

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**NUMBER: 03-1-0407 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 1 08/07/00**PART DATA**

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	: 17" DISC VALVE ASSY, ORB LH2 BOEING	MC284-0389-1461
LRU	: 17" DISC VALVE ASSY, ET LH2 BOEING	MC284-0389-0602

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

DISCONNECT, LH2 FEED (WITH LATCH) 17 INCH, ORBITER & ET HALF.

VALVE WAS ORIGINALLY DESIGNED AND MANUFACTURED BY PARKER-HANNIFIN. BOEING IS A CERTIFIED ALTERNATE PRODUCTION AGENCY.

REFERENCE DESIGNATORS: PD2**QUANTITY OF LIKE ITEMS:** 1**FUNCTION:**

ET/ORBITER FEED LINE DISCONNECT PROVIDES LH2 PROPELLANT TO THE MPS AND A MEANS OF LOADING AND DETANKING THE ET. EACH DISCONNECT HALF CONTAINS A PNEUMATICALLY ACTUATED FLAPPER CLOSURE DEVICE WHICH REMAINS IN ITS LAST ACTUATED POSITION (BISTABLE). THE VALVES ARE CLOSED AFTER MECO TO PREVENT PROPULSIVE VENTING LEADING TO ET/ORBITER RECONTACT, TILE/DOOR DAMAGE DUE TO EXPOSURE TO PROPELLANTS, LOSS OF HELIUM SUPPLY DURING MANIFOLD REPRESSURIZATION, AND SYSTEM CONTAMINATION DURING ENTRY. DURING UMBILICAL SEPARATION, THE VALVE SYSTEM IS DESIGNED TO MECHANICALLY CLOSE BOTH THE ORBITER AND ET DISCONNECT FLAPPERS IF UNABLE TO CLOSE THEM PNEUMATICALLY (POST MECO). REDUNDANT OPEN AND CLOSE (TWO EACH) VALVE POSITION SWITCHES ARE LOCATED ON THE ORBITER HALF OF THE DISCONNECT. THE FLAPPER DRIVE MECHANISM IS DESIGNED TO ALLOW RELIEF OF PROPELLANTS TRAPPED BETWEEN THE FLAPPERS AFTER DISCONNECT CLOSURE.

A PNEUMATICALLY ACTUATED LATCH MECHANISM IS PROVIDED TO PREVENT THE VALVE FLAPPERS FROM CLOSING DURING FLOW CONDITIONS. THE LATCH IS BISTABLE AND IS CONTROLLED BY A SEPARATE PNEUMATIC ACTUATOR ASSEMBLY WITH REDUNDANT

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LOCK AND UPLOCK (TWO EACH) POSITION SWITCHES. LATCH MECHANISM INCORPORATES TOGGLE PIVOT WHICH ALLOWS FLAPPER CLOSURE DURING BACK UP MECHANICAL SEPARATION WITH LATCH IN LOCKED POSITION. SEE LATCH FMEA/CIL 03-1-0454 FOR ADDITIONAL INFORMATION.

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SUBSYSTEM NAME: MAIN PROPULSION

LRU: 17" LH2 FEEDLINE DISC ORB/ET (PD2)

ITEM NAME: 17" LH2 FEEDLINE DISC ORB/ET (PD2)

CRITICALITY OF THIS

FAILURE MODE: 1R3

FAILURE MODE:

LOSS OF POSITION INDICATION - OPEN POSITION INDICATION FAILS ON (LCC DECEPTION).

MISSION PHASE:

PL PRE-LAUNCH

LO LIFT-OFF

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102 COLUMBIA

103 DISCOVERY

104 ATLANTIS

105 ENDEAVOUR

CAUSE:

POSITION SWITCH PIECE PART FAILURE

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN

A) PASS

B) FAIL

C) PASS

PASS/FAIL RATIONALE:

A)

B)

FAILS B SCREEN SINCE FAILURE INDICATION CANNOT BE READILY DISTINGUISHED FROM EXPECTED OUTPUT DURING LCC PERIOD.

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

NO EFFECT. CAPABILITY OF VALVE TO CONTROL FLUID FLOW IS NOT AFFECTED.

LCC VERIFIES THAT ONE OF TWO OPEN POSITION SWITCHES ARE ON AT T-31 SECONDS.

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(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

FIRST FAILURE - NO EFFECT.

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

SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:

1R/3 4 SUCCESS PATHS. TIME FRAME - ENGINE OPERATION

- 1) LH2 17-INCH DISCONNECT OPEN POSITION SWITCH FAILS ON.
- 2) LATCH FAILS TO RESTRAIN FLAPPER.
- 3) OPEN SOLENOID POWER FAILS OFF. BISTABLE FEATURE MAINTAINS VALVE IN OPEN POSITION.
- 4) FAILURE OF DISCONNECT THAT WOULD BACK DRIVE POSITION INDICATORS THROUGH VALVE MECHANISM. ASSUMES MOVEMENT DOES NOT CAUSE FULL CLOSURE OF VALVE AND SUBSEQUENT CATASTROPHIC DAMAGE DUE TO WATER HAMMER.

VALVE POSITION LCC IS ERRONEOUSLY SATISFIED DUE TO FIRST FAILURE, EVEN IF REDUNDANT SWITCH FUNCTIONS PROPERLY (LCC REQUIRES ONE OF TWO OPEN POSITION SWITCHES INDICATING ON. COMPLETE CLOSURE OF VALVE IS DETECTABLE BY CLOSE SWITCHES INDICATING ON AND VIOLATING LCC). AT SSME START, INCREASED PROPELLANT FLOW CAUSES ABRUPT FLAPPER CLOSURE.

SURGE PRESSURE FROM VALVE CLOSURE MAY CAUSE DAMAGE OR RUPTURE TO THE MPS SYSTEM, DEPENDING ON THE RATE OF CLOSURE. RUPTURE OF MPS LINES WILL LEAK LH2 INTO THE AFT COMPARTMENT. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CRITICAL FUNCTIONS DUE TO ADJACENT COMPONENT EXPOSURE TO CRYOS. POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

A PNEUMATIC ACTUATOR MOUNTED ON THE ORBITER HALF OF THE DISCONNECT DRIVES THE ET FLAPPER THROUGH A ROLLER/CLEVIS LINKAGE. THIS ACTION IN TURN DRIVES A SECOND ROLLER/CLEVIS LINKAGE WHICH OPERATES THE ORBITER FLAPPER AND THE POSITION INDICATOR ASSEMBLY. THE POSITION INDICATOR SWITCH ASSEMBLY IS MOUNTED ON THE ORBITER HALF OF THE DISCONNECT AND IS ACTUATED BY MOTION OF THE ORBITER FLAPPER DRIVESHAFT.

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THE SWITCH ASSEMBLY CONSISTS OF FOUR SWITCHES (TWO FOR CLOSE, TWO FOR OPEN) FOR REDUNDANCY. EACH SWITCH HAS AN INDEPENDENT ELECTRICAL CIRCUIT. THEY ARE MECHANICALLY ACTIVATED MICROSWITCHES.

EACH SWITCH IS SCREENED AT CRYOGENIC TEMPERATURE BEFORE INSTALLATION TO VERIFY PERFORMANCE CHARACTERISTICS. NEWLY MANUFACTURED SWITCHES ARE SUBJECTED TO PARTICLE IMPACT NOISE DETECTION TEST (PIND). VEHICLE IMPLEMENTATION IS ON AN ATTRITION BASIS.

THE POSITION INDICATOR HOUSING ASSEMBLY IS OF 6061-T651 AL ALLOY, ANODIZED. THE DRIVESHAFT AND LINK ARE OF 304 CRES, PASSIVATED. THE SPRING (PROVIDING FORCE IN COMPRESSION TO HOLD CAM AGAINST CAM TRACK) IS OF 302 CRES, PASSIVATED. THE CAM WHICH PROVIDES FORCE TO ACTUATE SWITCH ASSEMBLIES IS OF VESPEL SP-21, AND THE CAM TRACK IS OF 6061-T651 AL ALLOY ANODIZED. MATING SURFACE FINISHES ARE 16 MICROINCHES.

(B) TEST:

ATP (ACTUATOR)

PROOF: AMBIENT, 1275 PSIG

OPERATIONAL (TWO CYCLES): AMBIENT; 400, 740, 780 PSIG

RESPONSE TIME (OPENING/CLOSING): ROOM AMBIENT/-300 DEG F
RESPONSE TIME AT 400, 700 AND 780 PSIG

LEAKAGE: EXTERNAL AND INTERNAL, AMBIENT AND CRYO

ATP - ET/ORBITER MATED DISCONNECT ASSEMBLY

FLAPPER ANGLE: ET 0.75 +/- 0.25 DEG, ORB 2.4 +/- 0.25 DEG

TIP LOAD: ET 55 LBF MINIMUM, ORB 40 LBF MINIMUM

POSITION SWITCH VERIFICATION: LATCH IN LOCKED POSITION. ROTATION FROM FLAPPER POSITION OF REST ON DOWNSTRIKE SURFACE TO FLAPPER POSITION WHERE OPEN INDICATOR LIGHT TURNS ON MUST BE 4 DEG, MINIMUM.

PROOF: AMBIENT, 1275 PSIG, ACTUATOR
286 PSIG FOR ORBITER CLOSURE DEVICE
58 PSIG FOR ET CLOSURE DEVICE

OPERATIONAL CYCLE: CRYO, -300 DEG F, ACTUATOR PRESSURE 740 PSIG FOR 8 CYCLES
AND 450 PSIG FOR 5 CYCLES
AMBIENT, HE AT 400 PSIG (1 CYCLE) AND 740 PSIG (5 CYCLES)

OPERATING TORQUE: ET LH2 SECTION, -410 DEG F FOR 3.5 HOURS MINIMUM, 150 FT-LBS MAX.

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CLEANLINESS VERIFICATION: MOISTURE FREE AND CLEANED TO LEVEL 400A OF MA 0110-301

LEAKAGE: EXTERNAL

VALVE: LN2/AMBIENT TEMPS: 50 SCIM OF GHE AT 10 PSIG, 50 SCIMS OF GHE AT 50 PSIG; LATCH SHAFT SEAL, 80 SCIM OF GHE.
LH2 TEMPS: 200 SCIM OF GH2 AT 50 PSIG; LATCH SHAFT SEAL, 80 SCIM OF GH2.

VALVE ACTUATOR:

CRYO (BODY TEMP AT -300 DEG F, ACTUATOR AT -200 TO 0 DEG F)/AMBIENT TEMPS; 100 SCIM OF GHE AT 740 PSIG

INTERNAL

VALVE: AMBIENT TEMPS: 1000 TO 2500 SCIM OF GHE AT 1 TO 60 PSIG LN2 TEMPS: 2500 SCIM OF GHE AT 60 PSIG

VALVE ACTUATOR:

CRYO (BODY TEMP AT -300 DEG F, ACTUATOR AT -200 TO 0 DEG F)/AMBIENT TEMPS: 100 SCIM OF GHE AT 740 PSIG

RELIEF OPERATION: -300 DEG F, CRACKING/RESEAT PRESSURE, 0.1-5 PSID (ET ONLY)

ELECTRICAL CHARACTERISTICS (INSULATION RESISTANCE AND VOLTAGE DROP), AND DIELECTRIC STRENGTH

FLOW LINER - ROUNDNESS VERIFICATION (FREE END EIGHT POINTS MEASUREMENT)

OPERATING TORQUE: ET LH2 SECTION SHALL BE MANUALLY ACTUATED (OPEN/CLOSED) AFTER BEING STABILIZED AT -410 DEG F. TORQUE SHALL NOT EXCEED 150 FT-LBF.

CERTIFICATION

COMPONENT QUALIFICATION (INCLUDES TESTING FROM PREVIOUS CONFIGURATION WITHOUT LATCH)

SALT FOG

VIBRATION - THREE AXES:

SINUSOIDAL: 5 TO 35 HZ AT 0.25 G, ZERO TO PEAK

RANDOM: 20 TO 2,000 HZ 5.7 G RMS FOR X-AXIS, 5.2 G RMS FOR Y AND Z-AXIS, NO FLOW (LN2), FLAPPERS OPEN, LATCH ENGAGED

THE DISCONNECT IS CHILLED WITH LN2 AND STABILIZED AT -300 DEG F. 10 PSIG DISCONNECT, 740 PSIG ACTUATOR. THESE CONDITIONS ARE MAINTAINED THROUGHOUT SINUSOIDAL AND RANDOM VIBRATION. ACTUATOR VENTED DURING LAST TWO MINUTES OF VIBRATION.

THERMAL CYCLE: -400 TO 150 DEG F, 3 CYCLES

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OPERATING LIFE: AMBIENT, 740 PSIG HE FOR A TOTAL OF 2,400 CYCLES FOR ORBITER AND 100 CYCLES FOR ET. THE RELIEF MECHANISM WAS CYCLED DURING ET VALVE CYCLING.

CRYO, 740 PSIG HE, -400 DEG F FOR A TOTAL OF 1000 CYCLES FOR ORBITER AND 50 CYCLES FOR THE ET. THE RELIEF MECHANISM WAS CYCLED DURING ET VALVE CYCLING.

ELECTRICAL CHARACTERISTICS (INSULATION RESISTANCE AND VOLTAGE DROP)

LEAKAGE: EXTERNAL AND INTERNAL, AMBIENT AND CRYO

ENGAGE - DISENGAGE: ENGAGE FORCE = 1000 LBF MAX,
DISENGAGE FORCE = 6000 LBF MAX

BURST TEST: PNEUMATIC ACTUATOR, 1700 PSIG HYDROSTATIC PRESSURE FOR 2 MINUTES

TYPE I AND TYPE II MATED (OPEN POSITION) 450 PSIG HYDROSTATIC PRESSURE FOR 2 MINUTES

TYPE I AND TYPE II DEMATED (CLOSED POSITION) 330 PSID TO TYPE I, 68 PSID TO TYPE II FOR 2 MINUTES

UMBILICAL SEPARATION TEST: (WITHOUT LATCH)

THE DISCONNECT WAS INSTALLED IN THE UMBILICAL ASSEMBLY DURING THE SEPARATION TEST PROGRAM. THE UMBILICAL ASSEMBLY WAS SUBJECTED TO RANDOM VIBRATION TESTS (4.4 HOURS PER AXIS) WHILE FILLED WITH LN2. THE DISCONNECT WAS ALSO SUBJECTED TO UMBILICAL RETRACT TESTS AT BOTH NOMINAL CONDITIONS AND SIMULATED HYDRAULIC RETRACT ACTUATOR FAILURES.

UMBILICAL SEPARATION TEST: (WITH LATCH)

FLAPPER PNEUMATICS/LATCH PNEUMATICS/PYROS/RETRACTOR HYDRAULICS

- (1) PNEUMATIC CLOSURE (NORMAL) - 4 CYCLES
- (2) MECHANICAL CLOSURE (BACKUP) - 5 CYCLES

BOTH PERFORMED AT AMBIENT, LN2 AND LH2 CONDITIONS.

FLOW LINER WATER FLOW TESTS: (LH2 VALVE QUALIFIED BY SIMILARITY TO LO2).

DESIGN FLOW TO 13,100 GPM
ALLOWABLE DELTA P IS 10 PSID AT THE LINER

TO DETERMINE THE STABILITY OF THE FLOW LINER. THE FLOW TUBE HAD NO PERMANENT DAMAGE AFTER BEING SUBJECTED TO WATER FLOWS UP TO 20,000 GPM (TEST TIME OF 2 MINUTES / 6 RUNS MINIMUM). AFTER VERIFYING PERFORMANCE AT 20,000 GPM, THE UNIT WAS SUBJECTED TO 22,700 GPM TO VERIFY DESIGN MARGIN (NO PERMANENT DAMAGE).

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FLAPPER ANGLE STABILITY MARGIN WATER FLOW TESTS:

ELEVEN (11) EXPLORATORY TEST SERIES (FLOW 4,000 TO 14,200 GPM)
E.T. FLAPPER SETTING VARYING FROM -3.9 TO 2.5 DEG.
ORB. FLAPPER SETTING VARYING FROM -0.9 TO 4.6 DEG.

CERTIFICATION TEST RUN AT WORST CASE PRODUCTION SETTING (FLOW RANGE TO 109%
POWER LEVEL).

PRODUCTION ANGLE SETTINGS

E.T. 0.75 +/- 0.25 DEG
ORB. 2.4 +/- 0.25 DEG

FLAPPER TIP LOAD MARGIN WATER FLOW TEST:

SEVEN (7) EXPLORATORY TEST SERIES (FLOW RANGE TO 109% POWER LEVEL)

FLOW 4,000 TO 13,100 GPM
ORBITER: 2.4 +/- 0.1 DEG
TIP LOAD RANGE: 22 TO 60 LBF

ET: 0.75 +/- 0.1 DEG
TIP LOAD RANGE: 20 TO 61 LBF

RECOMMENDED TIP LOAD:

ORBITER: 40 LBF MINIMUM
ET: 55 LBF MINIMUM

LATCH WATER FLOW TESTS:

ELEVEN (11) EXPLORATORY TEST SERIES (FLOW 4,000 TO 14,800 GPM)

CERTIFICATION TEST RUN AT NOMINAL PRODUCTION SETTING (FLOW RANGE TO 109%
POWER LEVEL).

TWO PROOF TESTS: 15,650 GPM AND 15,850 GPM

FILL FLOW DIRECTION: SIMILARITY TO LO2 FILL FLOW TESTS.

LATCH CRYO FLOW TESTS: (LH2 VALVE QUALIFIED BY SIMILARITY TO LO2)

SIXTEEN (16) TESTS WITH LN2/LO2 (FLOWS VARY FROM ONE ENGINE AT 65% TO THREE AT
109%).

GROUND TURNAROUND TEST

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

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(C) INSPECTION:

RECEIVING INSPECTION

RAW MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIAL AND PROCESS CERTIFICATION. ALL MACHINED ITEMS ARE DIMENSIONALLY INSPECTED AND VERIFIED (MIL-STD-105). CHEMICAL/MECHANICAL PROPERTIES AND RECORDS OF RECEIVED MATERIALS ARE RETAINED FOR VERIFICATION. BODY FORGING IS ULTRASONICALLY AND DYE PENETRANT INSPECTED.

CONTAMINATION CONTROL

CLEANLINESS LEVEL TO 400A VIA FREON FLUSH AND SAMPLE VERIFIED. ALL SEAL GROOVES ARE INSPECTED FOR CLEANLINESS AND EVIDENCE OF DAMAGE.

ASSEMBLY/INSTALLATION

THREADED INSERTS AND CRITICAL DIMENSIONS VERIFIED BY INSPECTION. SEALING SURFACES ARE VISUALLY INSPECTED FOR DEFECTS. REPAIRED AND REWORKED ITEMS ARE DIMENSIONALLY CHECKED. LOG OF CLEAN ROOM VERIFIED. ALL ENGINEERING-DEFINED FEATURES AND SURFACE FINISHES AND TORQUE REQUIREMENTS ARE COMPLETELY INSPECTED AND VERIFIED.

THE PRIMARY INTERFACE SEAL IS CHECKED FOR ID, OD AND ROUNDNESS. ALL DIMENSIONS DEFINED IN DRAWING ARE VERIFIED BY INSPECTION.

CRITICAL PROCESSES

HEAT TREATMENT AND PART PASSIVATION ARE VERIFIED BY INSPECTION.

NON-DESTRUCTIVE EVALUATION

PARTS ARE RADIOGRAPHICALLY AND DYE PENETRANT INSPECTED AS IMPOSED BY ENGINEERING IN THE DRAWING REQUIREMENTS.

TESTING

ATP AND TEST MEASUREMENT EQUIPMENT CALIBRATION VERIFIED BY INSPECTION.

HANDLING/PACKAGING

PACKAGING FOR SHIPMENT VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:

TWO FAILURES OCCURRED DURING ATP WHEREBY THE POSITION INDICATOR SWITCHES DID NOT RESPOND CORRECTLY (REFERENCE CAR'S A6420, A6421). THE ACTUATOR LINK WAS REDESIGNED AND THE ASSEMBLY INSTRUCTIONS WERE ALSO REVISED TO SHOW VERIFICATION THAT BOTH SWITCHES WERE FUNCTIONING PROPERLY.

THREE INCIDENTS OF SWITCH ADJUSTMENT PROBLEMS OCCURRED (CAR'S AB3630, AB4043, AB4493). THE ASSEMBLY PROCEDURE WAS REVISED TO ASSURE SPECIFIC OVER TRAVEL AND VERIFICATION OF CORRECT OPERATION BY A CRYOGENIC SUBASSEMBLY TEST.

AN INTERMITTENT OPERATING UNIT WAS REPORTED FROM NSTL (REFERENCE CAR AB6951). THE ASSEMBLY WAS NOT THE LATEST REVISION AND WAS REPLACED.

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A ONE TIME ANOMALY, WHEREBY A MICROSWITCH FAILED TO PICK UP A CLOSED INDICATION, OCCURRED ON OV103 AT KSC (REFERENCE CAR AC9680). THE FAILURE COULD NOT BE REPEATED.

CURRENT DATA ON TEST FAILURE, FLIGHT FAILURE, UNEXPLAINED ANOMALIES, AND OTHER FAILURES EXPERIENCED DURING GROUND PROCESSING ACTIVITY CAN BE FOUND IN THE PRACA DATABASE.

(E) OPERATIONAL USE:

FLIGHT:
NO CREW ACTION CAN BE TAKEN.

GROUND:
GROUND OPERATIONS SAFING PROCEDURES CONTAIN SAFING SEQUENCE OF EVENTS FOR MAJOR LEAKS IN THE HYDROGEN SYSTEM.

- APPROVALS -

S&R ENGINEERING	: W.P. MUSTY	: /S/ W. P. MUSTY
S&R ENGINEERING ITM	: P. A. STENGER-NGUYEN	: /S/ P. A. STENGER-NGUYEN
DESIGN ENGINEERING	: KOUROSH ANVARI	: /S/ FOR - LUIS RODRIGUEZ
MPS SUBSYSTEM MGR.	: TIM REITH	: /S/ TIM REITH
MOD	: BILL LANE	: /S/ BILL LANE
USA SAM	: MIKE SNYDER	: /S/ MIKE SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	: /S/ SUZANNE LITTLE
NASA SR&QA	: ERICH BASS	: /S/ ERICH BASS