

SHUTTLE CRITICAL ITEMS LIST - ORBITER

SUBSYSTEM : ORBITAL MANEUVER FMEA NO 03-3 -4006 -1 REV:12/03/87

ASSEMBLY : ENGINE SUBSYSTEM CRIT. FUNC: 1  
 P/N RI : MC621-0009 CRIT. HDW: 1  
 P/N VENDOR: 1186900  
 QUANTITY : 2 VEHICLE 102 103 104  
 : 1 FOR EACH ENG SUBSYS EFFECTIVITY: X X -X  
 : PHASE(S): PL LO X OO X DO X LS

PREPARED BY: DES V F ROZNOS REL C M AKERS QE W J SMITH  
 REDUNDANCY SCREEN: A- B- C-  
 APPROVED BY: DES *[Signature]* SSM *[Signature]*  
 REL *[Signature]* REL *[Signature]*  
 QE *[Signature]* QE *[Signature]*

ITEM:  
 NOZZLE EXTENSION, ROCKET ENGINE.

FUNCTION:  
 PROVIDES ISENTROPIC EXPANSION OF THE COMBUSTION GASES FOR MAXIMUM EFFICIENCY IN VACUUM. EXTENSION IS FABRICATED FROM COLUMBIUM FS-88 WITH A REFRACTORY SILICIDE COATING TO LIMIT OXIDATION. A RING STIFFENER IS UTILIZED ON THE AFT FLANGE. ITEM IS BOLTED TO CHAMBER USING A GRAFOIL SEAL WITH TITANIUM BACK-UP RING TO INCREASE THERMAL RESISTANCE. MAX DIAMETER IS 45 IN. X 56 IN. LONG. EXPANSION RATIO IS 55: 1. MAX DESIGN TEMPERATURE IS 2480 F.

FAILURE MODE:  
 STRUCTURAL FAILURE, BURN THROUGH.

CAUSE(S):  
 HIGH TEMPERATURE/LOCALIZED HOT SPOT/INADEQUATE COOLING, WELD DEFECT, LEAK PATH, INCORRECT BOLT OR MATERIAL DEFICIENCY, HIGH AERODYNAMIC BUCKLING LOADS, BUCKLING LOADS FROM SSME START TRANSIENT, FAILURE OF ACTUATOR TO HOLD ENGINE IN STOW POSITION DURING ASCENT, DAMAGED/MISSING SILICIDE COATING.

EFFECT(S) ON:  
 (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE  
 (A) LOSS OF FUNCTION - LOSS OF ONE ENGINE.  
 (B) DEGRADATION OF INTERFACE FUNCTION - LOSS OF THRUST AND IMPROPER THRUST VECTOR.  
 (C) POSSIBLE EARLY MISSION TERMINATION. REDLINE ADDITIONAL PROPELLANT FOR RCS BACKUP DEORBIT. NEXT PLS DEORBIT IF SUFFICIENT PROPELLANT NOT AVAILABLE.

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(D) POSSIBLE LOSS OF CREW/VEHICLE - POSSIBLE VEHICLE STRUCTURAL DAMAGE DUE TO IMPINGEMENT OF EXHAUST GASES AND/OR POSSIBLE FIRE OR EXPLOSION DUE TO EXHAUST GASES DUMPING INTO POD IF FAILURE OCCURS AT FLANGE.

DISPOSITION & RATIONALE:

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

(A) DESIGN

COMPLETE THERMAL AND STRESS ANALYSIS HAS BEEN PERFORMED (COMBINED LOADS) FOR NORMAL AND ABORT CONDITIONS. COLUMBIUM FS 85 MATERIAL AND R512E SILICIDE COATING WILL WITHSTAND TEMPERATURES > 2480 F. ESTIMATED MAXIMUM MISSION TEMPERATURE IS APPROXIMATELY 1800 F (2180 F FOR RTLS). NOZZLE WALL THICKNESS INCREASED FROM .018" TO .034" IN CENTER SECTION TO PROVIDE ADDITIONAL BUCKLING STRENGTH.

(B) TEST

QUALIFICATION TESTS

RANDOM VIBRATION CONDUCTED AT ENGINE LEVEL. ACOUSTIC TEST AT AMBIENT TEMPERATURE. HOT-FIRE TEST PROGRAM - ENGINE LEVEL; 85 FIRINGS, 2562 SEC DURATION. SYSTEM LEVEL; 498 FIRINGS, 14831 SEC DURATION.

ACCEPTANCE TESTS

RAW MATERIAL LOT CERTIFICATION, INSPECTION OF PRODUCT, NDE EXAMINATION OF WELDS, PROOF PRESSURE AND LEAKAGE TESTS.

GROUND TURNAROUND

V43CBO.211 PERFORMS LEAK CHECK OF OME CHAMBER/NOZZLE JOINT FOR FIRST FLIGHT AND ON 5 FLIGHT INTERVALS.

V43CEO.020 DEFINES DETAILED VISUAL INSPECTION OF OME INJECTOR, ACOUSTIC CAVITIES, COMBUSTION CHAMBER WALL, AND NOZZLE; DOCUMENTATION IS REQUIRED FOR ANY ANOMALOUS INDICATIONS (PERFORMED EACH FLIGHT).

V43CEO.030 DEFINES DETAILED VISUAL INSPECTION OF ENGINE COMPONENTS WITHIN ENGINE BOX (REMOVAL OF HEAT SHIELD REQUIRED); REQUIREMENTS TO BE CARRIED OUT WHENEVER POD IS REMOVED (AT LEAST EVERY 5 FLIGHTS).

V43CHO.010 PERFORMS WATER INTRUSION INSPECTION AFTER FIREX USAGE ON PAD. V43CIO.010 REQUIRES OME NOZZLE INSPECTION AFTER PAD ABORT.

(C) INSPECTION

RECEIVING INSPECTION

MATERIALS AND PROCESSES CERTIFICATIONS ARE VERIFIED BY INSPECTION.

CONTAMINATION CONTROL

CLEANLINESS AND CORROSION PROTECTION PROVISIONS ARE VERIFIED BY INSPECTION.

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ASSEMBLY/INSTALLATION

MANUFACTURING, ASSEMBLY AND INSTALLATION PROCEDURES ARE VERIFIED BY INSPECTION. CRITICAL DIMENSIONS AND SURFACE FINISHES ARE VERIFIED BY INSPECTION. VISUAL AND DIMENSION INSPECTION OF NOZZLE EXTENSION IS VERIFIED BY INSPECTION.

CRITICAL PROCESSES

INSPECTION VERIFIES 100 PERCENT INSPECTION OF COATING THICKNESS CHARACTERISTICS. THE WELDING PROCESS AND VERIFICATION THAT WELDS MEET SPECIFICATION REQUIREMENTS ARE VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

PENETRANT AND RADIOGRAPHIC INSPECTION OF WELDS ARE VERIFIED BY INSPECTION.

TESTING

TEST EQUIPMENT AND TOOL CALIBRATION ARE VERIFIED BY INSPECTION. ACCEPTANCE TEST IS VERIFIED BY INSPECTION. CALIBRATION OF HEAT TREATING OVENS IS VERIFIED BY INSPECTION.

HANDLING/PACKAGING

HANDLING, PACKAGING, STORAGE AND SHIPPING REQUIREMENTS ARE VERIFIED BY INSPECTION.

(D) FAILURE HISTORY

CAR AC4919 IDENTIFIES LOCALIZED NOZZLE EXTENSION BUCKLING WHICH OCCURRED DURING OV-102 STS-5. IM30F011 RECORDS A SIMILAR TYPE OCCURRENCE FOR OV-099 STS-6 IN WHICH A CREASE DEVELOPED AND THE COATING SPALLED IN ONE AREA. CAR AC4919 INDICATES THAT THE SILICIDE COATING SPALLED OFF IN BUCKLED AREAS. CRACKS WERE OBSERVED IN TWO WELDS. REVIEW OF LAUNCH FILMS REVEALED "OIL CANNING" OF BOTH NOZZLES DURING SSME IGNITION TRANSIENT. A DESIGN CHANGE WAS MADE TO INCREASE THE NOZZLE WALL THICKNESS FROM .018" TO .034" IN CENTER SECTION. THE ORIGINAL (THINWALL) NOZZLE CALCULATED LIFE WAS 65 MISSIONS (BASED ON LOW CYCLE FATIGUE FROM COMBINED LOADS DURING ASCENT).

CAR AC448 RECORDS A CRACK ACROSS A MIDDIRTH WELD IN ONE SPALLED AREA AND SEVERAL ADDITIONAL AREAS WHERE SPALLING OCCURRED DUE TO BUCKLING. THIS WAS DETECTED DURING REINSPECTION AT DOWNEY. THIS THIN WALLED NOZZLE EXTENSION HAD BEEN USED ON 4 FLIGHTS OF OV-099. CORRECTIVE ACTION (REF MCR 10275) IS TO FLY ONLY THICK WALL NOZZLES WHICH HAVE 5 TIMES THE BUCKLING STRENGTH OF THIN WALLED NOZZLES.

(E) OPERATIONAL USE

FAILURE MAY BE DIFFICULT TO DIAGNOSE. ISOLATE FAILED ENGINE AND COMPLETE MISSION REQUIREMENTS USING CROSSFEED FOR PROPELLANT UTILIZATION. REDLINE ADDITIONAL PROPELLANT FOR RCS BACKUP DEORBIT. NEXT PLS DEORBIT IF PROPELLANT FOR RCS BACKUP NOT AVAILABLE. POSSIBLE MISSION IMPACT. DECREASED PROPELLANT AVAILABLE FROM OMS TO RCS THROUGH INTERCONNECT FOR ON-ORBIT OPERATION.