

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**NUMBER: 03-1-0309 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 2 11/08/00**PART DATA**

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	: LINE LH2 RECIRC RETURN SENIOR FLEXONICS (KETEMA DIVISION)	MC271-0075-0017 8-031169-3
LRU	: LINE LH2 RECIRC RETURN SENIOR FLEXONICS (KETEMA DIVISION)	MC271-0075-0018 8-031170-3
LRU	: LINE LH2 RECIRC RETURN SENIOR FLEXONICS (KETEMA DIVISION)	MC271-0075-0019 8-031171-5

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

LH2 RECIRCULATION LINES/MANIFOLD, 2 INCH AND 4 INCH DIAMETER LINES, MANIFOLD, ALL VACUUM JACKETED.

REFERENCE DESIGNATORS: FH17 - LH2 TOPPING VALVE TO MANIFOLD
FH18 - 4 INCH DISCONNECT TO MANIFOLD
MA3 - 4 INCH MANIFOLD

QUANTITY OF LIKE ITEMS: 3
ONE OF EACH PART NUMBER PER VEHICLE

FUNCTION:

THE LINE ASSEMBLY EXTENDS FROM THE 2 INCH RECIRCULATION LINE FOR EACH SSME TO THE ET/ORBITER RECIRCULATION DISCONNECT AND TO THE LH2 TOPPING VALVE. THE LINE PROVIDES A RECIRCULATION PATH FOR RETURNING LH2 TO THE ET. IT ALSO PROVIDES A MEANS OF TOPPING, DURING ET TANKING. THE LINE ASSEMBLY ALSO PROVIDES A MEANS FOR OFFLOADING LH2 RESIDUALS DURING DUMP/INERT. THE LINES AND MANIFOLD ARE VACUUM JACKETED, INCORPORATING A RUPTURE DISK, EVACUATION VALVE, THERMOCOUPLE GAGE AND GETTER ASSEMBLY.

FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE

NUMBER: 03-1-0309-01

REVISION#: 2 08/27/01

SUBSYSTEM NAME: MAIN PROPULSION

LRU: LH2 RECIRC RETURN LINES, 2" & 4"

ITEM NAME: LH2 RECIRC RETURN LINES, 2" & 4"

CRITICALITY OF THIS

FAILURE MODE: 1R2

FAILURE MODE:

LOSS OF VACUUM DURING PROPELLANT LOADING

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) PASS

B) PASS

C) PASS

PASS/FAIL RATIONALE:

A)

B)

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

RESULTS IN EXCESSIVE HEAT LEAK INTO LH2 SYSTEM INABILITY TO MAINTAIN PROPELLANT QUALITY DURING LOADING. RESULTS IN LCC TEMPERATURE VIOLATION AND LAUNCH SCRUB.

(B) INTERFACING SUBSYSTEM(S):

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0309-01**

SAME AS A.

(C) MISSION:

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

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

SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:

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

- 1) LOSS OF LINE VACUUM JACKET, RESULTING IN LH2 MANIFOLD TEMPERATURE OUT OF LCC LIMITS (HIGH).
- 2) LH2 MANIFOLD TEMPERATURE TRANSDUCER (V41T1428A) -ERRONEOUS INDICATION WITHIN LCC LIMITS.

POSSIBLE GAS FORMATION IN LH2 MANIFOLD RESULTING IN GAS INGESTION INTO SSMES AT ENGINE START. RESULTS IN POSSIBLE UNCONTAINED ENGINE DAMAGE DUE TO PUMP CAVITATION. HAZARDS ASSOCIATED WITH FIRE/EXPLOSION. POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

THE PRESSURE CARRIER SUB-ASSEMBLY OF THE MANIFOLD IS CONSTRUCTED OF INCONEL 718. THE RECIRC MANIFOLD HAS FOUR 2-INCH DIAMETER FLANGES TO PERMIT ATTACHMENT OF THREE ENGINE RECIRCULATION RETURN LINES AND THE LH2 REPLENISH LINE. IT ALSO HAS A 4-INCH OUTLET FLANGE. ALL FIVE FLANGES INCORPORATE LEAK DETECTION PORTS FOR MEASURING FLANGE JOINT LEAKAGE. THE 4-INCH DIAMETER FLANGE ALSO INCORPORATES TWO INSTRUMENTATION PORTS.

THE 4-INCH RETURN LINE PRESSURE CARRIER, INCLUDING GIMBAL JOINTS, IS CONSTRUCTED OF INCONEL 718. THE THREE GIMBAL ASSEMBLIES GIVE THE RETURN LINE FLEXIBILITY TO PROVIDE FOR DIFFERENTIAL MOVEMENT BETWEEN THE EXTERNAL TANK DISCONNECT AND THE RECIRCULATION MANIFOLD. THE GIMBAL ASSEMBLY CONSISTS OF TWO OPPOSITE FORMED FORKS LOCATED 90- DEGREES TO EACH OTHER AND LINKED TOGETHER WITH ENTRAPPED PINS THROUGH A GIMBAL RING. THE FLEXIBLE JOINTS INCORPORATE MULTI-PLY BELLOWS TO MINIMIZE STRESS LEVELS. THE FLANGE AT THE ET DISCONNECT END INCORPORATES A LEAK DETECTION PORT FOR MEASURING FLANGE JOINT LEAKAGE AND A 3/8 INCH PORT WHICH CONNECTS TO A LINE LEADING TO THE RECIRCULATION MANIFOLD RELIEF VALVE (RV7) AND THE REPRESS SYSTEM.

THE 2-INCH REPLENISH LINE PRESSURE CARRIER, INCLUDING GIMBAL JOINTS, IS CONSTRUCTED OF INCONEL 718. THE THREE GIMBAL ASSEMBLIES PROVIDE MOVEMENT BETWEEN THE TOPPING VALVE AND THE RECIRCULATION MANIFOLD. THE GIMBAL

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0309-01**

ASSEMBLY CONSISTS OF TWO OPPOSITE FORMED FORKS LOCATED 90- DEGREES TO EACH OTHER AND LINKED TOGETHER WITH ENTRAPPED PINS THROUGH A GIMBAL RING. THE FLEXIBLE JOINT INCORPORATE MULTI-PLY BELLOWS TO MINIMIZE STRESS LEVELS AND FLOW LINERS ELIMINATE FLOW INDUCED VIBRATION. THE FLANGE AT THE INLET END (TOPPING VALVE END) INCORPORATES A LEAK DETECTION PORT FOR MEASURING FLANGE JOINT LEAKAGE.

THE OPERATING LIFE, FOR THE MANIFOLD AND LINE ASSEMBLIES, IS 225 HOURS OF FLOW WHICH IS EQUIVALENT TO THE TOTAL FLOW PERIOD FOR 100 ORBITAL MISSIONS. THEY ARE DESIGNED FOR A MAXIMUM OPERATING PRESSURE OF 55 PSIG AT 423 DEG F AND A FLOW RATE OF 7.5 POUNDS PER SECOND (MA3 & FH18) AND 3.0 POUNDS PER SECOND (FH17). MAXIMUM STATIC PRESSURE IS 105 PSIG. THE PROOF PRESSURE FACTOR IS 1.5 AND THE BURST PRESSURE FACTOR IS 2.0.

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/MANIFOLD OPERATION. THE PRESSURE CARRIER WILL WITHSTAND AN IMPLOSION PRESSURE OF 40 PSID.

THE LINE ASSEMBLY IS ENCAPSULATED BY A SINGLE-PLY INCONEL 718 VACUUM JACKET, WITH THE EXCEPTION OF END FLANGES AND BOSSES. THE VACUUM JACKET CONSISTS OF STRAIGHT, CORRUGATED, AND BELLOWS SECTIONS INTERCONNECTED INTO A SINGLE ANNULUS. THE VACUUM JACKET IS SEPARATED FROM THE PRESSURE CARRIER BY APPROXIMATELY 0.5 INCH. IT IS DESIGNED TO ABSORB THE THERMAL CHANGES OF THE PRESSURE CARRIER. THE VACUUM JACKET IS SERVICED BY A SINGLE EVACUATION VALVE, THERMOCOUPLE GAGE, AND BURST DISC. THE BURST DISC RUPTURE PRESSURE IS 25 PSIG MAXIMUM. THE VACUUM JACKET WILL WITHSTAND A NEGATIVE DIFFERENTIAL PRESSURE OF 22 PSID. WHEN EVACUATED TO LESS THAN 1000 MICRONS, THE VACUUM JACKET MEETS THE LINE ASSEMBLY INSULATION REQUIREMENT OF 30.0 BTU PER HOUR PER SQUARE FOOT MAXIMUM.

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

(B) TEST:
ATP

EXAMINATION OF THE PRODUCT.

VACUUM JACKET PRESSURE RISE - 3 MICRONS/DAY; 60 MICRONS MAXIMUM.

PROOF PRESSURE TEST - 158 PSIG.

OPERATIONAL TEST -
LINE ASSEMBLIES ARE SUBJECTED TO 5 MOTION ENVELOPE CYCLES WHILE FILLED WITH LN2 AND PRESSURIZED TO 55 PSIG.

MANIFOLD IS FILLED WITH LN2, PRESSURIZED TO 55 PSIG, AND HELD FOR 5 MINUTES.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0309-01**

TEMPERATURE TEST - PRESSURIZE TO 55 PSIG; EXTERNAL TEMPERATURE STABILIZED AT 200 DEG F FOR 30 MINUTES, MEASURE VACUUM JACKET RISE RATE (3 MICRONS/DAY; 60 MICRONS MAXIMUM).

VACUUM JACKET LEAKAGE (CRYO/AMBIENT - DOES NOT INCLUDE THE END FLANGES WHICH ARE EXTERNAL TO VACUUM JACKET).

PRESSURE CARRIER LEAKAGE - AMBIENT TEMPERATURE; 15 PSID CERTIFICATION

COMPONENT QUALIFICATION

THE LINE ASSEMBLIES WERE SUBJECTED TO THE FOLLOWING QUALIFICATION TEST:

ENDURANCE - 2,200 STRUCTURAL DEFLECTION CYCLES WHILE PRESSURIZED TO 55 PSIG AT -320 DEG F. 2000 CYCLES WERE AT 80% OF THE SPECIFIED MOTION AND THE FINAL 200 CYCLES WERE AT 100% OF SPECIFIED MOTION.

FLOW TEST - TEST FLUID WAS LH2. INLET PRESSURE WAS 55 PSIG, WITH A FLOW RATE OF 7.5 LBS/SEC AND PRESSURE DROP OF LESS THAN 0.74 PSID (WAS RUN AS A SYSTEM TEST).

VIBRATION -
IN ALL THREE AXIS, ASSEMBLIES FILLED WITH LN2 AND PRESSURIZED TO 55 PSIG.

SINUSOIDAL SWEEP OVER FREQUENCY RANGE OF 5-35 HZ.

RANDOM VIBRATION (4 INCH RETURN LINE, MANIFOLD TO DISCONNECT) WAS MAINTAINED AT THE INLET AND OUTLET ENDS FOR 48 MINUTES. VIBRATION AT THE OUTLET END WAS CONTINUED FOR 12.5 HOURS.

RANDOM VIBRATION (2 INCH REPLENISH LINE, TOPPING VALVE TO MANIFOLD) WAS MAINTAINED AT THE INLET AND OUTLET END FOR 34 MINUTES. VIBRATION AT THE OUTLET END WAS CONTINUED FOR 12 HOURS AND 44 MINUTES.

RANDOM VIBRATION (RECIRC MANIFOLD) WAS MAINTAINED FOR 13.3 HOURS.

THERMAL CYCLE - (AMBIENT TO -150 DEG F FOR 4 HOURS; TO 275 DEG F FOR 30 MIN; TO AMBIENT).

THE LINE ASSEMBLIES AND MANIFOLD WERE FILLED WITH LN2, PRESSURIZED TO 57 PSIG AND SUBJECTED TO 3 THERMAL CYCLES.

THE 2- AND 4-INCH LINES WERE SUBJECTED TO 5 OPERATIONAL ANGULATION CYCLES AT EACH TEMPERATURE EXTREME.

PRESSURE CYCLE - (10 PSIG TO 105 PSIG).

100 CYCLES FILLED WITH LN2
50 CYCLES WERE WITH THE LINE 80% EXTENDED AND 50 CYCLES WERE WITH THE LINES 80% COMPRESSED.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0309-01**

VACUUM JACKET LEAKAGE - 500 MICRONS MAXIMUM INCREASE DURING THE QUALIFICATION TESTS.

IMPLOSION PRESSURE CARRIER - THE VACUUM ANNULUS WAS PRESSURIZED TO 40.0 PSID AND HELD FOR 3 MINUTES.

BURST PRESSURE - NO LEAKAGE OR DAMAGE AFTER 5 MINUTES AT 210 PSIG.

ET/ORBITER UMBILICAL SEP TEST

THE 4 INCH LINE WAS ATTACHED TO THE UMBILICAL ASSEMBLY DURING THE SEPARATION TEST PROGRAM. THE UMBILICAL/LINE ASSEMBLY WAS SUBJECTED TO RANDOM VIBRATION TESTS (4.4 HOURS PER AXIS) WHILE FILLED WITH LH2. THE LINE WAS ALSO SUBJECTED TO UMBILICAL RETRACT TESTS AT BOTH NOMINAL CONDITIONS AND SIMULATED HYDRAULIC RETRACT ACTUATOR FAILURES.

GROUND TURNAROUND TEST

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

(C) INSPECTION:

RECEIVING INSPECTION

RAW MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIALS AND PROCESSES CERTIFICATION.

CONTAMINATION CONTROL

CLEANLINESS TO LEVEL 400 IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

COMPONENTS ARE INSPECTED VISUALLY, DIMENSIONALLY, AND INCREMENTALLY DURING FABRICATION. MACHINING OPERATION OF FLANGE DETAIL PARTS IS VERIFIED PER DRAWING AND APPLICABLE SPECIFICATION. DRAWING TORQUE REQUIREMENTS, TOLERANCES, AND SURFACE FINISHES ARE VERIFIED BY INSPECTION. INSPECTION FOR ALIGNMENT AND VACUUM JACKET PRESSURE IS MONITORED AND VERIFIED. ELECTROETCH MARKING IDENTIFICATION OF LINES IS VERIFIED BY INSPECTION. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

CRITICAL PROCESSES

WELDING, PARTS PASSIVATION, HEAT TREATMENT, AND ELECTROPOLISH OF TUBING ARE ALL VERIFIED BY INSPECTION. LUBRICATION OF GIMBAL PINS IS VERIFIED.

NONDESTRUCTIVE EVALUATION

ETCHING AND DYE PENETRANT INSPECTION VERIFIED ON ALL MACHINED PARTS. X-RAY AND DYE PENETRANT INSPECTION OF WELDS ARE VERIFIED BY INSPECTION.

TESTING

ATP IS OBSERVED AND VERIFIED BY INSPECTION.

HANDLING/PACKAGING

PACKAGING FOR SHIPMENT IS VERIFIED BY INSPECTION.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0309-01**

(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:

NO CREW ACTION CAN BE TAKEN.

- 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