

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0251 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 07/25/00

PART DATA

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	: VALVE, RELIEF, 850 PSI VACCO INDUSTRIES	MC284-0398-0005, -0006 76130-3, -4

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

850 PSI RELIEF, PNEUMATIC HELIUM SUPPLY, 0.75 INCH DIAMETER.

REFERENCE DESIGNATORS: RV4

QUANTITY OF LIKE ITEMS: 1

FUNCTION:

PROVIDES A MEANS OF RELIEVING AN OVERPRESSURE CONDITION RESULTING FROM AN UPSTREAM REGULATOR FAILING TO REGULATE. ONE RELIEF VALVE IS PROVIDED FOR THE PNEUMATIC HELIUM SUPPLY SYSTEM.

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SUBSYSTEM NAME: MAIN PROPULSION

LRU: VALVE, RELIEF, 850 PSI

CRITICALITY OF THIS

ITEM NAME: MPS PNEU SUPPLY 850 PSI RELIEF VALVE (RV4)

FAILURE MODE: 1/1

FAILURE MODE:

FAILS TO RESEAT/REMAIN CLOSED, INTERNAL/EXTERNAL LEAKAGE, RUPTURE/LEAKAGE

MISSION PHASE:

PL PRE-LAUNCH
LO LIFT-OFF
DO DE-ORBIT

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102 COLUMBIA
103 DISCOVERY
104 ATLANTIS
105 ENDEAVOUR

CAUSE:

PIECE PART STRUCTURAL FAILURE, CONTAMINATION, BINDING.

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:

RESULTS IN LOSS OF HELIUM FROM PNEUMATIC HELIUM SUPPLY THROUGH THE RELIEF VALVE UNLESS BOTH HELIUM ISOLATION VALVES ARE CLOSED.

PRIOR TO T-0 EXCESSIVE HELIUM LEAKAGE MAY BE DETECTABLE USING HAZARDOUS GAS DETECTION SYSTEM (HGDS).

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ASCENT

IF FAILURE OCCURS DURING THE FIRST FORTY (40) SECONDS OF ASCENT, POSSIBLE OVERPRESSURIZATION OF THE AFT COMPARTMENT (FACTOR OF SAFETY FOR THE OMS DECK FRAMES IS 1.2 DURING ASCENT). THIS IS BASED ON THE DAY OF LAUNCH LOAD INDICATORS NOT TO EXCEED REDLINE (FACTOR OF SAFETY IS 1.4).

WHEN THE CROSSOVER VALVE (LV10) OPENS AT MECO, THE PNEUMATIC HELIUM DISTRIBUTION SYSTEM WILL BE FED FROM THE LEFT ENGINE HELIUM SUPPLY. WHEN THE ENGINE 1 AND 3 INTERCONNECT "OUT" VALVES OPEN AT MECO PLUS 20 SECONDS, THE ENGINE 1 AND 3 HELIUM SUPPLIES WILL LEAK THROUGH THE FAILED LINE.

STORED HELIUM PRESSURE IN THE ACCUMULATOR LEG SHOULD BE ADEQUATE TO OPERATE THE LO2 PREVALVES AT MECO. LOSS OF HELIUM MAY PREVENT OPERATION OF VALVES FOR MPS DUMP.

ENTRY

PURGE OF AFT COMPARTMENT AND LH2/LO2 SYSTEMS WOULD DEPEND SOLELY ON THE LEFT ENGINE HELIUM SYSTEM RESIDUALS, RESULTING IN INADEQUATE ABORT PURGE, INCOMPLETE PROPELLANT DUMP, AND INGESTION OF CONTAMINATION.

VENT DOORS ARE CLOSED TO PREVENT INGESTION OF RCS AND APU GASES. THE HELIUM ISOLATION VALVES ARE OPENED WHEN THE VEHICLE TRANSITIONS TO ORBITER SOFTWARE MAJOR MODE 304 (MM304). LEAKAGE DURING THE TIME PERIOD THAT THE VENT DOORS ARE CLOSED MAY RESULT IN OVERPRESSURIZATION OF THE AFT COMPARTMENT. VENT DOORS ARE OPENED WHEN VEHICLE VELOCITY DROPS BELOW 2400 FT/SEC.

ANALYSIS INDICATES AFT COMPARTMENT OVERPRESSURIZATION (SAFETY FACTOR FOR THE 1307 BULKHEAD DURING ENTRY IS 1.31 IF NO CREW ACTION IS TAKEN) WILL OCCUR IN APPROXIMATELY 17 SECONDS. TRAINING IN THE NORMAL LEAK ISOLATION PROCEDURE WILL ALLOW THE CREW TO REACT TO THE CAUTION AND WARNING SYSTEM IN LESS THAN 15 SECONDS. THE LOWER ENTRY SAFETY FACTORS WILL NOT RESULT IN LOSS OF VEHICLE; HOWEVER, STRUCTURAL DAMAGE WILL LIKELY OCCUR AND WILL REQUIRE THE VEHICLE TO BE TAKEN OUT OF SERVICE FOR THOROUGH INSPECTION AND REFURBISHMENT AS NECESSARY.

ON THE GROUND

ON THE GROUND, REACTIVE CONTROL SOFTWARE LOGIC (LPS) TO ISOLATE A FAILED OPEN REGULATOR IS ACTIVE WHEN PERSONNEL ARE IN THE AFT COMPARTMENT.

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

(C) MISSION:
POSSIBLE LAUNCH SCRUB DUE TO LCC VIOLATION.

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(D) CREW, VEHICLE, AND ELEMENT(S):
POSSIBLE LOSS OF CREW/VEHICLE.

(E) FUNCTIONAL CRITICALITY EFFECTS:
NONE.

-DISPOSITION RATIONALE-

(A) DESIGN:

THE RELIEF VALVE IS PILOT OPERATED AND PRESSURE ACTUATED. AS THE SENSE LINE PRESSURE EXCEEDS 790 PSIG THE INLET PRESSURE FORCE ON THE POPPET SEAT PISTON BECOMES GREATER THAN THE RESEATING FORCE OF THE BELLEVILLE SPRINGS. THE UNBALANCED FORCE CAUSES THE POPPET SEAT PISTON TO MOVE. THE PILOT SPRING CAUSES THE POPPET TO MOVE WITH THE SEAT PISTON UNTIL THE PILOT POPPET CONTACTS ITS UPPER SEAT. THE POPPET SEAT PISTON CONTINUES TO MOVE CAUSING SEPARATION BETWEEN THE POPPET SEAT PISTON AND THE PILOT POPPET.

PRESSURE MAINTAINING THE MAIN POPPET SEATED IS VENTED THROUGH THE UNSEATED PILOT POPPET INTO THE AFT FUSELAGE. A DIFFERENTIAL PRESSURE ACROSS THE MAIN POPPET IS CREATED FORCING THE MAIN POPPET TO UNSEAT. THIS RELIEVES INLET PRESSURES FROM 850 PSIG (MAXIMUM) DOWN TO 785 PSIG (MINIMUM RESEAT) INTO THE AFT FUSELAGE AT A RATE OF 1.0 LB/SEC (MINIMUM AT 850 PSIG).

AS THE SENSE LINE PRESSURE DECREASES, THE PRESSURE FORCE ON THE POPPET SEAT PISTON BECOMES LESS THAN THE RESEATING FORCE CAUSED BY THE BELLEVILLE SPRINGS. THIS UNBALANCED FORCE CAUSES THE POPPET SEAT PISTON TO MOVE INTO CONTACT WITH THE PILOT POPPET'S LOWER SEAT CAUSING THE PILOT POPPET TO LEAVE ITS UPPER SEAT. THIS ALLOWS INLET PRESSURE TO AUGMENT THE MAIN POPPET RETURN SPRING FORCE CLOSING THE VALVE. ONCE SEATED, THE POPPET IS HELD CLOSED BY THE DIFFERENTIAL PRESSURE ACROSS THE MAIN POPPET AND BY THE MAIN POPPET RETURN SPRING FORCE. THE PILOT VENT CLOSES BY SPRING FORCE TO SEAL AGAINST CRYO PUMPING.

THE RELIEF VALVE ALSO INCORPORATES A FAST SENSING POPPET TO CONTROL THE RATE AT WHICH UPSTREAM PRESSURE IS SENSED. THIS FAST SENSING POPPET IS CONNECTED TO THE MAIN PRESSURIZATION LINE BY A 0.25 INCH (OUTER DIAMETER) TUBE. UNDER STEADY STATE CONDITIONS, INLET PRESSURE IS SENSED THROUGH ORIFICES IN BOTH THE INLET PORT AND THE FAST SENSING POPPET. INSTANTANEOUS PRESSURE RISES THAT EXCEED 775 PSIG UNSEAT THE FAST SENSING POPPET EXPOSING FOUR ADDITIONAL LARGER ORIFICES IN THE POPPET. THIS INCREASES THE RATE OF RELIEF VALVE RESPONSE. WHEN THE PRESSURE DECREASES TO A PREDETERMINED DIFFERENTIAL ACROSS THE FAST SENSING POPPET, SPRING FORCE RESEATS THE POPPET, THUS DAMPENING VALVE RESPONSE.

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STRUCTURAL FAILURE OF ANY OF THE FOLLOWING PARTS WILL CAUSE A FAILURE TO REMAIN CLOSED. BELLEVILLE SPRINGS (FOUR, NI-SPAN-C), BELLEVILLE SPRING RETAINERS (INNER AND OUTER, ALUMINUM ALLOY 6061-T6511), PILOT POPPET (VESPEL SP21), PILOT POPPET RETURN SPRING (302 CRES), MAIN POPPET (ALUMINUM ALLOY 6061-T651), MAIN POPPET RETURN SPRING (ELGILOY), VENT CHECK DISC (302 CRES HALF HARD, TEFLON COATED), AND VENT CHECK SPRING (302 CRES). THE VALVE HAS A MINIMUM USEFUL LIFE OF 2000 CYCLES (100 ORBITER MISSION EQUIVALENT). FACTORS OF SAFETY ARE 2.0 PROOF AND 4.0 BURST. STRUCTURAL ANALYSES INDICATE 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.

THE RELIEF VALVE IS PROTECTED FROM CONTAMINATION BY A 25 MICRON ABSOLUTE FILTER UPSTREAM OF THE RELIEF VALVE. THE RELIEF VALVE IS CLEANED TO LEVEL 100A. HELIUM LOADED TO THE VEHICLE IS ALSO FILTERED BY GROUND SYSTEMS. THE PILOT MECHANISM IS PROTECTED BY A 25 MICRON ABSOLUTE FILTER AND A 10 MICRON ABSOLUTE FILTER IN SERIES IN THE VALVES INTERIOR.

BINDING OF THE PILOT SEAT PISTON, THE PILOT POPPET, AND THE MAIN POPPET WOULD CAUSE A FAILURE TO RESEAT. THE PILOT SEAT PISTON AND THE MAIN POPPET ARE GUIDED BY VESPEL 21 BEARINGS LUBRICATED WITH MOLYCOTE DRY LUBRICANT. ANALYSIS PERFORMED BY THE SUPPLIER SHOWS POSITIVE CLEARANCES AT THE BEARING INTERFACES. THE PILOT POPPET FLOATS FREELY WITHIN ITS CAVITY. IT IS HELD IN POSITION BY A RETURN SPRING AND ONLY MAKES CONTACT WITH ITS SEALING SURFACES.

THE VALVE BODY CONSISTS OF THREE ALUMINUM ALLOY 6061-T651 PARTS: THE HOUSING, THE END CAP, AND THE SEAT RETAINER. THE POTENTIAL LEAK PATHS ARE THE HOUSING/END CAP INTERFACE AND THE HOUSING/SEAT RETAINER INTERFACE. THE HOUSING/END CAP AND THE HOUSING/SEAT RETAINER INTERFACES ARE SEALED USING RAYCO TYPE SEALS. THE SEALS USE CRES 302 SPRINGS WITH TEFLON (TFE) JACKETS. THE SEAL GLANDS ARE MACHINED INTO THE HOUSING WITH AN 8 MICROINCH SURFACE FINISH. THE END CAP IS THREADED INTO THE HOUSING AND TORQUED TO 630 IN-LB BEFORE BEING LOCK WIRED TO THE HOUSING. THE RETAINER IS ATTACHED TO THE HOUSING USING SIX 19-32 CRES A286 SOCKET HEAD CAP SCREWS WITH A MINIMUM ULTIMATE TENSILE STRENGTH OF 160 KSI (NAS 1351). THESE CAP SCREWS ARE TORQUED TO 45 IN-LB BEFORE BEING LOCK WIRED TO EACH OTHER. FLAT AND LOCK WASHERS ARE USED WITH THE SCREWS.

RUPTURE OF THE INCONEL 718 BELLOWS (1 PLY) WOULD CAUSE EXTERNAL LEAKAGE. THE BELLOWS ACTS AS A LEAK BARRIER BETWEEN THE POPPET SEAT PISTON AND THE ATMOSPHERE. ALL BELLOWS ARE ACCEPTANCE TESTED BY THE SUPPLIER BEFORE BEING ASSEMBLED INTO THE RELIEF VALVE. BELLOWS ACCEPTANCE TESTS INCLUDE 200 MECHANICAL CYCLES AT -160 THROUGH 275 DEG F WHILE PRESSURIZED TO 850 PSIG EXTERNAL PRESSURE; PROOF PRESSURE TESTS TO 1700 PSIG; AND LEAKAGE TEST AT 1035 PSIG EXTERNAL PRESSURE.

RUPTURE OF THE 6061-T651 ALUMINUM MAIN POPPET WOULD CAUSE EXTERNAL LEAKAGE. THE VALVE HAS BEEN PROOF PRESSURE TESTED DURING ATP TO 1750 PSIG WITHOUT DAMAGE OR DISTORTION. IT HAS ALSO BEEN BURST PRESSURE TESTED TO 3400 PSIG DURING CERTIFICATION WITHOUT RUPTURE.

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THE FACTORS OF SAFETY ARE 2.0 PROOF AND 4.0 BURST. STRUCTURAL ANALYSES INDICATE 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.

THE -0006 850 PSIG RELIEF VALVE IS THE SAME AS THE -0004 AND -0005, EXCEPT THAT THE BELLEVILLE SPRING MATERIAL WAS CHANGED FROM NI-SPAN-C TO MARAGING STEEL GRADE 250. THE CRACK AND RESEAT PRESSURES CHANGED, AND NOW THE -0006 PILOT SHALL CRACK AT 800 PSIG AND RESEAT AT 795 PSIG OR HIGHER (PREVIOUSLY 790 PSIG AND 785 PSIG).

(B) TEST:

ATP

EXAMINATION OF PRODUCT

PROOF PRESSURE (1,750 PSIG)

INTERNAL LEAKAGE (GHE)

AMBIENT TEMPERATURE

INLET PRESSURES: 100, 500, 750, AND 785 PSIG

FUNCTIONAL TESTS

PILOT CRACK AND RESEAT

AMBIENT TEMPERATURE

CRACK 790 PSIG, RESEAT 785 PSIG

LOW TEMPERATURE (BODY: -75 DEG F OR COLDER)

INLET PRESSURES: 100, 500, 750, AND 785 PSIG

CRACK 790 PSIG, RESEAT 785 PSIG

SLAM START TESTS

(ORIFICE INSTALLED IN INLET LINE TO LIMIT FLOW TO 1.0 LB/SEC)

AMBIENT BODY TEMPERATURE (HELIUM AT 220 DEG F)

PRESSURE UPSTREAM OF THE ORIFICE:

4500 PSIG, FOLLOWED BY FULL FLOW, BLOW DOWN, AND RESEAT

2500 PSIG, FOLLOWED BY BLOWDOWN, AND RESEAT PRESSURE DOWNSTREAM OF THE

ORIFICE: NO GREATER THAN 850 PSIG

ELECTRICAL BONDING

CERTIFICATION

VIBRATION

TRANSIENT VIBRATION:

5 TO 35 HZ, Ñ0.25 G, IN EACH OF THREE AXES

RANDOM VIBRATION:

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60 MINUTES IN EACH OF THREE AXES

DURING THE LAST 5 MINUTES OF TESTING IN EACH AXIS CRACK AND RESEAT PRESSURE TESTS ARE PERFORMED.

PERFORM LEAK AND FUNCTIONAL TESTS AFTER EACH AXIS

DESIGN SHOCK
PER MIL-STD-810 IN EACH OF THREE AXES
PERFORM LEAK AND FUNCTIONAL TESTS AFTER EACH AXIS

SAND AND DUST
PER MIL-STD-810

THERMAL CYCLE (3 CYCLES, NO FLOW)
+70 DEG F TO -150 DEG F TO +250 DEG F TO +70 DEG F
INLET PRESSURE: 750 PSIG
PERFORM LEAK AND FUNCTIONAL TESTS

LIFE CYCLE (2000 CYCLES, 850 PSIG TO RESEAT)
CRACK AND RESEAT AND SLAM START TESTS AFTER EACH 400 CYCLES
PERFORM LOW TEMPERATURE LEAK AND FUNCTIONAL TESTS

BURST TEST (3400 PSIG)

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. PART PROTECTION COATING AND PLATING REQUIREMENTS ARE VERIFIED BY INSPECTION.

CONTAMINATION CONTROL
CLEANLINESS TO LEVEL 100A IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION
ALL CRITICAL DIMENSIONS ARE VERIFIED BY INSPECTION. TORQUE PER DRAWING REQUIREMENT IS VERIFIED BY INSPECTION. SURFACE FINISHES AND SURFACES REQUIRING CORROSION PROTECTION ARE VERIFIED BY INSPECTION. ALL SEALING SURFACES AND SEALS ARE VISUALLY EXAMINED BEFORE INSTALLATION USING 10X MAGNIFICATION. DRY FILM LUBRICANT AND ELECTROCHEMICAL ETCH MARKING IS VERIFIED BY INSPECTION. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE INSPECTION PROCEDURE.

CRITICAL PROCESSES
WELDING, HEAT TREATMENT, PARTS PASSIVATION, AND ANODIZING ARE VERIFIED.

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NONDESTRUCTIVE EVALUATION
HELIUM LEAK TEST IS VERIFIED BY INSPECTION.

TESTING
ATP VERIFIED BY INSPECTION.

HANDLING/PACKAGING
PACKAGING FOR SHIPPING IS VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:

SEVERAL CASES OF LEAKAGE OCCURRED DURING ATP (REFERENCE CAR A9866). WAIVERS WERE INITIATED TO USE THESE COMPONENTS ON THE MPTA ONLY. THE SUPPLIER'S CONTRACT WAS CANCELED AND AWARDED TO A NEW CONTRACTOR WITH A NEW DESIGN. RELIEF VALVES WERE REPLACED BY THE NEW DESIGN.

DURING QUALIFICATION, EXCESSIVE RESEAT LEAKAGE WAS DETECTED (REFERENCE CAR AB0190). THE PROCUREMENT SPECIFICATION WAS REVISED TO INCREASE THE MAXIMUM ALLOWABLE LEAKAGE FROM 10 SCIM TO 30 SCIM.

LEAKAGE WAS OBSERVED ON SEVERAL UNITS AFTER INSTALLATION AND DURING CHECKOUT AT DOWNEY AND KSC (REFERENCE CAR'S AB1468, AB1470, AB4810). THE FAILURES WERE ATTRIBUTED TO CONTAMINATION FROM THE SYSTEM GENERATED DURING INSTALLATION OF THE COMPONENTS. A COMPLETE RE-INSPECTION OF THE PANELS, PLUMBING AND FITTINGS WAS DONE TO INSURE CLEANLINESS. A FILTER WAS ADDED INTERNAL TO THE RELIEF VALVE TO SCREEN THE HELIUM FLOWING THROUGH THE PILOT POPPET/SEAT ASSEMBLY.

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:

PNEUMATIC TANK, REGULATOR, AND ACCUMULATOR PRESSURE ARE ON S/M ALERT FDA SYSTEM AND THE BFS SYSTEM SUMMARY DISPLAY. THIS ALLOWS THE FLIGHT CREW TO RESPOND TO A PNEUMATIC HELIUM SYSTEM LEAK INDEPENDENT OF GROUND CONTROL.

- 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	: CHARLES EBERHART	:/S/ CHARLES EBERHART
MPS SUBSYSTEM MGR.	: TIM REITH	:/S/ TIM REITH
MOD	: JEFF MUSLER	:/S/ JEFF MUSLER
USA SAM	: MIKE SNYDER	:/S/ MIKE SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	:/S/ SUZANNE LITTLE
NASA SR&QA	: BILL PRINCE	:/S/ BILL PRINCE