**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**
**NUMBER: 03-1-0418 -X**

**SUBSYSTEM NAME:** MAIN PROPULSION

**REVISION:** 1 11/08/00

**PART DATA**

| | **PART NAME** / **VENDOR NAME** | **PART NUMBER** / **VENDOR NUMBER** |
|---|---|---|
| LRU | : LINE, LO2<br>ARROWHEAD PRODUCTS | MC271-0074-0001<br>13541-302 |

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**
LINE, LO2. 17 INCH DIA. VACUUM JACKETED.

**REFERENCE DESIGNATORS:** FH2

**QUANTITY OF LIKE ITEMS:** 1

**FUNCTION:**
THE LINE EXTENDS FROM THE ORBITER/ET DISCONNECT TO THE FEED LINE MANIFOLD. PROVIDES MEANS OF LOADING/DRAINING LO2 INTO ET & LO2 FLOW FOR SSME OPERATION. THE LINE INCORPORATES PENETRATIONS FOR ENGINE CUTOFF SENSORS, AND LO2 PRESSURE & TEMPERATURE TRANSDUCERS; AND VACUUM JACKET FOR INSULATION. THE VACUUM JACKET INCORPORATES A RUPTURE DISK, EVACUATION VALVE, VACUUM GAGE, AND GETTER ASSEMBLY.

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

**NUMBER: 03-1-0418-02**

**REVISION#:** 1 11/08/00

**SUBSYSTEM NAME:** MAIN PROPULSION
**LRU:** LO2 17" FEEDLINE, VACUUM JACKETED
**ITEM NAME:** LINE, LO2

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

**FAILURE MODE:**
RUPTURE/LEAKAGE.

**MISSION PHASE:** PL PRE-LAUNCH
LO LIFT-OFF

**VEHICLE/PAYLOAD/KIT EFFECTIVITY:** 102 COLUMBIA

**CAUSE:**
FATIGUE, MATERIAL DEFECT

**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:**
HAZARDS ASSOCIATED WITH LEAKAGE OF CRYOGENIC PROPELLANTS. DURING ENGINE OPERATION, POSSIBLE PREMATURE SHUTDOWN OF ALL SSME'S DUE TO LOSS OF PROPELLANT. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE AFT COMPT OVERPRESS AND FIRE HAZARD. LEAKAGE IN THE AFT COMPT DETECTABLE DURING LOADING 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:**
NONE.

**-DISPOSITION RATIONALE-**

**(A) DESIGN:**
THE PRESSURE CARRIER PORTION OF THE LINE ASSEMBLY IS CONSTRUCTED OF INCONEL 718 AND INCORPORATES THREE FLEXIBLE JOINTS (BALL STRUT TIE ROD ASSEMBLIES) AND A FLANGE AT EACH END. THE FLEXIBLE JOINTS INCORPORATE MULTI-PLY BELLOWS (THREE PLY AT INLET JOINT, FOUR PLY AT OTHER TWO JOINTS) TO MINIMIZE STRESS LEVELS AND FLOW LINERS TO ELIMINATE FLOW INDUCED VIBRATIONS. THE FLEXIBLE JOINTS PROVIDE FREE MOVEMENT WITHOUT BINDING WHEN THE TEMPERATURE IS INCREASED FROM 70 DEG F TO 200 DEG F OR DECREASED FROM 70 DEG F TO MINUS 297 DEG F. THE LINE IS DESIGNED FOR A MAXIMUM OPERATING PRESSURE OF 200 PSIA AT 297 DEG F AND A NOMINAL FLOW RATE OF 2,658 POUNDS PER SECOND. MAXIMUM STATIC PRESSURE IS 260 PSIG. THE PROOF PRESSURE FACTOR IS 1.2 AND THE BURST PRESSURE FACTOR IS 1.5. THE USEFUL DYNAMIC LIFE IS 14.2 HOURS (EQUIVALENT TO 100 ORBITER MISSIONS). THE PRESSURE CARRIER MEETS THE FRACTURE ANALYSIS REQUIREMENT FOR 400 MISSIONS. STRUCTURAL ANALYSIS INDICATES POSITIVE (GREATER THAN 1.4) MARGINS OF SAFETY FOR ALL CONDITIONS OF LINE OPERATION. THE LINE ASSEMBLY WILL WITHSTAND AN IMPLOSION PRESSURE OF 22 PSI, PRESSURE SURGE FROM 200 PSIG TO 260 PSIG IN 200 MILLISECONDS, AND A THERMAL CHANGE FROM 200 DEG F TO MINUS 297 DEG F.

**(B) TEST:**
ATP

EXAMINATION OF PRODUCT.

VACUUM JACKET PRESSURE RISE.

PRESSURE CARRIER AND VACUUM JACKET LEAKAGE (AMBIENT).

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PRESSURE CARRIER AND VACUUM JACKET LEAKAGE (CRYO - DOES NOT INCLUDE THE END FLANGES WHICH ARE EXTERNAL TO VACUUM JACKET).

PROOF PRESSURE TEST.

OPERATIONAL TEST (CRYO).

ELEVATED AMBIENT TEMPERATURE TEST.

CERTIFICATION

THE 17 INCH VACUUM JACKETED LINE WAS SUBJECTED TO THE FOLLOWING QUALIFICATION TEST:

ENDURANCE - 2200 STRUCTURAL DEFLECTION CYCLES, FILLED WITH LN2, 200 PSIG.

THERMAL CYCLE - 100 CYCLES, ROOM AMBIENT TO -300 DEG F TO ROOM AMBIENT.

PRESSURE SURGE - 50 CYCLES COMPRESSED AND 50 CYCLES EXTENDED POSITION, FILLED WITH LN2 CYCLED 200 PSIG TO 260 PSIG TO 200 PSIG.

PRESSURE CYCLING - 1940 CYCLES, 300 DEG F, PRESSURE CYCLES VARYING IN RANGE FROM 0 TO 220 PSIG.

VIBRATION - ALL THREE AXES.

SINUSOIDAL VIBRATION FROM 5 TO 2000 HZ. LINE FILLED WITH LN2 AND PRESSURIZED TO 20 PSIG.

RANDOM VIBRATED FOR 3.9 HOURS FOR THE INLET END AND 13.3 HOURS FOR THE OUTLET END. FILLED WITH LO2, PRESSURIZED TO 100 PSIG FOR 48 MINUTES, 70 PSIG FOR 3.1 HOURS AND 180 PSIG FOR 9.4 HOURS.

BURST - NO LEAKAGE OR DAMAGE AFTER 5 MINUTES AT 395 PSIG.

EMERGENCY SHUTDOWN - NO LEAKAGE OR DAMAGE AFTER 3 MINUTES AT 440 PSIG.

ET/ORB UMBILICAL SEP TEST

THE 17" LINE WAS ATTACHED TO THE UMBILICAL ASSEMBLY DURING THE SEPARATION TEST PROGRAM. THE LINE WAS ALSO SUBJECTED TO UMBILICAL RETRACT TESTS AT BOTH NOMINAL CONDITIONS AND SIMULATED HYDRAULIC RETRACT ACTUATOR FAILURES.

OMRSD
ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

**(C) INSPECTION:**

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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 ARE PER DRAWING AND APPLICABLE SPECIFICATION AND IS VERIFIED BY INSPECTION.

NON DESTRUCTIVE EVALUATION
WELDS ARE FLUORESCENT PENETRANT AND RADIOGRAPHICALLY INSPECTED. MACHINED PARTS ARE FLUORESCENT PENETRANT INSPECTED.

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 800A VERIFIED BY INSPECTION.

HANDLING/PACKAGING
PACKAGING FOR SHIPMENT VERIFIED BY INSPECTION.

**(D) FAILURE HISTORY:**
THE OV104 LH2 TYPE II (12 INCH) LINE HAD EXCESSIVE VACUUM PRESSURE RISE AFTER ATP ELEVATED TEMPERATURE TEST. CRACKS IN THE SEALING WELD (NON-STRUCTURAL) OF THE BALL STRUT TIE ROD ASSEMBLY BELLOWS ADAPTER WERE FOUND. SEALING WELD WAS REVISED TO REDUCE THE NUGGET SIZE AND MINIMIZE THERMAL EFFECTS. EFFECTIVELY IS FOR ALL OV104 AND SUBS LINES (REFERENCE CAR AC5228). THIS IS A ONE TIME OCCURRENCE. ALL PRIOR AND SUBSEQUENT LINES HAVE PASSED ATP. THIS FAILURE IS ATP SCREENABLE.

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 -**

| | | |
|---|---|---|
| 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 |