FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE
NUMBER: 03-1-0436 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 07/27/00

PART DATA

	PART NAME / **VENDOR NAME**	**PART NUMBER** / **VENDOR NUMBER**
LRU	: VALVE, RELIEF UNITED SPACE ALLIANCE - NSLD	MC284-0501-0002 5760074-101

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
VALVE, RELIEF, 1 INCH, LH2 FEEDLINE MANIFOLD RELIEF.

REFERENCE DESIGNATORS: RV6

QUANTITY OF LIKE ITEMS: 1

FUNCTION:
RELIEVES PRESSURE BUILDUP FROM LH2 MANIFOLD. THE VALVE INLET IS ISOLATED FROM THE FEED SYSTEM UNTIL MECO BY THE UPSTREAM FEEDLINE RELIEF SHUTOFF VALVE (PV8). THE RELIEF VALVE INCORPORATES A SENSE PORT WHICH SENSES THE LH2 MANIFOLD PRESSURE VIA A SENSE LINE. THE CRACKING AND RESEAT PRESSURES ARE BETWEEN 40 & 55 PSIG.

FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE

NUMBER: 03-1-0436-01

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SUBSYSTEM NAME: MAIN PROPULSION
LRU: VALVE, RELIEF
ITEM NAME: LH2 FEEDLINE MANIFOLD RELIEF VALVE (RV6)

CRITICALITY OF THIS FAILURE MODE: 1R3

FAILURE MODE:
FAILS TO RELIEVE POST MECO, PRE DUMP.

MISSION PHASE: LO LIFT-OFF

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102 COLUMBIA
103 DISCOVERY
104 ATLANTIS
105 ENDEAVOUR

CAUSE:
BINDING, CONTAMINATION, PIECE PART STRUCTURAL FAILURE, CLOGGED PILOT SENSE PORT, CLOGGED PILOT REFERENCE PORT.

CRITICALITY 1/1 DURING INTACT ABORT ONLY? YES

RTLS RETURN TO LAUNCH SITE
TAL TRANS-ATLANTIC LANDING

REDUNDANCY SCREEN

A) PASS
B) N/A
C) PASS

PASS/FAIL RATIONALE:
A)

B)
RELIEF VALVE IS STANDBY REDUNDANT TO LH2 MANIFOLD OVERPRESSURIZATION.

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:
NO EFFECT FOR NOMINAL MISSION. LH2 MANIFOLD PRESSURE WILL NOT RISE TO RELIEVE PRESSURE BEFORE DUMP START.

ENOUGH RESIDUALS REMAIN IN THE LH2 MANIFOLD DURING AN RTLS/TAL ABORT TO CAUSE THE LH2 MANIFOLD PRESSURE TO RISE TO RELIEF PRESSURE. FAILURE RESULTS IN A LACK OF RELIEF CAPABILITY. POSSIBLE RUPTURE OF THE LH2 MANIFOLD CAUSING LH2 LEAKAGE INTO THE AFT COMPARTMENT, OVERPRESSURIZATION, AND FIRE/EXPLOSION

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL **FAILURE MODE NUMBER: 03-1-0436-01**

HAZARD. POSSIBLE LOSS OF ADJACENT CRITICAL COMPONENTS DUE TO CRYOGENIC EXPOSURE.

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

(C) MISSION:
NO EFFECT FOR NOMINAL MISSION. POSSIBLE LOSS OF CREW/VEHICLE DURING RTLS/TAL ABORT.

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

(E) FUNCTIONAL CRITICALITY EFFECTS:
CASE 1:
1R/3 3 SUCCESS PATHS. TIME FRAME – POST MECO THROUGH LH2 DUMP.
1) RELIEF VALVE (RV6) FAILS TO RELIEVE.
2) OUTBOARD FILL & DRAIN VALVE (PV11) FAILS TO OPEN/REMAIN OPEN.
3) EITHER ONE OF RTLS DUMP VALVES (PV17, 18) FAILS TO OPEN.

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.

CASE 2:
1R/3 3 SUCCESS PATHS. TIME FRAME - LH2 VACUUM INERT.
1) RELIEF VALVE (RV6) FAILS TO RELIEVE.
2) OUTBOARD FILL & DRAIN VALVE (PV11) FAILS TO OPEN/REMAIN OPEN.
3) EITHER ONE OF RTLS DUMP VALVES (PV17, 18) FAILS TO OPEN WHEN CREW COMMANDS OPEN WHEN ALERTED BY CAUTION AND WARNING.

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.

CASE 3:
1R/3 3 SUCCESS PATHS. TIME FRAME - POST MECO/PRE-DUMP.
1) RELIEF VALVE (RV6) FAILS TO RELIEVE.
2) ONE OF THE TWO RTLS DUMP VALVES (PV17, 18) FAILS TO OPEN/REMAIN OPEN.
3) LH2 MANIFOLD PRESSURE TRANSDUCER FAILS LOW PREVENTING OPENING OF OUTBOARD FILL & DRAIN VALVE (PV11) WHEN VEHICLE SOFTWARE WOULD OPEN THE VALVE AS LH2 MANIFOLD PRESSURE EXCEEDS 60 PSIG.

RESULTS IN A LACK OF RELIEF CAPABILITY PRIOR TO DUMP. POSSIBLE RUPTURE OF THE LH2 MANIFOLD CAUSING LH2 LEAKAGE INTO THE AFT COMPARTMENT,

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OVERPRESSURIZATION, AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF ADJACENT CRITICAL COMPONENTS DUE TO CRYOGENIC EXPOSURE.

POSSIBLE LOSS OF CREW/VEHICLE.

DESIGN CRITICALITY (PRIOR TO DOWNGRADE, DESCRIBED IN (F)): 1R2

(F) RATIONALE FOR CRITICALITY DOWNGRADE:
CREW WILL OPEN RTLS VALVES WHEN LH2 MANIFOLD PRESSURE EXCEEDS CAUTION AND WARNING LIMITS PER FLIGHT RULE A5.1.5-2.

-DISPOSITION RATIONALE-

(A) DESIGN:
VALVE

THE RELIEF VALVE CONSISTS OF TWO SECTIONS: A PRESSURE ACTUATED MAIN POPPET SECTION AND A PILOT SECTION WHICH SENSES MANIFOLD PRESSURE BY MEANS OF A SENSING LINE.

THE PILOT SECTION CONTROLS THE OPENING AND CLOSING OF THE MAIN POPPET BY ALLOWING THE MANIFOLD PRESSURE TO ENTER OR EXIT A CONTROL CHAMBER. WHEN THE MANIFOLD PRESSURE REACHES A PREDETERMINED PILOT SETTING, THE PILOT VENTS THE CHAMBER PRESSURE OVERBOARD ALLOWING THE PRESSURE DIFFERENTIAL ACROSS THE MAIN POPPET TO PUSH THE MAIN POPPET OPEN. ONCE THE MANIFOLD PRESSURE DROPS BELOW THE PILOT CONTROL SETTING, THE PILOT POPPET CLOSES, THE MANIFOLD PRESSURE ENTERS THE CONTROL CHAMBER, AND THE MAIN POPPET CLOSES.

STRUCTURAL FAILURE OF THE PILOT BELLOWS OR THE PILOT SPRING-SEAT COMPRESSION SPRING MAY CAUSE A FAILURE TO RELIEVE. THE PILOT BELLOWS SENSES/COMPARES FEEDLINE PRESSURE TO AMBIENT PRESSURE. RUPTURE OF THE PILOT BELLOWS WILL NOT ALLOW SUFFICIENT MOVEMENT OF THE PILOT POPPET CONTROL ASSEMBLY TO DUMP THE PILOT PRESSURE. THE PILOT SPRING-SEAT COMPRESSION SPRING PRELOADS THE SPRING-SEAT. FAILURE OF THE SPRING WILL NOT PROVIDE MOVEMENT OF THE PILOT SPRING SEAT WHICH RESULTS IN FAILURE TO DUMP PILOT PRESSURE.

THE PILOT BELLOWS ASSEMBLY CONSISTS OF A TWO-PLY BELLOWS, A FLANGE, AND A CAP; ALL OF INCONEL 625 AND PASSIVATED. THE SEAMS OF THE BELLOWS ARE FUSION WELDED (FULL PENETRATION). THE FLANGE AND CAP ARE FUSION WELDED TO THE BELLOWS. ALL WELDS ARE DYE PENETRANT INSPECTED. EACH BELLOWS ASSEMBLY IS PROOF TESTED AND LEAK CHECKED BEFORE BEING ELECTRON BEAM WELDED TO THE MIDDLE HOUSING ASSEMBLY. THE WELD IS DYE PENETRANT INSPECTED, PROOF PRESSURE TESTED, AND LEAK TESTED.

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THE PILOT SPRING-SEAT COMPRESSION SPRING IS 0.041 INCH DIAMETER ELGILOY WIRE AND HEAT TREATED.

TWO COMPONENTS MAY CAUSE A FAILURE TO RELIEVE DUE TO BINDING: THE MAIN POPPET ACTUATING ROD AND THE PILOT SPRING-SEAT. THE MAIN POPPET ACTUATING ROD TRANSFERS FORCE FROM THE MAIN BELLOWS TO THE MAIN POPPET. THE SPRING-SEAT PULLS THE PILOT POPPET COMPLETELY OPEN (WHICH DUMPS PILOT PRESSURE TO ALLOW FULL FLOW THROUGH THE VALVE) BY EQUALIZING THE PRESSURE WITHIN THE MAIN BELLOWS WITH THAT OF THE FEEDLINE, AS SENSED BY THE PILOT BELLOWS.

THE MAIN POPPET ACTUATING ROD PASSES THROUGH A HOLE IN THE THERMAL ISOLATOR. THE THERMAL ISOLATOR IS VESPEL SP-21. THE HOLE IS OVER SEVEN DIAMETERS IN LENGTH, PRECLUDING COCKING. THE ROD IS INCONEL 718 AND PASSIVATED. THE CENTER SECTION IS SMALLER IN DIAMETER THAN THE ENDS TO REDUCE CONTACT AREA, PRECLUDING BINDING DUE TO CONTAMINANT PARTICLES TRAPPED BETWEEN THE ROD AND ISOLATOR. THE CONTACT SURFACE HAS A 16 MICRO INCH FINISH WHICH MATES SMOOTHLY WITH THE THERMAL ISOLATOR.

THE SEAT-SPRING SLIDES SMOOTHLY AND FREELY WITHIN THE BORE OF THE RETAINER. THE RETAINER IS CRES (PH 13-8 MO), HEAT TREATED AND PASSIVATED. ITS BORE IS APPROXIMATELY ONE DIAMETER IN LENGTH AND HAS A 16 MICRO INCH SURFACE FINISH. THE SPRING-SEAT IS 304 CRES AND PASSIVATED. THE UPPER AND LOWER CIRCUMFERENTIAL CONTACT SURFACES ARE POLISHED TO A 16 MICRO INCH FINISH.

CONTAMINATION LODGED BETWEEN THE PILOT PUSH ROD AND THE PILOT HOUSING WILL PREVENT SUFFICIENT MOVEMENT OF THE PILOT PUSH ROD WHICH RESULTS IN FAILURE TO DUMP PILOT PRESSURE. CONTAMINATION MAY CLOG PILOT DUMP PASSAGES WHICH WILL PREVENT DUMP OF PILOT PRESSURE.

SYSTEM CONTAMINATION IS MINIMIZED DUE TO THE PRESENCE OF AN ET SCREEN, A GSE DEBRIS PLATE, AND A GSE FILTER.

STRUCTURAL ANALYSIS INDICATES POSITIVE MARGINS OF SAFETY FOR ALL CONDITIONS OF VALVE OPERATIONS.

(B) TEST:
ATP

VISUAL INSPECTION
STROKE VERIFICATION OF MAIN POPPET (0.225 +/- 0.002 INCH)

AMBIENT TEST

PROOF PRESS: VALVE BODY, 110 PSIG INLET & SENSE PORT, 300 PSIG OUTLET

INTERNAL LEAKAGE:
1 TO 35 PSIG GHE AT INLET AND SENSE PORT
10 SCIM MAX AT OUTLET PORT

EXTERNAL LEAKAGE: 55 PSIG GHE; 5 SCIM MAX

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CRACK/RESEAT: 40 TO 55 PSIG

REVERSE FLOW LEAKAGE:
10 PSID GHE OUTLET TO INLET
MAIN SEAT LEAKAGE 50 SCIM MAX
PILOT REVERSE LEAKAGE 1700 SCIM MAX.

CRYOGENIC TEST (GHE AT -300 DEG F):

CRACK/RESEAT: 40 TO 55 PSIG, VALVE BODY AMBIENT

EXTERNAL LEAKAGE: 55 PSIG, 10 SCIM MAX, VALVE BODY -100 DEG F

INTERNAL LEAKAGE: 35 PSIG, 10 SCIM MAX, VALVE BODY -100 DEG F

CERTIFICATION

LIFE TEST

CRYO - 4500 CYCLES OPEN AND CLOSED USING LN2, VALVE CHECKED FOR INTERNAL LEAKAGE AFTER EACH 500 CYCLES, VALVE CHECKED FOR CRYO INTERNAL LEAKAGE AFTER EACH 1500 CYCLES.

AMBIENT - 500 CYCLES, VALVE INTERNAL LEAK CHECK EACH 50 CYCLES.

CRYO STEADY STATE FLOW TEST

SENSES PORT PRESS AT 65 PSIG GHE AT -412 DEG F
FLOW RATE OF 272 GPM LH2 AT 23 PSID

CRYO RESPONSE TEST

1.5 SEC TO INDICATE STEADY FLOW AFTER CRACKING WITH LH2

CRYO FUNCTIONAL TEST USING LH2

CRACKED AT 51 PSIG; RESEAT AT 44 PSIG

RANDOM VIBRATION 13.3 HOURS IN EACH OF THE THREE AXES

FIRST 4 HOUR AND 26 MINUTE PERIOD
ENVIRONMENT: AMBIENT
SENSE PORT: 35 PSIG GHE AT -425 DEG F
MAIN INLET: AMBIENT

SECOND 4 HOUR AND 26 MINUTE PERIOD
ENVIRONMENT: AMBIENT TO +100 TO -100 TO AMBIENT
SENSE PORT: 35 PSIG GHE AT -425 DEG F
MAIN INLET: 35 PSIG GHE AT -425 DEG F

THIRD 4 HOUR AND 26 MINUTE PERIOD
ENVIRONMENT: AMBIENT
SENSE PORT: 35 PSIG GHE AT -425 DEG F
MAIN INLET: 35 PSIG LN2

CRACK/RESEAT AND INTERNAL LEAKAGE PERFORMED AT COMPLETION OF EACH AXIS OF VIBRATION.

BENCH HANDLING AND DESIGN SHOCK PER MIL-STD-810
FOLLOWED BY AMBIENT CRACK/RESEAT AND INTERNAL LEAKAGE TESTS.

THERMAL CYCLE TEST (3 CYCLES)

VALVE AT 70 DEG F; SHOCKED WITH -300 DEG F FLUID FOR 20 MINUTES MIN; VALVE ALLOWED TO WARM UP TO 70 DEG F; VALVE HEATED TO 275 DEG F FOR 15 MINUTES. DURING THE 15 MINUTES THE VALVE WAS TESTED FOR AMBIENT CRACK/RESEAT PRESSURE.

ELECTRICAL BONDING

BURST TEST
220 PSIG ON SENSE AND INLET PORTS, 600 PSIG ON OUTLET PORT

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 PROCESS CERTIFICATION. PART PROTECTION COATING AND PLATING REQUIREMENTS ARE VERIFIED BY INSPECTION.

CONTAMINATION CONTROL
CONTAMINATION CONTROL PROCESS AND CORROSION PROTECTION PROVISIONS ARE VERIFIED. CLEANLINESS TO LEVEL 400A (PROCUREMENT SPECIFICATION REQUIREMENT IS 400) VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION
ALL CRITICAL DIMENSIONS ARE VERIFIED BY INSPECTION. LOG OF CLEAN ROOM AND TOOL CALIBRATION IS VERIFIED BY INSPECTION. TORQUE PER DRAWING REQUIREMENTS AND SURFACE FINISH ARE VERIFIED BY INSPECTION. SURFACES REQUIRING CORROSION PROTECTION ARE VERIFIED BY INSPECTION. ALL SEALING SURFACES AND SEALS ARE VISUALLY EXAMINED BEFORE INSTALLATION USING 10X MAGNIFICATION. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE MANUFACTURING PROCEDURE.

CRITICAL PROCESSES
HEAT TREATMENT, WELDING, PARTS PASSIVATION, AND ANODIZING ARE VERIFIED. DRY FILM LUBRICANT APPLICATIONS ARE VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

ALL WELDS ARE VISUALLY EXAMINED AND VERIFIED BY DYE PENETRANT. IN ADDITION, BELLOWS WELDS (EXCLUDING END FITTING WELDS) ARE X-RAYED.

TESTING
ATP VERIFIED BY INSPECTION.

HANDLING/PACKAGING
PACKAGING FOR SHIPPING IS VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:
MPS SYSTEM CONTAMINATION HAS OCCURRED WHICH MAY LODGE ANYWHERE IN THE SYSTEM CAUSING THIS FAILURE MODE (REFERENCE THE FOLLOWING PARAGRAPHS).

CONTAMINATION FAILURES HAVE OCCURRED AT ALL PHASES OF MANUFACTURING AND PARTS REPLACEMENT. IN ALL CASES, STRICT ADHERENCE TO CLEANLINESS CONTROL PROCEDURES IS THE PRIMARY METHOD OF CONTAMINATION PREVENTION.

NUMEROUS LARGE PARTICLES OF BLACK RUBBER MATERIAL WERE FOUND DURING A POST FLIGHT EXAMINATION OF THE LH2 17 INCH DISCONNECT OF OV099 (FLIGHT 7, REFERENCE CAR AC9800). THE LO2 AND LH2 SYSTEMS OF ALL VEHICLES WERE EXAMINED. NO RUBBER WAS FOUND IN ANY OTHER VEHICLES. AFTER EXTENSIVE INVESTIGATION THE ORIGIN WAS NOT DETERMINED.

METAL SHAVINGS HAVE BEEN DISCOVERED IN LINES AND COMPONENTS, WHICH WAS MOST LIKELY GENERATED WHEN THEY WERE CUT OUT AND/OR REPLACED (REFERENCE CARS AC9868, A9654, AC2210, AB1706; DR AD2226). METHODS ARE BEING REVISED TO MINIMIZE PARTICLE GENERATION WHEN INSTALLING/REPLACING COMPONENTS, LINES, AND FITTINGS REQUIRING WELDED OR BRAZED JOINTS (PRODUCT QUALITY IMPROVEMENT COUNCIL). PERSONNEL HAVE BEEN CAUTIONED. PROCEDURES HAVE BEEN REVISED TO IMPROVE CLEANLINESS MAINTENANCE DURING COMPONENT BUILD UP AND REWORK (REFERENCE MCR 12512). SUPPLIER DOCUMENTS/PROCEDURES HAVE BEEN REVIEWED AND CLEANLINESS MAINTENANCE PROCEDURES HAVE BEEN IMPROVED.

A PIECE OF A BRAZING PREFORM LODGED IN A 2-WAY SOLENOID VALVE ON OV- 099 AT PALMDALE CAUSING A LEAKAGE FAILURE (REFERENCE CARS AC2111, AB2538). STEEL AND ALUMINUM PARTICLES CAUSED EXCESSIVE LEAKAGE ON THE 850 PSIG HELIUM RELIEF VALVE (REF CAR AC2229). FOR BOTH FAILURES CORRECTIVE ACTION WAS TO ADD SPECIAL PURGE PORTS TO THE MPS HELIUM PANEL ASSEMBLIES TO IMPROVE THE QUALITY OF FINAL CLOSEOUT BRAZES.

SEVERAL FOREIGN MATERIALS WERE INTRODUCED INTO THE MPS SYSTEM DURING MANUFACTURE AND PARTS REPLACEMENT. EXAMPLES ARE: GLASS CLOTH IN LINE TO PREVENT TRAVEL OF CHIPS DOWN LINE; POLYSTYRENE OBJECT TO HOLD VALVE POPPET OPEN WHILE PURGING; COTTON SWAB MATERIAL AND GLASS BEADS FROM CLEANING OPERATION; MISCELLANEOUS PLASTIC; FOAM; AND TAPE (REFERENCE CARS AB4751, AC2217, AC6768, AC9868, MPS3A0005, AC7912, AB0530). MATERIALS WERE REMOVED AND PERSONNEL WERE CAUTIONED. A HIGH FLOW DELTA P TEST AT PALMDALE WAS ADDED TO VERIFY THAT LINES WERE NOT PLUGGED. GRIT BLASTING (GLASS BEADS AND SAND USED TO CLEAN A LINE) IS NO LONGER PERFORMED. PROCEDURES HAVE BEEN REVISED TO IMPROVE CLEANLINESS MAINTENANCE DURING COMPONENT BUILD UP AND REWORK

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(REFERENCE MCR 12512). SUPPLIER DOCUMENTS/PROCEDURES HAVE BEEN REVIEWED AND CLEANLINESS MAINTENANCE PROCEDURES HAVE BEEN IMPROVED.

ONE PIECE OF WIRE WAS FOUND IN THE INTERNAL RELIEF VALVE OF THE LO2 PREVALVE ON OV103 (REFERENCE CAR AC9101). THE SOURCE OF THE CONTAMINATION WAS NEVER FOUND, BUT IT WAS BELIEVED TO BE FROM THE ET. OTHER CONTAMINATION HAS BEEN FOUND ON THE FEEDLINE SCREENS, SUCH AS AN UNIDENTIFIED ROUND OBJECT AND VARIOUS METALLIC PARTICLES (REFERENCE CARS AB0529 AND AB0530). SOURCE OF CONTAMINATION WAS UNDETERMINED. BORE SCOPE EXAMINATIONS ARE CONDUCTED ON ALL FEEDLINE SCREENS EVERY FIFTH FLIGHT TO VERIFY CLEANLINESS. CONTAMINATION WAS REMOVED WHEN POSSIBLE.

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:
LH2 MANIFOLD PRESSURE IS ON CAUTION AND WARNING. POST MECO/PRE DUMP: START MPS PROPELLANT DUMP AS SOON AS POSSIBLE. POST DUMP: OPEN THE LH2 FILL/DRAIN VALVES.

- 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	: CHARLES EBERHART	: /S/ CHARLES EBERHART
MPS SUBSYSTEM MGR.	: TIM REITH	: /S/ TIM REITH
MOD	: JEFF MUSLER	: /S/ JEFF MUSLER
USA SAM	: MICHAEL SNYDER	: /S/ MICHAEL SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	: /S/ SUZANNE LITTLE
NASA SR&QA	: ERICH BASS	: /S/ ERICH BASS