

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

NUMBER: 03-1-0221 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 08/02/00

**PART DATA**

	<b>PART NAME</b>	<b>PART NUMBER</b>
	<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU	:LO2 OUTBOARD FILL/DRAIN VALVE OPENING SOLENOID VALVE (LV28)	MC284-0404-0032, -0042
	UNITED SPACE ALLIANCE - NSLD	13111-5, -6

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

VALVE, SOLENOID, NORMALLY CLOSED 3 WAY 1/4 INCH. LO2 OUTBOARD FILL/DRAIN VALVE CONTROL, OPENING (LV28).

VALVE WAS ORIGINALLY DESIGNED AND MANUFACTURED BY WRIGHT COMPONENTS (NOW PERKIN ELMER) BUT IS NOW MANUFACTURED BY UNITED SPACE ALLIANCE-NSLD AS AN ALTERNATE PRODUCTION AGENCY.

REFERENCE DESIGNATORS: LV28

QUANTITY OF LIKE ITEMS: 1

**FUNCTION:**

CONTROLS PNEUMATIC PRESSURE TO OPEN THE OUTBOARD LOX FILL AND DRAIN VALVE. THE SOLENOID MUST DEACTUATE TO ALLOW FILL AND DRAIN VALVE ACTUATOR TO VENT WHEN FILL VALVE IS CLOSED. CLOSING SOLENOID (LV29) (REFERENCE FMEA/CIL 0222) MUST DEACTUATE TO ALLOW VALVE TO OPEN.

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**LRU: LO2 O/B F/D OPENING SOLENOID VALVE (LV28)**

**CRITICALITY OF THIS**

**ITEM NAME: LO2 O/B F/D OPENING SOLENOID VALVE (LV28)**

**FAILURE MODE: 1R2**

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**FAILURE MODE:**

PREMATURE DEACTUATION (FILL AND DRAIN VALVE FAILS TO REMAIN OPEN, REFERENCE FMEA/CIL 03-1-0311-05) CAUSING ACTUATOR OPENING PRESSURE TO VENT. DURING PROPELLANT LOADING, DETANKING, AND DUMP.

**MISSION PHASE:** PL PRE-LAUNCH  
LO LIFT-OFF

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

**CAUSE:**

PIECE PART STRUCTURAL FAILURE, ELECTRICAL SOLENOID FAILURE.

**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 SOLENOID VALVE DOES NOT HAVE POSITION INDICATOR. OPEN SOLENOID IS OPERATIONALLY REDUNDANT TO CLOSE SOLENOID

C)

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**- FAILURE EFFECTS -**

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**(A) SUBSYSTEM:**

LOSS OF REDUNDANCY ONLY. FAILURE RESULTS IN LOSS OF ACTUATOR OPENING PRESSURE. THE FILL AND DRAIN VALVE IS BISTABLE AND WILL REMAIN IN THE LAST

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COMMANDED POSITION. OPENING PRESSURE IS NORMALLY APPLIED DURING PROPELLANT LOADING.

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

SAME AS A.

**(C) MISSION:**

NO EFFECT. VALVE WILL REMAIN OPEN.

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

SAME AS C.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

CASE 1:

1R/2 2 SUCCESS PATHS. TIME FRAME - LOADING AND DETANKING

- 1) PREMATURE DEACTUATION OF OUTBOARD FILL AND DRAIN VALVE OPENING SOLENOID (LV28).
- 2) PREMATURE ACTUATION OF OUTBOARD FILL AND DRAIN VALVE CLOSING SOLENOID (LV29).

CAUSES TERMINATION OF PROPELLANT LOADING OR DETANKING. RESULTS IN PRESSURE SPIKE WHICH MAY CAUSE RUPTURE OF THE ORBITER FILL LINE, MANIFOLD, AND/OR GSE INTERFACE/FACILITY LINES. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF ADJACENT CRITICAL FUNCTIONS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:

1R/3 6 SUCCESS PATHS. TIME FRAME-MPS LO2 VACUUM INERTING.

- 1) PREMATURE DEACTUATION OF OUTBOARD FILL AND DRAIN VALVE OPENING SOLENOID (LV28).
- 2) PREMATURE ACTUATION OF OUTBOARD FILL AND DRAIN VALVE CLOSING SOLENOID (LV29).
- 3,4,5) ALL LO2 PREVALVES FAIL TO OPEN/REMAIN OPEN.
- 6) LO2 MANIFOLD RELIEF SYSTEM FAILS TO RELIEVE.

RESULTS IN RUPTURE OF THE 17-INCH FEEDLINE DUE TO EXPANDING LO2 RESULTS RESIDUALS AFTER LO2 DUMP. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSIVE HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 3:

1R/3 4 SUCCESS PATHS. TIME FRAME -- POST PAD ABORT DETANK.

- 1) PREMATURE DEACTUATION OF OUTBOARD FILL AND DRAIN VALVE OPENING SOLENOID (LV28).
- 2) PREMATURE ACTUATION OF OUTBOARD FILL AND DRAIN VALVE CLOSING SOLENOID (LV29).
- 3) 1 OF 3 PREVALVES (PV1,2,3) FAIL TO CLOSE.

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- 4) LO2 OVERBOARD BLEED (PV19) FAILS TO OPEN/REMAIN OPEN.

TO PREVENT GEYSERING, PREVALVE CLOSURE IS REQUIRED TO LIMIT HEAT SOAKBACK FROM THE MAIN ENGINES INTO THE FEED SYSTEM. FOR PREVALVE FAILURE TO CLOSE, HELIUM INJECTION IS NOT SUFFICIENT TO PREVENT GEYSERING AND OVERBOARD BLEED OR LO2 DRAIN MUST BE INITIATED WITHIN OMRSD REQUIREMENTS.

GEYSERING MAY RESULT IN FEEDLINE RUPTURE, EXTERNAL LEAKAGE OF LO2, AND POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION. FIRE/EXPLOSIVE HAZARD BOTH INTERIOR AND EXTERIOR TO THE VEHICLE. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF VEHICLE.

**CASE 4:**

1R/3 4 SUCCESS PATHS. TIME FRAME - RTLS (POST DUMP).

- 1) FAILURE RESULTING IN RTLS ABORT.
- 2) PREMATURE DEACTUATION OF OUTBOARD FILL AND DRAIN VALVE OPENING SOLENOID (LV28).
- 3) PREMATURE ACTUATION OF OUTBOARD FILL AND DRAIN VALVE CLOSING SOLENOID (LV29).
- 4) LO2 MANIFOLD RELIEF SYSTEM FAILS TO RELIEVE.

RESULTS IN RUPTURE OF THE 17-INCH FEEDLINE DUE TO EXPANDING LO2 RESIDUALS AFTER LO2 DUMP. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSIVE HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

FOR TAL ABORTS, THE MAIN OXIDIZER VALVE (MOV) IS OPEN FOR A SUFFICIENT DURATION TO VENT RESIDUAL LO2.

**CASE 5:**

1R/3 3 SUCCESS PATHS. TIME FRAME – LOADING

- 1) PREMATURE DEACTUATION OF OUTBOARD FILL AND DRAIN VALVE OPENING SOLENOID (LV28).
- 2) PREMATURE ACTUATION OF OUTBOARD FILL AND DRAIN VALVE CLOSING SOLENOID (LV29).
- 3) LO2 OVERBOARD BLEED (PV19) FAILS TO OPEN/REMAIN OPEN.

GEYSERING MAY RESULT IN FEEDLINE RUPTURE, EXTERNAL LEAKAGE OF LO2, AND POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION. FIRE/EXPLOSIVE HAZARD BOTH INTERIOR AND EXTERIOR TO THE VEHICLE. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF VEHICLE.

**CASE 6:**

1R/3 RTLS ABORT

- 1) FAILURE RESULTING IN A RTLS ABORT
- 2) PREMATURE DEACTUATION OF OUTBOARD FILL AND DRAIN VALVE OPENING SOLENOID (LV28).
- 3) PREMATURE ACTUATION OF OUTBOARD FILL AND DRAIN VALVE CLOSING SOLENOID (LV29).

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FAILURE TO ADEQUATELY LO2 DUMP MAY CAUSE VIOLATION OF MAXIMUM DOWNWEIGHT FOR HEAVY MANIFESTED PAYLOADS.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

VALVE IS DESIGNED FOR A PRESSURE FACTOR OF SAFETY OF 2.0 PROOF, 4.0 BURST. THE CLOSURE DEVICE IS A 430 CRES BALL ACTING UPON EITHER OF TWO VESPEL SEATS. THE VALVE FEATURES A BALANCED LOAD ON THE BALL BY APPLYING INLET PRESSURE (750 PSIG NOMINAL) DIRECTLY TO THE BALL AT THE INLET SEAT AND INDIRECTLY (VIA A BELLOWS) THROUGH THE VENT SEAT. THE BELLOWS IS ASSISTED BY A SPRING, THE FORCE OF WHICH INSURES THE BALL IS HELD SECURELY AGAINST THE INLET SEAT WHEN THE SOLENOID IS DEENERGIZED. UPON BEING ENERGIZED THE SOLENOID DEVELOPS THE FORCE TO OVERCOME THE SPRING LOAD AND SEATS THE BALL ONTO THE VENT SEAT TO ALLOW HELIUM FLOW. TOTAL POPPET MOVEMENT (STROKE) IS LESS THAN 0.040 INCH.

PREMATURE DEACTUATION MEANS THE FORCE HOLDING THE VALVE BALL TO THE VENT SEAT HAS BEEN REMOVED. MECHANICALLY, THE ONLY VALVE PARTS INVOLVED ARE THE SOLENOID PLUNGER, THE SOLENOID STOP, AND TWO PUSHRODS. THE PLUNGER AND STOP ARE MASSIVE BY COMPARISON TO THE PUSHRODS, AND ARE BOTH OF 430 CRES. THE PUSHRODS ARE ALIGNED IN SERIES WITHIN THE STOP. THE PUSHRODS ARE MADE OF CRES AND CARRY ONLY AXIAL LOADS. IF THE RODS WERE TO FAIL STRUCTURALLY, THEY WOULD CONTINUE TO PERFORM THEIR FUNCTION BECAUSE THEY ARE TOTALLY CONTAINED IN THE STOP (THE ROD OD IS 0.125 INCH AND THE STOP ID IS 0.126 INCH). THE ROD, IN CONTACT WITH THE BALL, IS GUIDED BY THE SOLENOID STOP FOR OVER 28% OF ITS LENGTH.

THE ONLY OTHER APPARENT WAY TO ACHIEVE PREMATURE DEACTUATION WOULD BE BY STRUCTURAL DAMAGE SUCH THAT A LEAK WOULD BE CREATED OF SUFFICIENT CAPACITY TO VENT THE VALVE ACTUATION PORT THROUGH THE VENT PORT. WITH THE POSSIBLE EXCEPTION OF BALL DISINTEGRATION, NO INTERNAL STRUCTURAL FAILURE WILL CAUSE PREMATURE DEACTUATION BECAUSE THE FAILURE POINT IS DOWNSTREAM OF THE ACTUATION PORT. IF A VALVE COMPONENT SHOULD FAIL STRUCTURALLY, IT WOULD NOT DISINTEGRATE AND DISAPPEAR. THE FAILURE WOULD CREATE A FLOW PATH FROM THE HIGH PRESSURE SIDE OF THE VALVE TO THE VENT AND SOMEWHERE IN THAT PATH THE FLOW WILL CHOKE. UPSTREAM OF THAT CHOKING POINT (INCLUDING THE ACTUATION PORT), THE PRESSURE WILL REMAIN ABOVE 400 PSIA. THIS RATIONALE ALSO APPLIES TO SEAT AND SEAL DAMAGE. THE BALL IS MADE FROM 430 CRES.

THE SOLENOID STRUCTURE IS CONSTRUCTED OF CRES AND IS EB WELDED. THE COIL IS VACUUM IMPREGNATED (POTTED). THE UNIT IS PRESSURE AND LEAK TESTED AT THE MAJOR ASSEMBLY POINTS.

THE -0022 CONFIGURATION WAS ADDED DUE TO A BELLOWS ASSEMBLY DESIGN CHANGE (P/N 24340 TO P/N 24340-1) TO ELIMINATE THE "SQUIRMED" CONDITION WHICH SOME OF THE ORIGINAL BELLOWS ASSEMBLIES EXPERIENCED DURING PROOF PRESSURE TESTING AT ATP. THE DESIGN CHANGE WAS MADE TO STRENGTHEN THE BELLOWS. BECAUSE THE

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DAMAGE OCCURRED DURING ATP, VALVES ALREADY IN THE FLEET (-0012 CONFIGURATION) WERE X-RAY TESTED AND ONLY VALVES WHICH HAD SQUIRMED BELLOWS WERE UPGRADED TO THE -0022 CONFIGURATION.

THE -0032 AND -0042 CONFIGURATION SOLENOID VALVES ARE IDENTICAL TO THE -0012 AND -0022 CONFIGURATION SOLENOID VALVES (RESPECTIVELY) WITH THE EXCEPTIONS OF ADDING THE FILTER (10 MICRON NOMINAL, 25 MICRON ABSOLUTE) IN THE VENT PORT OF THE SOLENOID VALVE AND REDESIGN OF THE VENT PORT CHECK VALVE. THIS FILTER WAS ADDED TO PREVENT CONTAMINATION AND METALLIC PARTICLES GENERATED DURING THE REMOVAL OF THE VENT PORT CHECK VALVE DURING OMRSD LEAKAGE MEASUREMENTS FROM ENTERING THE SOLENOID VALVE.

THE VENT PORT CHECK VALVE (P/N 11107-5) WAS REDESIGNED (P/N 11107-7) TO PREVENT THE POPPET FROM BEING EJECTED DUE TO SHEARING OF THE RETAINING NUT THREAD. A PIN WAS ADDED TO THE CHECK VALVE HOUSING, WHICH RETAINS THE POPPET WITHIN THE CHECK VALVE HOUSING. A NEW ALUMINUM NUT, WHICH PROVIDES A MINIMUM ENGAGEMENT OF THREE THREADS, WAS UTILIZED TO INCREASE RELIABILITY.

**(B) TEST:**  
ATP

AMBIENT TEMPERATURE TESTS:  
PROOF PRESSURE (1560 PSIG); EXTERNAL LEAKAGE (850 PSIG); ELECTRICAL CHARACTERISTICS AND RESPONSE; INTERNAL LEAKAGE (740 PSIG, ENERGIZED AND DEENERGIZED).

REDUCED TEMPERATURE TESTS (-160 DEG F):  
ELECTRICAL CHARACTERISTICS AND RESPONSE; INTERNAL LEAKAGE

ELECTRICAL BONDING TESTS

SOLENOID SUBASSEMBLY TESTS:  
ELECTRICAL CHARACTERISTICS; ENCLOSURE LEAKAGE (ONE ATMOSPHERE).

CERTIFICATION

TWO UNITS -

PORT AND FITTING TORQUE

SALT FOG EXPOSURE FOLLOWED BY ELECTRICAL AND LEAKAGE CHECKS

AMBIENT VIBRATION TESTS: TOTAL 13.1 HOURS BOTH AXES FOR TWO VIBRATION LEVELS PLUS TRANSIENT VIBRATION SWEEP - RUN WITH ONE UNIT ENERGIZED AND ONE DEENERGIZED - FOLLOWED BY ELECTRICAL CHARACTERISTICS AND LEAKAGE CHECKS

HANDLING SHOCK TEST

ENERGIZED AND DEENERGIZED FLOW TESTS

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FIFTY HOUR CONTINUOUS CURRENT TEST AT 130 DEG F

AMBIENT TEMPERATURE ENDURANCE (4500 CYCLES FOLLOWED BY ELECTRICAL AND LEAKAGE CHECKS); 130 DEG F ENDURANCE (500 CYCLES FOLLOWED BY ELECTRICAL AND LEAKAGE CHECKS); OPERATION CYCLES (REPEATED 20 TIMES); REPEAT OF AMBIENT TEMPERATURE ENDURANCE ; -160 DEG F ENDURANCE ( 500 CYCLES FOLLOWED BY ELECTRICAL AND LEAKAGE CHECKS)

DISASSEMBLY AND INSPECTION

BURST PRESSURE (3400 PSIG)

GROUND TURNAROUND TEST

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

**(C) INSPECTION:**

RECEIVING INSPECTION

RAW MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIAL AND PROCESSES CERTIFICATION. BODY HOUSING BAR STOCK IS ULTRASONICALLY INSPECTED.

CONTAMINATION CONTROL

CLEANLINESS LEVEL VERIFIED TO 100A. CORROSION PROTECTION IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

ALL PARTS ARE PROTECTED FROM DAMAGE AND CONTAMINATION. MICROSCOPIC EXAMINATION OF ALL DETAIL PARTS IS MADE PRIOR TO ASSEMBLY. ALL SURFACES REQUIRING CORROSION PROTECTION ARE VERIFIED. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE. MECHANICAL SURFACE FINISH AT 125 RMS IS INSPECTED AND VERIFIED WITH A PROFILOMETER. SURFACE FINISHES SMOOTHER THAN 125 RMS ARE INSPECTED USING A COMPARATOR AT 10X MAGNIFICATION. ALL CRITICAL DIMENSIONS ARE VERIFIED BY INSPECTION.

CRITICAL PROCESS

HEAT TREATMENT AND PARTS PASSIVATION VERIFIED BY INSPECTION. POTTING OF SOLDER CUPS, ELECTRICAL WIRE STRIPPING, AND SOLDERING OF CONNECTORS ARE VERIFIED BY INSPECTION. DRY FILM LUBRICATION APPLIED TO THE PLUNGER IS VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

WELDS VISUALLY EXAMINED & VERIFIED BY X -RAY, DYE PENETRANT, AND EDDY CURRENT. THE SOLENOID ASSEMBLY IS SUBJECTED TO LEAKAGE VERIFICATION USING RADIOACTIVE TRACER TECHNIQUES. THE VALVE BODY, PRIOR TO FINAL MACHINING, IS SUBJECTED TO ETCH AND DYE PENETRANT INSPECTION. BELLOWS ASSEMBLY IS PROOF PRESSURE TESTED AND LEAK CHECKED.

TESTING

ATP VERIFIED BY INSPECTION.

HANDLING/PACKAGING

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PACKAGING FOR SHIPMENT VERIFIED BY INSPECTION.

**(D) FAILURE HISTORY:**

A NUMBER OF ELECTRICAL CONNECTORS WERE BROKEN AT NSTL DUE TO EXCESSIVE PHYSICAL FORCE APPLIED TO THE CONNECTOR BY TECHNICIANS WORKING IN THE CONFINED AREA (CAR'S AB1813, AB1613, AND AB1208). CORRECTIVE ACTION RESULTED IN THE INSTALLATION OF PROTECTIVE COVERS TO PREVENT CONNECTOR DAMAGE IN HIGH TRAFFIC AREA. ALSO, CONNECTORS WERE WELDED TO THE VALVE BODY IN LIEU OF SOLDERING.

AN ELECTRICAL SHORT DUE TO INCORRECT ALIGNMENT OF SOLDER CUPS (PINS "A" AND "C") WAS DETECTED AT THE PALMDALE FACILITY (CAR AC2687). THE CORRECTIVE ACTION TAKEN WAS THE ADDITION OF HEAT SHRINK TUBING TO ISOLATE THE SOLDER CUPS AND THE ADDITION OF AN INSPECTION POINT AFTER POTTING.

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:**

FLIGHT: NO CREW ACTION CAN BE TAKEN.

GROUND: THE LO2 17" FEED DISCONNECT (PD1) CAN BE CLOSED IN ORDER TO ISOLATE THE ORBITER FROM THE ET TO DELAY/PREVENT GEYSERING PER APPLICABLE OMRSD.

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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	: DAVID NEARY	:/S/ DAVE NEARY
MPS SUBSYSTEM MGR.	: TIMOTHY REITH	:/S/ TIMOTHY REITH
MOD	: WILLIAM LANE	:/S/ WILLIAM LANE
USA SAM	: MIKE SNYDER	:/S/ MIKE SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	:/S/ SUZANNE LITTLE
NASA SR&QA	: BILL PRINCE	:/S/ BILL PRINCE