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PRINT DATE: 04/02/90

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL HARDWARE

NUMBER: 03-1-0226-X

330

SUBSYSTEM NAME: MAIN PROPULSION

REVISION : 1 04/02/90

	PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
■ LRU :	VALVE, SOLENOID, NC 3W, TYPE 1	MC284-0404-0021
■	EG XG WRIGHT COMPONENTS	13110-4

PART DATA

■ EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
VALVE SOLENOID, NORMALLY CLOSED, 3 WAY 3/8 INCH. LO2 PREVALVE CONTROL.
CLOSING (LV13, 15, 17, 80, 81, 82).

■ QUANTITY OF LIKE ITEMS: 6
SIX
TWO PER PREVALVE

■ FUNCTION:
CONTROLS PNEUMATIC PRESSURE TO CLOSE THE LO2 PREVALVE. TWO SOLENOIDS
ARE PROVIDED IN PARALLEL (REDUNDANT) TO ASSURE CLOSING ACTUATION
PRESSURE TO THE LO2 PREVALVE AT MECO UNDER ZERO G CONDITION. ONLY ONE OF
THE SERIES OPENING SOLENOIDS (LV12,14,16,83,84,85) (REFERENCE FMEA/CIL
0225) MUST DEACTUATE TO ALLOW THE OPEN SIDE OF THE ACTUATOR TO VENT FOR
PREVALVE CLOSURE. BOTH CLOSING SOLENOIDS MUST DEACTUATE TO ALLOW
ACTUATOR TO VENT FOR PREVALVE OPENING.

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SUBSYSTEM: MAIN PROPULSION
LRU : VALVE, SOLENOID, NC 3W, TYPE 1
ITEM NAME: VALVE, SOLENOID, NC 3W, TYPE 1

CRITICALITY OF THIS
FAILURE MODE: 1R2

- FAILURE MODE:
FAILS TO ACTUATE (PREVALVE FAILS TO CLOSE, REFERENCE FMEA/CIL 0401-4).
FAILS TO PROVIDE VENT TO CLOSE PREVALVE AT MECO.

MISSION PHASE:
PL PRELAUNCH
LO LIFT-OFF

- VEHICLE/PAYLOAD/KIT EFFECTIVITY: 102 COLUMBIA
: 103 DISCOVERY
: 104 ATLANTIS

- CAUSE:
PIECE PART STRUCTURAL FAILURE, BINDING, ELECTRICAL SOLENOID FAILURE,
INLET FILTER CLOGGED.

- CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

- REDUNDANCY SCREEN A) PASS
B) FAIL
C) PASS

PASS/FAIL RATIONALE:

- A)
- B)
FAILS B SCREEN BECAUSE SOLENOID VALVES DO NOT HAVE POSITION INDICATORS
AND VALVES ARE PARALLEL.
- C)

- FAILURE EFFECTS -

- (A) SUBSYSTEM:
ONLY FAILURE OF BOTH SOLENOIDS TO ACTUATE WILL PREVENT THE PREVALVE
FROM CLOSING. SINGLE SOLENOID FAILURE HAS NO EFFECT ON VALVE CLOSURE
(PARALLEL VALVE WILL PRESSURIZE ACTUATOR). PREVALVE FAILING TO CLOSE

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RESULTS IN INABILITY TO MAINTAIN INJECTED HELIUM AND LO2 PRESSURE TO THE HPCTP TO PREVENT PUMP OVERSPEED AND CAVITATION AT MECO. RESULTS IN OXIDIZER RICH SHUTDOWN AND UNCONTAINED ENGINE DAMAGE. POSSIBLE AFT COMPARTMENT OVERPRESS AND FIRE/EXPLOSIVE HAZARD.

ALSO RESULTS IN LOSS OF GHE SUPPLY DURING MANIFOLD REPRESS CAUSING POSSIBLE LOSS OF AFT COMPARTMENT PURGE (RTLS/TAL ABORT CRITICAL).

- (B) INTERFACING SUBSYSTEM(S):
SAME AS (A).
- (C) MISSION:
POSSIBLE LOSS OF CREW/VEHICLE FOR FAILURE OF BOTH SOLENOIDS.
- (D) CREW, VEHICLE, AND ELEMENT(S):
POSSIBLE LOSS OF CREW/VEHICLE FOR FAILURE OF BOTH SOLENOIDS.
- (E) FUNCTIONAL CRITICALITY EFFECTS:
1R/3, 3 SUCCESS PATHS. TIME FRAME - PAD ABORT, ASCENT.
 - 1) PREMATURE ENGINE SHUTDOWN WITH UNCONTAINED ENGINE DAMAGE (ASSUMES ENGINE IS DAMAGED ONLY TO THE EXTENT THAT ISOLATION OF THE DAMAGE WILL SAVE THE SYSTEM).
 - 2,3) BOTH PREVALVE CLOSING SOLENOIDS (FOR THE AFFECTED SSME) FAIL TO ACTUATE.

LO2 PREVALVE FAILS TO ISOLATE A SHUTDOWN ENGINE WHICH HAS UNCONTAINED ENGINE DAMAGE. POSSIBLE AFT COMPARTMENT OVERPRESS AND FIRE/EXPLOSIVE HAZARD DUE TO LO2 LEAKAGE. POSSIBLE LOSS OF CREW/VEHICLE.

- DISPOSITION RATIONALE -

- (A) DESIGN:
VALVE IS DESIGNED FOR A PRESSURE FACTOR OF SAFETY OF 2.0 PROOF, 4.0 BURST. THE CLOSURE DEVICE IS A 430 CRES BALL ACTING UPON EITHER OF TWO VESPEL SEATS. THE VALVE FEATURES A BALANCED LOAD ON THE BALL BY APPLYING INLET PRESSURE (750 PSIG NOMINAL) DIRECTLY TO THE BALL AT THE INLET SEAT AND INDIRECTLY (VIA A BELLOWS) THROUGH THE VENT SEAT. THE BELLOWS IS ASSISTED BY A SPRING, THE FORCE OF WHICH INSURES THE BALL IS HELD SECURELY AGAINST THE INLET SEAT WHEN THE SOLENOID IS DEENERGIZED. UPON BEING ENERGIZED THE SOLENOID DEVELOPS THE FORCE TO OVERCOME THE SPRING LOAD AND SEATS THE BALL ONTO THE VENT SEAT TO ALLOW HELIUM FLOW. TOTAL POPPET MOVEMENT (STROKE) IS LESS THAN 0.040 INCH.

TO FAIL TO ACTUATE MEANS THE FORCE TO MOVE THE BALL TO THE VENT SEAT IS NOT DELIVERED TO THE BALL. THE VALVE PARTS INVOLVED ARE THE SOLENOID, THE SOLENOID PLUNGER, THE SOLENOID STOP, TWO PUSHRODS AND A SPRING.

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THE PUSHRODS ARE ALLIGNED IN SERIES, SEPARATED BY THE SPRING FOR CHATTER PREVENTION. THE PUSHRODS ARE MADE OF CRES AND CARRY ONLY AXIAL LOADS. IF THE RODS WERE TO FAIL STRUCTURALLY, THEY WOULD CONTINUE TO PERFORM THEIR FUNCTION BECAUSE THEY ARE TOTALLY CONTAINED IN THE STOP (THE ROD OD IS 0.125 INCH AND THE STOP ID IS 0.126 INCH). THE ROD, IN CONTACT WITH THE BALL, IS GUIDED BY THE SOLENOID STOP FOR OVER 28% OF ITS LENGTH. BECAUSE OF THE CLOSE TOLERANCES IN THE SOLENOID ASSEMBLY, BINDING DUE TO CONTAMINATION IS A DESIGN CONCERN. TO PRECLUDE BURRS, THE SOLENOID BORE IS HONED. TO PREVENT BINDING, THE PLUNGER IS COATED WITH A DRY-FILM LUBRICANT. THE STOP IS MADE OF A MUCH HARDER MATERIAL THAN EITHER OF THE PUSHRODS TO PREVENT GALLING, AND THE PUSHROD SPRING NOT ONLY CONTROLS CHATTER, BUT REDUCES THE POTENTIAL FOR FRETTING.

CLOGGING OF THE 20 MICRON NOMINAL, 40 MICRON ABSOLUTE, RATED INLET FILTER IS PROTECTED AGAINST BY THE USE OF MULTI-FILTERED HELIUM IN THE ORBITER PNEUMATICS SYSTEM. THE HELIUM IS FILTERED BY THE GROUND SYSTEM BEFORE PRESSURIZING THE VEHICLE PNEUMATICS BOTTLE. IT IS AGAIN FILTERED (25 MICRONS, ABSOLUTE) BEFORE IT ENTERS THE VALVE ACTUATION SYSTEM. ALSO, TO INCREASE THE INLET FILTER'S EFFECTIVE SURFACE AREA THE FILTER IS OF A PLEATED DESIGN.

THE SOLENOID STRUCTURE IS CONSTRUCTED OF CRES AND IS EB WELDED. THE COIL IS VACUUM IMPREGNATED (POTTED). THE UNIT IS PRESSURE AND LEAK TESTED AT MAJOR ASSEMBLY POINTS.

■ (B) TEST:
ATP

AMBIENT TEMPERATURE TESTS:

PROOF PRESSURE (1560 PSIG); EXTERNAL LEAKAGE (850 PSIG);
ELECTRICAL CHARACTERISTICS AND RESPONSE; INTERNAL LEAKAGE (740
PSIG, ENERGIZED AND DEENERGIZED).

REDUCED TEMPERATURE TESTS (-160 DEG F):

ELECTRICAL CHARACTERISTICS AND RESPONSE; INTERNAL LEAKAGE

ELECTRICAL BONDING TESTS

SOLENOID SUBASSEMBLY TESTS:

ELECTRICAL CHARACTERISTICS; ENCLOSURE LEAKAGE (ONE ATMOSPHERE).

CERTIFICATION

TWO UNITS -

PORT AND FITTING TORQUE

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SALT FOG EXPOSURE FOLLOWED BY ELECTRICAL AND LEAKAGE CHECKS

AMBIENT VIBRATION TESTS: TOTAL 13.1 HOURS BOTH AXES FOR TWO VIBRATION LEVELS PLUS TRANSIENT VIBRATION SWEEP - RUN WITH ONE SPECIMEN ENERGIZED AND ONE DEENERGIZED - FOLLOWED BY ELECTRICAL CHARACTERISTICS AND LEAKAGE CHECKS

HANDLING SHOCK TEST

ENERGIZED AND DEENERGIZED FLOW TESTS

FIFTY HOUR CONTINUOUS CURRENT TEST AT 130 DEG F

AMBIENT TEMPERATURE ENDURANCE (4500 CYCLES FOLLOWED BY ELECTRICAL AND LEAKAGE CHECKS); 130 DEG F ENDURANCE (500 CYCLES FOLLOWED BY ELECTRICAL AND LEAKAGE CHECKS); OPERATION CYCLES (REPEATED 20 TIMES); REPEAT OF AMBIENT TEMPERATURE ENDURANCE ; -160 DEG F ENDURANCE (500 CYCLES FOLLOWED BY ELECTRICAL AND LEAKAGE CHECKS)

DISASSEMBLY AND INSPECTION

BURST PRESSURE (3400 PSIG)

GROUND TURNAROUND TEST

V4IAB0.240, 250, 260 PV1, PV2, PV3 MDM COMMAND/COPPER PATH VERIFICATION (EVERY FLIGHT)

V4IBIO.010, 020, 030 PV1 E-1, PV2 E-2, PV3 E-3 LO2 PREVALVE RESPONSE TIME (EVERY FLIGHT)

OV4IBIO.230 ORBITER MPS VALVE RESPONSE (IN FLIGHT)

■ (C) INSPECTION:

RECEIVING INSPECTION

RAW MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIAL AND PROCESSES CERTIFICATION. BODY HOUSING BAR STOCK IS ULTRASONICALLY INSPECTED.

CONTAMINATION CONTROL

CLEANLINESS LEVEL VERIFIED TO 100A. CORROSION PROTECTION IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

ALL PARTS ARE PROTECTED FROM DAMAGE AND CONTAMINATION. MICROSCOPIC EXAMINATION OF ALL DETAIL PARTS IS MADE PRIOR TO ASSEMBLY. ALL SURFACES REQUIRING CORROSION PROTECTION ARE VERIFIED. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE. MECHANICAL SURFACE FINISH AT 125 RMS IS INSPECTED AND VERIFIED WITH A PROFILOMETER. SURFACE FINISHES SMOOTHER THAN 125 RMS ARE INSPECTED USING A COMPARATOR AT 10X MAGNIFICATION. ALL CRITICAL DIMENSIONS ARE

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VERIFIED BY INSPECTION.

CRITICAL PROCESS

HEAT TREATMENT AND PARTS PASSIVATION VERIFIED BY INSPECTION. POTTING OF SOLDER CUPS, ELECTRICAL WIRE STRIPPING, AND SOLDERING OF CONNECTORS ARE VERIFIED BY INSPECTION. DRY FILM LUBRICATION APPLIED TO THE PLUNGER IS VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

WELDS VISUALLY EXAMINED & VERIFIED BY X-RAY, DYE PENETRANT, AND EDDY CURRENT. THE SOLENOID ASSEMBLY IS SUBJECTED TO LEAKAGE VERIFICATION USING RADIOACTIVE TRACER TECHNIQUES. THE VALVE BODY, PRIOR TO FINAL MACHINING, IS SUBJECTED TO ETCH AND DYE PENETRANT INSPECTION. BELLOWS ASSEMBLY IS PROOF PRESSURE TESTED AND LEAK CHECKED.

TESTING

ATP VERIFIED BY INSPECTION.

HANDLING/PACKAGING

PACKAGING FOR SHIPMENT VERIFIED BY INSPECTION.

■ (D) FAILURE HISTORY:

A NUMBER OF ELECTRICAL CONNECTORS WERE BROKEN AT NSTL DUE TO EXCESSIVE PHYSICAL FORCE APPLIED TO THE CONNECTOR BY TECHNICIANS WORKING IN THE CONFINED AREA (CAR'S AB1813, AB1613, AND AB1208). CORRECTIVE ACTION RESULTED IN THE INSTALLATION OF PROTECTIVE COVERS TO PREVENT CONNECTOR DAMAGE IN HIGH TRAFFIC AREA. ALSO, CONNECTORS WERE WELDED TO THE VALVE BODY IN LIEU OF SOLDERING.

THE SOLENOID VALVE EXPERIENCED ERRATIC BUT ACCEPTABLE PERFORMANCE AT KSC DUE TO EXCESSIVE SLIDING FRICTION CAUSED BY BURRS, AND SHARP EDGES ON THE ARMATURE (CAR AC1181). THE CONTROLLED PNEUMATIC VALVE OPERATION WAS ACCEPTABLE. THE CORRECTIVE ACTION RESULTED IN THE REDESIGN OF THE VALVE TO ELIMINATE THE BURRS AND SHARP EDGES. INSPECTION WAS IMPROVED AND AN OMRSD REQUIREMENT FOR CURRENT SIGNATURE TRACE WAS IMPOSED.

DURING QUALIFICATION TESTING AT THE SUPPLIER (CAR AC3193), AND SUBSEQUENTLY AT KSC (CAR AC8975 AND AD0352), THE VALVES FAILED TO CYCLE (ACTUATE OR DEACTUATE) WHICH OCCASIONALLY PREVENTED PROPER OPERATION OF THE CONTROLLED PNEUMATIC VALVE. FAILURE INVESTIGATION DISCLOSED FRETTING ON THE PLUNGER AND IN THE BORE AREA. THIS GENERATED SMALL PARTICLES LEADING TO BINDING OF THE VALVES. THE FRETTING WAS THE RESULT OF A LACK OF REQUIRED LUBRICANT. THE CORRECTIVE ACTION WAS THE APPLICATION OF MICROSEAL (DRY FILM LUBRICANT) ON ALL NEW PARTS AND THE REPLACEMENT OF PLUNGERS WITH MICROSEAL WHEN VALVES WERE RETURNED TO THE SUPPLIER FOR REWORK.

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AN ELECTRICAL SHORT DUE TO INCORRECT ALIGNMENT OF SOLDER CUPS (PINS "A" AND "C") WAS DETECTED AT THE PALMDALE FACILITY (CAR AC2687). THE CORRECTIVE ACTION TAKEN WAS THE ADDITION OF HEAT SHRINK TUBING TO ISOLATE THE SOLDER CUPS AND THE ADDITION OF AN INSPECTION POINT AFTER POTTING.

FOUR SOLENOID VALVES FAILED TO ACTUATE PROPERLY DURING ATP. TWO FAILED TO ACTUATE DUE TO BINDING (CARS AC0737, AC0894) AND THE OTHER TWO FAILED DUE TO INCORRECT STROKE OF THE PLUNGER (CARS AC0739, AC1469). DETAIL PARTS WERE INCORRECTLY FABRICATED/ASSEMBLED. THESE VALVE DEFECTS WERE REPAIRED AND ARE ATP SCREENABLE.

AFTER THE ACTUATION SIGNAL WAS REMOVED, TWO VALVES AT NSTL VENTED CONTINUOUSLY (CAR A7662) DUE TO BINDING OF THE PLUNGER CAUSED BY BURRS AND GALLING. DETAIL PARTS WERE INCORRECTLY FABRICATED/ASSEMBLED. THESE VALVE DEFECTS WERE REPAIRED.

■ (E) OPERATIONAL USE:

FLIGHT: NO CREW ACTION CAN BE TAKEN.

GROUND: OMI S1003 SEQUENCE TITLED "EMERGENCY PROCEDURE FOR A MAJOR LEAK OR FIRE IN THE ORBITER MPS" CONTAINS SAFING SEQUENCE OF EVENTS FOR MAJOR LEAKS IN THE OXYGEN SYSTEM.

- APPROVALS -

RELIABILITY ENGINEERING:	K. ANVARI	:	<u>[Signature]</u> 5/22/90
DESIGN ENGINEERING	: H. P. BAFFORD	:	<u>[Signature]</u> 4-12-90
QUALITY ENGINEERING	: O. J. BUTTNER	:	<u>[Signature]</u> 5/19/90
NASA RELIABILITY	:	:	<u>[Signature]</u> 10/18/90
NASA SUBSYSTEM MANAGER	:	:	<u>[Signature]</u> 10/17/90
NASA QUALITY ASSURANCE	:	:	<u>[Signature]</u> 7/22/90