

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE  
NUMBER: 02-6-E24-PT -X**

**SUBSYSTEM NAME: HYDRAULICS**

**REVISION: 1      07/24/98**

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**PART DATA**

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<b>PART NAME</b>	<b>PART NUMBER</b>
<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU      :TRANSDUCER, PRESSURE	ME449-0177

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**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**  
TRANSDUCER, ACCUMULATOR, BOOTSTRAP, HYDRAULIC

**REFERENCE DESIGNATORS:** 50V58MT54  
50V58MT55  
50V58MT56

**QUANTITY OF LIKE ITEMS: 3**  
ONE IN EACH HYDRAULIC POWER SYSTEM

**FUNCTION:**  
PROVIDE RESERVOIR PRESSURIZATION INDICATION FOR POSITIVE HEAD PRESSURE  
ON MAIN PUMP INLETS AT APU STARTUP IN ORBIT.

## FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE

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SUBSYSTEM NAME: HYDRAULICS

LRU: TRANSDUCER, PRESSURE

ITEM NAME: TRANSDUCER, PRESSURE

CRITICALITY OF THIS

FAILURE MODE: 1R2

## FAILURE MODE:

ERRONEOUS PRESSURE TRANSDUCER INDICATION

MISSION PHASE: OO ON-ORBIT  
DO DE-ORBITVEHICLE/PAYLOAD/KIT EFFECTIVITY: 102 COLUMBIA  
103 DISCOVERY  
104 ATLANTIS  
105 ENDEAVOUR

## CAUSE:

MECHANICAL FAILURE, OR RESISTANCE CHANGE IN THE BRIDGE ELEMENT DUE TO AGE RELATED MICRO STRUCTURE FAILURE, VIBRATION, THERMAL, SHOCK, ELECTROSTATIC DISCHARGE, AND CONTAMINATION

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN A) PASS  
B) FAIL  
C) PASS

## PASS/FAIL RATIONALE:

A)

B)

FAILS SCREEN "B" DUE TO BIAS HIGH READING WHICH CAN RESULT IN FALSE INDICATION FOR CIRCULATION PUMP ACTIVATION. RESERVOIR PRESSURE CAN BE USED AS A BACKUP TO A FAILED ACCUMULATOR SENSOR WHEN RECOGNIZED. HOWEVER, VARIABILITIES IN THE CORRELATION BETWEEN ACCUMULATOR PRESSURE AND RESERVOIR PRESSURE COULD DISGUISE A BIAS HIGH READING AND PREVENT ADEQUATE RESPONSE PRIOR TO LOSS OF SYSTEM

C)

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**- FAILURE EFFECTS -**

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**(A) SUBSYSTEM:**

A BIAS HIGH SENSOR READING COUPLED WITH IN-SPECIFICATION ON-ORBIT HYDRAULIC FLUID LEAKAGE COULD LEAD TO LOSS OF REQUIRED CIRCULATION PUMP ACTIVATION. THIS WOULD RESULT IN LOSS OF BOOTSTRAP HYDRAULIC FLUID PRESSURE WHICH WILL LEAD TO CORRESPONDING LOSS OF RESERVOIR PRESSURE (LOSS OF MAIN PUMP RESTART CAPABILITY) RESULTING IN LOSS OF ONE HYDRAULIC SYSTEM. A SUDDEN SENSOR SHIFT COULD OCCUR AT ANY TIME. AN OFF-SCALE HIGH OR LOW SENSOR IS NOT A CONCERN DUE TO DETECTABILITY. A BIAS-LOW SENSOR IS NOT A CONCERN DUE TO CIRCULATION PUMP ACTIVATION NOT BEING COMPROMISED.

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

HYDRAULIC LANDING GEAR DEPLOYMENT CAPABILITY WOULD BE LOST IF SYSTEM ONE WAS LOST. LOSS OF REDUNDANT NWS. LOSS OF ONE OF THREE HYDRAULIC POWER SYSTEMS TO FLIGHT CONTROL SURFACES AND BRAKES.

**(C) MISSION:**

ASCENT/ENTRY - NO EFFECT FOR FIRST FAILURE. FUNCTIONAL TRANSDUCER NOT REQUIRED DURING MAIN PUMP OPERATION. ORBIT - LOSS OF ONE HYDRAULIC SYSTEM FOR ENTRY. ABORT DECISION (POSSIBLE EARLY MISSION TERMINATION IF UNABLE TO MAINTAIN BOOTSTRAP PRESSURE), FUNCTIONAL TRANSDUCER REQUIRED FOR CIRCULATION PUMP SOFTWARE TO MAINTAIN BOOTSTRAP PRESSURE. MANUAL CIRCULATION PUMP ACTIVATION EXISTS IF FAILURE IS DETECTED.

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

NO EFFECT FOR FIRST FAILURE (LOSS OF ONE OF 3 HYDRAULIC SYSTEMS) - ADEQUATE FLIGHT CONTROL CAPABILITY EXISTS (CERTIFIED FOR SAFE RETURN WITH 2 OF 3 HYDRAULIC SYSTEMS).

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

POSSIBLE LOSS OF CREW/VEHICLE WITH TWO FAILURES: THIS FAILURE, PLUS LOSS OF SECOND HYDRAULIC SYSTEM.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

THE TRANSDUCER UTILIZES A STRAIN GAUGE PRESSURE MONITORING CONCEPT. A BEAM WITH A STRAIN GAUGE IS CONNECTED TO THE SENSING DIAPHRAGM WITH A

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LINKAGE PIN. THE DIAPHRAGM DEFLECTION DUE TO PRESSURE CHANGES IS TRANSMITTED TO THE BEAM THROUGH THE LINK CAUSING BEAM DEFLECTION. THE STRAIN GAUGE WILL MEASURE THIS DEFLECTION.

FOUR STRAIN GAUGES ARE SPUTTER OR VAPOR DEPOSITED ON AN INSULATING MATERIAL AND THEN CONNECTED INTO A WHEATSTONE BRIDGE CIRCUIT BY SPUTTER-DEPOSITED LEADS. PRODUCTION OF VAPOR DEPOSITED GAUGES ENDED IN 1993. ALL PRODUCTS MANUFACTURED AFTER THAT TIME ARE MADE BY THE SPUTTER DEPOSITION PROCESS. REPLACEMENT ON THE SPACE SHUTTLE PROGRAM IS ON AN ATTRITION BASIS.

TO ACTIVATE THE STRAIN GAGE BRIDGE, A CANTILEVERED BEAM IS CONNECTED TO THE DIAPHRAGM VIA A RIGID LINK PIN. AS THE DIAPHRAGM/LINK PIN/BEAM SYSTEM MOVES, TWO ARMS OF THE WHEATSTONE BRIDGE TENSE AND TWO COMPRESS. THE RELATIONSHIP OF THESE CHANGES DICTATES THE OUTPUT OF THE SENSOR.

A TERMINAL PLATE IS POSITIONED AROUND THE BRIDGE NETWORK AND CONNECTED ELECTRICALLY TO THE BRIDGE BY THIN LEAD WIRES. ONE PIECE IS CONNECTED TO THE BEAM AND THE SECOND IS CONNECTED TO THE DIAPHRAGM. STRAIN GAUGE LEAD WIRES CONNECT TO THE STATIONARY YOKE (STAINLESS STEEL). LEADS CONNECT THE STATIONARY YOKE TO THE FEED THROUGH CONNECTOR. MATERIALS AND PROCESSES USED ARE COMPATIBLE WITH THE ENVIRONMENTAL CONDITIONS.

THE TRANSDUCER IS DESIGNED TO EXPERIENCE MINIMUM OUTPUT SHIFT DUE TO NOMINAL ENVIRONMENTAL AND OPERATING CONDITIONS. ME449-0177 SPECIFICATION ALLOWS TRANSDUCER ZERO SHIFT OF  $\pm 2\%$  FULL SCALE. THE TRANSDUCER IS CAPABLE OF WITHSTANDING 1.5 TIMES MAXIMUM OPERATING PRESSURE (PROOF PRESSURE) WITHOUT CHANGING THE CALIBRATION. ITS CONSTRUCTION IS ENTIRELY INORGANIC AND, IN ADDITION, HERMETICITY IS ACHIEVED THROUGH EB-WELDING OF ALL PRESSURE-BEARING JOINTS.

RUPTURE/LEAKAGE OF THE TRANSDUCER IS PRECLUDED BY USE OF A PRIMARY AND SECONDARY BARRIER DESIGN CONCEPT. THE PRIMARY BARRIER UTILIZES WELDED INCONEL COMPONENTS (THREADED FITTING AND DIAPHRAGM). A CASE ASSEMBLY, INCLUDING FEED THROUGH TERMINALS, IS WELDED TO THE THREADED FITTING TO PROVIDE A SECONDARY BARRIER. THE SECONDARY BARRIER IS DESIGNED FOR A MINIMUM BURST PRESSURE OF 3 TIMES MAXIMUM OPERATING PRESSURE (FOR -6171, THE BURST PRESSURE IS 3.75 TIMES THE OPERATING PRESSURE).

STRUCTURAL ANALYSIS INDICATES A POSITIVE MARGIN OF SAFETY FOR ALL OPERATING CONDITIONS.

**(B) TEST:**

ALL STATHAM TRANSDUCERS ARE ASSEMBLED AND TESTED SUBJECT TO STRICT QUALITY ASSURANCE CONTROLS. ELECTRICAL AND TEMPERATURE TESTING STARTS AT THE FLEXURE ASSEMBLY LEVEL; AND PRESSURE TESTING STARTS AT AN EARLY UNIT ASSEMBLY LEVEL ONCE THE FLEXURE HAS BEEN ELECTRON BEAM WELDED TO THE ISOLATOR

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ONCE THE SENSOR SUBASSEMBLY IS COMPLETE, THE TRANSDUCER SYSTEM IS SUBJECTED TO PRESSURE, TEMPERATURE AND ELECTRICAL TESTING AND COMPENSATED TO ENSURE COMPLIANCE TO ITS PERFORMANCE SPECIFICATION.

**QUALIFICATION/CERTIFICATION:**

- **CERTIFICATION BY ANALYSIS**  
ENVIRONMENTAL REQUIREMENTS OF MF0004-014
  - FUNGUS, OZONE, SAND, DUST
  - EXPLOSION PROOFING
  - LIGHTNING
  - FLUID COMPATIBILITY
  - TRANSPORTATION AND PACKAGING
  - MECHANICAL SHOCK
  - STATIC ACCELERATION
  - OUTPUT SHORT CIRCUIT PROTECTION
- **CERTIFICATION BY SIMILARITY**
  - USEFUL LIFE (10 YEARS OR 100 MISSIONS)
  - VACUUM
  - HUMIDITY
  - ACCELERATION
- **CERTIFICATION BY TEST**
  - VIBRATION
  - TEMPERATURE
  - PRIMARY BARRIER

**ACCEPTANCE:**

- PRESSURE TRANSDUCER PROOFED TO 6,000 PSIG.
- EXAMINATION OF PRODUCT
- PERFORMANCE TESTS:
  - INSULATION RESISTANCE
  - TEMPERATURE CALIBRATION  
0, 20, 40, 60, 80, 100, 80, 60, 40, 20, 0 PERCENT OF FULL SCALE PRESSURE (4000 PSIA) AT -75 DEG F, +77 DEG F, AND 350 DEG F. RECORD ERROR DUE TO TEMPERATURE EFFECTS, LINEARITY, RESIDUAL IMBALANCE, REPEATABILITY, AND SENSITIVITY
  - CLEANLINESS - LEVEL 190 PER MA0110-301.

**GROUND TURNAROUND TEST**

ANY TURNAROUND CHECKOUT TESTING IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

**(C) INSPECTION:**

RECEIVING INSPECTION

ALL RAW MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIALS AND PROCESS CERTIFICATION.

CONTAMINATION CONTROL

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CLEANLINESS LEVEL 190 PER MA0110-301 IS VERIFIED BY INSPECTION. CORROSION PROTECTION IS VERIFIED BY INSPECTION.

CRITICAL PROCESSES  
THE FOLLOWING ARE VERIFIED BY INSPECTION:

SOLDERING  
WELDING  
HEAT TREATMENT  
PRESSURE CYCLING  
PART PASSIVATION

NONDESTRUCTIVE EVALUATION  
HELIUM LEAK TEST IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION  
PARTS ARE INSPECTED VISUALLY, DIMENSIONALLY, AND INCREMENTALLY PER REQUIREMENTS. TOOL CALIBRATION IS VERIFIED BY INSPECTION. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCESS.

TESTING  
ATP, INCLUDING PROOF PRESSURE TEST, IS OBSERVED AND VERIFIED BY INSPECTION.

HANDLING/PACKAGING  
SPECIAL HANDLING PER DOCUMENTED INSTRUCTIONS IS VERIFIED BY INSPECTION TO PRECLUDE DAMAGE, SHOCK, AND CONTAMINATION DURING COMPONENT HANDLING, TRANSPORTING, AND PACKAGING BETWEEN WORK STATIONS.

**(D) FAILURE HISTORY:**

CURRENT DATA ON TEST FAILURES, FLIGHT FAILURES, UNEXPLAINED ANOMALIES, AND OTHER FAILURES EXPERIENCED DURING GROUND PROCESSING ACTIVITY CAN BE FOUND IN THE PRACA DATABASE. THE FAILURE HISTORY DATA PROVIDED BELOW IS NO LONGER BEING KEPT UP-TO-DATE.

THREE SIGNIFICANT ACCUMULATOR SENSOR FAILURES WERE:

KB2380-010 "PRESSURE TRANSDUCER EXHIBITED A NON-LINEAR BIAS LOW CONDITION" (08/92)

KB2659-010 "HYD BOOTSTRAP ACCUMULATOR #3 GN2 PRESSURE IS INDICATING 1824 AT 72 DEG F; SHOULD BE 1750 PSIA AT 70 DEG F" (3/93)

KB2887-010 "HYD SYSTEM 3A PRESSURE IS BIASED LOW (-80 PSI)" (11/93)

**(E) OPERATIONAL USE:**

ATTEMPT A DELAYED START FOR AFFECTED SYSTEM TO ALLOW FOR INTERSYSTEM LEAKAGE FROM THE OTHER TWO SYSTEMS AND ATMOSPHERIC PRESSURE TO PROVIDE

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THE NECESSARY HEAD PRESSURE FOR THE FAILED SYSTEM. THIS METHOD HAS NOT BEEN PREVIOUSLY TESTED IN FLIGHT

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- APPROVALS -

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EDITORIALLY APPROVED : BNA : J. Komura 7-30-95  
TECHNICAL APPROVAL : VIA APPROVAL FORM : 95-CIL-009\_02-6