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## FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL HARDWARE

NUMBER: M4-1BG-LV015-X

SUBSYSTEM NAME: ELECTRICAL POWER GENERATION - CRYO, GENERIC

REVISION : 1 11/12/91

	PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
■ SRU :	SOLENOID VALVE, O2 GAS SUPPLY	MC284-0429-4100
■	EATON CONSOLIDATED CONTROLS	74405-4100

## PART DATA

- EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:  
SOLENOID VALVE, O2 GAS SUPPLY
- REFERENCE DESIGNATORS: 40V45LV015
- QUANTITY OF LIKE ITEMS: 1  
ONE PER VEHICLE
- FUNCTION:  
PROVIDES CAPABILITY TO SHUT OFF O2 GAS SUPPLY TO FCP'S DURING GROUND OPERATIONS.

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ITEM NAME: SOLENOID VALVE, O2 GAS SUPPLY  
CRITICALITY OF THIS FAILURE MODE: 1R3

■ FAILURE MODE:  
FAILS OPEN OR INTERNAL LEAKAGE

MISSION PHASE:

LO LIFT-OFF  
OO ON-ORBIT  
DO DE-ORBIT  
LS LANDING SAFING

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

■ CAUSE:  
MECHANICAL SHOCK, VIBRATION, CORROSION, PHYSICAL BINDING/JAMMING,  
CONTAMINATION, ELECTRICAL OPEN OR SHORT

■ CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

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

PASS/FAIL RATIONALE:

- A)
- B)  
REDUNDANCY SCREEN B - ISOLATION CAPABILITY AND/OR POSITION OF VALVE ARE NOT VERIFIABLE IN FLIGHT.
- C)

- FAILURE EFFECTS -

■ (A) SUBSYSTEM:  
NO EFFECT AFTER FIRST FAILURE. THE O2 GAS SUPPLY DISCONNECT PROVIDES A SECONDARY SEAL.

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- (B) INTERFACING SUBSYSTEM(S):  
SAME AS (A)
- (C) MISSION:  
SAME AS (A)
- (D) CREW, VEHICLE, AND ELEMENT(S):  
SAME AS (A)
- (E) FUNCTIONAL CRITICALITY EFFECTS:  
AN ADDITIONAL FAILURE OF THE GAS SUPPLY DISCONNECT, FAILING OPEN, MAY RESULT IN LOSS OF SYSTEM PRESSURE IF BOTH MANIFOLD ISOLATION VALVES FAIL TO CLOSE. LOSS OF SYSTEM PRESSURE RESULTS IN LOSS OF ALL THREE FUEL CELL POWERPLANTS (LOSS OF CREW/VEHICLE).

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- DISPOSITION RATIONALE -  
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- (A) DESIGN:  
VALVE IS MAGNETICALLY LATCHED. VALVE IS SPRING-LOADED CLOSED. 50 MICRON ABS FILTER AT THE INLET. VALVE CONTAINS NO SOFT GOODS IN CONTACT WITH THE FLUID. MOVING PARTS ARE GOLD PLATED TO REDUCE FRICTION. HOUSING IS CONSTRUCTED OF CRES 304 TO PREVENT CORROSION. ALL VALVE COMPONENTS ARE COMPATIBLE WITH WORKING FLUIDS. VALVE IS MOUNTED WITH BODY AXIS PERPENDICULAR TO VEHICLE X-AXIS TO MINIMIZE VIBRATION EFFECTS. VALVE IS DESIGNED TO CLOSE WITH A MINIMUM OF 18 VOLTS (NOMINAL ORBITER BUS VOLTAGE IS 28 VOLTS).
- (B) TEST:  
QUALIFICATION TEST VERIFIED NORMAL OPERATION DURING SHOCK (20 G) AND VIBRATION (0.1 G SQ/HZ MAXIMUM RANDOM, +/- 0.25 G PEAK SINUSOIDAL) AND THERMAL OPERATING LIFE TEST (TOTAL OF 3000 CYCLES FROM -284 TO +220 DEG F AT OPERATING PRESSURE).  
  
ACCEPTANCE TEST VERIFIES FUNCTIONAL OPERATION OF MAGNETIC LATCHES, NO EXCESSIVE INTERNAL OR EXTERNAL LEAKAGE AND THAT PRESSURE DROP IS WITHIN LIMITS. VALVE VERIFIED CLEANED TO LEVEL 200A BY PARTICLE COUNT AND NON-VOLATILE RESIDUE. VALVE IS FURTHER VERIFIED DURING PANEL MODULAR ASSEMBLY AND SUBSYSTEM CHECKOUT.  
  
OMRSD: VALVE OPERATION VERIFIED DURING TURNAROUND CHECKOUT AND DURING TERMINAL COUNT.
- (C) INSPECTION:  
RECEIVING INSPECTION  
MATERIAL AND PROCESS CERTIFICATION DOCUMENTS ARE REVIEWED FOR

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COMPLIANCE WITH PROGRAM REQUIREMENTS.

CONTAMINATION CONTROL

ALL DETAIL PARTS ARE CLEANED PER ROCKWELL APPROVED SUPPLIER PROCEDURES. ALL DETAIL PARTS AND SUBASSEMBLIES ARE VISUALLY INSPECTED FOR EVIDENCE OF CONTAMINATION AT 40X MAGNIFICATION. ALL CRES DETAILS ARE PASSIVATED TO PREVENT CORROSION. THE VALVE IS VERIFIED CLEANED TO LEVEL 200A.

ASSEMBLY/INSTALLATION

ALL DETAIL PARTS ARE INSPECTED UNDER 40X MAGNIFICATION FOR SURFACE FINISH BURRS AND DAMAGE. THREAD LUBRICATION, TORQUING AND LOCKWIRE IS VERIFIED BY QC. DOCUMENTATION IS REVIEWED TO VERIFY RECORDING OF SHIM AND GAP DIMENSIONS USED TO OBTAIN AND MEASURE ARMATURE STROKE.

CRITICAL PROCESSES

THE GOLD PLATING PROCESS IS WITNESSED AND THE PLATED ARMATURE IS VISUALLY INSPECTED UNDER MAGNIFICATION FOR PLATING DEFECTS. VALVE SEAT WELDS ARE LEAK CHECKED UNDER FULL PROOF PRESSURE AND VISUALLY INSPECTED UNDER 20X MAGNIFICATION. ELECTRON BEAM WELD PROCESS IS VERIFIED BY SECTIONING A SAMPLE VALVE SEAT TO DETERMINE WELD INTEGRITY (20X MAGNIFICATION INSPECTION).

TESTING

ALL SPRINGS ARE LOAD TESTED AT DETAIL LEVEL AND ARE LOT TRACEABLE. LATCH FORCES ARE CALIBRATED AND VERIFIED BY INSPECTION DURING FINAL ACCEPTANCE OF THE MAGNETIC LATCH. INTERNAL LEAKAGE IS VERIFIED LESS THAN 18 SCCM DURING VALVE ACCEPTANCE TESTING.

HANDLING/PACKAGING

HANDLING, PACKAGING, STORAGE AND SHIPPING PROVISIONS ARE VERIFIED BY INSPECTION.

• (D) FAILURE HISTORY:

CAR NO. A3634-010 DOWNEY, VALVE PANEL ATP  
 AN O2 BIDIRECTIONAL MANIFOLD SHUTOFF VALVE EXHIBITED INTERNAL LEAKAGE DURING DOWNEY O2 PANEL ACCEPTANCE TESTING. THE OUT OF SPECIFICATION LEAKAGE WAS ATTRIBUTED TO EXCESS POROSITY OF THE BALL (POPPET) MATERIAL. CORRECTIVE ACTION INCLUDED CORRECTION OF THE BALL'S MANUFACTURING PROCESSES TO ELIMINATE THE EXCESS POROSITY.

CAR NO. A9695-010 SUPPLIER, ATP

AN H2 BIDIRECTIONAL MANIFOLD SHUTOFF VALVE FAILED ITS INSULATION RESISTANCE TEST. AN ANALYSIS DETERMINED THE CAUSE TO BE BURNED LEADWIRES WHICH OCCURRED DURING WELDING OF THE UNIT'S CLOSEOUT PLUG. THE WIRES WERE IN CONTACT WITH THE VALVE'S OUTER COVER DURING THE WELDING PROCESS DUE TO THE LEADWIRES BEING EXCESSIVELY LONG. CORRECTIVE ACTION INCLUDED INCORPORATION OF AN INSPECTION STATION ON

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THE OPERATION ASSEMBLY SHEETS TO REQUIRE INSPECTION OF THE LEADWIRE LENGTH PRIOR TO INSTALLATION OF THE CONNECTOR.

CAR NO. AC7074-010 DOWNEY, VALVE PANEL ATP

AC7326-010 DOWNEY, VALVE PANEL ATP

AN H2 AND AN O2 BIDIRECTIONAL MANIFOLD SHUTOFF VALVE FAILED TO TRANSFER TO THE CLOSED POSITION DURING DOWNEY PANEL ACCEPTANCE TESTING.

INSPECTION REVEALED CORROSION AND FLAKING OF THE GOLD PLATING ON BOTH VALVES' ARMATURES. FAILURE OF THE VALVES TO TRANSFER WAS ATTRIBUTED TO THE PLATING PROBLEM. M&P EVALUATION INDICATED THE PLATING PROBLEM TO BE TYPICAL OF POOR PLATING PREPARATION TECHNIQUES. THE ARMATURE PLATING PROBLEM WAS ISOLATED TO TWO OF THREE PLATING MANUFACTURERS WITH PARTS PLATED BETWEEN 1981 AND 1983.

CORRECTIVE ACTION INCLUDED: THE RETURN OF ALL VALVES IDENTIFIED TO HAVE SUSPECT PLATING FOR ARMATURE INSPECTION AND REPLACEMENT AS REQUIRED, AND RETURN OF UNITS ALREADY INSTALLED WITHIN 5 YEARS OF ITS PLATING DATE. IN ADDITION, IMPROVED CONTROLS OVER PROCESSING AND INSPECTION OF ARMATURES AND VALVES AT THE VALVE MANUFACTURER WERE IMPOSED. SEE MCR 11065 FOR ADDITIONAL DETAIL.

CAR NO. A00900-010 DOWNEY, VALVE PANEL ATP

AN O2 BIDIRECTIONAL MANIFOLD SHUTOFF VALVE FAILED TO TRANSFER CLOSED AT THE REQUIRED INPUT VOLTAGE (18 VOLTS) DURING DOWNEY PANEL ACCEPTANCE TESTING. ONCE THE VALVE CLOSED AT A HIGHER THAN NORMAL INPUT VOLTAGE (23.2 VOLTS), THE VALVE OPERATED SATISFACTORILY WITH FURTHER CYCLING. INSPECTION WITHIN THE VALVE FAILED TO REVEAL ANY DISCREPANCIES.

THE PROBLEM WAS CLOSED WITH THE FOLLOWING RATIONALE: THIS IS THE FIRST REPORTED INSTANCE OF A BIDIRECTIONAL VALVE FAILING TO CLOSE WHOSE CAUSE COULD NOT BE IDENTIFIED. THERE HAS BEEN TWO OTHER BIDIRECTIONAL VALVE FAILURES WHICH FAILED TO CLOSE BUT THE CAUSE WAS ATTRIBUTED TO FLAKING OF THE ARMATURE'S GOLD PLATING. THE PLATING ON THE FAILED VALVE'S ARMATURE APPEARED SATISFACTORY. IN ADDITION, THE VEHICLE'S INPUT VOLTAGE IS ROUGHLY 28 VDC WHICH WOULD HAVE BEEN MORE THAN ADEQUATE TO CLOSE THE SUSPECT VALVE.

BIDIRECTIONAL SHUT OFF VALVES ARE USED ON THE O2 & H2 MANIFOLDS WHICH ARE LEFT OPEN THROUGHOUT A FLIGHT AND WOULD NOT BE CLOSED UNLESS REQUIRED DUE TO A SYSTEM FAILURE. THESE VALVES ARE ALSO USED FOR THE O2 & H2 GAS SUPPLY VALVES WHICH ARE VERIFIED TO BE CLOSED PRIOR TO LAUNCH.

CAR NO. A03199-010 SUPPLIER, RECEIVING INSPECTION

A03437-010 SUPPLIER, RECEIVING INSPECTION

A00925-010 KSC, OV-102, GROUND CHECK

TWO H2 BIDIRECTIONAL T-O SHUTOFF VALVES EXHIBITED EXCESSIVE INTERNAL LEAKAGE AT THE SUPPLIER. ONE VALVE HAD BEEN REMOVED FROM OV-104 AND ONE HAD BEEN REMOVED FROM OV-103, FOR INSPECTION OF THE GOLD PLATING ON THE VALVE'S ARMATURES. THE CAUSE OF LEAKAGE WAS IDENTIFIED IN BOTH CASES TO BE A RESULT OF RADIAL CRACKS ON THE VALVE SEATS. CRACKS WERE

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FOUND AT BOTH THE UPPER AND LOWER WELDS.  
AN H2 BIDIRECTIONAL MANIFOLD SHUTOFF VALVE EXHIBITED INTERNAL LEAKAGE DURING OV-102 SYSTEM CHECKOUT. LEAKAGE WAS VERIFIED AT ITS SUPPLIER AND INSPECTION REVEALED AN INDENTATION ON THE VALVE'S SEAT SEALING SURFACE. A LEAK CHECK OF THE SEAT ALSO REVEALED A CIRCUMFERENTIAL CRACK ALONG THE SEAT WELD. ANALYSIS IDENTIFIED RADIAL CRACKS AT THE BOTTOM WELD SIMILAR TO THE VALVES REPORTED ON CARS A03199-010 AND A03437-010.

SUCH LEAKAGES ARE OMRSD SCREENABLE EVERY TURNAROUND BY A MANIFOLD PRESSURE DECAY TEST (10 PSI/10 MIN REPRESENTING 18 SCCM ALLOWABLE LEAKAGE).

- (E) OPERATIONAL USE:  
NO CREW ACTION AFTER FIRST FAILURE. AFTER SECOND FAILURE CREW WILL ATTEMPT ISOLATION OF LEAK TO MANIFOLD 1 BY CLOSING ITS MANIFOLD VALVE.

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- APPROVALS -  
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RELIABILITY ENGINEERING:	M. D. WEST	:	<u>M. D. West</u> E.O.k.
DESIGN ENGINEERING	: M. M. SCHEIERN	:	<u>M. M. Scheiern</u>
QUALITY MANAGER	: O. J. BUTTNER	:	<u>O. J. Buttner</u>
NASA RELIABILITY	:	:	<u>Tom J. Stetler</u>
NASA SUBSYSTEM MANAGER	:	:	<u>Howard H. ...</u> 4/1/92
NASA QUALITY ASSURANCE	:	:	<u>Jeff Williams</u> 4/1/92