

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 04-2-PP11-IM -X

SUBSYSTEM NAME: AUXILIARY POWER UNIT (APU)

REVISION: 4

03/03/00

PART DATA

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	: AUXILIARY POWER UNIT (APU)	MC201-0001-0491
	SUNDSTRAND	742211E
SRU	: FUEL PUMP	753707
	SUNDSTRAND	SAME
LRU	: AUXILIARY POWER UNIT (APU)	MC201-0001-06XX
	SUNDSTRAND	99167

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
PUMP, FUEL (HYDRAZINE) - POSITIVE DISPLACEMENT (GEAR)

REFERENCE DESIGNATORS:

QUANTITY OF LIKE ITEMS: 3
ONE PER APU

FUNCTION:
TO TRANSFER FUEL AT INCREASED PRESSURE FROM SUPPLY TO DISCHARGE. THE PUMP INCORPORATES A START BY-PASS VALVE FOR STARTING, RELIEF VALVE TO PROTECT AGAINST DOWNSTREAM BLOCKAGE, AND FILTER AT THE OUTLET TO PREVENT CONTAMINATION FROM FLOWING DOWNSTREAM.

FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE

NUMBER: 04-2-PP11-IM- 11

REVISION#: 4 03/08/00

SUBSYSTEM NAME: AUXILIARY POWER UNIT (APU)

LRU: AUXILIARY POWER UNIT (APU)

ITEM NAME: FUEL PUMP

CRITICALITY OF THIS

FAILURE MODE: 1R2

FAILURE MODE:

LOSS OF OUTPUT

MISSION PHASE:

PL PRE-LAUNCH
LO LIFT-OFF
DO DE-ORBIT
LS LANDING/SAFING

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102 COLUMBIA
103 DISCOVERY
104 ATLANTIS
105 ENDEAVOUR

LUBRICANT, KRYTOX ON PISTON, INNER O-RING RETAINING WALL, AND POLYSULFIDE LUBRICANT AT SPLITLINE MODS, ONLY.

CAUSE:

INTERNAL MECHANICAL FAILURE (SHAFT SHEAR, BEARING SEIZURE, GEAR FRACTURE), START BYPASS VALVE OR RELIEF VALVE FAILURE, SHAFT SEAL LEAK, INTERNAL LEAKAGE (GROOVED CARBON BEARINGS), FUEL DETONATION, O-RING DAMAGE ON COVERPLATE, PLUGGED FILTER, CRACKED BEARINGS, ORIFICE FAILURE/DAMAGE.

CRITICALITY 1/1 DURING INTACT ABORT ONLY? YES

AOA ABORT ONCE AROUND
ATO ABORT TO ORBIT
RTLS RETURN TO LAUNCH SITE
TAL TRANS-ATLANTIC LANDING

REDUNDANCY SCREEN

A) PASS
B) PASS
C) PASS

PASS/FAIL RATIONALE:

A)

B)

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

LOSS OF ONE APU SYSTEM. APU FAILS TO START OR SHUTS DOWN - FUEL STARVATION, TURBINE UNDERSPEED.

(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 OR UNLESS FUEL LEAKS AND IS IGNITED. 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:

1ST FAILURE - LOSS OF ONE APU.
POSSIBLE VEHICLE LOSS IF TWO OUT OF THREE APU'S ARE LOST

-DISPOSITION RATIONALE-

(A) DESIGN:

GRAPHITAR BEARINGS ARE MATCHED SETS. DESIGN USES ECCENTRIC LOAD PISTONS. DRIVE GEAR SHAFT SEAL IS ELASTOMERIC TYPE. DRIVE GEAR FACE SEAL IS LAPPED. DUAL O-RING SEAL ON COVER, PLUS TEFLON LIP SEALS ON BEARINGS. FILTER AT OUTLET, 25-MICRON 50 DELTA P, 1 CC OF SOLIDS CAPABILITY. THE MARGIN OF SAFETY ON SHAFT SHEAR DUE TO FATIGUE IS 2.7. THE MARGIN OF SAFETY ON GEAR FRACTURE IS EXTREMELY HIGH. BYPASS AND RELIEF VALVES ARE OF STANDARD DESIGNS. HOUSING FATIGUE FAILURE MARGIN OF SAFETY @ 1500 PSIG DISCHARGE IS HIGH.

PER REDESIGN, THE START/BYPASS PISTON IS NOW LIGHTLY COATED WITH A LUBRICANT, KRYTOX, TO PREVENT STICTION (BINDING DUE TO FRICTION). ALSO, THE SEATING ON THE SLEEVE HAS BEEN CHAMFERED TO INCREASE THE CONTACT AREA AND TO PROVIDE A BETTER AND LONGER LASTING SEAL.

THE INNER O-RING OF THE DUAL/REDUNDANTLY SEALED FUEL PUMP HAS A REDESIGNED RETAINING WALL TO KEEP THE INNER O-RING IN PLACE. THIS REDESIGN

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 04-2-PP11-IM- 11

PREVENTS THE INNER O-RING FROM BEING KINKED DURING INSTALLATION/OPERATION WITH SUBSEQUENT LOSS OF SEAL REDUNDANCY. ALSO, BY REDESIGN, THE EXTERIOR OF THE FUEL PUMP AT THE FACEPLATE SPLITLINE IS NOW COATED WITH POLYSULFIDE TO PREVENT THE INGRESS OF ANY MOISTURE THAT CAN CAUSE CORROSION BETWEEN THE FUEL PUMP BODY AND THE FUEL PUMP COVER THAT CAN ULTIMATELY RESULT IN LEAKAGE.

(B) TEST:

OPERATIONAL ACCEPTANCE TEST PRIOR TO INSTALLATION ON APU. TEST STRUCTURED TO SIMULATE NORMAL AND HIGH SPEED APU OPERATION. AGAIN AT TOP ASSEMBLY PUMP ACCEPTANCE TESTED WITH ASSEMBLED APU.

FIRST CERTIFICATION TEST (QUAL 1) RESULTED IN SUCCESSFUL FUEL PUMP OPERATION FOR 50 HOURS. HIGH VALVE-ON TIME INDICATING PUMP PERFORMANCE DROP-OFF WAS DETECTED FOLLOWING 50 HOURS (REFERENCE CAR AD5152-010). THE APU IS NOW BEING SUBJECTED TO A SECOND CERTIFICATION TEST FOR 75 HOURS WHICH INCLUDES: 50 MISSION DUTY CYCLES, THERMAL VACUUM, BENCH SHOCK AND HUMIDITY. THIS SECOND QUAL TEST WILL CERTIFY THE APU FOR 47 HOURS OF OPERATION.

OMRSD: PUMP PERFORMANCE VERIFIED DURING CONFIDENCE RUN (HOT FIRE) FOR FOLLOWING EVERY APU INSTALLATION. PUMP PERFORMANCE MONITORED DURING EVERY OPERATIONS.

(C) INSPECTION:

RECEIVING INSPECTION
MATERIAL AND PROCESSES CERTIFICATIONS ARE VERIFIED.

CONTAMINATION CONTROL

CLEANLINESS 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. TORQUING IS VERIFIED BY INSPECTION. START BYPASS VALVE AND RELIEF VALVE ARE VERIFIED BY INSPECTION. SHAFTS, GEARS, BEARINGS, O-RINGS, AND SEALS ARE VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

RADIOGRAPHIC, PENETRANT, AND MAGNETIC PARTICLE INSPECTION FOR SURFACE AND SUBSURFACE DEFECTS IS VERIFIED BY INSPECTION.

CRITICAL PROCESSES

CHROME PLATING PER SPECIFICATION REQUIREMENTS IS VERIFIED BY INSPECTION.

TESTING

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

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE

NUMBER: 04-2-PP11-IM- 11

HANDLING/PACKAGING

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

(D) FAILURE HISTORY:

IMPROVED APU FUEL PUMP FAILURES:

CAR AD6834 - HIGH TORQUE OBSERVED DURING FUEL PUMP HIGH LOAD ATP. CRACKED DRIVE GEAR CARBON BEARING FOUND. CAUSE IDENTIFIED AS LUBE STARVATION DUE TO SUSTAINED HIGH LOAD. CORRECTIVE ACTION INCLUDED LIMITING HIGH LOAD TIME AND ESTABLISHING AN ATP REJECTION CRITERIA FOR HIGH TORQUE. LUBRICATION PASSAGES WERE ENLARGED.

CAR AD5152 - LOW FLOW OF QUAL 1 FUEL PUMP RESULTING IN THE PULSE CONTROL VALVE EXCEEDING THE 84% MAXIMUM ON TIME LIMIT AFTER 35 MISSION DUTY CYCLES (50+ HOURS). RELIEF VALVE LEAKAGE WAS ISOLATED AS THE MOST PROBABLE CAUSE. CORRECTIVE ACTION: THE RELIEF VALVE WAS REDESIGNED TO IMPROVE POPPET ALIGNMENT AND A FILTER WAS ADDED TO THE INLET TO PREVENT CONTAMINATION CAUSING LEAKAGE.

CAR AD6606 - LOW FLOW FUEL PUMP DUE TO RELIEF VALVE LEAKAGE. RELIEF VALVE REDESIGNED AND AN INLET FILTER ADDED. THE REDESIGNED VALVE IS NOW BEING QUALIFIED IN A 75 HOUR APU QUALIFICATION TEST.

CAR AD7756 - THREE FUEL PUMPS FAILED THE ATP FLOW REQUIREMENTS ON THE FUEL PUMP TEST STAND. CAUSES IDENTIFIED ARE IMPROPER DEBURRING OF THE COVER, ILL FITTING STOP WASHER DESIGN AND POSSIBLE DEFICIENCIES IN THE LOAD PISTON AND BEARING HOUSING MATCH SET. CORRECTIVE ACTION FOR SUBSEQUENT BUILDS INCLUDES IMPROVED TOLERANCES AND MANUFACTURING CHANGES.

BASELINE APU FAILURES (FOR REFERENCE):

CAR AD0252 - RELIEF VALVE O-RING DAMAGE DURING ATP. LEAKAGE INTERNAL. CORRECTIVE ACTION WAS MANDATORY O-RING REPLACEMENT AFTER EACH ORIFICE REMOVAL.

CAR AC0009 - DURING GREEN RUN FUEL PUMP RELIEF VALVE SPRING FOUND BROKEN, CAUSING INTERNAL LEAKAGE. DUE TO CONTAMINATION OF AN UNKNOWN SOURCE, CONSIDERED AS AN ISOLATED CASE.

CAR AC1457 - DAMAGED O-RING FOUND IN RELIEF VALVE. THE O-RING SUSTAINED DAMAGE BECAUSE OF AN OUT-OF-PRINT SEALING LIP. THESE O-RINGS DO NOT AFFECT APU PERFORMANCE; NO CORRECTIVE ACTION TAKEN.

AB6343 - O-RING IN FUEL PUMP PINCHED, LOSING SEALING AROUND BEARING, LEADING TO UNDERSPEED SHUTDOWN. ASSEMBLY TECHNIQUES WERE IMPROVED TO PRECLUDE O-RING ASSEMBLY AND A SECOND GREEN RUN TEST WAS ADDED TO THE FUEL PUMP MANUFACTURING CYCLE.

AB3119 - ASSEMBLY ERROR MISPOSITIONED COVER SEAL. THE FOLLOWING CHANGES IN THE MANUFACTURE AND TESTING OF THE FUEL PUMP WERE INCORPORATED AS A

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 04-2-PP11-IM-11

RESULT OF THIS FAILURE: (1) GEAR WIPE INSPECTION ON REBUILT PUMPS AFTER ATP.
(2) IMPROVE BEARING HEIGHT CONTROL BY WET LAPPING. (3) CONTROL PUMP FLOW
TO LOWER END OF THE ATP.

DURING THE CONFIDENCE RUN OF STS-64, PISTON STICTION IN THE START/BYPASS
VALVE CAUSED AN APU START DELAY. THERE WAS NO PROBLEM WITH THE SECOND
START.

(E) OPERATIONAL USE:

IF ONE APU SHUTS DOWN, THE REMAINING APUS GO TO HIGH SPEED AND AUTOMATIC
SHUTDOWN INHIBITED TO PRECLUDE AN INAOVERTENT SHUTDOWN DEPENDING ON
MISSION PHASE.

- APPROVALS -

S&RE ENGINEERING
S&RE MANAGER
DESIGN ENGINEER
SUBSYSTEM MGR
NASA MOD
USA SAM
USA ORBITER

: O. HOLT
: P. STENGER-NGUYEN
: B. KIM
: K. SMITH
: J. P. JASON
: M. S. SNYDERE-WILHARDT
: S. LITTLE

O. Holt 3/15/00
P. Stenger-Nguyen 3/16/00
B. Kim 3/16/00
J. P. Jason 3/16/00
M. S. Snyder-Wilhardt 3/21/00
S. Little 3/20/00