

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

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

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PART DATA

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	PART NAME	PART NUMBER
	VENDOR NAME	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

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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.

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SUBSYSTEM NAME: ELECTRICAL POWER GENERATION: FUEL CELL

LRU: FUEL CELL POWERPLANT

CRITICALITY OF THIS

ITEM NAME: FUEL CELL POWERPLANT

FAILURE MODE: 1R2

FAILURE MODE:

LOSS OF FCP POWER DUE TO CELL FLOODING.

MISSION PHASE: LO LIFT-OFF  
DO DE-ORBIT

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

CAUSE:

H2 PUMP SEPARATOR INOPERATIVE, BLOCKED SEPARATOR PLATE PORTS, WATER DISCHARGE LINES BLOCKED, THERMAL CONTROL ASSEMBLY FAILURES RESULTING IN WETTER THAN NORMAL ELECTROLYTE CONCENTRATION, INADEQUATE PRESSURE CONTROL

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN A) PASS  
B) PASS  
C) PASS

PASS/FAIL RATIONALE:

A)

B)

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

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LOSS OF REDUNDANCY - LOSS OF FCP DUE TO CELL FLOODING. CREW ACTION  
REQUIRED TO SHUT DOWN FCP TO PRECLUDE POSSIBLE VEHICLE DAMAGE.

**(B) INTERFACING SUBSYSTEM(S):**

DEGRADATION OF INTERFACE FUNCTION - REDUCED POWER SUPPLY TO EPD&C AND  
POSSIBLE CONTAMINATION OF PRODUCT WATER TO ECLSS.

**(C) MISSION:**

NO EFFECT. MINIMUM DURATION MISSION INVOKED. LOSS OF FUEL CELL REDUNDANCY.  
(CAPABILITY EXISTS FOR SAFE RETURN ON ONE OF THREE FUEL CELLS)

**(D) CREW, VEHICLE, AND ELEMENT(S):**

NO EFFECT ON CREW/VEHICLE AFTER LOSS OF ONE FCP. LOSS OF TWO FCP'S DURING  
ASCENT WILL RESULT IN LOSS OF CREW/VEHICLE. LOSS OF A SECOND FCP DURING  
DESCENT LOSES CREW/VEHICLE IF INSUFFICIENT TIME IS AVAILABLE FOR AN  
ELECTRICAL LOAD RECONFIGURATION RESULTING IN THE INABILITY OF THE SINGLE  
REMAINING FUEL CELL TO SUPPLY ADEQUATE ELECTRICAL POWER

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

SAME AS (D).

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

H2 PUMP, SEPARATOR AND MOTOR UTILIZE A SINGLE ROTATING SHAFT ON TWO  
KRYTOX LUBRICATED BALL BEARINGS. MOTOR HAS A CANNED STATOR; A BACK  
PRESSURE REGULATOR FUNCTIONING AS A PRODUCT WATER DISCHARGE VALVE  
ALLOWS WATER, NOT GAS, TO DISCHARGE.

THE HOUSINGS AND IMPELLER ARE CONSTRUCTED OF 7075-T73 ALUMINUM (ANODIZED).  
THE WATER SEPARATOR IS CONSTRUCTED OF 347 STAINLESS STEEL.

THE WATER DISCHARGE VALVE IS CONSTRUCTED OF 17-4PH STAINLESS STEEL.  
DISCONNECTS HAVE A RETAINER CLIP WHICH FUNCTIONS AS A BACKUP LOCKING  
DEVICE TO PREVENT UNCOUPLING WHEN DISCONNECTS ARE IN MATED CONDITION.  
CRITICAL COMPONENTS ARE PROTECTED BY FILTERS.

SEPARATOR PLATES HAVE MULTIPLE FLOW PORTS WHICH REDUCE THE PROBABILITY  
OF WATER OR CONTAMINATION BLOCKAGE.

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THERMAL CONTROL ACTUATORS HAVE MACHINED GROOVES TO PREVENT FLUID ENTRAPMENT. BOOT MATERIAL IS PRESOAKED IN COOLANT AND FUEL CELLS ARE SHIPPED AND STORED WITH THEIR COOLANT SYSTEMS SERVICED WITH FC-40 TO PRECLUDE SET POINT SHIFTS DURING OPERATION.

REGULATOR DESIGN MAINTAINS REACTANT PRESSURE BALANCE AT ALL FLOW CONDITIONS.

**(B) TEST:**

H2 PUMP AND DISCONNECTS EXPOSED TO MULTIPLE VIBRATION TESTS DURING DEVELOPMENT AND QUALIFICATION TESTING. PUMP SUCCESSFULLY PASSED 2000 HOUR LIFE TEST DURING QUALIFICATION.

ATP VERIFIES PROPER THERMAL CONTROL, WATER REMOVAL, AND PRESSURE CONTROL FUNCTIONS AS WELL AS ASSURING PROPER POWERSECTION PERFORMANCE. PRELAUNCH AND POSTFLIGHT ANALYSIS ESTABLISHES ACCEPTABLE CONTROL SYSTEM OPERATION AND WATER REMOVAL INCLUDING FLOW TO THE ECLSS WATER STORAGE TANKS.

PREFLIGHT CHECKS ARE USED TO VERIFY PROPER THERMAL AND PRESSURE CONTROL WITH NO H2 PUMP WATER BUILD-UP.

OMRSD: WATER RELIEF FLOW CAPABILITY VERIFIED DURING OMDP. ALTERNATE WATER PATH FUNCTIONAL VERIFICATION IS PERFORMED EVERY TURNAROUND. FCP PERFORMANCE IS VERIFIED DURING PRELAUNCH OPERATIONS.

**(C) INSPECTION:**

**RECEIVING INSPECTION**

DIMENSIONAL INSPECTIONS ARE PERFORMED AT 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**

ALL TORQUING OPERATIONS ARE VERIFIED BY QC. INLET/OUTLET ACCESS TUBES BRAZING PROCESS AND SEQUENCE IS VERIFIED BY INSPECTION. ALL SOLDER CONNECTIONS ARE VISUALLY INSPECTED AT A MINIMUM OF 4X MAGNIFICATION IN ACCORDANCE WITH NHB 5300.4 (3A).

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NONDESTRUCTIVE EVALUATION  
RADIOGRAPHIC INSPECTION PERFORMED ON ALL WELDS AND WELD REPAIRS.

TESTING  
FUNCTIONAL AND LEAKAGE REQUIREMENTS ARE VERIFIED DURING ACCEPTANCE TEST.  
RESULTS OF THE ATP ARE OBSERVED AND VERIFIED BY QC.

(D) FAILURE HISTORY:  
CURRENT DATA ON TEST FAILURES, FLIGHT FAILURES, UNEXPLAINED ANOMALIES, AND OTHER FAILURES EXPERIENCED DURING GROUND PROCESSING ACTIVITY CAN BE FOUND IN THE PRACA DATA BASE.

CAR NO. AB1457-010 SUPPLIER, ATP  
CELL #1 EXHIBITED A DEGRADATION IN PERFORMANCE. THE CAUSE OF DEGRADATION WAS A RESULT OF PORT BLOCKAGE DUE TO WATER DROPLETS FROM THE POWERPLANT'S ACCESSORY SECTION. THE WATER DROPLETS TRAVELED TO THE BOTTOM OF THE STACK (CELL NO. 1) DURING HANDLING OF THE POWERPLANT WHILE THE THERMAL CONTROL VALVE CARTRIDGES WERE BEING REPLACED. CORRECTIVE ACTION INCLUDED: REVISION OF THE SUBCONTRACTOR'S HANDLING PROCEDURES TO PRECLUDE PORT BLOCKAGE BY RESIDUAL WATER DROPLETS, AND REVISION TO THE SHUTTLE INFORMATION MEMORANDUM (SIM) NO. 007, "ORBITER FCP HANDLING PRECAUTIONS, RESIDUAL WATER".

CAR NO. AB4074-010 SUPPLIER, ATP  
HIGH AC POWER CONSUMPTION WAS OBSERVED DURING FCP STARTUP AND A RUBBING SOUND WAS HEARD FROM THE H2 PUMP/SEPARATOR ASSEMBLY. A 1/4 INCH PARTICLE, IDENTIFIED AS LOCTITE, WAS FOUND WITHIN THE H2 PUMP/SEPARATOR. THIS PARTICLE WAS DETERMINED TO BE THE CAUSE FOR THE ANOMALY. CORRECTIVE ACTION TAKEN BY THE SUBCONTRACTOR WAS TO ASSURE THAT EXCESSIVE AMOUNTS OF LOCTITE ARE NOT USED DURING PUMP ASSEMBLY.

CAR NO. AB6070-010 SUPPLIER, POST QUALIFICATION  
ONE OF THREE ASPIRATORS DRIVEN BY THE PUMP WATER SEPARATOR SYSTEM WAS OBSERVED TO BE INOPERATIVE. THE ASPIRATOR WAS FOUND TO BE BLOCKED BY A CONTAMINANT, MOST LIKELY TO BE CONFORMAL COATING INTRODUCED INTO THE FCP DURING RETROFIT FROM THE RIGHT-HAND TO THE LEFT-HAND CONFIGURATION. CORRECTIVE ACTION WAS TO IMPROVE CONTAMINATION CONTROL IN ALL FACETS OF ASSEMBLY OPERATIONS. ASSEMBLY PROCEDURES FOR THE HYDROGEN PUMP/SEPARATOR HAVE BEEN REVISED TO REQUIRE MORE ATTENTION TO THE PREVENTION OF CONTAMINATION. DOCUMENTS CONTROLLING THE CLEANLINESS OF THE ASSEMBLY AREA (ECP8.4.16 AND ECP8.4.18) HAVE BEEN REVIEWED AND REVISED TO ELIMINATE AMBIGUITIES IN THE CLEANLINESS REQUIREMENTS. THE REQUIREMENTS OF THESE DOCUMENTS HAVE BEEN VIGOROUSLY ENFORCED.

CAR NO. 02F001-010 OV-102, STS-2 MISSION  
THE H2 PUMP/SEPARATOR RIM ASPIRATOR WAS BLOCKED BY COMTAMINATION WHICH RESULTED IN FUEL CELL POWERPLANT FLOODING DURING OV-102 FLIGHT 2 (STS-2 MISSION).

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CORRECTIVE ACTION INCLUDED ASPIRATOR NOZZLES INSPECTION ON ALL FUEL CELL POWERPLANTS FOR CONTAMINATION AND H2 PUMP AC POWER MONITORING TO DETECT IRREGULARITIES.

(E) OPERATIONAL USE:

CREW ACTION IS REQUIRED TO SHUTDOWN AND/OR SAFE AFFECTED FCP DURING FLIGHT. ONBOARD PROCEDURES MANAGE POWER FOR LOSS OF ONE OR TWO FCP(S).

- APPROVALS -

PAE MANAGER : D. F. MIKULA  
PRODUCT ASSURANCE ENGR : L. X. DANG  
DESIGN ENGINEERING : MUSTIN, LLOYD  
NASA SSMA :  
NASA SUBSYSTEM MANAGER :

*D.F. Mikula 29 Mar 96*  
*L. X. Dang 3/29/96*  
*John Anderson 3-28-96*  
*SP3 G. J. ... 6/16/97*  
*Richard L. ... 6/16/97*