

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**NUMBER: 03-1-0515 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 2 07/27/00

PART DATA

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	:SIGNAL CONDITIONER PACIFIC SCIENTIFIC HTL K-WEST DIV.	MC476-0148-0005

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

SIGNAL CONDITIONER, ULLAGE PRESSURE, GO2/GH2

REFERENCE DESIGNATORS:**QUANTITY OF LIKE ITEMS:** 1**FUNCTION:**

EACH ULLAGE PRESSURE SIGNAL CONDITIONER (LOCATED IN AFT AVIONICS BAY 4, 5, OR 6) POWERS/MONITORS ONE PAIR OF GO2 AND GH2 ET ULLAGE PRESSURE TRANSDUCERS AND CONTROLS ONE GH2 FLOW CONTROL VALVE (FCV). THE SIGNAL CONDITIONERS TO THE GO2 FLOW CONTROL VALVES HAVE BEEN DISCONNECTED FOR THE FIXED ORIFICE CONFIGURATION. THE SIGNAL CONDITIONER GENERATES FCV CLOSE COMMANDS TO MAINTAIN ET ULLAGE PRESSURE WITHIN A REQUIRED RANGE. ADDITIONALLY, THE SIGNAL CONDITIONERS PROVIDE 0 TO 5 VDC ANALOG SIGNALS FOR GROUND CONTROL OF ET ULLAGE PRESSURE DURING PROPELLANT LOADING, TELEMETRY, AND COCKPIT ULLAGE PRESSURE DISPLAY/CAUTION AND WARNING.

A COCKPIT SWITCH ALLOWS THE CREW TO OVERRIDE GH2 FCV CLOSE COMMANDS FROM THE SIGNAL CONDITIONERS, CAUSING ALL GH2 FCVS TO OPERATE AT HIGH FLOW.

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SUBSYSTEM NAME: MAIN PROPULSION

LRU: SIGNAL CONDITIONER

CRITICALITY OF THIS

ITEM NAME: GO2/GH2 FCVS SIG COND ET ULLAGE PRESS

FAILURE MODE: 1R2

FAILURE MODE:

INADVERTENT/CONTINUOUS CLOSED COMMAND TO GO2 (FOR ACTIVE CONFIGURATION VALVES ONLY) OR GH2 FLOW CONTROL VALVE. (FCV CLOSED - LOW FLOW).

MISSION PHASE: LO LIFT-OFF

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

CAUSE:

ELECTRICAL CIRCUIT FAILURE.

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN	A) PASS
	B) PASS
	C) PASS

PASS/FAIL RATIONALE:

A)

B)

PASSES B SCREEN BECAUSE FLOW CONTROL COMMANDS ARE REMOVED AT ET SEPARATION DUE TO ZERO INPUT FROM LH2 ULLAGE PRESSURE TRANSDUCER

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

INADVERTENT COMMAND SIGNAL TO ONE FCV CAUSING IT TO CLOSE/REMAIN CLOSED.

(B) INTERFACING SUBSYSTEM(S):

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FOR NOMINAL MISSIONS, NO EFFECT. REDUNDANT FCVS WOULD COMPENSATE TO MAINTAIN ULLAGE PRESSURE AND NPSP.

FOR GH2 AND GO2 SYSTEMS, FCV CLOSE COMMANDS ARE VERIFIED OFF BY LCC PRIOR TO T-9 MINUTES.

DURING RTLS ABORTS DUE TO ONE SSME OUT AND THE REMAINING ENGINES AT A 104% RPL, A SUBSEQUENT FCV FAILED TO THE LOW FLOW POSITION WILL CAUSE THE ET LH2 ULLAGE PRESSURE TO FALL BELOW THE REQUIRED CONTROL BAND (32 - 34 PSIA) LATE IN THE MAIN ENGINE OPERATION. TANK MINIMUM STRUCTURAL REQUIREMENTS AND NPSP ARE MAINTAINED.

(C) MISSION:

POSSIBLE LAUNCH SCRUB DUE TO LCC VIOLATION.

(D) CREW, VEHICLE, AND ELEMENT(S):

NO EFFECT.

(E) FUNCTIONAL CRITICALITY EFFECTS:

CASE 1: LH2 SYSTEM

1R/2 2 SUCCESS PATHS. TIME FRAME - ENGINE OPERATION.

- 1) SIGNAL CONDITIONER FAILURE RESULTING IN INADVERTENT COMMAND SIGNAL TO ONE GH2 FCV CAUSING IT TO CLOSE/REMAIN CLOSED.
- 2) ONE OF THE FOLLOWING FAILURES ON A PARALLEL PRESSURIZATION LEG:
 - LOSS OF FCV CLOSE COMMAND HYBRID DRIVER
 - FCV FAILS IN THE LOW FLOW POSITION
 - LOSS OF ENGINE PRESSURANT FLOW

RESULTS IN INSUFFICIENT PRESSURIZATION GAS TO MAINTAIN LH2 ULLAGE PRESSURE IN THE REQUIRED FLIGHT CONTROL BAND (32 -34 PSIA). POSSIBLE VIOLATION OF TANK MINIMUM STRUCTURAL CAPABILITY REQUIREMENTS AND UNCONTAINED SSME SHUTDOWN DUE TO LOW NPSP.

POSSIBLE LOSS OF CREW/VEHICLE

CASE 2: LO2 SYSTEM (ACTIVE CONFIGURATION VALVES ONLY)

1R/2 2 SUCCESS PATHS. TIME FRAME - ENGINE OPERATION.

- 1) SIGNAL CONDITIONER FAILURE RESULTING IN INADVERTENT COMMAND SIGNAL TO ONE GO2 FCV CAUSING IT TO CLOSE/REMAIN CLOSED.
- 2) ONE OF THE FOLLOWING FAILURES ON A PARALLEL PRESSURIZATION LEG:
 - ET ULLAGE PRESSURE TRANSDUCER FAILURE
 - LOSS OF A SECOND SIGNAL CONDITIONER
 - LOSS OF FCV CLOSE COMMAND HYBRID DRIVER
 - FCV FAILS IN THE LOW FLOW POSITION
 - LOSS OF ENGINE PRESSURANT FLOW

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LOSS OF ET LO2 ULLAGE PRESSURE WILL RESULT IN VIOLATION OF TANK MINIMUM STRUCTURAL CAPABILITY REQUIREMENTS. MASS OF LO2 AND VEHICLE ACCELERATION SHOULD BE SUFFICIENT TO MAINTAIN PROPER ENGINE NPSP, DELAYING UNCONTAINED SSME SHUTDOWN DUE TO LOW NPSP UNTIL LATE IN POWERED FLIGHT.

POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

THE ULLAGE PRESSURE SIGNAL CONDITIONER HAS TWO PHYSICALLY AND ELECTRICALLY ISOLATED MODULES MOUNTED ON A 6061-T6 ALUMINUM FRAME; ONE FOR GO2 AND ONE FOR GH2. EACH MODULE CONTAINS A POWER SUPPLY, SIGNAL CONDITIONER, CHECKOUT CIRCUIT, AND FCV COMMAND CIRCUIT IN A 6061-T6 BLACK ANODIZED ALUMINUM HOUSING. DYNAMIC DAMPENING OF THE INTERNALLY MOUNTED COMPONENTS IS ACHIEVED BY ENCAPSULATION IN GLASS RESIN EPOXY. THE COMPONENTS ARE MOUNTED ON SEMI-RIGID NICKEL RIBBONS AND ARE HELD IN PLACE BY THE ENCAPSULANT. THE NICKEL RIBBONS ARE CONNECTED TO AN ELECTRICAL INTERFACE CONNECTOR. EACH MODULE IS THEN EXTERNALLY SEALED AFTER CHECKOUT WITH EPOXY SEALANT TO PROVIDE AN ENVIRONMENTAL SEAL.

EACH MODULE CONTAINS AN ELECTRICAL INTERFACE CONNECTOR, WHICH IS HERMETICALLY SEALED AND SOLDERED. THE CONNECTOR IS BUILT TO THE MSFC 40M SPECIFICATIONS FOR SPACE VEHICLES. ALL ELECTRONIC COMPONENTS WERE SELECTED SO THAT THEIR USAGE MEETS THE SHUTTLE DERATING REQUIREMENTS.

CHECKOUT COMMANDS FROM THE GROUND MDM ARE DISTRIBUTED THROUGH OPTICAL ISOLATION CIRCUITS IN EACH MODULE.

FCV CLOSE COMMANDS ARE CONTROLLED ON THE BASIS OF EXCITATION TO TRANSDUCER FEEDBACK VOLTAGE RATIO, REDUCING THE EFFECTS OF EXCITATION VOLTAGE SHIFTS.

EXCITATION POWER TO THE ET ULLAGE PRESSURE TRANSDUCER IS LIMITED TO 10 MA BY CURRENT LIMITING CIRCUITRY TO MAINTAIN A SAFE CONFIGURATION IN CASE OF AN EXTERNAL SHORT CIRCUIT.

SYSTEM

SEPARATE CABLE HARNESSSES ARE USED ON THE ORBITER FOR EACH SIGNAL CONDITIONER (EACH POWERED BY A SEPARATE ORBITER MAIN BUS). THE OUTPUTS ARE FED TO SEPARATE MDMS AND VALVE LOAD DRIVERS TO MAINTAIN SIGNAL ISOLATION. TWO CABLE HARNESSSES ARE USED ON THE EXTERNAL TANK (ET) FOR CONNECTION TO THE ET TRANSDUCERS. ET AND ORBITER CABLES TO THE TRANSDUCERS ARE SHIELDED WITH A SINGLE GROUND CONNECTION AT THE SIGNAL CONDITIONER TO MINIMIZE RF NOISE PROBLEMS. THE ET MAINTAINS AN EXTRA OUTER SHIELD FOR LIGHTNING PROTECTION WITH MULTIPLE POINT GROUNDS. ET TRANSDUCER FAILURE MODES ARE DOCUMENTED BY THE ET PROJECT.

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(B) TEST:

ATP

EXAMINATION OF PRODUCT

INSULATION RESISTANCE
50 VOLTS DC

DIELECTRIC STRENGTH
250 VRMS (60 HZ)

THERMAL CYCLE
+20 DEG F TO -40 DEG F TO +140 DEG F TO +70 DEG F
60 MINUTES AT EACH TEMPERATURE

RANDOM VIBRATION
30 SECONDS FOR EACH OF 3 AXES

EXTERNAL LEAKAGE
NOT GREATER THAN 1×10^{-4} SCCS OF HELIUM

PERFORMANCE TESTS

CERTIFICATION (3 UNITS)

VIBRATION
48 MINUTES FOR EACH OF 3 AXES.

EXTERNAL LEAKAGE
NOT GREATER THAN 1×10^{-4} SCCS OF HELIUM

SHOCK
PER MIL-STD-810
BENCH HANDLING
DESIGN

LIGHTNING
PER MF0004-002

EMC
PER MF0004-002 AND MIL-STD-462

THERMAL CYCLE
10 CYCLES: +70 TO +105 TO -65 TO +165 TO +70 DEG F
60 MINUTES AT EACH TEMPERATURE

THERMAL VACUUM
6 HOURS AT 1×10^{-6} TORR
TEMPERATURE: 160 DEG F

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PERFORMANCE TESTS

OPERATING LIFE

1000 HOURS OF CYCLING
CYCLE PERIOD: 6 HOURS (POWER ON FOR 3 HOURS, OFF FOR 3 HOURS)
DURING THE POWER ON PHASE THE ON/OFF COMMAND IS CYCLED EVERY 5
SECONDS

POST TEST INSPECTION

GROUND TURNAROUND TEST

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

(C) INSPECTION:

RECEIVING INSPECTION

INCOMING PARTS ARE VERIFIED FOR MATERIAL, PHYSICAL CHARACTERISTICS, AND
PROCESS CERTIFICATIONS. RECEIVING RECORDS ARE MAINTAINED FOR VERIFICATION.

CONTAMINATION CONTROL

PROPER CLEANLINESS IN ACCORDANCE WITH ASSEMBLY AND TEST REQUIREMENTS IS
INSPECTED AND VERIFIED.

ASSEMBLY/INSTALLATION

ALL SOLDER AND WELD JOINTS COATED WITH 2850/CAT9 EPOXY ARE INSPECTED.
INSPECTION VERIFIES ALL MODULES FILLED WITH XR-5068 ENCAPSULANT AND CURE TIME
OF 2 HOURS AT 160 DEG F. TIGHTENED SCREWS AND TORQUE ARE CHECKED TO
PRECLUDE STRIPPED SCREWS AND ENSURE PROPER MOUNTING. ALL EXTERIOR
SURFACES OF HOUSING AND COVER MACHINED TO 63 RMS ARE CHECKED. GAP BETWEEN
COVER AND CASE SEALED WITH 2850/CAT9 AND CURE TIME ARE MONITORED.
MANDATORY INSPECTION POINTS ARE INCLUDED IN ASSEMBLY PROCESS.

CRITICAL PROCESSES

CONFORMAL COATING ON PWB ARE VERIFIED BY INSPECTION. ADHESIVE BONDING OF
TYPE GE GLASS EPOXY BOARD TO PWB SURFACE IS CHECKED. WIRE WELDING AND
LEAD SOLDERING OF COMPONENTS ARE INSPECTED IN ACCORDANCE WITH APPLICABLE
REQUIREMENTS. ASSEMBLY POTTING IS VERIFIED.

NONDESTRUCTIVE EVALUATION

NOT APPLICABLE

TESTING

ATP, INCLUDING PERFORMANCE TEST, IS VERIFIED BY INSPECTION.

HANDLING/PACKAGING

PACKAGING FOR SHIPMENT IS VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:

EARLY PRODUCTION UNITS

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DURING ATP (-40 DEG F, 22 VOLT INPUT ANALOG OUTPUT ERROR TEST), THE MODULE DREW EXCESSIVE CURRENT (REFERENCE CAR AC0545). THE INTERMITTENT FAILURE WAS VERIFIED AT LOW TEMPERATURE AND WAS ATTRIBUTED TO A SHORT. END EFFECT (LOSS OF OR ERRONEOUS FCV CLOSE COMMAND, ERRONEOUS PRESSURE INDICATION) DEPENDS ON LOCATION OF THE SHORT. WIRING COULD HAVE BEEN DISPLACED DURING ENCAPSULATION; TEMPERATURE VARIATIONS COULD THEN HAVE CAUSED STRESS ON THE WIRING RESULTING IN AN INTERMITTENT SHORT. CORRECTIVE ACTION WAS TO PERFORM A POST-ENCAPSULATION CONFIDENCE TEST WITH THERMAL CYCLING PRIOR TO ATP.

DURING ATP, THE SIGNAL CONDITIONER FAILED THE FREQUENCY RESPONSE TEST BY DRAWING EXCESSIVE CURRENT (REFERENCE CAR A5038). DURING REMOVAL OF THE UNIT FROM THE CASE AND SHIELD, A WELD CONNECTION ON ONE MODULE LOCATED ADJACENT TO THE MODULE DIVIDER SHIELD WAS FOUND TO BE MAKING INTERMITTENT CONTACT WITH THE DIVIDER SHIELD. THE MODULE INTERCONNECTING RIBBON HAD WORN THROUGH THE DIVIDER SHIELD INSULATION DUE TO INSUFFICIENT CLEARANCE BETWEEN THE DIVIDER SHIELD AND MODULES. END EFFECT OF THIS CONDITION (INADVERTENT FCV CLOSE COMMAND, ERRONEOUS PRESSURE INDICATION) DEPENDS ON LOCATION OF THE SHORT. CORRECTIVE ACTION WAS TO CONTROL THE LENGTH OF THE RIBBONS. FOR ASSEMBLED HARDWARE, THE ATP THERMAL CYCLE AND VIBRATION TESTS WERE CONSIDERED SUFFICIENT SCREENING TO INSURE DETECTION OF THE POTENTIAL PROBLEM.

SEVERAL SIGNAL CONDITIONER FAILURES (VARIOUS MODES) AT KSC WERE ATTRIBUTED TO MOISTURE RETAINED IN THE GLASS RESIN EPOXY ENCAPSULATION MATERIAL CAUSING MULTIPLE SHORT CIRCUITS WITHIN THE WELDED MODULES (REFERENCE CAR AC4420). ALL UNITS WERE REFURBISHED TO THE -0005 CONFIGURATION TO IMPROVE SEALING AND PRECLUDE INTERNAL MOISTURE. ADDITIONAL EPOXY SEALANT WAS ADDED BETWEEN THE COVER AND HOUSING. THE UNIT IS VACUUM BAKED AFTER THE ENCAPSULANT IS ADDED TO INSURE ABSENCE OF INTERNAL MOISTURE PRIOR TO SEALING OF THE FILL HOLE WITH EPOXY. THE UNIT IS THEN LEAK CHECKED, AND EPOXY IS APPLIED TO SEAL ELECTRICAL CONNECTOR SOLDER JOINT POROSITY IF REQUIRED.

CURRENT DATA ON TEST FAILURE, FLIGHT FAILURE, UNEXPLAINED ANOMALIES, AND OTHER FAILURES EXPERIENCED DURING GROUND PROCESSING ACTIVITY CAN BE FOUND IN THE PRACA DATABASE.

(E) OPERATIONAL USE:

IF THE LH2 NPSP DROPS BELOW THE PRE-FLIGHT ACCEPTED LEVELS (PER FLIGHT RULES), THE CREW WILL MANUALLY THROTTLE THE ENGINES TO KEEP THE NPSP HIGH ENOUGH TO PREVENT LH2 TURBOPUMP CAVITATION.

NO CREW ACTION CAN BE TAKEN FOR LO2 SYSTEM FAILURES.

- APPROVALS -

S&R ENGINEERING	: W.P. MUSTY	:/S/ W.P. MUSTY
S&R ENGINEERING ITM	: P. A. STENGER-NGUYEN	:/S/ P.A. STENGER-NGUYEN

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DESIGN ENGINEERING	: HERB WOLFSON	:/S/ HERB WOLFSON
MPS SUBSYSTEM MGR.	: TIM REITH	:/S/ TIM REITH
EPD&C SUBSYSTEM MGR.	: RICHARD PHAN	:/S/ RICHARD PHAN
MOD	: JEFF MUSLER	:/S/ JEFF MUSLER
USA SAM	: MICHAEL SNYDER	:/S/ MICHAEL SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	:/S/ SUZANNE LITTLE
NASA SR&QA	: BILL PRINCE	:/S/ BILL PRINCE