FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE
NUMBER: 03-1-0204 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 07/24/00

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:
VALVE, HIGH-PRESSURE, 2-WAY, PILOT OPERATED SOLENOID, ENGINE HELIUM SUPPLY ISOLATION, NORMALLY CLOSED (0.5 INCH DIA).

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:
LV1
LV2
LV3
LV4
LV5
LV6

QUANTITY OF LIKE ITEMS: 6
TWO PER ENGINE HE SUPPLY

FUNCTION:
ISOLATES ENGINE HELIUM SUPPLY FROM REMAINDER OF SYSTEM WHEN IN CLOSED POSITION. ALL VALVES ARE OPEN DURING PRELAUNCH AND LIFT-OFF AND AT MM303 THROUGH LANDING. THE VALVES ARE LOCATED ON PARALLEL REDUNDANT PANELS (A&B) TO ASSURE HELIUM FROM EACH MAIN ENGINE SUPPLY TO ITS PARTICULAR ENGINE INTERFACE.

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SUBSYSTEM NAME: MAIN PROPULSION
LRU: VALVE, SOLENOID, NC 2W TYPE 5 **CRITICALITY OF THIS**
ITEM NAME: SSME GHE SUPPLY ISO SOL VLV (LV1-6) **FAILURE MODE:** 1R2

FAILURE MODE:
FAILS TO REMAIN OPEN.

MISSION PHASE: PL PRE-LAUNCH
LO LIFT-OFF

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

CAUSE:
ELECTRICAL SOLENOID FAILURE, PIECE PART STRUCTURAL 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 INDICATION AND BECAUSE DOWNSTREAM CHECK VALVE WILL PREVENT REGULATOR OUTLET PRESSURE CHANGE.

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:
LOSS OF REDUNDANCY. REDUNDANT HELIUM SUPPLY LEG CAN PROVIDE ENGINE REQUIREMENTS.

(B) INTERFACING SUBSYSTEM(S):

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SAME AS A.

(C) MISSION:
NO EFFECT.

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

(E) FUNCTIONAL CRITICALITY EFFECTS:
1R/2 2 SUCCESS PATHS. TIME FRAME - PRELAUNCH/ASCENT.
1) ONE ISOLATION VALVE FAILS TO REMAIN OPEN.
2) LOSS OF HELIUM FROM REDUNDANT LEG.

RESULTS IN LOSS OF HELIUM SUPPLY TO THE AFFECTED ENGINE. INTERRUPTION OF FLOW TO HIGH PRESSURE OXIDIZER TURBOPUMP INTERMEDIATE SEAL MAY RESULT IN UNCONTAINED ENGINE FAILURE PRIOR TO SAFE REDLINE SHUTDOWN.

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 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 (1)

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STRUCTURAL FAILURE OF THE PILOT BALL OR FORCE TRAIN CARRYING THE SOLENOID FORCE TO THE PILOT BALL, (2) SOLENOID FAILURE, OR (3) FAILURE OF INTERNAL SEALS.

1) 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.

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

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

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CYCLE VALVE CLOSED AND VERIFY CLOSURE BY LEAKAGE TEST

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

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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).

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