PRINT DATE: 03/29/96

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE
NUMBER: 04-1A-0101 -X

SUBSYSTEM NAME: ELECTRICAL POWER GENERATION: FUEL CELL
REVISION: 3 03/27/96

PART DATA

	PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
LRU	: FUEL CELL POWERPLANT IFC	MC464-0115-3020 807100
LRU	: FUEL CELL POWERPLANT IFC	MC464-0115-3021 808100
LRU	:FUEL CELL POWERPLANT IFC	MC464-0115-3030 814100
LRU	:FUEL CELL POWERPLANT. IFC	MC464-0115-3031 815100

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
FCP NO. 1, 2, 3

REFERENCE DESIGNATORS: 40V45A100
40V45A200
40V45A300

QUANTITY OF LIKE ITEMS:
TWO-RH
ONE-LH

FUNCTION:
THREE POWER SOURCES FOR MAIN ELECTRICAL POWER.

SUBSYSTEM: ELECTRICAL POWER GENERATION: FUEL CELL
LRU FUEL CELL POWERPLANT CRITICALITY OF THIS
ITEM NAME: FUEL CELL POWERPLANT FAILURE MODE: 1/1

FAILURE MODE:
INTERNAL LEAKAGE OF REACTANTS THROUGH CELL MATRIX OR SEPARATOR PLATE

MISSION PHASE:

PL	PRELAUNCH
LO	LIFT-OFF
OO	ON-ORBIT
DO	DE-ORBIT
LS	LANDING SAFING

VEHICLE/PAYLOAD/KIT EFFECTIVITY: 102 COLUMBIA
: 103 DISCOVERY
: 104 ATLANTIS

CAUSE:
DRYOUT DUE TO INSUFFICIENT ELECTROLYTE, LATENT DEFECT OF MATRIX, OR MAGNESIUM SEPARATOR PLATES. EXCESSIVE DELTA PRESSURE DUE TO FAILED REGULATOR.

CRITICALITY 1/1 DURING INTACT ABORT ONLY? Y

REDUNDANCY SCREEN A) N/A
B) N/A
C) N/A

PASS/FAIL RATIONALE:
A)

B)

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:
LOSS OF REDUNDANCY - CREW IS REQUIRED TO SHUTDOWN FCP IMMEDIATELY TO PREVENT POSSIBLE VEHICLE OR FCP DAMAGE. LOW LEVEL LEAKAGE WILL IMMEDIATELY REACT DUE TO CATALYST ACTION PRECLUDING REACTANT ACCUMULATION TO AN EXPLOSIVE MIXTURE. UNDETECTED GROSS LEAKAGE CAN RESULT IN REACTANT MIXING AND POTENTIAL FIRE. INCREASED LOCAL TEMPERATURE AND DECREASED VOLTAGE IN AFFECTED CELL.

(B) INTERFACING SUBSYSTEM(S):

DEGRADATION OF INTERFACE FUNCTION - REDUCED ELECTRICAL POWER SUPPLY TO EPD&C.

(C) MISSION:
NO EFFECT AFTER LOSS OF ONE FUEL CELL. MINIMUM DURATION MISSION INVOKED.

(D) CREW, VEHICLE, AND ELEMENT(S):
CREW IS REQUIRED TO SHUTDOWN AND SAFE AFFECTED FCP WHEN DETECTED. POSSIBLE LOSS OF CREW/VEHICLE IF GROSS LEAKAGE IS UNDETECTED.

(E) FUNCTIONAL CRITICALITY EFFECTS

- DISPOSITION RATIONALE -

(A) DESIGN:
INTERNAL LEAKAGE (REACTANT CROSSOVER) IS THE WEAROUT FAILURE MODE OF THE INDIVIDUAL CELLS. HOWEVER, THIS IS EXPECTED TO OCCUR IN THE 3000 TO 5000 HOUR TIME PERIOD RATHER THAN THE 2000 TO 2500 HOUR OPERATING LIFE OF THE FUEL CELL POWER SECTION.

THEREFORE, THE TENDENCY IF THIS FAILURE MODE WERE TO OCCUR WOULD BE FOR A TOLERABLE LOW LEVEL OR "PINHOLE" LEAK TO OCCUR LATE IN THE LIFE OF THE UNIT. HOWEVER, LATENT DEFECTS IN A CELL OR SEPARATOR PLATE COULD ESCAPE THE SCREENING PROCESS RESULTING IN A CROSSOVER LEAK EARLIER IN THE LIFE CYCLE OF THE FUEL CELL.

TO AID IN DETECTION OF THIS FAILURE MODE, CELL PERFORMANCE MONITOR INSTRUMENTATION HAS BEEN ADDED INCLUDING ALARM LEVELS SET SUFFICIENTLY LOW TO PERMIT SHUTDOWN AND ISOLATION PRIOR TO INCURRING FUEL CELL OR VEHICLE DAMAGE.

THE CELL ELECTROLYTE MATRIX IS DESIGNED TO WITHSTAND PRESSURES 8 TO 10 TIMES GREATER THAN OPERATING CONDITIONS. THE SEPARATOR PLATES ARE MAGNESIUM WITH A NICKEL PLATING FOR CORROSION PROTECTION AND AN OUTER GOLD PLATING TO MINIMIZE ELECTRICAL CONTACT RESISTANCE.

THE THERMAL CONTROL SYSTEM IS DESIGNED WITH A GREATER THAN 20 DEG F CONDENSER EXIT TEMPERATURE MARGIN FOR CONTROLLING ELECTROLYTE DRYOUT.

THE PRESSURE REGULATOR IS DESIGNED TO PRECLUDE PRESSURE IMBALANCE SUFFICIENT TO OVERCOME BUBBLE PRESSURE OF MATRIX. EXCESSIVE PRESSURE DETECTABLE BY COOLANT PRESSURE MEASUREMENT ON EACH FCP. VENT SYSTEM RELIEF FLOW CAPABILITY IS GREATER THAN SUPPLY FLOW CAPABILITY.

(B) TEST:
CELL ASSEMBLY AND SEPARATOR PLATE ARE HELIUM LEAK CHECKED AT 8 PSID (NORMAL PRESSURE 4-6 PSID). INDIVIDUAL SEPARATOR PLATE INTEGRITY IS TESTED AT 100 PSI PLUS X-RAY AND VISUALLY INSPECTED TO STANDARDS PRIOR TO ASSEMBLY.

EACH CELL IS EVALUATED FOR ELECTRICAL PERFORMANCE AT ASSEMBLY. POWER SECTION EXTERNAL LEAKAGE DECAY TEST AT SYSTEM PRESSURE (QUALIFICATION AND ATP).

ATP VERIFIES PROPER THERMAL CONTROL TO ASSURE ADEQUATE ELECTROLYTE VOLUME MAINTENANCE. INDIVIDUAL CELLS ARE WEIGHED DURING MANUFACTURE TO ASSURE PROPER ELECTROLYTE FILL.

CMRSD: N2 DIAGNOSTIC TEST IS PERFORMED DURING TURNAROUND TO DETECT LOW-LEVEL CROSSOVER UP TO SEVERAL HUNDRED HOURS PRIOR TO REACHING SIGNIFICANT LEVELS WHICH MIGHT AFFECT PERFORMANCE OR SAFETY. FUEL CELL PERFORMANCE VERIFIED DURING PRELAUNCH ONLOAD OPERATIONS.

(C) INSPECTION:
RECEIVING INSPECTION
DIMENSIONAL INSPECTIONS ARE PERFORMED DURING RECEIVING, IN-PROCESS, AND ACCEPTANCE SEQUENCES. MATERIAL LOT SAMPLES ARE FORWARDED TO A TEST LAB FOR CERTIFICATION ANALYSIS. WELD FILLER METAL IS CERTIFIED BY LAB TESTING AND MATERIAL CONTROL LAB SPECIFICATIONS.

CONTAMINATION CONTROL
DETAIL PARTS AND ASSEMBLIES ARE SOLVENT CLEANED PER APPROVED PROCEDURES AND DOUBLE BAGGED AS REQUIRED TO PREVENT CONTAMINATION. ASSEMBLY OPERATIONS ARE PERFORMED UNDER CONTROLLED CONDITIONS USING PROCEDURES WHICH MAINTAIN CLEANLINESS AND WHICH SPECIFY APPROPRIATE HANDLING PRECAUTIONS. CLEANLINESS OF OPERATING/TEST FLUIDS IS MAINTAINED THROUGH SAMPLING AND/OR FILTRATION. THE ASSEMBLED FUEL CELL UTILIZES CAPS OR CLOSURES ON ALL FLUID FITTINGS AND THE SHIPMENT/STORAGE OF THE FUEL CELL IS IN A NITROGEN PRESSURIZED METAL SHIPPING CONTAINER.

ASSEMBLY/INSTALLATION
CELL FILLING AND POWERSECTION ASSEMBLY ARE PERFORMED IN AN ATMOSPHERICALLY CONTROLLED CHAMBER USING FEED-THRU GLOVES. STACKING AND TORQUING OPERATIONS UTILIZE A FIXTURE FOR ALIGNMENT AND HYDRAULIC PRESSURE CONTROL FOR ESTABLISHING PROPER CONTACT PRESSURE (COMPRESSIVE LOAD) PRIOR TO TIEROD INSTALLATION. ALL CRITICAL ASSEMBLY OPERATIONS WITNESSED AND VERIFIED BY QC.

NONDESTRUCTIVE EVALUATION
CELL ELECTROLYTE MATRIX IS LIGHT BOX AND VISUALLY INSPECTED PRIOR TO ASSEMBLY. SEPARATOR PLATES ARE X-RAYED AND VISUALLY INSPECTED.

TESTING
CELL PERFORMANCE REQUIREMENTS ARE VERIFIED DURING ATP.

(D) FAILURE HISTORY:
CAR NO. AC9940-010 SUPPLIER, RE-ATP
CELL NUMBERS 22 AND 23 EXHIBITED SUBSTANDARD PERFORMANCE. THE CAUSE WAS A RESULT OF A LEAK PATH WITHIN A COMBO SEPARATOR WHICH WAS LOCATED BETWEEN THE TWO CELLS. A COMBINATION OF POROSITY AND/OR INCLUSION

WITHIN THE MAGNESIUM BASE ALLOY AND MICRO CRACKS IN THE PROTECTIVE NICKEL PLATING PROVIDED THE LEAK PATH.
THE PROBLEM WAS CLOSED AS "EXPLAINED" WITH THE FOLLOWING RATIONALE: LOW LEVEL CROSSOVER LEAKAGE WILL IMMEDIATELY REACT DUE TO CATALYST ACTION PRECLUDING REACTANT ACCUMULATION. THIS WILL RESULT IN A DEGRADATION OF CELL VOLTAGE WHICH IS DETECTABLE BY THE CELL PERFORMANCE MONITOR PRIOR TO AND DURING A FLIGHT. IN ADDITION, A FUEL CELL POWERPLANT DIAGNOSTIC TEST WHICH IS CAPABLE OF DETECTING VERY MINUTE LEVELS OF REACTANT CROSSOVER IS PERFORMED ON ALL POWERPLANTS PRIOR TO EVERY FLIGHT.

CAR NO. AC9841-010 SUPPLIER, RE-ATP
CELL #31 EXHIBITED UNSATISFACTORY NITROGEN DECAY CHARACTERISTICS. THE CAUSE WAS A RESULT OF CROSS LEAKAGE AT CELL #31 DUE TO A THIN SPOT IN THE ASBESTOS MATRIX OF THE UNTITIZED ELECTRODE ASSEMBLY. THE THIN SPOT IS BELIEVED TO HAVE BEEN A RESULT OF A MANUFACTURING DEFECT NOT DETECTED DURING VISUAL EXAMINATIONS.
CORRECTIVE ACTION INCLUDED INCORPORATION OF A PREFLIGHT DIAGNOSTIC TEST INTO THE OMRSD. THIS TEST WILL EFFECTIVELY SCREEN ANY POWERPLANTS EXHIBITING REACTANT CROSSOVER LEAKAGE. THE SUBCONTRACTOR IS ALSO INVESTIGATING THE USE OF AN OPTICAL SCANNER WHICH HAS BEEN FOUND TO BE EFFECTIVE AT DETECTING FLAWS WITHIN NEWLY MANUFACTURED ASBESTOS MATRICES.

(E) OPERATIONAL USE:
CELL PERFORMANCE MONITOR PROVIDES CREW ALERT FOR EARLY DETECTION OF THIS FAILURE. CREW ACTION IS REQUIRED TO SHUTDOWN AND SAFE AFFECTED FUEL CELL. ONBOARD PROCEDURES MANAGE POWER FOR LOSS OF ONE FCP.

- APPROVALS -

RELIABILITY ENGINEERING	G. M. PIRUS	
DESIGN ENGINEERING	J. F. WILLIAMS	2-17-89
QUALITY ENGINEERING	J. COURSEN	2-21-89
NASA RELIABILITY		3/6
NASA SUBSYSTEM MANAGER		
NASA QUALITY ASSURANCE		3/27/89