

## FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL HARDWARE

NUMBER: 04-2-TR11-X

SUBSYSTEM NAME: AUXILIARY POWER UNIT (APU)

REVISION : 3 12/18/91

	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 :	TURBINE ASSEMBLY SUNDSTRAND	755086 SAME

## PART DATA

- EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:  
TURBINE WHEEL AND BALANCE ASSEMBLY INCLUDING FORWARD AND AFT BEARINGS,  
SEALS, BEARING HOUSING AND SPUR DRIVE GEAR.
- QUANTITY OF LIKE ITEMS: 3  
ONE PER APU
- FUNCTION:  
TO PROVIDE ENERGY CONVERSION FROM HOT GAS TO DRIVE APU GEARBOX.

PAGE: 2

PRINT DATE: 12/18/91

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL FAILURE MODE  
 NUMBER: 04-2-TR11-11

SUBSYSTEM: AUXILIARY POWER UNIT (APU)  
 LRU :AUXILIARY POWER UNIT (APU)  
 ITEM NAME: TURBINE ASSEMBLY

REVISION# 3 12/18/91 R

CRITICALITY OF THIS  
 FAILURE MODE:1R2

■ FAILURE MODE:  
 LOSS OF OUTPUT

## 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:  
 STRUCTURAL FAILURE OF THE TURBINE WHEEL, TURBINE RUB DUE TO CRACKS OR  
 WARPAGE OF THE TURBINE HOUSINGS. BEARING FAILURE DUE TO LOSS OF OIL OR  
 GEARBOX GN2 PRESSURE, TURBINE BLADES/SHROUD OR EXCESSIVE VIBRATION.

■ CRITICALITY 1/1 DURING INTACT ABORT ONLY? YES

AQA ABORT ONCE AROUND  
 ATO ABORT TO ORBIT  
 RTLS RETURN TO LAUNCH SITE  
 TAL TRANS ATLANTIC ABORT

■ REDUNDANCY SCREEN A) PASS  
 ■ B) PASS  
 ■ C) PASS

## PASS/FAIL RATIONALE:

■ A)

■ B)

■ C)

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL FAILURE MODE  
 NUMBER: 04-2-TR11-11

-----  
 - FAILURE EFFECTS -  
 -----

- (A) SUBSYSTEM:  
LOSS OF ONE APU SYSTEM DUE TO UNDERSPEED SHUTDOWN.
- (B) INTERFACING SUBSYSTEM(S):  
LOSS OF SHAFT POWER TO ONE HYDRAULIC PUMP.
- (C) MISSION:  
ASCENT-ABORT OR ABORT DECISION, TIME DEPENDENT.
- (D) CREW, VEHICLE, AND ELEMENT(S):  
NO EFFECT UNTIL SECOND SYSTEM LOSS THEN POSSIBLE VEHICLE LOSS.  
CRITICALITY 1 FOR SSME-INDUCED RTLS, ATO, AOA, OR TAL DUE TO THE  
POSSIBLE ADDITIONAL LOSS OF ASSOCIATED APU/HYD AND MAIN ENGINE.
- (E) FUNCTIONAL CRITICALITY EFFECTS:  
POSSIBLE LOSS OF VEHICLE/CREW IF TWO OUT OF THREE APU'S ARE LOST.

-----  
 - DISPOSITION RATIONALE -  
 -----

- (A) DESIGN:  
TURBINE WHEEL HAS A MS $\pm$ .18 AT 93,600 RPM (130% SPEED (NOMINAL DISK  
PROFILE, MINIMUM ULTIMATE STRENGTH 148 KSI @ 1200 DEG F). FRACTURE  
MECHANICS ANALYSIS OF TURBINE DISK SHOWS >4X LIFE (>200 MISSIONS) WITH  
A DETECTABLE FLAW SIZE OF .094" (SPECIAL LEVEL PENETRANT NDE).  
BLADE/SIROUD CONFIGURATION HAS BEEN MODIFIED, IN COMPARISON TO PREVIOUS  
DESIGN, TO ELIMINATE BLADE CRACKING. ORBITER APU TURBINE WHEEL IS  
SIMILAR IN DESIGN TO THE SRB HPU (BLADE/SIROUD CONFIGURATION IS PRIMARY  
DIFFERENCE).

TURBINE WHEEL ROTATIONAL SPEED IS 72,000 RPM AT 100% SPEED. AUTOMATIC  
SHUTDOWN IS INITIATED AT UNDERSPEED SIGNAL WHEN SPEED IS BELOW 57,600  
RPM (80% SPEED) AFTER 10.5 SECOND START DELAY.

TURBINE ASSEMBLY IS DYNAMICALLY BALANCED IN TWO PLANES WITHIN 0.001  
IN-OZ. ASSEMBLY USES ANGULAR CONTACT BALL BEARINGS (ABEC CLASS 5),  
MADE FROM M-50 TOOL STEEL. SPUR GEAR (PINION) IS AMS 6487 STEEL WITH  
NITRIDED TOOTH AND ROOT PROFILE.

TURBINE HOUSING MATERIAL IS UDIMET LX. THIS MATERIAL IS NOT LIFE  
LIMITED.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL FAILURE MODE  
NUMBER: 04-2-TR11-11**

■ **(B) TEST:**

EACH APU IS SUBJECTED TO ATP FUNCTIONAL TEST. THE TURBINE WHEEL (P/N 752370) IS INTENDED TO BE CERTIFIED FOR 75 HOURS. CURRENTLY, THE CERTIFICATION IS FOR 20 HOURS WITH NO LIMIT ON STARTS OR HIGH SPEED RUNTIME. OVER 165 HOURS (240 PLUS STARTS) HAVE BEEN SUCCESSFULLY DEMONSTRATED DURING DEVELOPMENT, QUALIFICATION AND FLIGHT USING 7 DIFFERENT TURBINE WHEELS. ONE WHEEL HAS ACCUMULATED 90.7 HOURS, WITH A SECOND IN THE 45 HOUR RANGE.

OMRSD: TURBINE PERFORMANCE IS VERIFIED DURING T-5 MINUTE RUN.

■ **(C) INSPECTION:**

RECEIVING INSPECTION

MATERIALS AND PROCESSES CERTIFICATIONS ARE VERIFIED BY INSPECTION.

CONTAMINATION CONTROL

CLEANLINESS PER REQUIREMENTS IS VERIFIED BY INSPECTION. CORROSION PROTECTION REQUIREMENTS ARE VERIFIED BY INSPECTION. GLASS BEAD BLASTING IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

MANUFACTURING, ASSEMBLY, AND INSTALLATION REQUIREMENTS ARE VERIFIED BY INSPECTION. CRITICAL DIMENSIONS ARE VERIFIED BY INSPECTION. DYNAMIC BALANCE IS VERIFIED BY INSPECTION. BALL BEARING REQUIREMENTS ARE VERIFIED BY INSPECTION. LUBE OIL ORIFICES ARE CLEAR TO BEARINGS IS VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

TURBINE FORGING PENETRANT AND ULTRASONICALLY INSPECTED. SHAFT/DISK TIG WELD RADIOGRAPHICALLY INSPECTED. SHROUD ELECTRON BEAM WELD IS ULTRASONIC AND PENETRANT INSPECTED, BOTH PRIOR TO AND FOLLOWING HEAT TREAT. FINISH MACHINED TURBINE WHEEL ASSEMBLY IS PENETRANT INSPECTED; TURBINE DISK IS INSPECTED USING SPECIAL LEVEL PENETRANT TECHNIQUES (.050" THRESHOLD DETECTION LEVEL). TURBINE BLADES ARE INSPECTED UNDER MAGNIFICATION USING PENETRANT.

CRITICAL PROCESSES

INSPECTION AND/OR TEST VERIFIES FORGING, TIG AND ELECTRON BEAM WELDING, ELECTRO-CHEMICAL MACHINING, HEAT TREATMENT AND SPUR GEAR NITRIDING.

TESTING

ATP IS WITNESSED AND VERIFIED BY INSPECTION.

HANDLING/PACKAGING

HANDLING, PACKAGING, STORAGE, AND SHIPPING PROCEDURES ARE VERIFIED.

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL FAILURE MODE  
NUMBER: 04-2-TR11-11

■ (D) FAILURE HISTORY:  
NO FAILURES

■ (E) OPERATIONAL USE:  
SHUT DOWN APU BASED ON SYSTEM TEMPERATURES AND FLIGHT PHASE. ALSO, IF  
APU SHUTS DOWN, REMAINING APU'S GO TO HIGH SPEED AND AUTOMATIC SHUTDOWN  
IS INHIBITED TO PRECLUDE INADVERTENT SHUTDOWNS.

IF ENTRY, PERFORM HOT RESTART IF REQUIRED TO GAIN SECOND APU.

-----  
- APPROVALS -  
-----

RELIABILITY ENGINEERING:	D. R. ATAPATTU	:	<u>DRR</u> <u>[Signature]</u>
DESIGN ENGINEERING	: J. R. MUNROE	:	<u>[Signature]</u>
QUALITY MANAGER	: O. J. BUTTNER	:	<u>[Signature]</u>
NASA RELIABILITY	:	:	<u>[Signature]</u>
NASA SUBSYSTEM MANAGER	:	:	<u>[Signature]</u> 4/1/92
NASA QUALITY ASSURANCE	:	:	<u>[Signature]</u> 3-30-92
			<u>[Signature]</u> 2/19/92