

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL HARDWARE

NUMBER: 02-1E-067-X

SUBSYSTEM NAME: LANDING DECELERATION - WHEEL, BRAKE & TIRE

REVISION : 2 11/09/90

PART NAME
VENDOR NAME

PART NUMBER
VENDOR NUMBER

LRU : MLG WHEEL ASSEMBLY

MC621-0051

- EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
MAIN LANDING GEAR TIE BOLTS - FOR BERYLLIUM AND CARBON BRAKE WHEEL/BRAKE ASSEMBLIES.

QUANTITY OF LIKE ITEMS: 72
EIGHTEEN PER WHEEL

- FUNCTION:
SECURES THE TWO HALVES OF THE WHEEL.

PAGE: 2

PRINT DATE: 11/09/90

S050260E
ATTACHMENT -
Page 11 of 94

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL FAILURE MODE
NUMBER: 02-1E-067-01

SUBSYSTEM: LANDING DECELERATION - WHEEL, BRAKE & TIRE
LRU :MLG WHEEL ASSEMBLY
ITEM NAME: MLG WHEEL ASSEMBLY

REVISION# 2 11/09/90 R
CRITICALITY OF THIS
FAILURE MODE:1R2

■ FAILURE MODE:
STRUCTURAL FAILURE.

MISSION PHASE:
DO DE-ORBIT

■ VEHICLE/PAYLOAD/KIT EFFECTIVITY: 102 COLUMBIA
: 103 DISCOVERY
: 104 ATLANTIS
: 105 ENDEAVOUR

CAUSE:
OVERLOAD, IMPROPER BOLT PRELOAD, DEFECTIVE MATERIAL

CRITICALITY 1/1 DURING INTACT ABORT ONLY? N

REDUNDANCY SCREEN A) PASS
B) FAIL
C) PASS

B)
SCREEN "B" FAILS BECAUSE THERE IS NO INDICATION OF THIS FAILURE PRIOR
TO LANDING.

- FAILURE EFFECTS -

(A) SUBSYSTEM:
NO EFFECT - TWO TIE BOLT FAILURES REQUIRED TO CAUSE WHEEL FAILURE AND
LOSS OF ADJACENT TIRE/WHEEL ASSEMBLY AT TOUCHDOWN.

(B) INTERFACING SUBSYSTEM(S):
SAME AS(A).

(C) MISSION:
PROBABLE LOSS OF MISSION/PAYLOAD/CREW/VEHICLE WITH TWO TIEBOLT FAILURES
BEFORE NOSE GEAR TOUCHDOWN - VEHICLE WILL DEPART RUNWAY DUE TO
EXCESSIVE YAWING FORCES AND/OR LOSS OF 50 PERCENT BRAKING CAPABILITY.

FAILURE MODES EFFECTS ANALYSIS (FMEA) — CRITICAL FAILURE MODE
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(D) CREW, VEHICLE, AND ELEMENT(S):
SAME AS (C).

- DISPOSITION RATIONALE -

■ (A) DESIGN:

THE BOLTS ARE DESIGNED TO A MINIMUM FACTOR OF SAFETY OF 1.5 WITH STANDARD MATERIAL ALLOWABLES. FOLLOWING APPROACH AND LANDING TESTS, TIE BOLT DIAMETERS WERE INCREASED AND STRENGTH AND FATIGUE PROPERTIES WERE IMPROVED. INCREASED DIAMETER, STRENGTH AND IMPROVED FATIGUE PROPERTIES. BOLTS ARE NOT REUSED AFTER THEY HAVE BEEN TORQUED FOUR TIMES.

■ (B) TEST:

QUALIFICATION TESTS:

CERTIFICATION IS ACCOMPLISHED AS PART OF THE WHEEL ASSEMBLY. WHEEL/TIE BOLTS ARE SUBJECTED TO A 1000 MILE SLOW ROLL TEST, 6 LANDING LOAD PROFILE TESTS AND STATIC LOAD TESTS (YIELD AND ULTIMATE COMBINED LOAD TESTS). THE CURRENT CONFIGURATION OF THE WHEEL AND TIE BOLTS WAS CERTIFIED BY SIMILARITY TO THE BASELINE WHEEL AND WAS TESTED WITH THE THICK STATOR BRAKES. TIE BOLTS FOR THE CARBON BRAKE WHEEL ASSEMBLY WERE ALSO QUALIFIED AS PART OF THE WHEEL/BRAKE ASSEMBLY.

ONE (1) CARBON BRAKE WHEEL SUCCESSFULLY COMPLETED THE FOLLOWING DYNAMIC TESTS:

- 1) SLOW ROLL DYNAMOMETER TESTING FOR A TOTAL OF 990 MILES
- 2) ONE (1) LANDING PROFILE SIMULATING 211K LBS ORBITER WT AT AN INITIAL SOAKED TEMPERATURE OF 131 DEGREES F
- 3) ONE (1) LANDING PROFILE SIMULATING 211K LBS ORBITER WT AT AN INITIAL SOAKED TEMPERATURE OF -35 DEGREES F
- 4) THREE (3) LANDING PROFILES SIMULATING 211K LBS ORBITER WT AND 10 KNOT X-WIND AT AMBIENT TEMPERATURE
- 5) ONE (1) LANDING PROFILE SIMULATING AN ABORT 240K LBS ORBITER WT AND 20 KNOT X-WIND AT AMBIENT TEMPERATURE
- 6) ONE (1) LANDING PROFILE SIMULATING A MAXIMUM ABORT WEIGHT OF 256 K LBS AND 20 KNOT X-WIND AT AMBIENT TEMPERATURE.

STATIC WHEEL PRESSURE TEST - WHEEL IS INFLATED TO 1.5 TIMES RATED INFLATION PRESSURE (473 - 485 PSIG) - NO LEAKAGE WAS FOUND WHEN CHECKED.

DIFFUSION TEST - SUCCESSFULLY COMPLETED WITH NO LEAKAGE FOUND.

DYNAMIC PRESSURE TEST:

WHEEL AND TIRE ASSEMBLY WAS PRESSURED TO 320 PSI AND ROLLED FOR 25

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL FAILURE MODE
NUMBER: 02-1E-067-01**

MILES WITHOUT PRESSURE LOSS (5 PSI PRESSURE LOSS ALLOWED). WHEEL SUCCESSFULLY COMPLETED SLOW ROLL TEST (4 CYCLES) WHILE BEING SUBJECTED TO RADIAL LOADS FROM 53,944 LBS TO 60,000 LBS AND SIDE LOADS OF 12,000 LBS. TIE BOLTS WERE TORQUED TO 179 - 189 FT-LBS AND DID NOT FALL BELOW THAT RANGE (AFTER 4TH CYCLE RANGE WAS FROM 190-210 FT-LBS).

BURST TEST:

PRESSURE WAS APPLIED TO THE WHEEL/TIRE ASSEMBLY UP TO 945 PSI AND HELD FOR 10 SECONDS - WITH NO FAILURES. THE WHEEL/TIRE ASSEMBLY SUCCESSFULLY SATISFIED THE REQUIREMENTS WITH NO CRACKS OR EVIDENCE OF FAILURE FOUND IN THE WHEEL HALVES OR TIE BOLTS AFTER THE TIRE FAILED AT A PRESSURE OF 1137 PSI.

COMBINED LOADS TEST:

THE YIELD AND ULTIMATE COMBINED LOADS WERE SUCCESSFULLY PERFORMED. BERYLLIUM BRAKE WHEEL/TIRE ASSEMBLY WAS SUBJECTED TO THE FOLLOWING YIELD COMBINED LOADS:

ACTING INBD - 144,900 LBS RADIAL LOAD AND 6,800 LBS SIDE LOAD

ACTING OUTBD - 145,200 LBS RADIAL LOAD AND 6,800 LBS SIDE LOAD

THE CARBON BRAKE WHEEL/TIRE ASSEMBLY WAS SUBJECTED TO THE FOLLOWING YIELD COMBINED LOADS:

CONDITION 1 - 126,000 LBS RADIAL LOAD AND 5,800 LBS SIDE LOAD

CONDITION 2 - 64,000 LBS RADIAL LOAD AND 21,300 LBS SIDE LOAD

ULTIMATE COMBINED LOADS: WAS 1.4 TIMES THE YIELD LOAD.
ALL DESIGN REQUIREMENTS WERE MET (LEAKAGE INTERFERENCE ETC).
ACCEPTANCE TESTS INCLUDE DIMENSIONAL CHECKS, FINISH, CLEANLINESS AND CONFIRMATION OF CERTIFIED MATERIALS AND PROCESSES USED.

OMRSD:**MLG WHEEL INSPECTION:**

WHEELS ARE INSPECTED PER THE MLG WHEEL/TIRE ASSEMBLY AND INSPECTION SPECIFICATION MLO308-0142 WHICH STATES; "... VISUALLY INSPECT ALL COMPONENTS OF THE MAIN WHEEL ASSEMBLY FOR CRACKS, NICKS, CORROSION AND OTHER DAMAGE." THE WHEEL FLANGE SURFACES THAT CONTACT THE TIRE BEAD SEAT IS ALSO INSPECTED FOR CORROSION, NICKS, SCRATCHES AND OTHER DAMAGE. REPAIRS ARE PERFORMED PER THE MANUFACTURER'S RECOMMENDATIONS.

MLG WHEEL/TIRE CERT:

VERIFIES MLG WHEEL/TIRE ASSEMBLY HAS BEEN BUILT UP AND TESTED PER THE V070-510002 DRAWING, MLO308-0029 LANDING GEAR RIGGING SPECIFICATION AND MLO308-0142 MLG WHEEL/TIRE INSTALLATION AND INSPECTION SPECIFICATION.

THE MLG WHEEL/TIRE ASSEMBLY AND INSPECTION SPECIFICATION STATES;

" ...AFTER TIE BOLTS ARE DRAWN SNUG TIGHT, TORQUE IN A CRISS-CROSS ORDER TO 75 PLUS OR MINUS 20 FT-LBS, THEN CONTINUE THE CRISS-CROSS PATTERN TO 145 PLUS OR MINUS 20 FT-LBS, THEN CONTINUE IN A CRISS-CROSS

**FAILURE MODES EFFECTS ANALYSIS (FMEA) — CRITICAL FAILURE MODE
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PATTERN TO THE FINAL TORQUE OF 185 TO 195 FT-LBS..."
THE TIE BOLTS ARE ALSO INSPECTED FOR DAMAGE BEFORE INSTALLATION.

■ (C) INSPECTION:**RECEIVING INSPECTION**

SPS RECEIVING INSPECTION VERIFIES MP35N MATERIAL MEETS REQUIREMENTS OF SPS M646. B. F. GOODRICH RECEIVING INSPECTION SAMPLE CHECKS FOR TENSILE STRENGTH, HARDNESS, SURFACE FINISH AND ROUGHNESS AND ALL DIMENSIONS, INCLUDING GRIP LENGTH, SHANK LENGTH, HEAD RADIUS AND DIAMETERS.

CONTAMINATION CONTROL

CLEANLINESS AND CORROSION CONTROL REQUIREMENTS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

THREADS ROLLED TO B. F. GOODRICH SPECIFICATION SS 31.2 VERIFIED BY INSPECTION. THREADS PER MIL-S-8879 METHOD B CERTIFIED. FABRICATION PROCEDURES VERIFIED BY INSPECTION. FABRICATION OF BOLTS VERIFIED BY GOVERNMENT SOURCE INSPECTION. TORQUING OF BOLTS TO SPECIFICATION REQUIREMENTS VERIFIED BY INSPECTION.

CRITICAL PROCESSES

HEAT TREATING OF MP35N BOLTS VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

SPS CERTIFIES 100% FLUORESCENT PENETRANT EXAMINATION PER MIL-I-6866. NO INDICATIONS PERMISSABLE. B. F. GOODRICH CONDUCTS FLUORESCENT PENETRANT INSPECTION OF SAMPLE PARTS.

CARBON BRAKE WHEEL IS TREATED AS FRACTURE CRITICAL WITH COMPLETE FRACTURE CONTROL REQUIREMENTS IMPOSED. STANDARD NDE PER MT0501-508 IS REQUIRED FOR THE INNER WHEEL HALF, WHEEL SLEEVE, AND OUTER WHEEL HALF. SPECIAL NDE WILL BE REQUIRED FOR THE BEAD SEAT AND TIE BOLT HOLE AREAS OF THE WHEEL HALVES.

THE WHEEL WAS INSPECTED AT THE CONCLUSION OF TESTING AS FRACTURE CRITICAL HARDWARE AND WAS SUBJECTED TO SPECIAL NDE EDDY CURRENT INSPECTION AT THE FRACTURE CRITICAL AREA OF THE WHEEL (WHEEL BEAD SEAT AND TIE BOLTS) WITH NO CRACKS OR EVIDENCE OF MATERIAL FAILURE FOUND IN THE WHEEL HALVES OR TIE BOLTS.

TESTING

SPS CONDUCTS TENSILE TESTING, FATIGUE TESTING, BOLT PRELOAD TESTING, STRESS DURABILITY TESTING AND METALLURGICAL MICROSTRUCTURE EVALUATION OF SAMPLE PARTS FROM EACH LOT AND LISTS ACTUAL VALUES ON CERTIFICATIONS.

PACKAGING/HANDLING

HANDLING AND PACKAGING REQUIREMENTS VERIFIED BY INSPECTION.

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL FAILURE MODE
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■ (D) FAILURE HISTORY:
NONE.

(E) OPERATIONAL USE:

WHEEL FAILURE BEFORE NLG TOUCHDOWN - CREW WILL ATTEMPT TO USE AERO
RUDDER AND BRAKING ON THE OPPOSITE SIDE IN AN ATTEMPT TO MAINTAIN
DIRECTIONAL CONTROL.

WHEEL FAILURE AFTER NLG TOUCHDOWN - CREW WILL USE NWS, AERO RUDDER AND
DIFFERENTIAL BRAKING TO MAINTAIN DIRECTIONAL CONTROL.

- APPROVALS -

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|--------------------------|----------------|---|-----------------------------|
| RELIABILITY ENGINEERING: | G. T. TATE | : | <i>[Signature]</i> |
| DESIGN ENGINEERING | : M. T. PORTER | : | <i>[Signature]</i> 11/14/90 |
| QUALITY ENGINEERING | : D. DESAI | : | <i>[Signature]</i> 11/14/90 |
| NASA RELIABILITY | : | : | <i>[Signature]</i> 11/9/91 |
| NASA SUBSYSTEM MANAGER | : | : | <i>[Signature]</i> 11/9/91 |
| NASA QUALITY ASSURANCE | : | : | <i>[Signature]</i> 11-7-90 |