

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0304 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 11/07/00

PART DATA

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	: LH2 TOPPING VALVE, 2.0 INCH, NC, TYPE 1 VACCO INDUSTRIES	MC284-0395-0051 1397-513

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

LH2 TOPPING VALVE, 2 INCH, NORMALLY CLOSED, PNEUMATICALLY ACTUATED OPEN.

VALVE WAS ORIGINALLY DESIGNED AND MANUFACTURED BY VACCO INDUSTRIES (EATON). THE UNITED SPACE ALLIANCE-NSLD IS A CERTIFIED REPAIR DEPOT BUT HAS NOT YET BEEN CERTIFIED AS AN ALTERNATE PRODUCTION AGENCY.

REFERENCE DESIGNATORS: PV13

QUANTITY OF LIKE ITEMS: 1

FUNCTION:

PROVIDES CONTROL OF REPLENISH/TOPPING OF LH2 DURING COMPLETION OF PROPELLANT LOADING. OPENED AT THE START OF LH2 SLOW FILL. CLOSED FOR LH2 TANK PREPRESSURIZATION AND DRAINBACK OF LH2 FILL LINE. REMAINS CLOSED DURING ENGINE OPERATION. OPENED DURING DUMP/INERTING OPERATIONS.

FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE**NUMBER: 03-1-0304-03****REVISION#:** 2 11/07/00**SUBSYSTEM NAME:** MAIN PROPULSION**LRU:** LH2 TOPPING VALVE, PV13**ITEM NAME:** LH2 TOPPING VALVE, PV13**CRITICALITY OF THIS****FAILURE MODE:** 1R3**FAILURE MODE:**

ERRONEOUS INDICATION. VALVE OPEN, CLOSED POSITION INDICATION ON DURING REPLENISH TERMINATION.

MISSION PHASE: PL PRE-LAUNCH
LO LIFT-OFF

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102	COLUMBIA
103	DISCOVERY
104	ATLANTIS
105	ENDEAVOUR

CAUSE:

PIECE PART STRUCTURAL FAILURE OF VALVE, BINDING, CONTAMINATION

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN

- A) PASS
- B) FAIL
- C) PASS

PASS/FAIL RATIONALE:

A)

B)

FAILS B SCREEN SINCE A PARTIALLY OPEN VALVE MAY NOT DRAIN ENOUGH TO VIOLATE ET LCC PRESSURIZATION REQUIREMENTS. FOR A FULL OPEN VALVE LH2 DRAINING OVERBOARD THROUGH TOPPING VALVE WILL DRAIN ET LH2 TANK DURING TANK PRESSURIZATION. WILL VIOLATE LCC REQUIREMENTS ET PRE-PRESSURIZATION REQUIREMENTS (ET-04 & ET-05).

PIECE PART STRUCTURAL FAILURE MAY BE UNDETECTABLE BECAUSE POSITION SWITCHES ARE LOCATED IN THE ACTUATOR, NOT AT THE END OF THE VALVE DRIVE MECHANISM. LCC REQUIREMENT FOR TOPPING VALVE TO BE VERIFIED CLOSED (MPS-10) AT T-1:52 THRU T-31 SECONDS WOULD BE SATISFIED. VALVE POSITION INDICATOR HAS SUFFICIENT DEADBAND TO ALLOW A CLOSED INDICATION WHEN THE VALVE IS NOT FULLY CLOSED.

C)

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- FAILURE EFFECTS -

(A) SUBSYSTEM:

NO EFFECT, LH2 WILL FLOW FROM ET THROUGH FILL/DRAIN SYSTEM AND OUT TSM DURING THE TERMINAL COUNT DRAINBACK. THE ET ULLAGE PRESSURE LCC WILL BE VIOLATED DUE TO EXCESSIVE ULLAGE VOLUME.

(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

NO EFFECT, POSSIBLE LAUNCH SCRUB DUE TO VIOLATION OF ET ULLAGE PRESSURE LCC.

(D) CREW, VEHICLE, AND ELEMENT(S):

SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:

CASE 1:

1R/3 3 SUCCESS PATHS. TIME FRAME - ASCENT.

- 1) ERRONEOUS INDICATION TOPPING VALVE (PV13) - CLOSED POSITION INDICATOR ON, VALVE OPEN (PASSES VALVE LCC).
- 2) FILL AND DRAIN DISCONNECT (PD11) (GROUND HALF) FAILS TO REMAIN OPEN (ET ULLAGE PRESSURE LCC SATISFIED).
- 3) OUTBOARD FILL AND DRAIN VALVE (PV11) FAILS TO REMAIN CLOSED AFTER T-0.

LH2 WILL DUMP OVERBOARD (3200 LBM MAXIMUM) RESULTING IN LOSS OF PROPELLANT AND PREMATURE ENGINE SHUTDOWN. FIRE/EXPLOSION HAZARD BOTH INTERIOR (FILL AND DRAIN LINE) AND EXTERIOR TO THE VEHICLE. POSSIBLE VIOLATION OF ET MINIMUM STRUCTURAL REQUIREMENTS DUE TO REDUCED ULLAGE PRESSURE. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:

1R/3 3 SUCCESS PATHS. TIME FRAME - ASCENT.

- 1) ERRONEOUS INDICATION TOPPING VALVE (PV13) - CLOSED POSITION INDICATOR ON, VALVE OPEN (PASSES VALVE LCC).
- 2) FILL AND DRAIN DISCONNECT (PD11) (GROUND HALF) FAILS TO REMAIN OPEN (ET ULLAGE PRESSURE LCC SATISFIED).
- 3) FILL AND DRAIN LINE (FH6) RUPTURE/LEAKAGE.

LH2 WILL LEAK INTO THE AFT FUSELAGE CAUSING POSSIBLE AFT COMPARTMENT OVERPRESS AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

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-DISPOSITION RATIONALE-

(A) DESIGN:

THE VALVE ACTUATOR IS SPRING LOADED TO THE CLOSED POSITION. THE ACTUATOR PISTON DRIVES A SPRING LOADED RACK WHICH, IN TURN, DRIVES A PINION GEAR SHAFT WHICH ROTATES THE VALVE BALL CLOSURE DEVICE. THE SPRING IS MANUFACTURED FROM 0.177 INCH DIAMETER ELGILOY WIRE AND HAS A SPRING RATE OF 96 POUNDS PER INCH. IN THE INSTALLED POSITION, WITH THE ACTUATOR VENTED, THE SPRING EXERTS A FORCE OF 275 POUNDS. IF THE SPRING SHOULD BREAK WITH THE VALVE CLOSED, THE INTERNAL FRICTION OF THE ACTUATOR AND VALVE WOULD PREVENT THE VALVE FROM DRIFTING OUT OF THE CLOSED POSITION.

THE RACK AND PINION ARE OF INCONEL 718 AND THE PINION GEAR/SHAFT IS MACHINED FROM A SINGLE PIECE OF STOCK. PRESSURE LOADS ON THE VALVE BALL, FROM EITHER DIRECTION, ARE EVENLY DISTRIBUTED AND WOULD NOT TEND TO OPEN THE VALVE. STRUCTURAL ANALYSIS INDICATES POSITIVE MARGINS OF SAFETY FOR ALL CONDITIONS OF VALVE OPERATION; FRACTURE/FATIGUE ANALYSES SHOW THAT ALL CRITICAL PARTS ARE SATISFACTORY FOR FOUR TIMES EXPECTED LIFE.

VALVE CLOSE POSITION INDICATES PRIOR TO FULL TRAVEL OF VALVE BALL. VALVE BINDING (THAT OCCURS DURING FINAL CLOSURE MOTION) OR INTERNAL SYSTEM CONTAMINATION PREVENTING BALL MOVEMENT WILL RESULT IN AN ERRONEOUS INDICATION. SYSTEM CONTAMINATION IS MINIMIZED DUE TO THE PRESENCE OF AN ET SCREEN, A GSE DEBRIS PLATE, AND A GSE FILTER.

THE ACTUATOR AND VALVE BEARINGS ARE OF EITHER VESPEL OR FLUOROGOLD AND ARE DESIGNED SO THAT THEY WILL TURN WITHIN THEIR HOUSING IN THE EVENT OF SHAFT/BEARING SEIZURE/BINDING. TO PREVENT BINDING IN THE ACTUATOR, THE RACK IS GUIDED ON EACH END BY A FLUOROGOLD GUIDE RING. THE CHROME PLATED PISTON SLIDES THROUGH RETAINERS TREATED WITH A DRY FILM LUBRICANT.

FACTORS OF SAFETY FOR INTERNAL PRESSURE: PROOF - 1.5 BODY, 2.0 ACTUATOR;
BURST - 2.0 BODY, 4.0 ACTUATOR.

(B) TEST:

ATP

EXAMINATION OF PRODUCT

AMBIENT PROOF:

VALVE BODY - 195 PSIG, VALVE OPEN AND CLOSED
ACTUATOR - 1700 PSIG

VALVE RESPONSE TIMES - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):

VALVE: 55 PSIG
ACTUATOR: 500 AND 740 PSIG

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EXTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F): VALVE BODY: 130 PSIG ACTUATOR: 740 PSIG

INTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):
INLET-TO-OUTLET @ 55 PSIG
OUTLET-TO-INLET @ 40 PSIG
ACTUATOR: 740 PSIG

POSITION INDICATION: VERIFICATION OF OPERATION

ELECTRICAL CHARACTERISTICS - CONTACT RESISTANCE; INSULATION RESISTANCE; AND DIELECTRIC STRENGTH.

CERTIFICATION

LIFE -
CRYO - 500 CYCLES AT -400 DEG F
AMBIENT - 1500 CYCLES

RANDOM VIBRATION TESTS - IN ALL THREE AXES
13.3 HOURS IN EACH AXIS WHILE PRESSURIZED TO 35 PSIG AND AT -300 DEG F.

DESIGN SHOCK (ALL THREE AXES) - 18 SHOCKS OF 15G EACH, THREE IN EACH DIRECTION.

THERMAL CYCLE TESTS - PERFORMED THREE TIMES
70 DEG F TO -400 DEG F TO 70 DEG F TO 275 DEG F TO 150 DEG F

VALVE RESPONSE TIMES - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):
VALVE: 55 PSIG
ACTUATOR: 500 AND 740 PSIG

EXTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):
VALVE BODY: 130 PSIG
ACTUATOR: 740 PSIG

INTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):
INLET-TO-OUTLET @ 55 PSIG
OUTLET-TO-INLET @ 40 PSIG
ACTUATOR: 740 PSIG

ELECTRICAL CHARACTERISTICS - CONTACT RESISTANCE; INSULATION RESISTANCE; AND DIELECTRIC STRENGTH.

ELECTRICAL BONDING - LESS THAN 100 MILLIOHMS

BURST - 260 PSIG VALVE BODY, 3400 PSIG ACTUATOR

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

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(C) INSPECTION:

RECEIVING INSPECTION

RAW MATERIAL VERIFIED BY INSPECTION FOR MATERIAL AND PROCESS CERTIFICATION. TEST REPORTS REQUIRED ON CAST MATERIAL. COMPLETION OF HOT ISOSTATIC PRESSING (HIP) PROCESS IS VERIFIED. CAST HOUSING (ROUGH MACHINED) IS INSPECTED FOR POROSITY.

CONTAMINATION CONTROL

CONTAMINATION CONTROL PROCESS AND CORROSION PROTECTION PROVISIONS ARE VERIFIED. THE INTERNAL WETTED SURFACES ARE CLEANED TO LEVEL 400A AND VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

ALL DETAIL PARTS ARE INSPECTED FOR CRITICAL DIMENSIONS, SURFACE FINISH, BURRS, DAMAGE, AND CORROSION. CRITICAL POPPET AND SLEEVE SURFACES ARE LAPPED AND INSPECTED WITH 40X MAGNIFICATION. TORQUES ARE VERIFIED TO BE IN ACCORDANCE WITH DRAWING REQUIREMENTS. PRIOR TO INSTALLATION, SEALS ARE VISUALLY EXAMINED WITH 10X MAGNIFICATION FOR DAMAGE AND CLEANLINESS. ALL SPRINGS ARE LOT TRACEABLE AND LOAD TESTED AT THE PIECE PART LEVEL. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

CRITICAL PROCESSES

HEAT TREATMENT OF THE VALVE BALL AFTER MACHINING IS VERIFIED. PART PASSIVATION AND HARD ANODIZING ARE VERIFIED. CERTIFICATION OF WELDING, POTTING, AND SOLDERING IS VERIFIED. PAINTING (ON BODY), ELECTRICAL BONDING, AND DRY FILM LUBRICANT ARE VERIFIED BY INSPECTION. ALL CASTINGS ARE SUBJECTED TO A HIP PROCESS.

NONDESTRUCTIVE EVALUATION

PRIOR TO FINAL MACHINING, THE HOUSING IS X-RAYED, ETCH AND DYE PENETRANT INSPECTED, AND LEAK CHECKED AT PROOF PRESSURE. ALL WELDS ON THE ELECTRICAL CONNECTOR ARE DYE PENETRANT INSPECTED AND VERIFIED BY INSPECTION.

TESTING

ATP VERIFIED BY INSPECTION.

PACKAGING/HANDLING

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

(D) FAILURE HISTORY:

THERE HAVE BEEN NO ACCEPTANCE TEST, QUALIFICATION TEST, FIELD OR FLIGHT ERRONEOUS INDICATION FAILURES.

A FAILURE OF THE VALVE TO CLOSE OCCURRED DURING QUALIFICATION TESTING (REFERENCE CAR AC1189). THE CAUSE WAS INTERFERENCE DUE TO THE OVERSIZED DIAMETER OF THE PISTON GUIDE RING GROOVE. THE DESIGN WAS CHANGED (THE GROOVE DIAMETER WAS REDUCED) TO ELIMINATE THE PROBLEM.

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A FAILURE AT NSTL OF A VALVE TO ACTUATE WAS CAUSED BY BINDING OF THE ALUMINUM BRONZE BUSHING TO THE SHAFT. AN MCR AUTHORIZED DRAWING CHANGES TO TEFLON COAT AND POLISH THE SHAFT (REFERENCE CAR A7950).

GENERAL SYSTEM CONTAMINATION

GENERAL 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 HAVE BEEN 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. ROCKWELL PROBLEM ACTION CENTER MONITORS BRAZING/WELDING REWORK CONTAMINATION. 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 (REFERENCE MCR 12512). SUPPLIER DOCUMENTS/PROCEDURES HAVE BEEN REVIEWED AND CLEANLINESS MAINTENANCE PROCEDURES HAVE BEEN IMPROVED.

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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. BORESCOPE 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:

GROUND: VIOLATION OF THE ET PRESSURIZATION PERFORMANCE WILL RESULT IN A LAUNCH SCRUB.

FLIGHT: WHEN THE ULLAGE PRESSURE DROPS BELOW 28 PSI, THE CREW WILL OPEN THE LH2 FLOW CONTROL VALVE WITH THE COCKPIT SWITCH. WHEN THIS IS INEFFECTIVE AND THE NPSP DROPS BELOW A PREFLIGHT ACCEPTED VALUE, THE CREW WILL ABORT TO TAL OR ACLS.

- APPROVALS -

S&R ENGINEERING	: W.P. MUSTY	: /S/ W. P. MUSTY
S&R ENGINEERING ITM	: P. A. STENGER-NGUYEN	: /S/ P. A. STENGR-NGUYEN
DESIGN ENGINEERING	: EARL HIRAKAWA	: /S/ EARL HIRAKAWA
MPS SUBSYSTEM MGR.	: TIM REITH	: /S/ TIM REITH
MOD	: BILL LANE	: /S/ BILL LANE
USA SAM	: MIKE SNYDER	: /S/ MIKE SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	: /S/ SUZANNE LITTLE
NASA SR&QA	: ERICH BASS	: /S/ ERICH BASS