FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE
NUMBER: 03-1-0519 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 1 07/26/00

PART DATA

	PART NAME / **VENDOR NAME**	**PART NUMBER** / **VENDOR NUMBER**
LRU	: GO2 ET TANK PRESSURIZATION FLOW CONTROL VALVES	MC280-0017-1447, -2492
	VACCO INDUSTRIES	84400-2492

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
VALVE, FLOW CONTROL, SOLENOID, GO2 PRESSURANT, NORMALLY HIGH FLOW (0.625 INCH DIA INLET 1.0 INCH DIA OUTLET) (LV53, 54, 55).

REFERENCE DESIGNATORS: LV53
LV54
LV55

QUANTITY OF LIKE ITEMS: 3

FUNCTION:
THREE FLOW CONTROL VALVES (ONE PER SSME SYSTEM) CONTROL THE FLOW OF PRESSURIZATION GAS FROM THE ENGINES TO THE OXYGEN TANK TO MAINTAIN ULLAGE PRESSURE FOR TANK STRUCTURAL STABILITY AND SSME NPSP.

FOR ACTIVE CONFIGURATION VALVES (-1447) THE UNPOWERED SOLENOID VALVE POSITION IS HIGH FLOW. VALVE POSITION (HIGH FLOW / LOW FLOW) IS CONTROLLED BY STIMULI FROM THE ORBITER MOUNTED SIGNAL CONDITIONERS. SIGNAL CONDITIONER INPUT COMES FROM ET MOUNTED ULLAGE PRESSURE TRANSDUCERS.

FOR FIXED ORIFICE VALVES (-2492) THE VALVES ARE SHIMMED TO A FIXED FLOW SETTING (78% FLOW) AND THE SIGNAL CONDITIONER IS DISCONNECTED FROM THE VALVE SOLENOIDS.

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SUBSYSTEM NAME: MAIN PROPULSION
LRU: VALVE, FLOW CONTROL (GO2) **CRITICALITY OF THIS**
ITEM NAME: GO2 FLOW CONTROL VALVES (LV53, 54, 55) **FAILURE MODE:** 1/1

FAILURE MODE:
BODY BURN THROUGH DURING ENGINE OPERATION.

MISSION PHASE:
PL PRE-LAUNCH
LO LIFT-OFF

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

CAUSE:
VALVE IGNITION CAUSED BY IMPACT OF METAL PARTICLE(S) FROM AN UPSTREAM SOURCE.

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:
RELEASE OF HOT, HIGH PRESSURE GO2 INTO THE AFT COMPARTMENT WILL CAUSE OVERPRESSURIZATION. FCV BODY COMBUSTION IS LIKELY TO DAMAGE REMAINING ADJACENT FLOW CONTROL VALVES AND OTHER CRITICAL FUNCTIONS.

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LOSS OF ET LO2 ULLAGE PRESSURE WILL RESULT IN VIOLATION OF TANK MINIMUM STRUCTURAL CAPABILITY REQUIREMENTS.

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

(C) MISSION:
POSSIBLE LOSS OF CREW/VEHICLE.

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

(E) FUNCTIONAL CRITICALITY EFFECTS:
NONE.

-DISPOSITION RATIONALE-

(A) DESIGN:
THE ACTIVE CONFIGURATION VALVE IS A SINGLE FLOW PATH, DUAL POSITION TYPE. IT IS SHIMMED TO ALLOW FLOW AT THE REQUIRED HIGH AND LOW FLOW SETTINGS. IT IS SPRING LOADED TO THE HIGH FLOW POSITION AND SOLENOID ACTUATED TO THE LOW FLOW POSITION. A LABYRINTH-DESIGN SEAL REDUCES THE POTENTIAL FOR MARGINAL POPPET FORCE BALANCE BY MINIMIZING ACTUATION FORCE REQUIRED FROM THE SOLENOID. THE FIXED ORIFICE CONFIGURATION HAS HAD THE POPPET SHIMMED TO A 78% FLOW SETTING AND THE SIGNAL CONDITIONER INPUTS DISCONNECTED FROM THE VALVE SOLENOIDS.

VALVE BODY BURN-THROUGH COULD BE CAUSED BY CONTAMINANT PARTICLE IGNITION IN THE VALVE. IN A HIGH TEMPERATURE GO2 ENVIRONMENT IGNITION SUSCEPTIBILITY IS INCREASED BY HIGH VELOCITIES, DIRECT ANGLE IMPACTS, AND AREAS OF PARTICULATE ACCUMULATION.

THE VALVE DESIGN UTILIZES A POPPET, POPPET SLEEVE, AND OUTLET TUBE INSERT OF MONEL K500, WHICH HAS BEEN SHOWN TO BE HIGHLY IGNITION RESISTANT AND SELF-QUENCHING. THE VALVE BODY, INLET TUBE, AND OUTLET TUBE ARE OF INCONEL 718. THE DESIGN ONLY EXPOSES INCONEL 718 TO LOW VELOCITY GO2 WITH OBLIQUE FLOW PATHS. THE VALVE WILL REMAIN FUNCTIONAL AT TEMPERATURES UP TO 530 DEG F AND WILL BE STRUCTURALLY SOUND AT 710 DEG F.

THE VALVE FLOW PATH HAS ONLY ONE AREA OF DIRECT IMPACT AND ONE AREA OF SONIC FLOW. THE AREA OF DIRECT IMPACT IS AT THE INLET ON THE POPPET SLEEVE WHERE THE FLOW VELOCITY IS LOW. PARTICLES BEING CARRIED THROUGH THE AREA OF SONIC FLOW (POPPET/ANNULAR ORIFICE) WILL IMPACT THE OUTLET TUBE INSERT AT

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OBLIQUE ANGLES. EIGHTY PARTICLE IMPACT TESTS WERE SUCCESSFULLY PERFORMED DURING CERTIFICATION AT 490 DEG F (104% THRUST LEVEL). ANOTHER EIGHTY PARTICLE IMPACT TESTS WERE SUCCESSFULLY PERFORMED AT A HIGH TEMPERATURE (620°F, DETERMINED TO BE A WORST CASE TEMPERATURE FOR PARTICLE IMPACT IGNITION BETWEEN THE NORMAL OPERATING LEVEL AND THE THRUST LIMITING CONDITION). ALL TESTS WERE PERFORMED WITH A CONSERVATIVE AMOUNT OF PARTICULATE (10 MG PER TEST) WHICH IS REPRESENTATIVE OF THE CONTAMINANTS EXPECTED IN THE SYSTEM.

(B) TEST:
ATP

EXAMINATION OF PRODUCT

AMBIENT TESTS
- PROOF PRESSURE: VALVE HOUSING (9,860 PSIA OF GN2, TEMP CORRECTED)
- PRIMARY SEAL LEAKAGE (600 PSIA OF HELIUM)
- SECONDARY SEAL LEAKAGE (400 PSIA OF HELIUM)
- TOTAL EXTERNAL LEAKAGE (600 PSIA OF HELIUM)

ELECTRICAL CHARACTERISTICS
- INSULATION RESISTANCE
- BONDING
- DIELECTRIC STRENGTH
- COIL RESISTANCE
- COIL TEMPERATURE TEST

FLOW CALIBRATION VERIFICATION (GO2 AT +380 DEG F)
- HI FLOW POSITION
  - INLET PRESSURE: 3700 PSIA OR LESS
  - OUTLET PRESSURE: 600 PSIA MAXIMUM
- LOW FLOW POSITION
  - INLET PRESSURE: 3700 PSIA
  - OUTLET PRESSURE: 600 PSIA MAXIMUM

FUNCTIONAL TEST
- DEMONSTRATION DUTY CYCLE (720 SECONDS OF GO2 FLOW)
  - INLET PRESSURE (LOW FLOW): 3700 PSIA
  - GO2 FLOW TEMPERATURE: +380 DEG F
- PERFORMANCE VERIFICATION (ELECTRICAL)

CERTIFICATION

FUNCTIONAL TESTS
- DEMONSTRATION DUTY CYCLE (720 SECONDS OF GO2 FLOW)
- 12 SETS OF INITIAL CONDITIONS:
  - GO2 AT 260°F, 380°F, 530°F
  - 1,500 PSIA, 2,500 PSIA, 3,500 PSIA, 4,500 PSIA
  - (ALL PRESSURES AT ALL THREE TEMPERATURES)
- HIGH TEMPERATURE (4 DUTY CYCLES OF 600 SECONDS EACH)
  - GO2 AT 710°F

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3,600 (LOW FLOW) TO 4,200 PSIA (HIGH FLOW)
ONE HUNDRED MISSION FLOW (51 DUTY CYCLES)
GO2 AT 380°F AND 3,700 PSIA

SEAL LEAKAGE TESTS
PRIMARY SEAL (PERFORMED DURING OFF-LIMIT TEMPERATURE TEST)
SECONDARY SEAL
HELIUM AT AMBIENT
400 PSIA AT PRIMARY TEST PORT

LIFE TESTS

OPERATIONAL CYCLES (5000 CYCLES)
INLET PRESSURE: 4500 PSIA
INLET TEMPERATURE: +380 DEG F
PERFORMANCE VERIFICATION (ELECTRICAL AND FLOW)

AMBIENT CYCLES (5000 CYCLES)
INLET PRESSURE: 25 PSIA
INLET TEMPERATURE: AMBIENT
PERFORMANCE VERIFICATION (ELECTRICAL AND FLOW)

AT COMPLETION OF AMBIENT CYCLE TEST REPEAT PERFORMANCE VERIFICATION (ELECTRICAL) AND ELECTRICAL CHARACTERISTICS TEST

VIBRATION
RANDOM: 13.3 HOURS IN EACH OF THREE AXES PRESSURIZED WITH 600 PSIG GHE AT AMBIENT TEMPERATURE

DESIGN SHOCK (PER MIL-STD-810)

THERMAL SHOCK (100 CYCLES)
BODY TEMPERATURE: AMBIENT
INLET PRESSURE: 4500 PSIA
INLET TEMPERATURE: +70 DEG F TO -160 DEG F TO +380 DEG F

PARTICLE IMPACT TEST
10 MG SAMPLE MIXTURE OF 5 TO 250 MICRON DIAMETER INCONEL, ALUMINUM, AND CRES 21-6-9 PARTICLES 40 HIGH FLOW AND 40 LOW FLOW TESTS AT TEMPERATURES OF 490°F AND 620°F (160 TESTS TOTAL).

BURST TEST
19,340 PSIA AT 300 DEG F

NOTE: CERTIFICATION TESTING OF THIS COMPONENT IS STILL IN PROCESS.

GROUND TURNAROUND TEST
ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

(C) INSPECTION:

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RECEIVING INSPECTION
ALL INCOMING MATERIALS ARE INSPECTED FOR MATERIAL AND PROCESS CERTIFICATION.

CONTAMINATION CONTROL
ASSEMBLIES ARE MAINTAINED TO CLEANLINESS LEVEL 100A FOR OXYGEN. CORROSION PROTECTION PROVISIONS ARE VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION
ALL PARTS ARE CLEANED PRIOR TO ASSEMBLY. DIMENSIONS AND SURFACE FINISHES ARE VERIFIED BY INSPECTION. MANDATORY INSPECTION POINTS ARE ESTABLISHED TO VERIFY ASSEMBLY PROCEDURES. TORQUE REQUIREMENTS AND ELECTROCHEMICAL ETCH MARKINGS ARE VERIFIED BY INSPECTION.

CRITICAL PROCESSES
WELDING, INCLUDING SECTIONING WELD SAMPLES, AND SOLDERING ARE VERIFIED BY INSPECTION. ALL SOLDER JOINTS, INSULATED WITH HEAT SHRINK SLEAVINGS, ARE VERIFIED PER APPLICABLE REQUIREMENTS AND POTTED TO PROVIDE STABILITY. ELECTRO POLISHING AND PASSIVATION ARE VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION
WELDS ARE VISUALLY EXAMINED AND VERIFIED BY X-RAY AND DYE PENETRANT INSPECTION. RADIFLOW INSPECTION IS PERFORMED ON SOLENOID ASSEMBLY. ALL MATERIALS ARE EVALUATED FOR OXYGEN COMPATIBILITY.

TESTING
ATP IS VERIFIED BY INSPECTION.

HANDLING/PACKAGING
PACKAGING FOR SHIPMENT IS VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:
THE ORIGINAL GO2 FLOW CONTROL VALVE CONFIGURATION (MC280-0017-0028) HAS HAD SUBSTANTIAL GROUND AND FLIGHT FAILURE HISTORY. AS A RESULT OF CONCERNS OVER FRETTING, FORCE BALANCE PROBLEMS, AND SUSCEPTIBILITY TO IGNITION DUE TO PARTICLE IMPACT, THE VALVE HAS BEEN COMPLETELY REDESIGNED TO A NEW CONFIGURATION (-1447) WHICH WILL BE USED FOR STS-26 AND SUBS.

PREVIOUS CONFIGURATION FAILURE HISTORY

A VALVE WAS CAUGHT IN A FIRE (1-17-77) WHEN AN UPSTREAM FACILITY VALVE EXPLODED, CAUSING SUFFICIENT DAMAGE TO SCRAP THE TEST VALVE (DR A5878).

DURING A NASA/JSC PARTICLE SCRUB TEST (8-14-80) ON A DEVELOPMENT VALVE AT WSTF, THE VALVE BODY IGNITED AND BURNED (REF CAR AB7418) WHEN AN 800 MICRON ALUMINUM PARTICLE WAS INJECTED UPSTREAM WHILE FLOWING GO2 AT APPROXIMATELY 530 DEG F AND 3100 PSIG. THE VALVE BODY WAS A-286 STEEL. CORRECTIVE ACTION WAS TO ADD AN ENGINE ANTI-FLOOD VALVE FILTER UPSTREAM OF THE VALVE AND A MATERIAL CHANGE WAS MADE TO INCONEL 718.

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DURING INITIATION OF HOT GO2 FLOW FOR ATP (6-28-84), IMMEDIATELY AFTER THE VALVE SOLENOID WAS REPLACED, THE VALVE IGNITED AND BURNED (REF CAR AC8335). IT WAS DETERMINED THAT THE CAUSE OF THE FIRE WAS DUE TO THE FACT THAT THE VALVE WAS NOT WELDED INTO THE FIXTURE (AS PER FLIGHT CONFIGURATION) BUT UTILIZED THREADED JOINTS WITH SEALS. THE CHANGEOUT OF THE SOLENOID, WITH THE VALVE STILL MOUNTED IN THE TEST FIXTURE, CAUSED THE SEALS TO BE PINCHED BY THE TORQUING OF THE SOLENOID. THE TEST FIXTURE WAS REDESIGNED TO USE WELDED JOINTS.

DURING NASA/WSTF PARTICLE IMPACT TEST (JULY 1987), A FCV IGNITED AND BURNED UNDER VEHICLE SIMULATED FLOW CONDITIONS. THE TEST PROGRAM INVOLVED THE INJECTION OF UP TO 10 MG OF METALLIC PARTICLES (UP TO 250 MICRONS) UPSTREAM OF THE VALVE (REFERENCE CAR AD3194). MCR 11199 AUTHORIZED BOTH THE PARTICLE IMPACT TEST AND THE COMPLETE REDESIGN OF THE FCV. THE REDESIGNED VALVE HAS PASSED SUBSEQUENT PARTICLE IMPACT QUALIFICATION TESTING.

GENERAL SYSTEM CONTAMINATION

THIS FAILURE MODE HAS OCCURRED ON THE PREVIOUS CONFIGURATION OF THIS COMPONENT DUE TO CONTAMINATION (WSTF ONLY). ADDITIONALLY, 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. PROCEDURES HAVE BEEN 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 THE CORRECTIVE ACTION WAS TO ADD SPECIAL PURGE PORTS TO THE MPS HELIUM PANEL ASSEMBLIES TO IMPROVE THE QUALITY OF FINAL CLOSEOUT BRAZES.

SEVERAL FOREIGN MATERIALS WERE INTRODUCED INTO THE MPS SYSTEM DURING MANUFACTURE AND PARTS REPLACEMENT. EXAMPLES ARE: GLASS CLOTH IN LINE TO

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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 HAVE BEEN 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:
NO CREW ACTION CAN BE TAKEN.

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