CRITICAL ITEMS LIST (CIL)

SYSTEM:	Propulsion/Mechanical	FUNCTIONAL CRIT:	1
SUBSYSTEM:	LO2 Propellant Feed	PHASE(S):	a, b, c
REV & DATE:	J, 12-19-97	HAZARD REF:	P.03, P.06,
DCN & DATE:			P.07, P.09,
ANALYSTS:	J. Attar/H. Claybrook		P.10, S.07

FAILURE MODE: Leakage

FAILURE EFFECT:
a) Loss of mission and vehicle/crew due to fire/explosion.
b) Loss of mission and vehicle/crew due to fire/explosion.
Loss of mission due to premature engine shutdown.
c) Loss of mission and vehicle/crew due to ET/Orbiter collision.
(Results only from Failure Cause A)
Loss of life due to ET impact outside designated footprint.

TIME TO EFFECT: Seconds

FAILURE CAUSE(S):
A: Structural Failure of Hardline Component
B: Flange Mating Surface Defects
C: Structural Failure of Flex Joint Component
D: Seizure of Flex Joint

REDUNDANCY SCREENS: Not Applicable

FUNCTIONAL DESCRIPTION: The aft flex feedline section contains two flex joints and transports LO2 from the aft straight section to the aft elbow section of the LO2 feedline.

FMEA ITEM CODE(S)	PART NO.	PART NAME	QTY	EFFECTIVITY
2.1.12.1	PD4800175-090	LO2 Feedline, Aft Flex Assy	1	LWT-54 thru 88
	-509		1	LWT-89 & Up

REMARKS:

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FMEA ITEM CODE(S):	2.1.12.1		

RATIONALE FOR RETENTION

DESIGN:

The 17 inch diameter aft flexible line assembly consists of machined flanges, tube straight section, and two flexible joint assemblies. Each flexible joint contains a pressure carrier bellows and a ball strut assembly. The line assembly is installed between the last straight section and the LO2 aft elbow. Lugs built into the forward end of the aft flexible line assembly provide attachment provisions for a pivotal support on the LH2 tank to allow limited axial movement of the line assembly and compensate for relative motion during loading and boost.

A: The line assembly is an all welded configuration fabricated of 347 CRES and 21-6-9 ARMCO and has been designed to meet the required ultimate safety factors (1.4 for loads and 1.5 for pressure only), the required yield safety factors (1.1 for loads and 1.25 for pressure only) (ET Stress Report 826-2188 and Arrowhead ETS-SR-0001-1), and other operating and nonoperating requirements defined per P04800175. Material selected in accordance with MMC-ET-SE16 and controlled per MMMA Approved Vendor Product Assurance Plan assures conformance of composition, material compatibility and properties. Fusion and seam welding specifications, processes and quality controls are in accordance with MPS-MPQ-103 (Arrowhead).

To reduce weight, the SLWT tube wall thickness was reduced from .062 inch to .050 inch.

B: Mating surface flatness, waviness and finish are specified on engineering drawings to assure performance within the capability of the seal.

C, D: The Flexible Joint Assemblies provide for installation misalignments and recurring motions during loading and boost. The flexible joint assembly is fabricated from 21-6-9 Armco stainless steel. The ball, located within the ball strut assembly, is fabricated from Inconel 718. Vitrolube is applied to prevent seizure of the ball and strut. Compatibility testing is specified for oxygen service (MPS-MPQ-121, Arrowhead).

The pressure carrier bellows is a three ply construction with relatively low convolution height and open pitch. Each tube .016 inch thick is rolled and welded with a longitudinal buttweld. The tubes are telescoped one within the other and the convolutes are roll formed. The open pitch allow larger form radius for good stress distribution and is more resistant to vortex shedding. Assessment for flow induced vibration in accordance with MSFC Spec 20M02540 and Project Report 02 2119 (Southwest Research Institute) showed that the bellows could provide adequate life at specified conditions. No flow liners are incorporated into the design.

To further reduce SLWT weight, unnecessary material was removed from the LO2 feedline BSTRA back hub and struts were trimmed to match. The revised minimum ultimate factor of safety for the back hub/strut stability is now 2.68.

TEST:

The Aft Flex Assembly is qualified. Reference COO MMC-ET-TM06-014.

Development:

Bellows: A bellows assembly was subjected to the following tests: Spring rate, bending moment, 1000 motion cycles, 20 icing cycles, sinusoidal vibration, and burst pressure. Proof pressure and leakage test were performed three times with no deformation, structural damage, degradation or leakage detected. Burst pressure was greater than 600 psig with no evidence of failure. (ETS-DTR-0001, Arrowhead).

Flanges: Three flanges were subjected to proof and ultimate load tests (hydrostatic, pneumatic and cryogenic). Two flanges (floating flange configuration) exceeded the deflection limit. The third flange (fixed flange configuration) was within allowable limits. A completely redesigned flange (flight configuration, fixed flange with slotted holes) was subjected to loads vs. deflection tests. Results were within allowable deflection limits (ETS-DTR-0002, Arrowhead).

BSTRA: Testing of one BSTRA assembly with a Stoody 2 ball, included proof pressure, leakage, proof load, limit load, 1000 operating life and ten temperature cycles, sinusoidal and random vibration, and ultimate load. Proof pressure and leakage checks performed before and after the vibration tests showed no evidence of damage or leakage. (ETS-DTR-0003, Arrowhead)

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RATIONALE FOR RETENTION

TEST: (cont)

Ball/Socket Subassembly: Testing was performed on two ball-socket sets, (consisting of an inconel 718 ball and socket). Testing of one ball-socket set coated with vitrolube included proof load and 2,000 motion cycles under load at -320°F, angulating between +6.5° and -6.5°. The ball-socket assembly demonstrated the capability to withstand motion cycling in excess of the specified 500 cycle requirement, with bending moments remaining within limits after 2,000 cycles. Visual examination after 2,000 cycles revealed normal wear and no evidence of galling. A second ball-socket set was not coated and subjected to 30 temperature shock cycles. Subsequent inspection revealed no defects. (ET5-DTR-0004, Arrowhead)

No new or unique development activities are required for the SLWT Project.

Qualification:

LWT-54 thru 88:

BSTRA: Testing of one BSTRA, with an Inconel 718 ball, included proof pressure, proof load, operating cycle, operating life (500 cycles), temperature cycle (five excursion), vibration, and ultimate loads. Leakage tests (immersion or leak detector solution) were performed following the proof pressure, proof load and temperature cycle tests. No BSTRA leakage (bubbles) were detected. Leakage tests using a mass spectrometer were performed following the vibration and ultimate loads tests. Leakage was less than 3×10^{-9} SCCS (MMC-ET-RA09-23).

Line Assembly: Testing was conducted on a line assembly identical to LWT except the BSTRA ball material was Stoody 2 instead of Inconel 718, the line contained instrumentation bosses. There were no rainshields on the bellows and there were minor differences in lug dimensions and location. Testing included deflection, operating cycle, proof load and leakage for acceptance, 500 operating life and five temperature cycles, leakage and ultimate loads test. The leakage test was performed with GHe pressurized to 150 psig for 15 minutes. No bubbles were noted using a leak detector solution (MMC-ET-RA09-9).

Requalification: Testing was conducted on a SWT assembly, identical to LWT except the line contained instrumentation bosses. There were no rainshields on the bellows, and there were minor differences in lug dimension and location. Testing of the line assembly included deflection, proof loads/operating pressure and leakage for acceptance. An ultimate load test was conducted on the lugs to verify LWT requirements. There was no evidence of structural damage (MMC-ET-RA09-76).

LWT-89 & Up (SLWT Project):

The SLWT design was certified by similarity to the LWT (-090) design and by analysis (Stress Analysis document 4130-97-031 and Propulsion Analysis document 4140/P-97-4027). The SLWT design is identical to the LWT except that the BSTRAs have had excess material removed, and tube wall thickness reduced, both for weight reduction.

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RATIONALE FOR RETENTION

TEST: (cont)

Verification - Flow Induced Vibration: Flow tests were conducted on the aft flex line at the Denver Fill and Drain Test Facility. Five strain gages were attached to each of the line assembly bellows convolutes. There was no indication of flow induced vibration for flow rates within 26 to 114% power ratings (MMC-3515-87-003).

MPTA Firings/Tankings: A forward flexible feedline assembly similar to the above qualification unit has accumulated 62.5 minutes of firing time 27 cryogenic cycles and 42 pressurization cycles. There was no evidence of structural failure resulting from these exposures. Strain gages were attached to the bellows convolutes for the measurement of stress associated with flow vibration. No appreciable change in strain gage output was noted during firings, indicating that there was no flow induced vibration for the flow through 104% power rating.

Acceptance:

Vendor - (Subassembly):

A, C, D: Perform load vs deflection test on each BSTRA joint assembly (ATP 14175-390, Arrowhead for LWT-54 thru 88; ATP 14175-509, Arrowhead for LWT-89 & Up).

Vendor - (Line Assembly):

A-D: Perform operating pressure/deflection and proof loads tests (ATP 14175-390, Arrowhead for LWT-54 thru 88; ATP 14175-509, Arrowhead for LWT-89 & Up).

C: Perform 100% proof test of BSTRA pad welds (ATP 14175-390, Arrowhead for LWT-54 thru 88; ATP 14175-509, Arrowhead for LWT-89 & Up).

A-C: Perform leakage test after operating pressure/deflection tests, proof loads and 100% proof test (ATP 14175-390, Arrowhead for LWT-54 thru 88; ATP 14175-509, Arrowhead for LWT-89 & Up).

MAF - (Line Assembly):

B: Perform seal leakage test on flange joints after installation (MMC-ET-TM04k).

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INSPECTION:

Vendor Inspection - Lockheed Martin Surveillance:

A, C: Verify materials selection and verification controls (MMC-ET-SE16 and drawings 14175-15, 14175-33, 14175-17-19, 14175-17-21, 10950-71, 10950-79, 10950-95, 10950-99, 10950-51-7-7, 10950-79-3, 10950-79-5, 10950-51-5, 10950-51-3-3, 10950-51-7-3, 10950-51-7-5 and 10950-51-7-7, 10950-51-7-9, and 10950-91-3-3, Arrowhead).

A, C: Inspect welding (MPS-MPQ-103, Arrowhead).

A, C: Penetrant inspect welding for LWT-54 thru 88 (MIL-I-6866, Type 1, Method C, Group VI, Arrowhead).

A, C: Penetrant inspect welding for LWT-89 & Up (MIL-I-6866, Type 1, Method A, Sensitivity Level IV, Arrowhead).

A, C: Verify x-ray results (QCI-16-057, Arrowhead).

D: Inspect dimensions ball strut assembly (10950-71-3, Arrowhead for LWT-54 thru 88; 10950-91-3, Arrowhead for LWT-89 & Up).

B: Inspect flange surface flatness, finish, and dimensions (drawings 14175-15 and 14175-33, Arrowhead).

D: Verify lubrication (MPS-MPQ-121 and drawing 10950-71-3, Arrowhead for LWT-54 thru 88; MPS-MPQ-121 and drawing 10950-91-3-3, Arrowhead for LWT-89 & Up).

D: Witness cleaning (MPS-MPQ-105, Arrowhead).

Lockheed Martin Procurement Quality Representative:

A-D: Witness loads vs deflection, operating pressure/deflection, proof load and leakage tests (ATP 14175-390, Arrowhead for LWT-54 thru 88; ATP 14175-509, Arrowhead for LWT-89 & Up).

C: Witness 100% proof test of BSTRA pad welds (ATP 14175-390, Arrowhead for LWT-54 thru 88; ATP 14175-509, Arrowhead for LWT-89 and Up).

MAF Quality Inspection:

B: Inspect (visually) sealing surfaces for freedom of nicks, radial scratches or other imperfection (acceptance drawing 82620000001).

B: Verify installation (drawing 80921011009).

B: Witness seal leakage test (MMC-ET-TM04k).

Launch Site:

A-D: Visually monitor LO2 feedline system for no leakage (OMRSD File II).

FAILURE HISTORY:

Current data on test failures, unexplained anomalies and other failures experienced during ground processing activity can be found in the PRACA data base.