

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**NUMBER: 03-1-0308 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 2 11/08/00**PART DATA**

| | PART NAME | PART NUMBER |
|-----|--------------------------------------------------------|-------------------------------|
| | VENDOR NAME | VENDOR NUMBER |
| LRU | : LINE, LH2 FILL SENIOR FLEXONICS (KETEMA DIVISION) | MC271-0076-0011 8-031174-3 |
| LRU | : LINE LH2 FILL SENIOR FLEXONICS (KETEMA DIVISION) | MC271-0076-0021 8-031174-7 |

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

LINE, LH2 FILL 8 INCH DIAMETER, VACUUM JACKETED.

REFERENCE DESIGNATORS: FH6**QUANTITY OF LIKE ITEMS:** 1**FUNCTION:**

THE 8 INCH DIAMETER LINE EXTENDS FROM THE OUTBOARD FILL VALVE (PV11) TO THE INBOARD FILL VALVE (PV12). PROVIDES A MEANS OF LOADING & DRAINING THE ET LH2 TANK THROUGH THE PROPELLANT FEED SYSTEM. THE INBOARD VALVE IS CLOSED AT REDUCED FAST FILL. AFTER COMPLETION OF LOADING, THE TOPPING VALVE IS CLOSED IN ORDER TO GRAVITY-DRAIN THE FILL LINE (PRIOR TO CLOSING THE OUTBOARD FILL & DRAIN VALVE). BOTH THE INBOARD AND OUTBOARD VALVES REMAIN CLOSED DURING ENGINE OPERATION. THE INBOARD VALVE ALSO INCORPORATES A RELIEF VALVE, RELIEVING ANY PRESSURE BUILD-UP IN THE FILL LINE. THE LINE TRANSPORTS HYDROGEN OVERBOARD DURING PROPELLANT DUMP AND INERTING. THE LINE IS PRESSURIZED WITH HELIUM DURING ENTRY. THE LINE INCORPORATES A FLANGE FOR THE LH2 TOPPING LINE ATTACHMENT. THE LINE INCORPORATES PENETRATIONS FOR LH2 PRESSURE AND TEMPERATURE TRANSDUCERS, AND VACUUM JACKET FOR INSULATION. THE VACUUM JACKET INCORPORATES A RUPTURE DISK, EVACUATION VALVE, VACUUM GAGE, AND GETTER ASSEMBLY.

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SUBSYSTEM NAME: MAIN PROPULSION

LRU: LINE, LH2 FILL/DRAIN, VJ

ITEM NAME: LINE, LH2 FILL/DRAIN, VJ

CRITICALITY OF THIS

FAILURE MODE: 1/1

FAILURE MODE:

RUPTURE/LEAKAGE DURING PROPELLANT LOADING, DETANKING, AND DUMP/INERT.

MISSION PHASE:

PL PRE-LAUNCH

LO LIFT-OFF

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102 COLUMBIA

103 DISCOVERY

104 ATLANTIS

105 ENDEAVOUR

CAUSE:

MATERIAL DEFECT, FATIGUE

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN

A) N/A

B) N/A

C) N/A

PASS/FAIL RATIONALE:

A)

B)

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

PROPELLANT LEAK INTO AFT COMPARTMENT. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYOGENIC EXPOSURE. POSSIBLE AFT COMPT OVERPRESS AND FIRE/EXPLOSION HAZARD. LEAKAGE DETECTABLE ON GROUND USING HAZARDOUS GAS DETECTION SYSTEM (HGDS).

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(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

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

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

POSSIBLE LOSS OF CREW/VEHICLE.

(E) FUNCTIONAL CRITICALITY EFFECTS:

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

- 1) FILL & DRAIN LINE RUPTURE/LEAKAGE.
- 2) INBOARD FILL & DRAIN (PV12) OR LH2 TOPPING VALVE (PV13) FAILS TO REMAIN CLOSED.

RESULTS IN LH2 LEAKAGE INTO THE AFT COMPARTMENT. POSSIBLE AFT COMPARTMENT OVERPRESS AND FIRE/EXPLOSIVE HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. GROSS LINE LEAKAGE MAY ALSO CAUSE PROPELLANT DEPLETION RESULTING IN PREMATURE SSME CUTOFF. POSSIBLE UNCONTAINED ENGINE DAMAGE DUE TO PUMP CAVITATION AND VIOLATION OF ET MINIMUM STRUCTURAL REQUIREMENTS DUE TO REDUCED ULLAGE PRESSURE. POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

THE PRESSURE CARRIER PORTION OF THE LINE ASSEMBLY IS CONSTRUCTED OF INCONEL 718 AND INCORPORATES THREE FLEXIBLE JOINTS AND A FLANGE AT EACH END. THE FLEXIBLE JOINTS INCORPORATE MULTI-PLY BELLOWS TO MINIMIZE STRESS LEVELS AND FLOW LINERS TO ELIMINATE FLOW INDUCED VIBRATION. THE FLEXIBLE JOINTS PROVIDE FREE MOVEMENT WITHOUT BINDING TO ACCOMMODATE THERMAL, STRUCTURAL AND VIBRATION INDUCED DEFLECTIONS.

THE MAXIMUM OPERATING PRESSURE DURING GROUND FILL OR DRAIN IS 40 PSIG (AT 12,000 GPM, MINUS 423 DEG F) AND 60 PSIG AT STATIC CONDITIONS. THE MAXIMUM OPERATING PRESSURE DURING LIFTOFF, BOOST, ORBIT, REENTRY, AND LANDING (LINE EMPTY OF FLUID) IS 105 PSIG. THE PROOF PRESSURE FACTOR IS 1.2 (126 PSIG) AND THE BURST PRESSURE FACTOR IS 1.5 (158 PSIG). THE PRESSURE CARRIER WILL WITHSTAND AN IMPLOSION PRESSURE OF AT LEAST 40 PSID AND THERMAL CHANGE OF 90 DEG F TO MINUS 423 DEG F WITHOUT PERMANENT DISTORTION OR LEAKAGE.

THE USEFUL DYNAMIC LIFE IS 14.2 HOURS (EQUIVALENT TO 100 ORBITER MISSIONS). THE PRESSURE CARRIER MEETS THE FRACTURE ANALYSIS REQUIREMENT FOR 400 MISSIONS.

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(B) TEST:
ATP

EXAMINATION OF PRODUCT AND DIMENSIONAL VERIFICATION

PRESSURE CARRIER PROOF PRESSURE - 126 PSIG (GN2)

OPERATIONAL TEST - FILLED WITH LN2, PRESSURIZED TO 105 PSIG, SUBJECTED TO NON FLOW CONDITION FLIGHT MOTION CYCLE. NO BINDING ALLOWED.

ELEVATED AMBIENT TEMPERATURE - 105 PSIG (GHE) AT 200 DEG F FOR 30 MINUTES.

PRESSURE CARRIER LEAKAGE - 14.5 PSID (AMBIENT)

VACUUM JACKET LEAKAGE - 68 DEG F, 60 MICRONS MAXIMUM, RISE RATE 3 MICRONS PER DAY (AVERAGE)

CERTIFICATION

VIBRATION - IN ALL THREE AXES

SINUSOIDAL TEST FROM 5 TO 35 HZ WAS PERFORMED AT AMBIENT CONDITIONS.

RANDOM VIBRATION WAS MAINTAINED AT THE INLET AND OUTLET ENDS FOR 3.9 HOURS AND A PRESSURE RANGE OF ZERO TO 60 PSIG.

VIBRATION AT THE OUTLET END WAS CONTINUED FOR 9.4 HOURS AT A PRESSURE RANGE OF 40 TO 60 PSIG.

THE LINE ASSEMBLY WAS MAINTAINED AT LH2 TEMPERATURE WITH THE LINE DRAINED.

FLOW TEST -
LINE ASSEMBLY WAS TESTED WITH WATER IN THE COMPRESSED CONFIGURATION.

THE FLOW WAS IN THE FILL DIRECTION ONLY. AT A MAXIMUM FLOW PRESSURE OF 34.5 PSIG THE FLOW RATE WAS 12,506 GPM.

EQUIVALENT PRESSURE DROP AT 12,500 GPM (LH2) WAS 2.87 PSI (3.4 PSI ALLOWABLE).

ENDURANCE TEST -
THE LINE WAS MAINTAINED AT 249 DEG F OR COLDER.

2000 CYCLES WERE AT AMBIENT PRESSURE AND 80% MOTION.

200 CYCLES WERE AT AMBIENT PRESSURE AND AT THE EXTREME MOTION CYCLE.

THERMAL CYCLE -
THE LINE ASSEMBLY WAS STABILIZED AT -150 DEG F FOR FOUR HOURS

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THE PRESSURE CARRIER WAS FILLED WITH LN2, THEN DRAINED AND THEN THE TEST CHAMBER WAS RAISED TO +275 DEG F IN 2 HRS HELD FOR 30 MINUTES.

THE CHAMBER WAS RETURNED TO AMBIENT. THE LINE WAS FILLED WITH LN2 AND PRESSURIZED TO 105 PSIG.

5 OPERATION CYCLES WERE CONDUCTED.

IMPLOSION TEST -

THE VACUUM ANNULUS WAS PRESSURIZED TO 41 PSIG AND HELD FOR 3 MINUTES.

NO EVIDENCE OF DAMAGE OR DISTORTION TO PRESSURE CARRIER.

BURST TEST - THERE WAS NO LEAKAGE OR DAMAGE AFTER 5 MINUTES AT 158 PSIG.

GROUND TURNAROUND TEST

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

(C) INSPECTION:

RECEIVING/INSPECTION

RAW MATERIALS, INCLUDING CHEMICAL AND MECHANICAL REQUIREMENTS, ARE VERIFIED BY INSPECTION FOR MATERIAL AND PROCESS CERTIFICATION.

ASSEMBLY/INSTALLATION

SPECIAL CONSIDERATIONS GIVEN TO HIGH STRENGTH STRUCTURAL STEELS (INCONEL 718), DURING FABRICATION, IS VERIFIED. ALL COMPONENTS ARE VISUALLY, DIMENSIONALLY, AND INCREMENTALLY INSPECTED DURING FABRICATION. SEALING SURFACES PROTECTION IS VERIFIED. MACHINING OPERATION OF FLANGE DETAIL PARTS IS PER DRAWING AND APPLICABLE SPECIFICATION AND IS VERIFIED BY INSPECTION.

NON DESTRUCTIVE EVALUATION

WELDS ARE FLUORESCENT PENETRANT AND RADIOGRAPHICALLY INSPECTED. MACHINED PARTS ARE ETCHED PRIOR TO FLUORESCENT PENETRANT INSPECTION.

TESTING

ATP VERIFIED BY INSPECTION.

CRITICAL PROCESSES

HEAT TREATMENT VERIFIED BY INSPECTION.

CONTAMINATION CONTROL

PARTS PROTECTION FROM DAMAGE AND CONTAMINATION ARE VERIFIED. CLEANLINESS TO LEVEL 400 VERIFIED BY INSPECTION.

HANDLING/PACKAGING

PACKAGING FOR SHIPMENT VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:

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MC2271-0076-0011 CONFIGURATION EXPERIENCED A FATIGUE FAILURE IN THE PRESSURE CARRIER EYELET BOSS RADIUS DURING VIBRATION. THE FAILURE (REFERENCE CAR AB1220) WAS DUE TO EXCESSIVE MATERIAL THINNING IN THE ROOT RADIUS. A REDESIGN CHANGED THE INLET EYELET TO A SEPARATE DETAILED PART WITH INCREASED MATERIAL THICKNESS. THE EYELET IS WELDED TO THE PRESSURE CARRIER. IN THE OLD CONFIGURATION, THE EYELET WAS AN INTEGRAL PART OF THE PRESSURE CARRIER. THE REDESIGNED CONFIGURATION IS CERTIFIED FOR 100 MISSIONS. THE MC271-0076-0011 PRESSURE CARRIER ASSEMBLY WAS REMOVED FROM OV-102 PRIOR TO MISSION 27. IT IS CURRENTLY IN SPARES AS AN EMERGENCY FOR REPLACEMENT (14 MISSIONS LIFE REMAINING).

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.

- APPROVALS -

| | | |
|---------------------|------------------------|----------------------------|
| 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 | : EARL HIRAKAWA | : /S/ EARL HIRAKAWA |
| MPS SUBSYSTEM MGR. | : TIM REITH | : /S/ TIM REITH |
| MOD | : BILL LANE | : /S/ BILL LANE |
| USA SAM | : MIKE SNYDER | : /S/ MIKE SNYDER |
| USA ORBITER ELEMENT | : SUZANNE LITTLE | : /S/ SUZANNE LITTLE |
| NASA SR&QA | : ERICH BASS | : /S/ ERICH BASS |