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FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL HARDWARE

NUMBER: 04-2-GG11-1M-X

SUBSYSTEM NAME: AUXILIARY POWER UNIT (APU)

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	PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
■ LRU :	AUXILIARY POWER UNIT (APU)	MC201-0001-04XX
■	SUNSTRAND	X742211X
■ SRU :	GAS GENERATOR	5905135
■		SAME

PART DATA

- EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
GAS GENERATOR, CATALYTIC DECOMPOSITION CHAMBER
- QUANTITY OF LIKE ITEMS: 3
ONE PER APU
- FUNCTION:
TO CATALYTICALLY DECOMPOSE FUEL AND PORT HOT GAS TO TURBINE INLET.

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SUBSYSTEM: AUXILIARY POWER UNIT (APU)
LRU :AUXILIARY POWER UNIT (APU)
ITEM NAME: GAS GENERATOR

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CRITICALITY OF THIS
FAILURE MODE:1/1

■ FAILURE MODE:

EXTERNAL LEAKAGE OF HOT GAS AND/OR FUEL INTO APT COMPARTMENT

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
: 105 ENDEAVOUR

■ CAUSE:

DEFECTIVE SEAL, DEFECTIVE SEALING SURFACES, IMPROPER ASSEMBLY,
STRUCTURAL FAILURE OF INJECTOR TUBE, BODY, OR PC TUBE THAT CONNECTS THE
CHAMBER TO THE PRESSURE TRANSDUCER. SEAL DAMAGE DUE TO HIGH GAS
GENERATOR PRESSURE SPIKES (GAS GENERATOR ROUGHNESS OR BED LIFE),
UNCOOLED HOT RESTART, INJECTOR TUBE OR VALVE DAMAGE, LOSS OF THERMAL
SHUNT, ~~CHAMBER PRESSURE SENSING TUBE~~ AND/OR

■ 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)

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 - FAILURE EFFECTS -

- (A) SUBSYSTEM:
 POSSIBLE LOSS OF ONE APU. APU MAY SHUTDOWN DUE TO INABILITY TO CARRY LOAD. APU MAY BE MANUALLY SHUTDOWN IF LEAKAGE IS DETECTED.
- (B) INTERFACING SUBSYSTEM(S):
 POSSIBLE LOSS OF SHAFT POWER TO ONE HYDRAULIC PUMP. POSSIBLE DAMAGE TO ADJACENT HARDWARE COULD OCCUR.
- (C) MISSION:
 ABORT DECISION IS REQUIRED IF FAILURE OCCURS PRIOR TO ENTRY COMMITMENT.
- (D) CREW, VEHICLE, AND ELEMENT(S):
 POSSIBLE LOSS OF CREW/VEHICLE IF LEAKAGE OF FUEL OR GAS FROM GAS GENERATOR IS IGNITED. IGNITION SOURCE AVAILABLE FROM GAS GENERATOR SURFACE TEMPERATURE.
- (E) FUNCTIONAL CRITICALITY EFFECTS: *N/A (CRIT 1/1)*

 - DISPOSITION RATIONALE -

- (A) DESIGN:
 OPERATING LIFE IMPROVED TO 75 HRS BY INCORPORATING SPRING RETENTION OF ENTIRE BED. THE INJECTOR USES DUAL O-RINGS MANUFACTURED FROM EPR-E515-80. THE O-RINGS WERE DESIGNED FOR OPERATING TEMPERATURES FROM MINUS 65 TO 600 DEG F FOR 1000 HOURS. THE O-RING OPERATING TEMPERATURE IS 350 DEG F. A THERMAL SHUNT IS USED TO REDUCE THE TEMPERATURE IN THE O-RING AREA.

 THE GAS GENERATOR IS DESIGNED FOR A MAXIMUM OPERATING PRESSURE OF 1,500 PSI. CABOT HASTELLOY "B" INJECTOR TUBE MATERIAL (.098 I.D. WITH .020 WALL). MINIMUM TUBE BUCKLING PRESSURE IS 3,100 PSI AT 1,200 DEG F.

 CORROSION RESISTANCE IMPROVED BY ELIMINATING EDM AND CHROMIZING ID OF INJECTOR TUBE. INJECTOR TUBE STRESS AT GGVM INSTALLATION MINIMIZED. NO CHROMIZED INJECTOR HAS EXHIBITED INJECTOR WALL CRACKING UPON COMPLETION OF DEVELOPMENT TESTING. FOUR UNITS TESTED, WITH TWO OF THEM EXCEEDING 75 HOURS. HOT RESTARTS ARE PERFORMED ONLY AFTER COOLING THE INJECTOR. PC TUBE SIZE 0.06 IN. OD AND 0.010 IN. WALL THICKNESS. DYNATUBE SEAL FITTINGS ATTACHED WITH WELDED SLEEVE AND WITH SEALING SURFACE.

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PC TUBING BENDS ARE CONTROLLED BETWEEN FIXED POINT TO FACILITATE INSTALLATION AND ACCOMMODATE APU THERMAL EXPANSION AND MOVEMENT (VIBRATION).

■ (B) TEST:

GAS GENERATOR AND APU ATP FUNCTIONAL AND LEAK TESTS VERIFY GAS GENERATOR PERFORMANCE, *AND INTEGRITY.*

IAPU QUALIFICATION COMPLETED SUCCESSFULLY (75 HRS ON QUAL 1). FOUR (4) PRODUCTION SGG'S WITH CHROMIZED INJECTORS LIFE TESTED SUCCESSFULLY DURING DEVELOPMENT. TWO OF THEM WERE TESTED IN EXCESS OF 75 HOURS. NO CHROMIZED INJECTOR HAS EXHIBITED INJECTOR WALL CRACKING UPON COMPLETION OF DEVELOPMENT TESTING. QUAL II TESTING (75) HOURS) TO BE PERFORMED.

INITIAL PC TUBE WELD LEAK CHECK AT 1,500 +/-50 PSIG FOR 5 MINUTES MINIMUM USING GM2, NO LEAKAGE PERMITTED. AFTER INSTALLATION ON GG, PROOFED TO 2,250 +/-100 PSIG FOR 300 - 330 SEC. HELIUM EXTERNAL LEAK TEST AT 1,500 +/-50 PSIG AND 1.0E-4 SCC/SEC LEAKAGE MAXIMUM.

LCC: GG PERFORMANCE IS VERIFIED DURING T-5 MIN RUN EVERY FLOW *AND* DURING ENTRY FROM TAEM TO TOUCHDOWN WHILE IAPU IS UNDER LOAD.

OMRSD: GG PERFORMANCE IS VERIFIED DURING *CONDUCTED RUNS FOLLOWING EVERY INSTALL* ~~IAPU HOT FIRE WHEN NEW IAPU IS INSTALLED.~~ ALSO, HYDRAULIC LOAD TEST IS PERFORMED EVERY FIFTH FLIGHT TO VERIFY GG ROUGHNESS AND SPIKING.

■ (C) INSPECTION:

RECEIVING INSPECTION
MATERIALS AND PROCESSES CERTIFICATIONS ARE VERIFIED BY INSPECTION.

CONTAMINATION CONTROL
CLEANLINESS TO LEVEL 100 IS VERIFIED BY INSPECTION. FLUID SAMPLES ARE INSPECTED FOR CONTAMINATION. CORROSION PROTECTION IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION
TORQUING IS VERIFIED BY INSPECTION. MANUFACTURING, ASSEMBLY, AND INSTALLATION PROVISIONS ARE VERIFIED BY INSPECTION. INJECTOR STEM AND O-RINGS ARE VERIFIED CLEAN BY INSPECTION. DIMENSIONS AND SURFACE FINISHES ARE VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION
PENETRANT INSPECTION FOR SURFACE DEFECTS IS VERIFIED BY INSPECTION. HOUSING WELDS ARE INSPECTED USING 10X MAGNIFICATION.

CRITICAL PROCESSES

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WELDING PER SPECIFICATION REQUIREMENTS IS VERIFIED BY INSPECTION.

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

HANDLING/PACKAGING
HANDLING, PACKAGING, STORAGE, AND SHIPPING PROCEDURES ARE VERIFIED BY INSPECTION.

- (D) FAILURE HISTORY:
NO EXTERNAL LEAKAGE FAILURES OF SPRING GAS GENERATOR.

BASELINE APU CAR'S 09F012 AND 09F013, STS-9 APU 1 AND 2 INJECTOR TUBES CRACKED, RESULTING IN FIRE AND DETONATION. FAILURE REPRODUCED IN LABORATORY EXPOSURE OF SAMPLES TO AMMONIUM HYDROXIDE VAPOR. CORRECTIVE ACTION HAS INCLUDED INJECTOR TUBE CHROMIZING AND REDUCTION IN INJECTOR TUBE STRESSES DURING MANUFACTURE AND ASSEMBLY BY ELIMINATION OF THE ID CARBIDE LAYER WHICH MAKES THE MICROSTRUCTURE LESS SENSITIVE TO CRACKING.

- (E) OPERATIONAL USE:
SHUT DOWN APU AND CLOSE ISOLATION VALVES, IF DETECTED BY TEMPERATURE SENSORS ON GGVM OR FUEL PUMP. *APU IS CONSIDERED LOST (RISK AVE 10-1)*

- APPROVALS -

RELIABILITY ENGINEERING: D. R. ATAPATTU
 DESIGN ENGINEERING : J. R. MUNROE
 QUALITY MANAGER : O. J. BUTTNER
 NASA RELIABILITY :
 NASA SUBSYSTEM MANAGER :
 NASA QUALITY ASSURANCE :

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