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 **VENDOR NAME**	**PART NUMBER** **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.

FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE

NUMBER: 03-1-0251-02

REVISION#: 2 07/25/00

SUBSYSTEM NAME: MAIN PROPULSION
LRU: VALVE, RELIEF, 850 PSI **CRITICALITY OF THIS**
ITEM NAME: MPS PNEU SUPPLY 850 PSI RELIEF VALVE (RV4) **FAILURE MODE:** 1R2

FAILURE MODE:
FAILS TO RELIEVE

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, SENSE LINE RUPTURE.

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN
A) FAIL
B) N/A
C) FAIL

PASS/FAIL RATIONALE:
A)
FAILS A SCREEN BECAUSE GROUND CHECKOUT WOULD REQUIRE INVASIVE TESTING. NO PROVISIONS EXIST TO CONNECT A FLOW METER TO THE RELIEF VALVE MAIN VENT FOR HIGH FLOW RATE TESTING (1 LB/SEC). ALSO, INVASIVE PROCEDURES WOULD BE REQUIRED TO PROVIDE SUFFICIENT PRESSURE AND FLOW TO THE INLET OF THE RELIEF VALVE TO SIMULATE A REGULATOR FAILURE.

B)
SCREEN B IS N/A BECAUSE THE RELIEF VALVE IS STANDBY REDUNDANT TO THE UPSTREAM REGULATOR FAILS HIGH.

C)
FAILS C SCREEN BECAUSE CONTAMINATION CAN CAUSE THE REGULATOR TO REGULATE HIGH AND THE RELIEF VALVE TO FAIL TO RELIEVE.

- FAILURE EFFECTS -

(A) SUBSYSTEM:

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL **FAILURE MODE NUMBER: 03-1-0251-02**

NO EFFECT FOR THE FIRST FAILURE BECAUSE THE UPSTREAM REGULATOR WOULD HAVE TO REGULATE HIGH BEFORE THE RELIEF VALVE IS REQUIRED.

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

(C) MISSION:
NO EFFECT.

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

(E) FUNCTIONAL CRITICALITY EFFECTS:
1R/2 2 SUCCESS PATHS. TIME FRAME - PRELAUNCH, ASCENT.
1) RELIEF VALVE FAILS TO FUNCTION.
2) REGULATOR OUTLET PRESSURE HIGH.

RESULTS IN RUPTURE OF LINE DOWNSTREAM OF REGULATOR DUE TO PRESENCE OF HIGH PRESSURE HELIUM (DESIGN BURST OF 3000 PSI). POSSIBLE OVERPRESSURIZATION OF THE AFT COMPARTMENT. RESULTS IN LOSS OF HELIUM FROM THE PNEUMATIC HELIUM SUPPLY UNLESS BOTH THE HELIUM ISOLATION VALVES ARE CLOSED.

THE ENGINE 1 AND 3 HELIUM SUPPLIES WILL ALSO BE REDUCED IF THE FAILURES OCCUR WHILE THE INTERCONNECT "OUT" VALVES (LV60, 64) ARE OPEN (20 SECONDS AFTER MECO). HELIUM MAY NOT BE AVAILABLE FOR AFT COMPARTMENT PURGE (RTLS AND TAL ABORT CRITICAL).

IF A SYSTEM RUPTURE/LEAKAGE OCCURS UPSTREAM OF CV9, HELIUM TRAPPED IN THE ACCUMULATOR LEG OF THE PNEUMATIC SYSTEM SHOULD BE ADEQUATE FOR LO2 PREVALVE CLOSURE AT MECO. LOSS OF HELIUM WILL MAKE REPRESSURIZATION FOR MPS DUMP IMPOSSIBLE. THE PROPELLANT RELIEF SYSTEM WILL PROTECT AGAINST PROPELLANT MANIFOLD RUPTURE. VENTING OF PROPELLANTS DURING AN ABORT ENTRY WILL ALSO CREATE A FIRE/EXPLOSION HAZARD.

IF A SYSTEM RUPTURE/LEAKAGE OCCURS DOWNSTREAM OF CV9, HELIUM TRAPPED IN THE ACCUMULATOR LEG OF THE PNEUMATIC SYSTEM WILL LEAK OUT CAUSING INABILITY TO CLOSE LO2 PREVALVES AT MECO. POSSIBLE UNCONTAINED ENGINE DAMAGE AND FIRE/EXPLOSION DUE TO SSME HPOT OVERSPEED.

EXCESSIVE HELIUM LEAKAGE WILL BE DETECTABLE USING HAZARDOUS GAS DETECTION SYSTEM (HGDS).

AFTER LIFTOFF, HELIUM TANK AND/OR REGULATOR PRESSURE ANOMALIES WILL NOT BE INDICATED BY SM ALERT OR CAUTION AND WARNING.

POSSIBLE LAUNCH SCRUB DUE TO LCC VIOLATION. POSSIBLE LOSS OF CREW/VEHICLE.

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL **FAILURE MODE NUMBER: 03-1-0251-02**

-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.

THE SENSE LINE IS 0.25 INCH (OUTER DIAMETER) 21-6-9 CRES TUBING. RUPTURE OF THIS LINE WOULD CAUSE THE RELIEF VALVE TO FAIL TO RELIEVE. BOTH SENSE PATHS PRESSURIZE THE SAME SENSING CAVITY. THE CHECK VALVE IN THE FAST SENSE LINE HAS A SMALL BLEED ORIFICE THAT ALLOWS BOTH SENSE PATHS TO VENT INTO THE AFT COMPARTMENT. HOWEVER, PRESSURE WOULD BE RELIEVED THROUGH THE RUPTURED SENSE LINE AT A LOW RATE.

STRUCTURAL FAILURE OF THE FOLLOWING PARTS WILL CAUSE A FAILURE TO RELIEVE: PILOT POPPET RETURN SPRING (302 CRES), MAIN POPPET RING SEAL (TEFLON TFE), PILOT

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL **FAILURE MODE NUMBER: 03-1-0251-02**

SEAT PISTON RING SEAL (VESPEL 21), VENT CHECK DISC (302 CRES HALF HARD, TEFLON COATED), AND THE BELLOWS ASSEMBLY.

THE BELLOWS (1 PLY) IS INCONEL 718 AND 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.

STRUCTURAL FAILURE OF THE MAIN POPPET OR PILOT SEAT PISTON RING SEALS WOULD RESULT IN EXCESSIVE LEAKAGE PAST THE SEALS PREVENTING THE RELIEF VALVE FROM RELIEVING. LEAKAGE PAST EITHER RING SEAL WOULD PREVENT A PRESSURE DIFFERENTIAL ACROSS THE PISTONS. NO MOVEMENT OF THE PISTON WOULD BE POSSIBLE. EACH PISTON HAS REDUNDANT RINGS WHICH ARE INSTALLED TO MINIMIZE POTENTIAL LEAK PATHS AND SPRING LOADED TO MAINTAIN POSITIVE FORCE AGAINST THE HOUSING BORE (SLIDING SURFACE). THE HOUSING BORE HAS AN 8 MICRO INCH SURFACE FINISH AND IS DRY LUBRICATED TO PREVENT SEAL EROSION.

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.

BINDING OF THE PILOT SEAT PISTON, THE PILOT POPPET, THE PILOT POPPET RETURN SPRING, AND THE MAIN POPPET WOULD CAUSE A FAILURE TO RELIEVE. 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 THE PILOT POPPET RETURN SPRING AND ONLY MAKES CONTACT WITH ITS SEALING SURFACES. CONTAMINATION MAY CAUSE BINDING OF THE MAIN POPPET.

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.

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

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL **FAILURE MODE NUMBER: 03-1-0251-02**

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, +/- 0.25 G, IN EACH OF THREE AXES

RANDOM VIBRATION:

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

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL **FAILURE MODE NUMBER: 03-1-0251-02**

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.

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 INSTANCES OF HIGH CRACKING PRESSURE (RANGING FROM 853 - 859 PSIG) OCCURRED DURING ATP (REFERENCE CAR'S A5905, AB0237, AB1294, AB6752). IMPROPER SHIMMING DURING MANUFACTURING, LEAKAGE PAST THE PISTON SEALS, AND/OR SHIFT OF CRACKING PRESSURE AT LOW TEMPERATURE WAS DETERMINED TO BE THE CAUSE.

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL **FAILURE MODE NUMBER: 03-1-0251-02**

RESHIMMING RESOLVED THE PROBLEM. THE PROCUREMENT SPECIFICATION WAS REVISED TO INCREASE THE CRACKING PRESSURE FROM 850 PSIG TO 860 PSIG DURING LOW TEMPERATURE ATP.

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 ACTUATION HELIUM BOTTLE PRESSURE IS ON A DEDICATED DISPLAY IN COCKPIT. CREW ACTION IS TO FOLLOW NORMAL LEAK ISOLATION PROCEDURE. PRIOR TO MECO, ISOLATION VALVES (LV7, LV8) WILL BE REOPENED AND THE LEFT ENGINE HELIUM CROSSOVER VALVE (LV10) WILL BE OPENED.

- 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