

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

NUMBER: 03-1-0425 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 1 11/08/00

**PART DATA**

	<b>PART NAME</b>	<b>PART NUMBER</b>
	<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU	: LINE LH2 RECIRC RETURN SENIOR FLEXONICS (KETEMA DIVISION)	MC271-0075-0016 8-031168-3
LRU	: LINE LH2 RECIRC RETURN SENIOR FLEXONICS (KETEMA DIVISION)	MC271-0075-0024 8-031166-5
LRU	: LINE LH2 RECIRC RETURN SENIOR FLEXONICS (KETEMA DIVISION)	MC271-0075-0025 8-031167-5

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

LINE, LH2 RECIRCULATION RETURN, 2 INCH DIAMETER VACUUM JACKETED. (FH12, FH14, FH16).

**REFERENCE DESIGNATORS:** FH12  
FH14  
FH16

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

**FUNCTION:**

EACH LINE EXTENDS FROM THE INDIVIDUAL SSME INTERFACE TO THE FLANGES OF THE 4 INCH RECIRCULATION RETURN MANIFOLD. PROVIDES A PATH FOR RETURNING LH2 TO THE ET DURING ENGINE CONDITIONING (LOADING) AND A MEANS TO OFFLOAD RESIDUAL LH2 DURING DUMP. THE LINES HAVE A VACUUM JACKET THAT INCORPORATES A RUPTURE DISK, EVACUATION VALVE, INTEGRAL SUPPORT BRACKET, THERMOCOUPLE GAGE, AND GETTER ASSEMBLY.

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

**NUMBER: 03-1-0425-01**

**REVISION#: 1 08/27/01**

**SUBSYSTEM NAME: MAIN PROPULSION**

**LRU: LINE LH2 RECIRC RETURN**

**ITEM NAME: LINE LH2 RECIRC RETURN**

**CRITICALITY OF THIS**

**FAILURE MODE: 1R2**

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**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 FAILURE

**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)

C)

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**- FAILURE EFFECTS -**

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**(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):**

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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.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

THE RETURN LINE PRESSURE CARRIER, INCLUDING THE GIMBALS, IS CONSTRUCTED OF INCONEL 718. EACH LINE INCORPORATES THREE FLEXIBLE JOINTS (GIMBAL ASSEMBLIES) TO PROVIDE FOR DIFFERENTIAL MOVEMENT BETWEEN THE SSME 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 GIMBAL JOINTS INCORPORATE MULTI-PLY BELLOWS TO MINIMIZE STRESS LEVELS. THE FLANGE AT THE SSME INTERFACE END INCORPORATES A LEAK DETECTION PORT FOR MEASURING FLANGE JOINT LEAKAGE.

THE OPERATING LIFE FOR THE 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 1.5 POUNDS PER SECOND. 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.

THE PRESSURE CARRIER WILL WITHSTAND AN IMPLOSION PRESSURE OF 40 PSID. THE VACUUM JACKET WILL WITHSTAND AN IMPLOSION PRESSURE OF 22 PSID. THE LINE ASSEMBLY CAN WITHSTAND A PRESSURE SURGE OF 40 TO 50 PSIG IN 200 MILLISECONDS AND A THERMAL CHANGE 70 DEG F TO 200 DEG F AND 70 DEG F TO -423 DEG F.

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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.

**(B) TEST:**

ATP

EXAMINATION OF PRODUCT

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

PROOF PRESSURE - 158 PSIG.

OPERATIONAL TEST

LINE ASSEMBLIES ARE SUBJECTED TO A MINIMUM OF ONE MOTION ENVELOPE CYCLE WHILE FILLED WITH LN2 AND PRESSURIZED TO 55 PSIG.

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).

PRESSURE CARRIER LEAKAGE - AMBIENT; 15 PSID.

CERTIFICATION

EACH OF THE LINE ASSEMBLIES WERE SUBJECTED TO THE FOLLOWING QUALIFICATION TESTS.

VIBRATION - IN ALL THREE AXES, FILLED WITH LH2, AND PRESSURIZED TO 55 PSIG.

SINUSOIDAL SWEEP OVER THE FREQUENCY RANGE OF 5 TO 35 HZ.

RANDOM VIBRATION WAS MAINTAINED AT THE INLET AND OUTLET ENDS FOR 13.3 HRS.

FLOW TEST - TEST FLUID WAS LH2. INLET PRESSURE WAS 55 PSIG, WITH A FLOW RATE OF 1.5 LBS/SEC AND PRESSURE DROP OF LESS THAN 0.75 PSID OVER THE SYSTEM OF LINES.

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ENDURANCE TEST - 2000 CYCLES WERE AT 80% ANGULATION; 200 CYCLES WERE AT EXTREME MOTION WHILE FILLED WITH LN2 AND PRESSURIZED TO 55 PSIG.

PRESSURE CYCLING (ENGINE 1 LINE ONLY) - 100 CYCLES; 10 TO 105 PSIG; FILLED WITH LN2; 50 CYCLES WITH LINE 80% EXTENDED AND 50 CYCLES WITH LINE 80% COMPRESSED.

TEMPERATURE CYCLING TEST - (AMBIENT TO -150 DEG F FOR 4 HOURS; TO 275 DEG F FOR 30 MIN; TO AMBIENT).

3 CYCLES, LINE FILLED WITH LN2; PRESSURIZED TO 55 PSIG.

5 OPERATIONAL ANGULATION CYCLES DURING EACH TEMPERATURE EXTREME.

HEAT TRANSFER TEST (ENGINE 1 AND 2 ONLY) - FILLED WITH LN2; CHAMBER TEMPERATURE 80 DEG F OR GREATER; HEAT TRANSFER 30 BTUS PER HOUR PER SQUARE FOOT OF EXTERNAL SURFACE.

IMPLOSION TEST - 22 PSID ACROSS VACUUM JACKET FOR 3 MINUTES; VACUUM ANNULUS PRESSURIZED TO 50 PSIG AND HELD FOR 3 MINUTES.

PRESSURE CARRIER LEAKAGE - 14.5 PSI.

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

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

**OMRSD**

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

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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.

**(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.

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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	: 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