

**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: 1/1**

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**FAILURE MODE:**

PROBE STRUCTURAL FAILURE - ORBITER LO2 ECO SENSOR.

**MISSION PHASE: LO LIFT-OFF**

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

**CAUSE:**

FATIGUE, MATERIAL DEFECT

**CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO**

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<b>REDUNDANCY SCREEN</b>	A) N/A
	B) N/A
	C) N/A

**PASS/FAIL RATIONALE:**

A)

B)

C)

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**- FAILURE EFFECTS -**

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**(A) SUBSYSTEM:**

PROBE BREAKS OFF AND LODGES ON LO2 PREVALVE PREVENTING LO2 PREVALVE CLOSURE AT MECO. RESULTS IN THE INABILITY TO MAINTAIN INJECTED HELIUM AND LO2 PRESSURE TO THE HIGH PRESSURE OXIDIZER TURBOPUMP (HPOTP) TO PREVENT PUMP OVERSPEED AND CAVITATION AT MECO. CAUSES UNCONTAINED ENGINE DAMAGE, AFT COMPARTMENT OVERPRESSURIZATION, AND FIRE/EXPLOSION HAZARD.

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ALSO RESULTS IN LOSS OF GHE SUPPLY DURING MANIFOLD REPRESSURIZATION  
(THROUGH SSME HPOTP SEAL) CAUSING POSSIBLE LOSS OF AFT COMPARTMENT PURGE.

**(B) INTERFACING SUBSYSTEM(S):**  
SAME AS A.

**(C) MISSION:**  
POSSIBLE LOSS OF CREW/VEHICLE.

**(D) CREW, VEHICLE, AND ELEMENT(S):**  
SAME AS C.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**  
NONE.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

THE LO2 ECO SENSOR CONSISTS OF A 304 CRES MACHINED HOUSING TO WHICH IS WELDED (EB) A CONNECTOR AND A LEAK TEST FITTING, AND ON WHICH IS MOUNTED THE TWO ELEMENT ASSEMBLIES. THE ELEMENTS ARE COVERED BY A 304 CRES MACHINED SHROUD. THE SHROUD IS SECURED TO THE HOUSING BY TWO NAS SCREWS. THE ENTIRE SENSOR ASSEMBLY IS MOUNTED TO THE FEEDLINE WITH THE SENSOR PROBE WITHIN A WELL ON THE INSIDE OF THE FEEDLINE.

STRUCTURAL FAILURE OF ANY PART OF THE SENSOR IS UNLIKELY FOR ALL OF THE FOLLOWING REASONS:

THE INSTALLATION OF THE LO2 ECO SENSOR IS IN AN AREA OF SUCH LOW VIBRATION LEVELS THAT VIBRATION TESTING OF THE SENSOR IS NOT REQUIRED.

DYNAMIC LOADS ARE VERY LOW BECAUSE THE SENSOR IS LOCATED IN A RECESS (WELL) IN THE WALL OF THE 17-INCH LINE, WITH ONLY 0.125 INCHES PROTRUDING WITHIN THE LINE INSIDE DIAMETER.

FAILURE OF EITHER THE CONNECTOR OR THE LEAK TEST FITTING WOULD NOT CAUSE ANY DEBRIS TO ENTER THE FEED SYSTEM BECAUSE BOTH ARE ATTACHED TO THE OUTBOARD SIDE OF THE SENSOR MOUNTING FLANGE; DEBRIS WOULD GO INTO THE AFT COMPARTMENT.

THE COMPONENT PARTS OF THE ELEMENT ASSEMBLIES ARE PROTECTED BY THE SHROUD. THE SHROUD CONTAINS 5 HOLES TO PROVIDE RAPID DRAINAGE. THERE IS A 0.687 INCH BY 0.62 INCH RECTANGULAR HOLE AND A 0.437 INCH DIAMETER

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CIRCULAR HOLE ON THE SIDES OF THE SHROUD. IN THE END OF THE SHROUD (POINTING TOWARD THE FEEDLINE CENTERLINE) ARE THREE SLOTTED HOLES ALONG THE PERIMETER EACH BEING 0.126 INCH WIDE BY 1.147 INCHES LONG ON A 1.205 INCH MEAN DIAMETER. THE CONTAINED COMPONENTS ARE: SENSING WIRE (GOLD FLASHED PLATINUM, 0.0005 INCH DIAMETER BY APPROXIMATELY 7 INCHES LONG IN EACH SENSING ELEMENT); TWO TERMINAL POSTS (302 CRES, 0.039 INCH OD BY 0.214 INCH LONG) IN EACH ELEMENT; TWO TERMINAL WASHERS (302 CRES, 0.100 INCH OD BY 0.020 INCH THICK) SWAGED ONTO THE TERMINAL POSTS; TEN ELEMENT PINS (GOLD PLATED IRON-NICKEL-COBALT ALLOY [KOVAR], 0.015 INCH OD BY 0.140 INCH LONG) IN EACH ELEMENT ASSEMBLY; ELEMENT SUBSTRATE (AL2O3 CERAMIC, 1.094 INCH BY 0.891 INCH BY 0.120 INCH THICK) FOR EACH ELEMENT; A TEFLON PARTITION; AND A TEFLON INSULATION COVER.

THE MINIMUM SHROUD OUTSIDE DIAMETER IS 1.380 INCHES AND THE MAXIMUM WELL INSIDE DIAMETER IS 1.437 INCHES. IF THE SENSOR WERE INSTALLED SO THAT THE SHROUD WERE IN CONTACT WITH THE WELL, A GAP OF 0.067 INCH WOULD RESULT. EACH OF THE TWO SCREWS SECURING THE SHROUD TO THE HOUSING IS 0.125 INCHES LONG. THE SCREWS ARE THREADED INTO HELICOIL SCREW LOCK INSERTS IN THE HOUSING. IF THEY SHOULD BACK OUT THE WELL WILL PREVENT THEIR TOTAL REMOVAL.

**(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:**

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:**

FLIGHT: NO CREW ACTION CAN BE TAKEN.

GROUND: GROUND OPERATIONS SAFING PROCEDURES CONTAIN SAFING SEQUENCE OF EVENTS FOR MAJOR LEAKS IN THE OXYGEN SYSTEM.

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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