WATER SENSOR.
THE NASA SUBSYSTEM MANAGER AGREED WITH THE IOA ANALYSIS FOR THIS COMPONENT AND WILL RECOMMEND THIS FAILURE MODE TO ROCKWELL FOR ADDITION TO THE NASA FMEA LIST.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-145
NASA FMEA #: 04-1A-0151-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 145
ITEM: PRODUCT WATER LINE TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-146
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 146
ITEM: PRODUCT WATER LINE HEATER (A&B)

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
A HEATER CANNOT FAIL ON BY ITSELF. FOR A HEATER TO RECEIVE CONTINUOUS POWER, A SWITCH OR THERMOSTAT MUST FAIL CLOSED. THE FAILURE OF A SWITCH OR THERMOSTAT HAS BEEN EVALUATED IN OTHER NASA FMEAs. THE IOA ANALYSIS WORKSHEET 146 HAS BEEN CANCELLED.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-147
NASA FMEA #: 04-1A-0144-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 147
ITEM: PRODUCT WATER LINE HEATER (A&B)

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-148
NASA FMEA #: 04-1A-0136-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 148
ITEM: PRODUCT WATER LINE

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-148A
NASA FMEA #: 04-1A-0136-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 148
ITEM: PRODUCT WATER LINE

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-149
NASA FMEA #: 04-1A-0122-3

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 149
ITEM: WATER SUPPLY CHECK VALVE

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] * |
| IOA | [ 3 /2R ] | [ P ] | [ P ] | [ F ] | [ X ] |
| COMPARE | [ /N ] | [ ] | [ ] | [ N ] | [ N ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
THE DISCUSSION WITH THE NASA SUBSYSTEM MANAGER RESULTED IN A DECISION TO CHANGE THE IOA ANALYSIS RESULTS TO 3/1R AND AGREE WITH THE NASA FMEA. AN EXTERNAL LEAK WOULD FREEZE CAUSING THE CHECK VALVE TO FAIL CLOSE.

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-150
NASA FMEA #: 04-1A-0122-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 150
ITEM: WATER SUPPLY CHECK VALVE

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] * |
| IOA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-151
NASA FMEA #: 04-1A-0122-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 151
ITEM: WATER SUPPLY CHECK VALVE

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /2R ] | [ P ] | [ F ] | [ P ] | [ X ] * |
| IOA | [ 3 /2R ] | [ P ] | [ F ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-152
NASA FMEA #: 04-1A-0119-3

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 152
ITEM: WATER RELIEF VALVE

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /2 ] | [ NA] | [ NA] | [ NA] | [ X ] * |
| IOA | [ 3 /2R ] | [ P ] | [ P ] | [ F ] | [ X ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:
THE DISCUSSION WITH THE NASA SUBSYSTEM MANAGER RESULTED IN A DECISION TO CHANGE THE IOA ANALYSIS RESULTS TO 2/2 AND AGREE WITH THE NASA FMEA. THIS DECISION WAS MADE BECAUSE OF THE UNKNOWN AFFECTS OF WATER IN THE PAYLOAD BAY.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-153
NASA FMEA #: 04-1A-0119-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 153
ITEM: WATER RELIEF VALVE

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /2 ] | [ NA] | [ NA] | [ NA] | [ X ] * |
| IOA | [ 3 /2R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ N ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:
THE IOA ANALYSIS HAS BEEN CHANGED TO AGREE WITH THE NASA FMEA DUE TO A DISCUSSION WITH THE NASA SUBSYSTEM MANAGER. THE WATER RELIEF VALVE DOES NOT HAVE A REDUNDANT COMPONENT. THE FAILURE OF WATER VENTING MAY INTERFERE WITH THE MISSION OR PAYLOAD OBJECTIVES.

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-154
NASA FMEA #: 04-1A-0119-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 154
ITEM: WATER RELIEF VALVE

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /1R ] | [ P ] | [ NA] | [ P ] | [ ] * |
| IOA | [ 3 /1R ] | [ P ] | [ NA] | [ P ] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-155
NASA FMEA #: 04-1A-0138-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 155
ITEM: WATER RELIEF VALVE HEATER (A&B)

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /1R ] | [ P ] | [ NA] | [ P ] | [ ] * |
| IOA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ / ] | [ ] | [ N ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
THE WATER RELIEF SYSTEM IS A STANDBY REDUNDANT SYSTEM, THEREFORE THE WATER RELIEF VALVE HEATERS ARE STANDBY REDUNDANT. THE REDUNDANCY SCREEN B SHOULD BE NOT APPLICABLE (NA) BECAUSE OF PARAGRAPH 2.3.4 b.1.(b) IN NSTS 22206 FOR THIS HARDWARE. THE IOA ANALYSIS DID NOT CONSIDER THE WATER RELIEF SYSTEM AS REDUNDANT, BUT NOW AGREES WITH THE NASA FMEA.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-156
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 156
ITEM: WATER RELIEF VALVE HEATER A&B

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
A HEATER CANNOT FAIL ON BY ITSELF. FOR A HEATER TO RECEIVE CONTINUOUS POWER, A SWITCH OR THERMOSTAT MUST FAIL CLOSED. THE FAILURE OF A SWITCH OR THERMOSTAT HAS BEEN EVALUATED IN OTHER NASA FMEAs. THE IOA ANALYSIS WORKSHEET 156 HAS BEEN CANCELLED.

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-157
NASA FMEA #: 04-1A-0125-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 157
ITEM: WATER RELIEF VALVE TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-157A
NASA FMEA #: 04-1A-0125-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 157
ITEM: WATER RELIEF VALVE TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-158
NASA FMEA #: 04-1A-0133-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 158
ITEM: WATER RELIEF LINE TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-158A
NASA FMEA #: 04-1A-0133-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 158
ITEM: WATER RELIEF LINE TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-159
NASA FMEA #: 04-1A-0109-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 159
ITEM: WATER RELIEF (VENT) LINE

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /1R ] | [ P ] | [ NA] | [ P ] | [ ] * |
| IOA | [ 2 /1R ] | [ P ] | [ NA] | [ P ] | [ ] |
| COMPARE | [ N / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:
ADDITION OF THE ALTERNATE WATER LINE HAS MADE THIS HARDWARE CRITICALITY 3. IOA AGREES WITH THE NASA REEVALUATION.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-160
NASA FMEA #: 04-1A-0141-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 160
ITEM: WATER VENT LINE HEATER A&B AND BARREL HEATER A&B

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] * |
| IOA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-161
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 161
ITEM: WATER VENT LINE HEATER A&B AND BARREL HEATER A&B

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
A HEATER CANNOT FAIL ON BY ITSELF. FOR A HEATER TO RECEIVE CONTINUOUS POWER, A SWITCH OR THERMOSTAT MUST FAIL CLOSED. THE FAILURE OF A SWITCH OR THERMOSTAT HAS BEEN EVALUATED IN OTHER NASA FMEAs. THE IOA ANALYSIS WORKSHEET 161 HAS BEEN CANCELLED.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-162
NASA FMEA #:

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 162
ITEM: WATER NOZZLE HEATER (A&B)

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ / ] | [ ] | [ ] | [ ] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ N /N ] | [ N ] | [ N ] | [ N ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
A HEATER CANNOT FAIL ON BY ITSELF. FOR A HEATER TO RECEIVE CONTINUOUS POWER, A SWITCH OR THERMOSTAT MUST FAIL CLOSED. THE FAILURE OF A SWITCH OR THERMOSTAT HAS BEEN EVALUATED IN OTHER NASA FMEAs. THE IOA ANALYSIS WORKSHEET 162 HAS BEEN CANCELLED.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-163
NASA FMEA #: 04-1A-0106-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 163
ITEM: WATER NOZZLE HEATER (A&B)

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /1R ] | [ P ] | [ NA] | [ P ] | [ ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ ] |
| COMPARE | [ N / ] | [ ] | [ N ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:
THE WATER RELIEF SYSTEM IS A STANDBY REDUNDANT SYSTEM, THEREFORE THE WATER NOZZLE HEATERS ARE STANDBY REDUNDANT. THE REDUNDANCY SCREEN B SHOULD BE NOT APPLICABLE (NA) BECAUSE OF PARAGRAPH 2.3.4 b.2 (b) IN NSTS 22206 FOR THIS HARDWARE.
ADDITION OF THE ALTERNATE WATER LINE HAS MADE THIS HARDWARE CRITICALITY 3. IOA AGREES WITH THE NASA REEVALUATION.

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-164
NASA FMEA #: 04-1A-0150-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 164
ITEM: WATER RELIEF NOZZLE TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

[ / ] [ ] [ ] [ ] [ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-164A
NASA FMEA #: 04-1A-0150-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 164
ITEM: WATER RELIEF NOZZLE TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 3 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 11/28/86
ASSESSMENT ID: FCP-165
NASA FMEA #: 04-1A-0106-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 165
ITEM: WATER NOZZLE

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /1R ] | [ P ] | [ NA] | [ P ] | [ ] * |
| IOA | [ 2 /1R ] | [ P ] | [ NA] | [ P ] | [ ] |
| COMPARE | [ N / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:
ADDITION OF THE ALTERNATE WATER LINE HAS MADE THIS HARDWARE CRITICALITY 3. IOA AGREES WITH THE NASA REEVALUATION.

# APPENDIX C
# ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/23/86
ASSESSMENT ID: FCP-166X
NASA FMEA #: 04-1A-0128-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 166
ITEM: COOLANT RETURN TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/23/86
ASSESSMENT ID: FCP-167X
NASA FMEA #: 04-1A-0128-2

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 167
ITEM: COOLANT RETURN TEMPERATURE SENSOR

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/23/86
ASSESSMENT ID: FCP-168X
NASA FMEA #: 04-1A-0144-3

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 168
ITEM: FCP PRODUCT WATER LINE HEATER

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
THIS FAILURE CAN OCCUR ONLY BY CREW ACTION OR BY SWITCH OR THERMOSTAT FAILURE CAUSED BY VIBRATION OR MECHANICAL SHOCK. THE SWITCH AND THERMOSTAT HAVE BEEN EVALUATED IN FMEAs 05-6MA-2037-1 AND 04-1A-0151-1 RESPECTIVELY. CREW ERROR IS NOT WITHIN THE SCOPE OF THIS TASK. THEREFORE, FMEA 04-1A-0144-3 IS BEING RECOMMENDED FOR DELETION.
FMEA 04-1A-0144-3 HAS ALREADY BEEN DELETED BY THE NASA SUBSYSTEM MANAGER.

# APPENDIX C
## ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/23/86
ASSESSMENT ID: FCP-169X
NASA FMEA #: 04-1A-0144-4

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 169
ITEM: FCP PRODUCT WATER LINE HEATER

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] * |
| IOA | [ 3 /3 ] | [ NA] | [ NA] | [ NA] | [ ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |
| RECOMMENDATIONS: (If different from NASA) | | | | | |
| | [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
THIS FAILURE CAN OCCUR ONLY BY CREW ACTION OR BY SWITCH OR THERMOSTAT FAILURE CAUSED BY VIBRATION OR MECHANICAL SHOCK. THE SWITCH AND THERMOSTAT HAVE BEEN EVALUATED IN FMEA's 05-6MA-2037-1 AN 04-1A-0151-1 RESPECTIVELY. CREW ERROR IS NOT WITHIN THE SCOPE OF THIS TASK. THEREFORE, FMEA 04-1A-0144-4 IS BEING RECOMMENDED FOR DELETION.
THE NASA SUBSYSTEM MANAGER AGREED TO DELETE FMEA 04-1A-0144-4.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/19/86
ASSESSMENT ID: FCP-170X
NASA FMEA #: 04-1A-137-1

NASA DATA:
BASELINE [ ]
NEW [ X ]

SUBSYSTEM: EPG
MDAC ID: 170
ITEM: LINE FITTINGS COMPONENTS

LEAD ANALYST: M. HIOTT

ASSESSMENT:

| | CRITICALITY FLIGHT HDW/FUNC | REDUNDANCY SCREENS A | B | C | CIL ITEM |
|---|---|---|---|---|---|
| NASA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] * |
| IOA | [ 2 /1R ] | [ P ] | [ P ] | [ P ] | [ X ] |
| COMPARE | [ / ] | [ ] | [ ] | [ ] | [ ] |

RECOMMENDATIONS: (If different from NASA)

| | | | | |
|---|---|---|---|---|
| [ / ] | [ ] | [ ] | [ ] | [ ] (ADD/DELETE) |

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ X ]
INADEQUATE [ ]

REMARKS:
A GROSS EXTERNAL LEAK AT OR NEAR THE WATER RELIEF PANEL WILL CAUSE LOSS OF PRODUCT WATER FROM THE FUEL CELL TO THE ECLSS. A GROSS LEAK COULD SPRAY THE WATER RELIEF LINE AND PRODUCT WATER LINE TO THE ECLSS WITH WATER CAUSING THEM TO FREEZE INTERNALLY. THE ALTERNATE WATER PATH TO THE ECLSS WOULD THEN BE USED.

APPENDIX D

CRITICAL ITEMS

| NASA FMEA | MDAC ID | ITEM | FAILURE MODE |
|---|---|---|---|
| 04-1A-0101-2 | 108 | SEPARATOR PLATES | COOLANT LEAKAGE |
| 04-1A-0101-2 | 130 | H2/02 PREHEATER | RESTRICTED COOLANT FLOW |
| 04-1A-0101-2 | 131 | H2/02 PREHEATER, PUMP, THERMAL CONTROL VALVE, CONDENSER, FILTERS, START/SUSTAIN HEATER, ACCUMULATOR | EXTERNAL LEAK OF TSC COOLANT |
| 04-1A-0101-2 | 132 | COOLANT PUMP | LOSS OF OUTPUT |
| 04-1A-0101-2 | 141 | THERMAL CONTROL VALVE | ERRONEOUS OUTPUT |
| 04-1A-0101-3 | 104 | END CELL HEATER | FAIL OFF |
| 04-1A-0101-3 | 138 | WATER SEPARATOR PUMP | DEGRADED PERFORMANCE |
| 04-1A-0101-3 | 139 | WATER SEPARATOR PUMP/WATER CONDENSATE TRAP | RESTRICTED FLOW |
| 04-1A-0101-3 | 142 | WATER DISCHARGE VALVE | FAIL CLOSED |
| 04-1A-0101-3 | 143 | H2O DISCHARGE LINE | RESTRICTED FLOW |
| 04-1A-0101-4 | 106 | SEPARATOR PLATES/UEA | REACTANT LEAKAGE TO ORBITER (EXTERNAL LEAKAGE) |
| 04-1A-0101-4 | 117 | H2/O2 LINES AND FITTINGS AND ACCESSORY COMPONENTS | REACTANT LEAKAGE TO ORBITER (EXTERNAL LEAKAGE) |
| 04-1A-0101-5 | 101 | FUEL CELL | LOSS ELECTRICAL CONTACT IN THE POWER SECTION |
| 04-1A-0101-6 | 105 | END CELL HEATER | FAIL ON |
| 04-1A-0101-7 | 113 | INTEGRATED DUAL GAS REGULATOR | H2 STARVATION |
| 04-1A-0101-7 | 115 | INTEGRATED DUAL GAS REGULATOR | O2 STARVATION |
| 04-1A-0101-8 | 111 | INTEGRATED DUAL GAS REGULATOR | GROSS VENTING |
| 04-1A-0101-9 | 107 | SEPARATOR PLATES/UEA | INTERNAL LEAKAGE |
| 04-1A-0104-1 | 118 | O2/H2 PURGE-VENT LINES AND VENT NOZZLES | RESTRICTED FLOW |
| 04-1A-0105-1 | 118 | O2/H2 PURGE-VENT LINES AND VENT NOZZLES | RESTRICTED FLOW |
| 04-1A-0106-1 | 165 | WATER NOZZLE | RESTRICTED FLOW |
| 04-1A-0106-2 | 163 | WATER NOZZLE HEATER (A&B) | FAIL OFF |
| 04-1A-0107-1 | 118 | O2/H2 PURGE-VENT LINES AND VENT NOZZLES | RESTRICTED FLOW |
| 04-1A-0108-1 | 118 | O2/H2 PURGE-VENT LINES AND VENT NOZZLES | RESTRICTED FLOW |
| 04-1A-0109-1 | 159 | WATER RELIEF (VENT) LINE | RESTRICTED FLOW |

| NASA FMEA | MDAC ID | ITEM | FAILURE MODE |
|---|---|---|---|
| 04-1A-0119-2 | 153 | WATER RELIEF VALVE | FAILS OPEN |
| 04-1A-0119-3 | 152 | WATER RELIEF VALVE | EXTERNAL LEAKAGE |
| 04-1A-0122-1 | 151 | WATER SUPPLY CHECK VALVE | FAILS TO CHECK |
| 04-1A-0136-1 | 148 | PRODUCT WATER LINE | RESTRICTED FLOW (EXTERNAL LEAKAGE) |
| 04-1A-0136-2 | 148 | PRODUCT WATER LINE | RESTRICTED FLOW (EXTERNAL LEAKAGE) |
| 04-1A-0150-1 | 164 | WATER RELIEF NOZZLE TEMPERATURE SENSOR | ERRONEOUS OUTPUT |
| 04-1A-0150-2 | 164 | WATER RELIEF NOZZLE TEMPERATURE SENSOR | ERROENOUS OUTPUT |
| 04-1A-0137-1 | 170 | LINE FITTINGS COMPONENTS | GROSS EXTERNAL LEAKAGE |

# APPENDIX E
# DETAILED ANALYSIS

This appendix contains the IOA analysis worksheets supplementing previous results reported in STSEOS Working Paper 1.0-WP-VA86001-10, Analysis of the EPG/FCP, (05 December 1986). Prior results were obtained independently and documented before starting the FMEA/CIL assessment activity. Supplemental analysis was performed to address failure modes not previously considered by the IOA. Each sheet identifies the hardware item being analyzed, parent assembly and function performed. For each failure mode possible causes are identified, and hardware and functional criticality for each mission phase are determined as described in NSTS 22206, Instructions for Preparation of FMEA and CIL, 10 October 1986. Failure mode effects are described at the bottom of each sheet and worst case criticality is identified at the top.

## LEGEND FOR IOA ANALYSIS WORKSHEETS

Hardware Criticalities:

- 1 = Loss of life or vehicle
- 2 = Loss of mission or next failure of any redundant item (like or unlike) could cause loss of life/vehicle
- 3 = All others

Functional Criticalities:

- 1R = Redundant hardware items (like or unlike) all of which, if failed, could cause loss of life or vehicle.
- 2R = Redundant hardware items (like or unlike) all of which, if failed, could cause loss of mission.

Redundancy Screen A:

- 1 = Is Checked Out PreFlight
- 2 = Is Capable of Check Out PreFlight
- 3 = Not Capable of Check Out PreFlight
- NA = Not Applicable

Redundancy Screens B and C:

- P = Passed Screen
- F = Failed Screen
- NA = Not Applicable

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 12/18/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 166 ABORT: 3/3

ITEM: COOLANT RETURN TEMPERATURE SENSOR
FAILURE MODE: FAIL OPEN OR SHORTED

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) TCS
5)
6)
7)
8)
9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|---|---|---|---|
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA ] B [NA ] C [NA ]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-0003

CAUSES: VIBRATION, MECHANICAL SHOCK, CORROSION

EFFECTS/RATIONALE:
A FAILED TEMPERATURE SENSOR CAUSES LOSS OF MEASUREMENT. THE FAILURE CAN BE DETERMINED BY A CONSTANT LOW OR HIGH SCALE. A NORMAL STACK OUTLET TEMPERATURE AND A NORMAL CONDENSER EXIT TEMPERATURE CAN BE USED TO INDICATE A NORMAL COOLANT RETURN TEMPERATURE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 12/18/86
SUBSYSTEM: EPG
MDAC ID: 167

HIGHEST CRITICALITY HDW/FUNC
FLIGHT: 3/3
ABORT: 3/3

ITEM: COOLANT RETURN TEMPERATURE SENSOR
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) TCS
5)
6)
7)
8)
9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|---|---|---|---|
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA ] B [NA ] C [NA ]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-0003

CAUSES: VIBRATION, MECHANICAL SHOCK, CORROSION

EFFECTS/RATIONALE:
A FAILED TEMPERATURE SENSOR CAUSES LOSS OF MEASUREMENT. A NORMAL STUCK OUTLET TEMPERATURE AND A NORMAL CONDENSOR EXIT TEMPERATURE CAN BE USED TO INDICATE A NORMAL COOLANT RETURN TEMPERATURE AND A FAILING TEMPERATURE SENSOR.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 12/18/86
SUBSYSTEM: EPG
MDAC ID: 168

HIGHEST CRITICALITY HDW/FUNC
FLIGHT: 3/3
ABORT: 3/3

ITEM: FCP PRODUCT WATER LINE HEATER
FAILURE MODE: INADVERTENTLY TURNED ON DURING FCP OPERATION

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|---|---|---|---|
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA ] B [NA ] C [NA ]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0006

CAUSES: VIBRATION, MECHANICAL SHOCK, ACCELERATION, SWITCH FAILURE, THERMOSTAT FAILURE

EFFECTS/RATIONALE:
THIS FAILURE CAN OCCUR ONLY BY CREW ACTION OR BY SWITCH OR THERMOSTAT FAILURE CAUSED BY VIBRATION OR MECHANICAL SHOCK. THE SWITCH AND THERMOSTAT HAVE BEEN EVALUATED IN FMEAs 05-6MA-2037-1 AND 04-1A-0151-1 RESPECTIVELY. CREW ERROR IS NOT WITHIN THE SCOPE OF THIS TASK. THEREFORE, FMEA 04-1A-0144-3 IS BEING RECOMMENDED FOR DELETION.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 12/18/86 HIGHEST CRITICALITY HDW/FUNC
SUBSYSTEM: EPG FLIGHT: 3/3
MDAC ID: 169 ABORT: 3/3

ITEM: FCP PRODUCT WATER LINE HEATER
FAILURE MODE: BOTH ELEMENTS TURNED ON DURING FCP SHUTDOWN

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|---|---|---|---|
| PRELAUNCH: | 3/3 | RTLS: | 3/3 |
| LIFTOFF: | 3/3 | TAL: | 3/3 |
| ONORBIT: | 3/3 | AOA: | 3/3 |
| DEORBIT: | 3/3 | ATO: | 3/3 |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [NA ] B [NA ] C [NA ]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0006

CAUSES: VIBRATION, MECHANICAL SHOCK, SWITCH FAILURE

EFFECTS/RATIONALE:
THIS FAILURE CAN OCCUR ONLY BY CREW ACTION OR BY SWITCH OR THERMOSTAT FAILURE CAUSED BY VIBRATION OR MECHANICAL SHOCK. THE SWITCH AND THERMOSTAT HAVE BEEN EVALUATED IN FMEAs 05-6MA-2037-1 AND 04-1A-0151-1 RESPECTIVELY. CREW ERROR IS NOT WITHIN THE SCOPE OF THIS TASK. THEREFORE, FMEA 04-1A-0144-4 IS BEING RECOMMENDED FOR DELETION.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 12/19/86
SUBSYSTEM: EPG
MDAC ID: 170

HIGHEST CRITICALITY HDW/FUNC
FLIGHT: 2/1R
ABORT: 2/1R

ITEM: LINE FITTINGS COMPONENTS
FAILURE MODE: EXTERNAL LEAKAGE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

| FLIGHT PHASE | HDW/FUNC | ABORT | HDW/FUNC |
|---|---|---|---|
| PRELAUNCH: | 3/3 | RTLS: | 3/1R |
| LIFTOFF: | 2/1R | TAL: | 3/1R |
| ONORBIT: | 2/1R | AOA: | 3/1R |
| DEORBIT: | 3/1R | ATO: | 2/1R |
| LANDING/SAFING: | 3/3 | | |

REDUNDANCY SCREENS: A [ 1 ] B [ P ] C [ P ]

LOCATION: MID-BODY
PART NUMBER: V070-454110-124

CAUSES: VIBRATION, MECHANICAL SHOCK, CORROSION

EFFECTS/RATIONALE:
AN EXTERNAL LEAK AT A PRODUCT WATER LINE (BEFORE THE WATER RELIEF PANEL) CAUSES LOSS OF PRODUCT WATER FROM THE FUEL CELL TO THE ECLSS. THE FUEL CELL WOULD BE SHUTDOWN DUE TO THE POSSIBILITY OF FREEZING THE LINE. A LEAK COULD SPRAY THE TWO REMAINING PRODUCT WATER LINES CAUSING THEM TO FREEZE INTERNALLY. THIS WOULD RESULT IN FLOODING OF ALL FUEL CELLS.

REFERENCES:

# APPENDIX F

## NASA FMEA TO IOA WORKSHEET CROSS REFERENCE/RECOMMENDATIONS

This section provides a cross reference between the NASA FMEA and corresponding IOA analysis worksheet(s) included in Appendix E. The Appendix F identifies: NASA FMEA Number, IOA Assessment Number, NASA criticality and redundancy screen data, and IOA recommendations.

Appendix F Resolution/Issue/Rationale Codes

| Code | Definition |
|---|---|
| 1 | IOA Issue. |
| 2 | IOA recommends generating a FMEA for the subject failure mode. |
| 3 | IOA generated a non-credible failure mode. |
| 4 | IOA generated a failure mode covered by EPD&/C. |

APPENDIX F

NASA FMEA TO IOA WORKSHEET CROSS REFERENCE/RECOMMENDATIONS

| IDENTIFIERS | | NASA | | | | IOA RECOMMENDATIONS * | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| NASA FMEA NUMBER | IOA ASSESSMENT NUMBER | CRIT HW/F | SCREENS A | B | C | CRIT HW/F | SCREENS A | B | C | OTHER (SEE LEGEND CODE) | ISSUE |
| | FCP-109 | / | | | | / | | | | 3 | |
| | FCP-110 | / | | | | 2/1R | P | P | P | 1, 2 | X |
| | FCP-116 | / | | | | / | | | | 4 | |
| | FCP-124 | / | | | | / | | | | 3 | |
| | FCP-126 | / | | | | / | | | | 3 | |
| | FCP-127 | / | | | | / | | | | 4 | |
| | FCP-128 | / | | | | / | | | | 4 | |
| | FCP-129 | / | | | | / | | | | 3 | |
| | FCP-133 | / | | | | 3/3 | NA | NA | NA | 1, 2 | X |
| | FCP-134 | / | | | | 3/3 | NA | NA | NA | 1, 2 | X |
| | FCP-135 | / | | | | 3/3 | NA | NA | NA | 1, 2 | X |
| | FCP-136 | / | | | | 3/3 | NA | NA | NA | 1, 2 | X |
| | FCP-137 | / | | | | 3/3 | NA | NA | NA | 1, 2 | X |
| | FCP-144 | / | | | | 3/3 | NA | NA | NA | 1, 2 | X |
| | FCP-146 | / | | | | / | | | | 3 | |
| | FCP-156 | / | | | | / | | | | 3 | |
| | FCP-161 | / | | | | / | | | | 3 | |
| | FCP-162 | / | | | | / | | | | 3 | |
| 04-1A-0101-2 | FCP-108 | 2/1R | P | P | P | / | | | | | |
| | FCP-130 | 2/1R | P | P | P | / | | | | | |
| | FCP-131 | 2/1R | P | P | P | / | | | | | |
| | FCP-132 | 2/1R | P | P | P | / | | | | | |
| | FCP-141 | 2/1R | P | P | P | / | | | | | |
| 04-1A-0101-3 | FCP-104 | 2/1R | P | P | P | / | | | | | |
| | FCP-138 | 2/1R | P | P | P | / | | | | | |
| | FCP-139 | 2/1R | P | P | P | / | | | | | |
| | FCP-142 | 2/1R | P | P | P | / | | | | | |
| | FCP-143 | 2/1R | P | P | P | / | | | | | |
| 04-1A-0101-4 | FCP-106 | 1/1 | NA | NA | NA | / | | | | | |
| | FCP-117 | 1/1 | NA | NA | NA | / | | | | | |
| 04-1A-0101-5 | FCP-101 | 2/1R | P | P | P | / | | | | | |
| 04-1A-0101-6 | FCP-105 | 2/1R | P | P | P | / | | | | | |
| 04-1A-0101-7 | FCP-113 | 2/1R | P | P | P | / | | | | | |
| | FCP-115 | 2/1R | P | P | P | / | | | | | |
| 04-1A-0101-8 | FCP-111 | 2/1R | P | P | P | / | | | | | |
| | FCP-112 | 2/1R | P | P | P | / | | | | | |
| | FCP-114 | 2/1R | P | P | P | / | | | | | |
| 04-1A-0101-9 | FCP-107 | 1/1 | NA | NA | NA | / | | | | | |
| 04-1A-0104-1 | FCP-118 | 2/1R | P | P | P | / | | | | | |
| 04-1A-0105-1 | FCP-118A | 2/1R | P | P | P | / | | | | | |
| 04-1A-0106-1 | FCP-165 | 2/1R | P | NA | P | / | | | | | |

| IDENTIFIERS | | NASA | | | | IOA RECOMMENDATIONS * | | | |
|---|---|---|---|---|---|---|---|---|---|
| NASA FMEA NUMBER | IOA ASSESSMENT NUMBER | CRIT HW/F | SCREENS A | B | C | CRIT HW/F | SCREENS A | B C | OTHER (SEE LEGEND CODE) | ISSUE |
| 04-1A-0106-2 | FCP-163 | 2/1R | P | NA | P | / | | | | |
| 04-1A-0107-1 | FCP-118B | 2/1R | P | P | P | / | | | | |
| 04-1A-0108-1 | FPC-118C | 2/1R | P | P | P | / | | | | |
| 04-1A-0109-1 | FCP-159 | 2/1R | P | NA | P | / | | | | |
| 04-1A-0119-1 | FCP-154 | 3/1R | P | NA | P | / | | | | |
| 04-1A-0119-2 | FCP-153 | 2/2 | NA | NA | NA | / | | | | |
| 04-1A-0119-3 | FCP-152 | 2/2 | NA | NA | NA | / | | | | |
| 04-1A-0122-1 | FCP-151 | 3/2R | P | F | P | / | | | | |
| 04-1A-0122-2 | FCP-150 | 3/1R | P | P | P | / | | | | |
| 04-1A-0122-3 | FCP-149 | 3/1R | P | P | P | / | | | | |
| 04-1A-0125-1 | FCP-157 | 3/3 | NA | NA | NA | / | | | | |
| 04-1A-0125-2 | FCP-157A | 3/3 | NA | NA | NA | / | | | | |
| 04-1A-0128-1 | FCP-166X | 3/3 | NA | NA | NA | / | | | | |
| 04-1A-0128-2 | FCP-167X | 3/3 | NA | NA | NA | / | | | | |
| 04-1A-0131-1 | FCP-119 | 3/3 | NA | NA | NA | / | | | | |
| 04-1A-0131-2 | FCP-120 | 3/3 | NA | NA | NA | / | | | | |
| 04-1A-0132-1 | FCP-121 | 3/3 | NA | NA | NA | / | | | | |
| 04-1A-0132-2 | FCP-122 | 3/3 | NA | NA | NA | / | | | | |
| 04-1A-0133-1 | FCP-158 | 3/3 | NA | NA | NA | / | | | | |
| 04-1A-0133-2 | FCP-158A | 3/3 | NA | NA | NA | / | | | | |
| 04-1A-0136-1 | FCP-148 | 2/1R | P | P | P | / | | | | |
| 04-1A-0136-2 | FCP-148A | 2/1R | P | P | P | / | | | | |
| 04-1A-0138-1 | FCP-155 | 3/1R | P | NA | P | / | | | | |
| 04-1A-0141-1 | FCP-160 | 3/1R | P | P | P | / | | | | |
| 04-1A-0142-1 | FCP-123 | 3/1R | P | P | P | / | | | | |
| 04-1A-0143-1 | FCP-125 | 3/1R | P | P | P | / | | | | |
| 04-1A-0144-1 | FCP-147 | 3/3 | NA | NA | NA | / | | | | |
| 04-1A-0144-3 | FCP-168X | 3/3 | NA | NA | NA | / | | | | |
| 04-1A-0144-4 | FCP-169X | 3/3 | NA | NA | NA | / | | | | |
| 04-1A-0149-1 | FCP-125B | 3/1R | P | P | P | / | | | | |
| 04-1A-0150-1 | FCP-164 | 2/1R | P | P | P | / | | | | |
| 04-1A-0150-2 | FCP-164A | 2/1R | P | P | P | / | | | | |
| 04-1A-0151-1 | FCP-145 | 3/3 | NA | NA | NA | / | | | | |
| 04-1A-137-1 | FCP-170X | 1/1 | NA | NA | NA | / | | | | |