

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE****NUMBER: 03-1-0239 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 6 07/24/00**PART DATA**

	<b>PART NAME</b>	<b>PART NUMBER</b>
	<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU	: REGULATOR, 750 PSIG VACCO INDUSTRIES	MC284-0533-0006 73664-0006
LRU	:	
LRU	:	

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

PNEUMATIC HELIUM SUPPLY (PR4). 0.500 INCH DIAMETER INLET, 0.750 INCH DIAMETER OUTLET.

**REFERENCE DESIGNATORS:** PR4 - MPS PNEU REG**QUANTITY OF LIKE ITEMS:** 1**FUNCTION:**

REGULATES THE PNEUMATIC HELIUM SUPPLY PRESSURE OF 4500 - 900 PSIA DOWN TO 750 PSIG, WHICH IS THE NOMINAL OPERATING PRESSURE FOR THE MPS PNEUMATIC SYSTEM. THE DOWNSTREAM SYSTEM INCORPORATES A RELIEF VALVE TO PREVENT DOWNSTREAM OVERPRESSURIZATION IN EVENT THE REGULATOR FAILS HIGH.

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**REVISION#: 6 07/24/00**

**SUBSYSTEM NAME: MAIN PROPULSION**

**LRU: REGULATOR, 750 PSIG**

**CRITICALITY OF THIS**

**ITEM NAME: MPS PNEU SUPPLY 750 PSIG REGULATOR (PR4)**

**FAILURE MODE: 1R2**

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**FAILURE MODE:**

FAILS CLOSED/LOW OUTLET PRESSURE

**MISSION PHASE: LO LIFT-OFF**

<b>VEHICLE/PAYLOAD/KIT EFFECTIVITY:</b>	102	COLUMBIA
	103	DISCOVERY
	104	ATLANTIS
	105	ENDEAVOUR

**CAUSE:**

PIECE PART STRUCTURAL FAILURE, CONTAMINATION, BINDING

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

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**REDUNDANCY SCREEN**

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

**PASS/FAIL RATIONALE:**

A)

B)

FAILS B SCREEN BECAUSE DURING ASCENT THERE IS NO DEMAND ON THE PNEUMATIC SYSTEM AND THE REGULATOR OUTLET PRESSURE WILL NOT CHANGE. AT MECO, THE CROSSOVER VALVE (LV10) OPENS WHICH PREVENTS DETECTION OF A PRESSURE DROP IN THE PNEUMATIC REGULATOR OUTLET PRESSURE BY MAINTAINING CV8 CLOSED. AFTER MECO, THE PNEUMATIC HELIUM SUPPLY PRESSURE WILL DROP DUE TO THE FLOW DEMAND FOR PROPELLANT DUMP.

C)

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**- FAILURE EFFECTS -**

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**(A) SUBSYSTEM:**

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LOSS OF REDUNDANCY. REDUNDANT HELIUM SUPPLY THROUGH LV10 CAN PROVIDE PNEUMATIC ACTUATION SYSTEM REQUIREMENTS PRIOR TO VALVE ACTUATION FLOW DEMANDS.

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

**(C) MISSION:**  
SAME AS A.

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

**(E) FUNCTIONAL CRITICALITY EFFECTS:**  
1R/2 2 SUCCESS PATHS. TIME FRAME - PRELAUNCH, ASCENT.  
1) PNEUMATIC REGULATOR (PR4) FAILS CLOSED.  
2) CROSSOVER VALVE (LV10) FAILS TO OPEN/REMAIN OPEN.

THE HELIUM REGULATOR AND ACCUMULATOR PRESSURES ARE MONITORED BY THE LCC PRIOR TO T MINUS 31 SECONDS. FAILURE SUBSEQUENT TO COMPLETION OF OUTBOARD FILL AND DRAIN VALVE (PV9, 11) CLOSURES WILL NOT PREVENT LAUNCH. THERE SHOULD BE SUFFICIENT HELIUM REMAINING IN THE ACCUMULATOR LEG TO OPERATE THE LH2 PREVALVES PRIOR TO ENGINE START AND THEIR VALVE OPEN INDICATIONS WILL PASS THEIR LCC CHECKS AT T MINUS 7 SECONDS. ACTUATION OF VALVES PRIOR TO LIFT-OFF REDUCES THE PRESSURE OF THE GAS REMAINING IN THE ACCUMULATOR. AT MECO, IF LV10 DOES NOT REPLENISH THE ACCUMULATOR PRESSURE, THE REDUCED PRESSURE WILL NOT CLOSE THE LO2 PREVALVES WITHIN THE TIME REQUIRED BY THE ENGINE (0.95 +/- 0.20 SECONDS) AND UNCONTAINED ENGINE DAMAGE MAY RESULT.

POSSIBLE LOSS OF CREW/VEHICLE.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**  
THE HELIUM REGULATOR IS A PILOT OPERATED PRESSURE CONTROL VALVE THAT REGULATES HELIUM INLET PRESSURES FROM 4500 - 900 PSIA TO AN OUTLET PRESSURE BAND OF 705-775 PSIA FOR -0004 AND -0005 CONFIGURATION, 700- 770 PSIG FOR -0006 CONFIGURATION (750 PSI SET POINT). WHEN THE OUTLET PRESSURE FALLS BELOW 715 PSIA, THE BELLOWS/SPRING ASSEMBLY EXPANDS AND FORCES THE PILOT POPPET TO OPEN VIA THE PILOT SHAFT. THIS ALLOWS A PRESSURE DECREASE BEHIND THE MAIN POPPET CAUSING IT TO SLIDE TO THE OPEN POSITION. THE BELLOWS/DAMPER ASSEMBLY SENSES THE OUTLET PRESSURE AND CLOSSES WHEN THE OUTLET PRESSURE EXCEEDS 770 PSIA (765 PSIG FOR -0006 CONFIGURATION).

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A STRUCTURAL FAILURE OF THE BELLEVILLE SPRINGS, BELLEVILLE RETAINERS, DAMPER PISTON, OR THE PILOT SHAFT IN THE CAPSULE ASSEMBLY COULD CAUSE THE REGULATOR TO FAIL CLOSED. A FAILURE OF THIS TYPE WOULD DECREASE THE FORCE ON THE SHAFT OF THE PILOT POPPET PREVENTING THE PILOT POPPET FROM OPENING OR OPENING FULLY. THE DESIGN MINIMIZES THE PROBABILITY OF THIS TYPE OF FAILURE BY MAKING THE BELLEVILLE SPRINGS FROM ELGILOY (-0004 AND -0005 CONFIGURATION) AND MARAGING 250 STEEL FOR -0006 CONFIGURATION, THE RETAINERS FROM 6061-T651, THE DAMPER PISTON FROM 21-6-9 CRES, AND THE PILOT SHAFT FROM INCONEL 718. THE SPRING SEAT AREA IS LARGE ENOUGH TO PREVENT THE SPRING FROM SLIPPING OFF THE RETAINER. THE DAMPER PISTON IS MASSIVE RELATIVE TO THE PILOT SHAFT. THE PILOT SHAFT WAS REDESIGNED TO ACCEPT HIGHER LOADS AFTER A QUALIFICATION TEST FAILURE ON A -0003 UNIT. THE -0004 UNIT'S PILOT SHAFT FACTOR OF SAFETY IS NOW 3.69.

RESTRICTED POPPET MOVEMENT WOULD CAUSE A LOW OUTPUT FAILURE OF THE REGULATOR. THIS COULD BE DUE TO BINDING OF THE PILOT POPPET, THE MAIN POPPET RING AND GUIDE, OR THE DAMPER PISTON RING. RESTRICTED POPPET MOVEMENT COULD ALSO BE CAUSED BY GALLING/DAMAGE OF THE CAPSULE ASSEMBLY RETAINING RING. TO PREVENT THIS FAILURE THE SUPPLIER USES MOLY-KOTE DRY LUBE BETWEEN FINISHED 6061-T651 FOR PARTS THAT SLIDE AGAINST EACH OTHER AND ALSO USES VESPEL RINGS FOR THE POPPET AND DAMPER ASSEMBLIES. THESE PARTS ARE CLEANED, INSPECTED AND FUNCTIONALLY TESTED PRIOR TO SHIPMENT.

LOSS OF PRESSURE DIFFERENTIAL ACROSS THE MAIN POPPET RING CAN ALSO RESULT IN FAILURE OF THE MAIN POPPET TO STROKE. A TEFLON RING SEAL LOADED BY A WAVE SPRING IS USED TO MAINTAIN THE PRESSURE DIFFERENTIAL.

-0006 CONFIGURATION - LEAKAGE DUE TO BELLOWS FAILURE (I.E., CRACKED BELLOWS) THROUGH THE AMBIENT/VACUUM REFERENCE PORT CAN RESULT IN A DECREASE IN REGULATED PRESSURE AND LOSS OF HELIUM. THE -0004 AND -0005 BELLOWS INTERNAL CAVITY IS SEALED (ABSOLUTE PRESSURE REFERENCE) WHICH CAN RESULT IN A WIDE OPEN FAILURE WITH BELLOWS LEAKAGE.

CONTAMINATION CAN ALSO CAUSE A LOW OUTPUT FAILURE OF THE REGULATOR. ANY SLIDING ASSEMBLY WOULD HAVE TO BE CONTAMINATED TO THE EXTENT THAT MOVEMENT IS RESTRICTED OR PREVENTED. CONTAMINATION IS MINIMIZED BY THE USE OF MULTI-FILTERED HELIUM. GROUND SUPPLIED HELIUM (EITHER THROUGH THE T-0 UMBILICAL OR TEST POINT COUPLINGS) IS FILTERED TO 25 MICRONS ABSOLUTE. VEHICLE FILTERS (25 MICRONS ABSOLUTE) ARE LOCATED UPSTREAM OF THE REGULATOR INLET.

**(B) TEST:**  
ATP

EXAMINATION OF PRODUCT

PROOF PRESSURE (9250 PSIG INLET, 1950 PSIG OUTLET, -0005/-0006)

INTERNAL LEAKAGE, INLET TO OUTLET (4500 PSIG INLET, 760/775 PSIG OUTLET, AMBIENT AND LOW TEMPERATURE (-80 DEG F))

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EXTERNAL LEAKAGE (4500 PSIG INLET, 850 PSIG OUTLET, AMBIENT)

FUNCTIONAL

AMBIENT AND LOW TEMPERATURE (-80 DEG F)

REGULATION

INLET PRESSURE 900 TO 4500 PSIG

TRANSIENT RESPONSE

(SLAM START WITH FOLLOWING INITIAL CONDITIONS)

INLET PRESSURE 4500 AND 2500 PSIG

OUTLET PRESSURE 15 PSIG

FLOW TESTS (4500 TO 900 PSIG INLET PRESSURE, AMBIENT)

PURGE SEQUENCE 4 (260 TO 845 SCFM)

ENGINE START COMMAND (260 TO 720 SCFM)

MECO (WITH AND WITHOUT INTERCONNECT, 260 TO 1896 SCFM)

CERTIFICATION

TWO UNITS CERTIFIED FOR -0004. ADDITIONAL DELTA QUAL TEST WAS CONDUCTED FOR THE -0005 AND -0006 CONFIGURATION AS INDICATED BELOW.

VIBRATION TEST

TRANSIENT

5 TO 35 HZ AT +/- 0.25 G IN EACH OF THREE AXES

RANDOM

4.4 HOURS IN EACH OF THREE ORTHOGONAL AXES WHILE THE REGULATOR IS CONTROLLING THE OUTLET PRESSURE FROM 715 TO 770 PSIA WITH THE INLET PRESSURE AT 4500 AND 900 PSIG.

PERFORM AMBIENT INTERNAL AND EXTERNAL LEAKAGE, AND FUNCTIONAL TESTS IN EACH AXIS.

DESIGN SHOCK

PER MIL-STD-810 IN EACH OF THREE AXES.

PERFORM AMBIENT INTERNAL AND EXTERNAL LEAKAGE, AND FUNCTIONAL TESTS IN EACH AXIS.

THERMAL CYCLE TEST (ONE UNIT ONLY, INLET AT 750 PSIG AND NO FLOW)

CYCLE FROM -150 DEG F TO +250 DEG F: 3 CYCLES

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UPON COMPLETION, AMBIENT INTERNAL AND EXTERNAL LEAKAGE, AND FUNCTIONAL TESTS ARE PERFORMED.

LIFE CYCLE TESTS

SLAM START (WITHIN 8 MILLISECONDS)

250 CYCLES

INITIAL INLET PRESSURE 4500 PSIG

INITIAL OUTLET PRESSURE 0 PSIG

250 CYCLES

INITIAL INLET PRESSURE 2000 PSIG

INITIAL OUTLET PRESSURE 0 PSIG

ULLAGE TRANSIENT (1000 TO 1200 CUBIC INCHES)

5000 CYCLES

INITIAL INLET PRESSURE 4500 AND 900 PSIG

INITIAL OUTLET PRESSURE LOCKUP (715 TO 775 PSIA)

AMBIENT INTERNAL LEAKAGE TEST AFTER EACH 500 CYCLES

AMBIENT EXTERNAL LEAKAGE TEST AFTER 2500 CYCLES

BLOWDOWN (FLOW RATE NOT TO EXCEED 1.0 LB/SEC)

1 CYCLE (INLET PRESSURE 4500 TO 900 PSIG)

FLOW TEST (2 UNITS)

108 CYCLES (800 AND 600 SCFM, INLET PRESSURE 4500 TO 900 PSIG)

UPON COMPLETION OF LIFE CYCLE TEST PERFORM AMBIENT AND LOW TEMPERATURE INTERNAL AND EXTERNAL LEAKAGE, AND LOW TEMPERATURE FUNCTIONAL TESTS.

BURST TEST (ONE UNIT ONLY)

18,000 PSIG INLET, 3,400 PSIG OUTLET

DELTA CERTIFICATION FOR -0005 CONFIGURATION - THE PREVIOUS RESULTS FOR THE -0004 APPLY TO THE -0005 CONFIGURATION. THE ENGINE HELIUM PURGE SYSTEM REQUIREMENT HAS BEEN DEEMED TO BE MORE SEVERE THAN THE PNEUMATIC SYSTEM. THEREFORE, THE ENGINE PURGE SYSTEM REQUIREMENTS WERE USED TO CERTIFY THE REGULATOR FOR BOTH APPLICATIONS. SELECTED PNEUMATIC SYSTEM/REGULATOR TESTS WERE PERFORMED TO DEMONSTRATE THIS RATIONALE.

MPTA 12 MISSION (48 MISSION LIFE) CERTIFICATION TEST

TO DEMONSTRATE ADEQUATE REGULATOR LIFE CYCLE CAPABILITY, TWO MPTA REGULATORS WERE SELECTED AND TESTED IN THE ENGINE #3 HELIUM PURGE SYSTEM. THE ENGINE #3 SYSTEM WAS USED, SINCE IT IS IDENTICAL TO THE VEHICLE SYSTEM AS TO BASIC ROUTING AND LINE DIAMETERS. MINOR DEVIATIONS AS TO MECHANICAL FITTING AND MINOR BEND RADII EXISTS. THE REGULATOR PANELS CONTAINING THE REGULATOR,

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RELIEF VALVE, AND CHECK VALVE ARE IDENTICAL TO THE FLIGHT CONFIGURATION. IT WAS DETERMINED FROM THE FLOW TEST OF THE PNEUMATIC REGULATOR/SYSTEM (S/N 009) AND ALL FOUR ENGINE HELIUM REGULATORS TESTED IN ENGINE #3 SYSTEM, THAT S/N 011 AND S/N 019 REGULATORS EXHIBITED THE GREATEST OSCILLATION TENDENCIES AND WERE USED AS TEST ARTICLES. THE ENGINE TEST USED TO SELECT THE REGULATORS SHOWED MINOR DIFFERENCES BETWEEN REGULATORS (ALL STABLE). THE S/N 011 AND S/N 019 OSCILLATIONS WERE NOT SIGNIFICANT AND DID NOT EXCEED THE 40 PSI DOUBLE AMPLITUDE ALLOWABLE LIMIT.

EVEN THOUGH THE PNEUMATIC REGULATOR/SYSTEM WAS TESTED, THE REPRESSURIZATION FLOW CONDITIONS DURING ENTRY WERE NOT CONDUCTED. AT THE TIME, IT WAS THE OPINION THAT THIS CONDITION WAS NOT CRITICAL AND THE COMPLEXITY OF CONDUCTING THIS TEST DID NOT SEEM WARRANTED. ADDITIONAL FEED SYSTEM VALVING AND 20 PSIG REGULATOR SYSTEM WOULD HAVE HAD TO BE OPERATED TO CONDUCT THIS TEST.

EACH MISSION SIMULATION CONSISTED OF AN EQUIVALENT OF TWO ORBITER PROCESSING FACILITY (OPF) FLIGHT READINESS TESTS (FRTS), TWELVE LAUNCH PAD FRTS, ASCENT MISSION FLOW PROFILE AND BLOWDOWN FOR A TOTAL OF 48 MISSION SIMULATIONS. OVER 500 PURGE SEQUENCE 4/ENGINE START COMMAND AND MECO FLOW SEQUENCES WERE CONDUCTED. THE FIRST 30 MISSION SIMULATIONS WERE CONDUCTED WITH AN SSME INSTALLED. THE BALANCE OF 10 WAS CONDUCTED USING AN ENGINE HELIUM SYSTEM SIMULATOR (ENGINE HELIUM LINES AND VALVES WITH ORIFICES TO CONTROL FLOW RATES). THE PREVIOUS MPTA TESTING WAS DETERMINED TO BE EQUIVALENT TO EIGHT MISSIONS FOR A TOTAL OF 48 MISSIONS. THE REGULATOR FLOW BEHAVIOR FROM THE FIRST FLOW TEST TO THE LAST WERE FOR ALL VIRTUALLY IDENTICAL. SELF DAMPING OSCILLATIONS OCCURRED ON 16 OUT OF 50 MECOS WHEN THE 4400 PSIA PNEUMATIC SYSTEM WAS INTERCONNECTED "IN" TO THE ENGINE #3 SYSTEM.

#### OV-103 AND OV-104 REGULATOR FLOW TESTS

OV-103 AND OV-104 REGULATORS, USING THE SAME INSTRUMENTATION, INSTRUMENTATION INSTALLATION, AND RECORDING SYSTEM USED ON MPTA (HI-FREQUENCY KULITE PRESSURE TRANSDUCERS), WERE TESTED TO DETERMINE THEIR FLOW CHARACTERISTICS. THE TEST CONSISTED OF TESTING BOTH THE PNEUMATIC (ONE) AND ENGINE SYSTEM REGULATORS (SIX). THE TEST DUPLICATED THE FLOW CONDITIONS EXPERIENCED DURING BOTH GROUND AND FLIGHT OPERATIONS. THE TESTS WERE PRIMARILY RUN WITH 4000 TO 4500 PSIA HELIUM BECAUSE PRESSURE OSCILLATIONS ON THE VENDOR TEST STAND WERE OBSERVED PRIMARILY AT 4000 PSIA. THE VENDOR TEST STAND DATA ALSO INDICATED THAT OSCILLATION FREQUENCY AND MAGNITUDE DECAYED WITH DECREASED INLET PRESSURES AND WITH HIGHER FLOW RATE CONDITIONS (ABOVE 230 SCFM FLOW).

THE PNEUMATIC REGULATOR WAS TESTED AT THE 322 TO 500 SCFM RANGE CONSISTENT WITH ITS NORMAL FLOW CONDITION. EACH ENGINE HELIUM SYSTEM WAS TESTED FOR THE PURGE SEQUENCE FOUR, ENGINE START COMMAND, MECO, AND MECO WITH "INTERCONNECT" FLOWS. THESE FLOW CONDITIONS HAVE BEEN DETERMINED TO BE THE CRITICAL CONDITIONS THAT MUST BE SATISFIED TO DETERMINE THE STABILITY CHARACTERISTICS OF THE REGULATORS. THESE FLOW CONDITIONS WERE RUN AT LEAST TWICE ON EACH ENGINE HELIUM SYSTEM.

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THE OV-103 AND OV-104 TESTS RESULTED IN THE REJECTION OF 9 OF 12 ENGINE REGULATORS DUE TO PRESSURE OSCILLATIONS EXCEEDING THE 40 PSI DOUBLE AMPLITUDE ALLOWABLE LIMIT.

DELTA QUAL TEST FOR -0006 CONFIGURATION - PREVIOUS RESULTS OF THE -0004 AND -0005 QUAL TEST APPLY IN PART OR DIRECTLY TO THE CERTIFICATION OF THE -0006 CONFIGURATION AS INDICATED IN THE CERTIFICATION REQUIREMENTS. VIBRATION DELTA QUAL TEST CONSISTS OF RANDOM VIBRATION TEST OF .5 HOURS/AXIS (2 ORTHOGONAL AXES) AFTER 50 FLIGHT/MISSION FLOW CYCLE COMPLETION AND AGAIN AFTER 100 FLIGHT/MISSION CYCLES COMPLETION. DURING VIBRATION TEST, THE REGULATOR MAINTAINED OUTLET PRESSURE AT 715 TO 765 PSIG WITH 100 +/- 50 SCIM FLOW AND WITH AN INLET PRESSURE OF 4500 TO 3000 PSIG. THE ORIGINAL -0006 CONFIGURATION LIFE CYCLE TEST CONSISTS OF 5200 PRESSURE SLAMS AND 32,300 FLOW DEMAND CYCLES. IN 1997 AN ADDITIONAL 11,600 SLAM CYCLES WERE ADDED TO BRING THE TOTAL NUMBER OF SLAM CYCLES TO 16,800 CYCLES (100 MISSIONS)

**GROUND TURNAROUND TEST**

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

**(C) INSPECTION:**

**RECEIVING INSPECTION**

INCOMING MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIAL AND PROCESS CERTIFICATION.

**CONTAMINATION CONTROL**

ALL PARTS ARE CLEANED TO LEVEL 100A PRIOR TO ASSEMBLY.

**ASSEMBLY/INSTALLATION**

DIMENSIONS AND SURFACE FINISHES ARE VERIFIED BY INSPECTION. PARTS ARE VISUALLY INSPECTED AT 10X TO 40X MAGNIFICATION, INCLUDING CRITICAL POPPET, SLEEVE SURFACES, AND SEALS. TORQUE AND LOCKWIRE OF FASTENERS ARE VERIFIED PER REQUIREMENTS. MANDATORY INSPECTION POINTS ARE ESTABLISHED TO ENSURE THAT CORRECT MANUFACTURING PROCEDURES ARE FOLLOWED. ELECTRO CHEM-ETCHED MARKING IS VERIFIED PER SPECIFICATION.

**CRITICAL PROCESSES**

PART PASSIVATION AND WELDING PROCESSES ARE VERIFIED BY INSPECTION.

**NONDESTRUCTIVE EVALUATION**

HELIUM LEAK CHECK IS VERIFIED BY INSPECTION.

**TESTING**

ATP, INCLUDING PROOF PRESSURE TEST, IS VERIFIED BY INSPECTION.

**HANDLING/PACKAGING**

PACKAGING FOR SHIPMENT IS VERIFIED BY INSPECTION.

**(D) FAILURE HISTORY:**



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DURING QUALIFICATION TESTING (ULLAGE TRANSIENT TEST), THE LOCK-UP PRESSURE WAS 700 PSIG AT 3000 PSIG INLET PRESSURE (REFERENCE CAR A8649). MINIMUM ALLOWABLE LOCK-UP IS 750 PSIG. SECOND QUALIFICATION SPECIMEN AND A REGULATOR FROM MPTA ENGINE #3 EXPERIENCED A SIMILAR FAILURE (REFERENCE CAR'S A8692, AB0524). TEARDOWN OF THE REGULATORS FOUND THE PILOT LIFT SHAFT BROKEN DUE TO FATIGUE. THE PILOT SHAFT WAS REDESIGNED USING INCONEL 718 WITH CONTOUR CHANGES TO REDUCE STRESS CONCENTRATIONS AT THE FAILED AREA.

DURING ATP, THE REGULATORS S/N 001, 002, AND 003 DROPPED BELOW THE 715 PSIG MINIMUM BAND WITH A 1252 SCFM FLOW RATE (REFERENCE CAR A6750). FAILURE ANALYSIS ATTRIBUTED THE EXCESSIVE DROP IN THE OUTLET PRESSURE TO THE SENSOR SETTING AND TO THERMAL OVERCOMPENSATION. A DESIGN CHANGE WAS APPROVED FOR THE NEW CONFIGURATION (MC284-0533-0002) WHICH INCLUDED A MATERIAL CHANGE IN THE SENSOR RETAINER ASSEMBLY AND MAIN POPPET RING SEAL, DIMENSIONAL AND BELLOWS CHANGES. THE REGULATORS WERE WAIVERED FOR MPTA TESTING ONLY.

DURING ATP, THE OUTLET REGULATED PRESSURE WAS 702 PSIG AT 4500 PSIG INLET PRESSURE , FLOWING 1252 SCFM, AT -75 TO -150 DEG F (REFERENCE CAR A7584). MINIMUM OUTLET PRESSURE SHOULD BE 715 PSIG. IT WAS CONCLUDED THAT THE FLOW SPECIFICATION REQUIREMENTS WERE EXCESSIVE AND THE SPECIFICATION WAS CHANGED TO 652 SCFM AT INLET PRESSURE OF 4500 - 2000 PSIG. THE REGULATOR WAS RETESTED AND THE ATP REQUIREMENTS WERE MET.

DURING ATP TESTING AT 1200 PSIG INLET PRESSURE AND -75 DEG F, THE OUTLET PRESSURE WAS 708 PSIG (REFERENCE CAR A7639). REQUIRED OUTLET PRESSURE RANGE IS BETWEEN 715 - 755 PSIG. FAILURE ANALYSIS INDICATED THAT THE DECREASE IN REGULATOR PRESSURE WAS DUE TO A DECREASE IN THE SPRING RATE OF THE BELLEVILLE SPRINGS. THE REGULATOR WAS REBUILT WITH A SPRING SELECTED BY MORE STRINGENT PRESSURE DEFLECTION CHARACTERISTICS AND THEN MET ATP REQUIREMENTS. THE SUPPLIER CHANGED THE CRITERIA FOR SELECTION OF THE BELLEVILLE SPRINGS WITH A REDUCED POSITIVE SPRING RATE IN THE CRITICAL STROKE RANGE.

DURING ATP AT -175 DEG F, THE REGULATOR OUTLET PRESSURE DID NOT REACH THE 715 PSIG WITHIN 1 SECOND AS REQUIRED (REFERENCE CAR A7911). RESULTS OF FAILURE ANALYSIS INDICATED THAT THE MAIN POPPET RING SEAL HAD INSUFFICIENT CONTACT LOADING TO ASSURE PRESSURE ACTIVATION DURING CRYOGENIC TEMPERATURES. THE SEAL WAS REPLACED AND THE REGULATOR SUCCESSFULLY MET ATP REQUIREMENTS. THIS FAILURE WAS CONSIDERED TO BE A RANDOM OCCURRENCE.

DURING ATP WITH 1300 PSIG INLET PRESSURE AND 852 SCFM, THE OUTLET PRESSURE DROPPED BELOW 700 PSI (REFERENCE CAR A9718). OUTLET PRESSURE SHOULD BE BETWEEN 700 - 750 PSI WITH 1300 - 900 PSI INLET PRESSURE. REGULATOR TEARDOWN FOUND THE MAIN POPPET SEAL TO BE DISTORTED IN THE VICINITY OF THE TWO SLOTS MACHINED IN THE FACE OF THE GUIDE POPPET. SUPPLIER INITIATED 100 % DIMENSIONAL INSPECTION OF THE SEALS TO MEET THE REQUIRED TOLERANCES. ADDITIONALLY, SLOTS IN THE GUIDE POPPET HAVE BEEN DELETED EFFECTIVE S/N 0012. THE REGULATOR WAS REPAIRED AND ATP REQUIREMENTS WERE MET.

DURING ATP (MAIN ENGINE CUTOFF WITH AND WITHOUT CROSSOVER), THE REGULATED OUTLET PRESSURE DROPPED TO 695 PSIG, 5 PSI BELOW THE SPECIFIED MINIMUM OF 700

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PSIG AT A FLOW RATE OF 1740 SCFM (REFERENCE CAR AD4209). A WAIVER (#07986) WAS APPROVED TO ACCEPT THIS CONDITION. THE PROCUREMENT SPECIFICATION WAS REVISED TO CONDUCT THIS TEST FOR ENGINEERING TEST INFORMATION ONLY. THERE IS NO LIMIT PLACED ON THE MINIMUM OUTLET PRESSURE AT THE 1740 SCFM FLOW RATE.

DURING RE-ATP FOLLOWING A QUALIFICATION TEST FAILURE (DOCUMENTED AS CAR A8649), THE REGULATOR FAILED TO MEET THE 1000 MS OUTLET PRESSURE REQUIREMENT FOR THE LOW TEMPERATURE FUNCTIONAL TEST (REFERENCE CAR AB0198). DISASSEMBLY OF THE MAINSTAGE FOUND THE LIP OF THE MAIN POPPET RING SEAL CRACKED. FAILURE ANALYSIS DETERMINED THAT THE MAIN SEAL FAILED DUE TO HIGH REVERSE PRESSURE LOADING WITH INADEQUATE SUPPORT OF THE OUTER SEAL LIP. A MODIFICATION WAS INCORPORATED TO IMPROVE THE SUPPORT OF THE OUTER LIP OF THE MAINSTAGE SEAL. THE PILOT POPPET WAS REDESIGNED TO VENT INSIDE OF THE RING INSERT. THESE CHANGES WERE INCORPORATED INTO THE REGULATOR AND ATP REQUIREMENTS WERE MET.

**GENERAL SYSTEM CONTAMINATION**

GENERAL MPS SYSTEM CONTAMINATION HAS OCCURRED WHICH MAY LODGE ANYWHERE IN THE SYSTEM CAUSING THIS FAILURE MODE (REFERENCE THE FOLLOWING PARAGRAPHS).

CONTAMINATION FAILURES HAVE OCCURRED AT ALL PHASES OF MANUFACTURING AND PARTS REPLACEMENT. IN ALL CASES, STRICT ADHERENCE TO CLEANLINESS CONTROL PROCEDURES IS THE PRIMARY METHOD OF CONTAMINATION PREVENTION.

NUMEROUS LARGE PARTICLES OF BLACK RUBBER MATERIAL WERE FOUND DURING A POST FLIGHT EXAMINATION OF THE LH2 17 INCH DISCONNECT OF OV099 (FLIGHT 7, REFERENCE CAR AC9800). THE LO2 AND LH2 SYSTEMS OF ALL VEHICLES WERE EXAMINED. NO RUBBER WAS FOUND IN ANY OTHER VEHICLES. AFTER EXTENSIVE INVESTIGATION THE ORIGIN WAS NOT DETERMINED.

METAL SHAVINGS HAVE BEEN DISCOVERED IN LINES AND COMPONENTS, WHICH WAS MOST LIKELY GENERATED WHEN THEY WERE CUT OUT AND/OR REPLACED (REFERENCE CARS AC9868, A9654, AC2210, AB1706; DR AD2226). METHODS ARE BEING REVISED TO MINIMIZE PARTICLE GENERATION WHEN INSTALLING/REPLACING COMPONENTS, LINES, AND FITTINGS REQUIRING WELDED OR BRAZED JOINTS (PRODUCT QUALITY IMPROVEMENT COUNCIL). PERSONNEL HAVE BEEN CAUTIONED. ROCKWELL PROBLEM ACTION CENTER WILL CONTINUE TO MONITOR BRAZING/WELDING REWORK CONTAMINATION. PROCEDURES ARE BEING REVISED TO IMPROVE CLEANLINESS MAINTENANCE DURING COMPONENT BUILD UP AND REWORK (REFERENCE MCR 12512). SUPPLIER DOCUMENTS/PROCEDURES HAVE BEEN REVIEWED AND CLEANLINESS MAINTENANCE PROCEDURES HAVE BEEN IMPROVED.

A PIECE OF A BRAZING PREFORM LODGED IN A 2-WAY SOLENOID VALVE ON OV-099 AT PALMDALE CAUSING A LEAKAGE FAILURE (REFERENCE CARS AC2111, AB2538). STEEL AND ALUMINUM PARTICLES CAUSED EXCESSIVE LEAKAGE ON THE 850 PSIG HELIUM RELIEF VALVE (REF CAR AC2229). FOR BOTH FAILURES CORRECTIVE ACTION WAS TO ADD SPECIAL PURGE PORTS TO THE MPS HELIUM PANEL ASSEMBLIES TO IMPROVE THE QUALITY OF FINAL CLOSEOUT BRAZES.

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SEVERAL FOREIGN MATERIALS WERE INTRODUCED INTO THE MPS SYSTEM DURING MANUFACTURE AND PARTS REPLACEMENT. EXAMPLES ARE: GLASS CLOTH IN LINE TO PREVENT TRAVEL OF CHIPS DOWN LINE; POLYSTYRENE OBJECT TO HOLD VALVE POPPET OPEN WHILE PURGING; COTTON SWAB MATERIAL AND GLASS BEADS FROM CLEANING OPERATION; MISCELLANEOUS PLASTIC; FOAM; AND TAPE (REFERENCE CARS AB4751, AC2217, AC6768, AC9868, MPS3A0005, AC7912, AB0530). MATERIALS WERE REMOVED AND PERSONNEL WERE CAUTIONED. A HIGH FLOW DELTA P TEST AT PALMDALE WAS ADDED TO VERIFY THAT LINES WERE NOT PLUGGED. GRIT BLASTING (GLASS BEADS AND SAND USED TO CLEAN A LINE) IS NO LONGER PERFORMED. PROCEDURES ARE BEING REVISED TO IMPROVE CLEANLINESS MAINTENANCE DURING COMPONENT BUILD UP AND REWORK (REFERENCE MCR 12512). SUPPLIER DOCUMENTS/PROCEDURES HAVE BEEN REVIEWED AND CLEANLINESS MAINTENANCE PROCEDURES HAVE BEEN IMPROVED.

ONE PIECE OF WIRE WAS FOUND IN THE INTERNAL RELIEF VALVE OF THE LO2 PREVALVE ON OV103 (REFERENCE CAR AC9101). THE SOURCE OF THE CONTAMINATION WAS NEVER FOUND, BUT IT WAS BELIEVED TO BE FROM THE ET. OTHER CONTAMINATION HAS BEEN FOUND ON THE FEEDLINE SCREENS, SUCH AS AN UNIDENTIFIED ROUND OBJECT AND VARIOUS METALLIC PARTICLES (REFERENCE CARS AB0529 AND AB0530). SOURCE OF CONTAMINATION WAS UNDETERMINED. BORESCOPE EXAMINATIONS ARE CONDUCTED ON ALL FEEDLINE SCREENS EVERY FIFTH FLIGHT TO VERIFY CLEANLINESS. CONTAMINATION WAS REMOVED WHEN POSSIBLE.

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.

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**- APPROVALS -**

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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