

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 COOLANT, COOLANT FLOW OR FLOW CONTROL

MISSION PHASE: LO LIFT-OFF

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

CAUSE:

COOLANT PUMP FAILURE; COMPONENT/SEAL EXTERNAL LEAKAGE; COMPONENT INTERNAL LEAKAGE; BLOCKAGE IN CONDENSER, FILTER, ACCUMULATOR, PREHEATER, STARTUP AND SUSTAINING HEATER, PLUMBING AND DISCONNECTS, OR THERMAL CONTROL VALVE (TCV) ASSEMBLY; TCV ASSEMBLY FAILURES AFFECTING FCP THERMAL BALANCE.

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 - CREW ACTION REQUIRED TO SHUT DOWN AFFECTED FCP TO PRECLUDE POSSIBLE VEHICLE OR FCP DAMAGE. UNDETECTED LOSS OF COOLANT OR COOLANT FLOW MAY RESULT IN STACK OVERHEAT CONDITION. THIS CONDITION MAY RESULT IN GROSS EXTERNAL LEAKAGE OF REACTANTS DUE TO LOSS OF POWER SECTION SEAL INTEGRITY (REF. 04-1A-0101-4). UNDETECTED FLOW CONTROL FAILURE MAY RESULT IN DRYER THAN NORMAL ELECTROLYTE CONCENTRATION, LEADING TO POSSIBLE REACTANT CROSSOVER (REF. 04-1A-0101-9), OR WETTER THAN NORMAL ELECTROLYTE CONCENTRATION, LEADING TO FLOODING CONDITION. (REF. 04-1A-0101-3)

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

DEGRADED INTERFACE FUNCTION - REDUCED POWER SUPPLY TO EPD&C WHEN FCP SHUT DOWN.

**(C) MISSION:**

NO EFFECT. MINIMUM DURATTION MISSION INVOKED.

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

CREW ACTION REQUIRED TO IMPLEMENT CORRECTIVE ACTION. UNDETECTED FAILURE MAY RESULT IN VEHICLE DAMAGE DUE TO IGNITION OF REACTANTS. LOSS OF TWO FUEL CELLS DURING ASCENT WILL RESULT IN LOSS OF CREW/VEHICLE.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

ORBITER COOLING PUMP IS A CENTRIFUGAL IMPELLER PUMP. HOUSING IS CAST FROM 356-16 ALUMINUM. IMPELLERS ARE CONSTRUCTED FROM 6061-T651 ALUMINUM. O-RINGS ARE VITON.

FILL AND DRAIN CRES DISCONNECTS HAVE CRES SEALING CAP WITH VITON O-RING TO PROVIDE REDUNDANT SEAL. FLEX HOSES CONSIST OF CONVOLUTED CRES 321 INNERCORE COVERED BY A LAYER OF 321 CRES BRAID.

CONDENSER IS CONSTRUCTED OF 347 STAINLESS STEEL. ACCUMULATOR BLADDER IS CONSTRUCTED OF BUTYL RUBBER WITH 347 STAINLESS STEEL HOUSING. STAINLESS STEEL PREHEATER IS A LIQUID-TO-GAS DOUBLE PIPE HEAT EXCHANGER WITH TWO

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INDEPENDENT REACTANT HEATERS (LIQUID SIDES IN SERIES). POPPETS IN DISCONNECTS ARE PHYSICALLY HELD OPEN IN MATED MODE.

THERMAL CONTROL VALVE ASSEMBLY MAINTAINS THERMAL CONDITIONS IN FCP NECESSARY FOR PROPER PERFORMANCE. BODY IS CONSTRUCTED OF 2024-T6 ALUMINUM. ACTUATOR HOUSING IS CONSTRUCTED OF 6061-T6. ACTUATOR PISTONS ARE OF 303 STAINLESS STEEL. ACTUATOR FILLING IS ACTROFILL 1241. O-RINGS ARE VITON.

STARTUP/SUSTAINING HEATERS ARE CONTAINED WITHIN AN OUTER HOUSING THROUGH WHICH COOLANT FLOWS. HEATERS ARE ACTIVATED THROUGH ELECTRICAL CONTROL UNIT BY THE STACK EXIT TEMPERATURE TRANSDUCER. COOLANT SYSTEM MATERIALS ARE COMPATIBLE WITH INERT FC-40 COOLANT TO MINIMIZE CONTAMINATION GENERATION.

CRITICAL COMPONENTS PROTECTED BY FILTERS. FILTERS ARE SIZED TO ALLOW ADEQUATE FLOW WHEN PARTIALLY CLOGGED.

**(B) TEST:**

ALL COMPONENTS ARE PROOF TESTED TO TWICE MAXIMUM WORKING PRESSURE. ALL LINES AND COMPONENTS WITHSTOOD EXTENSIVE PRESSURE CYCLING DURING DEVELOPMENT PROGRAM. DEVELOPMENT VIBRATION TESTING GREATER THAN 10 TIMES EQUIVALENT DAMAGE OR ACCUMULATED ENERGY LEVELS EXPERIENCED IN FLIGHT. FLEXURE FATIGUE CERTIFICATION TESTING PERFORMED ON LINES: 200K IMPULSE FATIGUE CYCLES, 10,000K FLEXURE FATIGUE CYCLES.

ATP VERIFIES PROPER THERMAL CONTROL FUNCTION, HEAT REJECTION, AND COOLANT LOOP LEAKAGE INTEGRITY.

PRELAUNCH AND POSTFLIGHT ANALYSIS ESTABLISH ACCEPTABLE THERMAL CONTROL SYSTEM PERFORMANCE, HEAT REJECTION AND COOLANT LOOP LEAKAGE INTEGRITY.

OMRSD: GROUND CHECKS VERIFY COOLANT SYSTEM LEAKAGE INTEGRITY DURING OMDP. PRELAUNCH FUEL CELL OPERATIONS VERIFY PROPER THERMAL CONTROL, SYSTEM FUNCTION AND HEAT REJECTION CAPABILITY.

**(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

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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 ARE VERIFIED BY INSPECTION. ALL SOLDER CONNECTIONS ARE VISUALLY INSPECTED AT A MINIMUM OF 4X MAGNIFICATION IN ACCORDANCE WITH NHB 5300.4 (3A).

**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. A5180-010 SUPPLIER, ATP  
ATP A5256-010 SUPPLIER,  
A5257-010 SUPPLIER, ATP

A5258-010 SUPPLIER,  
ATP A8435-010 EDW, FREE FLIGHT

5 INSTANCES OF EXCESSIVE COOLANT SYSTEM CONTAMINATION. THREE OF THE CASES RESULTED IN OUT-OF-LIMIT THERMAL CONTROL OPERATION. THE CAUSE FOR THE EXCESS CONTAMINATION WAS A RESULT OF IMPROPER DESCALING AND CLEANING OF THE CONDENSER H2 AND COOLANT PASSAGES. CORRECTIVE ACTION IMPOSED NEW CONDENSER MANUFACTURING PROCESSES WHICH ELIMINATED THE CONTAMINATION PROBLEM.

CAR NO. AC0581-010 SUPPLIER, ATP  
FCP H2 AND COOLANT PUMPS WERE DETECTED TO BE OPERATING ON 2 OF 3 PHASES OF POWER. THE CAUSE WAS ISOLATED TO BE WITHIN THE ELECTRICAL CONTROL UNIT, BUT THE FAILURE WITHIN COULD NOT BE VERIFIED. THE ELECTRICAL CONTROL UNIT WAS DESTROYED AND THE PROBLEM CLOSED OUT AS AN ISOLATED CASE.

CAR NO. AC5006-010 SUPPLIER, ATP  
FCP CONDENSER EXIT TEMPERATURE CONTROL VALVE SCHEDULE SHIFTED DOWNWARD OUT OF SPECIFICATION. TO PRECLUDE CALIBRATION SHIFTS, CONTROL VALVE CARTRIDGES AND BOOTS ARE SOAKED IN FC-40 COOLANT FOR 2 WEEKS AT PRESSURE AND TEMPERATURE. FOR THESE PARTICULAR BOOTS THE TWO WEEK PERIOD WAS INSUFFICIENT TO FULLY CONDITION THE RUBBER MATERIAL. THE PROBLEM WAS CLOSED AS "EXPLAINED" WITH THE FOLLOWING RATIONALE: SHIFTS IN TCV CONTROL SCHEDULES DUE TO INADEQUATE ACTUATOR BOOT CONDITIONING ARE ATP SCREENABLE AS VERIFIED BY THE FAILURE HISTORY. SLIGHT SHIFTS, IF ENCOUNTERED, AFFECT CALIBRATION ONLY.

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CAR NO. AC5933-010 SUPPLIER, ATP

FCP CONDENSER EXIT AND STACK INLET TEMPERATURES WERE DETECTED TO BE BELOW LOWER LIMITS. THE OUT OF SPECIFICATION CONDITION WAS ISOLATED TO SWELLING OF THE CONTROL VALVE ACTUATORS' RUBBER BOOTS. THE CAUSE OF SWELLING WAS DETERMINED TO BE A RESULT OF CLEANING WITH FREON R AFTER COMPONENT ATP. CORRECTIVE ACTION INCLUDED DISCONTINUING THE USE OF FREON R AS A CLEANING FLUID, AND CONDUCTING AS RECEIVED SCREENING TESTS OF VALVES AND CARTRIDGES. NO ACTION IS REQUIRED ON DELIVERED HARDWARE AS SHIFTS IN TCV CONTROL SCHEDULES DUE TO FREON INDUCED SWELLING ARE SCREENABLE DURING END-ITEM ATP.

CAR NO. AD1006-010 SUPPLIER, RE-ATP

FCP STACK INLET TEMPERATURE WAS DETECTED TO HAVE EXCEEDED ITS UPPER LIMIT WHILE OPERATING AT 12 KW. THE OUT OF SPECIFICATION CONDITION WAS ISOLATED TO A 40% REDUCTION IN THE MAXIMUM AVAILABLE FLOW THROUGH THE FLOW CONTROL VALVE CARTRIDGE. THE CAUSE FOR THE REDUCED FLOW CAPABILITY IS THE RESULT OF ELASTOMER BOOT DRYOUT. CORRECTIVE ACTION INCLUDED SHIPPING AND STORING VALVE ACTUATORS, COMPLETED VALVE CARTRIDGES, AND THERMAL CONTROL VALVE ASSEMBLIES COMPLETELY WETTED WITH FC-40. IN ADDITION, FUEL CELL POWERPLANTS ARE NOW SHIPPED AND STORED WITH THEIR COOLANT SYSTEMS SERVICED WITH FC-40.

CAR NO. 30F004-010 KSC, OV-089, PRELAUNCH

FCP #1 EXPERIENCED CONDENSER EXIT TEMPERATURE CYCLING BETWEEN 160 AND 123 DEG F. AFTER LAUNCH, CYCLING WAS NOMINAL BETWEEN 150 AND 160 DEG F. A STICKING CONDENSER EXIT THERMAL CONTROL VALVE WAS SUSPECT SINCE, THE POWERPLANT WAS STORED DRY FOR APPROXIMATELY ONE YEAR FOLLOWING ITS ACCEPTANCE TEST. DRY STORAGE RESULTED IN ALTERED VALVE OPERATION DUE TO A CHANGE IN THE VALVE CARTRIDGE'S RUBBER BOOT CHARACTERISTICS. THE PROBLEM WAS CLOSED AS "EXPLAINED" WITH THE FOLLOWING RATIONALE: FUEL CELLS INSTALLED IN VEHICLES HAVE BEEN FLOWN WITH NO INDICATION OF A SIMILAR PROBLEM EXISTING. IN THE EVENT OF A NEED TO REPLACE A POWERPLANT, THE INTEGRITY OF THE REPLACEMENT WOULD BE VERIFIED DURING PRELAUNCH OPERATIONS. THE PROBLEM ONLY AFFECTS POWERPLANTS WHICH HAVE HAD THEIR COOLANT LOOPS DRY OVER A SUSTAINED PERIOD OF TIME. CORRECTIVE ACTION INCLUDED: SHIPPING AND STORING VALVE ACTUATORS, COMPLETED VALVE CARTRIDGES, AND THERMAL CONTROL VALVE ASSEMBLIES COMPLETELY WETTED WITH FC-40. IN ADDITION, FUEL CELL POWERPLANTS ARE NOW SHIPPED AND STORED WITH THEIR COOLANT SYSTEMS SERVICED WITH FC-40.

CAR NO. AB5470-010 KSC, OV-102, GROUND CHECK

FCP #3 COOLANT LOOP VERIFICATION REVEALED 17 CUBIC INCHES OF ULLAGE. SHOULD BE 27 +/- 2 CUBIC INCHES. LEAKAGE COULD NOT BE VERIFIED USING HALOGEN LEAK DETECTOR. NO CORRECTIVE ACTION SINCE LEAKAGE COULD NOT BE VERIFIED. VOLUME WILL BE CHECKED PERIODICALLY FOR SIGNS OF LEAKAGE. NOTE: THIS INCIDENT OCCURRED PRIOR TO THE IMPLEMENTATION OF HALOGEN LEAK DETECTION BY THE SUBCONTRACTOR, MODIFIED PROCEDURES AND LEAKAGE CRITERIA AT KSC, AND COOLANT VOLUME VERIFICATION EVERY TURNAROUND.

CAR NO. AB8139-010 KSC, OV-102, GROUND CHECK

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FCP COOLANT LOOP VERIFICATION REVEALED 22 CUBIC INCHES OF ULLAGE. SHOULD BE 27 +/- 2 CUBIC INCHES. CORRECTIVE ACTION INCLUDED APPROVAL OF RCN JV1865 ALLOWING A LEAK RATE OF 1 CUBIC INCH PER MONTH. NOTE: THIS INCIDENT OCCURRED PRIOR TO THE IMPLEMENTATION OF HALOGEN LEAK DETECTION BY THE SUBCONTRACTOR, MODIFIED PROCEDURES AND LEAKAGE CRITERIA AT KSC, AND COOLANT VOLUME VERIFICATION EVERY TURNAROUND.

CAR NO. AC4118-010 KSC, OV-102, GROUND CHECK  
FCP #1 COOLANT LOOP VERIFICATION REVEALED 23 CUBIC INCHES OF ULLAGE. SHOULD BE 27 +/- 2 CUBIC INCHES. SUBSEQUENT LEAK CHECKS RESULTED IN TOLERABLE LEAK RATES. A REVIEW OF LEAK RATE DATA REVEALED A LACK OF CORRELATION BETWEEN COOLANT LOSS AND TIME. CORRECTIVE ACTION INCLUDED INCORPORATION OF RCN OV5180M INTO THE OMRSD WHICH DELETED THE LEAK RATE CRITERIA IN FAVOR OF ABSOLUTE COOLANT QUANTITY LOSS LIMITS IN ORDER TO RELIABLY CHARACTERIZE THE FCP COOLANT SYSTEM QUANTITY AND QUALITY.

CAR NO. AC6529-010 KSC, OV-099, GROUND CHECK  
FCP #2 EXHIBITED A COOLANT PRESSURE DROP FROM 64.4 TO 44.8 PSI BETWEEN FLIGHTS OF OV-099. SHOULD BE 65 +/- 10 PSI. LEAKAGE WAS VERIFIED AND ISOLATED TO THE MAGNESIUM SEPARATOR PLATE BETWEEN CELLS 68 AND 70, THE SEALS OF WHICH SHOWED ABNORMAL COMPRESSION SET. THE EXCESSIVE COMPRESSION SET WAS ATTRIBUTED TO IMPROPER CURING. CORRECTIVE ACTION INCLUDED TIGHTER CONTROL ON THE SEAL MANUFACTURING PROCESSES AT THE SEAL MANUFACTURER. CHANGES INCLUDED: 1) RUBBER STOCK IS TESTED EVERY 30 DAYS AND BATCHES PROCURED IN SMALLER QUANTITIES AND MAINTAINED IN CONTROLLED STORAGE. 2) A MEANS WAS DEvised TO PREVENT THE MOLD CYCLE FROM BEGINNING UNTIL THE PROPER MOLD TEMPERATURE IS REACHED. THE TEMPERATURE SENSOR HAS ALSO BEEN RELOCATED TO THE MOLD ITSELF AND A STRIP CHART IS NOW USED TO RECORD THE TIME AND TEMPERATURE OF EACH MOLDING PROCESS. 3) COMPRESSION SET TESTS OF MOLDED SEALS ARE PERFORMED ON A REGULAR BASIS.

CAR NO. AD0635-010 KSC, OV-102, GROUND CHECK  
FCP #1 COOLANT LOOP VERIFICATION REVEALED 26 CUBIC INCHES OF FC-40 HAD LEAKED FROM THE COOLANT SYSTEM OVER A PERIOD OF 25 DAYS. TROUBLESHOOTING ISOLATED THE LEAKAGE TO THE POWERSECTION, NEAR CELLS # 87 AND 88. DISASSEMBLY AND INSPECTION REVEALED THE SEALS IN BOTH H2 AND O2 SEPARATOR PLATES ADJACENT TO CELLS 87 AND 88 TO BE PARTIALLY UNBONDED. MACHINE TOOL MARKS APPROXIMATELY 1 MIL DEEP WERE ALSO OBSERVED IN THE H2 PLATE SEAL GROOVE. NO OTHER DISCREPANCIES WERE FOUND. A REVIEW OF THE FCP'S HISTORY INDICATED IT TO HAVE BEEN DISASSEMBLED AND REPAIRED. EXPERIENCE HAS SHOWN THAT DISASSEMBLY MAY CAUSE SOME OF THE RUBBER SEALS TO COME LOOSE FROM THE SEPARATOR PLATE GROOVES DUE TO LACK OF ADHESION. SUBSEQUENT THERMAL CYCLING OF THE STACK AFTER REBUILD NORMALLY ENSURES ADEQUATE SEALING. THE DETECTED LEAK WAS CONCLUDED TO HAVE BEEN CAUSED AS A RESULT OF THE PREVIOUS REPAIR OF THE POWERSECTION. THE TOOLING MARKS DISCOVERED IN THE H2 SEPARATOR PLATE CONTRIBUTED TO THE PROBLEM. THE SUPPLIER OF THE SEPARATOR PLATES HAS ISSUED A CORRECTIVE ACTION REQUEST WITH DIRECTION TO REVIEW THEIR INSPECTION PROCEDURES TO INSURE PROPER INSPECTION OF THE FINISH IN THE SEAL GROOVE AND TO INSURE THAT THEIR REQUIREMENTS INCLUDE THE REJECTION OF TOOL MARKS, SCRATCHES AND OTHER SURFACE DISCONTINUITIES.

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CAR NO. AD0852-010 SUPPLIER, RE-ATP  
FCP HYDROGEN CONDENSER EXIT TEMPERATURE CYCLING. THE CAUSE OF EXCESSIVE CYCLING WAS IDENTIFIED TO BE A COMBINATION OF THE FLOW CONTROL CARTRIDGE EXHIBITING A HIGH GAIN AND DETERIORATED CARTRIDGE METERING SURFACES WHICH WAS A RESULT OF CORROSION. THE CORROSION WAS ATTRIBUTED TO THE CARTRIDGES EXPOSURE TO HYDROFLUORIC ACID, WHICH OCCURRED WHEN IT WAS INSTALLED IN FCP S/N P760104 DURING A COOLANT OVERTEMPERATURE INCIDENT. CORRECTIVE ACTION INCLUDED SUBJECTING ALL FLOW CONTROL CARTRIDGES TO A FLOW GAIN TEST AT THE SUBCONTRACTOR WHICH WOULD SCREEN ANY CARTRIDGES WITH EXCESSIVE GAIN AND DETECT ANY SIGNIFICANT CARTRIDGE METERING SURFACE IRREGULARITIES. IN ADDITION, ALL HARDWARE WHICH MAY HAVE BEEN IN CONTACT WITH HYDROFLUORIC ACID (TWO INSTANCES OF COOLANT OVERTEMPERATURE CONDITIONS HAVE OCCURRED, 2/23/83 AND 4/29/83 ON FCP S/N P760104) HAS BEEN DISPOSITIONED AND APPROPRIATE CORRECTIVE ACTION TAKEN.

CAR NO. AD0859-010 KSC, OV-102, GROUND CHECK  
FCP #2 COOLANT LOOP VERIFICATION REVEALED A DROP IN SYSTEM PRESSURE AFTER EXTRACTION OF 10.3 CUBIC INCHES OF FC-40. THE SUBCONTRACTOR VERIFIED A LEAK RATE OF 1 DROP PER MINUTE AT THE THERMAL CONTROL VALVE CARTRIDGE. THE CAUSE OF LEAKAGE WAS AN O-RING AT THE CARTRIDGE INTERFACE WITH THE FOLLOWING DISCREPANCIES; 1) A GROOVE SIMILAR TO A MOLD PARTING LINE ON THE OUTER CIRCUMFERENCE OF THE SEAL. 2) THE O-RING WAS MADE OF BUNA-N RUBBER INSTEAD OF FLUOROCARBON (VITON) AS SPECIFIED. CORRECTIVE ACTION INCLUDED: 1) INITIATED AND RELEASED AN O-RING SPECIFICATION ESTABLISHING CONFIGURATION REQUIREMENTS AND LIMITATIONS INCLUDING PACKAGING AND MATERIALS TRACEABILITY IDENTIFICATION. 2) LOT SAMPLING PERFORMED OF MATERIAL SPECIFIC GRAVITY TO VERIFY PROPER MATERIAL. 3) DIMENSIONAL VERIFICATION OF LOT SAMPLES. 4) THE REQUIREMENT OF MATERIALS CERTIFICATION DATA (TENSILE, ELONGATION, ETC.).

## (E) OPERATIONAL USE:

FCP THERMAL PERFORMANCE IS VERIFIED DURING PRELAUNCH OPERATIONS. COOLANT PUMP DELTA PRESSURE SENSOR IS MANDATORY FOR LAUNCH. CREW ACTION REQUIRED TO SHUTDOWN AFFECTED FUEL CELL DURING FLIGHT. ONBOARD PROCEDURES MANAGE POWER FOR LOSS OF ONE FCP.

## - 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 31 29 196*  
*Lloyd Mustin 3-28-96*  
*Mustin, Lloyd 6/16/97*  
*Howard L. Meppner 6/16/97*