

SHUTTLE CRITICAL ITEMS LIST - ORBITER

SUBSYSTEM : FWD - REACTION CONTROL FMEA NO 03-2F -101030-1 REV: 04/05/88

ASSEMBLY : PRESSURIZATION CRIT. FUNC: 13
P/N RI : MC284-041B-0011,-0012 CRIT. HDW: 3
P/N VENDOR: 74339000-011,-012 VEHICLE 102 103 104
QUANTITY : 4 EFFECTIVITY: X X X
: TWO PARALLEL, SERIES PHASE(S): PL X LO X OO X DO X LS X
: REDUNDANT UNITS PER TANK

REDUNDANCY SCREEN: A-PASS B-FAIL C-PASS
PREPARED BY: APPROVED BY: APPROVED BY (NASA):
DES R GONZALEZ DES R. D. Pugh SSM R. D. Pugh
REL R P DIEHL REL F. P. B... REL F. P. B...
QE W J SMITH QE W. J. Smith QE W. J. Smith

ITEM:
REGULATOR PRESS, HE SERIES REDUNDANT. SET AT UNEQUAL OUTLET PRESSURES (PR 101/102/103/104).

FUNCTION:
TO REGULATE STORED HELIUM PRESSURE FROM 4000 PSIG MAX TO ULLAGE PRESSURE OF 245 (+ OR - 4) PSIG FOR PURPOSE OF PROPELLANT FEED TO THRUSTERS. TWO PARALLEL PATHS WITH TWO SERIES REGS ARE PROVIDED FOR EACH PROPELLANT TANK. PRIMARY ELEMENT SET 11 PSI LOWER THAN SECONDARY (PRIMARY - 245 PSI, SECONDARY - 256 PSI).

FAILURE MODE:
FAILS OPEN, LEAKS INTERNALLY.

CAUSE(S):
CORROSION, FROZEN MOISTURE, CONTAMINATION, VIBRATION, PILOT OR MAIN POPPET SPRING FAILURE, GALLING OF PISTON/STEM, PLUGGED RESTRICTOR ORIFICES, CONTAMINATED INLET PILOT FILTER, CHECK VALVE, PROPELLANT DECOMPOSITION/CONTAMINATION.

EFFECT(S) ON:
(A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE
(A) LOSS OF REDUNDANCY (1 SERIES STAGE) - RISE IN ULLAGE PRESSURE TO SECONDARY PRESSURE (256 PSI). MIXTURE RATIO SHIFT. CONTAMINATION CAN CAUSE BOTH STAGES TO FAIL OPEN.
(B) NO EFFECT.
(C) MISSION MOD MAY BE REQUIRED.
(D) NO EFFECT.

SHUTTLE CRITICAL ITEMS LIST - ORBITER

SUBSYSTEM : FWD - REACTION CONTROL FMEA NO 03-2F -101030-1 REV:04/18.88

(E) FUNCTIONAL CRITICALITY EFFECT - POSSIBLE EARLY MISSION TERMINATION OR POSSIBLE CREW/VEHICLE LOSS DUE TO INABILITY TO SEPARATE ORBITER FROM ET. FAILS TO UTILIZE/DEplete PROPELLANT IF MOST OF PRESSURANT IS DEPLETED THROUGH RELIEF VALVE. POSSIBLE RUPTURE OF PROPELLANT TANK IF BOTH PRIMARY AND SECONDARY REGULATORS FAILED OPEN, AND RELIEF VALVE OR BURST DISK FAILS TO RELIEVE. UNABLE TO VERIFY A FAILED OPEN SECONDARY REGULATOR BECAUSE OF HIGHER SET POINT THAN PRIMARY REGULATOR.

DISPOSITION & RATIONALE:

(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY (E) OPERATIONAL USE

(A) DESIGN

SERIES REGULATORS LIMIT IMPACT OF LEAKAGE OR OPEN FAILURES. RELIEF VALV PREVENTS PROPELLANT TANK OVERPRESSURIZATION SHOULD DUAL REGULATOR FAILURE OCCUR. 25 MICRON INLET FILTER AND 10 MICRON PILOT FILTER IS PROVIDED TO LIMIT THE POSSIBILITY OF CONTAMINATION.

MULTI-PLY BELLOWS ARE UTILIZED TO LIMIT RUPTURE FAILURE CAUSING REG TO OPEN. CHECK VALVES LIMIT POTENTIAL FOR PROPELLANT MIGRATION TO THE REGULATOR. MANUAL ISOLATION VALVES ARE BEING CLOSED TO PROVIDE FOR ADDITIONAL VAPOR MIGRATION PROTECTION DURING INACTIVE GROUND PERIODS.

(B) TEST

THE QUALIFICATION TEST PROGRAM INCLUDED PROOF TEST (6000 PSI) AND BURST TEST (8000 PSI), LIFE CYCLES (100,000 CYCLES-PILOT STAGE AND 50,000 CYCLES MAIN STAGE), THERMAL CYCLING (-30 TO +155 DEG F), RANDOM VIBRATION, FUNCTIONAL TESTING, PARALLEL OPERATION AND PROPELLANT EXPOSURE (MATERIAL COMPATIBILITY VERIFIED).

THE REG WAS ALSO QUALIFIED AS PART OF THE POD ASSEMBLY DURING VIBRO-ACOUSTIC TEST AT JSC (131 EQUIVALENT MISSIONS) AND HOT-FIRE TEST PROGRAM AT WSTF INCLUDED 24 EQUIVALENT MISSION DUTY CYCLES AND APPROXIMATELY 7 YEARS PROPELLANT EXPOSURE.

ACCEPTANCE TESTING INCLUDES PROOF PRESSURE, OPERATING PRESSURE, SET POINT VERIFICATION, FUNCTIONAL, BLOWDOWN (THERMAL), INTERNAL LEAKAGE, CLEANLINESS AND DRYING, AND TESTING OF THE SENSE RESPONSE IN FULL UP ASSEMBLY.

OMRSD PERFORMS THE FOLLOWING: REGULATOR LEAK/FUNCTIONAL TESTS PRIOR TO EACH FLIGHT AND THEREAFTER ON A CONTINGENCY BASIS. MOISTURE CONTENT VERIFICATION AFTER THE FIRST FLIGHT AND THEREAFTER ON A CONTINGENCY BASIS. HE SYSTEM SAMPLE BEFORE THE THIRD FLIGHT AND THEREAFTER EVERY THIRD FLIGHT AND A CONTINGENCY BASIS IF EXCESSIVE PROPELLANT VAPOR OR MOISTURE IS SUSPECTED. HE SYSTEM ACTIVATION EACH FLIGHT. HE SERVICING TO FLIGHT LOADS FOR EACH FLIGHT. RCS HE OFF-LOADING FOR FWD AND APT FOR THE SECOND FLIGHT AND EACH FLIGHT THEREAFTER, THIS INCLUDES CLOSING THE MANUAL VALVE. A REGULATOR RESPONSE CHECK BEFORE EVERY FLIGHT. LOW PRESSURE REGULATOR RESPONSE TESTS ON A CONTINGENCY BASIS.

SHUTTLE CRITICAL ITEMS LIST - ORBITER

SUBSYSTEM : FWD - REACTION CONTROL FMEA NO 03-2F -101030-1 REV: 04/05/88

(C) INSPECTION

RECEIVING INSPECTION

INSPECTION VERIFIES MATERIALS AND PHYSICAL PROPERTIES. CERTIFICATION, MATERIAL, AND HEAT TREATMENT ARE VERIFIED BY INSPECTION.

CONTAMINATION CONTROL

CLEANLINESS TO LEVEL 100A IS VERIFIED BY INSPECTION. CORROSION PROTECTION IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

PISTONS ARE DIMENSIONALLY INSPECTED AND PISTON ASSEMBLY IS VERIFIED BY INSPECTION. TORQUING IS VERIFIED BY INSPECTION. SURFACE FINISH OF POPPET AND MAIN SPRING IS VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

PENETRANT INSPECTION OF THE MAIN BELLOWS WELDS AND OF THE HOUSING FORGINGS AT THE FORGING LEVEL IS VERIFIED BY INSPECTION.

CRITICAL PROCESSES

VISUAL INSPECTION OF THE TUNGSTEN INERT GAS (TIG) WELDS WITHIN THE PILOT ACTUATOR ASSEMBLY AND WITHIN THE PILOT POPPET ASSEMBLY ARE VERIFIED BY INSPECTION. ADDITIONAL TIG WELD INSPECTIONS INCLUDE THE WELDS THAT JOIN THE TUBING, BOTTOM CAPS, PILOT POPPET ASSEMBLY, PILOT ACTUATOR ASSEMBLY, AND THE MAIN BELLOWS TO THE BODY. THE ELECTRON BEAM (EB) WELDS OF THE PILOT ACTUATOR BELLOWS INTO THE PILOT ACTUATOR ASSEMBLY ARE VERIFIED BY INSPECTION. THE PROOF PRESSURE TEST/LEAK TEST PROVIDES FURTHER VERIFICATION OF THE WELD INTEGRITY. HEAT TREATMENT OF THE DETAIL PARTS, INCLUDING THE HOUSING FORGING TO DRAWING REQUIREMENTS IS VERIFIED BY INSPECTION. THE FORGING SUPPLIER CERTIFIES THAT THE HOUSING FORGINGS MEET THE REQUIREMENTS OF MIL-F-7190, AMENDMENT 1, GRADE A. TESTING OF EACH FORGING LOT FOR CHEMISTRY, AFTER HEAT-TREATMENT HARDNESS AND AFTER HEAT-TREATMENT TENSILE STRENGTH IS VERIFIED BY INSPECTION. CADMIUM PLATING OF BELLEVILLE WASHERS TO DRAWING REQUIREMENTS IS VERIFIED BY INSPECTION.

TESTING

ATP IS WITNESSED AND VERIFIED BY INSPECTION.

HANDLING/PACKAGING

RETURNED AND ACCEPTED GOODS ARE PLACED IN BONDED AREA. PACKAGING IS VERIFIED BY INSPECTION.

(D) FAILURE HISTORY

THERE WAS ONE FLIGHT FAILURE ON OV102 WHERE THE LOCKUP PRESSURE SHIFTED 100 PSI HIGH DUE TO A SHIFT OF BELLEVILLE SPRINGS IN THEIR GROOVE (REF CAR 02F011). THE SUPPLIER ADDED AN INSPECTION POINT TO ASSURE THAT THE BELLEVILLE SPRINGS HAVE THE PROPER CLEARANCE.

SHUTTLE CRITICAL ITEMS LIST - ORBITER

SUBSYSTEM : FWD - REACTION CONTROL FMEA NO 03-2F--101030-1 REV: 04/02/88

THERE HAVE BEEN TWO FLIGHT LEAKAGE FAILURES OF OXIDIZER REGULATORS WHICH DID NOT REPEAT DURING GROUND TURNAROUND (REF CAR'S 09F022 AND 32F007). ONE FLIGHT FUEL LEAKAGE REGULATOR FAILURE (REF 17F012) WAS ALSO NOT VERIFIED DURING GROUND TURNAROUND. CAR'S AC6471, AC4422, AC5495 AND AC7463 ARE ON FOUR DIFFERENT FUEL REGULATORS THAT LEAKED DURING FLIGHT OR DURING HELIUM PRESSURIZATION PRIOR TO FLIGHT.

DECOMPOSED MMH DEPOSITS WERE FOUND IN THREE OF THE REGULATORS THAT WERE REMOVED. THE THIRD REGULATOR IS STILL INSTALLED AND REPORTED CREEPING (REF CAR AD1951). ANOTHER FUEL REGULATOR ON OV099 WAS REPORTED LEAKING DURING SYSTEM PRESSURIZATION AND IS REPEATED AGAIN DURING SUCCEEDING FLIGHTS AND GROUND TURNAROUND. (REF CAR AC6471, DR AC7464, AND CAR AC9623 AND DR A0493) THE REGULATOR WAS REMOVED, BUT FAILURE WAS NOT VERIFIED AT THE SUPPLIER ALTHOUGH IT DID HAVE MMH VAPOR FUMES IN IT. IT WAS SUBSEQUENTLY ATP'G AND REINSTALLED INTO OV103 RIGHT POD WHERE THE PRIMARY STAGE SHOWED A SLIGHT DROOP (REF CAR AD1264) WHICH WAS NOT VERIFIED IN SUBSEQUENT RE-TEST. NOTE THE PARALLEL REGULATOR INSTALLED AT SAME TIME WAS REMOVED FOR THE SAME FAILURE MODE (REF CAR AD1222 AND FMEA 03-02A-201030-2).

TWO OTHER KSC CHECKOUT FUEL REGULATOR LEAKAGES OR CREEPAGE FAILURES (REF CAR ADO089 <DESTROYED IN 51L> AND AD1881) HAVE BEEN BOUGHT BY WAIVERS OR DID NOT REPEAT.

THREE OXIDIZER REGULATORS WHICH HAVE SLIGHTLY EXCEEDED THE LEAKAGE OR CREEPAGE TESTS REQUIREMENTS KSC CHECKOUT ARE STILL INSTALLED AND AWAITING ADDITIONAL CHECKOUT OR WAIVERS (REF DR'S ADO134 & AD1883, ON THE SAME REGULATOR, AD1882 AND AD1884).

TWO PARALLEL OXIDIZER REGULATORS FAILED LEAKAGE DURING THE OV102 MOD AT DOWNEY (REF CAR AC9134) AND WERE FOUND TO BE CORRODED DUE TO A MIXTURE OF N2O4 AND MOISTURE. IT IS ASSUMED THAT THE MOISTURE WAS INTRODUCED EITHER AT KSC OR DOWNEY DURING REMOVING OR REPLACING A COMPONENT IN THE SYSTEM (KSC HAD REPLACED THREE REGULATORS IN THIS SYSTEM PRIOR TO THE MODIFICATION PERIOD). TIGHTER MOISTURE CONTROLS HAVE BEEN ADDED TO THE OMRSD. THE HELIUM SYSTEM IS ALSO BEING SAMPLED FOR MOISTURE MORE FREQUENTLY. THE CORRECTIVE ACTION TO PRECLUDE PROPELLANT MIGRATION IS TO PURGE THE PRESSURIZATION SYSTEM AFTER LANDING TO REMOVE RESIDUAL PROPELLANT VAPORS AND CLOSING THE MANUAL VALVES AND LEAVING THEM CLOSED UNTIL PROPELLANT SERVICING. THIS PROCEDURE SHOULD ALSO LESSEN THE POSSIBILITY OF CONTAMINATING THE REGULATORS.

DURING CHECKOUT OF OV099'S AFT POD AT KSC PRIOR TO FIRST FLIGHT THE SECONDARY STAGE LOCKUP PRESSURE WAS 280 PSI (REF CAR AC4025-010). THE REGULATOR WAS GROSSLY CONTAMINATED WITH METALLIC CHIPS WHICH WAS LATER DISCOVERED TO COME FROM CUTTING A WELD DOWNSTREAM OF THE REGULATOR, WHICH WAS LOCATED VERTICALLY ABOVE THE REGULATOR DURING THE CUTTING OPERATION. IN THE MEAN TIME 9 OTHER REGULATOR LEAKAGE OR HIGH LOCKUP FAILURES WERE BEING EXPERIENCED ON OV099 AND OV103 PODS AT MDAC (REF CAR AC3830, AC3301, AC0778, AC4601, AC4676, AC4412, AC4418, AC4437, AC4854, AND AC8318). THE CORRECTIVE ACTION FOR THESE FAILURES WAS: (1) IMPROVE THE TEST PROCEDURES AT THE REGULATOR SUPPLIER TO ASSURE THAT THE REGULATORS WERE LEAK FREE DURING ATP. (NOTE A FACILITY VALVE LEAKING SLIGHTLY COULD

SHUTTLE CRITICAL ITEMS LIST - ORBITER

SUBSYSTEM : FWD - REACTION CONTROL FMEA NO 03-2F -101030-1 REV:04/08,88

PASS A MARGINAL LEAKING REGULATOR); (2) THE CLEANLINESS AND REWORK PROCEDURES WERE REVISED AT MDAC TO ASSURE THAT ALL LINES MET CLEANLINESS REQUIREMENTS PRIOR TO INSTALLING COMPONENTS. ALL WELD CUTS WOULD BE PURGED DURING CUTTING WITH A MAGNET ABOVE AND BELOW CUT. ALL LINES BEING CUT WOULD BE HORIZONTAL PRIOR TO CUT. OV104 PODS WERE BUILT WITHOUT INCIDENT.

DURING DOWNEY INSTALLATION AND CHECKOUT OF THE FRCS TWO REGULATORS WERE FOUND TO LEAK SLIGHTLY OVER SPECIFICATION ALLOWABLE (REF CAR'S AC1232 <OV099> AND AC7793 <OV104>). ONE REVEALED CONTAMINATION INTRODUCED FROM REVERSE FLOW. THE OTHER FAILURE WAS CAUSED BY PROTRUDING TEFLON IN THE MAIN SEAT INTERFERING WITH THE MAIN POPPET SEATING. CORRECTIVE ACTION FOR BACK FLOW WAS TO ADD CAUTION NOTES TO OMSRD AND SUBSYSTEM ASSEMBLY INSTRUCTION TO ELIMINATE BACK FLOW. THE SUPPLIER ADDED NOTES TO DRAWING TO CLARIFY THAT TEFLON SHOULD NOT EXTEND BEYOND THE RETAINER. THIS REQUIREMENT WAS TO BE VERIFIED BY A 20X MAGNIFICATION INSPECTION.

DURING QUALIFICATION LIFE TESTING THE REGULATOR LEAKED 3000 SCCH AFTER 6 AND 70K CYCLES BUT AT 80, 90 AND 100K CYCLES THE LEAKAGE WAS BACK IN SPECIFICATION (REF CAR AB3636). THE CAUSE OF LEAKAGE WAS ATTRIBUTED TO TRANSIENT CONTAMINATION.

THERE WERE ALSO 9 FAILURES OF EITHER LEAKAGE, HIGH LOCKUP OR CREEPY FAILURE MODE REPORTED FROM WSTF. ALL THESE WERE JUST SLIGHTLY OUT OF SPECIFICATION, AND REMAINED IN THE TEST ARTICLES, WHERE THEY FUNCTIONED UNTIL THE END OF THE TEST WHICH IS ALSO TYPICAL OF THE REGULATORS THAT HAVE BEEN WAIVERED FOR LEAKAGE ON FLIGHT VEHICLES.

(E) OPERATIONAL USE

OPS #2 SOFTWARE AUTOMATICALLY CLOSES THE HELIUM ISOLATION VALVE IN THE LEG CONTAINING THE FAILED OPEN REGULATOR. LOSS OF CAPABILITY MAY RESULT IN EARLY MISSION TERMINATION.

DURING LAUNCH AND RE-ENTRY THE CREW MAY NOT BE ABLE TO REACH THE HELIUM ISOLATION VALVE SWITCH, PRIOR TO LOSING EXCESSIVE HELIUM.