FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE
NUMBER: 03-1-0651 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 11/07/00

PART DATA

	PART NAME / **VENDOR NAME**	**PART NUMBER** / **VENDOR NUMBER**
LRU	: LH2 INBOARD RTLS DUMP VALVE, TYPE 3 (PV17)	MC284-0395-0053
	VACCO INDUSTRIES	1440-511
LRU	: LH2 OUTBOARD RTLS DUMP VALVE, TYPE 4 (PV18)	MC284-0395-0054
	VACCO INDUSTRIES	1441-511

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
VALVE, 1.5 INCH, RTLS DUMP, LH2 FEEDLINE MANIFOLD, 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: PV17
PV18

QUANTITY OF LIKE ITEMS: 2

FUNCTION:
TWO SERIES REDUNDANT VALVES PROVIDE A PATH TO DUMP LH2 OVERBOARD FROM THE LH2 FEEDLINE MANIFOLD. FOR NOMINAL, ATO AND AOA MISSIONS THE VALVES ARE SOFTWARE COMMANDED OPEN AT MECO+11 SECONDS AND CLOSED AT DUMP STOP. THE VALVES ARE THEN RE-OPENED FOR ENTRY TO PERFORM A FINAL VACUUM INERT PRIOR TO ENTRY. FOR RTLS AND TAL MISSIONS, THE VALVES ARE OPENED NOMINALLY AND THEN REMAIN OPEN UNTIL ENTRY AT VREL=5300 FT/SEC. THE RTLS INBOARD VALVE, PV17, PROVIDES A RELIEF FEATURE FOR LH2 TRAPPED BETWEEN THE INBOARD AND OUTBOARD, PV18, VALVES.

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SUBSYSTEM NAME: MAIN PROPULSION
LRU: LH2 RTLS DUMP VALVE, PV17, 18 **CRITICALITY OF THIS**
ITEM NAME: LH2 RTLS DUMP VALVE, PV17, 18 **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 VALVE CLOSE INDICATION ON, OPEN POWER AND OPEN INDICATION OFF AT T-31 SECONDS.

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

(C) MISSION:
FIRST FAILURE - NO EFFECT.

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

(E) FUNCTIONAL CRITICALITY EFFECTS:

1R/3, 3 SUCCESS PATHS. TIME FRAME - LOADING AND ASCENT.

1) DUMP VALVE CLOSED POSITION SWITCH FAILS ON.
2) SAME DUMP VALVE FAILS TO REMAIN CLOSED.
3) ERRONEOUS INDICATION FAILURE OF SERIES DUMP VALVE (VALVE OPEN, CLOSED POSITION INDICATION ON, REF. CIL 03-1-0651-7).

VALVE POSITION LCCS IS ERRONEOUSLY SATISFIED DUE TO FIRST AND THIRD FAILURES.

PRIOR TO LIFTOFF, LH2 WILL DUMP OVERBOARD RESULTING IN PROPELLANT LEAKAGE ON TO THE PAD SURFACE. FIRE/EXPLOSION HAZARD EXTERNAL TO THE VEHICLE AND ON THE PAD. FIRE AND/OR LEAKAGE MAY BE DETECTABLE USING TV CAMERAS AND FIRE DETECTOR SENSORS. POSSIBLE LOSS OF CREW/VEHICLE.

AFTER LIFTOFF, LH2 WILL DUMP OVERBOARD (1800 POUNDS MAXIMUM) RESULTING IN LOSS OF PROPELLANT AND PREMATURE ENGINE SHUTDOWN. FIRE/EXPLOSION 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 SEPARATE TRIP LEVERS ON THE PLATES RIDE ON A CAM CONNECTED TO THE VALVE CLOSURE DEVICE SHAFT. THESE TRIP LEVERS ACTUATE THE MICROSWITCH EXTERNAL

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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
ACTUATOR: 740 PSIG

POSITION INDICATION: VERIFICATION OF OPERATION

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

RELIEF VALVE CRACK AND RESEAT (PV17 ONLY)
AMBIENT AND CRYO (-300 DEG F): 15-40 PSID

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 105 PSIG AND AT -300 DEG F.

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

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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
ACTUATOR: 740 PSIG

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

ELECTRICAL BONDING - LESS THAN 100 MILLIOHMS

BURST - BY SIMILARITY TO THE TYPE V VALVE. 800 PSIG VALVE BODY, 3400 PSIG ACTUATOR

OMRSD
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.

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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:

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, ABO813).

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 LOCK WASHER AND USE HIGHER TORQUE ON THE RETAINING SCREW TO MAINTAIN PROPER ADJUSTMENT.

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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.

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:

FLIGHT: WHEN THE ULLAGE PRESSURE DROPS BELOW 31.6 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.

GROUND: GROUND OPERATIONS SAFING PROCEDURES CONTAIN SAFING SEQUENCE OF EVENTS FOR MAJOR LEAKS IN THE HYDROGEN SYSTEM.

- 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