

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0453 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 1 11/06/00

PART DATA

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	: VALVE, BALL (TYPE 2) VACCO INDUSTRIES	MC284-0395-0052 1397-501-511

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

VALVE, 2 INCH. LO2 POGO RECIRCULATION (PV20, PV21), NORMALLY OPEN, PNEUMATICALLY ACTUATED CLOSED.

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: PV20
PV21

QUANTITY OF LIKE ITEMS: 2

FUNCTION:

TWO PARALLEL VALVES PROVIDE A FLOW PATH FOR GO2 FROM THE ENGINE POGO ACCUMULATOR SYSTEM TO THE LO2 17 INCH DISCONNECT DURING ENGINE OPERATION. VALVES ARE CLOSED DURING LOADING TO PROVIDE A POSITIVE FLOW PATH FROM THE SSME TO THE OVERBOARD BLEED SYSTEM FOR ENGINE CONDITIONING. VALVES OPEN AT T-12.5 SECONDS AND REMAIN OPEN TO THE END OF THE MISSION. THE VALVES INCORPORATE A RELIEF CAPABILITY TO RELIEVE PRESSURE FROM THE POGO LINE INTO THE 17-INCH FEEDLINE.

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LRU: LO2 POGO RECIRCULATION VALVE, PV21,22

CRITICALITY OF THIS

ITEM NAME: LO2 POGO RECIRCULATION VALVE, PV21,22

FAILURE MODE: 1R3

FAILURE MODE:

RUPTURE/LEAKAGE OF THE ACTUATOR DURING PAD ABORT, FRF, AND ASCENT.

MISSION PHASE:

PL PRE-LAUNCH
LO LIFT-OFF

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102 COLUMBIA
103 DISCOVERY
104 ATLANTIS
105 ENDEAVOUR

CAUSE:

FATIGUE, MATERIAL DEFECT, DAMAGED OR DEFECTIVE ACTUATOR SEALS

CRITICALITY 1/1 DURING INTACT ABORT ONLY? YES

PAD PAD ABORT

REDUNDANCY SCREEN

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

PASS/FAIL RATIONALE:

A)

B)

FAILS B SCREEN BECAUSE FAILURE CANNOT BE DETECTED DURING FLIGHT; THE ACTUATOR IS UNPRESSURIZED DURING ASCENT

LEAKAGE IN THE AFT COMPARTMENT DETECTABLE DURING LOADING USING HAZARDOUS GAS DETECTION SYSTEM (HGDS) PRIOR TO T-9 MINUTES

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

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LOSS OF CAPABILITY TO CLOSE OR MAINTAIN CLOSED AN LO2 POGO RECIRCULATION VALVE (PV20 OR PV21) DURING PROPELLANT LOADING. FAILURE WILL RESULT IN THE INABILITY TO OBTAIN SSME START CONDITIONS.

FOR POST ENGINE SHUTDOWN (FRF), NO EFFECT FIRST FAILURE. LO2 OVERBOARD BLEED VALVE (PV19) IS OPENED WITHIN 2 MINUTES AND WILL PREVENT GEYSER FORMATION.

DURING A PAD ABORT THIS FAILURE RESULTS IN INABILITY TO ISOLATE AN SSME WITH UNCONTAINED DAMAGE (ASSUMES ENGINE DAMAGED ONLY TO THE EXTENT THAT ISOLATION OF THE DAMAGE WILL SAVE THE SYSTEM). POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD DUE TO LO2 LEAKAGE.

LEAKAGE IN THE AFT COMPARTMENT DETECTABLE DURING LOADING USING HAZARDOUS GAS DETECTION SYSTEM (HGDS) PRIOR TO T-9 MINUTES.

(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

VIOLATION OF HGDS LCC RESULTS IN LAUNCH SCRUB.

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

FOR PAD ABORTS, POSSIBLE LOSS OF CREW/VEHICLE.

(E) FUNCTIONAL CRITICALITY EFFECTS:

CASE 1:

1R/3 3 SUCCESS PATHS. TIME FRAME - POST ENGINE SHUTDOWN/FRF.

- 1) ACTUATOR RUPTURE/LEAKAGE OF EITHER LO2 POGO VALVE (PV20,21).
- 2) LO2 OVERBOARD BLEED VALVE (PV19) FAILS TO OPEN/REMAIN OPEN.
- 3) INBOARD OR OUTBOARD FILL & DRAIN VALVES (PV9,10) FAIL TO OPEN/REMAIN OPEN.

TO PREVENT GEYSERING, PREVALVE CLOSURE IS REQUIRED TO LIMIT HEAT SOAKBACK FROM THE MAIN ENGINES INTO THE FEED SYSTEM. FOR PREVALVE FAILURE TO CLOSE, HELIUM INJECTION IS NOT SUFFICIENT TO PREVENT GEYSERING AND OVERBOARD BLEED OR LO2 DRAIN MUST BE INITIATED WITHIN OMRSD REQUIREMENTS.

GEYSERING MAY RESULT IN FEEDLINE RUPTURE, EXTERNAL LEAKAGE OF LO2, AND POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION. FIRE/EXPLOSIVE HAZARD BOTH INTERIOR AND EXTERIOR TO THE VEHICLE. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF VEHICLE.

CASE 2:

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

- 1) ACTUATOR RUPTURE/LEAKAGE OF EITHER LO2 POGO VALVE (PV20,21).
- 2) PREMATURE ACTUATION OF EITHER POGO CLOSING SOLENOID VALVE (LV77,78).

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- 3) FAILURE OF PNEUMATIC ACCUMULATOR LEG ISOLATION CHECK VALVE (CV9) TO CHECK/REMAIN CLOSED.

CAUSES LOSS OF PNEUMATIC ACTUATION PRESSURE RESULTING IN THE INABILITY TO CLOSE LO2 PREVALVES AT MECO. THIS RESULTS IN FAILURE TO MAINTAIN INJECTED GHE AND LO2 PRESSURE AT THE SSME PUMP, RESULTING IN POSSIBLE PUMP OVERSPEED AND EXPLOSION. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. ENGINE PURGE HELIUM RESIDUALS ARE TRANSFERRED TO VALVE ACTUATION SUPPLY AT MECO BY SOFTWARE COMMAND, WHICH MAY NOT ACTUATE LO2 PREVALVES CLOSED. POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

FACTORS OF SAFETY: PROOF - 2.0; BURST - 4.0. DURING CERTIFICATION TESTING, ACTUATOR WAS BURST TESTED TO 3400 PSIG. ACTUATOR MAX OPERATING PRESSURE IS 850 PSIG. BOTH THE ACTUATOR BODY AND END CAP ARE MANUFACTURED FROM ALUMINUM ALLOY. 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.

EXTERNAL LEAKAGE FROM THE ACTUATOR END CAP IS PREVENTED BY THE USE OF A CREEVEY-TYPE SEAL (TEFLON COVER OVER A SANDVIK SPRING) AND A KEL-F STATIC SEAL. EXTERNAL LEAKAGE FROM THE ACTUATOR PISTON IS PREVENTED BY USE OF A KEL-F LIP SEAL.

(B) TEST:

ATP

EXAMINATION OF PRODUCT

AMBIENT PROOF

VALVE BODY - 600 PSIG VALVE OPEN; 157 PSIG VALVE CLOSED.
ACTUATOR - 1700 PSIG.

VALVE RESPONSE TIMES

AMBIENT AND CRYO (-300 DEG F) VALVE PRESSURIZED TO 105 PSIG
ACTUATOR PRESSURIZED TO 740 AND 600 PSIG

EXTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F)

VALVE BODY @ 220 PSIG
SHAFT SEAL @ 220 PSIG
ACTUATOR @ 740 PSIG

RELIEF FUNCTION (INLET-TO-OUTLET)

CRACK/RESEAT CRYO (-300 DEG F, 15-40 PSID)

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INTERNAL LEAKAGE
OUTLET-TO-INLET @ 105 PSIG

POSITION INDICATION: VERIFICATION OF OPERATION

ELECTRICAL CHARACTERISTICS: INSULATION RESISTANCE, DIELECTRIC STRENGTH AND RESISTANCE.

CERTIFICATION

VALVE RESPONSE TIMES
AMBIENT AND CRYO (-300 DEG F) - VALVE PRESSURIZED TO 105 PSIG
ACTUATOR PRESSURIZED TO 740 AND 600 PSIG

EXTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F)
VALVE BODY @ 220 PSIG
SHAFT SEAL @ 220 PSIG
ACTUATOR @ 740 PSIG

LIFE
CRYO (500 CYCLES @ -300 DEG F FOLLOWED BY CRYO LEAKAGE TESTS)
AMBIENT (1500 CYCLES. AFTER EACH 500 CYCLES PERFORM AMBIENT LEAKAGE TESTS AND AMBIENT CRACK/RESEAT TESTS).

VIBRATION
TRANSIENT VIBRATION - (5 TO 35 HZ) PRIOR TO EACH AXIS OF RANDOM VIBRATION TEST.

RANDOM VIBRATION - (13.3 HOURS IN EACH OF THREE AXES WHILE PRESSURIZED TO 105 PSIG AND AT -300 DEG F.

PRIOR TO EACH AXIS TEST, PERFORM CRYO VALVE RESPONSE TIMES TEST. FOLLOWING EACH AXIS TEST, PERFORM CRYO VALVE RESPONSE TIMES TEST, CRYO LEAKAGE TESTS, AND CRYO CRACK/RESEAT TESTS. AFTER TEST UNIT HAS WARMED, PERFORM ELECTRICAL CHARACTERISTICS TESTS, AMBIENT VALVE RESPONSE TIMES TEST, AMBIENT LEAKAGE TESTS, AND AMBIENT CRACK/RESEAT TESTS).

THERMAL CYCLE TEST (+70 DEG F TO -300 DEG F, TO +70 DEG F, TO +275 DEG F, TO +150 DEG F, TO AMBIENT)

ELECTRICAL CHARACTERISTICS TESTS AND ELECTRICAL BONDING TEST

DESIGN SHOCK - BY SIMILARITY TO THE TYPE I AND III VALVES

BURST TEST
VALVE BODY @ 800 PSIG
ACTUATOR @ 3400 PSIG

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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.

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 PRESSURE LEAK CHECKED. ALL WELDS ON THE ELECTRICAL CONNECTOR ARE DYE PENETRANT INSPECTED AND VERIFIED BY INSPECTION.

TESTING

ATP VERIFIED BY INSPECTION.

HANDLING/PACKAGING

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

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(D) FAILURE HISTORY:

ATP

DURING ATP PROOF PRESSURE TEST, EXCESSIVE LEAKAGE PAST THE ACTUATOR SEAL WAS NOTED (REF CAR A9705). TEARDOWN REVEALED A SCRATCH ON THE PISTON SEAL. THE SEAL WAS REPLACED AND ACTUATOR MET LEAKAGE REQUIREMENTS. CORRECTIVE ACTION WAS TO INCORPORATE A MANDATORY INSPECTION POINT OF THE SEALS PRIOR TO INSTALLATION.

QUALIFICATION

DURING QUALIFICATION TEST, ACTUATOR LEAKAGE WAS OBSERVED (REF CAR A9894). X-RAY OF THE ACTUATOR REVEALED A BROKEN RACK/PISTON SPRING. UPON TEARDOWN, A BROKEN STATIC SEAL WAS ALSO FOUND. FAILURE ANALYSIS OF THE SPRING DETERMINED THAT THE SPRING FAILED FROM IMPACT EMBRITTLEMENT. THE ACTUATOR SPRING MATERIAL WAS CHANGED FROM TITANIUM TO ELGILOY AND REDUNDANT ACTUATOR STATIC SEALS WERE ADDED. THE QUAL UNIT WAS REWORKED AND SUCCESSFULLY RETESTED.

DURING QUALIFICATION TEST AT CRYO TEMPERATURE, THE ACTUATOR SHAFT SEAL LEAKAGE WAS 400 SCIM, MAX ALLOWABLE IS 100 SCIM (REF CAR AC6963). THE CAUSE ATTRIBUTED TO NORMAL INTERNAL WEAR IN COMBINATION WITH MIGRATING LUBRICANT. THE SPECIFICATION FOR MAXIMUM ACTUATOR SHAFT SEAL LEAKAGE WAS REVISED TO 500 SCIM (TYPE II VALVES ONLY), TO BE MEASURED AFTER EXPOSURE TO QUALIFICATION VIBRATION TEST.

DURING CRYOGENIC QUAL TESTING, ACTUATOR PISTON SEAL LEAKAGE OF 130 SCIM WAS NOTED. MAX ALLOWABLE IS 100 SCIM (REFERENCE CAR AB1806). THE LEAKAGE WAS DUE TO METALLIC PARTICLE GENERATION DURING ASSEMBLY FROM IMPROPERLY CLEANED PARTS CAUSING GALLING DURING ASSEMBLY. SUPPLIER ACTUATOR ASSEMBLY PROCEDURE PS-352M WAS CHANGED TO ADD CAUTION AND INSPECTION NOTE.

DURING QUALIFICATION TESTING, ACTUATOR PISTON SEAL LEAKAGE OF 200 SCIM WAS DETECTED. MAX ALLOWABLE IS 100 SCIM. LEAKAGE WAS DUE TO METALLIC PARTICLES GENERATED DURING ASSEMBLY WITH AN INADEQUATE ASSEMBLY TOOL. REDESIGNED TOOL ELIMINATED THE PROBLEM (REFERENCE CAR AB0197).

DURING QUALIFICATION TESTING, LEAKAGE AT THE ACTUATOR PISTON SEAL RETAINER INTERFACE WAS 560 SCIM. MAX ALLOWABLE IS 100 SCIM (REFERENCE ARE AB0088). LEAKAGE WAS DUE TO INSUFFICIENT SEAL RETAINER TORQUE OF 70 FT-LBS. ASSEMBLY TORQUE WAS INCREASED TO 95 - 100 FT-LBS WITH REPEAT APPLICATIONS AT 5 MINUTE INTERVALS UNTIL SUB-ASSEMBLY STOPS MOVING. IMPLEMENTED OV-102 AND SUBS.

FIELD

DURING MPTA CHECKOUT, HELIUM WAS LEAKING THROUGH THE VENT PORT OF THE ACTUATOR CAUSING THE VALVE TO FAIL TO REMAIN OPEN (REF CAR A9630). DURING DISASSEMBLY, IT WAS FOUND THAT THE STATIC SEAL WAS PROTRUDING OUTSIDE ITS RETAINER AREA AND THAT THE SEAL RETAINER TORQUE WAS LOW. IT WAS CONCLUDED THAT THE ACTUATOR STATIC SEAL RETAINER TORQUE RELAXES EITHER FROM SEAL

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MATERIAL COLD FLOW OR RETAINER BACKING OFF. THE VALVE WAS REDESIGNED TO ADD REDUNDANT ACTUATOR SEALS AND LOCKTITE IS APPLIED TO THE RETAINER TO PREVENT TORQUE RELAXATION AND A SERIES OF RETORQUING TO MINIMIZE COLD FLOW. THE VALVE WAS REWORKED AND PASSED SUBSEQUENT LEAKAGE TESTS.

AT PALMDALE ACTUATOR LEAKAGE OCCURRED FROM UNDER THE ENDCAP OF THE ACTUATOR (REFERENCE CAR AD2446). THE ORIGIN OF THE LEAK WAS DUE TO TWO DAMAGED GASKETS P/N 1397-60 AND A SEAL P/N 1397-29-2. THE FAILURE WAS DUE TO A FAILURE TO BACK UP THE END CAP ON THE ACTUATOR WHILE TURNING A LINE FITTING DURING THE INSTALLATION OF THE VALVE. GASKETS AND SEAL REPLACED. NO FURTHER ACTION REQUIRED.

DURING CHECKOUT AT PALMDALE ON OV-099, THE ACTUATOR END CAP LEAKED EXCESSIVELY (REFERENCE CAR AC2152). NEW SEALS AND END CAP WERE INSTALLED ON THE VEHICLE BY THE SUPPLIER AND PASSED SUBSEQUENT LEAK TEST. CAUSE FOR LEAKAGE WAS NOT DETERMINED.

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: HELIUM BOTTLE PRESSURE IS ON DISPLAY IN COCKPIT. CREW ACTION CAN CLOSE PNEUMATIC ISOLATION VALVES (LV7,8) DURING ASCENT. PRIOR TO MECO, THE ISOLATION VALVES CAN BE REOPENED OR THE LEFT ENGINE LOW PRESSURE GHE CROSSOVER VALVE (LV10) CAN BE OPENED.

GROUND OPERATIONS SAFING PROCEDURES CONTAIN SAFING SEQUENCE OF EVENTS FOR MAJOR LEAKS IN THE OXYGEN 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	: BILL PRINCE	: /S/ BILL PRINCE