PRINT DATE: 09/08/93

FAILURE MODES EFFECTS ANALYSIS (FMEA) – CRITICAL HARDWARE
NUMBER: 04-2-V12-13-X

SUBSYSTEM NAME: AUXILIARY POWER UNIT (APU)

REVISION: 4 08/09/93

		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 X742211X
SRU	:	VALVE, SOLENOID	5905137 SAME
SRU	:	VALVE, SOLENOID	5907038 SAME
SRU	:	VALVE, SOLENOID	59906 SAME

PART DATA

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
GAS GENERATOR VALVE MODULE, TWO-THREE WAY SOLENOID VALVES IN SERIES, ONE NORMALLY OPEN AND THE OTHER NORMALLY CLOSED.

QUANTITY OF LIKE ITEMS: 3
ONE PER APU

FUNCTION:
WHEN VALVE CYCLES, IT PROVIDES APU TURBINE PRIMARY AND SECONDARY SPEED CONTROL. NORMALLY CLOSED VALVE SHUTS DOWN THE APU.

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FAILURE MODES EFFECTS ANALYSIS (FMEA) – CRITICAL FAILURE MODE
NUMBER: 04-2-V12-13-01

REVISION: 4 08/09/93

SUBSYSTEM NAME: AUXILIARY POWER UNIT (APU)
LRU: AUXILIARY POWER UNIT (APU)
ITEM NAME: VALVE, SOLENOID

CRITICALITY OF THIS FAILURE MODE: 1/1

FAILURE MODE:
RUPTURE OR EXTERNAL LEAK CAUSED BY DECOMPOSITION OF FUEL WITHIN THE MODULE.

MISSION PHASE:

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

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

CAUSE:
STRUCTURAL FAILURE OF TORQUE TUBE, TORQUE TUBE TO FLAPPER OR TORQUE TUBE TO FLEXURE ASSEMBLY WELD FAILURE, ALLOWING FUEL INTO THE SOLENOID CAVITY RESULTING IN DECOMPOSITION. SOLENOID COIL WINDING SHORTING, OR CONTROLLER POWER LEFT ON AND PC VALVE DRIVER FAILS ON RESULTING IN OVERHEAT AND HYDRAZINE DECOMPOSITION.

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:
APU UNDERSPEED SHUTDOWN AND LOSS OF AN APU OPERATION IF LEAK IS GROSS.

(B) INTERFACING SUBSYSTEM(S):

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ADJACENT REDUNDANT EQUIPMENT AND COMPONENTS EXPOSED TO RAW FUEL. LOSS OF SHAFT POWER TO ONE HYDRAULIC PUMP. POSSIBLE DAMAGE TO REDUNDANT EQUIPMENT.

(C) MISSION:
ABORT DECISION IS REQUIRED, IF FAILURE OCCURS PRIOR TO ENTRY COMMITMENT.

(D) CREW, VEHICLE, AND ELEMENT(S):
POSSIBLE LOSS OF VEHICLE IF FUEL ENTERS AFT FUSELAGE AND IS IGNITED OR IF DAMAGE EXTENDS TO REDUNDANT EQUIPMENT CAUSING LOSS OF ANOTHER HYDRAULIC/APU SYSTEM. THIS POSSIBILITY IS LESSENED BY THE AUTOMATIC CLOSURE OF TANK ISOLATION VALVES, WHICH LIMITS THE AMOUNT OF HYDRAZINE THAT CAN ENTER THE AFT COMPARTMENT.

(E) FUNCTIONAL CRITICALITY EFFECTS:
NONE

-DISPOSITION RATIONALE-

(A) DESIGN:
THE TORQUE TUBE IS MADE OF 17-7 CH900 CRES AND IS ELECTRON-BEAM WELDED TO 304L CRES STEEL FLEXURE ASSEMBLY BODY AND 17-7 PH TH1050 CRES FLAPPER. THE IGGVM HAS DUAL WELDS BETWEEN THE TORQUE TUBE AND BODY. THE BASELINE GGVM HAS A SINGLE WELD.

THE SOLENOID COILS ARE WOUND WITH 220FC MAGNET WIRE ON A SPLIT ALUMINUM FRAME WRAP WITH KAPTON TAPE AND FIBERGLASS YARN. THE COIL IS COVERED WITH FIBERGLASS YARN AND POTTED IN 813-9 COMPOUND.

(B) TEST:
THERE HAVE BEEN OVER 1200 HOURS OF VALVE MODULE OPERATION ON 79 DIFFERENT VALVES OVER A 9-YEAR PERIOD. THREE DEVELOPMENT GGVM'S HAVE 106 HOURS EACH (70 MISSIONS) DURING GROUND TESTING. EACH UNIT IS LEAK CHECKED AND PROOFED AT 2282 PSIG DURING ATP.

THE COILS ARE CHECKED FOR INSULATION RESISTANCE, HI POT AND OPERATING CURRENT AND VALVE TIMING DURING ATP. ACCEPTANCE LEAKAGE TEST CONDUCTED AT BOTH VALVE AND APU LEVEL

CERTIFICATION DEMONSTRATED 100 HOURS FLUID CAPABILITY. SIMILAR DESIGN PULSE CONTROL VALVES ON APU S/N 105, 102 HAVE EACH CYCLED OVER 200K WITH NO FAILURE. IMPROVED APU GGVM CYCLED 900K CYCLES.

CERTIFICATION TESTS CONDUCTED AT THE APU LEVEL WERE - THERMAL VACUUM, BENCH SHOCK, FOR A TOTAL OF 40 HR OPERATION. VIBRATION "X" AXIS 8.2 GRMS "Y" AND "Z" AXES 4.1 GRMS, DURATION EQUIVALENT TO 100 MISSIONS.

OMRSD: TOXIC VAPOR CHECKS, POST-FLIGHT INSPECTION AND FUEL VALVE COIL RESISTANCE TESTS PERFORMED EVERY FLOW.

(C) INSPECTION:
RECEIVING INSPECTION
MATERIAL AND PROCESSES CERTIFICATIONS ARE VERIFIED.

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CONTAMINATION CONTROL
CLEANLINESS OF INTERNAL FUEL SURFACES TO LEVEL 100 IS VERIFIED BY INSPECTION. FLUID SAMPLES ARE ANALYZED FOR CONTAMINATION AND VERIFIED BY INSPECTION. CORROSION PROTECTION REQUIREMENTS ARE VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION
MANUFACTURING, ASSEMBLY, AND INSTALLATION REQUIREMENTS ARE VERIFIED BY INSPECTION. CRITICAL DIMENSIONS AND SURFACE FINISHES ARE VERIFIED BY INSPECTION. O-RINGS AND O-RING INSTALLATION IS VERIFIED BY INSPECTION. TORQUE TUBE IS VERIFIED BY INSPECTION. SOLENOID FABRICATION IS VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION
NO NDE IS CURRENTLY PERFORMED ON ALL CRITICAL WELDS. ROCKWELL MATERIAL AND PROCESS ENGINEERING IS INVESTIGATING POTENTIAL NDE METHODS FOR CRITICAL WELDS.

P/N 59906:
MICRO X-RAY INSPECTION OF THE FLEX TUBE MATERIAL FOR FLAWS IS VERIFIED BY INSPECTION.

P/N 5905137:
IMPROVED GGVM EDDY CURRENT TEST PERFORMED ON FLEX TUBE WHICH IS VERIFIED BY INSPECTION.

CRITICAL PROCESSES
WELDING TO SPECIFICATIONS REQUIREMENTS IS VERIFIED BY INSPECTION. WELDING PROCEDURES, EQUIPMENT AND SCHEDULES ARE UNDER INVESTIGATION FOR POTENTIAL IMPROVEMENT. DESTRUCTIVE TESTING/INSPECTION OF LOT SAMPLES OF PRODUCTION HARDWARE IS UNDER CONSIDERATION TO EXAMINE FOR PROPER WELD PENETRATION/CONCENTRICITY. HEAT TREATING IS VERIFIED BY INSPECTION.

TESTING
TEST EQUIPMENT AND TOOL CALIBRATION ARE VERIFIED BY INSPECTION. ATP IS WITNESSED AND VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:
CAR AC3326 - FLEX TUBE WELD FAILURE. CORRECTIVE ACTION WAS TO IMPROVE ARMATURE FLEX TUBE WELDMENT AND TO CONDUCT MICRO X-RAY INSPECTION OF THE FLEX TUBE MATERIAL TO VERIFY THAT SMALL (.002 DIA AND .004 DEEP) FLAWS DO NOT EXIST. THE FLEX TUBE FAILURE WAS DISCOVERED DURING FLUSH AND DECONTAMINATION (F&D) AFTER ATP HOT FIRE. EXAMINATION OF THE FAILED TUBE DISCLOSED AN INCLUSION. THE CONCLUSION WAS THAT THIS DEFECT CREATED A STRESS CONCENTRATION POINT AND THE TUBE CRACKED DUE TO FATIGUE UNDER NORMAL OPERATING LOADS.

CAR AC9413 DOCUMENTS A GGVM COIL FAILURE DURING APU 208 (F&D) AT THE VENDOR. CORRECTIVE ACTION CONSISTED OF CHANGING THE OMRSD TO VERIFY THE COIL RESISTANCE OF EACH GGVM AND ISOLATION VALVE BEFORE EACH FLIGHT.

CAR AD0789 - AN APU TANK ISOLATION VALVE COIL CAVITY LEAK OCCURRED ON OV-102, FLIGHT 7. THE SEALING O-RING WAS FOUND TO BE DEFECTIVE. CORRECTIVE

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ACTION CONSISTED OF REPLACING THE OLD VALVE COVER WITH ONE HAVING STRICTER GROOVE DIMENSIONS TO ACHIEVE A BETTER SEAL.

CAR AD8687 - GGVM/IGGVM EB WELDS FOUND TO BE UNDER PRINT REQUIREMENT FOR WELD PENETRATION IN SOME LOCATIONS. WELD CRACKS FOUND IN FLEXTUBE TO FLAPPER WELDS. INTERIM REMEDIAL ACTION INVOLVES LIMITING GGVM RUNTIME.

(E) OPERATIONAL USE:
IF FAILURE IS DETECTED, CLOSE TANK ISOLATION VALVES AND SHUT OFF THE CONTROLLER POWER AS SOON AS POSSIBLE.

- APPROVALS -

EDITORIALLY APPROVED	: RI	: 9/9/93
EDITORIALLY APPROVED	: JSC	: 9/7/93
TECHNICAL APPROVAL	: VIA CR	: 550270L