FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE
NUMBER: 03-1-0262 -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 1	MC284-0403-0021
	UNITED SPACE ALLIANCE - NSLD	12199-5

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
TWO WAY, PILOTED SOLENOID VALVE, HELIUM SUPPLY INTERCONNECT "OUT", NORMALLY CLOSED, 0.375 INCH DIAMETER.

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: LV60
LV62
LV64

QUANTITY OF LIKE ITEMS: 3
ONE PER ENGINE HE SUPPLY

FUNCTION:
PROVIDES CONTROL OF THE FLOW PATH OF HELIUM FROM A PARTICULAR ENGINE HELIUM SUPPLY SYSTEM TO EITHER THE PNEUMATIC HELIUM SYSTEM OR ANOTHER ENGINE HELIUM SUPPLY SYSTEM. THE ENGINE 1 AND 3 VALVES ARE OPENED AT MECO PLUS 20 SECONDS TO ALLOW THEIR HELIUM SUPPLIES TO SUPPLEMENT THE PNEUMATIC AND ENGINE 2 HELIUM SUPPLIES DURING THE MPS DUMP SEQUENCES. THE SAME VALVES ARE ALSO OPENED DURING ENTRY TO SUPPLEMENT THE ENGINE 2 AND PNEUMATIC HELIUM SUPPLIES FOR MPS ENTRY REPRESSURIZATION AND AFT COMPARTMENT/OMS POD PURGE.

FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE

NUMBER: 03-1-0262-01

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SUBSYSTEM NAME: MAIN PROPULSION
LRU: VALVE SOLENOID, NC 2W **CRITICALITY OF THIS**
ITEM NAME: SSME GHE SUPPLY I/C OUT VALVE (LV60, 62, 64) **FAILURE MODE:** 1R3

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 DUE TO LACK OF POSITION INSTRUMENTATION. ENGINE SYSTEMS ARE AT LOWER PRESSURE THAN NOMINAL PNEUMATIC SUPPLY PRESSURE AND INTERCONNECT OUT CHECK VALVES WILL PRECLUDE VISIBILITY OF FAILED VALVE.

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

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RESULTS IN LOSS OF SUPPLEMENTAL HELIUM TO THE PNEUMATIC SYSTEM FROM ONE ENGINE.

(B) INTERFACING SUBSYSTEM(S):
SAME AS A.

(C) MISSION:
NO EFFECT.

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

(E) FUNCTIONAL CRITICALITY EFFECTS:
1R/3 4 SUCCESS PATHS. TIME FRAME - POST MECO.

1) ENGINE 2 HELIUM SYSTEM LEAK. CREW INTERCONNECTS PNEUMATIC HELIUM SUPPLY WHICH EXTENDS ENGINE OPERATION LONG ENOUGH TO AVOID AN ABORT. PNEUMATIC AND ENGINE 2 HELIUM SUPPLIES ARE EXHAUSTED AND ENGINE SHUTS DOWN SAFELY.
2,3) ENGINE 1 AND 3 INTERCONNECT OUT VALVES FAIL TO OPEN/REMAIN OPEN. PNEUMATIC ACTUATION PRESSURE IS NOT AVAILABLE TO SUPPORT MPS DUMP.
4) EITHER MANIFOLD RELIEF SYSTEM FAILS TO RELIEVE.

FAILURES RESULT IN LACK OF DUMP AND RELIEF CAPABILITY. POSSIBLE MANIFOLD RUPTURE CAUSING PROPELLANT LEAKAGE INTO AFT COMPARTMENT, OVERPRESSURIZATION, AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF ADJACENT CRITICAL FUNCTIONS DUE TO CRYOGENIC EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

-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 (9000 PSIG)
EXTERNAL LEAKAGE (4500 PSIG)
INTERNAL LEAKAGE (4500 PSID, ENERGIZED AND DEENERGIZED)
CHECK VALVE LEAKAGE (15 PSID)
ELECTRICAL CHARACTERISTICS
(PULL-IN/DROPOUT VOLTAGE, CURRENT SIGNATURE)
VALVE RESPONSE TIMES (4500 PSIG)

REDUCED TEMPERATURE TESTS (-160 DEG F):

INTERNAL LEAKAGE (4500 PSID, ENERGIZED AND DEENERGIZED)
ELECTRICAL CHARACTERISTICS (PULL-IN/DROPOUT VOLTAGE)
VALVE RESPONSE TIMES (4500 PSIG)

ELECTRICAL TESTS:

ELECTRICAL BONDING
DIELECTRIC WITHSTANDING VOLTAGE
INSULATION RESISTANCE

SOLENOID SUBASSEMBLY TESTS:

ELECTRICAL CHARACTERISTICS
ENCLOSURE LEAKAGE (1 ATMOSPHERE DIFFERENTIAL)

CERTIFICATION

SALT FOG TEST (1 UNIT)

PER MIL-STD-810
AMBIENT PERFORMANCE TEST

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ELECTRICAL CHARACTERISTIC
VALVE RESPONSE

SHOCK (1 UNIT)

PER MIL-STD-810
BENCH HANDLING
DESIGN

CONTINUOUS CURRENT TEST (2 UNITS)

50 HOURS WITH SOLENOID ENERGIZED
TEMPERATURE: +130 DEG F SURROUNDING ENVIRONMENT
INSULATION RESISTANCE TEST (+130 DEG F MAINTAINED)
INSULATION RESISTANCE TEST (AMBIENT TEMPERATURE)

VIBRATION (2 UNITS)

TRANSIENT: 5 TO 35 HZ

RANDOM (AMBIENT HELIUM):
INLET PRESSURE: 4500 PSIG
108 MINUTES FOR EACH OF 2 AXES
15 MINUTES ENERGIZED
15 MINUTES VALVE CYCLE (1 CYCLE/MINUTE)
78 MINUTES DEENERGIZED

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

THERMAL VACUUM AND ENDURANCE TEST (2 UNITS)

9000 CYCLES: 4500 PSIG, AMBIENT HELIUM
500 CYCLES: 4500 PSIG, +130 DEG F HELIUM
500 CYCLES: 4500 PSIG, -160 DEG F HELIUM

OPERATIONAL CYCLE TEST
3 CYCLES PERFORMED DURING EXPOSURE TO FOLLOWING CONDITIONS:
VALVE ENERGIZED/DEENERGIZED
INLET PRESSURE: 4000 TO 200 PSIG
TEMPERATURE: +130 TO +250 DEG F HELIUM
SURROUNDING TEMPERATURE: AMBIENT TO +275 DEG F
SURROUNDING ENVIRONMENT: AMBIENT TO VACUUM

ELECTRICAL CHARACTERISTICS AND INTERNAL LEAKAGE AFTER EACH SET OF CYCLES AT
APPROPRIATE TEMPERATURE CONDITIONS

FLOW TEST (1 UNIT)

DIFFERENTIAL PRESSURE TEST
INLET PRESSURE: 950 PSIG

FLOW RATES: 0.06 TO 0.10 LBS/SEC
PRESSURE DROP NOT TO EXCEED 50 PSID

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

BURST TEST (1 UNITS)
18,000 PSIG

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

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 (CAR A5449, 01F030, AB1208).

DURING ATP, AT -160 DEG F A LEAK PAST THE MAIN POPPET SEALING AREA INTO THE PILOT VALVE CAVITY CAUSING THE PILOT NOT TO VENT SUFFICIENTLY (REFERENCE CAR A4289). 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.

DURING ATP RESPONSE TEST, THE VALVE FAILED TO OPEN. THE POPPET ASSEMBLY WAS SLIGHTLY OVERSIZED CAUSING 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.

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