

**FAILURE MODES EFFECTS ANALYSIS (FMEA) – CRITICAL HARDWARE
NUMBER: 03-1-0407-X**

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 1 5/11/94

	PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
LRU	: DISCONNECT, LH2, 17 INCH	MC284-0389-0451 (ORB HALF)
LRU	: DISCONNECT, LH2, 17 INCH	MC284-0389-1451 (ORB HALF)
LRU	: DISCONNECT, LH2, 17 INCH	MC284-0389-0452 (ET HALF)

PART DATA

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
DISCONNECT, LH2 FEED, 17 INCH, ORBITER & ET HALF. (PD2)

QUANTITY OF LIKE ITEMS: 1
ONE

FUNCTION:

ET/ORBITER FEED LINE DISCONNECT PROVIDES LH2 PROPELLANT TO THE MPS AND A MEANS OF LOADING AND DETANKING THE ET. EACH DISCONNECT HALF CONTAINS A PNEUMATICALLY ACTUATED FLAPPER CLOSURE DEVICE WHICH REMAINS IN ITS LAST ACTUATED POSITION (BISTABLE). THE VALVES ARE CLOSED AFTER MECO TO PREVENT PROPULSIVE VENTING LEADING TO ET/ORBITER RECONTACT, TILE/DOOR DAMAGE DUE TO EXPOSURE TO PROPELLANTS, LOSS OF HELIUM SUPPLY DURING MANIFOLD REPRESSURIZATION (RTLS/TAL ABORT CRITICAL), AND SYSTEM CONTAMINATION DURING ENTRY. DURING UMBILICAL SEPARATION, THE VALVE SYSTEM IS DESIGNED TO MECHANICALLY CLOSE BOTH THE ORBITER AND ET DISCONNECT FLAPPERS IF UNABLE TO CLOSE THEM PNEUMATICALLY (POST MECO). REDUNDANT OPEN AND CLOSE (TWO EACH) VALVE POSITION SWITCHES ARE LOCATED ON THE ORBITER HALF OF THE DISCONNECT. THE FLAPPER DRIVE MECHANISM IS DESIGNED TO ALLOW RELIEF OF PROPELLANTS TRAPPED BETWEEN THE FLAPPERS AFTER DISCONNECT CLOSURE.

A PNEUMATICALLY ACTUATED LATCH MECHANISM IS PROVIDED TO PREVENT THE VALVE FLAPPERS FROM CLOSING DURING FLOW CONDITIONS. THE LATCH IS BISTABLE AND IS CONTROLLED BY A SEPARATE PNEUMATIC ACTUATOR ASSEMBLY WITH REDUNDANT LOCK AND UNLOCK (TWO EACH) POSITION SWITCHES. LATCH MECHANISM INCORPORATES A TOGGLE PIVOT WHICH ALLOWS FLAPPER CLOSURE DURING BACK UP MECHANICAL SEPARATION WITH LATCH IN LOCKED POSITION. SEE LATCH FMEA/CIL 0454 FOR ADDITIONAL INFORMATION.

SHUTTLE CRITICAL ITEMS LIST - ORBITER

SUBSYSTEM : MAIN PROPULSION FMEA NO: 03-1 -0407 -7 REV:12/17/87

ASSEMBLY :
P/N RI : MC284-0389-KXXX CRIT. FUNC: 1
ORB HALF 0451 CRIT. HDW: 1
ET HALF 0452

P/N VENDOR:
QUANTITY : 1 VEHICLE 102 103 104
EFFECTIVITY: X X X
: ONE PHASE(S): PL LO X OC DO LS
:

PREPARED BY: APPROVED BY: REDUNDANCY SCREEN: A- B- C-
DES J E OSLUND DES *[Signature]* APPROVED BY (NASA)
REL L H FINEBERG REL *[Signature]* SSM *[Signature]*
QE E M GUTIERREZ QE *[Signature]* REL *[Signature]*
[Signature] 1-27-88 *[Signature]* 1-27-88

ITEM:
DISCONNECT, LH2 FEED (WITH LATCH) 17 INCH, ORBITER & ET HALF. (PC2)

FUNCTION:
ET/ORBITER FEED LINE DISCONNECT PROVIDES LH2 PROPELLANT TO THE MPS AND A MEANS OF LOADING AND DETANKING THE ET. EACH DISCONNECT HALF CONTAINS A PNEUMATICALLY ACTUATED FLAPPER CLOSURE DEVICE WHICH REMAINS IN ITS LAST ACTUATED POSITION (BISTABLE). THE VALVES ARE CLOSED AFTER MECO TO PREVENT PROPULSIVE VENTING LEADING TO ET/ORBITER RECONTACT, TILE/DOOR DAMAGE DUE TO EXPOSURE TO PROPELLANTS, LOSS OF HELIUM SUPPLY DURING MANIFOLD REPRESSURIZATION (RTLS/TAL ABORT CRITICAL), AND SYSTEM CONTAMINATION DURING ENTRY. DURING UMBILICAL SEPARATION, THE VALVE SYSTEM IS DESIGNED TO MECHANICALLY CLOSE BOTH THE ORBITER AND ET DISCONNECT FLAPPERS IF UNABLE TO CLOSE THEM PNEUMATICALLY (POST MECO). REDUNDANT OPEN AND CLOSE (TWO EACH) VALVE POSITION SWITCHES ARE LOCATED ON THE ORBITER HALF OF THE DISCONNECT. THE FLAPPER DRIVE MECHANISM IS DESIGNED TO ALLOW RELIEF OF PROPELLANTS TRAPPED BETWEEN THE FLAPPERS AFTER DISCONNECT CLOSURE.

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FAILURE MODE
FAILS TO REMAIN CLOSED (ORBITER AND/OR ET FLAPPERS)
FOLLOWING ORB/ET UMBILICAL SEPARATION.

CAUSE(S)
PIECE PART STRUCTURAL FAILURE.

SHUTTLE CRITICAL ITEMS LIST - ORBITER

SUBSYSTEM : MAIN PROPULSION

FMEA NO: 03-1 -0407 -7

REV:12/17/87

EFFECT(S) ON:

(A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE

(A,B)

CASE I - ORBITER FLAPPER FAILS TO REMAIN CLOSED FOLLOWING ORBITER/ET UMBILICAL SEPARATION. RESULTS IN POSSIBLE TILE AND DOOR DAMAGE AT THE UMBILICAL AREA DUE TO CRYO EXPOSURE. FOR RTLS AND TAL ABORTS, RESIDUAL HZ WILL ENTER THE AFT COMPARTMENT CAUSING POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. ALSO RESULTS IN LOSS OF HELIUM SUPPLY DURING MANIFOLD REPRESS CAUSING LOSS OF AFT COMPARTMENT ENTRY PURGE (RTLS AND TAL ABORT CRITICAL).

CASE II - ET FLAPPER FAILS TO REMAIN CLOSED FOLLOWING ORBITER/ET UMBILICAL SEPARATION. RESULTS IN POSSIBLE TILE AND DOOR DAMAGE AT THE UMBILICAL AREA DUE TO CRYO EXPOSURE AND ORBITER/ET RECONTACT DUE TO PROPULSIVE VENTING FOLLOWING ET STRUCTURAL SEPARATION. ALSO MAY RESULT IN ET IMPACT OUTSIDE ALLOWABLE FOOTPRINT.

(C,D)POSSIBLE LOSS OF CREW/VEHICLE/LIFE/PROPERTY.

DISPOSITION & RATIONALE:

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

(A) DESIGN

ONCE THE FLAPPERS HAVE BEEN CLOSED, THE FOLLOWER ARM TORSION BARS AND SYSTEM INTERNAL PRESSURE PROVIDE THE FORCE NECESSARY TO MAINTAIN THE FLAPPERS IN THE CLOSED POSITION.

DESIGN FACTORS OF SAFETY FOR INTERNAL PRESSURE ARE 1.3 PROOF, 1.5 BURST FOR THE DISCONNECT. THE ORBITER FLAPPERS HAVE A MINIMUM USEFUL LIFE OF 3500 CYCLES WHICH IS EQUIVALENT TO 100 ORBITER MISSIONS. THE ET FLAPPER HAVE A MINIMUM LIFE OF 150 CYCLES WHICH IS EQUIVALENT TO ONE ORBITER MISSION. STRUCTURAL ANALYSIS INDICATES POSITIVE MARGINS OF SAFETY FOR ALL CONDITIONS OF VALVE OPERATION; FRACTURE/FATIGUE ANALYSIS SHOW THAT ALL CRITICAL PARTS ARE SATISFACTORY FOR FOUR TIMES EXPECTED LIFE (ET - ONE MISSION, ORBITER - 100 MISSIONS).

THE DISCONNECT VALVE CONSISTS OF COMPONENTS MANUFACTURED FROM 2024-T651 AL ALLOY (FLAPPER ASSEMBLY), INCONEL 718 (ARM FOLLOWER) AND A286 CRES (ARM DRIVE ASSEMBLY). THE VALVE HOUSING IS MANUFACTURED FROM 2219 AL ALLOY. THE FLAPPER FLEX SEAL IS MADE OF INCONEL 718 WITH A TEFLON COATING, AND THE SEAL SEAT IS MADE OF A286 CRES.

SHUTTLE CRITICAL ITEMS LIST - ORBITER

SUBSYSTEM : MAIN PROPULSION

FMEA NO: 03-1 -0407 -7

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(B) TEST

ATP (ACTUATOR)

PROOF: AMBIENT, 1275 PSIG

OPERATIONAL (TWO CYCLES): AMBIENT; 400, 740, 780 PSIG

RESPONSE TIME (OPENING/CLOSING): ROOM AMBIENT/-300 DEG F
RESPONSE TIME AT 400, 700 AND 780 PSIG

LEAKAGE: EXTERNAL AND INTERNAL, AMBIENT AND CRYO

ATP - ET/ORBITER MATED DISCONNECT ASSEMBLY

FLAPPER ANGLE: ET 0.75 +/- 0.25 DEG, ORB 2.4 +/- 0.25 DEG

TIP LOAD: ET 55 LB MINIMUM, ORB 40 LB MINIMUM

POSITION SWITCH VERIFICATION: LATCH IN LOCKED POSITION. ROTATION FROM
FLAPPER POSITION OF REST ON DOWNSTRIKE SURFACE TO FLAPPER POSITION
WHERE OPEN INDICATOR LIGHT TURNS ON MUST BE 4 DEG, MINIMUM.

PROOF: AMBIENT, 1275 PSIG, ACTUATOR
286 PSIG FOR ORBITER CLOSURE DEVICE
58 PSIG FOR ET CLOSURE DEVICE

OPERATIONAL CYCLE: CRYO, -300 DEG F, ACTUATOR PRESSURE 740 PSIG FOR 8
CYCLES AND 450 PSIG FOR 5 CYCLES
AMBIENT, He AT 400 PSIG (1 CYCLE) AND 740 PSIG (5
CYCLES)

OPERATING TORQUE: ET LH2 SECTION, -410 DEG F FOR 3.5 HOURS MINIMUM,
150 FT-LBS MAX

CLEANLINESS VERIFICATION: MOISTURE FREE AND CLEANED TO LEVEL 400A OF
MA 0110-301

LEAKAGE: EXTERNAL

VALVE: LN2/AMBIENT TEMPS: 50 SCIMS OF GHE AT 10 PSIG, 50
SCIMS OF GHE AT 50 PSIG; LATCH SHAFT SEAL, 80 SCIMS OF
GHE

LH2 TEMPS: 200 SCIMS OF GH2 AT 50 PSIG; LATCH
SHAFT SEAL 80 SCIMS OF GH2

VALVE ACTUATOR:

CRYO (BODY TEMP AT -300 DEG F, ACTUATOR AT -200 TO
0 DEG F)/AMBIENT TEMPS: 100 SCIMS OF GHE AT 740 PSIG

SHUTTLE CRITICAL ITEMS LIST - ORBITER

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INTERNAL

VALVE: AMBIENT TEMPS: 1000 TO 2500 SCIMS OF GHE AT 1 TO 60 PSIG

LN2 TEMPS: 2500 SCIMS OF GHE AT 60 PSIG

VALVE ACTUATOR:

CRYO (BODY TEMP AT -300 DEG F, ACTUATOR AT -200 TO 0 DEG F)/AMBIENT TEMPS: 100 SCIMS OF GHE AT 740 PSIG

RELIEF OPERATION: -300 DEG F, CRACKING/RESEAT PRESSURE, 0.1-5 PSID (ET ONLY)

ELECTRICAL CHARACTERISTICS (INSULATION RESISTANCE AND VOLTAGE DROP), AND DIELECTRIC STRENGTH

FLOW LINER - ROUNDNESS VERIFICATION (FREE END EIGHT POINTS MEASUREMENT)

OPERATING TORQUE: ET LH2 SECTION SHALL BE MANUALLY ACTUATED (OPEN/CLOSED) AFTER BEING STABILIZED AT -410 DEG F. TORQUE SHALL NOT EXCEED 150 FT LBS.

CERTIFICATION

COMPONENT QUALIFICATION (INCLUDES TESTING FROM PREVIOUS CONFIGURATION WITHOUT LATCH)

SALT FOG

VIBRATION - THREE AXES:

SINUSOIDAL: 5 TO 35 HZ AT 0.25 G, ZERO TO PEAK

RANDOM: 20 TO 2,000 HZ 5.7 G RMS FOR X-AXIS, 5.2 G RMS FOR Y AND Z-AXIS, NO FLOW (LN2), FLAPPERS OPEN, LATCH ENGAGED

THE DISCONNECT IS CHILLED WITH LN2 AND STABILIZED AT -300 DEG F. 10 PSIG DISCONNECT, 740 PSIG ACTUATOR. THESE CONDITIONS ARE MAINTAINED THROUGHOUT SINUSOIDAL AND RANDOM VIBRATION. ACTUATOR VENTED DURING LAST TWO MINUTES OF VIBRATION.

THERMAL CYCLE: -400 TO 150 DEG F, 3 CYCLES

OPERATING LIFE: AMBIENT, 740 PSIG HE FOR A TOTAL OF 2,400 CYCLES FOR ORBITER AND 100 CYCLES FOR ET. THE RELIEF MECHANISM WAS CYCLED DURING ET VALVE CYCLING.

CRYO, 740 PSIG HE, -400 DEG F FOR A TOTAL OF 1000 CYCLES FOR ORBITER AND 50 CYCLES FOR THE ET. THE RELIEF MECHANISM WAS CYCLED DURING ET VALVE CYCLING.

SHUTTLE CRITICAL ITEMS LIST - ORBITER

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ELECTRICAL CHARACTERISTICS (INSULATION RESISTANCE AND VOLTAGE DROP)

LEAKAGE: EXTERNAL AND INTERNAL, AMBIENT AND CRYO

ENGAGE - DISENGAGE: ENGAGE FORCE = 1000 LBS MAX, DISENGAGE
FORCE = 6000 LBS MAX

BURST TEST: PNEUMATIC ACTUATOR, 1700 PSIG HYDROSTATIC PRESSURE FOR
2 MINUTES

TYPE I AND TYPE II MATED (OPEN POSITION) 450 PSIG HYDROSTATIC
PRESSURE FOR 2 MINUTES

TYPE I AND TYPE II DEMATED (CLOSED POSITION) 330 PSIG TO
TYPE I, 68 PSIG TO TYPE II FOR 2 MINUTES

UMBILICAL SEPARATION TEST: (WITHOUT LATCH)

THE DISCONNECT WAS INSTALLED IN THE UMBILICAL ASSEMBLY DURING THE
SEPARATION TEST PROGRAM. THE UMBILICAL ASSEMBLY WAS SUBJECTED TO
RANDOM VIBRATION TESTS (4.4 HOURS PER AXIS) WHILE FILLED WITH LN2. THE
DISCONNECT WAS ALSO SUBJECTED TO UMBILICAL RETRACT TESTS AT BOTH
NOMINAL CONDITIONS AND SIMULATED HYDRAULIC RETRACT ACTUATOR FAILURES.

UMBILICAL SEPARATION TEST: (WITH LATCH)

FLAPPER PNEUMATICS/LATCH PNEUMATICS/PYROS/RETRACTOR HYDRAULICS

- (1) PNEUMATIC CLOSURE (NORMAL) - 4 CYCLES
- (2) MECHANICAL CLOSURE (BACKUP) - 5 CYCLES

BOTH PERFORMED AT AMBIENT, LN2 AND LH2 CONDITIONS.

FLOW LINER WATER FLOW TESTS: (LH2 VALVE QUALIFIED BY SIMILARITY TO LH2)

DESIGN FLOW TO 13,100 GPM
ALLOWABLE DELTA P IS 10 PSIG AT THE LINER

TO DETERMINE THE STABILITY OF THE FLOW LINER. THE FLOW TUBE HAD NO
PERMANENT DAMAGE AFTER BEING SUBJECTED TO WATER FLOWS UP TO 20,000 GPM
(TEST TIME OF 2 MINUTES / 6 RUNS MINIMUM). AFTER VERIFYING
PERFORMANCE AT 20,000 GPM, THE UNIT WAS SUBJECTED TO 22,700 GPM TO
VERIFY DESIGN MARGIN (NO PERMANENT DAMAGE).

SHUTTLE CRITICAL ITEMS LIST - ORBITER

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FLAPPER ANGLE STABILITY MARGIN WATER FLOW TESTS:

ELEVEN (11) EXPLORATORY TEST SERIES (FLOW 4,000 TO 14,200 GPM)
E.T. FLAPPER SETTING VARYING FROM -3.9 TO 2.5 DEG.
ORB. FLAPPER SETTING VARYING FROM -0.9 TO 4.6 DEG.

CERTIFICATION TEST RUN AT WORST CASE PRODUCTION SETTING (FLOW RANGE TO 109% POWER LEVEL).

PRODUCTION ANGLE SETTINGS
E.T. 0.75 +/- 0.25 DEG
ORB. 2.4 +/- 0.25 DEG

FLAPPER TIP LOAD MARGIN WATER FLOW TEST:

SEVEN (7) EXPLORATORY TEST SERIES (FLOW RANGE TO 109% POWER LEVEL)

FLOW 4,000 TO 13,100 GPM
ORBITER: 2.4 +/- 0.1 DEG
TIP LOAD RANGE: 22 TO 60 LBS

ET: 0.75 +/- 0.1 DEG
TIP LOAD RANGE: 20 TO 61 LBS

RECOMMENDED TIP LOAD:

ORBITER: 40 LBS MINIMUM
ET: 55 LBS MINIMUM

LATCH WATER FLOW TESTS:

ELEVEN (11) EXPLORATORY TEST SERIES (FLOW 4,000 TO 14,800 GPM)

CERTIFICATION TEST RUN AT NOMINAL PRODUCTION SETTING (FLOW RANGE TO 109% POWER LEVEL).

TWO PROOF TESTS: 15,650 GPM AND 15,850 GPM

FILL FLOW DIRECTION: SIMILARITY TO LO2 FILL FLOW TEST

LATCH CRYO FLOW TESTS: (LH2 VALVE QUALIFIED BY SIMILARITY TO LO2)

SIXTEEN (16) TESTS WITH LN2/LO2 (FLOWS VARY FROM ONE ENGINE AT 65% TO THREE AT 109%).

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OMRSD

V41AYO.020 LH2 EXTERNAL LEAK TEST (I5)
V41AYO.140 LH2 DECAY TEST (EVERY FLT)
V41AYO.221 HELIUM SIGNATURE TEST (EVERY FLT)
V41AYO.250 LH2 SHAFT SEAL LEAK CHECK (I5)
V41BBO.090 LH2 SEAT LEAKAGE TEST (EVERY FLT)
V41BIO.240 ORB/ET DISC RESPONSE TIME (POST FLT DATA ANALYSIS)
V41BUO.280 DISCONNECT FLAPPER ANGLE VERIFICATION (EVERY FLT)
V41BUO.320 DISCONNECT INSPECTION AND TIP LOAD VERIF (EVERY FLT)
V41BUO.330 MPS COMPONENT CAVITY INSPECTION (EVERY FLT)
V41BUO.370 ORB/ET DISC PREPARATION FOR OPF ROLLOUT (EVERY FLT)
V41BVO.020 MPS ORB/ET DISC CLEANING (EVERY FLT)
V41BVO.030 ORB/ET UMBILICAL DISC AND SEAL INSPECTION (EVERY FLT)
T41FUN.040 OPENING TORQUE BEFORE MATING (EVERY FLT)
T41FUN.061 ET 17" TIP LOAD/FLAPPER ANGLE INSPECTION (EVERY FLT)
T41QAL.090 LO2/LH2 17" DISCONNECT INSPECTION (EVERY FLT)
T41QAL.100 LO2/LH2 17" DISCONNECT CLEANING (EVERY FLT)
S00HCO.400 VERIFY ET/ORB DISC POSITIONS (PRIOR TO MATING) (EVERY FLT)
S00000.091 PD2 RESPONSE TIME (MATED) (EVERY FLT)

(C) INSPECTION

RECEIVING INSPECTION

RAW MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIAL AND PROCESS CERTIFICATION. ALL MACHINED ITEMS ARE DIMENSIONALLY INSPECTED AND VERIFIED (MIL-STD-105). CHEMICAL/MECHANICAL PROPERTIES AND RECORDS OF RECEIVED MATERIALS ARE RETAINED FOR VERIFICATION. BODY FORGING IS ULTRASONICALLY AND DYE PENETRANT INSPECTED.

CONTAMINATION CONTROL

CLEANLINESS LEVEL TO 400A VIA FREON FLUSH AND SAMPLE VERIFIED. ALL SEAL GROOVES ARE INSPECTED FOR CLEANLINESS AND EVIDENCE OF DAMAGE.

ASSEMBLY/INSTALLATION

THREADED INSERTS AND CRITICAL DIMENSIONS VERIFIED BY INSPECTION. SEALING SURFACES ARE VISUALLY INSPECTED FOR DEFECTS. REPAIRED AND REWORKED ITEMS ARE DIMENSIONALLY CHECKED. LOG OF CLEAN ROOM VERIFIED. ALL ENGINEERING-DEFINED FEATURES AND SURFACE FINISHES AND TORQUE REQUIREMENTS ARE COMPLETELY INSPECTED AND VERIFIED.

THE PRIMARY INTERFACE SEAL IS CHECKED FOR ID, OD AND ROUNDNESS. ALL DIMENSIONS DEFINED IN DRAWING ARE VERIFIED BY INSPECTION.

CRITICAL PROCESSES

HEAT TREATMENT AND PART PASSIVATION ARE VERIFIED BY INSPECTION.

NON-DESTRUCTIVE EVALUATION

PARTS ARE RADIOGRAPHICALLY AND DYE PENETRANT INSPECTED AS IMPOSED BY ENGINEERING IN THE DRAWING REQUIREMENTS.

TESTING

ATP AND TEST MEASUREMENT EQUIPMENT CALIBRATION VERIFIED BY INSPECTION.

SHUTTLE CRITICAL ITEMS LIST - ORBITER

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HANDLING/PACKAGING

PACKAGING FOR SHIPMENT VERIFIED BY INSPECTION.

(D) FAILURE HISTORY

SEVERAL INTERNAL LEAKS (ATP FAILURES) HAVE OCCURRED WHICH WERE SLIGHTLY OVER SPECIFICATION LIMITS OF 1000 SCIM AT LOW PRESSURE (REFERENCE CARS A6936, A6858, A5352 AND AB3730). THE UNITS WERE ACCEPTABLE BY INCREASING THE PROCUREMENT SPECIFICATION ALLOWABLE LEAKAGE RATE TO 2,000 SCIM MAXIMUM. NO FURTHER INCIDENTS HAVE OCCURRED.

IMPROPERLY INSTALLED FLAPPER FLEX SEAL DISKS ON FOUR DIFFERENT FLAPPERS CAUSED AN EXCESSIVE INTERNAL LEAKAGE DURING ATP (REFERENCE CAR'S AB8349, AC1997, AC4883 AND AD0131) THE ASSEMBLY FIXTURE HAS BEEN MODIFIED TO INSURE CENTERING OF THE SEAL DISK DURING SHRINK RING INSTALLATION.

(E) OPERATIONAL USE

NO CREW ACTION CAN BE TAKEN.