

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**

NUMBER: 03-1-0205 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 8 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	MC284-0533-0006
	VACCO INDUSTRIES	73664-0006
LRU	:	
LRU	:	

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

ENGINE HELIUM SUPPLY. 0.500 INCH DIAMETER INLET, 0.750 INCH DIAMETER OUTLET

**REFERENCE DESIGNATORS:** PR1, PR2, PR3  
PR7, PR8, PR9

**QUANTITY OF LIKE ITEMS:** 6  
TWO PER ENGINE HE SUPPLY

**FUNCTION:**

REGULATES THE ENGINE HELIUM SUPPLY PRESSURE OF 4500 - 900 PSIA DOWN TO 750 PSIA, WHICH IS THE NOMINAL OPERATING PRESSURE AT THE ORBITER/ ENGINE INTERFACE. THE DOWNSTREAM SYSTEM INCORPORATES A RELIEF VALVE TO PREVENT DOWNSTREAM OVERPRESSURIZATION IN EVENT THE REGULATOR FAILS HIGH. A REDUNDANT REGULATOR IS IN A PARALLEL LEG TO ASSURE GHE FROM EACH ENGINE SUPPLY TO ITS PARTICULAR ORBITER/ENGINE INTERFACE.

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

**SUBSYSTEM NAME: MAIN PROPULSION**

**LRU: REGULATOR, 750 PSIA**

**ITEM NAME: SSME GHE SUPPLY 750 PSIG REGULATOR**

**CRITICALITY OF THIS**

**FAILURE MODE: 1/1**

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**FAILURE MODE:**

RUPTURE/LEAKAGE.

**MISSION PHASE:**

LO LIFT-OFF  
DO DE-ORBIT

**VEHICLE/PAYLOAD/KIT EFFECTIVITY:**

102 COLUMBIA  
103 DISCOVERY  
104 ATLANTIS  
105 ENDEAVOUR

**CAUSE:**

MATERIAL DEFECT, FATIGUE.

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

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**REDUNDANCY SCREEN**

A) N/A  
B) N/A  
C) N/A

**PASS/FAIL RATIONALE:**

A)

B)

C)

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**- FAILURE EFFECTS -**

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**(A) SUBSYSTEM:**

DURING ASCENT, HELIUM SUPPLY TO ONE ENGINE WILL BE LOST. POSSIBLE OVERPRESSURIZATION OF THE AFT COMPARTMENT. POSSIBLE UNCONTAINED ENGINE SHUTDOWN IF REDUNDANT LEG CANNOT PROVIDE ENGINE HELIUM REQUIREMENTS. EXCESSIVE HELIUM TANK PRESSURE DECAY (SM ALERT: 20 PSI/3 SECONDS; CAUTION AND WARNING: 1150 PSIA LOWER LIMIT) AND/OR REGULATOR PRESSURE OUT OF LIMITS WILL

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BE INDICATED BY SM ALERT (BOTH LEGS: 679 LOWER AND 806 UPPER) OR CAUTION AND WARNING (LEG A ONLY: 680 LOWER LIMIT AND 810 UPPER LIMIT).

PRIOR TO T-9 MINUTES, EXCESSIVE HELIUM LEAKAGE WILL BE DETECTABLE USING HAZARDOUS GAS DETECTION SYSTEM (HGDS) AND SCREENED BY LCC REQUIREMENTS.

DURING ENTRY, VENT DOORS ARE CLOSED TO PREVENT INGESTION OF RCS AND APU GASES. ALL ISOLATION VALVES ARE OPENED WHEN VEHICLE TRANSITIONS TO ORBITER SOFTWARE MAJOR MODE 303 (MM303). RUPTURE ON THIS LINE 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.

**(B) INTERFACING SUBSYSTEM(S):**

SAME AS A.

**(C) MISSION:**

ON GROUND, POSSIBLE LAUNCH SCRUB DUE TO LCC VIOLATION. POSSIBLE ABORT DUE TO EARLY SHUTDOWN OF ONE ENGINE.

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

POSSIBLE LOSS OF CREW/VEHICLE.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

NONE.

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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 705-770 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 CLOSES WHEN THE OUTLET PRESSURE EXCEEDS 770 PSIA (765 PSIG FOR -0006 CONFIGURATION).

THE CRES 21-6-9 REGULATOR HOUSING IS DESIGNED TO WITHSTAND PRESSURES OF 9,000 PSIG PROOF AND 18,000 PSIG BURST ON ITS INLET SIDE AND 1700 PSIG PROOF AND 3,400 PSIG BURST ON ITS OUTLET SIDE WITHOUT RUPTURE. THIS PROVIDES FACTORS OF SAFETY OF 2.0 PROOF AND 4.0 BURST. THE END CAP AND SLEEVE ASSEMBLY ARE

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MANUFACTURED FROM 21-6-9 CRES. THE HOUSING IS LEAK TIGHT (TO 1.0 SCIM) BY TORQUING THE SLEEVE ASSEMBLY TO THE HOUSING (120 INCH-POUNDS), TORQUING THE END CAP TO THE HOUSING (30 INCH-POUNDS), AND SEAL WELDING (TIG) THE SLEEVE ASSEMBLY AND THE END CAP TO THE HOUSING. THE HOUSING ASSEMBLY FATIGUE LIFE IS DEMONSTRATED BY PERFORMING A 100 MISSION LIFE CYCLE PRESSURE TEST ON THE HOUSING (5500 CYCLES) DURING CERTIFICATION.

**(B) TEST:**

ATP

EXAMINATION OF PRODUCT

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

INTERNAL LEAKAGE, INLET TO OUTLET (4500 PSIG INLET, 760/765 PSIG OUTLET, AMBIENT AND LOW TEMPERATURE (-80 DEG F))

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

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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

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.

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**BURST TEST (ONE UNIT ONLY)**

18,000 PSIG INLET, 3,400 PSIG OUTLET

DELTA CERTIFICATION TESTS

DELTA CERTIFICATION FOR -0005 CONFIGURATION - THE PREVIOUS RESULTS FOR THE -0004 APPLY TO THE -0005 CONFIGURATION.

**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, 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

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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.

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**

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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:**

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:**

LOADING/PRELAUNCH:

PRIOR TO T-9 MINUTES GHE LEAKAGE IS SCREENED PER LCC. AFTER T-9 MINUTES THE LCC REQUIREMENT IS REMOVED DUE TO CYCLING OF MPS PNEUMATIC VALVES, HOWEVER, EXCESSIVE GHE LEAKAGE IN THE AFT COMPARTMENT IS DETECTABLE BY HGDS AND THE COUNT CAN BE TERMINATED BY GROUND CALL

ASCENT:

ENGINE HELIUM BOTTLE PRESSURE IS ON A DEDICATED DISPLAY IN COCKPIT. CREW ACTION IS TO FOLLOW LEAK ISOLATION PROCEDURE.

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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	: MICHAEL SNYDER	:/S/ MICHAEL SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	:/S/ SUZANNE LITTLE
NASA SR&QA	: BILL PRINCE	:/S/ BILL PRINCE