

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**NUMBER: 02-6-SYSTEM-IM -X****SUBSYSTEM NAME: HYDRAULICS****REVISION: 5****01/05/94****PART DATA**

PART NAME	PART NUMBER
VENDOR NAME	VENDOR NUMBER
LRU :HYDRAULIC SUBSYSTEM	NONE

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

QUANTITY OF LIKE ITEMS: 1
INCLUDES THREE REDUNDANT HYDRAULIC POWER SYSTEMS

FUNCTION:

THE HYDRAULIC SUBSYSTEM GENERATES, CONTROLS, CONTAINS AND TRANSMITS FLUID POWER FOR ACTUATION OF THE AERODYNAMIC FLIGHT CONTROL SURFACES, MAIN ENGINE GIMBALS, MAIN AND NOSE LANDING GEAR, MAIN LANDING GEAR BRAKES, NOSE WHEEL STEERING AND MAIN ENGINE PROPELLANT CONTROL VALVES.

FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE

NUMBER: 02-6-SYSTEM-IM-02

REVISION#: 1 07/24/98

SUBSYSTEM NAME: HYDRAULICS

LRU: HYDRAULIC SUBSYSTEM

ITEM NAME: HYDRAULIC SUBSYSTEM

CRITICALITY OF THIS

FAILURE MODE: 1/1

FAILURE MODE:

LEAKAGE, EXTERNAL, LINES (TUBE/HOSES) AND FITTINGS

MISSION PHASE:

DO DE-ORBIT

LS LANDING/SAFING

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102 COLUMBIA

103 DISCOVERY

104 ATLANTIS

105 ENDEAVOUR

CAUSE:

DEFECTIVE/INCORRECT SEALS OR MATERIALS, IMPROPER ASSEMBLY/INSTALLATION OF COMPONENTS OR TUBE/HOSE ASSEMBLIES

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN

A) N/A

B) N/A

C) N/A

PASS/FAIL RATIONALE:

A)

B)

A LEAK OF THE NWS SWITCHING VALVE CANNOT BE DETECTED UNTIL HYD ISOLATION VALVE OPENING (VREL=800FPS) AND EXTEND VALVE OPENING (LANDING GEAR DEPLOYMENT).

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

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LEAK DOWNSTREAM OF THE NWS SWITCHING VALVE (1/1) - LOSS OF TWO OF THREE (SYSTEM 1 AND SYSTEM 2) HYDRAULIC SYSTEMS FOLLOWING MAIN GEAR TOUCHDOWN DURING DEROTATION, LOAD RELIEF, OR ROLLOUT.

LEAK NOT DOWNSTREAM OF THE NWS SWITCHING VALVE (1R2) - LOSS OF ONE OF THREE HYDRAULIC SYSTEMS RESULTING IN LOSS OF VEHICLE'S HYDRAULIC SYSTEM REDUNDANCY

(B) INTERFACING SUBSYSTEM(S):

LEAK DOWNSTREAM OF THE NWS SWITCHING VALVE (1/1) - LOSS OF TWO OF THREE HYDRAULIC SYSTEMS (UNCERTIFIED CONFIGURATION) TO FLIGHT CONTROL SURFACES RESULTING IN LIMITED MOVEMENT RATES FOR DEROTATION CONTROL AND LOAD RELIEF. LOSS OF ALL NOSEWHEEL STEERING CAPABILITY DURING ROLLOUT (DIFFERENTIAL BRAKE STILL AVAILABLE). LOSS OF TWO OF THREE HYDRAULIC POWER SYSTEMS TO BRAKES (100% BRAKES STILL AVAILABLE)

LEAK NOT DOWNSTREAM OF THE NWS SWITCHING VALVE (1R2) - LOSS OF HYDRAULIC POWER FOR ENGINE VALVE CONTROL RESULTING IN LOSS OF ONE SSME THRUST CONTROL, HOWEVER, ENGINE VALVES WILL LOCK INTO POSITION AND ENGINE WILL CONTINUE TO OPERATE. LOSS OF REDUNDANT HYDRAULIC POWER SYSTEM FOR TVC ACTUATOR. LOSS OF HYDRAULIC REDUNDANT DEPLOYMENT CAPABILITY IF SYSTEM ONE IS LOST. LOSS OF ONE OF THREE HYDRAULIC POWER SYSTEMS TO FLIGHT CONTROL SURFACES AND BRAKES. LOSS OF ONE OF THREE ET UMBILICAL RETRACT ACTUATORS FOR EACH UMBILICAL PLATE. HYDRAULIC FLUID ON TPS SCREED MAY CAUSE DEGRADED TPS BONDS.

(C) MISSION:

LEAK DOWNSTREAM OF THE NWS SWITCHING VALVE (1/1) - POSSIBLE LOSS OF CREW/VEHICLE WITH THIS FAILURE. IF LEAK MAGNITUDE IS SUFFICIENT TO CAUSE LOSS OF HYD SYSTEM 1 BETWEEN GEAR DEPLOY AND TOUCHDOWN, AND LOSS OF HYDRAULIC SYSTEM 2 DURING DEROTATION (BRAKE ISOLATION VALVE 2 OPENS AT WOW + 160 MS). THIS REDUCES HYD FLOW TO ACTUATORS, CAUSES SWITCHING VALVE MOVEMENT, AND INDUCES HYD PRL (PRIORITY RATE LIMITING). THIS IS AN UNCERTIFIED CONFIGURATION RESULTING IN LIMITED AEROSURFACE RATES FOR DEROTATION CONTROL AND LOAD RELIEF. LOSS OF CONTROL DURING DEROTATION MAY RESULT CAUSING EXCESSIVE NOSEGEAR STRUCTURAL LOADS AT NOSEGEAR TOUCHDOWN.

LEAK NOT DOWNSTREAM OF THE NWS SWITCHING VALVE (1R2) - ABORT DECISION OR POSSIBLE EARLY MISSION TERMINATION.

(D) CREW, VEHICLE, AND ELEMENT(S):

LEAK DOWNSTREAM OF THE NWS SWITCHING VALVE (1/1) - SAME AS ABOVE FOR (C)

LEAK NOT DOWNSTREAM OF THE NWS SWITCHING VALVE (1R2) - NONE.

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(E) FUNCTIONAL CRITICALITY EFFECTS:

LEAK DOWNSTREAM OF THE NWS SWITCHING VALVE (1/1) - SAME AS ABOVE FOR (C).

LEAK NOT DOWNSTREAM OF THE NWS SWITCHING VALVE (1R2) - POSSIBLE LOSS OF CREW/VEHICLE WITH TWO FAILURES: THIS FAILURE PLUS LOSS OF SECOND HYDRAULIC SYSTEM OR LANDING GEAR PYROTECHNIC DEPLOYMENT IF SYSTEM ONE IS LOST. CRITICALITY 1 FOR SSME INDUCED RTLS.

-DISPOSITION RATIONALE-

(A) DESIGN:

SYSTEM INCORPORATES DESIGN MARGINS OR SAFETY: ENVIRONMENTAL STRESS FACTORS, FRACTURE MECHANICS (WHERE APPLICABLE), DUAL DYNAMIC SEALS, AND DUAL TUBE FITTING ADAPTER SEALS (METAL-TO-METAL SEAL AND ELASTOMERIC "O" RING SEAL). DYNATUBE FITTINGS ARE LOCKWIRED TOGETHER, EXCEPT FOR ORIGINAL FITTINGS ON OV-102. REPLACEMENT FITTINGS ON OV-102 ARE LOCKWIRED, IF BOTH HALVES OF FITTINGS HAVE LOCKWIRE HOLES.

(B) TEST:

QUALIFICATION:

EXAMINATION OF PRODUCT - MATERIALS, WORKMANSHIP, AND DIMENSIONS.

PROOF PRESSURE - TESTED AT 6,000 PSIG FOR PRESSURE, 3,000 PSIG FOR RETURN (EXCEPT DYNATUBE FITTINGS). PASS/FAIL CRITERIA: NO EXTERNAL LEAKAGE AND NO STRUCTURAL FAILURE.

MECHANICAL FLEXURAL TEST - TESTED AT 275 DEG F AT BENDING STRESS LEVEL OF 25,000 PSI, 3,000 PSIG PRESSURE, 1,500 PSIG RETURN FOR 10 MILLION CYCLES AND 45 HZ. (1 OF 8 FITTING AND 1 OF 6 TUBING SPECIMENS) PASS/FAIL CRITERIA: THE S/N CHARACTERISTIC CURVE NUMBER SHALL BE NO GREATER THAN 4.

MECHANICAL FLEXURAL (ROTORY) TEST - TESTED AT 275 DEG F AT BENDING STRESS OF 19,000 PSI, 3,000 PSIG PRESSURE, 1,500 PSIG RETURN FOR 2 MILLION CYCLES AND 45 HZ. (1 OF 6 FITTING AND 1 OF 6 TUBING SPECIMENS.) (TELEDYNE AND LINAIR ONLY.) PASS/FAIL CRITERIA: THE S/N CHARACTERISTIC CURVE NUMBER SHALL BE NO GREATER THAN 4.

TORSIONAL FLEXURAL TEST - TESTED AT 275 DEG F AT BENDING STRESS OF 25,000 PSI, 3,000 PSIG PRESSURE, 1,500 PSI RETURN FOR 2 MILLION CYCLES AND 45 HZ. (PERMASWAGE AND DYNATUBE FITTINGS/TUBING ASSEMBLIES) PASS/FAIL CRITERIA: THE S/N CHARACTERISTIC CURVE NUMBER SHALL BE NO GREATER THAN 4

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IMPULSE TEST - 200,000 PRESSURE WAVE CYCLES AT 275 DEG F. FIRST PEAK PRESSURE OF 4,500 PSIG, SECOND PEAK OF 92 PERCENT OF FIRST PEAK, DOWN TO 3,000 PSIG AT 60-70 HZ. PASS/FAIL CRITERIA: NO EXTERNAL LEAKAGE OR STRUCTURAL FAILURE.

BURST TEST - 12,000 PSIG PRESSURE, 6,000 PSIG RETURN. PASS/FAIL CRITERIA NO LEAKAGE OR RUPTURE.

N2 LEAK TEST - 100 PSIG FOR 24 HOURS; 3,000 PSIG PRESSURE, 1,500 PSIG RETURN, 6,000 PSIG PRESSURE, 3,000 PSIG RETURN WITH 14,000 PSI STRESS LEVEL FOR 7 HOURS. (PERMASWAGE AND DYNATUBE FITTINGS/TUBING ASSEMBLIES.) PASS/FAIL CRITERIA: EXTERNAL LEAKAGE OF NO MORE THAN 10 CC/HR.

VIBRATION TEST - RANDOM VIBRATION LEVELS ACCORDING TO THE PARTICULAR LOCATION AS INSTALLED IN THE VEHICLE AT VARIOUS VIBRATION SPECTRUMS ACCORDING TO MF0004-014 (ENVIRONMENTAL REQUIREMENTS AND TEST CRITERIA FOR THE ORBITER VEHICLE).

GROUND TURNAROUND TEST

ANY TURNAROUND CHECKOUT TESTING IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD

(C) INSPECTION:**RECEIVING INSPECTION**

ALL RAW MATERIAL AND COMPONENTS ARE VERIFIED BY INSPECTION. MC SPEC HARDWARE IS VERIFIED BY SOURCE INSPECTION FOR FABRICATION/ASSEMBLY AND FUNCTIONAL OPERATION, AT SUPPLIER, TO SPECIFICATION REQUIREMENTS. INSPECTION VERIFIES THAT 3A1-2.5V TITANIUM TUBING IS CERTIFIED TO THE REQUIREMENTS OF MBO170-084.

CONTAMINATION CONTROL

CLEANLINESS LEVEL 190 PER MAO110-301 IS VERIFIED BY INSPECTION

CRITICAL PROCESSES

PERMASWAGE PROCESS IS VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

PENETRANT AND ULTRASONIC INSPECTION ARE VERIFIED BY INSPECTION.

ASSEMBLY/INSPECTION

ALL COMPONENTS/HARDWARE ARE VERIFIED BY INSPECTION AT DETAIL FABRICATION AND ASSEMBLY. LEAK AND PRESSURE TEST AT SUB-ASSEMBLY AND INSTALLATION LEVELS ARE VERIFIED BY INSPECTION. INSTALLATION PER MAO102-306 IS VERIFIED BY INSPECTION. INSPECTION VERIFIES THAT ALL PROCESSING MATERIALS IN CONTACT WITH TITANIUM ARE PER MFO004-018. SEALING SURFACES ARE VERIFIED BY INSPECTION.

TESTING

FUNCTIONAL TEST AND SUBSYSTEMS, AND FULL INTEGRATION, PER TMO/TCP, SYSTEM SERVICING REQUIREMENTS PER MLO/TCP. TESTING IS VERIFIED BY INSPECTION.

HANDLING/PACKAGING

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INSPECTION VERIFIES PACKAGING PRIOR TO SHIPMENT.

(D) FAILURE HISTORY:

CURRENT DATA ON TEST FAILURES, FLIGHT FAILURES, UNEXPLAINED ANOMALIES, AND OTHER FAILURES EXPERIENCED DURING GROUND PROCESSING ACTIVITY CAN BE FOUND IN THE PRACA DATA BASE. THE FAILURE HISTORY DATA PROVIDED BELOW IS NO LONGER BEING KEPT UP-TO-DATE.

(AB1531-010) (1978) DURING SUBSYSTEM CHECKOUT AT NSTL, HYDRAULIC OIL WAS NOTED AT THE FLEX HOSE CONNECTING TO THE TVC ACTUATOR WHEN 3,000 PSI WAS APPLIED. THE HOSE WAS REMOVED AND SENT TO THE SUPPLIER. THE SUPPLIER WAS UNABLE TO DUPLICATE THE LEAKAGE. THE HOSE ASSEMBLY WAS CLEANED AND SUCCESSFULLY PASSED ATP.

(AB2259-010) (1978, OV102) DURING SUBSYSTEM CHECKOUT, LEAKAGE WAS NOTED AT THE FLEX HOSE CONNECTING TO THE TVC ACTUATOR. DURING DISASSEMBLY, THE CAUSE WAS DETERMINED TO BE MINOR DAMAGE TO THE SEALING SURFACE INCURRED BY THE SWIVEL BALL SURFACE DURING INITIAL MOVEMENTS AND INSTALLATION HANDLING, WHILE COMPLETELY FREE OF LUBRICANT (HYDRAULIC OIL). THE USE OF FREON TO CLEAN THE HOSES REMOVED ALL RESIDUAL HYDRAULIC OIL FROM THE SWIVEL AREA. THE SUPPLIER REVISED THE REQUIREMENT FOR HOSE CLEANING TO USE ISOPROPYL ALCOHOL INSTEAD OF FREON.

(AB4334-010) (1979) SUBSEQUENT TO SUBSYSTEM PRESSURIZATION OF FCHL, THE FLEX HOSE ASSEMBLY CONNECTING THE TVC ACTUATOR TO THE FCHL HYDRAULIC SUPPLY LINES WERE NOTED TO BE LEAKING AT THE SWIVEL JOINT. THE CAUSE OF THIS LEAKAGE WAS CONCLUDED TO BE DEGRADATION OF THE "O" RING SEAL IN THE SWIVEL JOINT. DEGRADATION OF THE "O" RING WAS CAUSED BY LONG TERM EXPOSURE TO FREON CLEANING AGENTS USED ON THE FCHL. THE HOSE CLEANING PROCEDURE WAS CHANGED BY THE SUPPLIER.

(AB6804-010) (1980) DURING ACCEPTANCE TESTING WHILE CONDUCTING THE PROOF PRESSURE TEST, LEAKAGE WAS NOTED AT THE TVC ACTUATOR HOSE ASSEMBLY. THE CAUSE OF THE FAILURE WAS CONSIDERED TO BE DEGRADATION OF THE SWIVEL "O" RING SEAL IN THE FORM OF REDUCTION OF CROSS SECTION DUE TO EXPOSURE TO FREON PERMITTING "O" RING MOVEMENT IN THE GROOVE. FOR CORRECTIVE ACTION, SEE AB2259-010 ABOVE.

(AB7450-010) (1980) 1.25 INCH TITANIUM PERMASWAGE FITTING CRACKS. SPECIFIC CAUSE WAS NOT DETERMINED; REPLACE WITH STAINLESS STEEL FITTING ON AS REQUIRED BASIS. SMALLER FITTINGS HAVE NO EVIDENCE OF CRACKS. THERE WERE NINE DIFFERENT OCCURRENCES OF THIS FAILURE, AND ALL OF THEM WERE HANDLED UNDER THIS CAR NUMBER.

(AB8580-010) (1981) DURING ACCEPTANCE TESTING WHILE CONDUCTING THE PROOF PRESSURE TEST, LEAKAGE WAS NOTED AT THE HOSE ASSEMBLY AT 6,000 PSI. IT WAS FOUND THAT THE "O" RING GROOVE WAS INCORRECTLY DIMENSIONED CAUSING IMPROPER SEALING. ALL UNITS HAVE THE PROPER DIMENSIONED "O" RING GROOVE TO OBTAIN THE DESIRED "O" RING SQUEEZE.

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(AC1407-010) (1982) DURING DELTA QUALIFICATION TESTING WHILE CONDUCTING THE ENDURANCE TEST, THE HOSE ASSEMBLY EXHIBITED LEAKAGE NEAR THE SWIVEL ASSEMBLY COLLAR. THE CAUSE OF THE FAILURE WAS DETERMINED TO BE EXCESSIVE TORSIONAL LOADING OF THE HOSE DURING THE TEST DUE TO THE METHOD OF TEST AND FIXTURE DESIGN. THE HOSE WAS REPLACED AND THE TEST WAS SUCCESSFULLY COMPLETED.

(AC2610-010) (1983, OV103) DURING SUBSYSTEM CHECKOUT THE HOSE ASSEMBLY EXHIBITED LEAKAGE AT THE TVC ACTUATOR WHILE PRESSURIZED AT 2,500 PSIG THE FAILURE WAS CAUSED BY A WIRE BRAID STRAND THAT WAS INADVERTENTLY LEFT BETWEEN THE HOSE TEFLON LINER AND THE 90 DEGREE FITTING INSERT DURING SWAGING. THIS WAS AN ISOLATED CASE. ASSEMBLY OPERATORS WERE CAUTIONED TO CHECK THE CIRCUMFERENCE OF THE INSERTS AT A PARTIAL INTRODUCTION INTO THE TEFLON LINER TO ASSURE NO BRAID WIRES ARE TRAPPED.

(AD3558-010) (1987, OV103) DURING SUBSYSTEM CHECKOUT A PERMASWAGE TEE FITTING WAS FOUND LEAKING HYDRAULIC FLUID. THIS PROBLEM WAS SIMILAR TO AB7450 AND THE CORRECTIVE ACTION WAS TO REPLACE THE CRACKED FITTING WITH A STAINLESS STEEL FITTING.

(AD4326-010) (1988, OV-103) DURING SUBSYSTEM CHECKOUT A 1.25 PERMASWAGE TEE FITTING WAS FOUND LEAKING HYDRAULIC FLUID. THE CHARACTERISTICS OF THIS FAILURE WAS JUDGED TO BE THE SAME FAILURE MECHANISM AS EXPERIENCED PREVIOUSLY UNDER CAR AB7450. CORRECTIVE ACTION WAS TO REPLACE THE CRACKED FITTING WITH A STAINLESS STEEL FITTING. THERE WERE THREE OTHER CRACKED FITTINGS COVERED BY THIS CAR (REF. CARS AD4327, KB0290, KB1411).

(KB1314-010) (1990, OV-102) DURING SUBSYSTEM CHECKOUT A PERMASWAGE TEE FITTING WAS FOUND LEAKING HYDRAULIC FLUID (ALL PREVIOUS FAILURES HAVE OCCURRED ON TEE FITTINGS WHICH HAVE AT LEAST ONE 1 1/4 INCH DIAMETER STUB). THE CHARACTERISTICS OF THIS FAILURE WAS JUDGED TO BE THE SAME FAILURE MECHANISM AS EXPERIENCED PREVIOUSLY UNDER CAR AD4326. CORRECTIVE ACTION WAS TO REPLACE THE CRACKED FITTING WITH A SIMILAR TITANIUM FITTING. THERE WERE TWO OTHER CRACKED FITTINGS COVERED BY THIS CAR (REF. CARS KB0770, KB0847).

(AD9080-010) (1992, OV-102) DURING VEHICLE MAJOR MODIFICATION A PERMA- SWAGE UNION FITTING WAS FOUND LEAKING HYDRAULIC FLUID FINDINGS TO DATE INDICATE THE CHARACTERISTICS OF THIS FAILURE WAS JUDGED TO BE THE SAME FAILURE MECHANISM AS EXPERIENCED PREVIOUSLY UNDER CAR AD4326. THE INVESTIGATION IS CONTINUING.

(36RF11-010) (1990, OV-104) DURING MISSION STS-36 THE MAIN PUMP OUTLET FLEXHOSE EXHIBITED A LEAK. LEAKAGE WAS CAUSED BY A CRACK IN THE TEFLON INNER CORE WHICH IS SUSPECTED TO BE A RESULT OF A MANUFACTURING DEFECT WITH BUCKLING AND/OR PUMP RIPPLE CONTRIBUTING TO THE FAILURE SUPPLIER FABRICATION PROCESS CHANGES WERE IMPOSED TO IMPROVE QUALITY ASSURANCE. MINIMUM BEND RADIUS REQUIREMENTS WERE ALSO IMPOSED ON ALL HIGH AND MEDIUM PRESSURE HOSES.

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(E) OPERATIONAL USE:

LEAK DOWNSTREAM OF THE NWS SWITCHING VALVE - LEAK IS NOT DETECTABLE PRIOR TO LANDING GEAR DEPLOYMENT. SUFFICIENT TIME MAY NOT BE AVAILABLE FOR CREW ACTION FOLLOWING GEAR DEPLOYMENT. THE CREW MAY BE ABLE TO CONTROL VEHICLE DEROTATION RATE SUFFICIENTLY FOR A SAFE NOSEGEAR TOUCHDOWN AND ROLLOUT.

LEAK NOT DOWNSTREAM OF THE NWS VALVE - A RAPID LEAK WOULD DEplete THE HYDRAULIC SYSTEM BEFORE ACTION COULD BE TAKEN. ACTION MAY BE TAKEN BY THE CREW FOR SMALL LEAKS. THE ISOLATION VALVE MAY BE CLOSED FOR LEAK ISOLATION. THE HYDRAULIC MAIN PUMP MAY BE DEPRESSURIZED TO DECREASE THE LEAK RATE. TIMING OF THE ACTION WOULD BE DEPENDENT ON THE FLIGHT PHASE AND THE SYSTEM REQUIREMENTS.

- APPROVALS -

EDITORIALLY APPROVED
 TECHNICAL APPROVAL

: BNA
 : VIA APPROVAL FORM

: J. Kamura 7-30-98
 : 95-CIL-009_02-6