

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: 03-1-0304-06****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:**

LOSS OF POSITION INDICATION - CLOSED POSITION INDICATION FAILS ON (LCC DECEPTION)

MISSION PHASE: PL PRE-LAUNCH
LO LIFT-OFF

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102	COLUMBIA
103	DISCOVERY
104	ATLANTIS
105	ENDEAVOUR

CAUSE:

POSITION SWITCH PIECE PART 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 SINCE FAILURE INDICATION CANNOT BE READILY DISTINGUISHED FROM EXPECTED OUTPUT DURING LCC PERIOD.

C)

- FAILURE EFFECTS -**(A) SUBSYSTEM:**

NO EFFECT. CAPABILITY OF VALVE TO CONTROL FLUID FLOW IS NOT AFFECTED.

LCC VERIFIES THAT CLOSED POSITION SWITCH IS OFF PRIOR TO T-5 MINUTES. VALVE IS CYCLED CLOSED AT T-1:57. LCC THEN VERIFIES THAT CLOSED POSITION SWITCH IS ON

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0304-06**

FROM T-1:52 THROUGH T-31 SECONDS. MANUAL CALLS FOR SWITCH VIOLATION WILL RESULT IN A HOLD AT T-31 SECONDS.

(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

FIRST FAILURE - NO EFFECT.

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

FIRST FAILURE - NO EFFECT.

(E) FUNCTIONAL CRITICALITY EFFECTS:

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

- 1) TOPPING VALVE (PV13) CLOSED POSITION SWITCH FAILS ON (MUST FAIL CLOSE ENOUGH TO VALVE CYCLE AT T-1:57 TO BE INDISTINGUISHABLE FROM EXPECTED STATE FROM VALVE CYCLE) .
- 2) TOPPING VALVE FAILS TO CLOSE/REMAIN CLOSED. LCC IS ERRONEOUSLY SATISFIED DUE TO FIRST FAILURE.
- 3) LH2 OUTBOARD FILL/DRAIN VALVE (PV11) HAS ERRONEOUS INDICATION (VALVE OPEN, CLOSED POSITION SWITCH ON) DURING TERMINAL COUNT OR FAILS TO REMAIN CLOSED DURING ASCENT.

FAILURES RESULT IN LOSS OF LH2 DURING TSM DRAIN AFTER TERMINATION OF REPLENISH. IF LEAKAGE RATE IS EXCESSIVE, MAY RESULT IN A VIOLATION OF ET PRE-PRESSURIZATION LCC.

IF THE PREPRESS LCC IS NOT VIOLATED, LH2 WILL BE LOST OVERBOARD WHEN THE T-0 UMBILICAL SEPARATES, POSSIBLY RESULTING IN A PREMATURE MECO WITHOUT INTACT ABORT CAPABILITY. FIRE/EXPLOSIVE HAZARD EXTERNAL TO THE VEHICLE. POSSIBLE VIOLATION OF ET MINIMUM STRUCTURAL REQUIREMENTS DUE TO REDUCED ULLAGE PRESSURE.

POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

TWO VALVE POSITION INDICATION MICROSWITCHES ARE PROVIDED TO MONITOR VALVE OPEN AND CLOSED POSITIONS. THE HERMETICALLY SEALED, CAM OPERATED MECHANICAL MICROSWITCHES ARE MOUNTED AND SECURED TO PLATES WITH TWO SCREWS. RTV IS USED IN THE SCREW HOLES AND BETWEEN THE SWITCH HOUSING AND MOUNTING PLATE TO MINIMIZE SHIFTING DUE TO TEMPERATURE CHANGES. TWO

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0304-06**

SEPARATE TRIP LEVERS ON THE PLATES RIDE ON A CAM CONNECTED TO THE VALVE CLOSURE DEVICE SHAFT. THESE TRIP LEVERS ACTUATE THE MICROSWITCH EXTERNAL SPRING ARMS WHICH IN TURN ACTUATE THE SWITCH INTERNAL ELECTRICALLY CONDUCTING METALLIC SPRINGS WITH ELECTRICAL CONTACTS. THESE SPRINGS ARE ATTACHED TO TERMINAL POSTS WHICH ARE EXTERNALLY SOLDERED TO LEAD WIRES.

EACH SWITCH IS SCREENED AT CRYOGENIC TEMPERATURE BEFORE INSTALLATION TO VERIFY PERFORMANCE CHARACTERISTICS. ACTUATING ARM MOVEMENT BETWEEN THE ACTUATED AND DEACTUATED POSITIONS IS VERIFIED TO BE 0.005 INCH MINIMUM.

(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

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

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0304-06**

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.

(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

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0304-06**

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:

SEVERAL POSITION INDICATION FAILURES AT MPTA EARLY IN THE PROGRAM WERE ATTRIBUTED TO FASTER VALVE OPERATION IN THE FIELD THAN ORIGINALLY TESTED FOR IN DEVELOPMENT, QUAL, AND ATP. THE FAST OPERATION RESULTED IN SHOCK DAMAGE AFFECTING THE VALVE POSITION INDICATION FUNCTION. CORRECTIVE ACTIONS INCLUDED ADDITION OF AN ACTUATOR ORIFICE/FILTER WHICH PRECLUDED RAPID OPERATION AND REVISION OF THE SPECIFICATION TO ESTABLISH A MINIMUM VALVE ACTUATION TIME AT CRYOGENIC TEMPERATURES (REFERENCE CARS AB0332, AB0794, AB0813).

DURING QUALIFICATION TESTING (VIBRATION IN THE X-AXIS DIRECTION), THE OPEN POSITION SWITCH FAILED TO INDICATE (REFERENCE CAR AB3014). THE SWITCH ACTUATOR WAS FOUND TO BE WORN DUE TO VIBRATION. A REDESIGN WAS AUTHORIZED TO INCORPORATE A CAM OPERATED SWITCH AND A NEW HOUSING.

DURING QUALIFICATION LIFE CYCLING TEST, THE OPEN INDICATOR SWITCH FAILED TO INDICATE (REFERENCE CAR AB0142). TEARDOWN REVEALED THAT TWO SWITCH WIRES HAD FAILED DUE TO FATIGUE. CORRECTIVE ACTION WAS TO REROUTE THE WIRES AND PROVIDE ADDITIONAL SUPPORT.

TWO POSITION INDICATION FAILURES DURING QUAL AND ATP WERE ATTRIBUTED TO A GRADUAL LOSS OF ADJUSTMENT (REFERENCE CAR AB0160). CORRECTIVE ACTION WAS TO ADD A LOCKWASHER AND USE HIGHER TORQUE ON THE RETAINING SCREW TO MAINTAIN PROPER ADJUSTMENT.

DURING ATP, A CLOSED INDICATION SWITCH FAILED TO OPERATE (REFERENCE CAR AB0097). THE DIAPHRAGM SEAL FOR THE ACTUATING ARM WAS FOUND TO BE DEFORMED, REDUCING THE STROKE. THE VALVE WAS REDESIGNED USING THE APPROVED SWITCH ASSEMBLY ACTUATING MECHANISM DESIGN FOR THE TYPE V VALVE.

DURING STS-3, THE LO2 BLEED VALVE INDICATED "CLOSED" 4.64 SECONDS (SHOULD BE 1.5 SECONDS) AFTER THE CLOSED COMMAND WAS GIVEN (REFERENCE CAR AC3003). NO ANOMALIES WERE DETECTED AND THE MICROSWITCH WAS READJUSTED TO ACTIVATE DURING THE LAST 7 DEGREES OF CAM ROTATION. THE IMPROVED SWITCH ADJUSTMENT TECHNIQUE WAS USED ON THE -0055 BALL VALVES, WHICH WILL REPLACE THE CURRENT VALVES ON ALL VEHICLES.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0304-06**

DURING QUALIFICATION OF THE -0041 BALL VALVE, THE POSITION SWITCH INDICATION DURING CLOSING AT CRYOGENIC TEMPERATURES WAS ERRATIC (REFERENCE CAR AC3007). NO PHYSICAL ANOMALIES WERE DETECTED. THE ASSEMBLY PROCEDURES WERE REVISED TO ADJUST THE MICROSWITCH TO ACTIVATE DURING THE END OF THE SWITCH ACTUATION CAM TRAVEL. ADDITIONALLY, THE BRACKETS SUPPORTING THE MICROSWITCHES WERE KNURLED ON ONE END AND LUBRICATED WITH DRI-LUBED ON THE OTHER.

DURING ATP AT DOWNEY, VALVE CLOSING TIMES WERE OUT OF TOLERANCE (REFERENCE CAR AC7436). FAILURE ANALYSIS CONCLUDED THAT A LARGER ORIFICE WAS NECESSARY TO OBTAIN FASTER VENTING. THE VENDOR DRAWING WAS REVISED TO INCORPORATE THE LARGER ORIFICE.

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 TOPPING VALVE SWITCH QUALIFICATION AFTER THE LCC TERMINATES AT T-5 MINUTES UNTIL TOPPING VALVE CLOSING AT T-1:57 MAY RESULT IN A MANUAL HOLD CALL.

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. STENGER-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