FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL HARDWARE
NUMBER: M4-1BG-HE010-F

SUBSYSTEM NAME: ELECTRICAL POWER GENERATION - CRYO, GENERIC
REVISION : 2 09/30/92

		PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
LRU	:	TANK SUBASSEMBLIES, O2 BEECH	MC282-0063-0300 15548-1001
LRU	:	TANK SUBASSEMBLIES, O2 BALL AEROSPACE	MC282-0112-0100 163195-500
SRU	:	HEATER, TANK, LO2	15548-2005 (BEECH)
SRU	:	HEATER, TANK, LO2	163203 (BALL AERO.)

- PART DATA -

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
LO2 TANK HEATER

REFERENCE DESIGNATORS: FOR LO2 TANK SUBASSEMBLIES
: 40V45TK010
: 40V45TK020
: 40V45TK400
: 40V45TK450
: 40V45TK600
: 40V45TK760
: 40V45TK770
: 40V45TK780
: 40V45TK790

QUANTITY OF LIKE ITEMS: 2
TWO ELEMENTS PER LO2 TANK HEATER, TWO HEATERS PER LO2 TANK, 3-9 TANKS - MISSION DEPENDENT

FUNCTION:
PROVIDES HEAT TO THE LO2 TANKS TO MAINTAIN TANK PRESSURE.

PRINT DATE: 10/07/92

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL FAILURE MODE
NUMBER:M4-1BG-HE010-03

REVISION# 2 09/30/92

SUBSYSTEM: ELECTRICAL POWER GENERATION - CRYO, GENERIC
LRU TANK SUBASSEMBLIES, O2
ITEM NAME: HEATER, TANK, LO2

CRITICALITY OF THIS FAILURE MODE:1R3

FAILURE MODE:
INTERNAL SHORT OF TANK HEATER

MISSION PHASE:

PL	PRELAUNCH
LO	LIFT-OFF
OO	ON-ORBIT
DO	DE-ORBIT
LS	LANDING SAFING

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102	COLUMBIA
103	DISCOVERY
104	ATLANTIS
105	ENDEAVOUR

CAUSE:
STRUCTURAL FAILURE, VIBRATION, CONTAMINATION, MECHANICAL SHOCK, PROCESSING ANOMALY, THERMAL STRESS

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN
A) FAIL
B) FAIL
C) PASS

PASS/FAIL RATIONALE:
A) REDUNDANCY SCREEN "A" FAILS BECAUSE THE FAILURE MODE OF THE FIRST LAYER OF INSULATION SHORTING IS NOT DETECTABLE DURING GROUND TURNAROUND TESTS.

B) REDUNDANCY SCREEN "B" FAILS BECAUSE THE FAILURE MODE OF THE FIRST LAYER OF INSULATION SHORTING IS NOT DETECTABLE IN FLIGHT.

C)

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- FAILURE EFFECTS -

(A) SUBSYSTEM:
LOSS OF THE AFFECTED LO2 TANK HEATER.

(B) INTERFACING SUBSYSTEM(S):
LOSS OF REDUNDANCY. LOSS OF ONE METHOD OF PROVIDING REQUIRED HEAT TO LO2 TANK.

(C) MISSION:
NO EFFECT - FIRST FAILURE

(D) CREW, VEHICLE, AND ELEMENT(S):
NO EFFECT - FIRST FAILURE

(E) FUNCTIONAL CRITICALITY EFFECTS:
POSSIBLE LOSS OF CREW/VEHICLE DUE TO THE FOLLOWING SCENARIO: 1) LO2 TANK HEATER SHORTS THROUGH ONE OF ITS DOUBLE LAYERS OF INSULATION, 2) SAME LO2 HEATER SHORTS THROUGH ITS SECOND LAYER OF INSULATION - SHORTS TO STRUCTURE, 3) CURRENT LEVEL DETECTOR FAILS TO RESPOND TO THE UNBALANCED HEATER CURRENT, 4) REDUNDANT CURRENT LEVEL DETECTOR FAILS TO RESPOND, POSSIBLY INDUCING LOCALIZED HOT SPOTS, RESULTING IN POSSIBLE RUPTURE/EXPLOSION OF THE LO2 TANK.

- DISPOSITION RATIONALE -

(A) DESIGN:
FUNCTIONAL DESCRIPTION
THE HEATER PROVIDES TANK PRESSURIZATION AFTER GSE DISCONNECT BY ADDING ENERGY TO THE STORED CRYOGEN WHICH IS ACHIEVED THROUGH CYCLING HEATERS INSIDE THE TANKS. THERE ARE TWO HEATERS (A AND B) IN EACH TANK WITH INDEPENDENT CONTROL. EACH LO2 TANK HEATER CIRCUIT OPERATES TWO HEATING ELEMENTS IN PARALLEL. A HEATER IS ACTIVATED BY A THREE-POSITION SWITCH (ON/OFF/AUTO) THAT ALLOWS MANUAL OPERATION BY THE CREW OR AUTOMATIC OPERATION BY THE HEATER CONTROL BOX. THE CONTROLLER, ONE PER LO2/LH2 TANK SET, HAS BUILT-IN LOGIC TO CONTROL HEATER CYCLING (OV-102 HAS LO2/LH2 TANKS 4 AND 5 CONTROLLED BY A COMMON HEATER CONTROL BOX). IN THE "AUTO" MODE OF OPERATION, THE HEATER CONTROLLER BOX TURNS THE HEATER "ON" FOR PRESSURE INCREASE OR "OFF" FOR PRESSURE DECREASE. MANUAL SWITCHING TO "ON/OFF" POSITION BY THE CREW IS FOR SPECIAL OPERATIONS ONLY.

PHYSICAL DESCRIPTION
THE LO2 TANK HEATER IS COMPRISED OF A 16 AWG NICHROME V WIRE ELEMENT WITH A DOUBLE INSULATION SHEATH OF POWDERED SILICA DIELECTRIC. THE INNER INSULATION LAYER IS SHEATHED WITH CRES WHICH IS ISOLATED FROM STRUCTURAL GROUND AND THE OUTER INSULATION LAYER IS SHEATHED WITH CRES WHICH IS CONNECTED TO STRUCTURAL GROUND. NICKEL LEAD WIRES ARE WELDED TO THE NICHROME V HEATER ELEMENT. THE CRES SHEATH TRANSITIONS FROM A DOUBLE SHEATH TO A SINGLE SHEATH NEAR THE ENDS OF THE HEATER. THE NICKEL LEAD WIRES ARE SEALED AT THE ENDS OF THE SINGLE CRES SHEATH WITH EPOXYLITE. AT THE COLD END OF THE ELEMENT, THE NICKEL LEAD WIRE IS JOINTED TO COPPER

WIRE USING A BI-METAL SPLICE. THE HEATER ELEMENTS ARE BENT TO FIT INSIDE THE HEATER ASSEMBLIES AND ARE GOLD-BRAZED TO THE ASSEMBLY TO MAINTAIN GOOD HEAT TRANSFER. THE ASSEMBLIES ARE OXIDE COATED TO GIVE HIGH EMISSIVITY.

THE CERTIFIED PART NUMBERS ARE 163203 (BALL AEROSPACE) AND 15548-2005 (BEECH).

(B) TEST:
HEATER ASSEMBLY QUALIFICATION TESTS INCLUDED: ACCEPTANCE TESTING, RANDOM VIBRATION (X-AXIS: 0.003 G SQ/HZ TO 0.4 G SQ/HZ, Y AND Z-AXIS: 0.01 G SQ/HZ TO 0.3 G SQ/HZ; 48 MINUTES PER AXIS), SINUSOIDAL VIBRATION (5 TO 35 HZ +/- 0.25 G PEAK, 2 MINUTE 45 SECOND MINIMUM AT EACH AXIS), PASS/FAIL FOR HEATER CONTINUITY AND RESISTANCE (3.36 TO 3.58 OHMS AT 73 +/- 18 DEGREE F), AND HEATER ELEMENT INSULATION RESISTANCE (500 +/- 25 VDC, 500 MEGOHMS FOR 2 MINUTES).

ACCEPTANCE TESTS VERIFIED FUNCTIONAL OPERATION OF HEATER ASSEMBLY. DIELECTRIC STRENGTH IS TESTED FOR THE HEATER ELEMENT (1000 VRMS FOR 1 MINUTE AND FOR THE HEATER SUBASSEMBLY AT 1128 +/- 21 VDC WITH RETEST VOLTAGE AT 900 VDC WHERE THE LEAKAGE CURRENT SHALL NOT EXCEED 2.83 MILLIAMPERES). INSULATION RESISTANCE BETWEEN THE HEATER LEADS AND INNER SHEATH (500 MEGOHMS MINIMUM). OUTER CRES HEATER SHEATH IS VACUUM LEAK TESTED (1X10 TO MINUS 8 SCC/SECOND HELIUM AT 1 ATMOS PRESSURE) AND ALL WELD AND BRAZE JOINTS ARE RADIOGRAPH INSPECTED.

OMRSD: ANY TURNAROUND CHECKOUT TESTING IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

(C) INSPECTION:
RECEIVING INSPECTION
MATERIAL AND PROCESS CERTIFICATION DOCUMENTS ARE REVIEWED FOR COMPLIANCE WITH PROGRAM REQUIREMENTS BY INSPECTION.

CONTAMINATION CONTROL
ALL DETAIL PARTS ARE CLEANED PER ROCKWELL APPROVED SUPPLIER PROCEDURES. SUBASSEMBLIES ARE VERIFIED CLEANED TO LEVEL 200A BY INSPECTION.

ASSEMBLY/INSTALLATION
DETAILED INSPECTION PERFORMED ON ALL PARTS PRIOR TO NEXT ASSEMBLY. BRAZING AND WELDING VERIFIED BY RADIOGRAPH INSPECTION. HEATER SHEATH IS VACUUM LEAK TESTED. CORROSION PROTECTION PROVISIONS VERIFIED BY INSPECTION.

CRITICAL PROCESSES
ALL CRITICAL PROCESSES AND CERTIFICATIONS, INCLUDING BRAZING AND WELDING, ARE MONITORED AND VERIFIED BY INSPECTION.

TESTING
ACCEPTANCE TESTS, INCLUDING INSULATION RESISTANCE, DIELECTRIC STRENGTH, FUNCTIONAL AND PERFORMANCE ARE OBSERVED AND VERIFIED BY QC.

HANDLING/PACKAGING
HANDLING, PACKAGING, STORAGE AND SHIPPING PROVISIONS ARE VERIFIED BY INSPECTION.

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(D) FAILURE HISTORY:
THERE HAVE BEEN NO INTERNAL SHORT FAILURES OF A LO2 TANK HEATER ASSEMBLY IN THE SHUTTLE ORBITER PROGRAM.

(E) OPERATIONAL USE:
CURRENT LEVEL DETECTOR WILL AUTOMATICALLY SHUT OFF FAILED LO2 TANK HEATER ELEMENT AFTER SECOND FAILURE. CREW WILL DISABLE HEATERS IN AFFECTED TANK.

- APPROVALS -

PAE MANAGER	T. J. EAVENSON	K.L. Preston for 10/8/92
PRODUCT ASSURANCE ENGR	T. K. KIMURA	T.K. Kimura 10/7/92
DESIGN ENGINEERING	M. M. SCHEIERN	M.M. Scheiern 10/7/92
NASA RELIABILITY		[illegible] 11/13/92
NASA SUBSYSTEM MANAGER		Donald L Nguyen 11/10/92
~~NASA EPD&C RELIABILITY~~		
NASA QUALITY ASSURANCE		K.O. [illegible] 10/8/92
~~NASA EPD&C SUBSYS MGR~~		