

**FAILURE MODES EFFECTS ANALYSIS (FMEA) - CRITICAL HARDWARE
NUMBER: 04-2-HR17-X**

SUBSYSTEM NAME: AUXILIARY POWER UNIT (APU)

REVISION: 6 01/10/94

	PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
LRU	: AUXILIARY POWER UNIT (APU) SUNDSTRAND	MC201-0001-02XX 729867XX/754949
LRU	: AUXILIARY POWER UNIT (APU) SUNDSTRAND	MC201-0001-03XX 729867XX/754949A
LRU	: AUXILIARY POWER UNIT (APU) SUNDSTRAND	MC201-0001-04XX 742211
LRU	: FUEL TANK HEATER COX & CO.	MC363-0025-000X 2744
LRU	: FUEL FEED LINE HEATER COX & CO.	MC363-0026-0XXX 2743-XX
LRU	: FUEL SERVICE/TEST LINE HEATER COX & CO.	MC363-0026-00XX 2743-XX
LRU	: FUEL DRAIN LINE HEATER COX & CO.	MC363-0026-000X 2743-XX
SRU	: FUEL LINE HEATER SUNDSTRAND	58886 SAME
SRU	: FUEL PUMP HEATER SUNDSTRAND	58902 SAME
SRU	: APU FUEL HEATERS SUNDSTRAND	59653 SAME

PART DATA

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
HEATER, APU SYSTEM FUEL LINES (HR1X6, HR1X7, HRX4, HRX5, HR1X1, HR1X2), TANK
(HRX1, HRX2), APU FUEL PUMP/VALVE (GGYM)/FUEL LINES

QUANTITY OF LIKE ITEMS: 3

1 DESCRIBED ABOVE PER APU SYSTEM, EACH WITH REDUNDANT ELEMENTS (A AND B)

FUNCTION:

TO MAINTAIN FUEL TEMPERATURE ABOVE 45 DEG-F TO PREVENT FUEL FROM
FREEZING. COCKPIT SWITCHES ON PANEL A12 ARE USED TO POWER HEATERS AND

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TO SELECT A OR B SYSTEMS. THERMOSTATS IN EACH SYSTEM AUTOMATICALLY
REGULATE TEMPERATURE.

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SUBSYSTEM NAME: AUXILIARY POWER UNIT (APU)
LRU: AUXILIARY POWER UNIT (APU), FUEL TANK, FUEL LINES CRITICALITY OF THIS
ITEM NAME: APU FUEL HEATERS FAILURE MODE: 1/1

FAILURE MODE:

SHORT TO GROUND OR WIRE TO WIRE SHORT OF HEATER ELEMENTS, LEAD WIRES,
TERMINAL BLOCKS OR ELECTRICAL CONNECTORS

MISSION PHASE:

PL PRELAUNCH
OO ON-ORBIT
LS LANDING SAFING

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

CAUSE:

ELECTRICAL INSULATION BREAKDOWN OR DAMAGE

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

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

PASS/FAIL RATIONALE:

A)
B)
C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

LOSS OF ONE OR MORE APU SYSTEMS IF EXCESSIVE HEAT APPLIED TO FUEL
LINES/COMPONENTS RESULTS IN FUEL DECOMPOSITION, RUPTURE AND EXTERNAL
LEAKAGE. LOSS OF HEATER REDUNDANCY IF SWITCHED TO ALTERNATE HEATER.

(B) INTERFACING SUBSYSTEM(S):

LOSS OF ONE OR MORE HYDRAULIC SYSTEMS. DAMAGE TO ADJACENT EQUIPMENT
DUE TO FIRE/EXPLOSION.

(C) MISSION:

ABORT DECISION IS REQUIRED.

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IF FAILURE IS DETECTED BY INSTRUMENTATION, THE FAULT DETECTION ANNUNCIATION (FDA) ALARM REQUIRES CREW RESPONSE TO SWITCH ALL APU HEATER SYSTEMS OFF IMMEDIATELY BEFORE FUEL DECOMPOSITION TEMPERATURE IS REACHED. POSSIBLE LOSS OF VEHICLE DUE TO FIRE/EXPLOSION IF FUEL DECOMPOSITION, RUPTURE AND EXTERNAL LEAKAGE OCCUR PRIOR TO CREW RESPONSE.

(E) FUNCTIONAL CRITICALITY EFFECTS:

NONE.

-DISPOSITION RATIONALE-

(A) DESIGN:

LINE HEATERS: UNITS ARE MANUFACTURED BY COX AND COMPANY. HEATING ELEMENT INSULATION IS MIL-W-81381. ELEMENTS FOR HEATER A & B ARE TWISTED TOGETHER AND COVERED BY SILICON INSULATION. TERMINAL BLOCK IS SILICON RUBBER. LEAD WIRES INSULATED WITH TEFLON. ALL EXTERNAL INSULATING MATERIALS ARE RESISTANT TO CORROSION AND/OR DETERIORATION WHEN IN CONTACT WITH HYDRAZINE OR OIL. ENVIRONMENTAL TEMPERATURE REQUIREMENT IS -65 DEG F TO 350 DEG F.

FUEL PUMP HEATER: HEATER UNIT HERMETICALLY SEALED. LEAD WIRES TEFLON INSULATED.

GGVM HEATER: FLAT ELEMENT RESISTANCE HEATER SANDWICHED BETWEEN LAMINATES. LEAD WIRES TEFLON INSULATED.

TANK HEATER: PAD HEATER WITH TEFLON INSULATED LEAD WIRES.

(B) TEST:

DIELECTRIC STRENGTH BETWEEN EXTERNAL SURFACE TO HEATER ELEMENT AND BETWEEN HEATER TO HEATER ELEMENT. INSULATION RESISTANCE BETWEEN EXTERNAL SURFACE TO EACH HEATER ELEMENT AND BETWEEN TWO HEATER ELEMENTS PER DRAWING REQUIREMENT.

OMRSD: APU 1/2/3 HEATER TEST BY COCKPIT COMMAND PERFORMED FIRST FLOW AND ON A CONTINGENCY BASIS THEREAFTER ANY TIME HEATER OR LINES ARE DISTURBED. FLIGHT DATA IS USED TO VERIFY HEATER OPERATION EVERY FLOW AFTER THE FIRST FLIGHT. ADDITIONALLY, BOTH A & B GAS GENERATOR (GG)/FUEL PUMP SYSTEMS ARE VERIFIED TO BE FUNCTIONING NOMINALLY AFTER AFT COMPARTMENT CLOSEOUT AND PRIOR TO LAUNCH.

(C) INSPECTION:

RECEIVING INSPECTION
MATERIAL AND PROCESSES CERTIFICATIONS ARE VERIFIED BY INSPECTION.

CONTAMINATION CONTROL
CLEANLINESS AND CORROSION PROTECTION REQUIREMENTS ARE VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

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INSPECTION VERIFIES CONFIGURATION OF THE HEATER TO DRAWING REQUIREMENTS. THE LOCATION AND SPACING OF THE HEATER ELEMENTS AND LEAD WIRE CONNECTIONS AND JOINTS WITHIN THE HEATER ARE VERIFIED TO DRAWING REQUIREMENTS.

NONDESTRUCTIVE EVALUATION
INSPECTION VERIFIES HEATER ELEMENT RESISTANCE INSPECTION AND X-RAY INSPECTION PER DRAWING REQUIREMENTS.

CRITICAL PROCESSES
CRIMPING OF LEAD WIRES WITH HEATER WIRING PER COX PROPRIETARY PROCESS IS VERIFIED BY INSPECTION.

TESTING
PERFORMANCE OF THE HEATER IS EVALUATED VIA ACCEPTANCE TEST PROCEDURE WHICH IS VERIFIED BY INSPECTION.

HANDLING/PACKAGING
OF THE HEATER PER DRAWING REQUIREMENTS IS VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:

CAR 41RF01 FUEL LINE HEATER (P/N 58886) (GROUND SIDE LEAD) SHORTED TO GROUND CAUSED BY A WIRE BUNDLE CLAMP PINCHING THE INSULATION. CLAMP WAS DISTURBED DURING THERMOSTAT REPLACEMENT PRIOR TO FLIGHT. THE WATER LINE AND FUEL LINE HEATER EXPERIENCED EXCESSIVE CURRENT WHICH WAS OBSERVED AS A 38 DEG F/MIN TEMPERATURE RISE ON THE BYPASS FUEL LINE TEMPERATURE INDICATOR. (THE NORMAL RISE RATE WAS 7 DEG F/MIN). FDA ALARM OCCURRED AT 180 DEG F AND THE CREW RESPONDED WITHIN 2.5 MINUTES AND SWITCHED TO THE REDUNDANT HEATER AS THE TEMPERATURE REACHED 255 DEG F. THE REDUNDANT HEATER OPERATED NOMINALLY FOR THE REMAINDER OF THE MISSION.

INTERIM CORRECTIVE ACTION IS TYING WIRE BUNDLES TOGETHER TO PREVENT CLAMPS FROM PINCHING WIRES. THE APU GG/FUEL PUMP HEATER SYSTEM B WILL BE OPERATED AFTER SYSTEM A CHECKOUT, FOLLOWING AFT CLOSEOUT AND PRIOR TO LAUNCH. THE BYPASS LINE TEMPERATURE FDA LIMIT DECREASED TO 150 DEG F (FROM 180 DEG F) TO ALLOW MORE RESPONSE TIME FOR CREW ACTION. CREW PROCEDURES CHANGED TO RESPOND IMMEDIATELY TO APU HEATER FDA BY TURNING OFF ALL APU FUEL HEATERS.

FINAL CORRECTIVE ACTION INVOLVES MODIFYING THE IMPROVED APU HEATER AND THE APU SUBSYSTEM HEATERS AS DESCRIBED BELOW. THE EFFECTIVITY FOR THESE CHANGES IS IN WORK (REFERENCE MCR 16920).

THE HEATER ON THE IMPROVED APU (-04XX) WILL BE MODIFIED TO REWIRE OVERTEMPERATURE THERMOSTATS ON THE BYPASS LINE. THE OVERTEMPERATURE THERMOSTATS ARE REWIRED TO THE POWER SIDE, AND WILL REMOVE POWER TO ALL THE SERIES HEATER ELEMENTS. THEY CAN AUTOMATICALLY PROTECT THE FUEL BYPASS LINE, REFERENCE LINE, GGVM AND FUEL PUMP AGAINST OVERHEATING FROM A GROUND SHORT. THE FUEL SUPPLY LINE HEATER IS THE FIRST SERIES HEATER ELEMENT OF THE THREE FUEL LINES (SUPPLY, BYPASS, REFERENCE). THE OVERTEMPERATURE THERMAL SWITCHES COULD NOT BE MOUNTED ON THIS LINE DUE TO SPACE CONSTRAINTS. THEREFORE, THE FUEL SUPPLY LINE IS NOT PROTECTED AGAINST GROUND SHORTS IF THE SHORT OCCURRED ON THAT LINE.

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HOWEVER, A TEMPERATURE SENSOR HAS BEEN RELOCATED TO THIS LINE TO MAKE GROUND SHORTS DETECTABLE. THE MEASUREMENT IS MONITORED BY FDA. NOTE THAT THE ONLY PLACE THE FUEL SUPPLY LINE HEATER CAN SHORT IS FROM THE ELEMENT TO THE FUEL LINE. THE ELEMENTS HAVE TWO LAYERS OF INSULATION.

ELECTRICAL POWER SHORTS OF THE APU FUEL LINE HEATERS WILL RESULT IN THE CONTROL THERMOSTAT AUTOMATICALLY REGULATING TEMPERATURE. POWER SHORTS OF THE GGVM AND FUEL PUMP WOULD BE DETECTABLE BY TEMPERATURE SENSORS.

ALL APU SUBSYSTEM FUEL HEATERS ARE REGULATED BY THERMOSTATS ON THE POWER SIDE. CHANGES IN THE FORM OF RELOCATING THE TEMPERATURE SENSORS OR ADDING AN OVERTEMPERATURE THERMOSTAT IS PLANNED FOR THESE HEATERS TO AUTOMATICALLY PROTECT AGAINST GROUND SHORTS AS FOLLOWS: SERVICE AND TEST LINE - MOVE ONE OF THE TWO TEMPERATURE SENSORS SUCH THAT BOTH ELEMENTS HR1X6 AND HR1X7 ARE MONITORED. FEEDLINE - ADD OVERTEMPERATURE THERMOSTAT TO HRX4. DRAIN LINE (APU 1 ONLY) - MOVE ONE OF THE TWO TEMPERATURE SENSORS SUCH THAT BOTH ELEMENTS HR111 AND HR112 ARE MONITORED. REVERSE HEATER SEQUENCE TO HAVE THE THERMOSTAT ON THE POWER SIDE.

(E) OPERATIONAL USE:
POWER DOWN ALL APU FUEL HEATERS UPON THERMAL FDA. RECONFIGURE FAILED HEATERS AND REACTIVATE.

- APPROVALS -

EDITORIALLY APPROVED : RI
EDITORIALLY APPROVED : JSC
TECHNICAL APPROVAL : VIA CR

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