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, P.09, P.10, S.05, S.07
DCN & DATE:			
ANALYSTS:	A. Attar/H. Claybrook		

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.

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 forward flex feedline section located in the intertank contains two flex joints and transports LO2 from the LO2 dome to the fwd elbow section of the LO2 feedline.

FMEA ITEM CODE(S)	PART NO.	PART NAME	QTY	EFFECTIVITY
2.1.6.1	P048000175-080	LO2 Feedline, Fwd Flex Assy	1	LWT-54 thru 56
	-099	(Intertank)	1	LWT-57 thru 88
	-510		1	LWT-89 & Up

REMARKS:

SYSTEM:	Propulsion/Mechanical	REV & DATE:	J, 12-19-97
SUBSYSTEM:	LO2 Propellant Feed	DCN & DATE:	
FMEA ITEM CODE(S):	2.1.6.1		

RATIONALE FOR RETENTION

DESIGN:

The 17 inch diameter forward flexible line assembly consists of machined flanges, tube straight section, elbow tube band, and two flexible joint assemblies. Each flexible joint contains a pressure carrier bellows and a ball strut assembly. The line assembly is located within the intertank and is installed between the LO2 suction fitting and the LO2 forward elbow 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), the required yield safety factors (1.1 for loads and 1.25 for pressure only) (ET Stress Report 826-2189 and ET5-SR-0001-1 Arrowhead). The line assembly also meets 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-MPO-103 (Arrowhead).

To reduce weight, the SLWT elbow wall thickness was reduced from .100 inch to .080 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 of the vitrolube is specified for oxygen service (MPS-MPO-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 buttwelds. 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 LO2 Feedline, FWD Flex Assy (Intertank) is qualified. Reference CDD MMC-ET-TM06-013.

Development:

Bellows: A bellows assembly was subjected to the following test: spring rate, bending moment, 1002 motion cycles, 20 icing cycles, sinusoidal vibration, and burst pressure. Proof pressure and leakage tests were performed three times. No deformation, structural damage, degradation or leakage was 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 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. (ET5-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 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).

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 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 $3x10^{-7}$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 and the line contained instrumentation bosses. Testing included deflection, operating cycle, proof load and leakage for acceptance, 500 operating life cycles (450 at LN2 temperature, pressurized to 75 psig, 50 at ambient temperature, unpressurized), five temperature cycles, line leakage check, and ultimate loads at LN2 temperature with internal pressure up to 295 psig. The leakage check was conducted with the line pressurized to 75 psig for 15 minutes. No line leakage was noted. (MMC-ET-RA09-7).

LWT-89 & Up (SLWT Project):

The SLWT design was certified by similarity to the LWT (-099) 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 design except that the BSTRAs have had excess material removed, and elbow wall thickness reduced, both for weight reduction.

MPTA Firings/Tankings: A forward flexible feedline assembly similar to the above qualification unit has accumulated 52.5 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.

SYSTEM: Propulsion/Mechanical
SUBSYSTEM: LO2 Propellant Feed
FMEA ITEM CODE(S): 2.1.6.1

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

TEST: (cont)

Acceptance:

Vendor - (Subassembly):

A, C, D: Perform load vs deflection test each BSTRA joint assembly (ATP 175-380, Arrowhead for LWT-54 thru 56; ATP 14175-399, Arrowhead for LWT-57 thru 88; ATP 14175-510, Arrowhead for LWT-89 & Up).

Vendor - (Line Assembly):

A, C, D: Perform operating pressure/deflection and proof loads tests (ATP 175-380, Arrowhead for LWT-54 thru 56; ATP 14175-399, Arrowhead for LWT-57 thru 88; ATP 14175-510, Arrowhead for LWT-89 & Up).

C: Perform 100% proof test of BSTRA pad welds (ATP 14175-399, Arrowhead for LWT-57 thru 88; ATP 14175-510, Arrowhead for LWT-89 & Up).

A-C: Perform leakage test after operating pressure/deflection, proof loads and 100% proof tests (ATP 175-380, Arrowhead for LWT-54 thru 56; ATP 14175-399, Arrowhead for LWT-57 thru 88; ATP 14175-510, Arrowhead for LWT-89 & up).

MAF - (Line Assembly):

B: Perform seal leakage test after installation (MMC-ET-TN04k).

INSPECTION:

Vendor Inspection - Lockheed Martin Surveillance:

A, C: Verify materials selection and verification controls (MMC-ET-SE16 and drawings 14175-47, 14175-3, 14175-19, 14175-49, 14175-17-3, 10950-51-3-3, 10950-51-7-7, 10950-51-7-3, 10950-51-7-9, 10950-51-5, 10950-51-7-11, 10950-71, 10950-91 10950-91-3-3-3, 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).

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

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

B: Inspect mating surface flatness, finish and dimensions (drawings 14175-47 and 14175-3, Arrowhead).

D: Inspect dimensions (drawings 10950-71-3, Arrowhead).

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-D: Witness loads vs deflection, operating pressure/deflection, proof load, post test inspection/examination and leakage tests (ATP 175-380, Arrowhead for LWT-54 thru 56; ATP 14175-399, Arrowhead for LWT-57 thru 88; ATP 14175-510, Arrowhead for LWT-89 & Up).

C: Witness 100% proof test of BSTRA pad welds (ATP 14175-399, Arrowhead for LWT-57 thru 88; ATP 14175-510, Arrowhead, for LWT-89 & Up).

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RATIONALE FOR RETENTION

INSPECTION: (cont)

MAF Quality Inspection:

B: Witness seal flange leakage tests (MMC-ET-TMD4k).

B: Inspect (visually) sealing surfaces are free of nicks and radial scratches (acceptance drawing 82620000001).

B: Verify installation (drawing 80921111900).

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.