

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**

NUMBER: 03-1-0427 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 1 02/22/01

**PART DATA**


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	<b>PART NAME</b>	<b>PART NUMBER</b>
	<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU	: SENSOR, ET LH2 BF GOODRICH	MC432-0205-0013 (OR EQUIVALENT ET P/N)
LRU	: SENSOR, ET LO2 BF GOODRICH	MC432-0205-0019 (OR EQUIVALENT ET P/N)
LRU	: ELECTRONICS BF GOODRICH	MC432-0205-0021
LRU	: SENSOR, ORBITER BF GOODRICH	MC432-0205-0027

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**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

SENSORS AND ELECTRONICS, LO2/LH2 POINT LEVEL, ECO.

**REFERENCE DESIGNATORS:**

QUANTITY OF LIKE ITEMS: 1

**FUNCTION:**

THIS SYSTEM PROVIDES A MEANS OF MONITORING THE PROPELLANT LEVEL IN THE LO2/LH2 EXTERNAL TANKS DURING LOADING AND ASCENT. POINT SENSOR TRANSDUCERS ARE LOCATED IN THE ET AND ON THE ORBITER (LO2 17-INCH FEEDLINE) WITH SIGNAL CONDITIONING ELECTRONICS ON THE ORBITER TO MONITOR AND CONTROL LOADING AND DRAINING OF PROPELLANTS. SENSORS ARE REDUNDANT AT ALL CRITICAL LEVELS.

FOUR SENSORS IN THE ORBITER LO2 FEEDLINE AND FOUR IN THE BOTTOM OF THE ET LH2 TANK PROVIDE A SAFE BACKUP SSME CUTOFF SIGNAL TO PRECLUDE ENGINE PROPELLANT STARVATION, IN CASE A GUIDED (VELOCITY) MECO IS NOT ATTAINED. THE ECO LOGIC IS ARMED WHEN THE CALCULATED TOTAL PROPELLANT MASS REMAINING REACHES 32,000 LBS OR UPON SECOND ENGINE FAILURE FOLLOWING SRB SEPARATION. ANY TWO QUALIFIED LH2 OR LO2 DRY SENSORS WILL GENERATE A MECO COMMAND AFTER THE SYSTEM IS ARMED.

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**SUBSYSTEM NAME:** MAIN PROPULSION  
**LRU:** LH2/LO2 LIQUID LEVEL SENSOR  
**ITEM NAME:** LH2/LO2 LIQUID LEVEL SENSOR

**CRITICALITY OF THIS FAILURE MODE:** 1R2

**FAILURE MODE:**

INADVERTENT OUTPUT - FALSE DRY ECO SIGNALS (LO2 OR LH2) AFTER SYSTEM IS ARMED.

**MISSION PHASE:** LO LIFT-OFF

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

**CAUSE:**

HIGH RESISTANCE IN ET/ORBITER TRANSDUCER CIRCUIT, FAILURE OF POINT SENSOR ELECTRONICS BOX

**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 FAILURE INDICATION (DRY SIGNAL) CAN BE DISTINGUISHED FROM EXPECTED OUTPUT (WET SIGNAL). NO CORRECTIVE ACTION REQUIRED FOR FIRST FAILURE.

C)

**- FAILURE EFFECTS -**

**(A) SUBSYSTEM:**

LOSS OF REDUNDANCY. TWO OF FOUR DRY INDICATIONS REQUIRED TO INITIATE CUTOFF. ORBITER SOFTWARE WILL DISABLE A SINGLE FALSE DRY SENSOR PER PROPELLANT SYSTEM AT ARM COMMAND. LCC REQUIREMENT EXISTS FOR ALL POINT LEVEL SENSORS TO INDICATE WET PRIOR TO LAUNCH.

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**(B) INTERFACING SUBSYSTEM(S):**

SAME AS A.

**(C) MISSION:**

ON GROUND, VIOLATION OF LCC WILL RESULT IN LAUNCH SCRUB.

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

NO EFFECT.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

1R/2 2 SUCCESS PATHS. TIME FRAME-ASCENT, AFTER ECO SENSORS ARE ARMED.  
1,2) 2 LO2 OR LH2 ECO SENSORS INADVERTENT OUTPUT (DRY INDICATION).

RESULTS IN PREMATURE MECO. SSME CUTOFF MAY OCCUR TOO LATE FOR A TAL OR BE SHORT OF VELOCITY REQUIRED FOR AOA (OMS CANNOT SUPPLY THE REQUIRED DELTA-VELOCITY NEEDED FOR AOA). POSSIBLE LOSS OF CREW/VEHICLE.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

THE POINT SENSOR TRANSDUCERS UTILIZE 0.0005 INCH DIAMETER PLATINUM WIRE SENSING ELEMENTS MOUNTED ON A CERAMIC FRAME. THE ORBITER TRANSDUCER (LO2 ECO) HAS TWO SENSING ELEMENT ASSEMBLIES CONTAINED WITHIN A FLANGE-MOUNTED HOUSING (304 CRES) AND CONTAINS ONE ELECTRONIC CONNECTOR. THE ET TRANSDUCERS HAVE ONE SENSING ELEMENT ASSEMBLY IN A HOUSING WHICH IS MOUNTED ON MASTS AND ON THE LH2 SIPHON ASSEMBLY (BAFFLE) WITHIN THE LH2/LO2 TANKS. THE ET SENSOR USES A 356-T6 ALUMINUM INVESTMENT CASTING HOUSING WHICH IS TEFLON COATED ON THE INTERIOR TO ASSIST SYSTEM PERFORMANCE.

A SINGLE POINT SENSOR ELECTRONICS BOX IS HOUSED IN THE AFT AVIONICS BAY #5 ON A COLD PLATE. THE BOX HOUSING IS MADE OF DIP BRAZED 6061-T6 ALUMINUM. THE BOX CONTAINS A SERIES OF PRINTED CIRCUIT BOARDS WHICH ARE PLUGGED INTO A MOTHER BOARD. FLEX CIRCUITS INTERCONNECT THE PRINTED CIRCUIT BOARDS WITH THE INTERFACE ELECTRICAL CONNECTORS. THE BOX CONTAINS 14 SIGNAL CONDITIONING BOARDS, 2 POWER SUPPLY BOARDS, AND 1 CHECKOUT COMMAND ISOLATION BOARD. EACH SIGNAL CONDITIONING BOARD HAS ONE HYDROGEN AND ONE OXYGEN SIGNAL CONDITIONING CIRCUIT. PHYSICAL AND ELECTRICAL ISOLATION FOR EACH SIGNAL CONDITIONING CIRCUIT IS MAINTAINED.

EACH POWER SUPPLY BOARD HAS 2 SECTIONS. EACH SECTION CONVERTS VEHICLE 28 VDC POWER TO 14.5 VDC AND 12 VDC. VEHICLE POWER FROM THE THREE MAIN BUSES IS DISTRIBUTED TO THE POINT SENSOR ELECTRONICS POWER SUPPLIES. LOSS OF ANY ONE

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BUS WILL RESULT IN THE LOSS OF NO MORE THAN ONE POWER SUPPLY BOARD. EACH POWER SUPPLY POWERS A GROUP OF SIGNAL CONDITIONING BOARDS. POWER IS DISTRIBUTED WITHIN THE BOX SO THAT ADJACENT SENSORS UTILIZE DIFFERENT POWER SUPPLIES.

SIGNALS FOR GROUND CHECKOUT ARE DISTRIBUTED THROUGH OPTICAL ISOLATION CIRCUITS ON THE CHECKOUT COMMAND ISOLATION BOARD. GROUND CHECKOUTS ARE PERFORMED PRIOR TO AND DURING PROPELLANT LOADING OPERATIONS. SENSOR CABLE AND CONNECTOR RESISTANCES ARE VERIFIED DURING OPF CHECKS.

VEHICLE CABLING/CONNECTORS ROUTING MAINTAINS CIRCUIT ISOLATION. SIX INTERFACE ELECTRICAL CONNECTORS ARE INSTALLED ON THE HOUSING. TWO ARE USED FOR ATP CHECKOUT AND THE REMAINING FOUR ARE USED FOR OPERATIONAL FUNCTIONS. THE SYSTEM IS DESIGNED TO PROVIDE A WET SIGNAL FOR THE PREDOMINANT FAILURE MODES (PREVENT OVERFILLING OF ET TANKS AND PREMATURE MECO). EACH CRITICAL SENSING LOCATION HAS TRANSDUCERS LOCATED TO PROVIDE EITHER VERTICAL OR HORIZONTAL REDUNDANCY (BY LOCATION).

THE POINT SENSOR ELECTRONICS BOX IS BUILT USING EEE COMPONENTS SCREENED TO MIL-STD-883 LEVEL B REQUIREMENTS. ALL EEE COMPONENTS WERE SELECTED SO THAT THEIR USAGE MEETS THE SHUTTLE DERATING REQUIREMENTS.

**(B) TEST:**

ATP - ELECTRONICS BOX

EXAMINATION OF PRODUCT  
DIMENSIONAL  
WEIGHT  
TRACEABILITY RECORDS

ELECTRICAL CHARACTERISTICS  
DIELECTRIC STRENGTH  
INSULATION RESISTANCE

PERFORMANCE @ 28 VDC, 24 VDC, AND 32 VDC INPUT POWER  
INVERSE VOLTAGE PROTECTION  
CURRENT CONTROLLERS  
WET/DRY TRIGGER LEVEL  
POWER CONSUMPTION  
OUTPUT SIGNAL PERFORMANCE  
BUILT IN TEST EQUIPMENT (BITE) - OPERATION

THERMAL CYCLE  
+70 DEG F TO -60 DEG F TO +160 DEG F TO +70 DEG F  
REPEAT PERFORMANCE TEST AT EACH TEMPERATURE

VIBRATION  
RANDOM - FOR 30 SECONDS IN EACH OF THREE AXES

LEAKAGE - 15PSIG GHE

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ATP - SENSORS

EXAMINATION OF PRODUCT  
DIMENSIONS  
WEIGHT  
TRACEABILITY RECORDS

ELECTRICAL CHARACTERISTICS  
DIELECTRIC STRENGTH  
INSULATION RESISTANCE

THERMAL SHOCK (7 CYCLES)  
AMBIENT (DRY GN2) TO LN2 TO AMBIENT

PERFORMANCE - LN2  
RESPONSE (WET TO DRY) REPEAT 5 TIMES

PROOF PRESSURE (ORBITER UNIT; FLANGE AND CONNECTOR)  
390 PSIG FOR 5 MINUTES

LEAKAGE (ORBITER UNIT; FLANGE AND CONNECTOR)  
CRYO: 200 PSIG GHE @ -320 DEG F

D.C. RESISTANCE (SENSOR ELEMENT)

CERTIFICATION

RANDOM VIBRATION (POWER ON)  
ELECTRONICS BOX - 48 MINUTES IN EACH OF 3 AXES  
ET SENSORS - 3 MINUTES IN EACH OF 3 AXES IN LHE  
- 3 MINUTES IN EACH OF 3 AXES IN LN2  
ORBITER SENSOR - 48 MINUTES IN EACH OF 3 AXES IN LN2  
ELECTRONICS BOX (QAVT) - 5 MINUTES IN EACH OF 3 AXES

RANDOM VIBRATION (POWER OFF)  
ET SENSORS - LH2 3 MINUTES IN EACH OF 3 AXES @ 360 DEG F  
- LO2 3 MINUTES IN EACH OF 3 AXES @ 500 DEG F

SINUSOIDAL (ELECTRONICS BOX AND ORBITER SENSOR)  
5 TO 35 HZ

MECHANICAL SHOCK (MIL-STD-810)  
DESIGN

ELECTROMAGNETIC COMPATIBILITY (ELECTRONICS BOX ONLY)  
CONDUCTED AND RADIATED INTERFERENCE AND SUSCEPTIBILITY PER MIL-  
STD-462

THERMAL CYCLE (ELECTRONICS BOX ONLY) - 40 CYCLES

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AMBIENT TO +165 DEG F TO -65 DEG F TO +165 DEG F TO AMBIENT  
 PERFORM ATP PERFORMANCE TEST @ EACH TEMPERATURE EVERY 10  
 CYCLES

## PERFORMANCE

ELECTRONICS BOX - REPEAT ATP PERFORMANCE TEST  
 ET SENSORS

LO2 UNIT - REPEAT ATP PERFORMANCE IN LO2  
 LH2 UNIT - REPEAT ATP PERFORMANCE IN LH2

## ORBITER SENSORS

PERFORM RESPONSE FLOW TEST IN 6 INCH DIAMETER PIPE WITH  
 LO2 - REPEAT 5 TIMES

## SENSOR

VERIFY UNIT RESISTANCES  
 EXPOSURE TO HIGH VELOCITY FLUID

ORBITER - 27 FT/SEC LN2  
 ET - 3 FT/SEC LN2

EXPOSURE TO HIGH PRESSURE

ORBITER (LO2) - 260 PSIA  
 ET (LO2) - 75 PSIA  
 ET (LH2) - 50 PSIA

## SENSOR INTEGRATED SYSTEMS TEST (IN LH2/LO2)

RAISE AND LOWER FLUID PAST SENSOR CLUSTERS TO SIMULATE ET  
 FILLING AND DRAINING OPERATIONS

## ORBITER SENSORS

TERMINAL DRAIN FLOW TEST IN LO2 USING 17 INCH O.D. LINE AND  
 SIMULATED VEHICLE (ET/ORB) CONFIGURATION. VERIFY SENSORS  
 PERFORMANCE

## EXPLOSIVE ATMOSPHERE (SENSORS)

LH2 UNIT - GH2/AIR MIXTURE @ 160 DEG F FOR 2 MINUTES USING 12 VDC  
 LO2 UNIT - (ET) GO2 @ 500 DEG F AND 25 PSIG  
 (ORB) GO2 @ 200 DEG F AND 25 PSIG  
 SENSING ELEMENTS POWERED WITH 14.5 VDC

## OPERATING LIFE

## ORBITER ELECTRONICS BOX

600 HOURS TOTAL (POWER ON)  
 300 CYCLES - 2 HOURS POWER ON; 1 HOUR POWER OFF  
 50 CYCLES - AMBIENT TO VACUUM  
 PERFORM POST TEST BOX CHECKOUT WITH CHECKOUT  
 COMMANDS ONCE EACH DAY

## ET SENSORS (TEST FLUID: LN2/LH2)

19 HOURS OF 1 MINUTE WET AND 1 MINUTE DRY CYCLES; WARM UP  
 TO AMBIENT EVERY 6 HOURS. LAST CYCLE WARM UP TO 500 DEG F  
 (LO2 UNIT), 360 DEG F (LH2 UNIT)

## ORBITER SENSORS (TEST FLUID LN2)

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62.5 HOURS OF 1 MINUTE WET AND 1 MINUTE DRY CYCLES; WARM UP TO AMBIENT EVERY 6 HOURS. LAST CYCLE WARM UP TO 200 DEG F.

BURST (ORBITER SENSOR - FLANGE AND CONNECTOR)  
440 PSIG

OMRSD

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

**(C) INSPECTION:**

RECEIVING INSPECTION

RAW MATERIALS ARE VERIFIED FOR MATERIALS AND PROCESS CERTIFICATION. CERTIFICATES AND RECEIVING RECORDS ARE MAINTAINED FOR VERIFICATION. SAMPLING TESTS ARE PERFORMED ON ELECTRONIC PARTS PER DRAWING REQUIREMENTS.

CONTAMINATION CONTROL

CLEANLINESS LEVELS OF SENSORS ARE VERIFIED TO 400 FOR LH2 UNITS AND 800A FOR LO2 ET UNITS AND THE WETTED PORTION OF THE ORBITER LO2 ECO SENSORS.

ASSEMBLY/INSTALLATION

ALL SOLDERING IS INSPECTED TO NHB5300.4 (3A) REQUIREMENTS. ALL DIMENSIONAL, FINISHES AND TORQUE INSTALLATION REQUIREMENTS ARE VERIFIED. ALL SENSOR ELEMENT WELDS ARE INSPECTED WITH 7.5X MAGNIFICATION; SAMPLE WELDS ARE VERIFIED BY PULL TESTS. THE WELD ATTACHMENTS TO THE ELECTRICAL CONNECTOR PINS ON THE ORBITER SENSOR ARE 100% PULL TESTED. CONTINUITY OF SENSOR SUBSTRATE ELEMENT GOLD PATHS IS VERIFIED. WIRE TO TERMINAL POST WRAP IS CHECKED WITH 7.5X MAGNIFICATION. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

CRITICAL PROCESS

BRAZED AND WELDED SENSING WIRE TERMINATIONS ARE INSPECTED IN COMPLIANCE WITH DRAWING REQUIREMENTS. SWAGED TERMINAL POSTS OVER TERMINAL WASHERS ARE VERIFIED PER REQUIREMENT. ELECTRON BEAM WELDING IS VERIFIED ON ORBITER SENSOR HOUSING. ELECTRO CHEM-ETCH PROCESS IS VERIFIED.

NONDESTRUCTIVE EVALUATION

HELIUM LEAK DETECTION IS CONDUCTED ON ELECTRONICS BOX AND ORBITER SENSOR HOUSINGS. RADIOGRAPHIC AND DYE PENETRANT OF EB WELDS ARE VERIFIED.

TESTING

ATP IS PERFORMED AND VERIFIED BY INSPECTION.

HANDLING/PACKAGING

PARTS PACKAGED AND PROTECTED TO APPLICABLE REQUIREMENTS ARE VERIFIED. SPECIAL HANDLING PER DOCUMENTED INSTRUCTIONS IS VERIFIED TO PRECLUDE DAMAGE, SHOCK AND CONTAMINATION DURING HANDLING/SHIPPING/PACKAGING BETWEEN WORK STATIONS.

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**(D) FAILURE HISTORY:**

DURING SUPPLIER TESTS (REFERENCE CAR'S AB8240 AND A7965 - QUALIFICATION TESTS; A7527 - ATP), HIGH RESISTANCE OCCURRED ON THE LOX ECO TRANSDUCERS SENSING ELEMENT CIRCUIT DUE TO LOOSE TERMINAL POSTS. THIS RESULTED IN HIGH RESISTANCE CONTACT BETWEEN THE GOLD PADS AND THE TERMINAL POSTS. CORRECTIVE ACTION FOR ALL UNITS INCLUDED IMPROVED ATTACHMENT OF THE POSTS TO THE CERAMIC FRAME AND IMPROVED INSPECTION.

VARIOUS FALSE DRY OR WET SIGNALS HAVE OCCURRED DUE TO DEFECTIVE HYBRID INTEGRATED CIRCUITS (REFERENCE CAR AB6709 AT KSC AND CAR'S A6390, A7100, A9315, AB0132 AT SUPPLIER). CORRECTIVE ACTION CONSISTED OF USE OF NEW HYBRID MANUFACTURER PLUS USE OF IMPROVED MANUFACTURING TECHNIQUES, TESTING AND SCREENING.

DURING SUPPLIER ATP TESTING, FALSE DRY SIGNALS OCCURRED DUE TO A DEFECTIVE TRANSISTOR IN ONE OF THE 12-VOLT POWER SUPPLIES WITHIN THE POINT SENSOR ELECTRONICS BOX (REFERENCE CAR AC0149). TRANSISTORS FROM THE DEFECTIVE LOT WERE REMOVED AND REPLACED ON ALL BOXES.

DURING STS-1 CHECKOUT OF OV-102 AT KSC, FALSE DRY SIGNALS OCCURRED DUE TO OSCILLATION IN THE CURRENT CONTROLLER CIRCUITS OF THE POINT SENSOR ELECTRONICS BOX (REFERENCE CAR AB5389). ALL BOXES WERE MODIFIED WITH IMPROVED CIRCUITS TO PREVENT THE OSCILLATION OCCURRENCE.

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:**

PRIOR TO THE ARM COMMAND: CREW WILL PERFORM TAL ABORT IF THERE ARE THREE OR MORE FALSE DRY SIGNALS AND UPHILL CAPABILITY DOES NOT EXIST.

AFTER THE ARM COMMAND: NO CREW ACTION CAN BE TAKEN.

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**- APPROVALS -**

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S&R ENGINEERING	: W.P. MUSTY	: /S/ W. P. MUSTY
S&R ENGINEERING ITM	: P. A. STENGER-NGUYEN	: /S/ P. A. STENGER-NGUYEN
DESIGN ENGINEERING	: HERB WOLFSON	: /S/ HERB WOLFSON
MPS SUBSYSTEM MGR.	: TIM REITH	: /S/ TIM REITH
MOD	: JEFF MUSLER	: /S/ JEFF MUSLER
USA SAM	: MIKE SNYDER	: /S/ MIKE SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	: /S/ SUZANNE LITTLE
NASA SR&QA	: ERICH BASS	: /S/ ERICH BASS