

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

NUMBER: 03-1-0193 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 02/21/01

**PART DATA**

PART NAME	PART NUMBER
VENDOR NAME	VENDOR NUMBER
LRU : LINE ASSEMBLY BOEING	V070-415141

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

LINES UPSTREAM OF HELIUM PNEUMATIC CHECK VALVE CV9, NORMALLY PRESSURIZED DURING ASCENT. EACH LINE CONNECTS A THREE WAY SOLENOID VALVE TO A VALVE ACTUATOR PORT AND ANTI SLAM PORT.

LINES ARE BETWEEN THE FOLLOWING SOLENOID VALVES AND PNEUMATIC ACTUATORS:

LV29 TO PV9  
LV31 TO PV10

LV33 TO PV11  
LV35 TO PV12

**REFERENCE DESIGNATORS:**

**QUANTITY OF LIKE ITEMS:** 4

**FUNCTION:**

EACH LINE TRANSMITS PNEUMATIC PRESSURE TO OPERATE ITS CORRESPONDING PNEUMATIC VALVE. THE VALVES CONNECTED TO THESE LINES ARE:

LO2 OUTBOARD FILL & DRAIN VALVE (PV9) AND CLOSING SOLENOID (LV29),  
LO2 INBOARD FILL & DRAIN VALVE (PV10) AND CLOSING SOLENOID (LV31),  
LH2 OUTBOARD FILL & DRAIN VALVE (PV11) AND CLOSING SOLENOID (LV33),  
LH2 INBOARD FILL & DRAIN VALVE (PV12) AND CLOSING SOLENOID (LV35).

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**SUBSYSTEM NAME: MAIN PROPULSION**

**LRU: GHE REG LEG LINE ASSEMBLY-PRESSURIZED**

**CRITICALITY OF THIS**

**ITEM NAME: GHE REG LEG LINE ASSEMBLY-PRESSURIZED**

**FAILURE MODE: 1R2**

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**FAILURE MODE:**

RUPTURE/LEAKAGE

**MISSION PHASE: LO LIFT-OFF**

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

**CAUSE:**

FATIGUE, MATERIAL DEFECTS, IMPROPER BRAZE, DAMAGED/DEFECTIVE JOINT SEAL

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

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**REDUNDANCY SCREEN**

- A) PASS
- B) PASS
- C) PASS

**PASS/FAIL RATIONALE:**

A)

B)

PASSES SCREEN B BECAUSE HELIUM LOSS IS DETECTABLE AND SYSTEM CAN BE ISOLATED. PRESSURE BOTH UPSTREAM AND DOWNSTREAM OF CV9 IS MONITORED. CV9 PREVENTS PRESSURE LOSS FROM PREVALVE ACCUMULATOR LEGS.

C)

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**- FAILURE EFFECTS -**

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**(A) SUBSYSTEM:**

MAY PREVENT THE:

APPLICATION OF CLOSING PRESSURE TO THE ACTUATOR ON THE LO2 OUTBOARD FILL & DRAIN VALVE (REFERENCE FMEA/CIL 03-1-0222), THE LO2 INBOARD FILL & DRAIN VALVE (REFERENCE FMEA/CIL 03-1-0224), THE LH2 OUTBOARD FILL & DRAIN VALVE (REFERENCE FMEA/CIL 03-1-0271),

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THE LH2 INBOARD FILL & DRAIN VALVE (REFERENCE FMEA/CIL 03-1-0273).

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

LEAKAGE MAY BE DETECTABLE ON GROUND USING HAZARDOUS GAS DETECTION SYSTEM (HGDS). LINES ARE LOCATED ON HELIUM PNEUMATIC LEG UPSTREAM OF CHECK VALVE CV9 (NON-ACCUMULATOR LEG). RESULTS IN DEPLETION OF THE MPS VALVE ACTUATION HELIUM SUPPLY. HELIUM REMAINING DOWNSTREAM OF CV9 (ACCUMULATOR LEG) IS SUFFICIENT TO CLOSE LO2 PREVALVES AT MECO. RESULTS IN LACK OF AFT COMPARTMENT PURGE DURING REENTRY.

**(C) MISSION:**

ON GROUND, POSSIBLE VIOLATION OF HGDS LCC WILL RESULT IN LAUNCH SCRUB. LOSS OF HELIUM SUPPLY HAS NO EFFECT FOR NOMINAL, AOA, AND ATO MISSIONS (RESULTS IN POSSIBLE SYSTEM CONTAMINATION DURING ENTRY).

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

SAME AS C.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

CASE 1: LINES BETWEEN LV31 AND PV10 (LO2 I/B F/D VALVE) OR LV35 AND PV12 (LH2 I/B F/D VALVE).

1R/2 2 SUCCESS PATHS. TIME FRAME - ASCENT.

- 1) RUPTURE/LEAKAGE OF A PRESSURIZED GHE ACTUATOR LINE RESULTING IN LOSS OF ACTUATION PRESSURE TO I/B FILL/DRAIN VALVES.
- 2) INADVERTANT ACTUATION OF ASSOCIATED FILL/DRAIN VALVE OPENING SOLENOID (LV30 OR LV34) RESULTING IN OPENING OF INBOARD FILL/DRAIN VALVE.

FOR LH2 VALVE, CAN RESULT IN A GAS BUBBLE FROM LH2 FILL/DRAIN LINE BEING INGESTED BY SSME AT ENGINE START. POTENTIAL PUMP CAVITATION AND UNCONTAINED ENGINE DAMAGE(REF CIL 03-1-0301-04).

FOR LO2 VALVE, CAN RESULT IN WATER HAMMER AND RUPTURE OF THE FILL/DRAIN LINE (REF CIL 03-1-0310-04).

EITHER CASE RESULTS IN FIRE/EXPLOSION HAZARD AND POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:

LINES BETWEEN LV29 AND PV9 (LO2 O/B F/D VALVE) OR LV33 AND PV11 (LH2 O/B F/D VALVE).

1R/3 3 SUCCESS PATHS. TIME FRAME - ASCENT.

- 1) RUPTURE/LEAKAGE OF A PRESSURIZED GHE ACTUATOR LINE RESULTING IN LOSS OF ACTUATION PRESSURE TO O/B FILL/DRAIN VALVES.
- 2) INADVERTANT ACTUATION OF ASSOCIATED FILL/DRAIN VALVE OPENING SOLENOID (LV28 OR LV32) RESULTING IN OPENING OF OUTBOARD FILL/DRAIN VALVE.

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- 3) INADVERTANT OPENING OF ASSOCIATED INBOARD FILL/DRAIN VALVE (OR LH2 TOPPING VALVE) RESULTING IN OVERBOARD LEAKAGE OF LO2 OR LH2 RESPECTIVELY.

RESULTS IN FIRE/EXPLOSION HAZARD AND POSSIBLE LOW LEVEL CUTOFF OF SSME. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 3: (ALL FOUR LINES)

1R/3 3 SUCCESS PATHS. TIME FRAME - ASCENT.

- 1) RUPTURE/LEAKAGE OF A PRESSURIZED GHE ACTUATOR LINE.
- 2) FAILURE OF CV9 TO CHECK/REMAIN CLOSED.
- 3) GHE PNEUMATIC ISOLATION VALVE (LV7 OR LV8) FAILS TO CLOSE WHEN COMMANDED BY CREW TO ISOLATE PNEUMATIC SYSTEM LEAKAGE.

POSSIBLE DEPLETION OF PNEUMATIC HELIUM SUPPLY (BOTH THE ACCUMULATOR AND NON-ACCUMULATOR LEGS) CAUSING FAILURE TO CLOSE LO2 PREVALVES AT MECO. RESULTS IN THE INABILITY TO MAINTAIN INJECTED HELIUM (PROVIDED BY THE ENGINE HELIUM SUPPLY) AND LO2 PRESSURE AT THE SSME PUMP CAUSING POSSIBLE PUMP OVERSPEED AND CAVITATION AT MECO. MAY RESULT IN UNCONTAINED ENGINE DAMAGE, POSSIBLE AFT COMPARTMENT OVERPRESS, AND FIRE/EXPLOSIVE HAZARD. AT MECO, THE ENGINE NUMBER TWO HELIUM SUPPLY IS SWITCHED INTO THE PNEUMATIC VALVE SYSTEM (VIA LV10) AS A BACKUP, BY SOFTWARE COMMAND, WHICH MAY ACTUATE THE LO2 PREVALVES CLOSED. POSSIBLE LOSS OF CREW/VEHICLE.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

DESIGNED TO A MINIMUM FACTOR OF SAFETY OF 2.0 PROOF AND 4.0 BURST. THE MECHANICAL FITTINGS (DYNATUBE) ARE MANUFACTURED FROM INCONEL 718. THE TUBE SEGMENTS ARE MANUFACTURED FROM 304L CRES TUBING. THE TUBE SEGMENTS AND FITTINGS ARE CONNECTED TOGETHER BY INDUCTION BRAZING USING A CRES UNION AND A BRAZE ALLOY PREFORM (81.5 AU, 16.5 CU, 2 NI). THE ROCKWELL INTERNATIONAL BRAZE ALLOY WAS SELECTED DUE TO ITS LOWER BRAZING TEMPERATURE REQUIREMENT THAN THE INDUSTRY STANDARD, AIDING IN THE PREVENTION OF EXCESSIVE GRAIN GROWTH AND REDUCING EROSION OF TUBE ENDS.

**(B) TEST:**

ATP

THE LINE ASSEMBLY IS PROOF PRESSURED TO 1225 PSIG AND LEAK CHECKED AT 750 PSIG AFTER INSTALLATION IN THE VEHICLE.

CERTIFICATION

CERTIFICATION OF THE TUBING INSTALLATION WAS ACCOMPLISHED BY ROCKWELL INTERNATIONAL PER THE "ORBITER TUBING VERIFICATION PLAN SD75-SH-205". 304L CRES

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TUBING WAS CERTIFIED FOR THE APOLLO PROPULSION SYSTEMS, THE F5E, A-9, C130A, 707, 727, AND 737 AIRCRAFT. THE TUBING WAS QUALIFIED BY SIMILARITY AND BY ANALYSIS FOR ORBITER USAGE EXCEPT FOR FLEXURAL FATIGUE AND RANDOM VIBRATION FOR THE LONG-LIFE ORBITER REQUIREMENTS. DATA FROM THE MISSION DUTY CYCLES CONDUCTED ON MPTA WERE ALSO USED TO CERTIFY TUBING INSTALLATIONS.

DYNATUBE FITTINGS AND SEALS WITH 304L TUBING WERE SUBJECTED TO THE FOLLOWING QUALIFICATION TESTS:

PROOF PRESSURE - PRESSURIZED TO TWO TIMES OPERATING PRESSURE AND HELD FOR 5 MINUTES.

EXTERNAL LEAKAGE - LEAK CHECKED AT 1-1/2 TIMES OPERATING PRESSURE. MAXIMUM ALLOWABLE LEAK RATE IS  $1 \times 10^{-6}$  SCCS.

BURST TEST - EXCEEDED 4 TIMES OPERATING PRESSURE.

IMPULSE FATIGUE - 200,000 CYCLES AT A CYCLIC RATE OF 70 +/- 5 CYCLES PER MINUTE FROM ZERO PSIG TO OPERATING PRESSURE TO ZERO PSIG.

FLEXURE FATIGUE - SPECIMENS WERE FILLED WITH HYDRAULIC FLUID AND PRESSURIZED TO OPERATING PRESSURE. THE SPECIMENS WERE THEN TESTED TO 10 MILLION CYCLES OF FLEXURE.

VIBRATION - 7 TEST SPECIMENS WERE SUBJECTED TO 45 MINUTES OF RANDOM VIBRATION AT 0.4 G<sup>2</sup>/HZ, 30 MINUTES AT 0.7 G<sup>2</sup>/HZ AND 10 MINUTES AT 0.2 G<sup>2</sup>/HZ AT AMBIENT PRESSURE AND TEMPERATURE CONDITIONS.

OMRSD

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

**(C) INSPECTION:**

RECEIVING INSPECTION

ALL DETAIL HARDWARE IS VERIFIED, BY INSPECTION, INDIVIDUALLY AT THE DETAIL LEVEL ON MANUFACTURING ORDERS, WITH ALL PROCESSES INCORPORATED.

CONTAMINATION CONTROL

CLEANLINESS LEVEL IS VERIFIED TO 100A. CORROSION PROTECTION IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

PARTS PROTECTION FROM DAMAGE AND CONTAMINATION IS VERIFIED. COMPONENTS ARE INSPECTED VISUALLY, DIMENSIONALLY, AND INCREMENTALLY DURING FABRICATION. TUBE AND AXIAL ALIGNMENT OF DYNATUBE FITTINGS ARE VERIFIED. TORQUES ARE VERIFIED. SEALING SURFACE IS VERIFIED BY INSPECTION. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURES.

CRITICAL PROCESS

LUBRICATION OF ALL THREADED FLUID FITTING COUPLINGS IS VERIFIED. ELECTRICAL BONDING IS VERIFIED. HEAT TREATMENT AND PART PASSIVATION ARE ALSO VERIFIED.

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NON DESTRUCTIVE EVALUATION  
RADIOGRAPHIC INSPECTION OF INDUCTION BRAZES IS VERIFIED BY INSPECTION.

TESTING  
ATP IS VERIFIED BY INSPECTION.

HANDLING/PACKAGING  
PACKAGING FOR SHIPMENT VERIFIED BY INSPECTION.

**(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:**

PNEUMATIC TANK, REGULATOR, AND ACCUMULATOR PRESSURE ARE ON S/M ALERT FDA SYSTEM AND THE BFS SYSTEM SUMMARY DISPLAY. THIS ALLOWS THE FLIGHT CREW TO RESPOND TO A PNEUMATIC HELIUM SYSTEM LEAK INDEPENDENT OF GROUND CONTROL.

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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	: LEE DURHAM	:/S/ LEE DURHAM
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	: BILL PRINCE	:/S/ BILL PRINCE