

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.05,
			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: This fwd elbow feedline section incorporates one flex joint and transports LO2 from the fwd flex assy to the forward straight section of the LO2 feedline. This elbow section penetrates the intertank wall for the continuation of the LO2 feedline down the exterior of the LH2 tank.

<u>FMEA ITEM CODE(S)</u>	<u>PART NO.</u>	<u>PART NAME</u>	<u>QTY</u>	<u>EFFECTIVITY</u>
2.1.7.1	PD4800175-089 -500	LO2 Feedline, Fwd Elbow (Intertank Penetration)	1 1	LWT-54 thru 88 LWT-89 & Up

REMARKS:

CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Propulsion/Mechanical
SUBSYSTEM: LO2 Propellant Feed
FMEA ITEM CODE(S): 2.1.7.1

REV & DATE: J, 12-19-97
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RATIONALE FOR RETENTION

DESIGN:

The 17 inch diameter forward elbow line assembly consists of machined flanges, tube straight sections, and elbow tube bend and a flexible joint assembly. The flexible joint contains a pressure carrier bellows and a ball strut assembly. The line assembly penetrates the intertank skin and is installed between the LO2 forward flexible line assembly and the first straight line assembly.

- 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), and the required yield safety factors (1.1 for loads and 1.25 for pressure only) (ET Stress Report 826-2188 and Arrowhead ET5-SR-0001-1). The line assembly also meets other operating and nonoperating requirements defined per PD4800175. Material selected in accordance with MMC-ET-SE16 and controlled per MMA 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-MPG-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 ensure performance within the capability of the seal.

- C, D: The flexible joint assemblies provide for installation misalignments of recurring motions during loading and boost. The flexible joint assembly is fabricated from 21-6-9 ARMCO. 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-MPG-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 butt welds. The tubes are telescoped one within the other and the convolutes are roll formed. The open pitch allows 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 Forward Elbow Line Assembly is qualified. Reference COO MMC-ET-TM06-012.

Development:

Bellows: A bellows assembly was subjected to the following test: spring rate, bending moment, 1000 motion cycles, 20 icing cycles, sinusoidal vibration, and burst pressure. Proof pressure and leakage tests 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 (ET5-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 (ET5-DTR-0002, Arrowhead).

BSTRA: Testing of one BSTRA assembly with a Stooddy 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. (ET5-DTR-0003, Arrowhead).

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

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RATIONALE FOR RETENTION

TEST: (cont)

Qualification:

LWT-54 thru 88:

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 2000 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 moment remaining within limits after 2000 cycles. Visual examination after 2000 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. (ETS-DTR-0004, Arrowhead).

BSTRA: Testing of one BSTRA, with an Inconel 718 ball, included proof pressure, proof load, operating cycle, operating life (500 cycles), temperature cycle (five excursions), 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 of a similar line assembly (identical configuration except that the BSTRA ball was fabricated from Stoodly No.2) included 500 operating life and five temperature cycles, leakage and ultimate loads tests. The leakage test was performed with GHe pressure at 80 psig for 15 minutes. No line leakage was noted using a leak detector solution (MMC-ET-RA09-8).

LWT-89 & Up (SLWT Project):

The SLWT design was certified by similarity to the LWT (-089) 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 BSTRA has had excess material removed, and tube wall thickness reduced, both for weight reduction.

MPTA Firings/Tankings: A forward flexible feedline assembly, similar to the 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 region through 104% power rating.

Acceptance:

Vendor - (Subassembly):

- A, C, Perform load vs deflection test on BSTRA joint assembly. (ATP 14175-389, Arrowhead for LWT-54 thru 88; ATP 14175-500, Arrowhead for LWT-89 & Up).
D:

Vendor - (Line Assembly):

- A-D: Perform operating pressure/deflection and proof loads tests (ATP 14175-389, Arrowhead for LWT-54 thru 88; ATP 14175-500, Arrowhead for LWT-89 & Up).
C: Perform 100% proof test of BSTRA pad welds (ATP 14175-389, Arrowhead, for LWT-54 thru 88; ATP 14175-500, Arrowhead for LWT-89 & Up).
A-C: Perform leakage test after operating pressure/deflection, proof loads, and 100% proof tests (ATP 14175-389, Arrowhead for LWT-54 thru 88; ATP 14175-500, Arrowhead for LWT-89 & Up).

MAF - (Line Assembly):

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

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INSPECTION:

Vendor Inspection - Lockheed Martin Surveillance:

- A, C: Verify materials selection and verification control (MMC-ET-SE16 and drawings 14175-29, 14175-33, 14175-17-5, 14175-17-7, 14175-21, 10950-91, 10950-51-5, 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 (MIL-I-6866, Type 1, Method C, Group VI, Arrowhead for LWT-54 thru 88; MIL-I-6866, Type 1, Method A, Sensitivity Level IV, Arrowhead for LWT-89 & Up).
- A, C: Verify x-ray results (QCI-16-057, Arrowhead).
- B, D: Inspect flange surface flatness, finish and dimensions (drawings 14175-29, 14175-33, Arrowhead).
- D: Inspect dimensions (drawing 10950-71-3, Arrowhead for LWT-54 thru 88; drawing 10950-91-3, Arrowhead for LWT-89 & Up).
- D: Verify lubrication (MPS-MPQ-121 and drawing 10950-91-3-3, Arrowhead).
- D: Witness cleaning (MPS-MPQ-105, Arrowhead)

Lockheed Martin Procurement Quality Representative:

- A, C, D: Witness loads vs deflection, proof load, operating pressure/deflection and leakage test (ATP 14175-389, Arrowhead for LWT-54 thru 88; ATP 14175-500, Arrowhead for LWT-89 & Up).
- C: Witness 100% proof test of BSTRA pad welds (ATP 14175-389, Arrowhead for LWT-54 thru 88; ATP 14175-500, Arrowhead for LWT-89 & Up).

MAF Quality Inspection:

- B: Inspect sealing surfaces for freedom of nicks, radial scratches or other imperfections during installation (acceptance drawing 82620000001).
- B: Verify installation (drawing 80921011009).
- B: Witness seal leakage test (MMC-ET-TM04k).

Launch Site:

- A-C: 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.