FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE
NUMBER: 03-1-0260 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 07/25/00

PART DATA

	PART NAME / **VENDOR NAME**	**PART NUMBER** / **VENDOR NUMBER**
LRU	: HIGH PRESSURE TWO WAY SOLENOID VALVE, NC TYPE 5	MC284-0403-0027
	UNITED SPACE ALLIANCE - NSLD	12238-3

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
TWO-WAY SOLENOID VALVE, NORMALLY CLOSED, PILOT OPERATED, INTERCONNECT "IN" VALVE.

VALVE WAS ORIGINALLY DESIGNED AND MANUFACTURED BY WRIGHT COMPONENTS (NOW PERKIN ELMER) BUT IS NOW MANUFACTURED BY UNITED SPACE ALLIANCE-NSLD AS AN ALTERNATE PRODUCTION AGENCY.

REFERENCE DESIGNATORS: LV59
LV61
LV63

QUANTITY OF LIKE ITEMS: 3
ONE PER ENGINE

FUNCTION:
PROVIDES CONTROL OF HELIUM INTO A PARTICULAR ENGINE PURGE SUPPLY FROM THE VALVE ACTUATION SYSTEM OR ANOTHER ENGINE PURGE SUPPLY. THE VALVE IS OPENED AT MECO (BEFORE THE ENGINES SHUTDOWN) TO ALLOW THE VALVE ACTUATION HELIUM SUPPLY TO SUPPLEMENT THE ENGINE HELIUM PURGE SUPPLY DURING THE POST SHUTDOWN PURGE IF THE PRESSURE IS LESS THAN 2000 PSIA.

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SUBSYSTEM NAME: MAIN PROPULSION
LRU: VALVE, SOLENOID, NC 2W TYPE 5 **CRITICALITY OF THIS**
ITEM NAME: SSME GHE SUPPLY I/C IN VALVE (LV59, 61, 63) **FAILURE MODE:** 1R2

FAILURE MODE:
FAILS TO OPEN/REMAIN OPEN

MISSION PHASE: LO LIFT-OFF

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

CAUSE:
FAILS TO REMAIN OPEN: PIECE PART STRUCTURAL FAILURE, ELECTRICAL SOLENOID FAILURE

FAILS TO OPEN: BINDING, PILOT VENT CHECK VALVE FAILS TO OPEN, PIECE PART STRUCTURAL FAILURE, ELECTRICAL SOLENOID 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 BECAUSE ENGINE 2 INTERCONNECT IN VALVE IS OPERATIONALLY REDUNDANT TO MPS PNEUMATIC SYSTEM FOR POST-MECO OPERATIONS (CASES 2 & 3). INTERCONNECT IN VALVES ARE STANBY REDUNDANT FOR LOSS OF ENGINE HELIUM SYSTEM DURING ENGINE OPERATION (CASE 1).

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

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LOSS OF SUPPLEMENTAL HELIUM TO ONE ENGINE THROUGH THE HELIUM INTERCONNECT SYSTEM.

(B) INTERFACING SUBSYSTEM(S):
NO EFFECT.

(C) MISSION:
NO EFFECT.

(D) CREW, VEHICLE, AND ELEMENT(S):
SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:
CASE 1:
1R/2 2 SUCCESS PATHS. TIME FRAME - MECO
1) ENGINE HELIUM SYSTEM LEAKS TO LESS THAN 1150 PSIA AT MECO.
2) INTERCONNECT "IN" VALVE FAILS TO OPEN/REMAIN OPEN.

RESULTS IN INTERRUPTION OF ENGINE HELIUM PURGE AND FAILURE TO MAINTAIN INJECTED HELIUM AND LO2 PRESSURE TO THE HIGH PRESSURE OXYGEN TURBOPUMP TO PREVENT PUMP OVERSPEED AND CAVITATION AT MECO. RESULTS IN UNCONTAINED ENGINE DAMAGE, AFT COMPARTMENT OVERPRESSURIZATION, AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:
1R/3 3 SUCCESS PATHS. TIME FRAME – RTLS/TAL ABORT
1) ENGINE 2 HELIUM SYSTEM LEAKS AND CAUSES ENGINE REDLINE SHUTDOWN AND RTLS/TAL ABORT.
2) MPS PNEUMATIC REGULATOR FAILS OFF.
3) ENGINE 2 INTERCONNECT “IN” VALVE (LV61) FAILS CLOSED.

RESULTS IN INABILITY TO PROVIDE AFT COMPARTMENT AND MANIFOLD PURGES DURING RE-ENTRY (RTLS AND TAL ABORT CRITICAL). POSSIBLE LOSS OF CREW/VEHICLE.

CASE 3:
1R/3 4 SUCCESS PATHS. TIME FRAME – POST MECO/DUMP
1) ENGINE 2 HELIUM SYSTEM LEAKS AND CAUSES LOSS OF ENGINE 2 HELIUM SUPPLY (ASSUMES LEAK IS SMALL ENOUGH TO ALLOW REACHING SAFE ORBIT)
2) MPS PNEUMATIC REGULATOR FAILS OFF.
3) ENGINE 2 INTERCONNECT “IN” VALVE (LV61) FAILS CLOSED.
4) LH2 MANIFOLD RELIEF VALVE (RV5) FAILS TO RELIEVE.

RESULTS IN LACK OF RELIEF CAPABILITY. POSSIBLE RUPTURE OF THE LH2 MANIFOLD CAUSING LH2 LEAKAGE INTO AFT COMPARTMENT, OVERPRESSURIZATION, AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYOGENIC EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

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-DISPOSITION RATIONALE-

(A) DESIGN:
THE VALVE IS A PILOT OPERATED SOLENOID VALVE CONTROLLING THE APPLICATION OF VALVE INLET PRESSURE TO THE POPPET. THE POPPET IS PART OF A RING ASSEMBLY (PISTON) THAT IS SPRING LOADED TO THE CLOSED POSITION. THE VALVE INLET PRESSURE IS ALWAYS EXERTING AN OPENING FORCE ON THE PISTON. WHEN THE SOLENOID IS DEENERGIZED, THE PILOT VALVE DIRECTS THE INLET PRESSURE TO THE CLOSING SIDE OF THE POPPET, UNBALANCING THE FORCE FROM THE INLET SIDE. THIS ALLOWS THE SPRING FORCE PLUS THE PRESSURE-AREA DIFFERENTIAL FORCE TO HOLD THE VALVE CLOSED. WHEN THE SOLENOID IS ENERGIZED, THE PILOT VALVE VENTS THE PRESSURE AT THE CLOSING SIDE OF THE PISTON TO AMBIENT. THIS ALLOWS THE INLET PRESSURE TO OVERCOME THE VALVE SPRING FORCE AND OPEN THE VALVE.

THE PILOT VALVE UTILIZES A 430 CRES BALL AS A CLOSURE DEVICE SEALING AGAINST EITHER OF TWO 17-4PH CRES SEATS. IN THE DEENERGIZED STATE, THE BALL IS HELD AGAINST THE CLOSING SEAT BY A SPRING ACTIVATED PUSHROD. WHEN ENERGIZED, THE SOLENOID FORCE OVERCOMES THE SPRING FORCE AND TRANSLATES THE PUSHROD AND BALL AND HOLDS THE BALL AGAINST THE OPENING SEAT. TOTAL BALL MOVEMENT (STROKE) IS LESS THAN 0.05 INCH.

FAILURE OF THE VALVE TO OPEN CAN BE CAUSED BY (1) BINDING OF THE VALVE PISTON OR INSUFFICIENT VENTED PRESSURE. INSUFFICIENT VENTING CAN BE CAUSED BY (2) SOLENOID FAILURE, (3) STRUCTURAL FAILURE OF THE PILOT BALL OR FORCE TRAIN CARRYING THE SOLENOID FORCE TO THE PILOT BALL, (4) BINDING OF THE SOLENOID PLUNGER, OR (6) FAILURE OF THE PILOT VENT CHECK VALVE TO OPEN.

FAILURE OF THE VALVE TO REMAIN OPEN REQUIRES APPLICATION OF SUFFICIENT PRESSURE TO THE CLOSING SIDE OF THE PISTON TO BALANCE THE OPENING PRESSURE ALLOWING THE MAIN SPRING TO CLOSE THE VALVE. THIS CAN BE CAUSED BY (2) SOLENOID FAILURE, (3) STRUCTURAL FAILURE OF THE PILOT BALL OR FORCE TRAIN CARRYING THE SOLENOID FORCE TO THE PILOT BALL, OR (5) FAILURE OF INTERNAL SEALS.

(1) BINDING BETWEEN THE PISTON ASSEMBLY AND THE VALVE BODY IS PRECLUDED BY MANUFACTURING THEM AS A "MATCHED SET." THE RING ASSEMBLY OD IS FINAL MACHINED TO BE 0.0001-0.0003 INCH LESS THAN THE BODY ID. THE BODY BORE IS POLISHED TO A 16 MICROINCH FINISH.

(2) THE SOLENOID COIL IS HOUSED IN AN EB WELDED AND LEAK-TESTED CRES ASSEMBLY. THE COIL UTILIZES HIGH TEMPERATURE WIRE WOUND ON A CORE. AN ELECTRICAL CONNECTOR IS WELDED ON THE HOUSING. HIGH TEMPERATURE WIRES BETWEEN THE CONNECTOR AND THE COIL ARE SILVER SOLDERED AT THEIR CONNECTIONS. THE COMPLETE ASSEMBLY IS IMPREGNATED WITH EPOXY UNDER VACUUM CONDITIONS. THIS TYPE OF SOLENOID CONSTRUCTION HAS BEEN SUCCESSFULLY USED ON MANY PROGRAMS AND HAS BEEN SUBJECTED TO OVER 10,000 LIFE AND THERMAL QUALIFICATION CYCLES.

(3) THE FORCE TRAIN CONSISTS OF THE SOLENOID PLUNGER, THE SOLENOID STOP, AND TWO PUSHRODS. THE PLUNGER AND STOP ARE MASSIVE BY COMPARISON TO THE PUSHRODS, AND ARE BOTH OF 430 CRES. THE 17-4PH CRES PUSHRODS ARE ALIGNED IN SERIES WITHIN THE STOP, AND CARRY ONLY AXIAL LOADS. IF THE ROD NEAREST THE SOLENOID WERE TO FAIL STRUCTURALLY, IT WOULD CONTINUE TO PERFORM ITS FUNCTION BECAUSE IT IS 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 PILOT BALL IS ALSO CONTAINED WITHIN AND GUIDED BY THE SOLENOID STOP FOR NEARLY 60% OF ITS LENGTH. WITHIN THE REMAINING 40%, THE ROD TAPERS TO A DIAMETER OF .030 INCH. THIS PORTION OF THE ROD PASSES THROUGH THE CLOSING SEAT (WHICH GUIDES IT) TO MAKE CONTACT WITH THE BALL. THIS ROD IS HEAT TREATED.

(4) BINDING OF THE 430 CRES SOLENOID PLUNGER WITHIN THE 304L SOLENOID SPOOL ASSEMBLY IS PRECLUDED BY A DRY FILM LUBRICANT APPLIED TO THE PLUNGER.

(5) THE HIGH PRESSURE AND VENTED PORTIONS OF THE VALVE ARE SEALED FROM ONE ANOTHER BY USE OF SOFT SILVER PLATED, INCONEL "V" SEALS.

(6) THE VENT CHECK VALVE, WHICH SCREWS INTO THE SOLENOID VALVE VENT PORT, IS OF SIMPLE DESIGN, CONTAINING ONLY 5 PARTS. CRACK AND RESEAT PRESSURES ARE 0.5 PSID AND THE UNIT IS DESIGNED FOR 10,000 CYCLES. HIGH INLET PRESSURE (710 PSIA NOMINAL) ACTING ON A LARGE POPPET (0.603 INCH DIAMETER) PRODUCES A FORCE IN EXCESS OF 400 POUNDS TO ASSURE CHECK VALVE OPENING. THE CHECK VALVE BODY AND POPPET ARE OF 2024-T6 ALUMINUM, AND TO PREVENT GALLING OR BINDING, HAVE BEEN HARD ANODIZED.

THE VENT PORT CHECK VALVE WAS REDESIGNED TO PREVENT THE POPPET FROM BEING EJECTED DUE TO SHEARING OF THE RETAINING NUT THREAD. A PIN WAS ADDED TO THE CHECK VALVE HOUSING, WHICH RETAINS THE POPPET WITHIN THE CHECK VALVE HOUSING. A NEW ALUMINUM NUT, WHICH PROVIDE A MINIMUM ENGAGEMENT OF THREE THREADS, WAS UTILIZED TO INCREASE RELIABILITY.

(B) TEST:
ATP

EXAMINATION OF PRODUCT

AMBIENT TEMPERATURE TESTS
PROOF PRESSURE (6750 PSIG)
EXTERNAL LEAKAGE (4500 PSIG)
INTERNAL LEAKAGE (4500 PSID, ENERGIZED AND DEENERGIZED)
CHECK VALVE LEAKAGE (15 PSID)
ELECTRICAL CHARACTERISTICS
VALVE RESPONSE TIMES (4500 PSIG)

REDUCED TEMPERATURE TESTS (-160 DEG F)
INTERNAL LEAKAGE (4500 PSID, ENERGIZED AND DEENERGIZED)
ELECTRICAL CHARACTERISTICS
VALVE RESPONSE TIMES (4500 PSIG)

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ELECTRICAL TESTS
ELECTRICAL BONDING
DIELECTRIC WITHSTANDING VOLTAGE
INSULATION RESISTANCE

SOLENOID SUBASSEMBLY
TESTS ELECTRICAL CHARACTERISTICS
ENCLOSURE LEAKAGE (1 ATMOSPHERE DIFFERENTIAL)

CERTIFICATION

VIBRATION

TRANSIENT: 5 TO 35 HZ

RANDOM (AMBIENT HELIUM):
INLET PRESSURE: 4500 PSIG
2.2 HRS ENERGIZED IN EACH OF 2 AXES
FLOWING 100 SCIMS
2.2 HRS DEENERGIZED IN EACH OF 2 AXES
OUTLET PORT LEAKAGE MONITORED

ELECTRICAL CHARACTERISTICS, VALVE RESPONSE, AND INTERNAL LEAKAGE TESTS
AFTER EACH AXIS

LIFE CYCLE TESTING (10,000 CYCLES)
(ALL TESTING WITH UNITS IN VACUUM ENVIRONMENT)

5000 CYCLES:
INLET PRESSURE: 4500 PSIG
TEMPERATURE: +130 DEG F SURROUNDING ENVIRONMENT

5000 CYCLES:
INLET PRESSURE: 4500 PSIG
TEMPERATURE: -160 DEG F SURROUNDING ENVIRONMENT

ELECTRICAL CHARACTERISTICS, VALVE RESPONSE, AND INTERNAL LEAKAGE TESTS
AFTER EACH 2500 CYCLES

FLOW TESTS

DIFFERENTIAL PRESSURE TEST
INLET PRESSURE: 950 PSIG
FLOW RATES: 0.14 TO 0.25 LBS/SEC
PRESSURE DROP NOT TO EXCEED 50 PSID

HIGH FLOW CLOSURE TEST
12 CYCLES:
INLET PRESSURE: 4500 PSIG
FLOW RATE: 1 LBS/SEC
CYCLE VALVE CLOSED AND VERIFY CLOSURE BY LEAKAGE TEST

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BURST TEST (18,000 PSIG)

PARTLY CERTIFIED BY SIMILARITY TO MC284-0403-0001

SHOCK:
BENCH HANDLING
DESIGN
SALT FOG
CONTINUOUS CURRENT TEST
THERMAL VACUUM AND ENDURANCE TEST

GROUND TURNAROUND TEST
ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

(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 IS VERIFIED TO 100A. CORROSION PROTECTION IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION
ALL DETAIL PARTS AND ASSEMBLIES ARE EXAMINED FOR BURRS, DAMAGE AND CORROSION (AT 10X MAGNIFICATION) AND INSPECTED FOR CORRECT DIMENSIONS PRIOR TO ASSEMBLY. CRITICAL SURFACE FINISHES ARE INSPECTED USING A COMPARATOR AT 10X MAGNIFICATION. OTHER SURFACE FINISHES ARE INSPECTED AND VERIFIED WITH A PROFILOMETER. TORQUES ARE VERIFIED TO BE IN ACCORDANCE WITH DRAWING REQUIREMENTS. BELLOWS ASSEMBLY IS PROOF PRESSURE TESTED AND LEAK CHECKED. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

CRITICAL PROCESS
THE FOLLOWING ARE VERIFIED BY INSPECTION:

WELDING
HEAT TREATMENT
PARTS PASSIVATION
POTTING OF SOLDER CUPS
ELECTRICAL WIRE STRIPPING
DRY FILM LUBRICATION
CHROME PLATING

NONDESTRUCTIVE EVALUATION
ALL WELDS ARE VISUALLY EXAMINED AND VERIFIED BY X-RAY OR DYE PENETRANT INSPECTIONS. THE SOLENOID ASSEMBLY IS SUBJECTED TO LEAKAGE VERIFICATION USING RADIOACTIVE TRACER TECHNIQUES. SOME VALVE BODIES WERE SUBJECTED TO 10X MAGNIFICATION INSPECTION ONLY. OTHER VALVE BODIES WERE SUBJECTED TO EDDY

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CURRENT INSPECTION, IN ADDITION TO 10X MAGNIFICATION. REFURBISHED VALVE BODIES ARE SUBJECTED TO 40X MAGNIFICATION INSPECTION.

TESTING
ATP VERIFIED BY INSPECTION.

HANDLING/PACKAGING
HANDLING, PACKAGING, STORAGE AND SHIPPING REQUIREMENTS ARE VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:
THE CURRENT CONFIGURATION USES WELDING INSTEAD OF SOLDERING FOR THE ELECTRICAL CONNECTOR-TO-COIL ASSEMBLY JOINT. IN ALL VEHICLES, SOLDERED SOLENOID VALVES HAVE BEEN REPLACED WITH WELDED VALVES. SOLDERED CONNECTOR JOINTS ON EARLIER CONFIGURATIONS HAVE FAILED DUE TO POOR SOLDERING TECHNIQUES OR BEING STEPPED ON AFTER BEING INSTALLED IN THE VEHICLE (REFERENCE CAR A5449, 01F030, AB1208).

DURING ATP, AT -160 DEG F A LEAK PAST THE MAIN POPPET SEALING AREA INTO THE PILOT VALVE CAVITY CAUSED THE PILOT NOT TO VENT SUFFICIENTLY. THE LEAK PREVENTED THE VALVE FROM ESTABLISHING AN ADEQUATE PRESSURE DIFFERENTIAL ACROSS THE MAIN POPPET PREVENTING IT FROM FULLY OPENING. CORRECTIVE ACTION REQUIRED THE REWORK OF ALL PRODUCTION HARDWARE, ADDING A TEFLON PISTON RING SEAL TO THE MAIN POPPET. THE REDESIGN WAS SUBJECTED TO A LIFE CYCLE TEST (REFERENCE CAR A4289).

DURING ATP RESPONSE TEST, THE VALVE FAILED TO OPEN. THE POPPET ASSEMBLY WAS SLIGHTLY OVERSIZED WHICH CAUSED THE POPPET TO BIND IN ITS BORE WHEN SUBJECTED TO COLD TEMPERATURE. THE FIT WAS CORRECTED AND THE VALVE WAS RESUBMITTED TO ATP. THE RESPONSIBLE PERSONNEL HAVE BEEN CAUTIONED. THIS CONDITION ATP SCREENABLE (REFERENCE CAR AB7128).

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:
NO CREW ACTION CAN BE TAKEN.

- 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	: DAVE NEARY	:/S/ DAVE NEARY
MPS SUBSYSTEM MGR.	: TIM REITH	:/S/ TIM REITH
MOD	: JEFF MUSLER	:/S/ JEFF MUSLER
USA SAM	: MIKE SNYDER	:/S/ MIKE SNYDER

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USA ORBITER ELEMENT	: SUZANNE LITTLE	:/S/ SUZANNE LITTLE
NASA SR&QA	: ERICH BASS	:/S/ ERICH BASS