

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0301 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 4 08/04/00

PART DATA

| | PART NAME | PART NUMBER |
|-----|---|---------------------------------|
| | VENDOR NAME | VENDOR NUMBER |
| LRU | : LH2 8" INBOARD FILL/DRAIN VALVE UNITED SPACE ALLIANCE - NSLD | MC284-0397-0031 74328000-159 |

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

FILL VALVE, INBOARD LH2, 8 INCH, PNEUMATICALLY OPERATED, INCLUDES A RELIEF VALVE.

VALVE WAS ORIGINALLY DESIGNED AND MANUFACTURED BY FAIRCHILD CONTROLS BUT IS NOW MANUFACTURED BY UNITED SPACE ALLIANCE-NSLD AS AN ALTERNATE PRODUCTION AGENCY.

REFERENCE DESIGNATORS: PV12

QUANTITY OF LIKE ITEMS: 1

FUNCTION:

PROVIDES A MEANS OF LOADING AND DRAINING THE ET THROUGH THE PROPELLANT FEED SYSTEM. THE VALVE, ALONG WITH LH2 TOPPING VALVE (PV13) AND THE OUTBOARD FILL AND DRAIN VALVE (PV11), PROVIDES A REDUNDANT MEANS OF CONTAINING PROPELLANT IN THE FEED SYSTEM. THE VALVE IS MOUNTED ON THE FEED LINE MANIFOLD TO ISOLATE THE FILL LINE FROM THE FEED SYSTEM. IT IS REQUIRED TO BE CLOSED FOR PROPELLANT TOPPING/REPLENISHMENT OPERATIONS. BOTH THE INBOARD AND OUTBOARD VALVES REMAIN CLOSED DURING ENGINE OPERATION. POST MECO, THE INBOARD & OUTBOARD FILL VALVES ARE SOFTWARE COMMANDED OPEN FOR DUMP OF RESIDUAL LH2. FOR A NOMINAL MISSION THE INBOARD VALVE REMAINS OPEN AFTER INERTING THROUGH REENTRY AND LANDING. FOR AN RTLS/TAL THE INBOARD VALVE IS COMMANDED CLOSED AFTER 20 SECONDS (OI-23). VALVE INCORPORATES AN ANTI-SLAM MECHANISM TO PREVENT VALVE SLAMMING DAMAGE DURING IMPROPER VALVE OPEN/CLOSE OPERATIONS. THE VALVE ALSO INCORPORATES A RELIEF VALVE, RELIEVING FROM THE FILL LINE INTO THE MANIFOLD; AND A PORT FOR INSTALLATION OF LH2 RELIEF SHUTOFF ISOLATION VALVE (PV8).

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ERRONEOUS INDICATION. VALVE OPEN, CLOSED INDICATION ON.

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, BINDING, CONTAMINATION

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO**REDUNDANCY SCREEN**

A) N/A

B) N/A

C) N/A

PASS/FAIL RATIONALE:

A)

B)

C)

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

IF LEAKAGE RATE IS NOT EXCESSIVE (NO LCC VIOLATION), THE FILL & DRAIN LINE WILL FILL WITH LH2 UPON CLOSURE OF OUTBOARD FILL & DRAIN VALVE. THE FILL LINE CAN WITHSTAND ACCELERATION LOADS WITH LH2 PRESENT. DISPLACED GAS MAY ENTER ENGINE CAUSING POSSIBLE PUMP CAVITATION AND UNCONTAINED ENGINE DAMAGE. POSSIBLE SHUTDOWN OF ONE OR MORE SSME(S). GATE SEAL PIECES OR FAILED BEARING WOULD BE CONTAINED BY THE ENGINE INLET SCREENS, BUT LARGER DEBRIS

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MAY RUPTURE THE SCREEN AND ENTER THE LPFTP CAUSING UNCONTAINED ENGINE DAMAGE. LOSS OF REDUNDANCY TO PROTECT AGAINST OVERBOARD LEAKAGE OF PROPELLANT.

LOSS OF LH2 DURING TSM DRAIN AT TERMINATION OF REPLENISH. IF LEAKAGE RATE IS EXCESSIVE, THE FAILURE MAY RESULT IN LCC VIOLATION FOR ET PRE- PRESSURIZATION.

(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

POSSIBLE LOSS OF CREW/VEHICLE. POSSIBLE LAUNCH SCRUB IF LCC IS VIOLATED.

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

SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:

1R/2 2 SUCCESS PATHS. TIME FRAME – ASCENT.

- 1) LH2 INBOARD VALVE FAILS OPEN, PI INDICATES CLOSED.
- 2) OUTBOARD FILL & DRAIN ALSO FAILS TO REMAIN CLOSED DURING ASCENT.

LH2 WILL DUMP OVERBOARD RESULTING IN A LOSS OF PROPELLANT AND PREMATURE ENGINE SHUTDOWN DUE TO LOW NPSP. POSSIBLE UNCONTAINED ENGINE DAMAGE DUE TO PUMP CAVITATION. POSSIBLE VIOLATION OF ET MINIMUM STRUCTURAL REQUIREMENTS DUE TO REDUCED ULLAGE PRESSURE. POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

THIS FAILURE MODE CAN OCCUR WITH AN ACTUATOR RUPTURE, STRIPPING/SHEARING OF THE ACTUATOR SHAFT SPLINE OR FAILURE OF THE VALVE SHAFT/DRIVER KEY. THE VALVE MAIN SHAFT IS MADE OF INCONEL 718, THE ACTUATOR MAIN PINION SHAFT OF BERYLLIUM-COPPER ALLOY 172 AND THE KEY OF A286 CRES. BASED UPON AN ANALYSIS PERFORMED BY THE VALVE MANUFACTURER, A POSITIVE MARGIN OF SAFETY EXISTS FOR ACTUATOR POWER TRAIN, FROM THE POSITION INDICATION CAM TO AND INCLUDING THE ACTUATOR VALVE INTERFACE SPLINE, FOR ALL RANGES OF ACTUATOR PRESSURES. THE WEAK LINK IN THE VALVE/ACTUATOR MECHANISM IS THE VALVE SHAFT/DRIVER KEY. THE ACTUATOR PROVIDES ENOUGH FORCE AT FULL ACTUATION PRESSURE TO APPLY A SHEARING LOAD TO THE KEY. A SEIZURE OF THE VALVE MAIN BLADE OR DRIVER MECHANISM WILL RESULT IN THE ACTUATOR LOAD BEING APPLIED TO SHEAR THE KEY AND CAN RESULT IN ACTUATOR FREE TRAVEL.

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VALVE CLOSE POSITION INDICATED PRIOR TO FULL TRAVEL OF VALVE BLADE. VALVE BINDING (THAT OCCURS DURING FINAL CLOSURE MOTION) OR INTERNAL SYSTEM CONTAMINATION PREVENTING BLADE MOVEMENT WILL RESULT IN AN ERRONEOUS INDICATION. SYSTEM CONTAMINATION IS MINIMIZED DUE TO THE PRESENCE OF A SCREEN, A GSE DEBRIS PLATE, AND A GSE FILTER. BINDING IS GUARDED AGAINST BY THE USE OF NEEDLE AND COPPER-BERYLLIUM JOURNAL BEARINGS IN THE VALVE ROLLER AND VESPEL JOURNAL TYPES IN THE ACTUATOR; AND DRY FILM LUBRICANT COATING.

DURING THE CERTIFICATION TESTING THIS VALVE WAS CYCLED OPEN/CLOSED A TOTAL OF 5256 TIMES UNDER BOTH CRYOGENIC AND AMBIENT TEMPERATURE CONDITIONS AND AT BOTH NORMAL AND ACCELERATED (SLAM) CYCLE TIMES; THIS REPRESENTS OVER 100 MISSIONS. NO FAILURES OF THIS TYPE OCCURRED.

(B) TEST:

ATP

ANTI-SLAM VALVES (BEFORE ASSEMBLY INTO THE ACTUATOR) - EXAMINATION OF PRODUCT; AMBIENT PROOF (1275 PSIG); AMBIENT AND CRYO FLOW; AMBIENT AND CRYO CRACKING PRESSURE; POST TEST EXAMINATION.

ACTUATOR (BEFORE ASSEMBLY ONTO THE FILL AND DRAIN VALVE) - EXAMINATION OF PRODUCT; POSITION INDICATION; AMBIENT PROOF (1275); ELECTRICAL CHARACTERISTICS; AMBIENT EXTERNAL LEAKAGE.

RELIEF VALVE ASSEMBLY (BEFORE INSTALLATION INTO THE FILL AND DRAIN VALVE) - EXAMINATION OF THE PRODUCT; AMBIENT PROOF (340 PSIG); AMBIENT AND CRYO CRACK/RESEAT (15-50 PSID) AND INTERNAL LEAKAGE; POST TEST EXAMINATION.

FILL AND DRAIN VALVE ASSEMBLY -

EXAMINATION OF PRODUCT

ELECTRICAL BONDING

AMBIENT AND CRYO PROOF WITH VALVE OPEN AND CLOSED - 143 PSIG

AMBIENT AND CRYO EXTERNAL LEAKAGE OF VALVE BODY (110 PSIG)

CRYO EXTERNAL LEAKAGE OF ACTUATOR (740 PSIG)

AMBIENT AND CRYO RESPONSE TIME (NORMAL AT 400 AND 740 PSIG ACTUATOR PRESSURE, AND SLAM AT 740 PSIG)

AMBIENT AND CRYO ACTUATOR LEAKAGE FROM PORT TO PORT

AMBIENT AND CRYO VALVE SHAFT SEAL (PRIMARY AND SECONDARY) LEAKAGE WITH 110 PSID ACROSS THE SEAL

AMBIENT AND CRYO VALVE INTERNAL LEAKAGE (INLET-TO-OUTLET WITH 15 PSID, OUTLET-TO-INLET WITH 110 PSID)

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AMBIENT AND CRYO RELIEF VALVE CRACK AND RESEAT (15 TO 50 PSID)

POST TEST EXAMINATION

CERTIFICATION

STRUCTURAL LOAD AT CRYO TEMPS (-400 DEG F) (AXIAL, SHEAR, TORSION, BENDING) WITH THE VALVE IN TENSION, PERFORM VALVE RESPONSE TIME (NOMINAL AND SLAM) ACTUATOR INTERNAL LEAKAGE, PRIMARY AND SECONDARY SHAFT SEAL LEAKAGE, INTERNAL LEAKAGE (OUTLET-TO-INLET AND INLET-TO-OUTLET), CRACK AND RESEAT, AND, EXTERNAL LEAKAGE (BODY AND ACTUATOR) TESTS. REPEAT WITH THE VALVE IN COMPRESSION.

VALVE LIFE CYCLING:

2400 AMBIENT TEMPERATURE CYCLES WITH 5 PSIG INTERNAL PRESSURE (525 NORMAL CYCLES AND 1875 SLAM CYCLES)

100 AMBIENT CYCLES (50 NORMAL AND 50 SLAM CYCLES) WITH VALVE INLET VENTED TO ATMOSPHERE AND VALVE OUTLET CONNECTED TO A 4 CUBIC FOOT VOLUME PRESSURIZED TO 110 PSIG WITH GN2

2400 CRYO TEMPERATURE (-400 DEG F) CYCLES WITH 50 - 60 PSIG INTERNAL PRESSURE (1775 NORMAL CYCLES AND 625 SLAM CYCLES)

100 NORMAL CRYO CYCLES WITH THE VALVE INLET VENTED TO ATMOSPHERE AND THE OUTLET PRESSURIZED TO 110 PSIG.

FOR THE FOREGOING LIFE TEST, PRIOR TO AND EVERY 100 CYCLES THEREAFTER, ACTUATOR INTERNAL LEAKAGE, PRIMARY AND SECONDARY SHAFT SEAL LEAKAGE, AND VALVE INTERNAL LEAKAGE (OUTLET-TO-INLET) TESTS WERE PERFORMED.

RELIEF VALVE LIFE CYCLING:

2500 CYCLES AT CRYO (-400 DEG F) TEMP, 2500 CYCLES AT AMBIENT.

FOLLOWING EACH 500 CYCLES PERFORM FILL AND DRAIN VALVE INTERNAL LEAKAGE (OUTLET-TO-INLET AND INLET-TO-OUTLET), AND CRACK/RESEAT TESTS. POST CYCLE EXAMINATION.

VIBRATION:

PRE-VIBRATION TESTS - VALVE RESPONSE TIME (NORMAL AND SLAM), ACTUATOR INTERNAL LEAKAGE, PRIMARY AND SECONDARY SHAFT SEAL LEAKAGE, INTERNAL LEAKAGE (OUTLET-TO-INLET AND INLET-TO-OUTLET), CRACK AND RESEAT, AND EXTERNAL LEAKAGE (BODY AND ACTUATOR).

TRANSIENT SINUSOIDAL VIBRATION -
(AT 110 PSIG AND -250 DEG F) IN EACH AXIS

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RANDOM VIBRATION TESTS -

13.3 HRS IN EACH OF THREE AXES WITH VALVE CLOSED AND AT -250 DEG F MAXIMUM. HALF OF THE TIME THE VALVE INTERNAL PRESSURE IS 110 PSIG; THE OTHER HALF AT 5 PSIG. ONCE EACH HOUR, CLOSING PRESSURE IS REMOVED FROM THE ACTUATOR. ALSO BOTH CLOSING AND OPENING PRESSURES ARE APPLIED CONCURRENTLY TO THE ACTUATOR. IN BOTH CASES THE VALVE REMAINS CLOSED.

DESIGN SHOCK: 18 SHOCKS OF 15G EACH - THREE IN EACH DIRECTION ALONG EACH OF THREE AXES, ALL WITH VALVE OPEN AND ACTUATOR VENTED

DESIGN SHOCK POST TEST:

AMBIENT - VALVE RESPONSE, INTERNAL AND EXTERNAL LEAKAGES. CRYO - VALVE RESPONSE, INTERNAL AND EXTERNAL LEAKAGES. ELECTRICAL CHARACTERISTICS; POSITION INDICATION.

BURST: 165 PSIG VALVE OPEN 165 PSIG ON OUTLET OF CLOSED VALVE, 1700 PSIG ACTUATOR

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. BODY HOUSING FORGING IS ULTRASONICALLY AND PENETRANT INSPECTED.

CONTAMINATION CONTROL

PARTS ARE VERIFIED CLEAN TO LEVEL 400. THE ACTUATOR IS CLEANED TO 400A.

ASSEMBLY/INSTALLATION

ALL PARTS ARE PROTECTED FROM DAMAGE AND CONTAMINATION. LOG OF CLEAN ROOM AND TOOL CALIBRATION ARE VERIFIED BY INSPECTION. ALL SURFACES REQUIRING CORROSION PROTECTION ARE VERIFIED. VISUAL (3X TO 7X) AND DIMENSIONAL INSPECTION OF VALVE BODY AND COMPONENTS ARE VERIFIED DURING ASSEMBLY. THREADED FASTENER TORQUES ARE VERIFIED BY INSPECTION. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

CRITICAL PROCESSES

HEAT TREATMENT AND DRY FILM LUBE APPLICATION ARE VERIFIED BY INSPECTION.

NON DESTRUCTIVE EVALUATION

VALVE BODY, PRIOR TO FINAL MACHINING, IS SUBJECTED TO DYE PENETRANT INSPECTION. REQUIREMENTS FOR DETAIL PARTS PENETRANT INSPECTION ARE BASED UPON CONFIGURATION, MATERIAL, AND MANUFACTURING PROCESSES.

TESTING

ACCEPTANCE TEST VERIFIED BY INSPECTION.

HANDLING/PACKAGING

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PACKAGING FOR SHIPMENT VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:

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:

ASCENT - NO CREW ACTION CAN BE TAKEN.

GROUND – ORBITER/GROUND PRESSURES AND TEMPERATURES MAY INDICATE AN INBOARD FILL/DRAIN VALVE FAILED OPEN AT REDUCED FAST-FILL. EXCESSIVE PRE-PRESSURIZATION CYCLES MAY INDICATE LEAKAGE PAST INBOARD FILL/DRAIN VALVE.

- APPROVALS -

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